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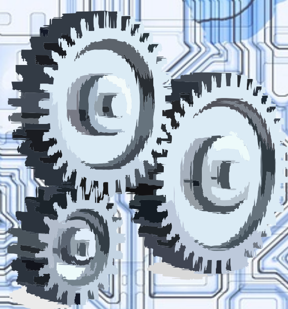

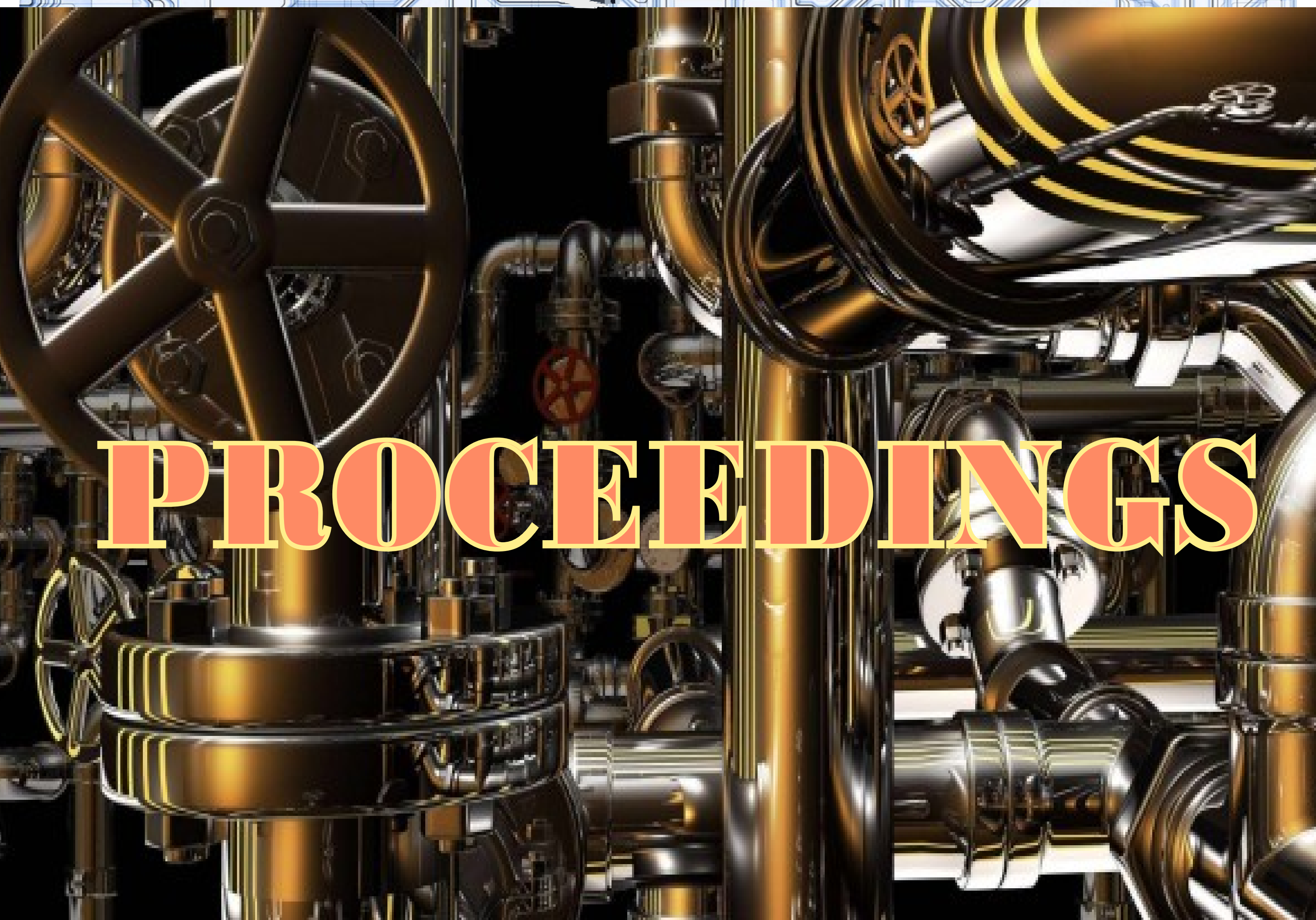

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C O N T E N T S

EMERGENCY BRAKING OF FAST RUNNING LOADING / UNLOADING HOISTS

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Abstract: *Cranes integrated in the logistic chain are vital elements to ensure safety and economic efficiency of transport. So safety is an essential factor for service of cranes in nuclear plants or metallurgical plants. For service of ship-to-shore-cranes the economic efficiency is an additional dominating aspect. A main assembly of every crane is the hoist. Following is shown, which internal forces occur in the components of a hoist with safety brake and are to be considered while dimensioning. In addition a concept for the design and the control of the braking system is shown in order to reduce the internal forces in hoist components of the rotational part of the drivetrain as couplings and gearing.*

Keywords: CRANE, HOIST, SHIP-TO-SHORE CRANES, BRAKING SYSTEM

1. Starting point

Due to instationary service hoists are dynamically loaded structures. Especially for the case of emergency-off of safety oriented hoists with a safety brake on the rope drum disc high dynamic internal forces occur in the drivetrain [1, 2, 3]. Thus exists the risk of component failure, which can be observed in practical applications. The failure of a component, especially the hoist gearing, results in consequences relating safety and availability and is to be prevented. Thus a target oriented approach in planning of open winches is of special relevance.

2. Hoist structure

Generally hoists consist of a drive train, to the ends of which loads are applied: At one end the motor and the brake are located, at the other end the load is attached. At safety oriented hoists as in ship-to-shore-cranes (Fig. 1), in nuclear plant cranes and in cranes for transporting molten metal this looks a little bit different.

Fig. 1 *Container Terminal Wilhelmshaven.*

To cover a rupture of the drive train an additional safety brake is located on the board disc of the rope drum mostly. Thus a load can be applied in the middle of the drive train [1]. In comparison to the general hoist structure a modified dynamic behavior of the hoist is the consequence.

3. Braking process

It is task of brakes in hoists, if required, to stop the hoist within a certain time or without exceeding a certain further hoisting distance or lowering distance. Subsequent the hoist is to be hold in the reached position in the first instance.

During deceleration a braking torque must be delivered by the brakes. Amount and direction of the braking torque comply with the considered load case, which can be understood as the transition between two service conditions. The service conditions respectively the transitions between them can be visualized in the four-quadrant-diagram (Fig. 2).

The actions of motor and brakes during a braking procedure are not permanent. In fact a sequence of omitting and adding loads on the drive train occurs. Especially the case of emergency-off is considered here with its special chronological scenario.

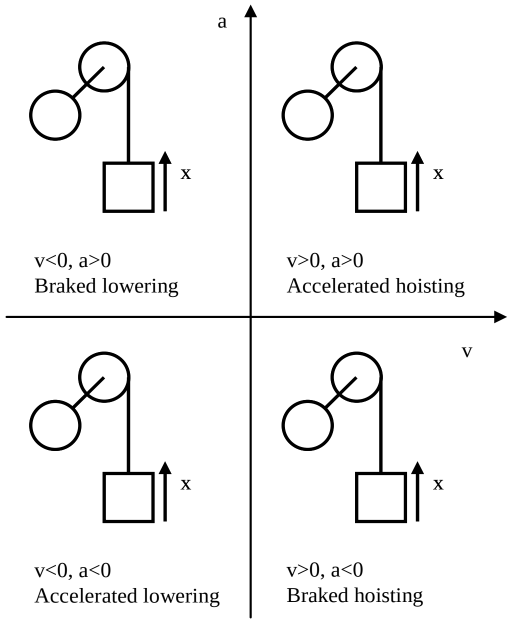

Fig. 2 *Container Terminal Wilhelmshaven.*

4. Reference system

For a closer look a partly redundant hoist with safety brakes is considered (Fig. 3).

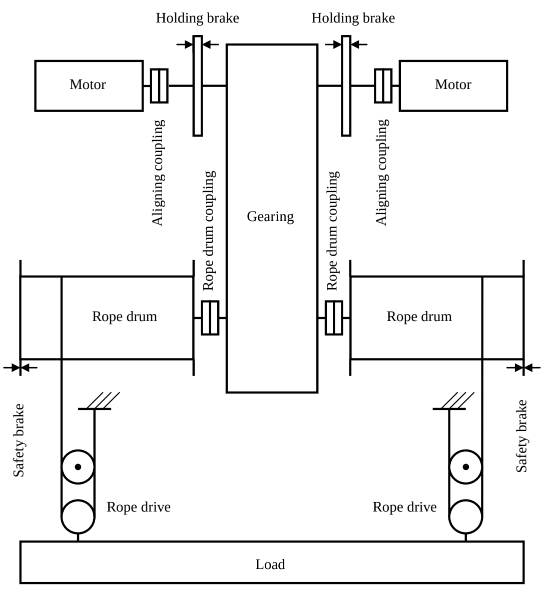

Fig. 3 *Reference System.*

Central element of the hoist is the gearing. The load is suspended by a load attachment device and a rope drive with 8/2 reeving. Both ropes are running onto a drum each, which are coupled with the gearing output shafts. On the board disc of each rope drum a safety brake is located. The hoist is driven by two motors which are connected to the gearing input shafts. On the motor shafts axis a service brake is located each.

The reference hoist is described by following data:

Motor speed	$n_1=1500min^{-1}$
Hoisting speed	$v_H=45m/min$
Mass motor shaft	$\theta_1=20kgm^2$
Mass rope drum shaft	$\theta_2=500kgm^2$
Mass load attachment device	$m_{LAM}=10t$
Mass SWL	$m_{SWL}=52t$
Radius rope drum	$r=0.5m$
Gearing ratio	$i_G=26.2$
Rope drive ratio	$i_S=4$
Service brake torque	$M_{BB}=5.8kNm$
Dead time service brake	$t_{totBB}=0.4s$
Safety brake torque	$M_{SB}=130kNm$
Dead time safety brake	$t_{totSB}=0.1s$
Gearing stiffness	$c=4e4Nm/rad$
Clearance drum coupling	$s=3°$

5. *Load cases*

The hoist underlies in service different load cases, described by following parameters:

- Concerning the direction of movement holding, hoisting and lowering can be distinguished.
- Concerning the variation of speed constancy, acceleration and deceleration can be distinguished.
- Concerning the load suspended at the rope drive loads from dead load (load attachment device) to full load (load attachment device plus safe working load) may occur.

Concerning the internal forces are switching processes of interest. In doing so changes between following service conditions can occur:

- Suspended load
- Hoisting
- Lowering
- Service-stop
- Emergency-stop
- Emergency-off

Following load cases are considered, which will lead to high internal forces in the drivetrain by trend. Considered is the case of emergency-off for a hoist, which disposes of a fast acting safety brake and a slow acting service brake. Emergency-off means, that energy supply is cut off spontaneously and all components react accordingly. The motor torque is omitted and the brakes apply mechanically.

6. *Kinetics*

For the hoist represented as a rigid body model the behavior of load speed over time can be calculated. As a result for example the speed over time for different mechanical braking scenario out of hoisting/lowering the dead load are gained (Fig. 4).

The rigid body approach does not consider elasticity and clearance in the hoist system. Accordingly it is of interest to investigate the influence of these properties. Therefore the rigid body model is expanded by adding the elasticity of the gearing and the clearance in the rope drum coupling.

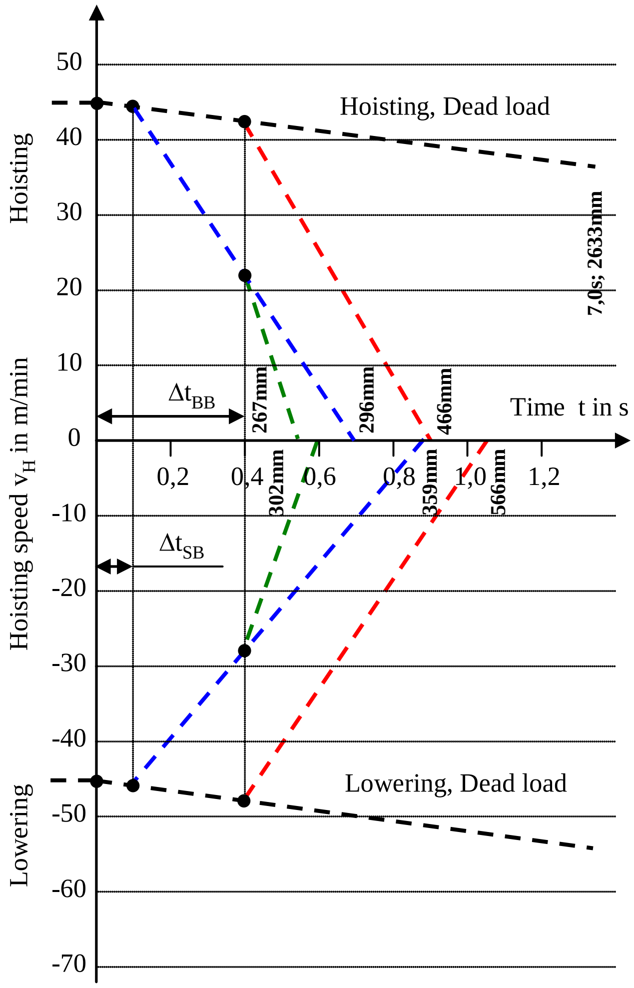

Fig. 4 *Speed characteristics for braking dead load*

7. *Braking during hoisting*

Examinations show the special relevance of the load case emergency-off out of hoisting the maximum load.

As observed the deceleration of the hoist occurs quickly. This is caused mainly due to the braking by the high load. Thus the deceleration process is finished as fast that the service brake (holding brake) with greater dead time in general is not or fairly not coming into action anymore. Firstly the torque for braking the motor mass is supplied by the load and the safety brake and transferred to the motor mass via the drive train.

With several assumptions the maximum relative gearing input torque for braking with the safety brake out of hoisting (+) or lowering (-) is calculated as

$$M_{G\,rel\,max} = \phi_5\left(MF\left(LF \pm BF_{SB}\right) - LF\right) + LF$$

Here the torque jump resulting out of the change of service condition according to the rigid body model is assessed with the dynamic factor for drives ϕ_5 corresponding EN 13001-2 [4].

The dynamic peak torques (Fig. 5) can occur, as far as they are supported by the static load, braking torque and inertia torque. Details regarding this are to be determined by an elasto-kinetic analysis. It is obvious for the considered load case that internal forces resulting in the drive train are a multiple of the static holding torque.

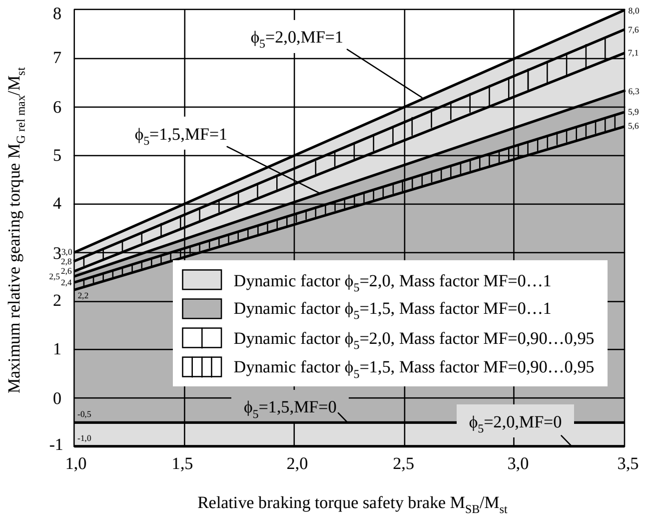

Fig. 5 *Maximum relative gearing torque*

8. Braking during lowering

Analyses show that especially the load case of emergency-off out of lowering the dead load is of interest.

Emergency-off immediately initiates switch-off of the motor and activation of the safety brake. For the mentioned data a maximum relative gearing input torque of $M_{G\ rel\ max} = 8.9$ is calculated (Fig. 6). That means the gearing torque is factor 8.9 higher than the maximum static loading of the drive train.

During lowering the hoist is driven by the load, which is hold in steady state condition by the motor. When the safety brake gets into action, the stoppage is executed very fast for this case as well. On one hand this is caused by the low load level, dead load. Assuming clearances in the drive train (in gearing and/or couplings) it is expected furthermore, that a flank change will occur. During this the motor side masses and the braked load side are uncoupled. Respectively the motor side masses need not to be decelerated.

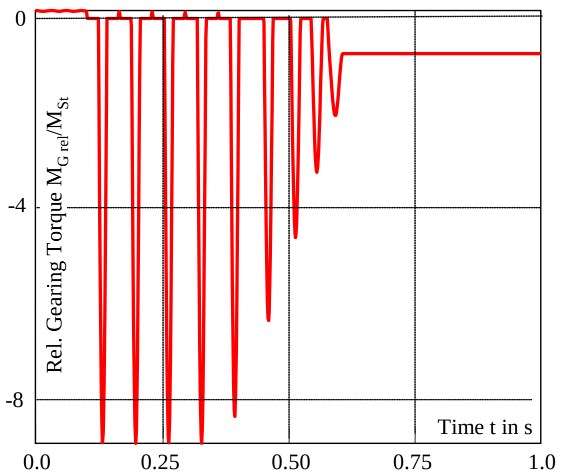

Fig. 6 *Gearing torque according to elasto-kinetic hoist model*

At an appropriate constellation the load side will stand still before running through the clearance is finished. In this case after running through the clearance a shock will occur. The motor side pitches on the standing load side. Toothed wheels and bearings in the gearing are loaded significantly by this shock. A special shock load may occur to the bearings of helical gearings. In this case the shock is led in axial direction of the shafts and with it on the roller bearing acting as fixed bearing.

9. Gearing loading

From the calculations maximum internal gearing torques much higher than according to static or rigid body approaches can be derived. Especially in the gearing such shock-like internal loads appear after running through clearances in relation with Hertzian contacts (toothing, roller bearings). To ensure safety such maximum internal loads must be covered statically. To ensure durability such maximum internal loads should not lead to pre-damages, which would lead to fatigue under further service loading.

10. „Intelligent“ braking

As measure to reduce peak values and amplitudes of the internal loads is considered: Synchronous and balanced action of all brakes participating in the braking process, here the service brake and the safety brake. This leads to a direct participation of the service brake in the braking process. This ideally results in a switching scenario with dead times of the service brake and the safety brake of $\Delta t_{BB} = \Delta t_{SB} = 0s$. Requirement is a holding of the motor torque until both brakes get into action.

Remains the question with which amount of torque the safety brake and the service brake should act. Favourable would be braking in a way that the quasi static internal torque before braking is still present during braking. Assuming these requirements given for the structure of the reference hoist following braking factors for the safety brake and the service brake for the braking out of hoisting (-) or lowering (+) are calculated:

$$BF_{BB} = \mp\left(LF + MF\frac{\theta^*_{ges}}{M^*_{st}}\frac{\Delta\omega}{\Delta t}\right)$$

$$BF_{SB} = \mp(1-MF)\frac{\theta^*_{ges}}{M^*_{st}}\frac{\Delta\omega}{\Delta t}$$

For the reference hoist the brake factors and their sums are calculated as shown for braking out of hoisting (Fig. 7) and out of lowering (Fig. 8).

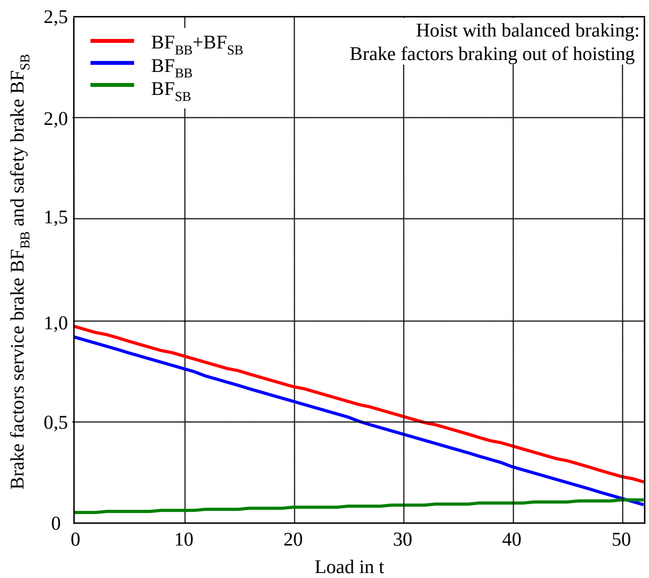

Fig. 7 *Braking factors for braking out of hoisting*

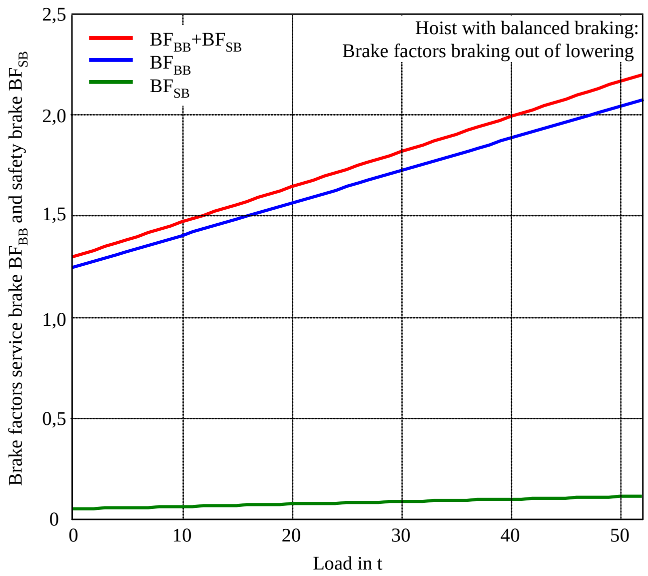

Fig. 8 *Braking factors for braking out of lowering*

For braking out of hoisting the safety brake has to be applied to a little account only (BF_{SB}=5%-12%). The service brake has to deliver a significant torque under partial load. With increasing loads up to full load the braking torque of the service brake is decreasing continuously (BF_{BB}=92%-8%).

For braking out of lowering the safety brake has to deliver only a small torque (BF_{SB}=5%-12%). The service brake has to deliver a significant torque under partial load. With increasing loads up to full load the braking torque of the service brake is increasing continuously (BF_{BB}=124%-208%).

11. Conclusions

For the higher internal loads occurring especially due to emergency-off [3] the hoist may be not dimensioned reasonably and efficiently. Assuming a corresponding hoist concept this also applies for emergency-stop, a load case occurring more often. Accordingly measures have to be considered in order to reduce internal loads induced to the drive train. The internal loads in the drivetrain are reduced especially by “intelligent braking”. Ideally the braking process is designed in a way, that during braking in the drivetrain between motor and safety brake the torque during static hoisting is present also. Hereby the maximum values as well as the amplitudes of the internal forces are reduced significantly. Suitable measures to be applied are:

- Reduction of clearances and increase of system elasticity. As result shocks can be reduced and absorbed, as well as internal loads are reduced in connection with system damping.
- Minimization of dynamic effects. Following EN 13001-2 [4] this may be realized by little clearance and a gradual implementation of the braking torque.
- Reduction of mass factor MF. By a small share of the motor mass in relation to the total mass of the drivetrain the torque put through the gearing is reduced.
- Minimization of brake factor BF_{SB}. A small braking torque of the safety brake generally leads to less braking action and reduced internal forces.
- Braking action synchronous to motor switch-off. Is he motor moment decreasing before braking action takes place, the drivetrain is relieved slightly. The resulting internal forces can be prevented by synchronity of the events.
- Synchronized application of safety brake and service brake. In order to prevent torques put through the drive train a synchronized application of both brakes is inevitable. As a result the collision of the non-braked massive drive side mass (motor) and the braked load side mass (rope drum) is prevented. Corresponding shocks in assemblies with clearances as gearing and rope drum coupling are reduced. In typical hoist structures the dead time of the safety brake is significantly lower than that of the service brake. An expandation of dead time of the safety brake in most cases cannot be accepted. Accordingly a suitable approach is to shorten the dead time of the service brake [5].
- Balanced braking torque of safety brake and service brake. For adjusting the torques in the drive train defined braking torques at safety brake and service brake are required. Advisable is the balancing of both braking torques according to the energies to be dissipated at the locations of brakes. These braking torques depend on the service condition and the suspended load. Brakes with controllable torques are applied ideally. For cranes they are not state of the art today. Instead of the step less adjustment of torques a stepped adjustment of braking torques may be considered. This is realized by a parallel arrangement of several smaller brakes at one braking location. Hereby an approximation of the ideal condition is achieved.

References

[1] RWTÜV Schriftenreihe, Heft 8, Krane, Bemessung und Sicherheit, 1981

[2] Vöth: Safety Systems for Container Cranes, 17th ITI-Symposium, Dresden, 2014

[3] Schmeink: Dynamische Beanspruchung von Hubwerks-getrieben, Tagungsband 22. Internationale Kranfachtagung, Magdeburg, 2014

[4] EN 13001-2: Crane safety, General design, Part 2: Load actions

[5] Römer: Difference between dynamic and static coefficient of friction, Port Technology International, 56. Edition, Winter 2012, P. 49-51

ПАРТНЬОРСКИ ПРОДУКТОВИ ИНОВАЦИИ, БАЗИРАНИ НА КОМПЕТЕНЦИИТЕ НА ДОСТАВЧИЦИТЕ

COLLABORATIVE PRODUCT INNOVATIONS BASED ON SUPPLIERS' COMPETENCES

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Abstract: *Collaborative product design is an approach for supporting designers connected by network, to participate in distributed and dynamic product development environment. In the globally competitive business environment, collaborative product development has become an important strategy for enterprises to reduce risks and enhance their competitiveness. Nowadays, designers usually interact with teams of distributed stakeholders using information and communication technology, aiming time/cost reductions and quality improvement. In new product development, the buyer-supplier relationship is changing. Using 4 case studies of small and medium-sized suppliers of a medium-sized Bulgarian enterprise doing business in the LED lighting industry, the author recognize several problems resulting from the interaction and coordination between customer and supplier in new development processes.*

Keywords: COLLABORATION, INNOVATIONS, PRODUCT DESIGN, SMALL AND MEDIUM-SIZED ENTERPRISES

1. Въведение

Днес способността на бизнес организациите да ползват знания от външната среда се счита ключов елемент на иновативните способности. Днес иновациите все по-малко се реализират в отделни лаборатории и организационни звена, а в логистични вериги и бизнес мрежи, които включват и доставчици на ресурси и компоненти.

За преодоляване на неопределеността, свързана със споменатия факт настоящата работа има за цел да изучи принципните връзки между снабдяването с ресурси и иновационната дейност на бизнес организациите и да насочи вниманието върху една от основните дейности, свързани с ресурсното осигуряване – прецизният подбор на доставчици, притежаващи значителен потенциал да допринесат за иновативността на бизнес организациите. За да се изучат характеристиките на такива доставчици е извършен общ литературен преглед и са идентифицирани характеристиките, които са типични за иновативните доставчици. На тази основа може да се постигне развитие на традиционния, базиран разходи подход за избор на доставчици.

Логично възниква въпросът за идентифицирането на доставчици, които познават свързаните със сътрудничество проблеми и които биха имали принос за създаване на иновативни решения. Друг значим проблем е свързан с бизнес организации, които възнамеряват да повишат иновативността си чрез прецизен подбор на доставчици, които активно да бъдат включени в иновационни проекти. До момента в специализираната литература няма данни за специализирано средство или система от критерии, които да се ползват за прецизен подбор на иновативни доставчици. Целта на настоящата работа е да се разработят предложения за такива критерии.

От много години доставчиците, подобно но потребителите, се считат за значим източник на иновации [1]. Чрез използване на ресурсите, уменията и способностите на доставчиците и най-вече ангажираността им при проектиране, бизнес организациите могат да поддържат и засилват конкурентното си предимство чрез: редуциране на разходите и продължителността на жизнения цикъл за създаване на продуктите; създаване на къстамизируеми продукти; постигане на много високо качество на продуктите.

При съвместното разработване на продукти вниманието е било върху свързване на изискванията на създателите на продуктите с гледната точка на доставчиците на базата на традиционен подход на интегриране [2]. На приобщаването на доставчиците не се е отделяло значимо внимание. Затова много мениджъри считат процеса за интегрирането на доставчиците като черна кутия [3], [4].

Целта на настоящата работа е изясняване на същността на процеса на съвместно разработване на продукти между създатели и доставчици и особено върху идентифициране на проблемите, свързани с оперативното управление на процеса на съвместно разработване. Предложени са средства и процедури за преодоляване на проблемите.

2. Идентифициране на доставчици, които потенциално могат да допринесат за организационните иновации

Една от основните слабости на свързаните с иновациите публикации е липсата на ясно определение за понятието иновация. Тази неяснота затруднява сравняването на иновативността на бизнес организациите.

В бизнес аспект значително допълнение към общата представа за иновация е обектът, свързан с иновацията – новост за отделна бизнес организация или новост за цялата бизнес среда. Ако се вземе под внимание основната цел на настоящата работа – идентифицирането на доставчици с потенциално максимален принос за иновативността на една бизнес организация, иновациите трябва да се разглеждат като новости за отделна организация, без да се разглежда новостта в бизнес средата.

В този смисъл иновации са не само разработването на нови продукти, но и придаване на нови характеристики на съществуващи продукти, замяна на материали за продукти или въвеждане но ново оборудване и технологии. От тази гледна точка не само субекти надолу по логистичната верига (потребители, дистрибуционни канали), но и предходни звена (доставчици) могат да играят значима роля за иновативността. Т. е. днес взаимодействията „продавач-купувач" имат критичен характер. Затова изборът на точните доставчици, които биха могли да допринесат за иновативността на една бизнес организация се превръща в нова значима задача на ресурсното осигуряване.

Хакансон и Ериксон [5] констатират връзка между ресурсното осигуряване и иновативността като се базират на идеята за мрежите. От такава гледна точка новите идеи се разработват в тесни взаимодействия с мрежа от партньори, което има за ефект кооперативна иновативна мощ, базирана на дейностите на контрагентите. Общо схващане при свързаните с иновациите подходи е, че бизнес организациите никога не иновират изолирано. Те винаги взаимодействат с други организации за придобиване, обогатяване и обмен на различни видове знания, информация и други ресурси. Затова бизнес организациите не трябва да се третират като изолирани субекти, които взимат решения.

Ако се възприеме системен подход към иновациите, възниква въпросът, кой извършва иновациите. Традиционното схващане е, че това са отделни лица или отделни организации. Фриман и Сьоте [6] застъпват тезата за т.нар. „Мрежови иновации" като противоположност на т.нар."Изобретателски иновации" (изобретения, които са предпоставка за комерсиализирането на принципно нови продукти) и на т.нар. „Лабораторни иновации" (при които значителни екипи от сътрудници систематично усъвършенстват процеси или продукти). Мрежови иновации възникват когато действащи лица от различни организации с различни бази знания съчетават усилията си и по този начин усъвършенстват съществуващи продукти и дори създават нови продукти. За разлика от добре структурираната научно-изследователска дейност мрежовите иновации възникват спонтанно без планиране.

Фокусът на настоящата работа е върху съвместното разработване на иновации чрез интегриране на дейността на доставчиците при разработване на нови продукти или процеси..

При публикациите, свързани с избора на доставчик възникват различни класификации. Една такава схема за класифициране е първоначално оценяване на иновативните способности на доставчиците последвано от групирането им и дефиниране на типовете доставчици [7]. Доставчиците от т.нар. „група А" са силно иновативни. Те са в състояние да създават технологично наситени завършени продукти и предлагат пъстра палитра от възможности за партниране. Най-слабо иновативни са доставчиците от т.нар. „група С" които са слабо специализирани и оперират в значителен брой индустриални сектори. Друга система за класификация на доставчиците е разработена от Кауфман и кол. [8] и се основава върху схващането за т.нар. „технологични експерти".

Друг значим момент, свързан с организационните иновации, е капацитетът за възприемане на иновации от бизнес организациите. Бизнес организациите могат да извличат ползи от коопериране при иновации при определено ниво на собствени специфични знания [9]. Когато става въпрос за доставчици, те трябва да притежават опредено ниво на компетенции за да могат да имат принос при иновации. Създателите на крайни продукти (възложителите) се доверяват на компетенциите на доставчиците, затова способността на доставчиците да намират решения на проблеми и да удовлетворяват изисквания е ключов фактор за иновативните резултати [10],[11]. От тази гледна точка са идентифицирани параметрите на иновативността на доставчиците [12]. Когато един създател на крайни продукти констатира неудовлетворителни параметри на способностите на доставчици (зле подготвени сътрудници, неподходящи информационни системи, зле разработена документация и др.) успешното сътрудничество е застрашено. Проектантските способности на доставчиците, процесите им и познанията им за продуктите и доказателствата за тях (сертификати за качество, референции и т.н.) са индикатори за иновативни доставчици [13]. Капрал и Трайл [12] разкриват, че иновативните доставчици са ангажирани в множество колаборативни отношения и в различни форми на сътрудничество (бизнес мрежи, клъстери, алианси, виртуални организации и т.н.), а не само в отношения с един купувач. Миналият опит на доставчиците в различни форми на сътрудничество е индикатор за способностите им да иновират.

Когато доставчиците притежават потенциал за принос към иновационните процеси на създателите на продукти това не се проявява автоматично, а посредством взаимодействие между двете страни. Успехът на създаването на нови продукти и способността за иновиране зависят от качеството на сътрудничеството между създатели и доставчици [14]. Резултатите от извършени проучвания показват, че за успеха на разработването на продукти способността за коопериране на доставчиците е два пъти по-важна от техническите компетенции на създателите [15]. Чен и кол. [16] стигат до извода, че най-релевантен показател за оценяване на доставчиците е качеството на взаимодействие с тях.

Връзката „Създател на продукт-доставчик" има такова значение защото в процеса на иновации се създава стойност, чийто обхват не може да се предвиди. Това създава проблеми при предварителното договориране на очакваните резултати. Трябва да съществува убеденост, че ще има справедливо разпределение на ползите, които ще се получат. Без такава увереност свободният обмен на идеи ще бъде застрашен. Без процес на обмен ще бъде твърде трудно да се иновира. Затова може да се направи заключението, че при иновации връзката с доставчиците ще бъде по-плодотворна, ако създателите на продукти имат увереността, че по-слабият контрол няма да ги направи уязвими. Могат да се различат два вида взаимоотношения между създатели на продукти и доставчици [11]: технически (дялово капиталово участие или съвместни инвестиции); ориентирани към стойност гаранции (норми на поведение). Такива норми са солидарност; хармонизиране на възникващи конфликти; почтеност на изпълняваните роли; коректност на използваните средства; взаимопомощ; открити комуникации и др. Проучвания [17] показват, че най-релевантни показатели са ангажираността на страните и доверието. Те са основни предпоставки за качеството на взаимодействията.

Съществуват група фактори, които имат косвено влияние, но са значими за успешните взаимодействия при реализиране на иновации. Хакансон [18] идентифицира три характеристики на подходящите партньори при реализиране на иновации: да са на разположение; да притежават необходимия производствен капацитет; да са се доказали като партньори. Резултати от проучвания показват, че регионалните взаимоотношения формират 70-80% от сътрудничеството, докато международното коопериране е по-скоро изключение [18]. На пръв поглед значението на близостта на контрагентите звучи нелогично в контекста на съвременния глобализиран дигитален свят. След еуфорията по електронния бизнес има индикации за преувеличаване на значението на електронните тържища.

3. Проектно сътрудничество при разработване на нови продукти

Възможни са различни механизми на сътрудничество, които могат да се класифицират според типа и интензивността на договорните отношения. Най-значимите форми са: разработване по договор; координирано разработване; съвместно разработване.

Разработването по договор се основава на официални договорености с бизнес организации (доставчици и други бизнес организации) и институции [19]. Договорите определят: обектите за разработване; задачите, които трябва да се извършат; ограниченията, които трябва да се отчитат; продължителността на дейността; финансовите ограничения; условията за използване на резултатите от разработката [19], [20]. Въз основа на такива договори доставчиците изпълняват развойни дейности независимо от възложителя. Следователно възможностите на възложителите да влияят върху процеса на разработване са ограничени. Разработването по договор има смисъл при недостиг на ресурси във възлагащата организация. За прилагане на тази форма на сътрудничество е от първостепенно значение обектът на разработка да е ясно дефиниран, резултатите от разработката да са количествено измерими и развойните дейности да могат да се отделят от други проекти [19], [21].

Координираното разработване се базира на разделяне на задачите между ангажираните бизнес организации. Това означава, че всяка бизнес организация се концентрира върху определени задачи или компоненти. Едни от дейностите се изпълняват самостоятелно от възложителя, а при други са ангажирани и доставчиците. Съществуват три основни форми на координирано сътрудничество [21]:

- Асиметрично сътрудничество (подробни инструкции от възложителя);

- Свободно сътрудничество (доставчиците разработвате отделни компоненти или модули за краен продукт);

- Системно партниране (доставчиците отговарят за разработване на сложна под система на крайния продукт и за интегрирането й с останалите под системи на продукта).

Приносът на всички ангажирани страни определя крайния резултат. Такава форма на сътрудничество се използва при сложни развойни проекти, при които са ангажирани група от доставчици. Всеки доставчик разработва определен компонент от крайния продукт или решава отделни задачи в рамките на развойния проект. Такъв подход спомага за паралелно извършване на развойни дейности и в крайна сметка времето за разработка значително се съкращава

При **съвместното разработване** има по-интензивна форма на сътрудничество спрямо разработването по договор и координираното сътрудничество. То се използва при разработване на продукти, които не могат да са разделят на модули. Следователно възложители и доставчици трябва да предоставят своите ресурси за разработването на проектите [21].

4. Иновации чрез сътрудничество при създаване на LED осветление в български индустриални предприятия

Както е добре известно, изучаването на казуси е емпирично проучване на съвременни конкретни ситуации от реална бизнес среда. Изучаването на казуси е изследователска стратегия за изучаване на динамиката на конкретната ситуация. Процесите за разработване на продукти са твърде хетерогенни и съществуват значими различия при разработването на продуктите. Както бе констатирано при литературното проучване, натрупаното на познание върху процесите за разработване на продукти е все още твърде повърхностно. Затова по мнението на автора изучаването на казуси е един адекватен метод за събиране на първична информация. Целите на придобиването на знания чрез изучаване но казуси са следните:

- да се идентифицират релевантните проблеми, свързани с процесите на съвместна обработка;

- да се предложат възможни решения на проблемите.

Изучаването на казуси може да обхваща отделен случай (ситуация) или няколко случая. Могат да се правят сравнения след анализиране на избраните ситуации. В настоящата работа ще се изучат четири случая, които са свързани с едно средно голямо предприятие – Хаусмайстер АД.

Хаусмайстер АД е бизнес организация, която предлага комплексни решения за дома и офиса. Хаусмайстер АД трансферира водещия немски опит и стандарти, коректност към клиентите и добри практики за интериорен дизайн, качествени ремонтни и довършителни работи, инвестиционно строителство, поддръжка, управление, финансиране и застраховане на имотите на работещите и заети градски хора.

Изследвани са различни форми на сътрудничество между Хаусмайстер АД и три негови доставчика. Доставчиците са български малки индустриални предприятия – Ледлайт БГ ООД; Ентел ТТТ АД; Неосвет ЕООД.

Оперативната дейност за изучаване на ситуациите е извършена на два етапа:

- за всеки от случаите са интервюирани ключови сътрудници относно дейностите между възложителя и бизнес организацията доставчик по протежение на целия жизнен цикъл на съответната разработка. Тази информация е документирана и структурирана под формата на схеми. Описани са в подробности проблемите в процеса на взаимодействие;

- Въз основа на получената и анализирана първична информация относно съвместната дейност по развойни проекти са проведени срещи със сътрудници от възложителя и от доставчиците. Интервюирани са сътрудници, които са отговаряли за проектите за съвместна разработка на продукти. Избрани са такива сътрудници, защото те са се сблъсквали с проблеми по сътрудничеството с възложителя. Проведени са пет половин часови структурирани интервюта на базата на анкетни карти. Въпросите в картите засягат проблеми, свързани с разработваните проекти и по-конкретно въпроси на съвместното разработване на продуктите.

Анализът на казусите се базира на различни фази от жизнения цикъл на разработване на продукти. Въз основа на информацията от интервютата, се стига до заключението, че проблемите и решенията зависят от етапите на процеса на разработка на продукти. Резултатите от изучаването на казусите са представени съобразно четирите стадия в процеса на разработка: Начален стадий; Концептуален стадий; Стадий на детайлно проектиране; Инженерингов и производствен стадий.

Изучаването на казусите е извършено за да се изяснят някои значими аспекти за оперативното управление на проекти при разработване на продукти в сътрудничество доставчици. В четирите казуса са идентифицирани следните процеси за съвместно разработване на продукти:

- извършено е класифициране според формата на сътрудничество. Разграничаването се прави въз основа на трите основни форми на сътрудничество (разработване по договор; координирано разработване; съвместно разработване);

- съществуват различни степени на иновация. Някои от продуктите са модификации на съществуващи продукти с ниска степен на иновация, докато други са изцяло нови изделия с висока степен на иновация (степените са: ниска; умерена; висока);

- Спецификациите (ограниченията) за разработване могат да са строги; умерени; общи. При строги спецификации възложителят получава точно изискваните резултати, стига това да е по силите на доставчика. При общите спецификации доставчиците имат по-широко поле за свои идеи;

- Извършена е класификация на база характеристиките на връзката между възложител и доставчик – доверие, откритост и готовност на сътрудничество и обмен на информация. Степените на отношенията са: добри; умерени; лоши;

- Проектирането и оперативното управление на процеса на разработка предимно се извършват от двете страни (съвместно оперативно управление на процеси) или се влияят от единия от партньорите (оперативно управление на процеси от възложителя или доставчика). Неблагоприятна ситуация възниква ако е налице незначително оперативно управление па процеса на разработка (липса на оперативно управление).

Оценяването е извършено въз основа на информацията получена при интервютата и субективната оценка на автора. В четирите развойни проекта са ангажирани три основни доставчика на възложителя. Данните от изследването са представени в долната таблица.

Таблица 1. *Данни от изследването*

	Продукт	Доставчик	Форма на сътрудничество	Степен на иновативност	Взаимо отношения	Оперативно управление на проектирането
1	Улично LED осветление	Ледлайт БГ ООД	Договорно	Ниска	Добри	Липсва
2	Промишлено LED осветление	Ентел ТТТ АД	Съвместно	Висока	Умерени	Съвместно
3	Интериорно LED осветление	Неосвет ЕООД	Координирано	Средна	Лоши	Възложител
4	Интериорно LED осветление	Ентел ТТТ АД	Съвместно	Средна	Умерени	Съвместно

5. Заключение

Изследователските резултати са получени на база на изучаването на казуси. Такъв подход е счетен за подходящ за целите на работата, защото включва интервюта със сътрудници, които са пряко ангажирани в проекти за съвместна разработка на продукти. В някои от казусите са идентифицирани добри практики за оперативно управление на продуктови разходи и координиране и оперативно управление на дейности съобразно набелязани календарни планове.

В някои от казусите са идентифицирани специфични характеристики на взаимодействие, които са оценявани, доколко са присъщи на процесите за съвместно разработване на продукти. Анализираните процеси за разработване на нови продукти не притежават обща структура, тъй като се отнасят до различни доставчици на възложителя, имат различна продължителност и ангажират сътрудници с различни характеристики. Забелязват се известни различия в процесите на съвместно разработване на продукти, тъй като развойните процедури се базират върху различни конструкции на продуктите. Въпреки тези различия е възможен трансфер на резултати между различните доставчици на възложителя. Процесите на съвместно разработване на продукти се инициират от значимо средно по големина предприятие, което възлага на група малки предприятия роли на доставчици. Разработките се осъществяват от съвместни екипи на възложителя и съответния доставчик. Поради това е възможен трансфер на резултати от предходни проекти към бъдещи такива.

Изследванията, базирани на изучаване на казуси, водят само до качествено определими резултати. Не може да се получат количествено измерими оценки, но такива изследвания са предпоставка за извършване на бъдещи количествени анализи на характеристики, които са идентифицирани при изучаване на казусите. Друга възможност за бъдещи изследвания е изучаване на възприятията на мениджърите относно проблемите и възможните решения, свързани със сътрудничеството при разработване на продукти.

Литература

[1] von Hippel, E. The sources of innovation. New York: Oxford University Press, 1988;

[2] Urban, G. L., & von Hippel, E. Lead user analysis for the development of new industrial products - Management Science, Vol. 34, 1988, pp. 569-582;

[3] Petersen, K. J., Handfield, R. B., & Ragatz, G. L. A model of supplier integration into new product development - Journal of Product Innovation Management, Vol.20, 2003, pp. 284-299;

[4] Petersen, K. J., Handfield, R. B., & Ragatz, G. L. Supplier integration into new product development: Coordinating product, process and supply chain design - Journal of Operations Management, Vol.23, 2005, pp. 371-388;

[5] Hakansson, H., & Eriksson, A. Getting Innovations Out of Supplier Networks - Journal of Business-to-Business Marketing, Vol. 1(3), 1989. pp. 3—34;

[6] Freeman, C, & Soete, L. The Economics of Industrial Innovation, (3. ed.). London, Washington: Continuum, 1997;

[7] Petroni, A., & Panciroli, B. Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry - European Journal of Purchasing and Supply Management, Vol. 8, 2002, pp. 135—149;

[8] Kaufman, A., Wood, C. H., & Theyel, G. Collaboration and technology linkages: a strategic supplier typology - Strategic Management Journal, Vol. 21, 2000, pp. 649-663;

[9] Prabhu, J. C, Chandy, R. K., & Ellis, M. E. The Impact of Acquisitions on Innovation: Poison Pill, Placebo or Tonic? - Journal of Marketing, Vol. 69(1), 2005, pp. 114-130;

[10] Roy, S., Sivakumar, K., & Wilkinson, I. Innovation Generation in Supply Chain Relationships: A Conceptual Model and Research Propositions - Journal of the Academy of Marketing Science, Vol. 20(10), 2003, pp. 1—19;

[11] Sako, M. Prices, quality and trust. Inter-firm relations in Britain and Japan. Cambridge: Cambridge University Press, 1992;

[12] Cabral, J. E. O., & Traill, W. B. Determinants of a firm's likelihood to innovate and intensity of innovation in the Brazilian food industry - Journal on Chain and Network Science, Vol. 1(1), 1999, pp. 33—48;

[13] Croom, S. The dyadic capabilities concept: examining the processes of key supplier involvement in collaborative product development - European Journal of Purchasing and Supply Management, Vol. 7(1), 1999, pp. 29—37;

[14] Hoegl, M., & Wagner, S. M. Buyer-Supplier collaboration in product development projects - Journal of Management, Vol. 31(4), 2005, pp. 530—548;

[15] McCutcheon, D. M., Grant, R. A., & Hartley, J. Determinants of new product designers' satisfaction with suppliers' contributions - Journal of Engineering and Technology Management, Vol. 14, 1997, pp. 273—290;

[16] Chen, I. J., Paulraj, A., & Lado, A. A. Strategic purchasing, supply management, and firm performance - Journal of Operations Management, Vol. 22(5), 2004, pp. 505-523;

[17] Medlin, C. J., Aurifeille, J., & Quester, P. G A collaborative interest model of relational coordination and empirical results - Journal of Business Research, Vol. 58, 2005, pp. 214-222;

[18] Hakansson, H. and Snehota, I. No business is an island - Scand. J. Manage., 5(3), 1989, pp.187–200;

[19] Hauschildt, J. Innovations management [innovation management] (3rd ed.). Munich: Vahlen, 2004;

[20] Wynstra, F., van Weele, A., & Axelson, B. Purchasing involvement in product development: A framework - European Journal of Purchasing and Supply Management, Vol. 5, 1998, pp. 129-141;

[21] Gerpott, T. J. Strukturwandel des deutschen Telekommunikationsmarktes. In D. Fink, & A. Wilfert (Eds.), Handbuch Telekommunikation und Wirtschaft. Muenchen: Vahlen, 1999.

STUDIES AND RESEARCH ON THE DESIGN AND CONSTRUCTION OF A MACHINE FOR TENDERIZE MEAT WITH THE PNEUMATIC ACTION AND AUTOMATION MODULES.

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Abstract: *The mechanical tenderization , during meat processing, can be the advantageous solution for rapid maturation of the product. This method represents the possibility to modulate the working process on optimal variants of applying the impact force, the pressing time and the relaxation time of the product.*

In this paper there is presented an experimental model of machine of our own conception for the optimization of the tenderization process of the meat.

The paper, presents the adequate system of pneumatic action and the automation elements of the working parameters which were made as our own conception for construction of a machine for meat tenderization. Within the elaborated pneumatic scheme of driving there are identified the elements that can be electrically driven and the basis established scheme includes the programmable controller of the process.

Keywords: TENDERIZATION, PRESSING FORCE, PNEUMATIC, AUTOMATION, OPTIMIZATION PROCESS, MICROCONTROLLER.

1. Introduction

The mechanical tenderization methods, most used have been the ones that involve pins or blades that do not have possibilities of changing the working parameters. The method proposed by us for meat tenderization is made by beating and it allows adjusting the working parameters of the machine to different types of processed meat.

In this paper the authors present a machine for meat tenderization by mechanical method. The authors present a pneumatic machine for meat tenderization with elements of automation of the entire working process of tenderization.[9],10].

By own conception of the pneumatic action scheme and automatic system which endow the machine, the authors create the possibility to modulate the working process (of tenderization) in diverse variants of applying the impact force, the pressing time and the release time of the product after each working cycle [1][3]. The entire process is controlled by a microcontroller which has programing possibilities after a cyclograme which was established by the operator.

2. The mechanical structure of the machine. Design and description of scheme kinematical

In figure 1 there is presented the design of this machine, with the following components [9] :

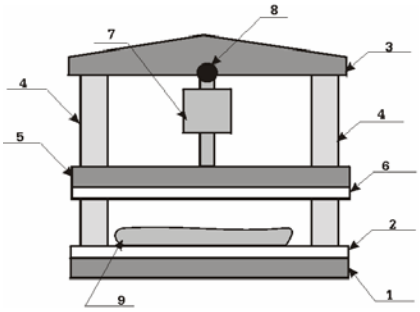

Fig. 1. *The machine for meat tenderization with mechanical operation*

1. Frame
2. Meat placement place – (PTFE)
3. Upper securing cross part
4. Guiding colons
5. Pressing mobile plate
6. Pressing element (PTFE)
7. Pneumatic driving cylinder
8. Coupling ball
9. Product for processing (meat)

The construction and the role of elements are given by their features needed for function. This way, the two guiding colons (4) are jointed with the machine frame (1) and with the upper securing cross part (3). On the two colons (4) slides the pressing plate (5). The movement of the pressing plate (5) is ensured by the driving pneumatic cylinder (7). In turn, the driving pneumatic cylinder (7) is fixed on the upper securing cross part (3) by coupling ball (8) that has the role of taking possible coaxial deviations. The rod of the driving pneumatic piston (7) is jointed with the pressing plate (5) determining its movement.

The functioning of the machine consists of pressing the product (9) between the placement element (2) that is fixed on the machine frame (1) and the pressing element (6) that is jointed with the pressing plate (5). The elements (2) and (6) are made of PFTE (Polytetrafluoroethylene, teflon) in order to meet the requirements of the machine that processes food.

During the function the machine has the following states:

1. Repose – the pressing plate is located in the upper part, the space between the placement element and pressing element is maximal. In this position the product can be put into the machine.
2. The movement of the pressing plate until the product is caught between the two elements. This movement is produced by the pneumatic cylinder.
3. The effective pressing, when the product is caught between the two elements, it is pressed with a force that is proportional with the air pressure from the pneumatic cylinder.
4. Upward movement of the pressing plate done by the pneumatic cylinder until repose position. This state shows the finishing of the processing.[8],[9],[10].

The operator places the product on the surface of the placement element when the machine is at repose state. Then there is given a command of descending of the pressing plate until the effective pressing is made. In this state the product stays a time established by the technology of processing a certain type of meat. When this time ends there is given the command for lifting the pressing plate until the repose state. During the pressing state of the machine the operator can either modify the time of pressing or the pressing force in function of the technology of a specific meat (see below).

The function of the machine is determined by a series of constructive and technological factors. They have been determined in function of the necessities of product processing.

The result of processing is mainly determined by the following factors:

- The processing degree – this refers to the ratio between the initial and final states of the product.
- The quality of processing – it refers to the range of maintaining the product features at the end of processing.

It is obvious that the higher the processing degree, the lower its quality. By determining and choosing the best technological parameters we try to reduce this tendency.

The mechanical construction of machine assumes the knowing of the kinematical scheme so that the operation condition to be fulfilled. On the basis of its design and working principle that have been already presented the kinematical scheme is presented in the figure 2.

1. Placement plate
2. Mobile pressing plate.
3. Guiding colons – jointed with the placement plate.
4. Sliding bearings; they are jointed with the mobile plate for pressing and they glide on the guiding colons.
5. Upper securing cross part – it is jointed with the guiding colons.
6. Coupling ball – for correcting eventual coaxial deviations.
7. Driving pneumatic cylinder.

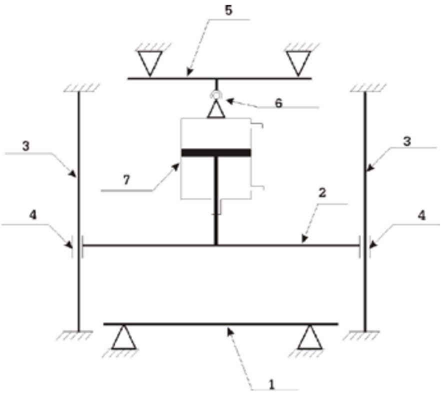

Fig. 2. *The kinematical scheme of the machine*

3. The pneumatic installation for action.

The machine is driven by mean of a pneumatic cylinder. In order to adjust the working parameters in a wide range and to achieve the automation goal of machine there was adopted a pneumatic scheme of operating which is presented in the figure 3.

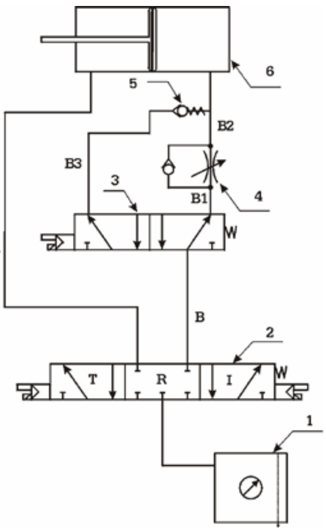

Fig. 3. *Pneumatic operating scheme.*

In figure 3 is presented pneumatic scheme with the following components :

1. Air pressuring unit – compressor.
2. Distributor with electrical command 5 HP/3 positions – it determines the working status (direction).
3. Distributor with electrical command 5 HP/2 positions – it determines the working way.
4. One-way switch of flow – drosel.
5. Anti – back flap.
6. Pneumatic cylinder.

The functioning of the pneumatic installation is characterized by three states:

- Release state – distributor (1) position R.
- Operating – piston pushing – distributor (1), position I
- Operating withdrawal of piston – distributor (1), position T.

In function of the distributor state (2) there are possible two working ways:

- With operation – controlled piston pushing (adjusting the speed at pressing) – distributor (2) not operating.
- No control at piston pushing (maximal speed) – distributor (2) operating.

With the first working way the impact force will equal the pressing force. With the second one the impact force will be given by the following formula (.1.):

$$Fi = \frac{Ep}{d} = \frac{\frac{m_p \times v_p^2}{2}}{Gi - Gp} = \frac{m_p \times v_p^2}{2 \times (Gi - Gp)}$$

(1)

where:

Fi = the impact force
Ep – the energy of pressing plate
d – the distance of pressing action
mp – the mass of the pressing plate plus the mass of the pressing element
vp – the speed of the pressing plate at the impact moment
Gi – the initial thickness of the product
Gp – the thickness of the pressed product

With the controlled speed working way the functioning is as follows:

- Distributor (3) not in action
- Distributor (1) is brought in position I
- The air from the preparing unit follows the way branch B – branch B1 – flow flap – branch B2 – pneumatic cylinder. The air from cylinder will be evacuated on A way into the atmosphere. Due to flow flap (4), the speed of the piston will be determined by the flap adjustment. It is important that on the B3 way air will not circulate due to anti back flap (5).
- In order to withdraw the piston, the distributor (2) is brought to T position where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made as follows: piston – B2 branch – flow flap – B1 branch – B branch – atmosphere. In this case, the flow flap will have no effect because of the direction sense of the air circulation. As for the previous case, on the B3 branch there will not be any air circulation due to the anti back flap.[6].

For the working way with maximal speed, the functioning will be as follows:

- Distributor (3) in action
- Distributor (2) brought in I position
- The air from the preparing unit follows the following path: branch B3 – flap (5) – branch B2 – pneumatic cylinder. The air from the cylinder will be evacuated on the A path into the atmosphere.
- For piston withdrawal, the distributor (2) is brought in position T, where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made through the following path: piston – branch B2 – flow flap – branch B1 – branch B – atmosphere. In this case the flow flap will have no effect due to the direction sense of the air circulation. On the B3 branch will be no air circulation due to the anti back flap.

4.The electrical installation for operation and the automation modules.

For the achievement of the operating and automation electrical scheme are needed the operation conditions for each state of machine as described above. In parallel, the operating must comply with the technological conditions of the process. Besides that the operating should follow the requirements imposed by the functioning parameters.[8],[10].

4.1 Operating principles and conditions

The operating principles result from the technological requirements as well as from the researching methods that are desired to be applied. The establishing of the working pressure that influence both moving speed of the mobile plate will be made exclusivelly by hand through adjusting the pressure at the air preparation unit as well as by adjusting the one way flow flap.

Firstly, there will be adopted two operation ways:

- ➢ Manual operation – where the operator controls manually the movement of the mobile plate;
- ➢ Automation operation – where the operator establishes the functioning parameters and the cycle if automation driven by automation component.

On the contrary with the manual operation, the automatic operation makes an entire functioning cycle. This cycle can be described as having the following states:

1. Descending the mobile plate until the pressing of the product is done.
2. Keeping the product under pressure for a certain time called **pressing time**.
3. The release of the pressing by removing the pressure and lifting the mobile plate on a reduced distance enough for removing pressure on the product.
4. Keeping the release state for a certain time called **release time.**
5. Return to the pressure state (# 2).
6. Repeating points 2 and 3 by a number of times called **number of subcycles**.
7. Withdrawal of the mobile plate in the upper part, finishing a cycle.

The operating conditions are determined by a series of factors as follows:

- Machine architecture
- Technological parameters
- Flexibility in changing the value of the functioning parameters
- Ensuring operation protection
- Ensuring the functioning within the limits of the working parameters.

4.2 The block operating scheme

From the pneumatic operation scheme result the elements that can be electrically driven; they are:

- Distributor of machine states (sense of direction) – this has two driving coils by which the distributor is brought to one of the three states: R, I and T (see above).
- Distributor of the working way – by which there will be established the way the piston will be driven, the controlled speed or the maximal speed.

The block scheme is presented in figure 4.:

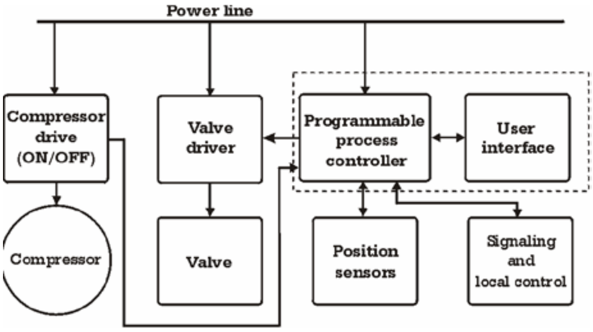

Fig. 4 *The operating block scheme*

The block scheme with the following components :

- Power line – electricity supply line
- Compressor drive – on/off switch of the compressor
- Valve drive – air valve operating block
- Position sensors – position sensors and state; they are:
  - Superior course cut-off
  - UP position of mobile plate transmitter
  - DOWN position of mobile plate transmitter
  - Cut – off protection flap – the machine is endowed with a flap that limits the working space of the machine in order to ensure operator protection [5].
  - Sensor of compressor state – it signals the state of the compressor ON/OFF
  - Programmable process controller, User interface.
- Signaling and local control – through these features the operator can make functioning commands; they are:
  - Signaling of UP movement of the mobile plate
  - Signaling of DOWN movement of the mobile plate
  - Signaling the working way – manual/automatic
  - Signaling the driving mode – normal speed/maximal speed
  - Command of DOWN movement of the mobile plate
  - Command of UP movement of the mobile plate
  - Command START automatic cycle
  - Command STOP automatic cycle

4.2.1. Scheme electric drive

Pneumatic scheme resulting from items that can be electrically operated. These are:
• Distributor machine states (sense) - it has two coils is operated by the retailer brought in one of three states, R, I, T (see above)
• Distributive approach - that will determine how to drive the piston, controlled speed or full speed.

Compressor drive circuitry is shown in the figure below. Also in this scheme it is and transformer that provides the necessary voltage supply 24V DC-dispensers shareholders. In figure.5 is presented electric drive compressor scheme.

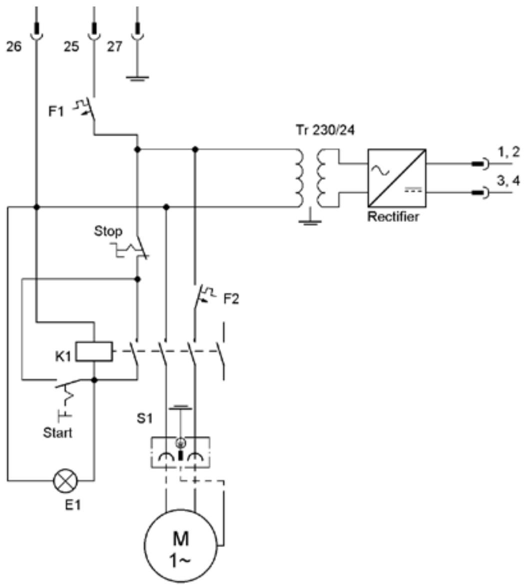

Fig.5 *Electric drive compressor scheme*

Notations in the figure represent:
- 1, 2, 3, 4, 25, 26, 27 - is generally placed in positions of connector switchboard
- F1 - Breaker - general
- F2 - breaker / thermal - compressor motor protection
- K1 - power contactor compressor
- S1 - connecting compressor outlet
- Start - start button compressor
- Stop - stop button compressor
- E1 - compressor status signaling lamp
- Tr 230/24 - the processed 230V / 24V
- Rectifier - 24V DC voltage rectifier + filtering shareholder distribution

Scheme of electric drive pneumatic distributor is shown in Figure 6. Also in this scheme are summarized these elements:

- Adapters level position sensors
- Local signaling Power
- Power Position Sensor

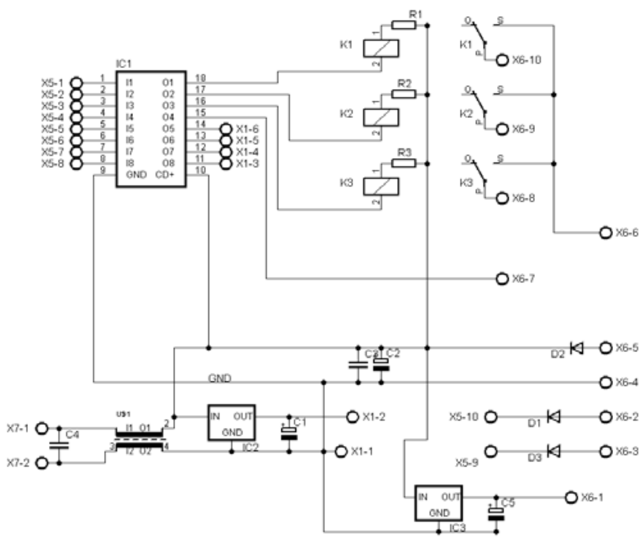

Fig. 6 *Scheme of electric drive pneumatic distributor.*

4.3 Elements of automation and possibilities to use

The block scheme of electrical operation is endowed with the programmable controller of the process that is the main element of machine commands [8],[9].

Programmable process controller is a real time programmable module with 8 digital entries and 8 digital exits. The implemented program into the controller has to comply with the functioning requirements of the machine. The controller is presented in the figure below.

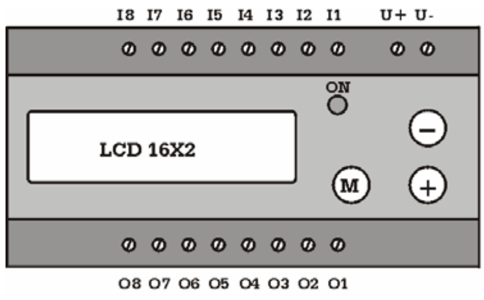

Fig. 7 *The programmable controller*

In the upper part there are 8 entries, from I1-I8. Also, here is mounted the power switch U+, U-. The exits O1-O8 are located in the bottom part. The connections to the controller are made by coupling the signal cables with the screw connectors according with the signal. The interface with the user is made of an alphanumeric screen of LCD type which has 2 rows and 16 characters on each row. Also, there is a small bulb signaling that the processor is ON. The user can change the parameters by operating one of three buttons:

M- menu

+ - plus – increase a value

- minus – decrease a value

The implemented program in the controller implies the approaching of some aspects related to the state of the machine, the working way and the working parameters. The controller having as signals of entry the position sensors, the state of the compressor starting connector, the state of the protection flap and the state of the switchers of working way and driving mode can operate separately each state of the machine.The states of the machine are given by the working way and the position of the mobile plate.

With manual mode, the state of the machine is not limited by the program but for the lifting of the mobile plate so that the pneumatic cylinder of driving should not reach at the end of the course (at the limit).

With automatic mode the machine states have been described below and they are:

- Repose
- Descending the plate
- Pressing
- Release
- Lifting the plate

Also, the programmer should allow the user to set values for the working parameters. The working parameters are:

- Pressing time
- Release time
- Number of subcycles
- Time of error for movement

The last one, the time of error for movement is a parameter that limits any movement in time. If this time is exceeded, it is assumed that a defect has occured and a system error is started. The error is removed by stopping and starting the air compressor. The program is structured in several sections:

- Initialization
- Detecting the state of the machine
- Manual working way – if selected
- Automatic working way – if selected
- Parameters setting mode
- Error into the machine

The two active machine working ways, automatic and manual, can be graphically represented.[5],[10]. With the same aspect there can be represented each of the working states of the machine: the working graph of the repose state, of the pressing state, of the release state, etc. For instance, for the automatic working way, the graph of the function is presented below:

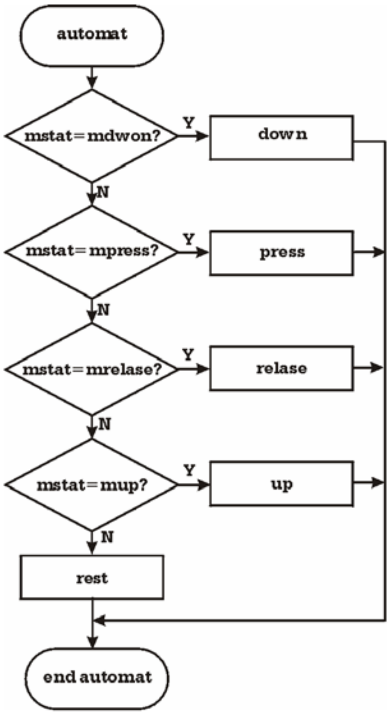

Fig. 8 *The working graph of the automatic working way*

In this working mode the states are tested and for every one it is executed the specific function. The states noted in the figure with their correspondents are:

- mrest – repose
- mdown – Down movement
- mpress – Pressing
- mrelase – Release
- mup – Up movement

If the system variable is not something that implies movement (mdown, mpress, mrelase or mup) it results that it is in mrest – repose.

5. Conclusions

- The mechanical tenderization is a modern technological component of the process of meat manufacture. It allows the worker to modulate the working state of the machine on different optimal variants of applying the impact force, the pressing time and release of the product. It permits the worker to adjust the working parameters to the type of the meat; this issue makes this paper original;

- The experimental model of the machine presented in the paper is of our own conception and it can solve the problem of meat tenderization within the meat processing technology;

- The authors have designed and constructed a pneumatic installation of operating the machine for mechanical tenderization where all working states of the process are automatic;

- The programmable controller of the process has his own software program that ensures a programming variant after a cyclograme that was established by the operator;

- The working graphs that are presented in the paper determine the recording of the functioning cyclograme that is needed for the performance of functioning.

- The present paper opens directions for researching in automation of different steps of technologies for meat processing.

References

1. Davis, K. A., D. L. Huffman, and J. C. Cordray - Effect of mechanical tenderization, aging, and pressing on beef quality. Journal of Food Science. Volume 40, Pages: 1222-1224, 1975.
2. Heller, C. E et all. - Decontamination of beef subprimal cuts intended for blade tenderization or moisture enhancement. Journal of Food Protection. Volume 70, Pages: 1174-1180, 2007.
3. Jeremiah L. E., L. L. Gibson, and B. Cunningham - The influence of mechanical tenderization on the palatability of certain bovine muscles. Food Research International. Volume 32, Pages: 585-591, 1999.
4. Loucks, L. J., et all., - Effect of mechanical tenderization and cooking treatments upon product attributes of pre-rigor and post-rigor beef roasts. Journal of Animal Science. Volume 58, Pages: 626-630, 1984.
5. Măcuţa S., - Elemente de mecanică fină şi servomecanisme. Editura Didactică şi Pedagogică Bucureşti, 2003.
6. Oprean A. şi al., - Acţionări şi automatizări hidraulice. Sisteme mecano-pneumo-electrohidraulice. Editura Tehnică Bucureşti, 1983.
7. Oprean A., - Hidraulica maşinilor unelte. Editura Didactică şi Pedagogică Bucureşti, 1978.
8. Aurel Simion,Thesis of PhD, University of Craiova , june 2015.
9. Simion Aurel, Badescu Mircea-Studies and researches on designing and constructing a machine for meat tenderization in order to obtain traditionally products.- Annals of “Dunarea de jos” University of Galati,Mathematics,Physics,Theoretical,Fascicle II,year V(XXXVI),2013.
10. Simion Aurel,Mircea Badescu, Silviu Macuta-Studies and researches on the pneumatic action of a machine used for meat tenderization and possibilities for automation of this operation- Annals of “Dunarea de jos” University of Galati,Mathematics,Physics,Theoretical,Fascicle II,year V(XXXVI),2013.

METHODOLOGICAL ASPECTS OF A SUSTAINABLE DEVELOPMENT TRAINING IN THE HIGHER EDUCATION IN BULGARIA

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Abstract: *Learning different aspects of the international quality standards turned into an urgent necessity in the students' training, which gives them a possibility quickly to adapt to the practice during their professional realization as specialists. Generally, the preparation of the students of quality management in our country is well accepted in the different educational institutions and is conformable to their specific features. As a disadvantage it may be shown the fact, that the students' training is limited only to the knowledge for quality management receiving. It may achieve a wider range, including a preparation for environment standards (ISO 14000), for safety (ISO 18000) and for quality, which basic principles further the management of this combination and, in the long run, for one sustainable development.*

The purpose of the present article is to be worked-out and presented the basic methodological aspects for sustainable development training in the higher education, which will give an opportunity to the students to receive wider knowledge in this field.

With the help of the basic methodological aspects, has been worked-out a concrete model syllabus for sustainable development training of the students from the higher technical schools in our country.

Keywords: ASPECTS, TRAINING, SUSTAINABLE DEVELOPMENT, HIGHER EDUCATION,

1. Introduction

Learning different aspects of the international quality standards turned into an urgent necessity in the students' training, which gives them a possibility quickly to adopt to the practice during their professional realization as specialists. Generally, the preparation of the students of quality management in our country, is well accepted in the different educational institutions and is conformable to their specific features. This training has been still restricted only in receiving knowledge for quality management [1, 2, and 3].

In recent years, in a number of European universities is being quickly introduced sustainable development training of students. Here the question is about training according to the environment standards (ISO 14000), for safety (ISO 18000) and for quality, the combination of which corresponds to the needs of production enterprises their articles to answer to the complex conditions for high quality and environment protection. All these demands, staked from the very stage of the development of the relevant article (product) and executed in the process of its production, form prerequisites for one sustainable development.

The purpose of the present article is to be worked-out and presented the basic methodological aspects for steady development training in the higher education, which will give an opportunity to the students to receive wider knowledge in this field. In order to achieve this aim, a correspondent syllabus is necessary.

2. Character of the sustainable development training

Sustainable development training's introducing in the higher education aims at both making the student acquainted with the basic normative documents and developing habits needed for working-out high quality products, minimum production expenses and maximum corresponding to the demands for environment protection.

In the present article are worked-out the basic methodological aspects of such students' training in specialties, connected with the machine-building production [4].

Basic methodological aspects

1. Training for production technologies' choice, constituent elements and appropriate materials, which to allow the recycling of the products after the term expiration of working.
2. Training on determination of the effect of the already produced article on the environment during its whole term of working.
3. Learning all laws and standards, connected with the environment protection, which have connection with the article being produced, and their correspondent application from its development stage to its going out of production.
4. Receiving the knowledge, necessary in connection with suppliers, trades and customers, who to be informed and made literate enough, in order to the trade and exploitation of the article to be relevant to the staked on it demands for environment protection.
5. Learning and determining the expenses, connected with the environment protection during the term of article's exploitation.
6. Training on determining the influence of the energy and fluids used on the environment during the time of the whole exploitation cycle.
7. Creating habits for presenting a new product and emphasis on innovations, used in its working-out, in order to protect the environment.

The presented basic methodological aspects of the sustainable development training for students from machine-building specialties, suppose working-out a syllabus with a concrete matter [5].

3. Sustainable development training syllabus

The offered syllabus for training students from machine-building specialties consists of the next modules (Fig. 1):

1. Industrial production and eco-development.
2. Instruments and methods for sustainable development of the industrial production.
3. "Clean" technologies and innovations.
4. Science and communications.
5. Project of an article (product).
6. Production experience in an industrial enterprise.

Each of the modules shown, has its own aim, and the first four modules have a number of disciplines, being learnt, too. After taking an examination in them, the students receive the needed knowledge and a level of competency and they can go on to a next module.

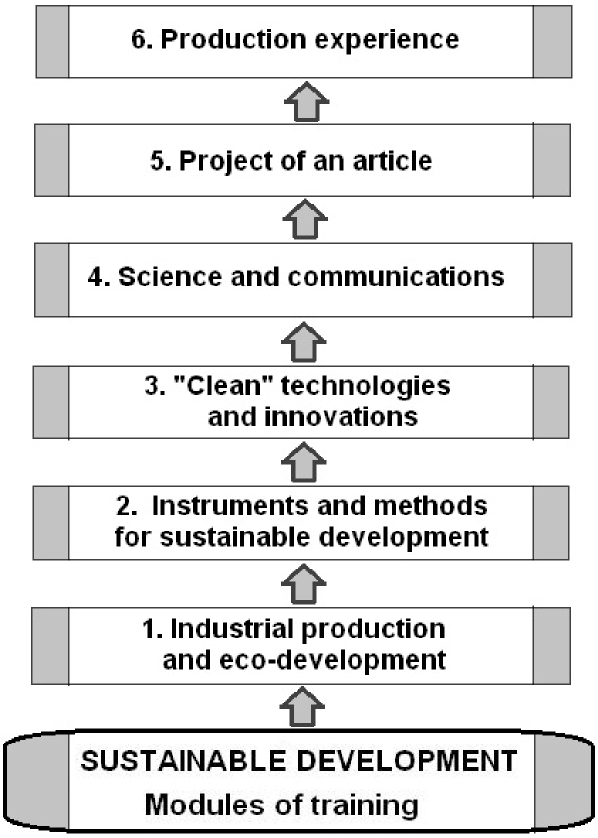

Fig.1. *Sustainable development training syllabus*

Module 1. ***Industrial production and eco-developments***

Aim:

- Achieving the necessary scientific and organizational competency for realization industrial production, corresponding to the sustainable development requirements;
- Knowledge according to legislation requirements for ecological production;
- Made acknowledged with new technologies and their connection with the innovations;
- Enlargement of the culture on environment protection;
- Determining the place of the industrial enterprise in the conditions of a global competition.

Disciplines being learnt:

1. Eco-management
   - Law and environment;
   - Industrial production and ecology;
   - Sociology of the industrial production;
   - Products and systems for sustainable industrial production and indicators for its sustainable development;
   - Management, oriented to production, corresponding to the ecological requirements.
2. Eco marketing
   - Competition and environment;
   - Trade communication;
   - Industrial ownership;
   - Laws, standards, normals, etc.;
   - Forthcoming introducing of new regulations;
   - Eco-labels.
3. Production treatment after the term of exploitation
   - Eco-toxicology;
   - Recycling of the production and materials;
   - Throwing-out the recycled products;
   - Economic effect of the recycling;
   - Treatment and valuation of the waste matter.

In this module of training are included meetings and discussions with specialists from the industrial production, experts on standardization and visits of industrial enterprises, too.

Module 2. ***Instruments and methods for sustainable development of the industrial production***

This module could provisionally be divided into two parts. Each of them has an aim and correspondingly forming it disciplines.

The first part's of the module aim:

- Giving the parameters for environment protection and the safety in the stage of the task for working-out the article;
- Ways of determining the exploitation term of the article;
- Clearing-up and concrete formulation of the criteria for ecology in the working-out stage;
- Presenting of an eco-plan for choosing materials, way of transportation and treatment of the waste matter;
- Research the effect of the ready product on the environment and the consumption of energy during its whole exploitation cycle;
- Using different methodological means of working-out of ecological products: computer software;
- Presenting the optimal way of recycling.

Disciplines being learnt in this part of the module:

1. Exploitation term of the articles
   - Analysis of the possible term for exploitation of the article;
   - Quality assessment of the article in the exploitation term;
   - Indicators for determining the achieving the staked ecological parameters from the article in the exploitation term.
2. Quality assessment
   - Functional analysis;
   - Evaluation of the article in a connection with the achieving of the parameters staked;
   - Experiment plan.
3. Means for working-out of eco-articles
   - Using of appropriate computer software;
   - Safety and ergonomy of the article being worked-out.
4. Used energy and fluids
   - Sources of renewed energy;
   - Managing energy consumption;
   - Energetic calculations.

The second part's of the module aim:

- Practical acknowledgment with CAD software products for working-out of the articles, choosing materials, determining the exploitation term: CATIA, FUSIMAT, PLM-Catia, etc.;
- Training on using different inter discipline connections at working-out the articles;
- Acknowledging with the methodological approaches at working-out different variants eco-articles: with "a continuing exploitation term and weak spreading-out" and "a short exploitation term and great spreading-out";
- Acknowledging with the methods and approaches at working-out of already produced similar eco-articles.

In the second part of the module have been learnt the computer software and have been worked-out projects in different fields of the machine-building: auto building, electrical equipment, electronic articles, aeronautics, shipbuilding, etc.

In the task of each of the projects are staked requirements the article to be relevant to certain ecological demands at using innovation technologies.

Module 3. ***"Clean" technologies and innovations***

Aim:

- Deepening the students' knowledge and widening their competences in the sphere of technologies;
- Discovery of new and innovative technologies;

- Analysis of advantages and disadvantages of the technologies, used until now.

Disciplines being learnt:

1. Technology of production
   - In the machine-building;
   - In the electro technical production;
   - In the automation;
   - Production processes: founding, welding, etc.;
   - Surfaces treatment;
   - Metrological control.
2. Technical servicing
   - During the exploitation cycle;
   - Current and planned technical servicing;
   - Integration of the technical servicing from the very stage of working-out the article.

Module 4. ***Science and communications***

Aim:

- Deepening the knowledge in using the scientific methods and approaches at working-out the articles;
- Argumentation of the choice of the production technology and the choice of the most
- appropriate materials;
- Using of existing and working-out new documentation for the article;
- Training in a team at working-out articles with ecological requirements.

For execution of the aims shown, the students study:

- Applies science: physics-chemical and mechanical qualities of the materials, technologies for treatment of different kinds of materials, etc.
- Communications: the ways of integration in teams on working-out similar projects.

Module 5. ***Project of an article (product)***

The teaching staff, with the participation of production enterprises, offers to the students to work-out a project for an article, with included requirements for environment protection. It is necessary to be ensured adequateness of the project with the aims of the sustainable development training.

Module 6. ***Production experience in an industrial enterprise***

The training of the students has to finish with a practical experience in an industrial enterprise not less than one semester. During the practice, the students work-out their personal project, or take part in a team on working-out another concrete project for an article. The requirement is to be ensured to the students a correspondence between the aims of the sustainable training and the content of the production practice in the enterprise. At the end of the practice, the students present a written report and go in for an oral defense.

4. Conclusions

1. There are worked-out the basic methodological aspects of students' training on sustainable development in the universities in Bulgaria. These aspects are for the students from the machine-building specialties of the universities.
2. On their foundation, a syllabus for sustainable development training has been worked-out, which consists of six independent modules. For each module has been shown the aim, which has to be reached and have been shown the disciplines, or the ways, in which it to be realized.
3. The worked-out basic methodological aspects could be used successfully at training students from another specialties of the higher education, too, as for them to be offered the existing, corresponding to them, syllabus.

5. References

[1] Pandev G. Learning of the international standards of quality – factor for increasing the level of higher education in our country. *4th International Conference "Standardization, Protypes&Quality: A Means of Balkan Countries' Collaboration"*, May 18-19, 2007, Thessaloniki, Greece.

[2] "Le management de la qualité des normes ISO 9000: 2000 est-il applicable aux EPLE?". *Technologies&Formation*,№105.

[3] "Enseignement de la qualité et enseignement industriel de qualité". T&F № 107.

[4] Quénet P.& Soudjian G. Cultiver le developpement industriel. *Technologies&Formation*, 96.

[5] Une licence professionnelle en éco-conception. *Technologies&Formation*, № 120, 2005.

FINANCIAL - ECONOMIC ASSESSMENT OF INNOVATIVE PROJECTS

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Abstract: *The national economy restructuring ,the European Union membership and globalization clearly outline the necessity of implementation of various activities, including innovation by which companies to form long-term competitive advantages. This creates the need for implementation of systematic and reliable research of the effectiveness of the implemented innovation as a component of overall efficiency. This requires improvement and grounded updating of traditional approaches to financial and economic evaluation of the planned innovation and related activities. In the proposed work are presented the opportunities for planned innovations economic assessment with the help of financial and economic instruments through the use of information technology.*

Keywords: INNOVATION, INNOVATION PROJECT, ECONOMIC EVALUATION, FINANCIAL-ECONOMIC INDICATORS, INFORMATION TECHNOLOGY

1. Introduction

The national economy restructuring, the European Union membership and globalization clearly outline the need for the implementation of various activities, including innovation by which companies to form long-term competitive advantages. This creates the necessity of implementation of systematic and reliable research of the implemented innovation effectiveness as a component of overall efficiency. This requires improvement and grounded updating of traditional approaches to financial and economic evaluation of the planned innovation and related activities. The reason is that this tool is not used in an adequate level by industrial enterprises managers, plans developing for implementing innovation is rather random in nature, and appropriateness analysis of the planned rarely does.

Determination of appropriateness of the implemented resources in any innovation and related activities at the planning stage allows the decision maker to assess whether this innovation is justified in respect of implementation funds.

The successful innovation implementation is a prerequisite for a competitive market presence in the industrial enterprises economy. In the existing conditions, the use of appropriate tools for determining financial and economic feasibility of implementing an innovation and related activities is necessary.

Important role for the economy prosperity plays the ability of creation and implementation of innovation. Innovations implementation is a determining factor for enterprises competitiveness increasind. An important step to overcome the existing lagging behind the developed European economies is to promote innovation process in the country. The European and global experience points that skillful use of research, advanced technologies and innovation, makes it possible to take active steps to increase the competitiveness of the economy and raise living standarts. The transition to the knowledge economy and joining global information society appears to be the main challenge.

Industrial Enterprise is a multifaceted entity having social, technical, legal, economic, product-market and organizational and managerial aspects, and builds specific policies for implementation of various activities. Effectiveness evaluation of the activities in industrial enterprises does not contribute for improving the decision quality. The used criteria to evaluate the businesses performance needs systematization and respective inclusion in the summary approach to the assessment of their activities.

The planed innovation financial-economic analysis performance for the development of any industrial establishment and development of a common approach to financial and economic evaluation of innovation is a necessary task in modern society[4].

The planned innovations assessment opportunity is presented in the proposed work understandably with the help of financial and economic instruments through the use of information technology.

2. Theoretical assumptions about the innovation nature and related activities

The innovation process is a sequence of actions, from generating ideas for innovation to develop the final product and its commercialization, which are described and justified in the innovation project. This is a creative, cyclical, complex and expensive process, a result of a number of interrelated activities, which type and specificity depend of the scale of the innovation project and are not always innovative. For the realization and implementation in their entirety and complexity specific interdisciplinary knowledge and skills are required [1].

Whatever field of application is innovation is associated with novelty, which should be a value above all because the enterprise is on the way to realize it. The essence of innovation due to the specifics of its manifestation, enables multifaceted interpretation which leading to the formulation of new questions that need to be addressed. Innovation is a knowledge-based and involves product creation, creation of process or technology and innovation is measured by the degree of novelty for the firm and / or market. Innovation leads to increased competitiveness of the enterprise, industry, economy, or to increased user satisfaction. It is a process and result of the process in the core of which is innovation.

The effective use and implementation of innovations should be well planned, adequate to market realities and financial capabilities of industrial enterprises. This requires further development of existing tools for assessing the appropriateness of the expenses for innovation and development of a common approach for evaluation.

Innovation is most often defined as a change aimed at renewal or introduce something new and useful in practice, it is possible to happen in different areas: business, society, politics, science, art and more. There are different concepts of innovation, in 1934. Joseph Schumpeter first defines innovation as a useful change - an engine for economic development. He specifies 5 main cases of innovation in the economy:

- New product introduction;
- New method of production;
- New market opening;
- New source of raw materials / resources for production use;
- Creation of new organization of work or relationships between companies in the same industry.

Depending of the adopted principle of classification different types of innovation are known. Depending on the degree of novelty distinguish radical (revolutionary) and incremental (compilations, improvements, imitations, etc.). Innovate. The most common innovations are compilations (such as mergers characteristics of multiple devices in one as a printer / scanner / copier), improvements and modifications. According to the outcome distinguish product, process, market, financial, organizational, logistics and others. innovation. The creation of new products and services, and the change in the ways of selling, advertising, delivery are among the most - popular innovation today. Usually innovations are seeking a solution to a problem such as:

- Customers unmet needs;
- Unused opportunities for production and sales of product sought;
- Basic model unsatisfactory performance characteristics;
- Basic product unsatisfactory reliability, quality;
- Basic product production, delivery, sale higher cost;
- Technical and structural difficulties in the production process.

Key factors determining the success of an innovation is its relevance and utility, the company's ability to mobilize quickly knowledge and skills for implementation and the possibility of organizing production and sales faster than competitors, flexibility in modifying innovation for different markets and customers.

Innovation process stages.[3]

1. Market analysis, including analysis of customer needs, and analysis of the existing and future competition.
2. Evaluation of the technical and organizational resources of the company and their own potential sources of innovation.
3. Defining the subject of innovation activities and terms of reference.
4. Establishing and structuring team for the realization of design.
5. Development of a concept for the realization of innovation with a linear schedule and an estimate of the project cost and the expected results. Comparative analysis.
6. Decision on the implementation or rejection of the project.
7. Development of technical project in detail remit.
8. Feasibility study of innovation. Adoption of the final budget for its realization.
9. Making innovation.
10.Testing.
11.Innovation implementation.
12.Promotion.
13.Results evaluation. Conclusion.

Basic steps in the innovation implementation.

(1). Generating ideas for innovation.
(2). Selection and evaluation of idea for innovation.
(3). Protection of the idea.
(4). Investigation of the idea usefulness and market opportunities.
(5). Check of the idea feasibility.
(6). Planning and organizing of the implementation.
(7). Development of a test sample (prototype).
(8). Testing.
(9). Manufacturing of the new product / service.
(10). Monitoring, control and adjustment of the new product / service.

It is possible unification of some of these steps or another sequence, depending on the specific situation and capabilities of the enterprise.

3.Financial economic evaluation of innovative projects[2]

Project evaluation is aimed to determine whether and to what extent new or advanced technologies and products will improve the competitive position of the company. The assessment of innovative projects can be viewed in different ways: economic evaluation; social; evaluation from a strategic perspective; environmental assessment; independent risk assessment; net present value, calculated on the basis of equivalent risk-free flows; net present value calculated based on risk-adjusted discount rate. That ultimate goal of any innovation requires investment and projects to be evaluated by the financial economic perspective. Evaluation of the innovation project should reflect the full potential of new or advanced technologies and products to bring benefit to the company not only for one year but for a certain period. This allows to reflect the time factor, appearing in the different starting point of production commencement[5].

In the present publication the author is considering the step " Selecting and evaluating of idea for innovation."in the stage "Feasibility study of innovation", and the author of the publication offers for - optimal assessment of innovative projects to apply the following assessment methods:

- Net present value (NPV - Net Present Value)
- Internal rate of return (IRR - Internal Rate of Return)
- Payback period (PVP - Payback Period)
- Profitability Index (IP - Index Probability)

Method of net present value

Present days investment and innovation analysis assumes that the net present value is the most practical application. [4] It is the leading indicator for evaluating the effectiveness of investment projects, as best indicator to what extend has improved the welfare of the owners (shareholders) of the company. This method determines whether the sum of the discounted net cash income over the duration of the economic life of the project exceeds the amount of discounted investment costs. The formula for calculation of the "net present value for the investment that has more than one cash flow has the form:

$$NPV = -C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + ... + \frac{C_n}{(1+r)^n}$$

The criterion for evaluating and ranking the projects under consideration is the method: the maximum positive net present value. On this basis, displays the following rule of decision:

NPV> 0 - the project is considered

NPV <0 - the project is rejected

NPV = 0 - the project is on the verge profitable / unprofitable and further analysis is needed.

Method of internal rate of return

IRR represents that discount rate that equalizes the amount of positive cash flows discounted by the amount of negative (cost) cash flows generated by the project. In other words, IRR is the discount rate at which the net present value becomes zero. If we use the formula for finding the net present value, internal rate of return will be the rate of discounting in the following equation:

$$-C_0 + \frac{C_1}{(1+IRR)} + \frac{C_2}{(1+IRR)^2} + ... + \frac{C_n}{(1+IRR)^n} = 0$$

To assess the project effectiveness by using the IRR indicator is necessary to know what is the market rate.As market interest rate can be used interest rate at which the bank would grant a loan. In this case, if:

IRR> r - project is considered

IRR <r - the project is rejected

IRR = r - project on the border profitable / unprofitable

Payback period method

This method is one of the most popular and widely used methods of evaluation and selection of investment options. The method payback period determining the length of time needed to recover the initial investment at the expense of financial results of the investment. If the cash incomes in the years are the same, the formula for determining the payback period is as follows:

$$PBP = \frac{IC}{NI}$$

PBP - payback period

IC - initial investment

NI - average net cash flow

Index Profitability Method

The index of profitability shows the value (income) obtained from every lev initial investment while respecting the time value of money. The formula for calculation of the profitability index is as follows:

$$PI = \frac{\frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + ... + \frac{C_n}{(1+r)^n}}{C_0}$$

The criterion of selection the project is as follow:
If PI> 1 project is considered
If PI <1 project is not accepted
If PI = 1 project on the border profitable / unprofitable

Information technology use for financial - economic evaluation of innovative projects[1]

To provide investment evaluation, especially for the calculation of economic indicators, and especially for IRR it is mandatory to apply software - an essential element of information technology. The author has developed a method by which, after analysis and preparation of input data for the calculation of economic fundamentals and relevant calculations assessing the economic efficiency. As a result of calculation of financial indicators, net present value, internal rate of return, payback period and profitability index the method valued the planned innovation activities. It is a tool to assist management practice in planning innovation activities and various associated with them to.

4 Conclusion

Innovations are one of the main factors for the successful development of business in a competitive market environment. There are a variety of methods for the assessment of innovative projects. The main methods used by international financial institutions are described in the development of net present value method and the internal rate of return. Other specified methods serve to introduce additional criteria for assessing innovation, but also complement the information on the return of investments for realization of innovative projects. We must seize the opportunities of modern information technologies. Each innovative project itself is unique depends of the company and particular area of application which fact gives flexibility to not necessarily apply unified approach to financial - economic evaluation. It is recommendable analysts to reconsider which methods are best suited for use in different versions for innovation. Nevertheless of the manner of conducting assessment of each project this is a tool for increasing the efficiency of operations in Bulgarian enterprises and their sustainable development .

References

1. Славов Здр., Брусева М, Николаева В., Ненков Ст., Стоилов Т., Стоилова Кр., Владимиров М. Методи и одели за взимане на бизнес решения, ВСУ, Варна, 2013
2. Брусева М., Съвременни подходи за оценка на инвестиционните проекти и ролята им за повишаване на конкурентноспособността на фирмите в процеса на инвестиране, МЕЖДУНАРОДНА НАУЧНО–ПРАКТИЧЕСКА КОНФЕРЕНЦИЯ „УСТОЙЧИВО РАЗВИТИЕ- 2013” 14 – 19.06.2013, х-л „Ханът” – КК „Св.Константин и Елена”, Варна
3. ВИСОКОТЕХНОЛОГИЧЕН БИЗНЕС ИНКУБАТОР, Ръководство за иновации за малки и средни предприятия ,Регионална Агенция предприемачество и Иновации - Варна, по проект№ 014664 „Регионална иновационна стратегия на Североизточен район за планиране” , 2012
4. Костова В.,Оценка на иновационната дейност на малки и средни предприятия, Автореферат, ВСУ, Варна, 2011
5. http://www.e-dnrs.org/?page_id=3388

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INTRODUCTION OF AN INNOVATIVE TECHNOLOGICAL PROCESS IN THE GEAR GRINDING WORKSHOP AT ZMM NOVA ZAGORA

ВНЕДРЕНИЯ ИННОВАЦИОННОГО ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА НА ЗУБОШЛИФОВАЛЬНОМ УЧАСТКЕ ЗММ НОВА ЗАГОРА

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Abstract: *The article studies the prerequisites for the introduction of process innovations at ZMM Nova Zagora JSC. The main principles of an original approach for decreasing the degree of discrete manufacturing by introducing an innovative technological process for mechanical machining of tooth gears are expounded. The results of its introduction in the gear grinding workshop are presented.*

Keywords*: TECHNOLOGICAL INNOVATIONS, UNIFICATION OF TECHNOLOGICAL PROCESSES, GROUP TECHNOLOGY, GEAR GRINDING*

1. Introduction

The dominant factors on the world markets in the field of machine building are price, quality and flexibility. Nowadays the modern market situation also concerns the production of metal cutting machines, which more and more frequently makes manufacturers offer new variants or modifications of existing machines. A change in the character of production is observed when the product range expands and the series decreases.

The companies, manufacturing components and units, apply different approaches in order to adapt their organisational and production structure to fast adjustment when changing from one product to another. Process innovations are a good basis for optimisation of technological expenses, for the quality of the manufactured products and for the flexibility of the production process.

2. Prerequisites for the introduction of an innovative technological process

The production of tooth gear occupies a major share in the product structure of ZMM Nova Zagora JSC and it has the following technological profile:

- Wide product range – over 560 types;
- Primarily single and small series production – from 4 to 200 items;
- Wide scope of parameters – outside diameter from 30 to 500 mm, module from 1 to 15 mm;
- Average gear accuracy grade – 6.

Conventional methods and typical technological processes are applied in the gear manufacturing process. Gear grinding, which is carried out according to the generating method, is the finishing operation for the majority of them (over 60%).

The gear grinding workshop is organised according to the object-locked areas principle, preserving its operational specialisation. The average coefficient of the ratio of operations performed per workstation is $K_{op} = 11$ and the production flexibility coefficient is $K_{pf} = 0.91$. There are six gear grinding machines in the workshop dating from 1972 to 1987, which are outdated and have exhausted service life. The cutting conditions are low: feed rate – 1000 mm/min (for rough machining) and 300 mm/min (for finish machining). The time losses for changing the machine settings, for dressing and changing the tools, and the expenses for labour and maintenance of the technological equipment are considerable.

According to company data for 2014 gear grinding machining time amounts to 13% of the total gear manufacturing time and gear grinding cost constitutes 7% of the total cost.

The analysis of the company production programme for 2012-2014 (Fig. 1) shows:

- 61 types of tooth gears drop out of production and 154 new types are introduced;
- tooth gears with external diameter of up to 400 mm (over 98.7%) and with module of up to 4 mm (about 99%) predominate;
- over 80% of tooth gears are manufactured in series of up to 200 items, which amount to between 28.6% and 40.6% of all gears in terms of quantity;
- the range of different gears manufactured in series of up to 10 items has increased 1.5 times and the range of those manufactured in series of up to 100 items has decreased insignificantly while preserving the same quantities;
- the range of different gears manufactured in series of up to 500 items has decreased more than by half whereas the quantities have decreased over 1.5 times;
- the range of different gears and quantities of the remaining types of gear are relatively stable.

As seen from the production programme data and the manufacturing conditions the production of tooth gears in ZMM Nova Zagora JSC is characterised by dynamics as to range of different gears and series production, and a high degree of production flexibility. Economically justified adaptation of this type of production can be achieved by introducing new innovative highly effective technological solutions and up-to-date highly productive technological equipment.

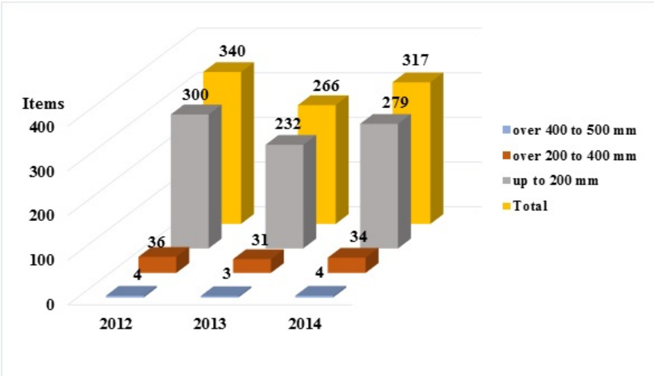

Fig. 1 *Range and serial production of ground tooth gears*

3. Innovative technological process

The main purpose of introducing an innovative technological process in the gear grinding workshop at ZMM Nova Zagora JSC is achieving optimal usage of the technological equipment and reducing technological expenses while guaranteeing stability of the gear grinding process, by target regulating the degree of production flexibility. A new approach to designing and implementing technological processes for machining tooth gears has been adopted in order to achieve this goal. The innovative approach is based on the principles of technology unification and group technologies [1, 2, 3, 4] and contains two main components:

• Introducing unified group technological processes taking into consideration the technological equipment in the gear grinding workshop.

• Development of engineering and technical tools for the implementation of a flexible gear grinding process guaranteeing optimal technological expenses.

The main differences between the existing conception and the innovative one amount to the organizational and technological structure of the preparation and implementation of production processes.

The innovation encompasses the current for 2014 317 types of tooth gears, whose individual technological processes (ITP) are systematized according to the type and sequence of the implemented technological operations. The tooth gears are grouped according to technological characteristics in 6 complex technological groups, for each one of which a complex tooth gear is created. Intelligent parametric 3D models are developed for complex tooth gears within the SolidWorks engineering design system. The group technological operations for machining tooth gears from each complex technological group (76 group technological operations for 317 tooth gears in total) are specified. The complex operational groups are formed by classifying the tooth gears from the complex technological groups by module. Twelve unified technological operations (UTO) are intended for them, each one of them with a defined unified setting for gear grinding machines.

The content of route and operational groups for each complex technological group is specified. Route groups comprise tooth gears, machined at different settings of the machines of one and the same group route technological process. Operational groups include tooth gears, whose technological operations are performed at the same unified settings of the machines.

The aggregate of group route technological processes of a complex technological group forms a unified group route technological process (UGRTP) for machining the tooth gears from this group. The developed structural variants of UGRTP for machining the 317 tooth gears are illustrated through the structure of UGRTP of one of the complex technological groups (Fig. 2). The abbreviations below the graphical images of this figure constitute accepted alphabetical codes for formal description of types of technological operations. This UGRTP comprises ITP of 9 types of tooth gears, divided in 4 route groups – Group D, Group E, Group J and Group I. The tooth gears from each group can be manufactured in one batch.

The sequence of UTO for machining the tooth gears from one operational group determines the group operational technological process for this group. The aggregate of the group operational technological processes for tooth gears from the same complex operational group form the unified group operational technological process (UGOTP) for this group. The approach of forming UGOTP is illustrated through the structure of technological processes for machining the tooth gears from Group D (Fig. 3).

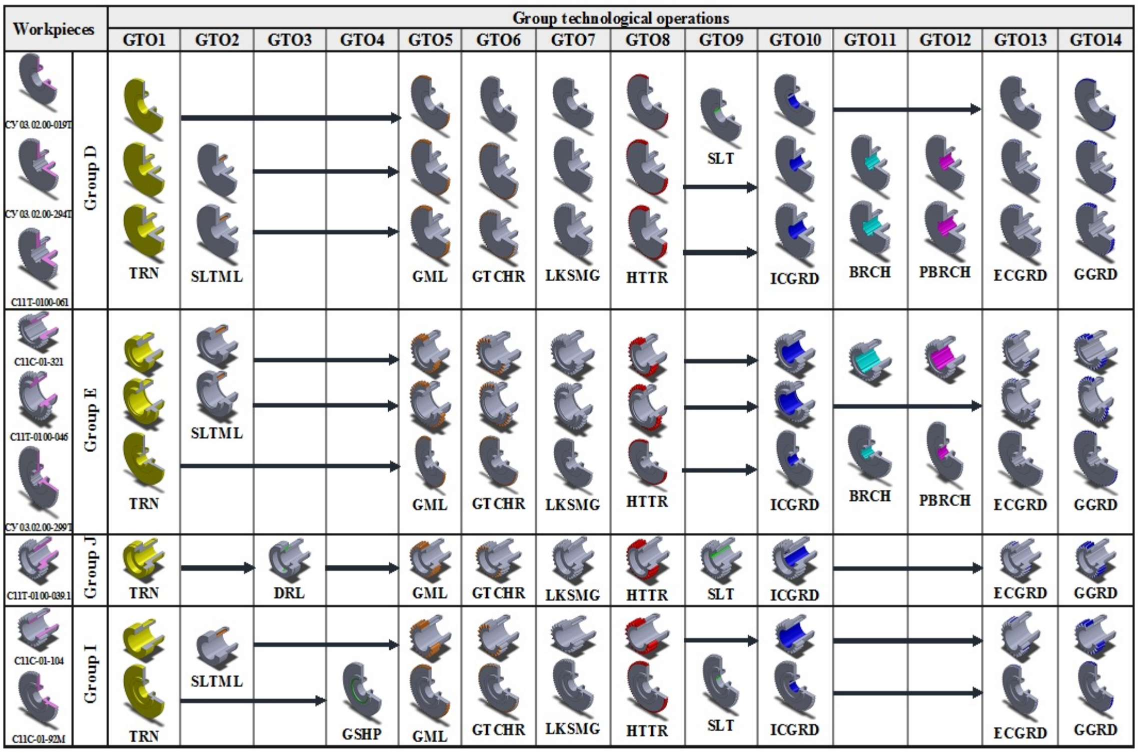

Fig. 2 *Structure of a unified group route technological process*

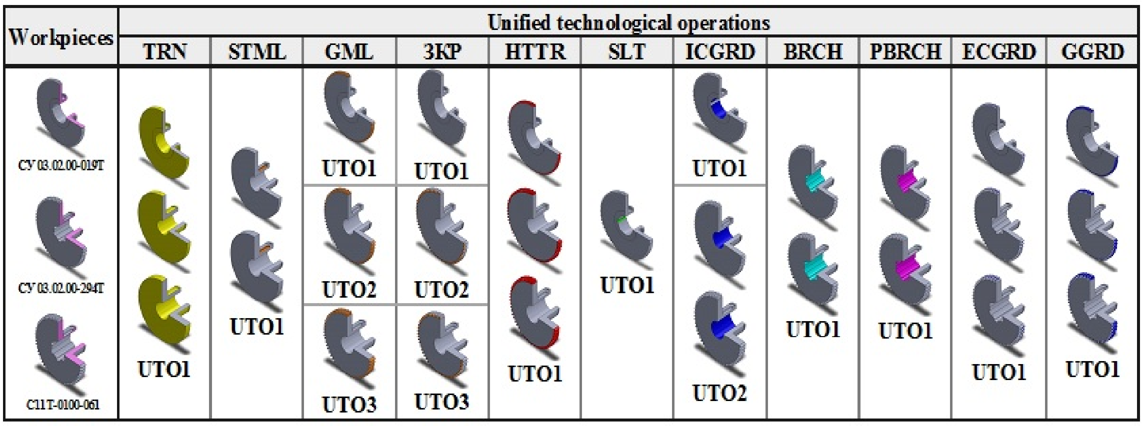

Fig. 3 *Structure of a unified group operational technological process*

conditions of a complex technological process – a wide product range and small series production.

The effective realization of innovative solutions necessitated the restructuring of the gear grinding workshop which includes updating the machines with a new CNC gear grinding machine Niles ZE400/500.

4. Results of introducing an innovative technological process

The company policy envisages the process innovation should encompass the whole production range of tooth gears step by step. The results of introducing an innovative technological process for 30 types of pilot tooth gears, divided in 5 complex technological groups, are commented on in this report (Fig. 4). Eight unified settings of the Niles ZE400/500 gear grinding machine are specified for their machining.

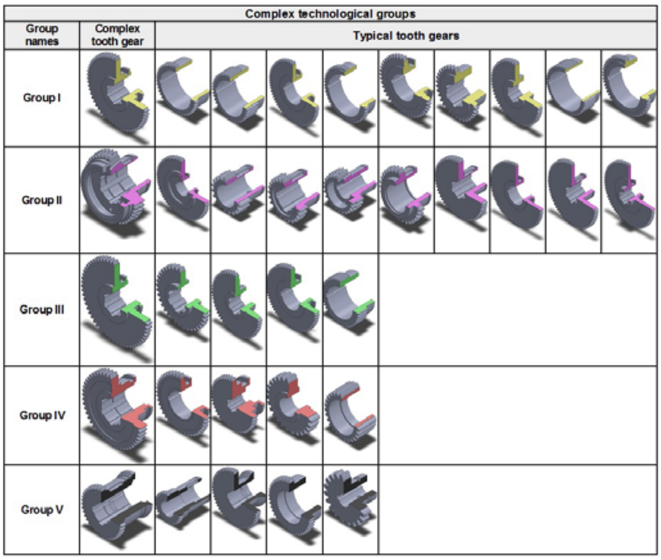

Fig. 4 *Distribution of pilot tooth gears in complex technological groups*

After comparing the data for machining pilot tooth gears before and after introducing the innovative technological process and the highly technological CNC gear grinding machine Niles ZE400/500 (Fig. 5), the following summary can be made:

- Automatic execution of the machining cycle, of monitoring and measuring operations, and intensified cutting modes with Niles ZE400/500 contribute to decreasing the total gear grinding time over two times (see Fig. 5a).
- The introduction of group technological processes and unified settings decreases the annual time for resetting Niles ZE400/500 over 2.8 times (see Fig. 5b), which amounts to 0.7% of the effective annual working time.
- After introducing the innovative approach, gear grinding cost price fell by 20% (see Fig 5c).

5. Conclusion

After introducing the innovative technological process and the gear grinding machine Niles ZE400/500 in the gear grinding workshop ZMM Nova Zagora JSC is expected to achieve the following positive results:

- Increasing the serial production and the production capacity through introducing unified group technological processes and decreasing the gear grinding resetting time.
- Decreasing the finished products cost price as a result of reducing the expenses for the technological preparation of the production and optimizing the production costs for gear grinding.
- Improving and guaranteeing stability of the finished products quality by also ensuring conditions for manufacturing tooth gears with up to 4 gear accuracy grade.
- Preserving and expanding the product range by ensuring a high degree of flexibility of the gear grinding process under the conditions of a complex technological process – a wide product range and small series production.

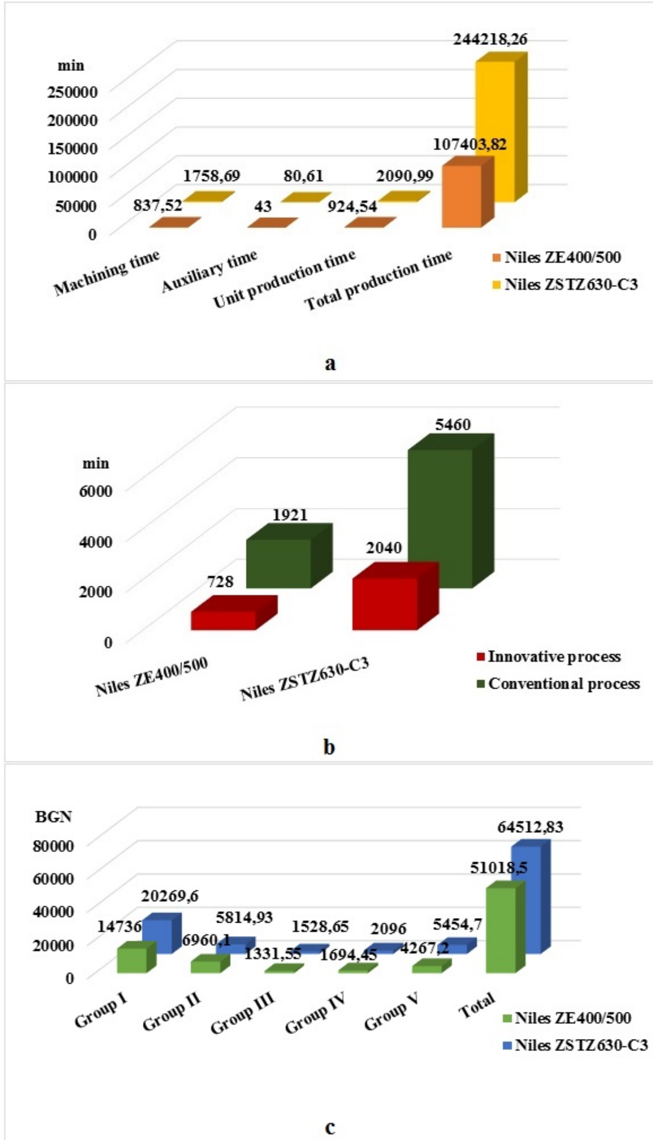

Fig. 5 *Comparative analysis of production results before and after introducing the innovative technological process*
a, b – production time; c – cost price;

- Increasing the degree of automation of the technological preparation and the production in the gear grinding workshop by introducing information technologies and computer technologies in design and production.
- Achieving maximum productivity in the gear grinding workshop under the conditions of a wide product range and small series production by optimizing the frequency of resetting the machines and the size of the batches.
- Improving the competitiveness and the market positions of the company.

6. Bibliography

1. Митрофанов С. П. Групповая технология машиностроительного производства. В 2-х томах. Т. 1. Организация группового производства. Л., Машиностроение, 1983, 407 с.
2. Петухов А.В. Системы автоматизировонного проектирования технологических процессов. Учебное пособие/А.В. Петухов, Д.В. Мельников, В.М. Быстреков, Гомель, 2011, 144 с.
3. Group Technology and Cellular Manufacturing. A State of the Art Synthesis of Research and Practice. Edited by N.

Suresh and J. Kay, Springer Science & Business Media, New York, 1998, 545 pp. //ISBN 978-1-4613-7497-8.
4. Ham Inyong, Katsundo Hitomi, Teruhiko Yoshida. Group Technology. Applications to Production Management. Kluwer-Nijhoff Publishing, Boston, 1985, 187 pp. //ISBN 978-94-010-8702-5.

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PREPARATION OF MULTI-COMPONENT POWDER OF ANY HIGH SOLIDS PROCESS

ТЕХНОЛОГИЯ ПОЛУЧЕНИЯ УЛЬТРАДИСПЕРСНЫХ ПОРОШКОВ ВЫСОКОСКОРОСТНЫМ СПОСОБОМ

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Abstract: *The possibility of obtaining ultra-disperse powders by high speed way with a particle size that does not exceed the declared value. The research of the mechanical method of obtaining ultra-disperse powders. Dispersion of obtained powder was defined for various materials. The dependence of the dispersion of the obtained powder was indentified from the choice of abrasive tools on Bakelite and metal bonds.*

KEYWORDS: *NANO- AND ULTRA-DISPERSE POWDER, HIGH SPEED WAY, MECHANICAL METHOD, ABRASIVE DISK, LIQUID NITROGEN*

Currently, the key factor of economic development and national defense capability is the development of new materials, their processing and use. Current direction of development of modern science is to provide nano- and ultrafine powders of various metals and study their properties. Because ultrafine particle size powders have unique combinations of chemical, electrical, magnetic, radio-mechanical and other properties that determine new functionality, constructional and operational characteristics. The structure of the powder has a significant effect on the properties, depending on the production method [1]. There are following requirements for the methods:

1) The high speed of forming of particles birth centre and the low speed of their growth;

2) The provision of temporary stability of the particles, the surface protection from spontaneous oxidation and sintering in the manufacturing process;

3) Preparation of the particles or grains of a prescribed size;

4) Effective production and efficiency;

5) Control of the parameters [2,3].

Methods of preparation of nano- and ultrafine materials are divided into physical, chemical, biological and mechanical.

The main methods of mechanical grinding are crushing and grinding of solid materials, melt dispersion, processing of solid (compact) materials by cutting. Mechanical methods are based on the effects of large deforming stresses: dragging, pressure, pressing, vibration, cavitation processes and etc. [4].

Mills of various types are applied for the mechanical grinding of solids: planetary, ball, ink, swirl, vibration and others. Due to the fact that in the preparation of ultrafine and nano powders grinding work is proportional to the surface area, it is necessary to use high power mills [2].

The main advantages of using a mechanical method of grinding (mills) are:

1) Preparation of nano and ultrafine powders of multicomponent alloys in a single step;
2) The ability to grind various materials and produce alloys powders in large quantities;
3) The relative simplicity of the technology.

Disadvantages of the mechanical methods:

1) The size distribution of the particles and the variety of forms;

2) The difficulty of controlling the composition of the product during grinding;

3) The more complex components and accuracy the factor of merit, the harder it is to control the metal structure, and the higher the cost of the production;

4) The possibility of contamination of nano and ultrafine powders with the attrition of grinding bodies or working bodies of mills [5.6].

The mechanical method is promising for the development of nano- and ultrafine powders of multicomponent alloys, however, for a more efficient use of it, knowledge of the physical processes occurring during mechanical stresses are very useful [7,8]. Therefore, it's necessary to determine the possibility of a high-speed method and experimental study of the processes occurring in solids in the manufacture of powders [9]. Installation, applied in the experiment, represents the mill.

Processing of the material was carried out at the circumferential speed of the grinding disk up to 300 m / s, while the synchronistic rotational and reciprocating motions of the workpiece. The grinding wheel was used as the grinding disc with abrasive elements (abrasive head with diameter of 12 mm). The workpiece carried order was about 1 mm / min while feeding nitrogen from the cryogen reservoir through the thermohose to the work zone was about 1 l/ min. The particle sizes of the powder were regulated by circumferential speed of the grinding disc, choice of abrasive heads and workpiece supply [10].

The workpiece set coaxially to one of abrasive heads in the clamping device was rotated. After reaching predetermined rotational speed by the grinding disc, the workpiece was continuously cooled with liquid nitrogen during the whole abrasion process. Grinding wheel was linked up with workpiece until the contact, whereby the workpiece was grinding by abrasion. The powder was removed from the grinding chamber, using a blowing trap of the particles, connected to a device for collecting ground product. After abrasion of the workpiece, the device was disconnected, the ground material was removed from the collection device, set a new workpiece (Figure 1) [11].

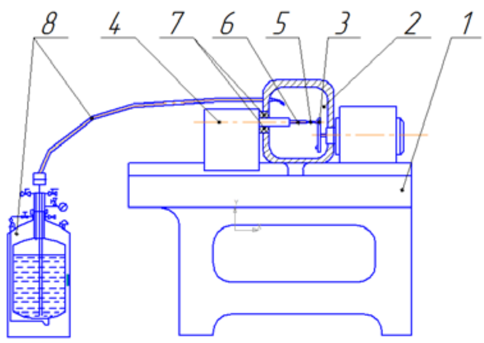


Fig. 1. *Installation scheme: 1 – frame; 2 - airtight enclosure; 3-abrasive wheel; 4-work feeder; 5-workpiece; 6-work holder; 7- airproof cell; 8- feeder of liquid nitrogen to the work zone.*

Experiments were carried out with materials having different hardness, friability, toughness (Fig. 2) [12,13].

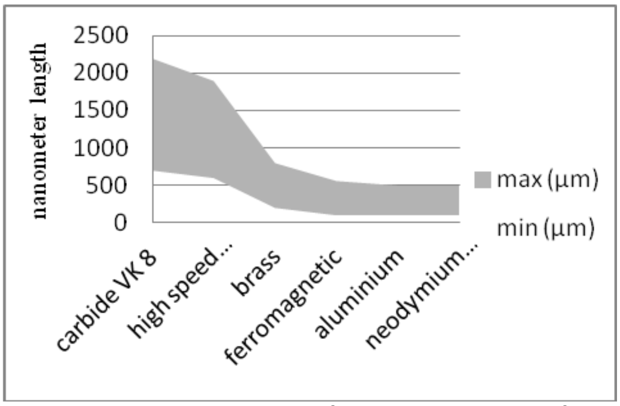
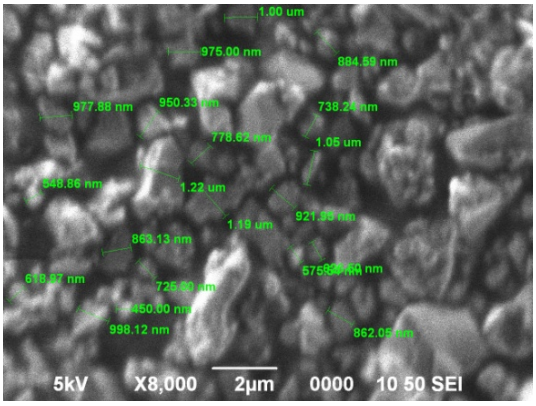
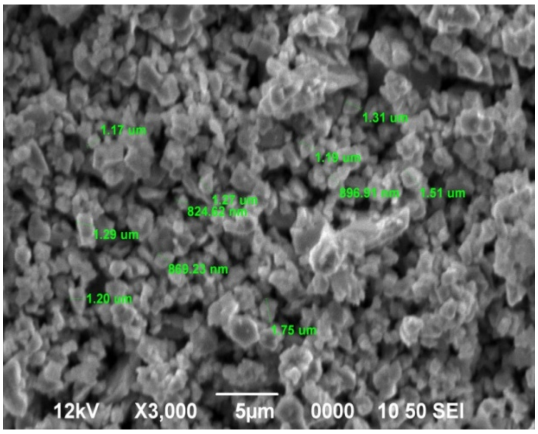


Fig. 2 *The dispersion of the obtained powder of variety materials*

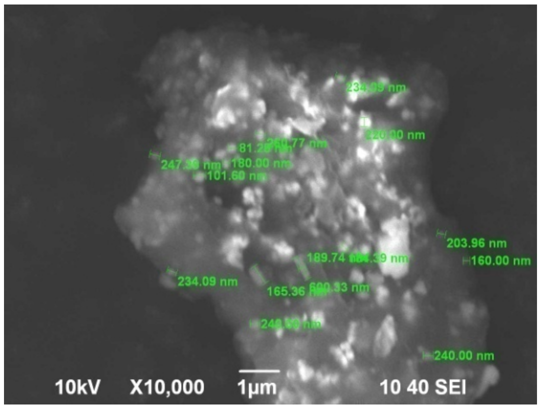
The collected powders had a particle size in the range from 100 nm to 1.5 microns (Fig. 3). The average particle size of the steel powder VK8 was 1100 nm, HSS P18 - 950 nm, of brass - of 400 nm from a ferromagnet - 280 nm. The best results were obtained with powders of aluminum and neodymium magnet (Fig. 3c).



a



b

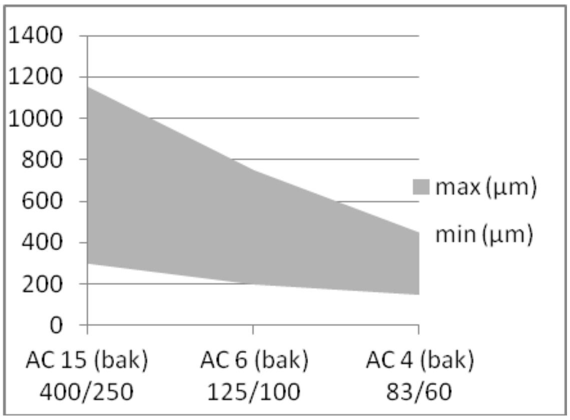


c

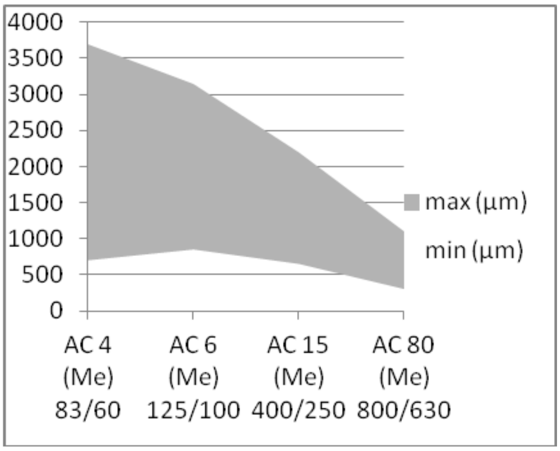
Fig. 3 *The dispersion of the obtained alloy powder P18 (a), alloy VK 8(b), neodymium magnet (c).*

During the experiments were used abrasive elements on the bakelite and metal bonds.

From the obtained data follows that the variation in the dispersion decreases with decreasing of grain of abrasive elements range (Fig. 4).



a



b

Fig 4. *The dependence of the dispersion of the obtained powder by the choice of grinding tool on bakelite bond (a) and metal bond (b).*

The mechanical processing method with using of a grinding wheel provides wasteless processing of the workpiece, reducing the spread of sizes and the possibility of obtaining particles less than 0.1 mm. Adding liquid nitrogen reduces the occurrence of high temperatures generated by abrasion at high speeds, thus decreasing the fire hazard in the work [14,15,16].

The detection of the dispersion dependence of obtained powder from the material, from which it was derived, as well as the choice of abrasive tools - undoubtedly important. More important will be to identify the dependence of different properties of the material on dispersion of the obtained powder for understanding the fundamentals and principles of high-speed particles chipping from different material from abrasive elements. It is also necessary to investigate the properties of the obtained powder of a magnetic material on X-ray apparatus for determining the magnetic properties, compared with the starting material.

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References

1. A.Izgorodin. Nanoindustry and training. - A. Izgorodin, G. Chistoborodov; - "In the world of hardware." - 5 (80). - 2008. [А.Изгородин. Наноиндустрия и подготовка специалистов. – А. Изгородин, Г. Чистобородов; - «В мире оборудования». - 5 (80). – 2008.]
2. BM Balayan, AG Kolmakov, MI Crimson AM Moles. Nanomaterials. Classification, characteristics of properties, application and production technology. Moscow, 2007.- 125 p. [Б.М. Балоян, А.Г. Колмаков, М.И. Алымов, А.М. Кротов. Наноматериалы. Классификация, особенности свойств, применение и технологии получения. Москва, 2007.- 125 с.]
3. R.Hanninka, A.Hill. Nanostructured materials. Moscow: Technosphere, 2009. - 488 p. [Р.Ханнинка, А.Хилл. Наноструктурные материалы. Москва: Техносфера, 2009. - 488 с.]
4. S.S.Kiparisov, G.A.Libenson. Powder metallurgy. - M .: Metallurgy, 1991, 432 p. http://www.twirpx.com/file/403354/
5. DI Ryzhonkov, VV Levina, E.L.Dzidziguri. Nanomaterials: a tutorial. -2 Ed. - M.: BINOM. Knowledge Laboratory, 2010. - 365 p. [Д.И. Рыжонков, В.В. Лёвина, Э.Л.Дзидзигури . Наноматериалы: учебное пособие. -2-е изд. - М.:БИНОМ. Лаборатория знаний, 2010. - 365 с.]
6. SV Matrenin, BB Ovechkin. Nanostructured materials in mechanical engineering: a tutorial / Tomsk Polytechnic University. - Tomsk: Publishing house of Tomsk Polytechnic University, 2009. - 186 p. [С.В. Матренин, Б.Б. Овечкин. Наноструктурные материалы в машиностроении: учебное пособие / Томский политехнический университет. - Томск: Изд-во Томского политехнического университета, 2009. - 186 с.]
7. Yu.N.Polyanchikov, A.G.Shirtladze, A.N.Vorontsova (et al.). Nanotechnology in Engineering: a tutorial. - Stary Oskol: TNT, 2012. - 92 p. [Ю.Н.Полянчиков, А.Г.Схиртладзе, А.Н.Воронцова (и др.). Нанотехнологии в машиностроении: учебное пособие. - Старый Оскол: ТНТ, 2012. - 92 с.]
8. A.N.Kovshov, Yu.F.Nazarov, I.M.Ibragimov. Nanotechnology-based technique: Proc. Guide for students. Executive. Proc. institutions. - M .: Publishing Center "Academy", 2009. - 240 p. [А.Н.Ковшов, Ю.Ф.Назаров, И.М.Ибрагимов. Основы нанотехнологии в технике: учеб. пособие для студ. высш. учеб. заведений. - М.: Издательский центр "Академия", 2009. - 240 с.]
9. Lerner MI, Davidovich VI, Svarovskaya NV Dependence of dispersion of metal nanopowders and their agglomeration process the temperature of the gaseous medium in the electric explosion of conductors // Physical Mesomechanics. - 2004. - № 7. - Part 2. - 340 - 343. [Лернер М. И., Давыдович В. И., Сваровская Н. В. Зависимость дисперсности нанопорошков металлов и процесса их агломерации от температуры газовой среды при электрическом взрыве проводников // Физическая мезомеханика. – 2004. - № 7. - Ч. 2. - С 340 – 343.]
10. Patent - 146455 Russian Federation, IPC B22F 9/04. The apparatus for producing metal powders. / AY Popov, DS Rechenko, Y. Titov, KK Gosina, RW stones; Omsk State. Tech. Univ. - № 2014119229/02; Appl. 05/13/14; Publ. 10.10.14. Bull. № 28. - 3 .: silt. 1 [Патент – 146455 РФ, МПК B22F 9/04. Устройство для получения металлических порошков. / А.Ю. Попов, Д.С. Реченко, Ю.В. Титов, К.К. Госина, Р.У. Каменов; Омский гос. Техн. Ун-т. - № 2014119229/02; Заявл. 13.05.14; Опубл. 10.10.14. Бюл. № 28. – 3 с.: ил. 1]
11. Patent - 55665 RF, IPC B24D 17/00. Grinding wheel for rough and abrasive machining. / DS Rechenko, YR Nurtdinov, AY Popov; Omsk State. Tech. Univ. - № 2006111080/22; Appl. 05.04.06; Publ. 27.08.06. Bull. № 24. - 2 .: silt. [Патент – 55665 РФ, МПК B24D 17/00. Шлифовальный круг для алмазно-абразивной обработки. / Д.С. Реченко, Ю.Р. Нуртдинов, А.Ю. Попов; Омский гос. Техн. Ун-т. - № 2006111080/22; Заявл. 05.04.06; Опубл. 27.08.06. Бюл. № 24. – 2 с.: ил.]
12. Powder metallurgy. Materials, technology, properties, fields of application: Manual IM Fedorchenko, I.N Franzevich, ID Radomyselsky etc .; Ans. Ed. IM Fedorchenko.- Kiev Sciences. Dumka, 1985.- 624 p. [Порошковая металлургия. Материалы, технология, свойства, области применения: Справочник И.М. Федорченко, И.Н Францевич, И.Д. Радомысельский и др.; Отв. ред. И.М. Федорченко.- Киев: Наук. думка, 1985.- 624 с.]Proskurovskaya L.T Physico-chemical properties of ultrafine aluminum powders electroexplosion: dis. ... Cand. chem. Sciences. - Tomsk: TSU, 1988. - 155 p. [Проскуровская Л.Т Физико-химические свойства электровзрывных ультрадисперсных порошков алюминия: дис. ... канд. хим. наук. - Томск: ТГУ, 1988. - 155 с.]
13. IM Fedorchenko, Franzevich IN, Radomyselsky ID Powder metallurgy. - Kiev: Naukova Dumka, 1985. - 624 p. [Федорченко И.М., Францевич И.Н., Радомысельский И.Д. Порошковая металлургия. - Киев: Наукова думка, 1985. - 624 с.]
14. Kissel AG Rechenko DS Popov AY Titov VR Preparation of ultrafine powder by mechanical method using liquid nitrogen / nanotech. - №1 (37). - 2014. - P. 73-74. [Кисель А.Г. Реченко Д.С. Попов А.Ю. Титов В.Р. Получение ультрадисперсного порошка механическим методом с применением жидкого азота/НАНОТЕХНИКА. - №1 (37). – 2014. - С. 73-74.]
15. Rechenko DS Kissel AG Popov AY AV Titov Preparation soot ferromagnets an attritor with liquid nitrogen cooling. / Omsk Univ OmSTU, 2013. - S. 165-168. [Реченко Д.С. Кисель А.Г. Попов А.Ю. Титов А.В. Получение ультрадисперсного порошка ферромагнетиков на мельнице тонкого помола с охлаждением жидким азотом. /Омск: Изд-во ОмГТУ, 2013. – С. 165-168.]

A STUDY ON THE IMPLEMENTATION OF THE DISCIPLINED CONVEX OPTIMIZATION METHOD FOR THE IDENTIFICATION OF THE DYNAMIC SYSTEMS' MODELS

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Abstract: *In this paper the author investigated the implementation of the convex optimization method in the area of the estimation of model parameters from experimental data. The investigation focused on the identification of processes within the technical environment such as: the liquid flow process, the mechanical vibrating process and the electric arc discharge. The theoretical support related to the convex optimization algorithm is emphasized in the first section of the paper. The preconditions for the implementation of the algorithm within the system identification context are also presented. In the third and the fourth sections, the main analysis is made. The mathematical models of the processes under investigation and the software implementations are depicted. The results showed that for an input signal, equivalent with the Dirac impulse, the disciplined convex optimization algorithm provide consisted estimate of the process under investigation which is similar to the results from the classical least-squares identification algorithm. These results are the basis for further investigations on the implementation of the convex optimization algorithm for system identification.*

Keywords: SYSTEM IDENTIFICATION, CONVEX OPTIMIZATION, DYNAMIC MODEL

1. Introduction

The convex optimization method has been introduced since decades to solve a special class of mathematical optimization problems which includes least-squares and linear programming problems.

The method has been implemented in areas such as, [1] automatic control systems, estimation and signal processing, communications and networks, electronic circuit design, data analysis and modeling, statistics, and finance. Recently, the convex optimization method was successfully used in real-time optimization within computers embedded in products. The main advantage of the convex optimization method is that this method is reliable and can solve the convex optimization problems in a predictable amount of time.

The convex optimization has been studied for about a century. The first systematic study of convex sets was made by Minkowski. The mathematics of convex sets was then developed by Bonnesen, Fenchel, Eggleston and others. During the 1960's, Luenberger introduced the generalized inequalities in nonlinear optimization. In the 1980's, the convex optimization method has developed due to Nesterov and Nemirovski, [1] who were the first to point out that the interior-point methods - developed to solve linear programming problems - may be used to solve convex optimization problems as well. Nowadays, important contributions in convex optimization algorithms and related topics, including software developments are due to Boyd and Vandenberghe.

In this paper, the author investigated the implementation of the convex optimization algorithm for the identification of the dynamic systems' models parameters from experimental data. This approach is less quoted in the technical literature, [1], [5].

In systems identification and in its related adaptive control, the predictable demand of hardware, software, and computational time resources are crucial. In this direction, the convex optimization proves more efficient than the classical system identification methods.

2. Prerequisites and means for solving the problem

An optimization problem has the following form:

$$\begin{array}{ll} \text{minimize} & f_0(\mathbf{x}) \\ \text{subject to} & f_i(\mathbf{x}) \le b_i \quad i=\overline{1;m} \end{array} \qquad (1)$$

Where the vector $\mathbf{x} = \begin{pmatrix} x_1 & \dots & x_n \end{pmatrix}^T$ is the optimization variable of the problem, the function $f_0 : \mathbf{R}^n \to \mathbf{R}$ is the objective function, the functions $f_i : \mathbf{R}^n \to \mathbf{R}$, $i = \overline{1;m}$ are the constraint functions, and the constants $b_1 \dots b_m$ are the bounds for the constraints.

In the linear program, the objective and constraint functions are linear and satisfy the equality:

$$\begin{array}{l} f_i(\alpha \cdot \mathbf{x} + \beta \cdot \mathbf{y}) = \alpha \cdot f_i(\mathbf{x}) + \beta \cdot f_i(\mathbf{y}) \\ (\forall)\mathbf{x}, \mathbf{y} \in \mathbf{R}^n;\ \alpha, \beta \in \mathbf{R} \end{array}. \qquad (2)$$

If the objective and constraint functions are not linear, then the optimization problem is called a nonlinear program.

If the objective and constraint functions satisfy the inequality:

$$\begin{array}{l} f_i(\alpha \cdot \mathbf{x} + \beta \cdot \mathbf{y}) \le \alpha \cdot f_i(\mathbf{x}) + \beta \cdot f_i(\mathbf{y}) \\ (\forall)\mathbf{x}, \mathbf{y} \in \mathbf{R}^n;\ \alpha, \beta \in \mathbf{R} \text{ with } \alpha + \beta = 1 \text{ and } \alpha \ge 0\ \beta \ge 0 \end{array}, \qquad (3)$$

then, the optimization problem is called a convex optimization problem.

The solution of the optimization problem is a vector ξ^* which has the smallest objective value among all vectors that satisfy the constraints: $f_0(\xi) \ge f_0(\xi^*)$ for any ξ with $f_i(\xi) \le b_i$; $i = \overline{1,m}$.

In the least-squares optimization problem with no constraints, the objective function is of the following form:

$$f_0(\mathbf{x}) = \|\mathbf{A} \cdot \mathbf{x} - \mathbf{b}\|_2^2 = \sum_{i=1}^{k} \left(\mathbf{a}_i^T \cdot \mathbf{x} - \mathbf{b}_i\right)^2 . \qquad (4)$$

Where: $\mathbf{A} \in \mathbf{R}^{k \times n}$ with $k \ge n$, $\mathbf{a}_i^T$ are the rows of $\mathbf{A}$, and the vector $\mathbf{x} \in \mathbf{R}^n$ is the optimization variable.

The analytical solution of the least-squares problem is given by the following expression.

$$\mathbf{x} = \left(\mathbf{A}^T \cdot \mathbf{A}\right)^{-1} \cdot \mathbf{A}^T \cdot \mathbf{b} \qquad (5)$$

The least-squares problem has known high accuracy and high reliability algorithms such as the linear least-squares algorithm. The computer time needed to solve a least-squares optimization problem is approximately proportional to $n^2 \cdot k$. The convex optimization problem also benefits of dedicated algorithms such as the interior-point algorithm. The amount of steps needed to solve some optimization problems by means of the interior-point algorithm is in the range between 10 and 100. Each step requires on the order of

$\max\{n^3; n^2 \cdot m; F\}$, where F is the cost of evaluating the first and the second derivatives of the objective and constraint functions, [1].

Given a dynamic process, the aim in system identification is to determine an estimate of the system's model from input / output sequences of data acquired from the given process.

In the followings we will consider the problem of system identification as a convex optimization problem.

3. Solution of the examined problem

Consider two sequences of data $\{u[k]\}_{k=1}^{N}$ and $\{y[k]\}_{k=1}^{N}$, related to the signals at the input / output ports of a given linear, time-invariant system.

As known, a single-input, single-output, dynamic process may be represented in the discrete time domain by means a difference equation given in the general form as follows:

$$M : y[k] = -\sum_{i=1}^{na} a_i \cdot y[k-i] + \sum_{j=1}^{nb} b_j \cdot u[k-j] \qquad (6)$$

Where $a_i\,; i = \overline{1;na}$ and $b_j\,;\ j = \overline{1;nb}$ are the model's parameters.

Based on the general form of the dynamic process above and on N sequence of data acquired from the process, a set of N equations with $na + nb + 1$ unknowns is obtained. The matrix - vector form of the given set of equations is the following.

$$S : \mathbf{\Phi} \cdot \mathbf{\Theta} = \mathbf{Y}\,. \qquad (7)$$

Where: $\mathbf{\Theta} = [a_1, \ldots, a_{na}; b_0, \ldots, b_{nb}]^T$ is the vector of the true parameters, $\mathbf{Y} = [y_1, \ldots, y_N]^T$ is the vector of the noise free output data, and $\mathbf{\Phi}$ is the noise free input / output data, [6] In reality, the measured sequences of data are corrupted by noise. Therefore, the least-squares identification problem reduces to the computation of the pseudo-solution of the above set of equations. This is equivalent to the problem of the Euclidean norm minimization:

$$V_N(\hat{\mathbf{\Theta}}) = \left\| \mathbf{\Phi} \cdot \hat{\mathbf{\Theta}} - \mathbf{Y} \right\|. \qquad (8)$$

Where $\hat{\mathbf{\Theta}}$ is the vector of the estimated parameters and $V_N(\hat{\mathbf{\Theta}})$ is the objective / the cost function. Follows that the least-squares identification of the parameters may be interpreted as a convex optimization too.

The least-squares algorithms used in system identification require the input sequence is a white - noise process with zero mean and known variance, [2]. In contrast, the convex optimization algorithm will not work properly with random processes sequences. In this case the convex optimization should reduce to finding a maximum likelihood estimate of the parameter vector, [1].

However, the simple least-squares algorithm in system identification will also work if the input is a discrete Dirac impulse. In this case, the system's response is a sequence of the discrete weighting function. In this case the convex optimization algorithm will work too. In the followings, we will use this approach to determine the model estimates of parameters from experimental input / output data with known pulse inputs. The proposed processes were: a liquid flow process, a mechanical vibrating process and an electric discharge.

4. Results and discussion

In purpose to investigate the ideas presented above, the following tools were used: (a) a liquid flow test band and a mechanical vibratory test band from the Electrical Machines Laboratory at the "Transilvania" University from Brașov; the liquid flow test had two flow meters with 5% accuracy in the range of $0.01 - 1.0$ [dm^3]. The flow was computed by means of a microcontroller application and an RS232 communication - which is part of the test-band. (b) For the experiment, the mechanical vibratory test - band was equipped with a 12-bit/8-bit digital accelerometer, MMA8452Q from FreescaleSemiconductor and a MSP430 microcontroller. (c) The algorithm implementation used the cvx, SeDuMi library, [3] and the MatLab software environment. The serial communication between the microcontrollers and the PC was made by means of the RS232 port and a software application written in the VisualBasic. The main interface of the communication application is depicted in Figure 1. The interface consists in several objects that allow the user to control de data stream from the microcontroller.

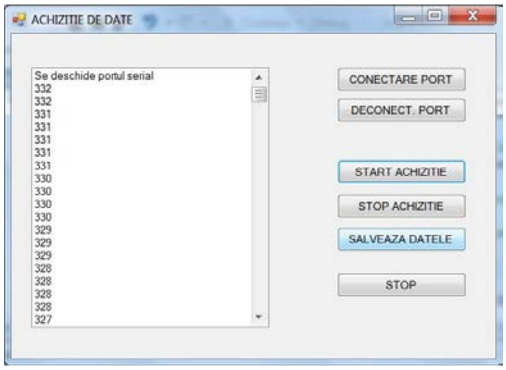

Fig. 1 *The communication application - graphical interface.*

The implementation of the convex optimization algorithm and the associated computations were made within the MatLab environment by means of a dedicated application.

4.1. The identification of a liquid flow process

Consider the flow of the liquid from a tank, (C - the surface of the tank) within pipes and a valve (R_h - the equivalent hydraulic resistance); the input / output signals are the input and the output flow.

The reduced - order linear model of the liquid flow process is given by equivalent transfer function is represented in the following expression [4].

$$G(s) = \frac{1}{R_h \cdot C \cdot s + 1}; \quad s = \sigma + j \cdot \omega;\ s \in \mathbf{C}\,. \qquad (9)$$

Given the sampling period of the discrete dynamic processes, **Грешка! Показалецът не е дефиниран.**T_e, the given transfer function may be translated into the discrete space.

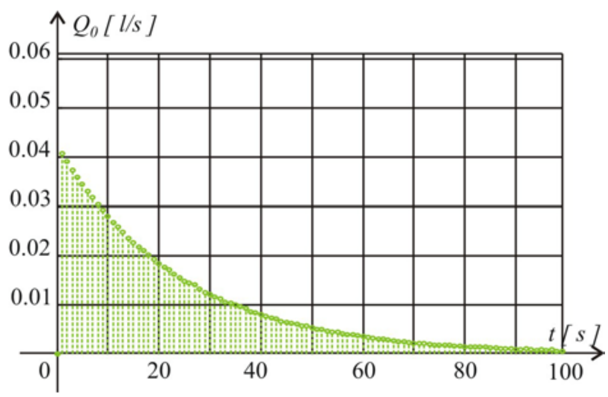

Fig. 2 *The experimental measurements of the weighting function of the liquid flow system.*

The expression of the equivalent operational transfer function is of the following form:

$$G\left(q^{-1}\right)=\frac{b \cdot q^{-1}}{1+a \cdot q^{-1}}. \qquad (10)$$

Where q^{-1} is the shift operator. The difference equation that depicts the flow process will result from the expression above as follows.

$$M_1 : y[k]=-a \cdot y[k-1]+b \cdot u[k-1] \qquad (11)$$

The expression above is of the form given in (6).

In this experiment the liquid flow test band was used. A measured sequence of the outlet flow is depicted in Figure 2.

The implementation of the disciplined convex optimization algorithm produced the results summarized in Table 1.

Table 1: *The true values and the estimations of the liquid flow model parameters in the expression (10).*

	a	b
True values [-]	-0.9591895	0.04081054
Average of estimations [-]	-0.9557563	0.03401063
Residuals [%]	75.0894818	79.16553542

4.2. The identification of a mechanical vibratory process

We consider a two-sided pendulum implemented as shown in Figure 3.

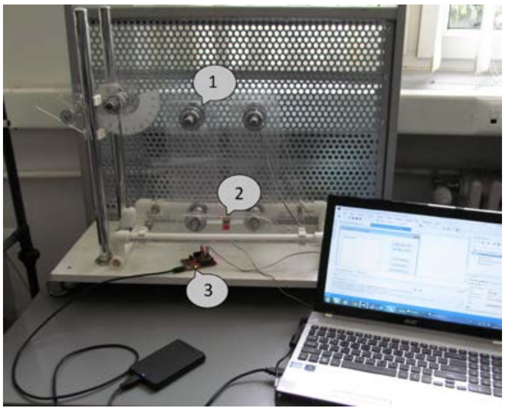

Fig. 3 *Two-sided pendulum test-band.*
1 - the mechanical part of the test band; 2 - the digital accelerometer; 3 - the microcontroller.

The test-band's hammer shuts the pendulum ensemble with a known impulse; the mobile part oscillates. The oscillations of the mobile part are measured by means of the accelerometer and the displacement of the mobile part is estimated and recorded within the computer.

The mechanical vibratory process may be represented by a second-order element with the transfer function given by the following expression.

$$G(s)=\frac{k_a \cdot \omega_n^2}{s^2+2 \cdot \zeta \cdot \omega_n \cdot s+\omega_n^2}; \quad s=\sigma+j \cdot \omega; s \in \mathbf{C} \qquad (12)$$

Where k_a is the gain / the proportional coefficient, ζ is the damping ratio and ω_n is the natural frequency of the given system.

The expression above may be transformed into the discrete domain as previous and a second - order operational transfer function is obtained:

$$G\left(q^{-1}\right)=\frac{b_0+b_1 \cdot q^{-1}}{1+a_1 \cdot q^{-1}+a_2 \cdot q^{-2}}; \qquad (13)$$
$$y[k-1]=q^{-1} y[k]; k \in \mathbf{Z}$$

The expression above lead to a second - order difference equation as follows.

$$M_2 : y[k]=-a_1 \cdot y[k-1]-a_2 \cdot y[k-2] + b_0 \cdot u[k]+b_1 \cdot u[k-1], \qquad (14)$$

which also is of the general form (6).

The experimental results are depicted in Figure 4. The measurements were affected by noise and nonlinearities due to the frictions within the mechanical system.

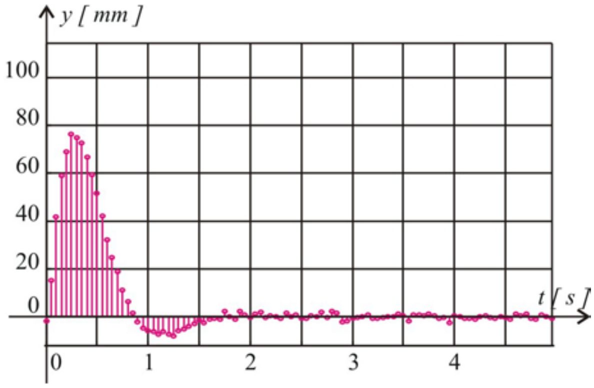

Fig. 4 *The experimental measurements of the weighting function of the mechanical vibratory system.*

In Table 2 were presented the results of the implementation of the disciplined convex optimization algorithm.

Table 2: *The true values and the estimations of the mechanical vibratory model parameters in the expression (14). *Note: the parameter b_0 is equal to zero both in the true model and in the resulting estimations and it was omitted.*

	a_1	a_2	b_1
True values [-]	-1.7144	0.75999	0.79665
Estimations Test no 1 [-]	-0.93306	0.5489	0.56422
Estimations Test no 2 [-]	-1.1189	0.22025	0.41354
Estimations Test no 3 [-]	-0.90722	0.54706	0.53752
Estimations Test no 4 [-]	-1.0369	0.37758	0.49148
Residuals [%]	41.7277	44.2820	37.0250

The residuals is not as good as in the previous experiment due to the higher level of the measurements noise.

4.3. The identification of an electric arc discharge

In the followings, the convex optimization was used to estimate the mathematical model of a time series from a practical experiment described in [7] referring to the study of the electric discharge in inert gas (argon). The experimental setup, presented in Figure 5 consisted of one closed combustion chamber provided with a plasma nozzle, a DC voltage supply (0 ... 220 V / 5A) and a DC boost converter. The converter was commutated at 12.5 Hz. The arc occurred at each commutation for a short period of time. The voltage drop and the arc current intensity were measured by means of a voltage transducer of type UxTT2 (0-400V / -10V ...+10V) and a current transducer of type LEM HP05(0-5A / 0 - 10V). The data were recorded by means of a two channel oscilloscope, Metrix OX6202. The plasma gas was argon. During the discharge, at the nozzle outlet, an indirect water vapor was injected. The arc current and the arc voltage drop were measured and recorded.

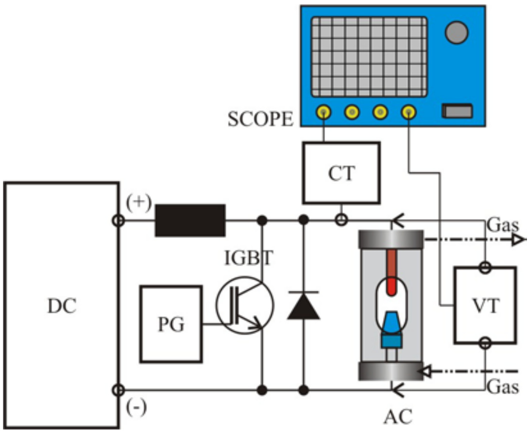

Fig. 5 *The schematic of the experimental setup*
DC - voltage supply, PG - pulse generator, AC-plasma chamber, CT - current transducer, VT - voltage transducer

The analytical model proposed for experimental identification of the time-series is given in the following expression.

$$i(t) = A \cdot e^{-\alpha \cdot t} + B \cdot e^{-\beta \cdot t} \cdot \cos(\omega_1 \cdot t) + C \cdot e^{-\beta \cdot t} \cdot \sin(\omega_1 \cdot t) \qquad (15)$$

Where: the proportional factors $A; B; C \in \mathbf{R}$ are constants, the attenuations $\alpha; \beta \in \mathbf{R}_+$ and the angular frequency $\omega_1 = 2 \cdot \pi \cdot f_1$.

After the implementation of the *z*-transform, in the previous expression, the following complex representation results.

$$I(z) = A \cdot \frac{1}{1 - e^{-\alpha \cdot T_e} \cdot z^{-1}} + B \cdot \frac{1 - \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e)}{1 - 2 \cdot \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e) + \left(z \cdot e^{\beta}\right)^{-2}} + C \cdot \frac{1 - \left(z \cdot e^{\beta}\right)^{-1} \cdot \sin(\omega_1 \cdot T_e)}{1 - 2 \cdot \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e) + \left(z \cdot e^{\beta}\right)^{-2}}; z \in \mathbf{C} \qquad (16)$$

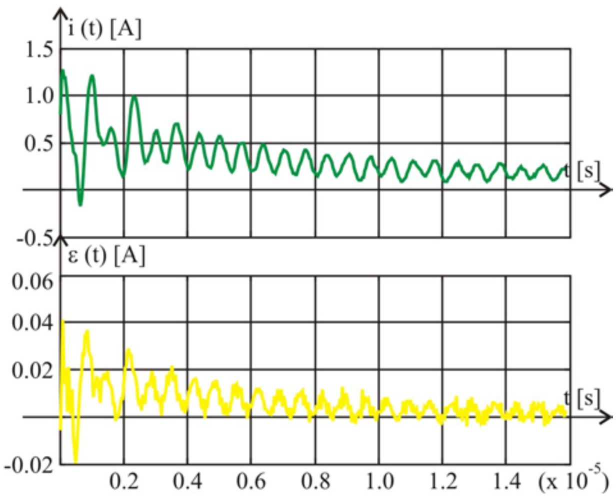

Fig. 6 *Sample sequences.*
The upper: plot the discharge current. The lower plot: the estimation error.

Taking into account the properties of the shift operator, q^{-1}, the discrete-time equivalent model of the time series results from the expression above as follows:

$$i[k] = -a_1 \cdot i[k-1] - a_2 \cdot i[k-2] - a_3 \cdot i[k-3] + b_0 \cdot \delta[k] + b_1 \cdot \delta[k-1] + b_2 \cdot \delta[k-2]; k \in \mathbf{Z} \qquad (17)$$

Where were $\delta[k]$ is the value of the discrete Dirac pulse at step k . The expressions of the coefficients $a_i; b_j; i = \overline{1;3}; j = \overline{0;2}$ are complicated and are not given here.

In Figure 6 an example of the samples sequence plot is given.

The implementation of the disciplined convex optimization algorithm produced the results presented in Table 3.

Table 3: *Estimated parameters of the model in expression of the electric arc discharge. *Note: The parameters b_1 and b_2 resulted much smaller than b_0 and were omitted..*

	a_1	a_2	a_3	b_0
Estimated parameters [-]	-0.16823	0.22173	0.91494	0.019069

The residuals of the identification are depicted graphical in Figure 6.

5. Conclusion

The paper presented a study on the implementation of the disciplined convex optimization method in the field of system identification. The classical least-squares algorithms used to estimate the parameters lead to the minimization of the residuals cost function. The best accuracy of the estimate is obtained if the input signal is a white-noise process. The analysis in this paper proved that an equivalent minimization problem may be solved by means of the disciplined convex optimization algorithm in the case the input signal is a digital Dirac impulse (in practical experiments a short pulse). Further studies are to be made to examine the implementation of the disciplined convex optimization algorithm in the case the input signal is a random sequence.

6.References

[1] Boyd, S. , L. Vandenberghe . Convex Optimization, Cambridge, UK, Cambridge University Press, 2004.

[2] Söderström, T. , P. Stoica . System Identification, Cambridge, UK, Prentice Hall International, 1989.

[3] Grant, M. , S. Boyd, CVX: Matlab Software for Disciplined Convex Programming (web page and software. http://stanford.edu/boyd/cvx, 2015.

[4] Ogata, K., Modern Control Engineering, Upper Saddle River, New Jersey, USA, Prentice Hall, 1997.

[5] Manchester I. R., in: Joint 48th IEEE Conf. on Decision and Control and 28th Chinese Control Conf. Shanghai, P.R. China, December, 16-18, 2009., page 1551-1556.

[6] Danila, A. , Dynamic Systems Modeling and Identification, Brașov, Editura Universității ,,Transilvania", 2013, (in Romanian).

[7] Danila A., in: Electrical and Power Engineering (EPE), 2014 Int. Conf. and Exposition, Iași, România, October 16 - 17, 2014, file no. 547 on CD.

STUDY ON THE LUBRICATING FILM FORMATION OF COOLANT WHEN MACHINING TITANIUM ALLOYS AND HEAT-RESISTANT

ИССЛЕДОВАНИЕ ОБРАЗОВАНИЯ СМАЗЫВАЮЩЕЙ ПЛЕНКИ СМАЗОЧНО-ОХЛАЖДАЮЩЕЙ ЖИДКОСТИ ПРИ ОБРАБОТКЕ ЖАРОПРОЧНОГО И ТИТАНОВОГО СПЛАВОВ

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Аннотация: *Проблемы, возникающие в процессе резания авиационных материалов, вызывают необходимость комплексного исследования процесса обработки с применением смазочно-охлаждающей жидкости (СОЖ), разработку методов определения эффективности СОЖ и методов подачи в зону резания, с учетом обрабатываемого материала, режимов обработки и режущего инструмента, с целью увеличения ресурса инструмента, производительности и точности обработки. Конечно, это вызывает дополнительные технологические трудности, так как существует большое количество видов и марок СОЖ. Учесть влияние всех факторов в комплексе можно, задавшись условиями ограничения.*

Существующие взгляды сводятся к тому, что СОЖ в процессе резания оказывает смазывающее и охлаждающее, диспергирующее и моющее действия. В процессе резания металлов химически активные поверхности режущего инструмента и стружки входят в реакцию с компонентами смазочной среды. Данная гипотеза развивается специалистами по трению и резанию металлов [1, 2, 3, 4].

Наибольший интерес влияния СОЖ вызывает обработка авиационных материалов, так как данная область наиболее востребована в повышении и сохранении качества обработки. В авиационных двигателях широко применяют сплавы ХН60ВТ (ВЖ98, ЭИ868), ХН50ВМТЮБ (ЭП648), ХН68ВМТЮК (ЭП693), ХН56ВМТЮ (ЭП199), ХН73МБТЮ (ЭИ698), ХН77ТЮР, ВТ8, ВТ3-1, ВТ9, ВТ8, ВТ8М, ВТ18У и т.д. В данной работе рассматривались жаропрочный сплав на никелевой основе ХН77ТЮР и титановый сплав ВТ3-1, являющихся яркими представителями своих групп материалов.

В некоторых работах приводятся положения об отрицательном влиянии СОЖ на процесс резания, которое связано с особенностями образования пленки и ее проникающего действия. Механизм образования пленки и ее проникающее действие при резании остается предметом исследований. Проникновение СОЖ в клиновидный зазор между стружкой и поверхностью режущего инструмента происходит из-за капиллярного эффекта [4]. По некоторым данным при низких и средних скоростях обработки контакт стружки с резцом имеет точечный характер 0,5-1 мкм, что обеспечивает эффективное и постоянное поступление СОЖ и ее паров.

Проникающая способность СОЖ характеризуется толщиной пленки *h* и имеет зависимость:

$$h = \eta \frac{S \cdot V}{F},$$

где η – абсолютная вязкость масла, Н·с/м^2; S – площадь соприкосновения трущихся тел, м^2; V – скорость перемещения трущихся поверхностей, м/с; F – сила жидкостного трения, Н.

При этом должна соблюдаться закономерность:

$$h_{\min} \geq 1{,}5(\delta_1 + \delta_2),$$

где δ_1 и δ_1 – максимальные высоты выступов на поверхностях трения, обеспечивающие устойчивое и надежное жидкостное трение.

При высоких скоростях обработки, контакт стружки с резцом имеет сплошной характер, поэтому проникновение СОЖ возможно лишь в парообразном состоянии или при значительном давлении струи.

Проникающее действие СОЖ зависит от ее физических свойств (вязкость, плотность, химическая активность и т.д.) и от способа подвода ее в зону резания. По последним исследованиям установлено, что эффективность смазывающего действия усиливается при подаче СОЖ под давлением, так как это повышает проникающую способность струи или жидкости в распыленном состоянии. Значительное повышение давление свыше 10 бар позволяет производить эффективное стружкодробление и ее отвод.

По некоторым данным, проникающая способность зависит от размера молекул СОЖ. Молекулы олеиновой кислоты имеют длину органической цепи 19 Å, а молекулы таких соединений, как H_2S, SO_2, ClO_3, CCl_4, имеют длину связей атомов 1,5-2 Å, вследствие чего являются более эффективными [4].

Общие представления влияния СОЖ на процесс резания сводятся к тому, что в некоторых зонах происходит искажение кристаллической решетки обрабатываемого материала, за счет его охрупчения вследствие резкого перепада температур. При этом возникает и смазывающее действие за счет образования защитных пленок. Конечным проявлением смазывающего действия является уменьшение работы сил трения и повышение стойкости режущего инструмента.

Исследование толщины пленки проводились на машине трения ИИ5011.

Для проведения исследований применялись следующие марки СОЖ:

1) Водоэмульсионные СОЖ с концентрацией 10% марок: Смальта-3, Смальта-3*ЕР, Смальта ЕР, Биосил М, Addinol WH430, Blasocut 2000, Blasocut 4000, Emulcut 100, Росойл-500, Укринол-1М, Аквол-6, Mobilcut 140 и 1,5% водный раствор кальцинированной соды (1,5% в.р.к.с.);

2) Синтетические СОЖ с концентрацией 10% марок: Биосил С, Экол-3, Isogrind-130ЕР, Акремон-Д-1, Конкрепол-ВЦ, а также полусинтетическая СОЖ Смальта-11;

3) Масляные СОЖ, масла и основы масляных СОЖ: жидкий парафин (Ж.П.), РЖ8У, ПС-28, И-40А, И-20А, И-12А, И-5А, Льняное масло, Масло Б-3В, Г.К., МР-1У, МР-3, МР-7, МБХ-5, Полигликоль, Эфир Т.

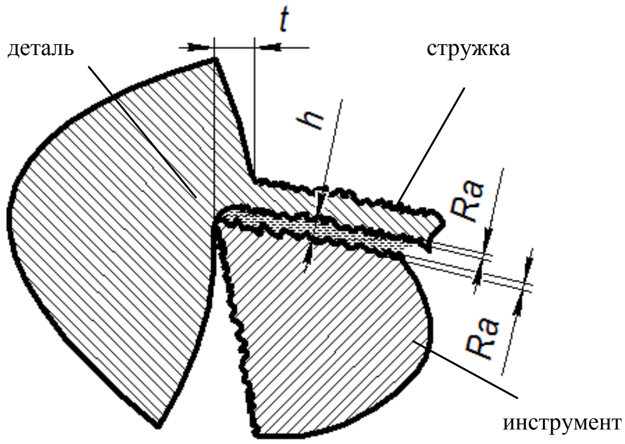

Рис. 1. *Схема действия СОЖ при резании*

Ниже приведены зависимости толщины смазочной пленки h от кинематической вязкости СОЖ μ и зависимости коэффициента трения $K_{тр}$ от толщины смазочной пленки h для пар трения ХН77ТЮР – ВК8 (Рис. 2 и 3) и ВТ3-1 – ВК8 (Рис. 4 и 5).

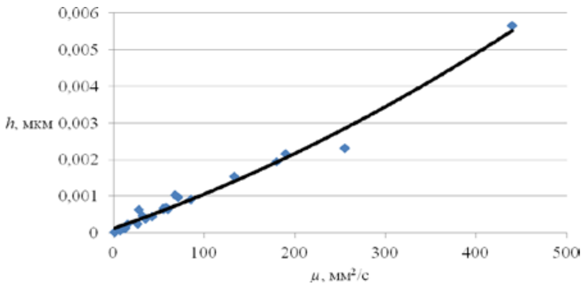

Рис. 2. *Зависимость толщины смазочной пленки от кинематической вязкости СОЖ для пары трения ХН77ТЮР – ВК8*

Зависимость толщины смазочной пленки от кинематической вязкости СОЖ для пары трения ХН77ТЮР – ВК8 имеет вид:

$h = 9 \cdot 10^{-9} \cdot \mu^2 + 10^{-5} \cdot \mu$, при достоверности аппроксимации $R^2 = 0{,}977$.

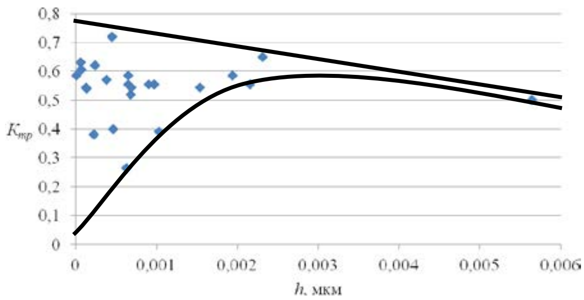

Рис. 3. *Зависимость коэффициента трения от толщины смазочной пленки для пары трения ХН77ТЮР – ВК8*

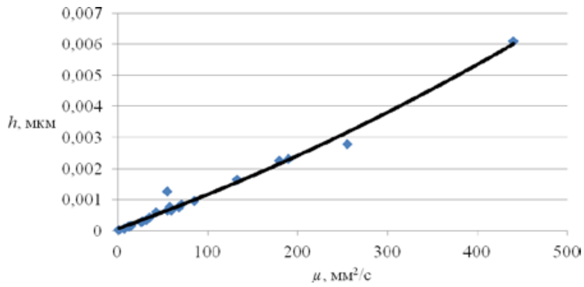

Рис. 4. *Зависимость толщины смазочной пленки от кинематической вязкости СОЖ для пары трения ВТ3-1 – ВК8*

Зависимость толщины смазочной пленки от кинематической вязкости СОЖ для пары трения ВТ3-1 – ВК8 имеет вид:

$h = 7 \cdot 10^{-9} \cdot \mu^2 + 10^{-5} \cdot \mu + 7 \cdot 10^{-5}$, при достоверности аппроксимации $R^2 = 0{,}985$.

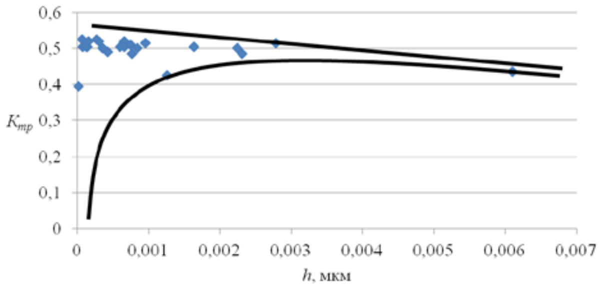

Рис. 5. *Зависимость коэффициента трения от толщины смазочной пленки для пары трения ВТ3-1 – ВК8*

Как видно из представленных зависимостей с увеличением кинематической вязкости увеличивается толщина смазочной пленки и уменьшается коэффициент трения. На зависимостях коэффициента трения от толщины смазочной пленки показана ограниченная область, показывающая диапазон изменения коэффициента трения от толщины смазочной пленки. Как видно из зависимостей с увеличением смазочного слоя до 0,002 мкм и более диапазон коэффициентов трения значительно сужается, что говорит о большей стабильности работы пар трения.

Ссылка

1. Химушин Ф. Ф. Жаропрочные стали и сплавы. — М.: «Металлургия», 1969.
2. Колачев Б.А., Полькин И.С., Талалаев В.Д. Титановые сплавы разных стран. Справочник. М.: ВИЛС, 2000. 316 с.
3. Ильин А.А., Колачев Б.А., Полькин И.С. Титановые сплавы. Состав, структура, свойства. Справочник. М.: ВИЛС МАТИ, 2009. 520.
4. Латышев В.Н. Повышение эффективности СОЖ. - М.: Машиностроение, 1975.

ИНОВАТИВНИ ИНСТРУМЕНТИ ЗА ИНТЕЛИГЕНТНО ПРОИЗВОДСТВО НА ДЕТАЙЛИ С ВЪТРЕШНИ РЕЗБИ

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Abstract:*The article discussed different thread tools developed innovative projects in production.*

Keywords: INNOVATION, TOOLS, TAPS, PROJECTS

1. Увод

Иновацията е въвеждане в употреба на някакъв нов или значително подобрен продукт (стока или услуга) или производствен процес, на нов метод за маркетинг или на нов организационен метод в търговската практика, организацията на работните места или външните връзки. Минимален признак за една иновация е изискването продуктът, производственият процес, методът за маркетинг или организация да е нов (или значително подобрен) за практиката на дадена фирма. Това включва в категорията на иновациите продукти, производствени процеси и методи, които фирмите са създали първи и/или продукти, производствени процеси и методи, заимствани от други фирми или организации.

Иновационната дейност представлява всички научни, технологични, организационни, финансови и търговски действия, от които реално произтича реализацията на иновациите, или които са замислени с тази цел. Някои видове иновационни дейности са иновационни сами по себе си, други не притежават това свойство, но също са необходими за осъществяването на иновацията. Иновационната дейност включва също и изследвания и експериментални разработки, несвързани пряко с разработването на конкретна иновация. Общ признак на иновацията е обстоятелството, че тя следва задължително да се внедри. Нов или усъвършенстван продукт се счита за внедрен, когато е излязъл на пазара. Новите производствени процеси, маркетингови методи или организационни методи се считат за внедрени, когато те реално се използват в дейността на фирмата. Характерът на иновационните дейности в различните фирми е различен. Някои фирми се занимават със съвсем ясно изразени иновационни проекти – в това число разработка и внедряване на определен нов продукт, докато други се занимават предимно с това да внасят нови и нови подобрения в своята продукция, производствени процеси и операции. И двата вида фирми могат да се считат за иновационни, тъй като иновацията може да се състои от реализацията на единично съществено изменение или от цяла редица по-малко значителни подобряващи изменения, които в своята съвкупност образуват значително изменение. Иновационната фирма е фирма, която е внедрила някаква иновация за определен по време на проучването период от време. Продуктово/производствена иновационна фирма е фирма, която е внедрила някакъв нов или значително подобрен продукт или производствен процес за определен по време на проучването период.

Иновациите биват четири типа: продуктови, производствени, маркетингови и организационни

Продуктовата иновация е внедряване на стока или услуга, която е нова или значително подобрена по отношение на нейните свойства или начини на използване. Тук се включват и значителните усъвършенствания в техническите характеристики, компонентите и материалите, във вграден софтуер, в степента на удобството при ползване или в някакви други функционални характеристики.

Производствената иновация е внедряване на нов или значително подобрен начин на производство или доставка на продукта. Производствените иновации могат да имат за цел намаляване на себестойността или разходите за доставка на продукцията, повишаване качеството на продукцията или производството или доставката на нови или значително подобрени продукти.

Маркетинговата иновацията е внедряване на нов метод за маркетинг, включително на значителни изменения в дизайна или опаковката на продукта, неговото складиране, реклама на пазара или в определянето на неговата продажна цена. Маркетинговите иновации са насочени към по-добро задоволяване нуждите на потребителя, отваряне на нови пазари или завоюване на нови позиции за продукцията на фирмата на нейния пазар с цел увеличаване обема на продажбите.

Организационната иновацията е внедряване на нов организационен метод в търговската практика на фирмата, в организацията на работните места или външните връзки.

2. Изложение

Основните видове иновации на резбонарезни инструменти в производството могат да се разделят както следва:

- Guehring

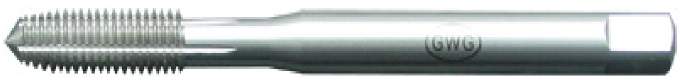
На зависимо дали става дума за чугун, алуминий или алуминиеви сплави, неръждаеми стомани или обикновена стомана серията PawerTap на фирма Гюринг произвежда високопроизводителни метчици за изготвяне на най-разпространените резби в почти всички видове материали.

- GWG
- Резбовалцоващи метчици;

Метчици машинни за метрична ISO резба с едра стъпка по DIN 13 клас на точност ISO 2 (6H)

За обработка на меки материали.Осигурява се по-голяма издръжливост от обикновените метчици. Повишава се допустимата скорост на рязане.

Разработени са резбовалцоващи метчици с канали за охлаждаща течност, с помощта на които се улеснява проникването на смазочна течност до обработваната повърхнина.



Фиг.1 *Разбовалцоващ метчик с канали за охлаждане.*

Фиг.2 *Разбовалцоващ метчик без канали за охлаждане.*

- Инструменти по проект Alfa PLUS ;

метчици машинни за метрична iso резба по din 13
клас на точност iso 2 (6h)
- с подточени канали
форма b: 4 - 5 навивки захващащ конус
- с винтови канали
форма с: 2 - 3 навивки захващащ конус
Нова геометрия на метчиците
· Оптимирани видове стомани за производство - HSSE и PM 30
· Нови технологии на производство
· Нови машини за производство на инструменти
· Оптимирани методи на термообработка
· High Tech – покритие

PM 30 е високолегирана, кобалтова, прахова, бързорезна стомана. Високата якост на натиск 67 HRC, както и добрата износоустойчивост, прави PM 30 подходяща за прецизна студена обработка и производство на режещи инструменти като алтернатива на конвенционалната легирана с кобалт бързорезна стомана.
Процесът на леене PM спомага добрата обработваемост на стоманата и запазването на линейните размери на инструментите по време на термообработката.

- Инструменти от прахова металургия;

PM класове стомана
PM 23, PM4, PM 30, PM 39, PM52, PM 60
PM 23-е на chromium- молибден-волфрам легирана стомана ванадий, който е икономичен висока степен на прах металургични студена стомана работа, Подходящ за нулиране и формиране на по-тънки работни материали, където се сблъска с абразивни тип износване
PM4 - е високо ванадий-chromium- молибден-волфрам легирана стомана, която е с висока степен на прах металургични студена стомана работа, Подходящ където лепило износване и чакъла са доминиращите проблеми да се появят като SS, Mild стомана, мед, алуминий или по-дебела работата материал
PM 30 - е много висока производителност Powder металургичния материал с оптимално висока кобалт - ванадий - chromium- молибден-волфрам легирана стомана, подходящ за обработка на никел-базови и титанови сплави, за тежки и прекъснати съкращения, като зъбни котлони, фрези , фрези, бормашини, кранове обрат и изтеглящи инструменти
PM 60 - е най-високата производителност PM материал сред всички категории. С високо кобалт - ванадий-chromium-молибден-волфрам легирана стомана. Това е за машинна обработка и е достъпно само за няколко размери. Подходящ за бързо, бързо износване и чакъла обработваемост, работи с висока степен на стомана алуминий, въглерода, съдържащ сплави и т.н. Включване и фрезови инструменти за грубо и довършителните работи, дървообработващи инструменти, силно подчерта студени работни инструменти, работните инструменти.

Въвеждане на pm steel
с новите технологии и иновации, идващи пътя ни, високо категоризирани висока скорост стомана с прахово използва технология е въведена като прахова металургия (pm).
С високи изисквания от цял свят, Powder направена стомана започна да заменя по-рано направи HSS. Тя се превърна в широко популярен избор за различни разнообразни приложения за инструментална екипировка в машиностроенето, както и CNC. Тя е идеална за пълноценен различни потребители, които мелят, не изключение операции с сплави на високата температура и екзотика.
С живот на инструментите, както почти равни на два пъти, PM стомана е дал най-добро представяне в сравнение дори карбид, напускат рано употребяван HSS. Поради високата химически състав на кобалт, ванадий, волфрам, никел стоманата зърна се придържат към неговите свойства силна с който ни най-стоманата да се използват инструменти за висока производителност. Висока скорост на стомана, произведена по метода на праховата металургия за инструменти тежкотоварни машинни например за обработка на цветни метали, сплави като Ti-база и Ai сплави. Инструменти, изложени на високи напрежения на натиск, например в фини инструменти бланкиране за високоякостни материали.

- Машинни метчици с централен отвор за охлаждане;

Те са предназначени за нарязване или формоване на резби в дълбоки, глухи отвори.
Размери от M6 до M16

- С винтови
- С прави канали
- Резбовалцоващи, с външни канали за охлаждане

Предимствата на тези метчици са:

- по – добро охлаждане;
- по – добро стружкоотделяне;
- по – високи скорости на рязане;
- по – дълъг живот на инструмента;

Фиг.3 *Машинни метчици с централен отвор за охлаждане*

3. Изводи:

- Използвано е известно определение за иновация, което намира в конкретно приложение за резбообработващи инструменти;

- Разграничени са в 5 групи на който е направен анализ на техните предимства и недостатъци;

- Настоящата информация е разработена с цел използване в обзор – анализа на дисертационен труд финансиран по проект M14 – 06 УЦНИИТ към ТУ – Габрово.

4. Литература:

1. Фирма резбонарезни инструменти Габрово, http://www.gwg-gabrovo.com/ .
2. От Уикипедия, свободната енциклопедия.
3. *http://guehring-bg.net/*
4. http://www.hssmetal.com/powder_metallurgy_steel.html
5. Инженеринг ревю

INVOLUTES CYLINDRICAL GEARBOXES WITH NONCIRCULAR GEARS

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Abstract: *In this article present necessary and sufficiently condition for geometrical synthesis in involutes, cylindrical gearboxes with noncircular gears. In base for equivalently contour velocity in this article present the basic relation for movement in external and internal gears contact.*

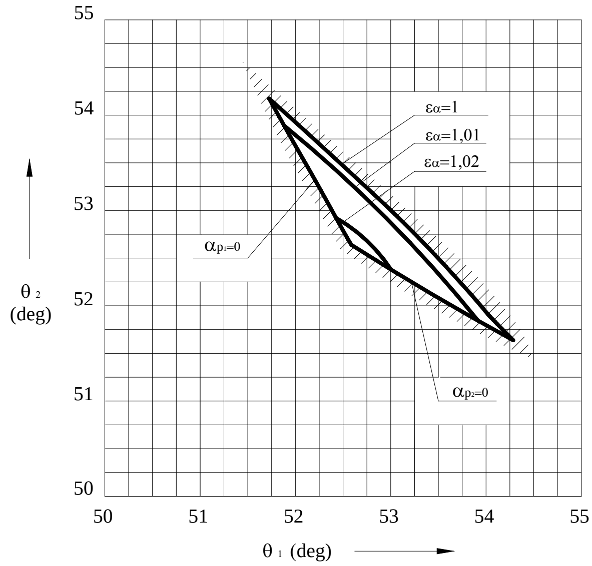
Keywords: GEARBOX, NONCIRCULAR GEARS, VARIABLE TRANSFER RATIO

1. Въведение

Зъбните предавки с некръгли колела са намерили ограничено приложение поради усложнения начин на конструиране и изработване в продължителен период от време. В следствие развитието на съвременните технологии и софтуерни продукти, разработката и производството на такива зъбни предавки се е превърнала в изпълнима задача и техният потенциал може да се използва в много и различни области [1, 2, 3, 4, 5, 6].

Зъбните предавки с некръгли колела са приложими за подобряване функционалността на различни механизми и опростяване на много процеси. Дават възможност за скоростно сглобяване на компоненти на конвейрни линии, линейно движение и бързо позициониране, движение със стоп и пауза (stop and dwell motion). Съвременни публикации и издания потвърждават, че интересът към некръглите зъбни предавки е голям, както от теоретичен аспект, така и от гледна точка на производство и приложение във високопроизводителни машини и автоматизирани производствени процеси.

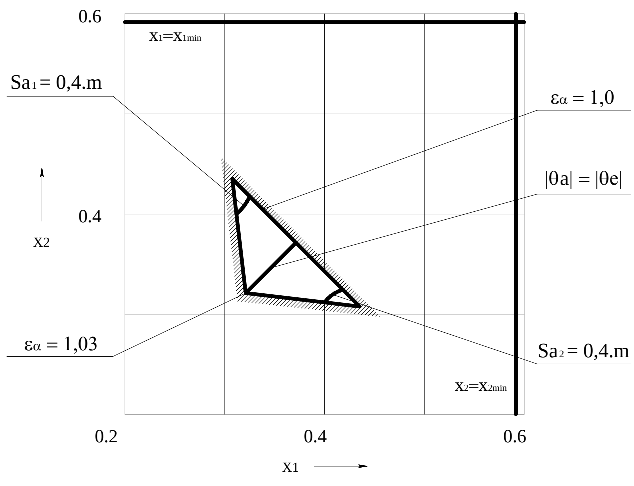
Зъбните предавки с некръгли колела са създадени главно за предаване на въртеливо движение между паралелни оси при постоянно междуосово разстояние и променливо предавателно отношение [3].



Фиг. 1 *Област на съществуване на зъбна предавка с външно зацепване със симетричен профил и брой на зъбите* z_1*=*z_2*=5*

2. Центроиди на некръгли зъбни колела

Изследванията върху областите на съществуване при еволвентен симетричен профил и кръгли центроиди са показали, че при u = 1 най – малкият възможен брой зъби който може да се произведе със стандартен контур, е $z_1 = z_2 = 7$ [7, 8, 9, 10]. Такава предавка може да се реализира при минимален и постоянен коефициент на радиална хлабина (фиг.2). В този случай е възможна изработката на предавката с един стандартен инструмент, но коефициентът на челно препокриване също не надвишава стойността от 1,04 в зоната на интерференция. От тази област на съществуване на предавката (фиг.1) се установява, че профилът на зъба е силно подрязан.



Фиг. 2 *Блокиращ контур при симетричен зъбен профил, реализиран със стандартен изходен контур и брой зъби* $z_1 = z_2 = 7$

Следователно областите на съществуване, изобразени на фиг. 1 и фиг. 2, имат повече теоретично отколкото практическо значение.

Когато условията към зацепването не могат да се удовлетворят от класическите зъбни предавки с кръгли центроиди се преминава към некръгли центроиди.

Цел на настоящият доклад е да разгледа условията за движения без приплъзване на еволвентни зъбни предавки, с външно и вътрешно зацепване във векторна форма.

Началните криви на некръглите зъбни колела се определят в зависимост от закона за движение, който те трябва да удовлетворяват. На фиг. 3 е показан пример на центроиди на елиптични зъбни колела [3]. Центроидите са в контакт в точката C, която се движи по отсечката на междуцентровото разстояние $O_1 - O_2$.

Векторите v_1 и v_2 представляват линейните скорости на ротация съответно около O_1 и O_2 и се определят:

$$v_1 = \omega_1 \times \overline{O_1C}\,, \quad v_2 = \omega_2 \times \overline{O_2C} \qquad (1)$$

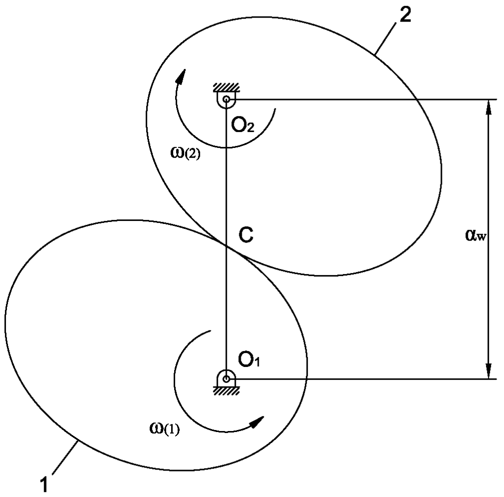
Състоянието на обтъркалване на центроиди една по друга се дефинира с векторното уравнение:

$$v_1 = v_2 \qquad (2)$$

Уравнение (2) показва, че релативната скорост в точката на тангентност на центроидите е равна на нула. По този начин състоянието на обтъркалване на центроидите се определя с

векторните уравнения:

$$v_{12} = v_1 - v_2 = 0\,, \quad v_{21} = v_2 - v_1 = 0\,. \qquad (3)$$



Фиг. 3 *Центроиди, които се търкалят една по друга.*

Точката на тангентност C на центроидите е моментен център на ротация в релативното движение и ако едната центроида е неподвижна, например 2, тогава може да се приеме, че центроида 1 се върти около центроида 2 в точката C с ъглова скорост: $|\omega_{12}| = |\omega_1| + |\omega_2|$.

3. Запазване на затворени центроиди за генериране на функция

Зъбните предавки с некръгли колела спомагат за генериране на функция от вида: $y(x), x_1 \le x \le x_2$, която е формулирана в [3] при спазване на следните условия:

– функцията $y'(x)$ трябва да бъде периодична в рамките на периода $\dfrac{x_2 - x_1}{n_1}$, където n_1 е цяло число;

– скаларните коефициенти k_1 и k_2 [3] трябва да удовлетворяват следните условия:

$$k_1 = \frac{2\pi}{x_2 - x_1}\,; \qquad (4)$$

$$k_2 = \frac{2\pi}{f(x_2) - f(x_1)}\,. \qquad (5)$$

4. Условия за изпъкналост на центроида

От уравненията за радиуса на кривина ρ [3] се извежда следното условие за изпъкналост на центроида $(\rho > 0)$:

$$r(\phi)^2 + 2\left(\frac{dr}{d\phi}\right)^2 - r(\Theta)\frac{d^2 r}{d\phi^2} > 0\,. \qquad (6)$$

Центроида 1 е изпъкнала при спазване на следното условие [3]:

$$1 + m_{12}(\phi_1) + m''_{12}(\phi_1) \ge 0\,. \qquad (7)$$

Условията за изпъкналост на центроида 2 са [3]:

$$1 + m_{12}(\phi_1) + [m'_{12}(\phi_1)]^2 - m_{12}(\phi_1)m''_{12}(\phi_1) \ge 0\,, \qquad (8)$$

където:

$$m'_{12}(\phi_1) = \frac{d}{d\phi_1}(m_{12}(\phi_1))\,; \quad .$$

$$m''_{12}(\phi_1) = \frac{d^2}{d^2\phi_1}(m_{12}(\phi_1))\,. \qquad (9)$$

Когато неравенства (7) и (8) се преобразуват в равенства съществува точка от центроидата в която $\rho = \infty$.

Ако се приеме, че некръглите колела са проектирани за генериране на функцията $z = f(u)$ се получава:

$$m_{12}(u) = \frac{k_1}{k_2 f'(u)} \qquad (10)$$

където връзката между ϕ_1 и u е:

$$\phi_1 = k_1(u - u_1) \qquad (11)$$

Съответно:

$$m'_{12}(\phi_1) = \frac{d}{d\phi_1}(m_{12}(\phi_1)) = \frac{d}{du}(m_{12}(\phi_1))\frac{du}{d\phi_1} = -\left(\frac{1}{k_2}\right)\frac{f''(u)}{[f'(u)]^2}\,, \qquad (12)$$

$$m''_{12}(\phi_1) = \left(\frac{1}{k_1 k_2}\right)\frac{2[f''(u)]^2 - f'(u)f'''(u)}{[f'(u)]^3}. \quad (13)$$

Окончателно състоянията на изпъкналост за центроиди 1 и 2, са:

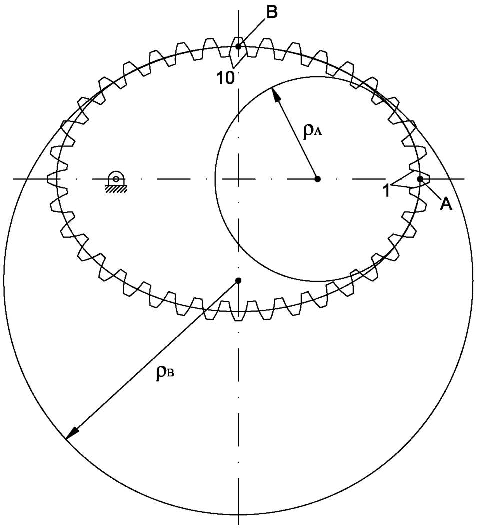
$$k_1k_2[f'(u)]^3 + k_1^2[f'(u)]^2 + 2[f''(u)]^2 - f'''(u)f'(u) \geq 0, \quad (14)$$

$$k_2[f'(u)]^3[k_1 + k_2 f'(u)] + f'(u)f'''(u) - [f''(u)]^2 \geq 0. \quad (15)$$

5. Локално представяне на некръгли зъбни колела

Различните зъби от едно некръгло зъбно колело имат различни профили. Вариацията на зъбните профили се дължи на променливата кривина на центроидта на некръглото зъбно колело [3].

Визуализацията на зъбните профили на некръгло зъбно колело е базирана на идеята, че профилите на едно и също колело могат да бъдат представени като група профили от кръгли зъбни колела [3]. С използване на този подход, например на елиптично зъбно колело на фиг. 4 са показани профили на зъби 1 и 10 като профили от кръгли зъбни колела с радиуси ρ_A и ρ_B съответно. Радиусите ρ_A и ρ_B са радиуси на кривина в съответните точки A и B от елиптичната центроида за зъби 1 и 10 (фиг. 4).



Фиг. 4 *Локално представяне на некръгло зъбно колело*

Заключение

Когато изискванията към зъбната предавка не могат да се удовлетворят от кръгли центроиди, с и без изместване на изходния контур, се приема некръгли центроиди, осигуряващи равенство на периферните скорости.

Литература

[1] Литвин Ф. Некруглые зубчатые колеса. Конструирование, теория зацепление и производство. Москва 1950.

[2] Litvin F., Fuentes A. Gear Geometry and Applied Theory. Cambridge University Press 2004

[3] Sclater N., Chironis N. Mechanisms And Mechanical Devices Sourcebook. McGraw – Hill 2001.

[4] Sclater N., Chironis N. Mechanisms And Mechanical Devices Sourcebook. McGraw – Hill 2001.

[5] Litvin F., Perez I., Fuentes A., Hayasaka K. Design and Investigation of Gear Drives with Non–circular Gears Applied for Speed Variation and Generation of Functions. Computer Methods in Applied Mechanics and Engineering, Elsevier 2008.

[6] Litvin F., Perez I., Fuentes A., Hayasaka K. Generation of Planar and Helical Elliptical Gears by Application of Rack–cutter, Hob, and Shaper. Computer Methods in Applied Mechanics and Engineering, Elsevier 2007.

[7] Болотовский И. А. и др. Цилиндрические эвольвентные зубчатые передачи внешнего зацепления – Расчет геометрии. “Машиностроение” – 1974.

[8] Котельников В. П. Минимальное число зубьев прямозубого колеса, нарезанного стандартным долбяком. Станки и инструмент, 1973.

[9] Котельников В. П. Изв. Вузов. Най – меньшие числа прямых внешних зубьев, нарезанных нестандартном инструментом. Машиностроение, 1974.

[10] Справочник по геометрическому расчету эвольвентых зубчатых и червячных передач – под ред. И. А. Болотовского,М., “Машиностроение” – 1986.

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DEVELOPMENT AND IMPLEMENTATION OF MANAGEMENT SYSTEM OF QUALITY - MAIN FACTOR FOR SUSTAINABLE DEVELOPMENT OF PRODUCTION SYSTEMS

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Abstract: *Quality management systems based on the International Standards ISO (International Organization for Standardization) is a revolutionary way to increase the competitiveness of Bulgarian companies in the energy sector on the European and international energy market. The implementation of international standards and management systems is becoming a major tool to reduce production costs, increase productivity, reduce the cost of manufactured products and services through the creation of optimal models of governance and organization of the key processes in the energetic sector companies. Development and implementation of management systems, good manufacturing practices and achieving product compliance with European and international standards is a promising trend. In proposed authors post after presentation of the International Organization for Standardization ISO is studying and analyzing systems applied quality management in projects in the field of energy development.*

Keywords: ISO (International Organization for Standardization), INTEGRATED OPERATIONAL MANAGEMENT SYSTEM, STRATEGIC MANAGEMENT, QUALITY.

1. Introduction

In the rapidly changing business environment as a result of expressed in the global financial and economic crisis, many Bulgarian companies reorient medium- and long-term development strategies, looking for new ways and mechanisms to safeguard the market position by changing the product portfolio, reduce costs and eliminate inefficient business processes.

In these conditions, the implementation of international standards and management systems is becoming a major tool to reduce production costs, increase productivity, reduce the cost of manufactured products and services through the creation of optimal models of governance and organization of the key processes in the business of enterprises. Development and implementation of management systems, good manufacturing practices and achieving product compliance with European and international standards is a promising trend. Businesses in Bulgaria, following this trend, continuously strive to improve management activities by applying models of planning and use of resources that enable effective and efficient organization of business, improving products and services and expand market presence in the long-term satisfaction the needs and expectations of end users.

In today's world, economic development and competitiveness of a country depends on many indicators - implemented innovations, energy efficiency, consumed resources, production facilities and human resources, the national transport system and others. The possibility of free movement of people, goods and services within the European Union (EU) contributes to acquire economic benefits at each Member State. Solving economic national plan requires long-term investment, clearly aware of the low level of return on the funds for the initial period. Methodologies of national and international organizations indicate guidelines and general principles governing project management. The application of standards in each case requires compliance with national legislation and customer requirements. Every successful project is one if not only met the criteria in the charter, but if through him achieve customer satisfaction, improve public scheme and gaining economic advantage.

Implementation of strategic management in organizations is becoming more popular and significance, evaluated through the prism of intense globalization processes and dynamic environment. In times of economic instability make business decisions often have strategic character, even if not so designed. The reasons for this are different, but most often the reaction of business organization in her attempt to adapt or to anticipate certain and expected of her events. Management is a complex and dynamic process, the results of which depend on the action of objective and subjective factors [1]. In this dissertation the focus is on identifying the scope of the international management standard ISO (International Organization for Standardization) and different methods of decision-making in strategic management and planning. In the exhibition offers an interpretation on the review of scientific literature by offering the author's view on the peculiarities of management decision and the types of problems in the organization. Submit the appropriate management methods and said their degree of applicability of the various stages in the process of strategic management.

In proposed authors post after presentation of the International Organization for Standardization ISO is studying and analyzing systems applied quality management in projects in the field of energy development. Based on thorough analysis concludes that the implementation of ISO standards is the main tools of sustainable production systems.

2. International Organization for Standardization

International Organization for Standardization (English International Organization for Standardization) or ISO (from the Greek ίσος - equal) is the largest international body for developing and publishing standards, composed of representatives of 148 national standards organizations (data from the end of 2004.). Founded in London on February 23, 1947 delegates from 26 countries. Central Secretariat of the organization is located in Geneva, Switzerland. Published by the (far more than 13,700 in number) industrial and commercial standards are used by all countries. It is a worldwide federation of national standards bodies (bodies - members of ISO) from different countries. ISO develops voluntary standards

ISO standards.

The ISO organization develope only required by the market standards. This is done by experts from industry sectors that have requested standards and which will subsequently apply them.

Etymology: The organization is usually referred to simply as ISO ("ISO"). This name is often wrongly deciphered by an international standardization organization or something. It should know that in fact the word ISO is not an acronym, but came from the Greek word ίσος (Issos), meaning the same. The English name is International Organization for Standardization (IOS), while French is the Organisation internationale de normalisation (OIN). It was difficult to establish a common acronym, so the founders chose ISO as the universal short name of the organization. However, it should be noted that ISO in its documents identify themselves precisely as International Organization for Standardization.

Hystory, structures and activity

The organization known as ISO, was established in 1926 as the International Federation of National Associations of standardization (ISA). Activities and halted in 1942 and during World War II. After the war, ISA (Industry Standard Architecture) is approached by a coordination committee of the newly created United Nations Organization (United Nations) and the standards functioning her UNSCC (United Nations Standards Coordinating Committee), a proposal for the formation of new global standards together one NGO. In October 1946, delegates from 25 countries of ISA and UNSCC met in London and decided to join forces to create a new international organization for standardization. The new organization officially became operational on February 23, 1947 under the name International Organization for Standardization official languages English, French and Russian. The organization is based in Geneva, Switzerland, and from 2013 worked in 164 countries.

ISO standards contribute to the development, manufacture and supply of safer and environmentally friendly products and services that facilitate international trade and make economic actors impartial[2]. Standards help to transfer technology to developing countries. They protect users and consumers and make their lives more secure.

Fig. 1 *Global distribution if ISO standards*

ISO standards management system should not be confused with product standards.

The creation of standards done by specialists of member countries organized in almost 200 number of technical committees (Technical Committee, TC), formed in various areas of industry and services. Examples:

• TC 1 - Screw threads (thread);
• TC 68 - Financial services (Services in the field of Finance);
• TC 193 - Natural gas (natural gas);
• TC 228 - Tourism and related services (tourism and services in the field);

A specific case is the formation of the **Common Technical Committee** of ISO and IEC standardization activities in the enormous volume of information technology. The Committee is the first and only of its kind at the time and is called **ISO/IEC JTC1** (Joint Technical Committee 1). His work is distributed between **18 subcommittees** (Sub-Committees, SC).

Each ISO standard has name and the format is „ISO HHHH: yyyy Name" where „HHHH" is the number of standard „yyyy" is the year of issue, „Name" describes the object of standardization. For example: **ISO 9000: 2000 Quality management systems - Fundamentals and vocabulary** (Systems of quality management. Basic principles and vocabulary) [3].

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Bulgaria became a full member of the International Organization for Standardization on January 1, 1955 On May 1, 1958 our country took part in the International Electrotechnical Commission (IEC) as well as full member.

3. Analysis of applied systems for quality management in projects in the field of energy development.

After the accession of Bulgarian economy to the European Union is particularly relevant question to increase its competitiveness. In the Bulgarian management theory problem for the certification of enterprises in the field of energy under international ISO standard is not enough depth studies and world practice shows fairly good results. The study of this problem and its application in business practice are especially relevant, given this and that today in a global economy and a strong turbulent environment of the competitiveness of individual companies depends on the successful development of the national economy as a whole.

In the present publication have been studied and analyzed 14 sites in the field of energy development, which are distributed as follows: 3 with international participation, three are of strategic importance for the Republic of Bulgaria, 8 were from the distribution network. In all embedded objects function integrated IMS. The survey was conducted in accordance with the sampling method for conducting audits inner. From the analysis it is found that the total number of tested sites only 8 (57%) are very well integrated operational management system. Of these 6 (43%) sites were found slight discrepancies in mandatory procedures of ISO 9001: 2008 and BS OHSAS 18001: 2007.

The research and analyzed data relied on reports of past and internal control audits for the 2009-2013 year. Conducting audits made by teams of external auditors (consultants) and representatives of the relevant systems in facilities with adequate competence. Only 3 of the 27 sites is unappreciated and unproven competence of the auditors in the energy sphere.

Continuous improvement is provided by the management of 27 sites and the sites of the teams who have realized the need to continually improve efficiency the integrated system of quality management and health and safety at work. The managements of the 27 sites take actions aimed at improving the quality policy and objectives quality and safety, audit results, analysis of the data, corrective and preventive actions and improving processes in their management, but experienced some difficulty in updating quality policies and actually set achievable targets and the quality control and safety at work[4].

Although all sites developed systems in internal checks made at the expert level, most of them were identified significant gaps. For the purpose of the study was developed with the program plan and a questionnaire that preliminary were agreed with the management of companies. In the process of study and conducting internal audits it was estimated up to date an embedded system.

The scope of the study includes information and evidence of compliance with all requirements of ISO specifications included in IMS:

• Monitoring, measuring, reporting and reviewing progress against the objectives and related key tasks performance indicators;

- Operational control of key processes;
- Management responsibilities for policy at all sites;
- The links between the basic requirements, policies, goals and objectives for achieving compliance;
- Legal requirements, responsibilities and competence of staff, according actions and procedures;

The analysis is the study of existing models Management System (QMS) ISO 9001: 2008 27 energy facility, which was built system and there is realized voluntary certification.

We will separate the energetic sites in two groups:

- Energy projects with perceived need for quality management, which are implemented, maintained and certified integrated systems;
- Energy projects that meet the statutory requirements in energy regulations;

Analyze the risks have been assessed risks identified in critical control points and monitor the critical limits. Only 8 of the 27 sites is created procedure and monitor the ongoing processes to their subsequent analysis. Based on the conclusions from the observations recommended the management of objects continuation of embedded IMS meeting the requirements of ISO 9001: 2008 and BS OHSAS 18001: 2007.

General requirements for the documents in the 27 sites developed and implemented IMS according to the requirements of ISO 9001: 2008 and BS OHSAS 18001: 2007 are covered with some exceptions in 7 projects.

Management of documents and records is governed by the order determined in mandatory procedures of ISO 9001: 2008 for management of documents and records. For these clauses is not acceptable to have major discrepancies in identification documents and records[5].

Based on the extensive research we can conclude that this is a prerequisite for the low quality of the product to maintain IMS and inability of understanding and that there will be systemic problems with product quality controlled by IMS.

Hazards identified in the risk assessment and the measures envisaged to limit, control and prevention are complied with only 19 of the auditees.

After identifying opportunities to improve corporate governance and increase technological readiness and competitiveness of Bulgarian energy companies, by way of their certification standards ISO (International Organization for Standardization) is needed in each building, implementation and certification of IMS / integrated system / control, to reach a higher level of competitiveness. Integrated system management of the business to be based on the requirements of international standards BS EN ISO 9001: 2008, BS EN ISO 1401: 2004 and BS OHSAS 18001: 2007[6].

As a summary of the research we can say that the requirements of ISO 9001 can be interpreted elastic. This allows each project to IMS according to ISO 9001: 2008 and BS OHSAS 18001: 2007 to migrate in the direction and at the EMS System (environmental management) ISO 14001: 2004.

This means that the integrated management systems IMS purposefully can bring in as much as possible a large number of sites and the requirements of ISO 14001: 2004 can analyze and develop a new model of integrated system.

4. Conclusion

International standards have strategic tools and guidance that help companies respond to some of the complex challenges of modern business. They ensure that business operations are possible - effective, increase productivity and help companies reach new markets. ISO International Standards ensure that products and services are safe, reliable and of good quality. For businesses, they are strategic tools that reduce costs by minimizing waste and errors and increasing productivity. They help companies to access new markets and create a level playing field for developing countries and facilitate free and fair world trade.

Advantage of international standards is that they are carriers of technological, economic and social benefits. They help to harmonize the technical specifications of products and services of the industry to more effectively remove barriers to international trade.

Business international standards are strategically tools and guidance that help companies to deal with some of the most complex challenges of modern reality. They ensure that business operations are as efficient as possible, to increase productivity and help companies gain access to new markets.

Following the successful model implemented an integrated management system for quality is achieved improvement of quality management in the company, meeting the requirements of customers, suppliers, partners and regulatory requirements. To be competitive in the European, Bulgarian companies have to meet a number of requirements related to the quality and safety of products, introduction of new technologies, environmental protection, safety, quality control and others.

Apart from raising serious competitiveness, implementation and effective use of quality standards leads to lower production costs, increase productivity at a reduced cost, increase profits and eliminate inefficient business processes.

Using of Management systems, are a tool for increasing the efficiency of operations in Bulgarian enterprises and their sustainable development.

References

1. В. А. Качалов, „Аудит систем менеджмента на соответствие требованиям ISO 9001, ISO 14001, OHSAS 18001", Москва- ИздАТ, Година на издаване: 2012 г.;

2. А. М. Шаммазов, Р. Н. Бахтизин, Р. Г. Шарафиев, К. Э. Писаренко, В. Ж. Квитко, „От контроля количества к управлению качеством. История развития системы менеджмента качества ГОУ ВПО УГНТУ", Уфа, Година на издаване: 2009 г.;

3. JNN Консулт ЕООД & Saga Technology Ltd, "Бяла книга на съвременните интелигентни системи за управление на бизнеса в България", Saga Technology, Година на издаване: 2006 г.;

4. Георги Тасев, "ISO 9001: Практическо ръководство на отговорника по качество", Раабе България, Година на издаване: 2009 г.;

5. Творчески колектив, "ISO 9001 за малките и средните предприятия", БДС Компас, Година на издаване: 2007 г.;

6. http://www.bds-bg.org

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FORCES AND DEFORMATIONS IN THE LINEAR ROLLER BEARING

СИЛИ И ДЕФОРМАЦИИ В ЛИНЕЕН РОЛКОВ ЛАГЕР

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Abstract: *To the modern machines, especially those for the workflow automating, have been made more greater demands regarding the accuracy of their work under different conditions. In relation to this, in most constructions have been used linear bearings, which are especially suitable because of a number of their advantages.*

The present article aims to show the determination of the forces and deformations of a linear roller bearing of specifically selected series, depending on the speed and acceleration at work, as forces and friction coefficients in different parts of the bearing have been previously specified and taken into account in the calculation.

As a result of the dimensioning it becomes possible to determine the duration of operation of the linear roller bearing of the so-set conditions, and the deformations in the various parts under load.

Keywords: LINEAR ROLLER BEARING, DIMENSIONING,

1. Introduction

Comparing the characteristics of different systems allows bearings to identify their advantages and disadvantages when operating in specific conditions and in certain construction of machinery.

The linear bearings are widely used in the precise mechanics, automation, and devices to measure and control because of their following advantages over the other types of bearings: sliding, hydrostatic and others :

- Absence of any kind of windage;
- A guaranteed interchangeability, based on the rapid development of their standardizing, resulting in minimizing the operating costs;
- Very low friction, depending on the speed of displacement.

In the present publication it will be considered a specific type of linear bearings [3,4], which are characterized by a very high precision of manufacturing and load capacity. This allows them to be put in constructions, requiring absence of windage, specified stiffness, low coefficient of friction. As a result, the construction of the machine is characterized by a long duration of operation. The load capacity, rigidity and duration of operation are highly dependent on the number and shape of the rolling elements constituting the construction of the linear bearing.

The friction coefficient μ while sliding, depends to a large extent on the nature of the material of the contacting elements, the state of their surfaces, load and speed. Its values are in the range 0.05 to 0.2 [1]. It increases very quickly when the sliding speed tends to 0 - then the value of μ can reach a maximum value of 0.3. Depending on the construction embodiment, the coefficient of friction μ in the linear bearings in question has a value from 0.0005 to 0.005, which is approximately 10 to 400 times smaller than that of a sliding bearing of the same dimensions.

The dynamic load (load capacity) C of a linear bearing corresponds to the duration of operation, equivalent to 100,000 m displacement, wherein the load of the elements remains constant – it does not change in value and in direction. At the same time, the static load must not be in any case greater than the dynamic one.

The duration of the exploitation (resource of work) of the linear bearing is defined as the distance in meters traveled by one of its guiding to the first signs of fatigue from one of the constituent elements.

The constructional varieties of linear bearings are the following:

- With a separator for pellets, rolls, or needles;
- With an insert for recirculation of the pellets or rolls;
- With a monorail (Fig. 1). This type of a linear bearing is characterized by a high rigidity, great dynamic and static load capacity, stable functioning, and a very good sealing of the support.

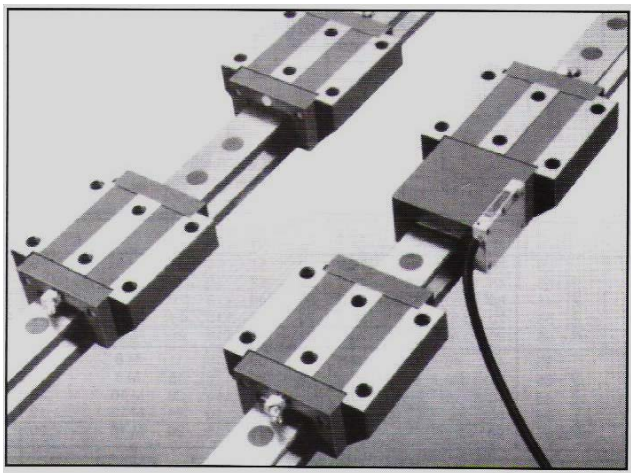

Fig. 1. *Linear roller bearing type monorail*

The objective of this article is to show the determination of the forces and deformations of linear roller bearing and choosing a particular series, depending on the load, speed and acceleration at work, as the frictional forces in different parts of the bearing and the coefficient of friction have been specified in advance and taken into account when calculating.

2. Characteristics of linear roller bearing

They are the following (Fig. 2) [3]:

- Four classes of tolerances : from G0 to G3;
- Three classes of preloading: V1, V2 and V3, defined as a percentage of the load capacity C;
- Five type sizes (series) : 25, 35, 45, 55 and 65;

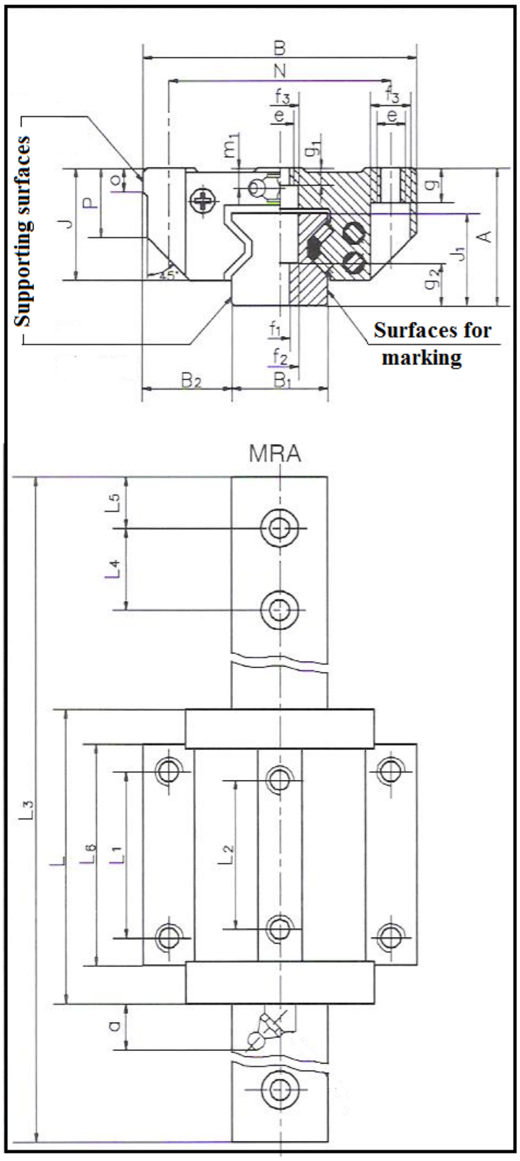

Fig. 2. Construction of the linear roller bearing series MRA

- Four series : Table 1.

Table 1. Series of linear roller bearing

Indication	MRA	MRB	MRC	MRD
Type of the support	standard	standard long	compact	Compact long

- The linear roller bearing operates in a temperature range from **-40°C** to **+80°C**, as for a short period can last up to +120°C.
- The standard length of the rail is calculated by the formula

(1) $\mathbf{L_3 = (n + k.p).L_4 + 2.L_5\ (\pm\ 2\ mm)}$, (Fig. 2) [3]

as the values of n, p and k are given in Table 2.

*Table 2. The value of the coefficients **n**, **p** and **k***

Series	n	p	k
MR 25	9	6	1 to 16
MR 35	14	5	1 to 13
MR 45	10	4	1 to 11
MR 55	12	4	1 to 9
MR 65	7	4	1 to 7

- The loading and the types of variations of the support of the bearing are shown on Figure 3.

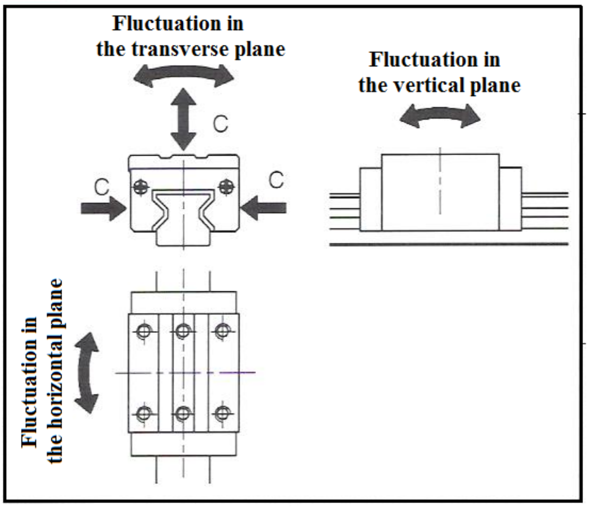

Fig. 3. Loading C and fluctuations of the support

The functioning of a linear roller bearing in normal conditions is performed at a speed up to 3 m/s (180 m/min) and acceleration up to 50 m/s^2 [2,3].

In cases where the lubrication of the bearing is carried out with oil, the power for moving F_R can be determined under dependency (2) for speeds lower than 30 m / min, as the coefficients of friction are shown in Table 3.

(2) $\mathbf{F_R = F_{A,G} + v\ .\ f_{A,v} + F_{w,G} + v\ .\ f_{w,v} + F_j\ .\ \mu,}$

where :

$\mathbf{F_R}$ – force for moving, N
v – speed, m/min
$\mathbf{F_{A,G}}$ – friction force of cleaner of lubricant at low speed, N
$\mathbf{f_{A,v}}$ – friction coefficient of cleaner of lubricant in a function of the speed, (N)/(m/min)
$\mathbf{F_{w,G}}$ – friction force of the the support at low speed, N
$\mathbf{f_{w,v}}$ – coefficient of friction of the support in a function of the speed, (N)/(m/min)
$\mathbf{F_j}$ – the sum of all external forces applied to the the support, N
μ – friction coefficient of the bearing.

When lubricating of the bearing with grease the friction force in the support $\mathbf{F_{w,G}}$ is initially the same as with the lubrication with an oil, but decreases after a few operation cycles outward - return.

Table 3. Values of the coefficients and the forces of friction lubrication with oil for linear bearing with a class of pretension V2

			MRA/MRC	MRB/MRD		
Series	**$F_{A,G}$ (N)**	**$f_{A,v}$**	**$F_{w,G}$ (N)**	**$F_{w,G}$ (N)**	**$f_{w,v}$**	**μ**
25	7	0,15	5	6	0,25	0,001
35	9	0,20	8	10	0,35	0,001
45	11	0.25	12	15	0,50	0,001
55	13	0,30	16	20	0,70	0,001

3. An example for dimensioning a linear roller bearing

The presented example shows how to determine the limit of resistance against fatigue. It has not yet been developed a method for determining the limit of wear resistance.

The forces acting on the linear roller bearing, can be determined by approximation of the linearized characteristic curve of the deformations in all cases of its application.

As a result has always been obtained an approximate value, as the characteristic curve of the support can be linearized, while the elastic deformations of the rest of the structure of the bearing are overlooked.

3.1. Determination of the impacts on the support (Fig. 4)

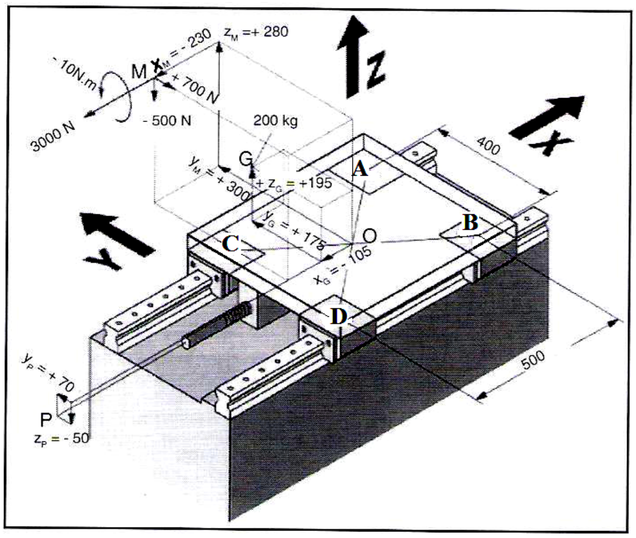

Fig. 4. *Coordinates and load applied on the the support*

The matrix of external influence on the bearing, seen in point **M** (-230, +300, +280), has the following form:

$$\tau_1 = \tau_{(ext \to syst)} = {}_M\begin{Bmatrix} -3000, & -700, & -500 \\ -10, & 0, & 0 \end{Bmatrix}$$

This matrix is calculated for point O (0,0,0) by:

$$\tau_1 = {}_O\begin{Bmatrix} -3000, & -700, & -500 \\ -10+(0,3x\text{-}500)-(0,28x\text{-}700), & 0+(0,28x\text{-}3000)-(-0,23x\text{-}500), & 0+(-0,23x\text{-}700)-(0,3x\text{-}3000) \end{Bmatrix}$$

The moment to point O is determined by the relationship

$\vec{M_O} = \vec{M_M} + \vec{OM} \wedge \vec{R}$ and then for τ_1, reduced in point O is obtained

$$\tau_1 = {}_O\begin{Bmatrix} -3000, & -700, & -500 \\ 36, & -955, & 1061 \end{Bmatrix}.$$

The impact of the transmission mechanism on the system of the linear bearing is applied in point **P** (0, +70, -50) and then the matrix has the form:

$$\tau_2 = \tau_{(transm \to syst)} = {}_P\begin{Bmatrix} F, & 0, & 0 \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} F, & 0, & 0 \\ 0, & -0,05.F, & -0,07.F \end{Bmatrix}$$

The interaction between of the bearing and the rail of the support is seen in the following four points – A, B, C и D (Fig. 4).

In point **A** (+K/2, +Q/2, 0) the rail of the bearing has an impact on the support A and the matrix τ_3 is:

$$\tau_3 = \tau_{(rail \to supp.A)} = {}_A\begin{Bmatrix} X_A, & Y_A, & Z_A \\ L_A, & M_A, & N_A \end{Bmatrix} = {}_O\begin{Bmatrix} 0, & Y_A, & Z_A \\ 0,5\,Q.Z_A, & -0,5\,K.Z_A, & 0,5\,K.Y_A \end{Bmatrix}$$

as $X_A = 0$, the friction forces are negligible, $L_A = 0$, $M_A = 0$ и $N_A = 0$ provided that the rigidity of the system is high enough and the geometry is sufficiently accurate to disregard the moments of the fluctuations of the support in the three planes as shown in Figure 3.

In an analogous manner is defined the impact of the rail and the support in the remaining three points – B, C and D.

In point **B** (+K/2, -Q/2, 0) the rail impacts on the support B :

$$\tau_4 = \tau_{(rail \to supp.B)} = {}_B\begin{Bmatrix} 0, & Y_B, & Z_B \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} 0, & Y_B, & Z_B \\ -0,5Q.Z_B, & -0,5K.Z_B, & 0,5K.Y_B \end{Bmatrix}$$

In point **C** (-K/2, +Q/2, 0) the rail impacts on support C :

$$\tau_5 = \tau_{(rail \to supp.C)} = {}_C\begin{Bmatrix} 0, & Y_C, & Z_C \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} 0, & Y_C, & Z_C \\ 0,5Q.Z_C, & 0,5K.Z_C, & -0,5K.Y_C \end{Bmatrix}$$

In point **D** (-K/2, -Q/2, 0) the rail impacts on support D :

$$\tau_6 = \tau_{(rail \to supp.D)} = {}_D\begin{Bmatrix} 0, & Y_D, & Z_D \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} 0, & Y_D, & Z_D \\ -0,5Q.Z_D, & 0,5K.Z_D, & -0,5K.Y_D \end{Bmatrix}$$

In point **G** (-105, +175, +195) the weight force acts on the system and then

$$\tau_7 = \tau_{(weight \to syst)} = {}_G\begin{Bmatrix} 0, & 0, & -P \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} 0, & 0, & -P \\ -0,175.P, & -0,105.P, & 0 \end{Bmatrix}$$

After bringing all matrices to point O, it can be applied the principle of the dynamics :

(3) $$\tau_1 + \tau_2 + \tau_3 + \tau_4 + \tau_5 + \tau_6 + \tau_7 = \delta$$

as

(4) $$\delta = {}_G\begin{Bmatrix} -m.\gamma, & 0, & 0 \\ 0, & 0, & 0 \end{Bmatrix} = {}_O\begin{Bmatrix} -m.\gamma, & 0, & 0 \\ 0, & 0,195.\,m.\gamma, & -0,175.m.\gamma \end{Bmatrix}$$

m = 200 kg, the mass of the system

$\gamma = 6$ m/s^2, the maximum acceleration.

As a result is obtained the following system of six equations

(5.1) $-3000 + F = -m.\gamma$
(5.2) $-700 + Y_A + Y_B + Y_C + Y_D = 0$
(5.3) $-500 + Z_A + Z_B + Z_C + Z_D - P = 0$
(5.4) $36 + 0,5Q(Z_A - Z_B + Z_C - Z_D) - 0,175P = 0$
(5.5) $-955 - 0,05F + 0,5K(-Z_A - Z_B + Z_C + Z_D) - 0,105P = 0,195m.\gamma$
(5.6) $1061 - 0,07F + 0,5K(Y_A + Y_B - Y_C - Y_D) = -0,175m.\gamma$

From equation (5.1) can be determined the force F :

(6) $\mathbf{F} = 3000 - m.\gamma = 3000 - (200\,.\,6) = 3000 - 1200 = \mathbf{1800}$ **N.**

Equations (5.2) and (5.6) contain 4 unknowns. From the hypothesis that the geometry is perfect and rigidity of the system is infinite, it can be assumed that under the influence of moments around an axis z, we have $Y_A = Y_B$ и $Y_C = Y_D$.

These two equations can be presented as

$$700 + 2Y_A + 2Y_C = 0$$

$$1061 - 0,07.1800 + 0,5K.\,2(Y_A - Y_C) = -0,175\,.\,200\,.\,6$$

from where is obtained: $\mathbf{Y_A = Y_B = -550}$ **N**, $\mathbf{Y_C = Y_D = +900}$ **N.**

Equations (5.3), (5.4) and (5.5) contain four unknowns. The acceptance of the same hypothesis as above allows to make the following assumptions:

- $Z_{A/F} = Z_{B/F} = Z_{C/F} = Z_{D/F} = \mathbf{Z_F}$, where $Z_{A/F}$ is the vertical force, exerted by the rail on support A, and it represents the sum of the vertical forces (the same goes for $Z_{B/F}$, $Z_{C/F}$ and $Z_{D/F}$);
- $Z_{A/Mx} = -Z_{B/Mx} = Z_{C/Mx} = -Z_{D/Mx} = \mathbf{Z_{Mx}}$, where $Z_{A/Mx}$ is the vertical force, acting through the rail on the support A, and occurring a sum of the moments, relative to an axis x (the same goes for $Z_{B/Mx}$, $Z_{C/Mx}$ and $Z_{D/Mx}$);
- $Z_{A/My} = Z_{B/My} = -Z_{C/My} = -Z_{D/My} = \mathbf{Z_{My}}$, where $Z_{A/My}$ is a vertical force, acting through the rail on support A, and occurring a sum of the moments, relative to an axis y (the same definition goes for $Z_{B/My}$, $Z_{C/My}$ and $Z_{D/My}$).

Then from equation (5.3) is obtained

$Z_A + Z_B + Z_C + Z_D = 4.Z_F = (m.g) + 500 =$
$= (200.9,81) + 500 = 1962+500 = 2462$ N.

Or $\mathbf{Z_F} = 2462/4 = Z_{A/F} = Z_{B/F} = Z_{C/F} = Z_{D/F} = 615,5$ N.

From equation (5.4) follows

$Q/2 . (Z_A - Z_B + Z_C - Z_D) = Q/2 . (4 . \mathbf{Z_{Mx}}) = 0{,}175 P – 36$
$= (0{,}175 . 200 . 9{,}81) – 36 =$
$= 343{,}36 – 36 = 307{,}35$ N.m

Then $\mathbf{Z_{Mx}} = 307{,}35/2.Q = 307{,}35 /2.0{,}4 = 384$ N =
$= Z_{A/Mx} = - Z_{B/Mx} = Z_{C/Mx} = - Z_{D/Mx}$

From equation (5.5) is obtained

$K/2 . (- Z_A - Z_B + Z_C + Z_D) = K/2 . (4.Z_{My}) = - 2.K.Z_{My} =$
$= - 0{,}195 . m .\gamma + 0{,}105 . P + 0{,}05 . F + 955 =$
$= - 0{,}195.200.6 + 0{,}105.200.9{,}81 + 0{,}05.1800 + 955 = 1017$ N.m

Then $\mathbf{Z_{My}} = 1017/2.K = 1017/2.0{,}5 = 1017$ N =
$= Z_{A/My} = Z_{B/My} = - Z_{C/My} = - Z_{D/My}$

Then we receive

$Z_A = Z_{A/F} + Z_{A/Mx} + Z_{A/My} = 615{,}5 + 384 – 1017 = - 17$ N
$Z_B = Z_{B/F} + Z_{B/Mx} + Z_{B/My} = 615{,}5 – 384 – 1017 = - 786$ N
$Z_C = Z_{C/F} + Z_{C/Mx} + Z_{C/My} = 615{,}5 + 384 + 1017 =+2017$ N
$Z_D = Z_{D/F} + Z_{D/Mx} + Z_{D/My}= 615{,}5 – 384 + 1017 = +1248$ N.

From the obtained results it can be concluded that the vertical force impacting by the rail on the supports A and B shall be designed in a negative direction of z-axis and thus subjecting them to strength.

The vertical force acting through the rail respectively on the supports C and D, is designed in a positive direction of z-axis and subjecting them to pressure.

From the calculations made was established, that the linear roller bearings of the series **MRC 25 V1** may incur without a problem values obtained for the forces [4].

3.2. Resource of working of the bearing L

It is determined by the equivalent force P and a dynamic load C by the relationship:

(7) $L = a (C/P)^{10/3} . 10^5$ m,

where a – safety coefficient.

The equivalent force P_i, which is used in formula (7) depends on the one hand on the calculated above forces in the four points of the the support, and on the other hand on the applied preloading :

(8) $P_i = F_P + 2/3 . F_i \rightarrow$ when $F_i \leq 3. F_P$

(9) $P_i = F_i \rightarrow$ when $F_i > 3 . F_P$

where F_P – force of preloading,

and $F_i = |Y_i| + |Z_i|$.

For the selected in the above section linear roller bearing, the dynamic load C = 27 700 N [4], and the preloading is 3% for it. Then

$F_P = 27\,700 . 0{,}03 = 831$ N,

which allows to determine the following equivalent workloads :

$F_A = | - 550 | + | - 17 | = 567$ N or $P_A = 831 + 2/3.567 = 1209$ N.

$F_B = | - 550 | + | - 786 | = 1336$ N or $P_B = 831 + 2/3.1336 = 1722$ N.

$F_C = | + 900 | + | - 2017|= 2917$ N or $P_C = 2917$ N.

$F_D= | + 900 | + | - 1248 | = 2148$ N or $P_D= 2263$ N.

From the above results it is established that the support is the busiest in p. C. Its resource of working L at a safety coefficient a = 1.0.

(10) $L = 1{,}0 . (27\,700/1980)^{10/3} . 10^5 = 660 . 10^6$ m.

3.3. Determination of deformations

To determine the values of deformations under load the bearing is used Formula 11. It linearizes the elastic deformations of the support at a load.

(11) $\delta = (D . F)/C$,

where :

D – Elastic deformations of the the support under load equal to dynamic load C;

F – load on the the support (compression, tension, torsion).

For linear roller bearing of the series **MRC 25** the values of D are the following :

MRA/MRC 25	Compression	Tension	Torsion
V1	36	62	52
V2	34	56	46
V3	30	53	44

The values of the estimated deformations are given in Table 4.

Table 4. *Values of the deformations in the support*

Supp.	Condition	Calcul	Value exact
A	Tension	δ_1 = 62.17/27 700 = 0 µ	≈ 0 µ
A	Torsion	δ'_1 = 52.550/27 700 = 1 µ	≈ 1 µ
B	Tension	δ_2 = 62.786/27 700 = 1,76 µ	≈ 1,5 µ
B	Torsion	δ'_2 = 52.550/27 700 = 1 µ	≈ 1 µ
C	Compr.	δ_3 = 36.2017/27 700 = 2,62 µ	≈ 4 µ
C	Torsion	δ'_3 = 52.900/27 700 = 1,7 µ	≈ 1,5 µ
D	Compr.	δ_4 = 36.1248/27 700 = 1,62 µ	≈ 2,5 µ
D	Torsion	δ'_4 = 52.900/27 700 = 1,7 µ	≈ 1,5 µ

4. Conclusions

There have been analyzed the advantages of linear roller bearings relative to other constructions of bearings. It was found that the coefficient of friction in the linear roller bearing is for example 10 to 400 times smaller than that of the sliding bearing of the same size, which is beneficial to the bearing capacity and its operation.

There have been considered in detail the characteristics of the linear roller bearing – the classes of the tolerances, of the preloading, the series, the temperature range, and the conditions under which it can work - speed, acceleration, load. There have been determined the friction forces between different parts of the bearing at oil lubrication.

It has been solved an example with predefined specific output values, and has been chosen a corresponding series of a linear roller bearing, taking into account all impacts on the support, based on which has been solved a system of six equations. It allows to be identified the forces, acting in the four points of the support, as well as the type of tensions - tension and compression. It has been specified the resource of working on the linear roller bearing, according to the specified busiest point of the the support, as well as the deformations in those points.

References

1. АРНАУДОВ К., И.Димитров, П.Йорданов, Л.Лефтеров. Машинни елементи. Техника, София, 1980.
2. CHEVALIER A. Guide du dessinateur industriel. Edition HACHETTE *Technique*, 2004.
3. Corbet J.-Cl., A. Ducruet, L. Huchet. Le CODOTEC, 1996.
4. Prospect SCHNEEBERGER, 2012.

METHOD OF INTENSITY ASSESSMENT OF POWER LINES SWINGING

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Abstract: *On the basis of long-term statistics data of wires swinging accumulated by energy systems of Kazakhstan the swinging intensity linear regressional dependence has been elucidated as a function of wind speed and its direction to the power line, as well as the length of a span and the number of half-waves in the span. Lower and upper limits of regression equations parameters has been estimated.*

Keywords: WIRE SWINGING, REGRESSIONAL DEPENDENCE, SWINGING INTENSITY

In the development of countermeasures for wires swinging and in the design of power lines it is necessary to take into account information about the possible intensity (range) of wires oscillations, depending on the wind speed and the characteristics of power lines. This information can be obtained from the accumulated by energy systems long-term statistical observations of wire swinging during the operation of power lines.

As shows the analysis of statistical data on the wires swinging, which took place in energy systems of West - Kazakhstan region, wires are exposed to swinging regardless of voltage classes, type of lines, effective span and the magnitude of mechanical stresses in wire. Moreover, wires oscillations appear with different number of half-waves in the span [1].

The article is devoted to the establishment of the empirical wind speed, angle of wind flow attack to the lines, span and number of half-wave dependences of swinging intensity. Selected materials cover one half-wave (18 cases), two half-wave (15 cases) and three half-wave (5 cases) swinging. The total number of observations is n = 38. According to the sample material, the minimum span length is 90 m. and the maximum is 367 m..

To establish an empirical dependence, the following variables were introduced:

$$A_P = \begin{pmatrix} A_{P1} \\ \cdot \\ \cdot \\ A_{P38} \end{pmatrix} \qquad X = \begin{pmatrix} 1 & x_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ 1 & x_{38} \end{pmatrix}$$

where A_p - observation vector, dimension (38 × 1), $X = \tilde{\lambda} V_\perp$ - matrix of independent variables, dimension (38 × 2), $\tilde{\lambda} = \frac{\ell}{m}$; (ℓ – span length), x_i – constituting the independent variables X.

Notably, A_p – determines the intensity of swinging, $V_\perp$ – vertical component of the wind speed, $\tilde{\lambda}$ – the length of the half-waves, m – number of half-waves in the span.

b - vector of parameters which are to be evaluated, dimension (2 × 1):

$$b = \begin{pmatrix} b_0 \\ b_1 \end{pmatrix}$$

E - vector of errors (residuals), dimension (38 × 1):

$$E = \begin{pmatrix} e_1 \\ \cdot \\ \cdot \\ e_{38} \end{pmatrix}$$

Model equations represented in matrix form

$$A_p = Xb + E \tag{1}$$

By the least squares method (LSM - method) for evaluation b [2].

$$b = \begin{bmatrix} b_0 \\ b_1 \end{bmatrix} = \left(X^T X \right)^{-1} X^T A_p \tag{2}$$

where "T" - symbol of transposition.

As a result of calculations based on accumulated statistical data we obtain a linear regression model of the first order.

$$A_p = b_0 + b_1 \tilde{\lambda} V_\perp = b_0 + b_1 \frac{\ell}{m} V Sin\alpha \tag{3}$$

where $b_0 = 1{,}785$; $b_1 = 0{,}0011$ - parameters of equation.

Adequacy assessing of regression model is made by F - Fisher criterion. Estimated (actual) value of F according to [3].

$$F_{act} = \frac{\sum_1^n (A^{\mathrm{T}}_{pi} - \overline{A}_p)^2}{s^2} \tag{4}$$

$$s = \sqrt{\frac{\sum_1^n (A_{pi} - A^{\mathrm{T}}_{pi})^2}{n-2}} \ ;$$

$$\overline{A}_p = \frac{1}{n} \sum_1^n A_{pi} ;$$

where A_p - observed value, A^T - theoretical (predicted) value, S - assessment of dispersion adequacy.

Comparison results of actual value $F_{act} = 46.78$ and table $F_{table} = 4.12$ $(F_{act} > F_{table})$ shows the reliability of regression equations. Tabulated values are defined for significance level 0.05 and degree of freedom $n - r = 36$, where r - number of coefficients of the regression equation.

Valuation of b_i coefficients is made by Student's t-test [3].

$$t_{b_0} = \frac{b_0\sqrt{n}}{s}\sqrt{\frac{\sum_1^n (x_i - \bar{x})^2}{\sum_1^n x_i^2}};$$

$$t_{b_1} = \frac{b_1\sqrt{\sum_1^n (x_i - \bar{x})^2}}{s}; \qquad (5)$$

where $\bar{x} = \frac{1}{n}\sum_1^n x_i$ (x_i − independent variables).

Calculated values of t-statistics:

Tabular value of tα – criteria, which was calculated for the significance level $\alpha = 0{,}05$ and the number of degrees of freedom 36, equals to $t_\alpha = 2{,}03$. Seeing that $t_{b_0} > t_\alpha$ and $t_{b_1} > t_\alpha$, corresponding coefficients of the regression equation is considered significant.

For confidence interval calculation the marginal error for each indicator is to be defined [3].

$$\Delta b_0 = \frac{t_\alpha s}{\sqrt{n}}\sqrt{\frac{\sum_1^n x_i^2}{\sum_1^n (x_i - \bar{x})^2}};$$

$$\Delta b_1 = t_\alpha \frac{s}{\sqrt{\sum_1^n (x_i - \bar{x})^2}}; \qquad (6)$$

The lower and upper limits of regression equations parameters

$$b_0 - \Delta b_0 \le b_0 \le b_0 + \Delta b_0;$$
$$b_1 - \Delta b_1 \le b_1 \le b_1 + \Delta b_1;$$

In view of numerical values $\Delta b_0 = 0{,}5$ and $\Delta b_1 = 0{,}00033$

$$1{,}285 \le b_0 \le 2{,}285; \qquad (7)$$
$$0{,}00077 \le b \le 0{,}00143;$$

Analysis of these predictable swinging intensity boundaries shows that the intensity of swinging increases with the length of span, wind flow speed and the number of half-waves in the span.

The regression model (3) will be used in research of power lines swinging phenomena and in the development of methods and means of protection against swinging.

References

1 Murat A. DJAMANBAYEV, (Kazakh National Techn. University – Almaty, Kazakhstan), Alexander A. VINOGRADOV (JSC "Elektrosetjstroyproekt" - Moscow, Russia) OBSERVATIONS OF GALLOPING IN THE NORTHERN PART OF KAZAKHSTAN. – Seventh International Symposium on CABLE DYNAMICS, Vienna (Austria), December 10-13, 2007

2 Dreyper N., Smit G. Prikladnoy regressionnyiy analiz /perevod s angliyskogo/.- M.: «Statistika», 1973. Str. 393

3 Eliseeva I.I., Kuryisheva S.V. i.dr. Praktikum po ekonometrike /uchebnoe posobie/.- M.: «Finansyi i Statistika», 2001. 192 str.

CALCULATION OF FREQUENCY CHARACTERISTICS OF SPLIT PHASE OF POWER TRANSMISSIONS LINES

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Annotation: *The article discusses the free-running sweep split phase (SP) power lines. We derive a nonlinear differential equation of torsional movement split phase by using Lagrange's equation of the 1st kind. In order to obtain an approximate solution of the nonlinear problem applied the method of Van der Pol. Analyzed degree of influence of parameters of power lines on the frequency of torsional vibrations of SP.*

Keywords: POWER TRANSMISSIONS LINES, SPLIT PHASE (SP), KINETIC ENERGY OF SP, AMPLITUDE OF THE TORSION, LAGRANGE EQUATION, METHOD OF VAN DER POL

Equation of twisting movement of split phase (SP) is determined from Lagrange equation [1]

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\varphi}(t)}\right) - \frac{\partial L}{\partial \varphi(t)} = 0 \qquad (1)$$

where $L = E_k - E_d$ – Lagrange function (E_k - kinetic energy , E_d - deformation energy).

Kinetic energy of SP from rotational motion [2].

$$E_k = \int_0^\ell \frac{J_\phi}{2}\left(\frac{\partial \Phi(z,t)}{\partial t}\right)^2 dz \qquad (2)$$

where $F(z,t)$ - function, which determines phase twisting in random point and in random moment of time, ℓ – length of span, J_ϕ - inertia moment of split phase

$$J_\phi = \frac{nP_0}{g}R^2 \qquad (3)$$

where R - radius of splitting, n - number of splitting (number of wires in phase), P_0 – weight of 1 meter wire, g – acceleration of gravity.

For approximation of SP by the single degree of freedom system we assume, that its twisting along the span occurs only by single space form $\psi(z)$. In this case we imagine the function $F(z,t)$ as follows.

$$F(z,t) = \varphi(t)\psi(z) = \varphi(t) Sin\frac{\pi z}{\ell} \qquad (4)$$

where $\varphi(t)$ - generalized coordinate, $\psi(z)$ - coordination function, which satisfies the boundary conditions.

Kinetic energy of SP considering formula (4) converts to

$$E_k = \frac{nP_0R^2\dot{\varphi}^2(t)}{2g}\int_0^\ell Sin^2\frac{\pi z}{\ell}dz = \frac{nP_0\ell R^2}{4g}\dot{\varphi}^2(t) \qquad (5)$$

Considering the condition, that relation between extending and tension of wire has linear character, then deformation energy of *i* split phase wire is determined by formula [3]

$$E_{d\,i} = T_0\left(L_\varphi - L_0\right) + \frac{EF}{2\ell}\left(L_\varphi - L_0\right)^2 \qquad (6)$$

where E - Young's modulus, F - cross sectional area of the wire.

Wire length in static equilibrium L_0 and length L_φ, corresponding to twisted state of *i* wire of SP, are determined by approximate formula, known from higher mathematics course.

$$L_0 = \int_0^\ell \left[1 + \frac{1}{2}\left(\frac{\partial y(z)}{\partial z}\right)^2\right]dz \qquad (7)$$

$$L_\varphi = \int_0^\ell \left[1 + \frac{1}{2}\left(\frac{\partial q_\varphi(z,t)}{\partial z}\right)^2\right]dz \qquad (8)$$

where $q_\varphi(z,t)$ – function, describing the configuration of SP wire considering its twisting.

After geometrical calculations of SP twisting along the span the expression for function $q_\varphi(z,t)$ is determined

$$q_\varphi(z,t) = y(z) - RF(z,t)\cos\mu_i \qquad (9)$$

where $y(z)$ - coordinate function, describing the position of static equilibrium of wire in span, is determined by known formula

$$y(z) = \frac{P_0}{2T_0}z(\ell - z) \qquad (10)$$

In the expression (9) the angle μ_i determines mutual location of separate wires in a bundle. If we denote initial angle coordinate one of the wires, which is conditionally taken as a first, by μ_1, then next angles μ_i will be determined by formula

$$\mu_i = \mu_1 + \frac{2\pi(i-1)}{n}\;; \qquad (i = \overline{1-n}) \qquad (11)$$

Difference of wire lengths with (9) and (10) (prime is a derivative by z)

$$L_\varphi - L_0 = 0{,}5RCos\mu_i\left\{RCos\mu_t\int_0^\ell \left(F'(z,t)\right)^2 dz - 2\int_0^\ell y'(z)F'(z,t)dz\right\} \qquad (12)$$

Omitting the intermediate transformations and calculations, we can represent the final result for the deformation energy of the SP, taking into account the difference in the lengths of wires (12)

$$E_d = \sum_1^n E_{di} = \frac{\pi^4 EFR^4\sum_1^n Cos^4\mu_i}{32\ell^3}\varphi^4(t) +$$

$$\frac{\pi^2 R^2 T_0 \sum_1^n Cos^2\mu_i}{4\ell}\left(1-\frac{4EFP_0^{\ 2}\ell^2}{\pi^4 T_0^{\ 3}}\right)\varphi^2(t) \qquad (13)$$

It should be noted that for transformation into account following relationships

$$\sum_1^n Cos\mu_i = 0 \quad \text{and} \quad \sum_1^n Cos^3\mu_t = 0$$

Forming Lagrange function and substituting in equation (1), we obtain the nonlinear differential equation,

$$\ddot{\varphi}(t) + \omega_k^{\ 2}\varphi(t) = -\nu\varphi^3(t) \qquad (14)$$

Where V – a small parameter, which depends on the characteristics of the SP.

$$\nu = \frac{\pi^4 gEF}{4P_0\ell^4}\frac{1}{n}\sum_1^n Cos^4\mu_i \qquad (15)$$

ω_k - Is the frequency of the twisting motion of the linearized system

$$\omega_k^{\ 2} = \frac{\pi^2 gT_0}{P_0\ell^2}\left(1+\frac{8EFP_0^{\ 2}\ell^2}{\pi^4 T_0^{\ 3}}\right)\frac{1}{n}\sum_1^n Cos^2\mu_i \qquad (16)$$

The solution of the nonlinear differential equation (14) is performed by method of Van der Pol [4]. According to the method of Van der Pol, we shall seek solutions (14) and its first derivative with respect to time in that form

$$\varphi(t) = f(t)Sin[\omega_k t + \alpha(t)] \qquad (17)$$

$$\dot{\varphi}(t) = \omega_k f(t)Cos[\omega_k t + \alpha(t)] \qquad (18)$$

Where $f(t)$ - variable amplitude, $\alpha(t)$ - variable initial phase, ω_k -proper frequency of the linearized system, determined by the formula (16).

Omitting the intermediate calculations, we represent the final result

$$\varphi(t) = f_0 Cos\left[\left(\omega_k + \frac{3\nu}{8\omega_k}f_0^2\right)t\right] \qquad (19)$$

From (19) we can see, that the wave circular frequency SP ϖ_k which depends from the amplitude of the torsion f_0 is equal to

$$\varpi_k = \omega_k + \frac{3\nu}{8\omega_k}f_0^2 \qquad (20)$$

Equation (20) represents the amplitude frequency response of SP and sets dependence of the frequency of free torsion motion from the amplitude of the torsion and SP characteristics.

Analysis of the equation allows making the following conclusions:

- at small amplitudes f_0 of frequency autonomous oscillation of SP ϖ_k is close to the frequency of the linearized system ω_k. The increase in frequency with increasing amplitude of torsion occurs theoretically up to infinity.

- In practical calculations, the influence of the amplitude of the torsional movement of the split phase on the frequency autonomous oscillation can be neglected as the calculation formulas with sufficient accuracy can take a simplified expression (16). For example, when the amplitude φ_0 = 600 (slightly higher than the actual amplitude of the torsion SP at the dance), the maximum difference between the ϖ_k and ω_k is not more than 1.5%.

References

1 Guliaev V.I., Bazhenov V.A., Popov S.L. Applications of the theory of nonlinear oscillations of mechanical systems.-Moscow «High school» ,1989.

2 Bekmetev R.M., Zhakaev A.S., Shirinskih N.V. Swinging of conductors of power lines. – Alma-Ata, «Science» KazSSR, 1979. Page 152.

3 Bekmetev R.M., Dzhamanbayev M.A. Methods of calculating the dynamic loads at swinging of conductors/ collection of reports of Soviet experts at an international meeting on swinging of conductors of ETL/.-Sochi, October, 1985.

4 Bat' M.I., Dzhanelidze G.U., Kelzon A.S. Theoretical Mechanics in examples and problems III. –Moscow.: «Science»,1973, page 487.

APPLICATION OF CAD / CAM SYSTEM FOR FINDING INTERSECTION OF GEOMETRIC OBJECTS IN THE LEARNING PROCESS

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Abstract: *This work is predstaveno decision of task of finding the intersection of geometric objects with the use of CAD / CAM systems in particular graphical programming environment Autocad .. The problem is solved by the method of auxiliary secant planes. Based on the studies and analyzes on resolving this type of geometric tasks is summarized methodology for finding the intersection between the two geometric objects. The process of the graphic finding the intersection by using the CAD / CAM system is illustrated step by step on the basis of the methodology.*

Keywords: GEOMETRIC OBJECT, METHODS, CAD / CAM, LINE OF INTERSECTION

1. Introduction

The actual units are usually built of parts of geometric bodies. When viewing them receive limited lines crossing each other and contours. Most - great interest in the depiction of faces and bodies are lines like sections and surfaces. These lines are essential for certain technical applications, when searching the shape and dimensions of the surfaces, for example the construction of flat patterns. It is allowed in some cases complicated to build lines of intersection can be displayed approximately. The way to solve these tasks depends on the location of geometrical objects relative to the projection planes and their form. The process of finding a graphic projections of the common elements of intersecting geometric objects through various stages, including reading assignment and build a mental image of the spatial geometric objects and auxiliary geometric elements (lines, secant planes, etc.) Needed for solving mission. This often difficult to beginners in engineering graphics. Using CAD / CAM system for finding the points and the intersection of geometric lens significantly facilitates this task [1]. Formulated above problem is solved by using the graphical programming system AutoCAD, which allows for viewing of objects from different angles, off parts of objects, displaying objects in different views, creating three-dimensional images. The tasks of the graphical construction of the projections of the common elements (dots or lines of intersection) are solved by known literature methods.

Developed dozens of examples of finding the points or the intersection of various geometric objects - lines, planes, rotary and angular surfaces. With AutoCAD graphics system is presented the process of finding the intersection between the two geometric objects using the method of auxiliary secant planes. The process is illustrated step by step on the basis of the presented methodology.

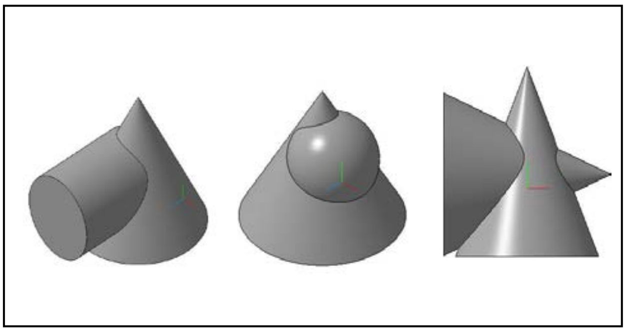

Fig. 1 *Three-dimensional images of intersecting solid of revolution: a) cone and cylinder; b) cone and sphere b) cone and the cone*

2. Methods for the construction of the line of intersection of the geometrical objects

2.1. Methodology for the construction of the intersection of geometric objects by the method of auxiliary secant planes in graphical programming environment Autocad. The projections of the intersection is built in points (1, 2, 3, 4,5 ......) belonging simultaneously to both surfaces. To find such points in the series at - generally used auxiliary secant planes i.e. intermediary. Can distinguish the following stages:

2.1.1. Analysis of the body - the body is examined from what surfaces is made, what is their relationship and their position relative to the projection plane.

2.1.2. Enter series auxiliary secant planes.

2.1.3. Designate points of the intersection, obtained without any additional constructions.

2.1.4. Located intersection of the secant with surfaces default.

2.1.5. The intersections of the lines are found points connected line of intersection.

2.1.6. Merging intersections and analyzes visibility.

2.2. Condition of the task: to build the intersection of geometric objects - hemisphere and cone with the software Autocad based on formulated - above methodology.

To find the intersection (each line of intersection) of the two bodies had been used method auxiliary secant planes whose planes are parallel to the horizontal plane π 2

The method of auxiliary secant planes comprises the following:

2.2.1. Construction of the two projections π 1 and π 2 task in the sizes Fig.2.

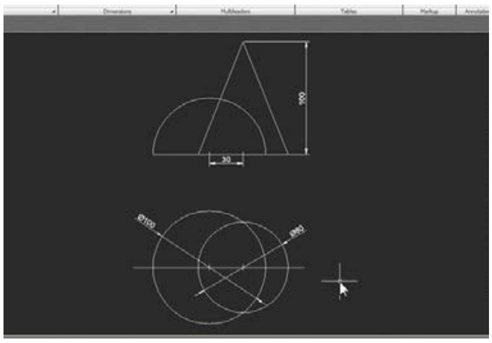

Fig. 2

2.2.2. Selects a random number secant planes planes parallel to the horizontal plane of projection, shown in Figure 3

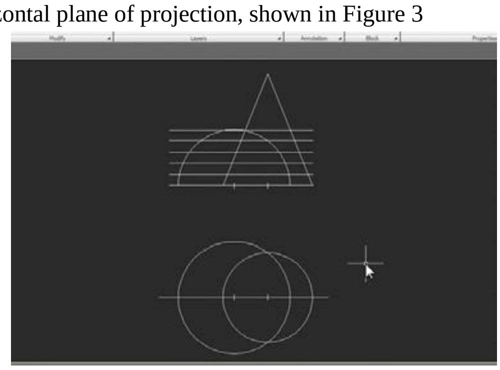

Fig. 3

2.2.3. Secant planes intersect the cone in circles with radii corresponding starting t.O top view (Figure 4).

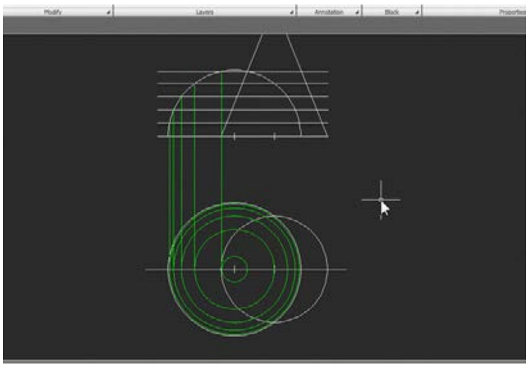

Fig. 4

2.2.4. Located projections of the basic points in the horizontal projection plane in ordinala and mean index 2. Located projections and other points in π 2.

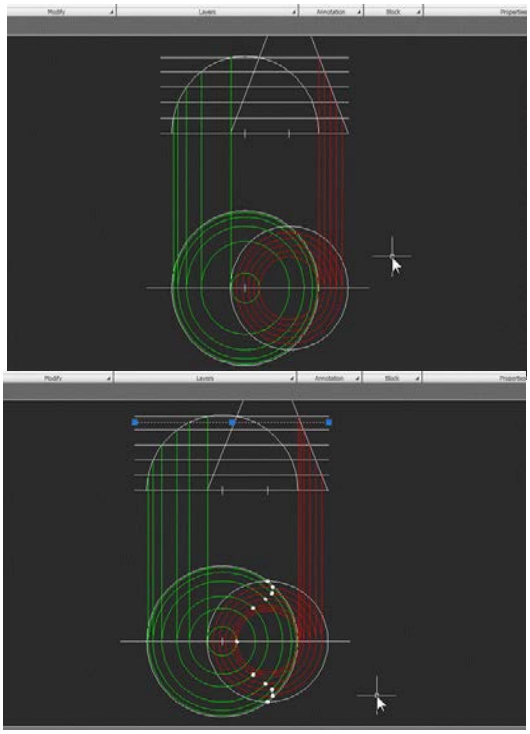

Fig. 5

2.2.5. Connecting the points obtained by using the command Spline, obtain approximate line of intersection of two surfaces in top view Figure 6.

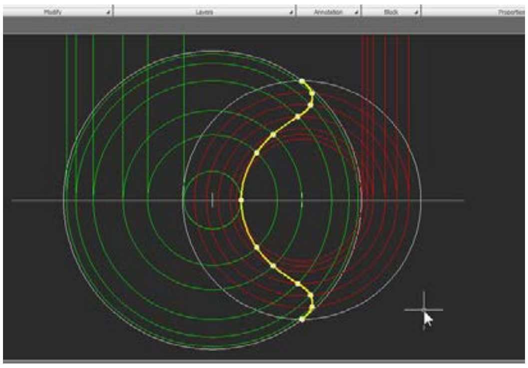

Fig. 6

2.2.6. To get the intersection in the frontal projection plane raise the points ordinala respective planes and receive the projections of points in π 1. Construction of the points shown in yellow in Fig. 7.

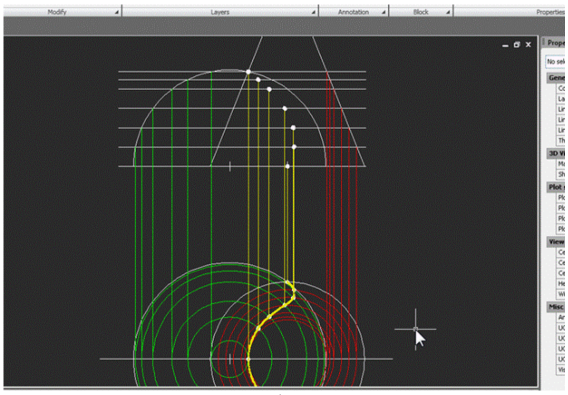

Fig. 7

2.2.7. Connecting the Dots and receiving line in π 1 (figure 8).

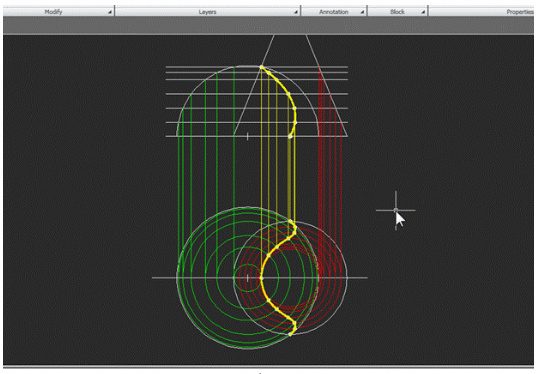

Fig. 8

2.2.8. Option in the software 3D Modeling allows to check the correctness in the construction of the intersection of the geometries shown in Figure 9 in front view and top.

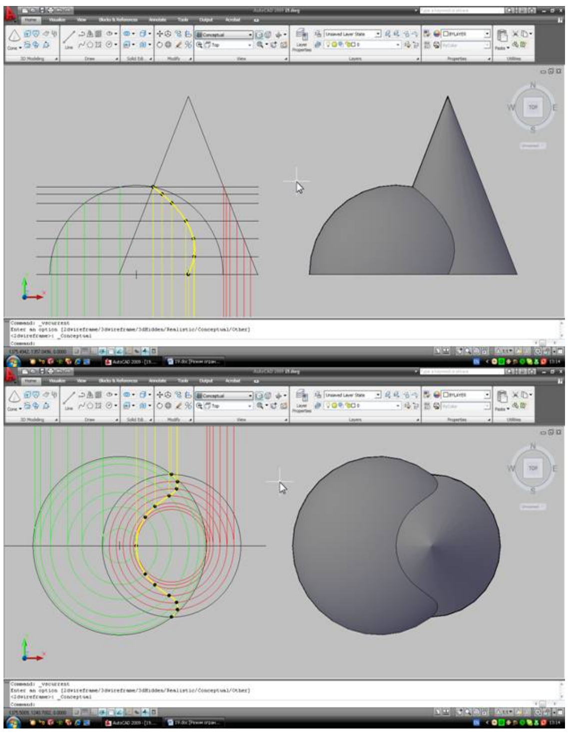

Fig. 9

3. Conclusion

Based on the application of CAD / CAM system for finding the points and the intersection of two geometric objects in the learning process can draw the following conclusions:

1. The tasks of mutual crossing of geometric objects belong to the position tasks. In their search for an item is a line belonging to both of the two geometric objects.

2. By AutoCAD graphics system creates three-dimensional geometric models, which contributes to a better absorption of the tasks of this kind through their visualization.

3. 3D modeling of geometric objects helps to accurate and clear visualization of search sections.

4. References

[1]. Nikolov N.Trimerno presentation using a computer task to find the points and the intersection of geometric objects in the drawings. Scientific University of Rousse, 2010,Vol. 49Series 4

[2]. Sandalski B. Goranov P. and others. Applied geometry and engineering graphics. Sofia, 2006.

[3]. autocad-lessons.ru

[4]. Sandalski B. Goranov P. and others. Applied geometry and engineering graphics. Sofia, 2006.

[5]. Reshetov AL, Karmanova VN etc .. Inzhenernaya graphics. KontrolynЬIe assignments nachertatelynoy geometries and chercheniyu. Chelyabinsk. 2012.

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THE APPLIANCE OF OPEN INNOVATION CONCEPT IN SMEs IN REPUBLIC OF MACEDONIA

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Abstract: *The open innovation is a concept of growing acceptance in the field of innovation management. It is based on the idea that companies can leverage the knowledge generated externally to improve their innovation performance. Open innovation as a process can promote shorter innovation cycles, increase in industrial research, and better optimization of the resources. However the process of open integration is much harder for implementations in SMEs than larger enterprises. The reasons behind the low integration of the open innovation as a process can be seen in the low capacity of the SMEs to deal with the open innovation process, low awareness of the benefits of the open innovation process, lack of knowledge for the intellectual law and rights, etc. This paper is based on the empirical research on 63 SMEs, in order to determine the factors (reasons) for low implementation of the open innovation process in the SMEs in Republic of Macedonia.*

Keywords: OPEN INNOVATION, SME, SMALL AND MEDIUM-SIZED ENTERPRISES, INNOVATION ABSORPTION, INNOVATION PROCESS

1. Introduction

The open innovation is a concept of growing acceptance in the field of innovation management. It is based on the idea that companies can leverage the knowledge generated externally to improve their innovation performance. Open innovation is based on the traditional innovation process which represents a crucial aspect of promoting the growth and development of SMEs. But the process of innovation is usually foreseen as a great financial burden for the SMEs, and inquiring finance for the relatively long and enduring process of research and innovation can present a devastating process for the SMEs [1]. Therefore, new ways of innovation must be looked for, in which open innovation represents a viable alternative for companies. Open innovation as a process can promote shorter innovation cycles, increase in industrial research, increased innovation and better optimization of the resources [2]. Open innovation is defined as "the purposive use of inflows and outflows of knowledge to, respectively, accelerate internal innovation, and expand the markets for external use of innovation process" [3]. Open innovation can be a part of any of the four different types of innovation including the innovation in process of production, innovations in business model, innovations in product and innovation in organization. All of these types of innovations can be made easer through the concept of open innovation, by creating a mutual trust between the SMEs and their innovation partners.

The SMEs sector is very important for Macedonian economy. According to the data of the State Statistical Office [4], the number of active business entities in the Republic of Macedonia in 2014 was 70,659 and SMEs represent 99.7 percent of them. They engaged about 76.7 percent of total number of employees and created 65.6 percent of the value added [5].

According to the Innovation Union Scoreboard 2014 [6] Republic of Macedonia is a modest innovator ranking 31st out of 35 countries with Summary Innovation Index of 0.2458 much below 0.5539 which is the EU average. Situation with SME's innovation are even worst. Macedonia is ranked 31st based on SMEs innovating in-house indicator (0.0155), and 19th regarding Innovative SMEs collaborating with others indicator (0.3590) which gives some perception on open innovation adoption by the SMEs in Republic of Macedonia. Regarding innovation outputs, SMEs introducing products or process innovations indicator is 0.5938 (ranked 15th) and SMEs introducing marketing/organizational innovations indicator is 0.3615 (ranked 24th). So, the open innovation is still a relatively new process in Republic of Macedonia with only small portion of enterprises actually practicing it [7]. The reasons behind the low commitment to the innovation in general can be seen in the lack of innovation network, lack of funding and venture capitalist and very small percentage of GDP devoted to research and development [7]. The low capacity of absorption and the technical problems which SMEs face considering the implementation of new research and developments techniques puts the SMEs into an utmost difficult position on the bargaining side of the process that is open innovation. Despite the larger enterprises witch can reserve a lot more assets into the research and development program SMEs rely on having their idea and innovation process increase their chances of market success. But, the lack of information and data concerning the process of open innovation is one of the possible reasons for low level of awareness for the process of open innovation amongst the Macedonian SMEs. [7]. Also, the lack of networking structure at national and regional level on tackling Open Innovation issues can be foreseen as one of the crucial problems for implementation of open innovation process especially among SMEs.

This paper concerns awareness and constraints for adoption open innovation strategies in SMEs in Republic of Macedonia. The constrains have been categorized and reviewed concerning four open innovation aspects: human constrains, general constrains, policy constrains, and constrains that have evolved due to the rise of global competition [8].

2. Theoretical Review

Open innovation is a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with each organization's business model [9]. This means knowledge inflows to the focal organization (leveraging external knowledge sources through internal processes), knowledge outflows from a focal organization (leveraging internal knowledge through external commercialization processes) or both (coupling external knowledge sources and commercialization activities) [9]. The traditional (closed) innovation system has some serious shortcomings and there is an urgent need of establishing a contemporary innovation system – an open innovation system. The contrasting principles of closed and open innovation are presented on Table 1.

Table 1: *Comparison between Closed and Open Innovation Principles.*

Closed Innovation principles	Open Innovation principles
The smart people in the field work for us.	Not all the smart people in the field work for us. We need to work with smart people inside and outside the company.
To profit from R&D and Innovation, we must discover it, develop it, and ship it ourselves.	External R&D and Innovation can create significant value: internal R&D and Innovation is needed to claim some portion of that value.
If we discover it ourselves, we will get it to the market first.	We don't have to originate the research to profit from it.
The company that gets an innovation to the market first will win.	Building a better business model is better than getting to the market first.
If we create the most and the best ideas in the industry,	If we make the best use of internal and external ideas, we will win.

We should control our IP, so that our competitors don't profit from our ideas	We should profit from others' use of our IP, and we should buy others' IP whenever it advances our business model.

There are two important kinds of open innovation: outside-in and inside-out. The outside-in part of open innovation involves opening up a company's innovation processes to many kinds of external inputs and contributions. Inside-out open innovation requires organizations to allow unused and underutilized ideas to go outside the organization for others to use in their businesses and business models [10]. In contrast to the outside-in branch, this portion of the model is less explored and hence less well understood, both in academic research and also in industry practice. In order to further improve the scientific capabilities and commercialize the research output from projects such as the LHC, new businesses and business models must be identified, explored, and undertaken [10].

In addition to being beneficial for large "firms as well as for small and medium-sized enterprises (SMEs) [3], SMEs can open their own innovation processes to implement internal ideas otherwise unexplored, to ensure access to external ideas, to enable better utilization of their partially hidden innovation potential, to share the wealth and efficiency in resource allocation (e.g. per unit cost accounting basis), to extend their potential for growth via alliances and or attraction of funding, to be offered ample opportunities by larger companies to access resources/knowledge otherwise far too expensive for them [11].

3. Empirical Research

The research aims to acquire knowledge about open innovation adoption by SMEs in Republic of Macedonia. The focus is to identify SMEs characteristics especially related to their innovation activities in general, and in open innovation process in particular. The main goal is to identify Macedonian open innovation trends and practices and identify constraints for open innovation adoption. Several specific objectives of this research are:

- To assess the level of open innovation awareness amongst Macedonian SMEs
- To assess the open innovation adoption by SMEs
- To identify the key actors involved in open innovation process in Macedonia
- To recommend measures to improve open innovation adoption rate by SMEs

The survey was conducted using a questionnaire as a research tool for data collection. The questionnaire was developed and placed online using the Google Drive, and emails with a request to fill in the questionnaire were sent to 63 SMEs. Responses were received from 36 respondents, representing 57 percent response rate which is much higher than the average response rate of 35.7 percent for studies that utilized data collected from organizations [12]. Still, the margin of error for this sample size is 16.7 percent, so the survey results are not representative, but only indicative and will use as a pilot for tuning the final design of full research that will be carried out in the next phase.

Respondent sample is consisted of 21 micro, 14 small and 1 medium enterprises. Almost one fifth of all enterprises (19.4 percent) do not have innovation budget at all, and 44.4 percent spent only 0-1 percent from their income on innovation activities (Table 2).

Table 2: *Percentage of income spent on innovation activities.*

Percentage of income spend on innovation [%]	Percentage of enterprises [%]
0	19.4
0-1	44.4
1-2	8.3
2-4	25.0
4-6	0.0
6-10	0.0
10-15	0.0
15+	2.8
Grand Total	100.0

SMEs in Macedonia do not pay much attention on innovation activities. The results also show that 72.3 percent of all enterprises do not have employees dedicated to any innovation activities (16.7%) or only 0-3 percent of the employees are part of some innovation activities in the company (55.6%) (Table 3).

Table 3: *Employees dedicated to innovation activities.*

Percentage of employees dedicated to innovation from all employees [%]	Percentage of enterprises [%]
0	16.7
0-3	55.6
3-6	11.1
6-10	2.8
10-15	0.0
15-20	8.3
20-30	0.0
30+	5.6
Grand Total	100.0

83.3 percent of all SMEs have not heard about the concept of Open Innovation, and 94.4 percent have no knowledge about Open Innovation concept at all. Despite the low awareness amongst Macedonian SMEs, 54.5 percent of all SMEs have cooperated with other companies or organizations in any of their innovation activities, so the SME are not aware of, but still they use the Open Innovation concept.

Table 4: *Main Innovation Partners of Macedonian SMEs.*

Type of Innovation Partner	Mean	n
Suppliers of equipment, materials, components or software	7.5	21
Clients or customers from the private sector		9
Government, public or private research institutes		8
Universities or other higher education institutes		7
Clients or customers from the public sector		5
Competitors or other enterprises in the sector		5
Consultants or commercial labs institutes		0

Table 4 illustrates the type of innovation partners of the SMEs. According to the results the most common partners into their innovation activities are their suppliers (38.2 percent) and clients from the private sector (16.4 percent). The most unlikely partners of the SMEs in innovation activities are the clients from the public sector, competitors and consultants or commercial labs.

Table 5: *Open Innovation Concept Applicable per Type of Innovation.*

Open Innovation Concept Used or Intended to be Used per Type of Innovation		n	Response rate [%]
Product Innovation	Yes	28	84.8
	No	5	15.2
Process Innovation	Yes	15	83.3
	No	3	16.7
Business Model Innovation	Yes	21	80.8
	No	5	19.2
Organization Innovation	Yes	20	18.7
	No	3	13.0

Table 5 shows the percentage of SMEs that intent to use or are already using the concept of Open Innovation for different type of innovation activities. According to the results, all four types of innovation activities are appropriate to be implemented with the Open Innovation concept.

80.6 percent of the SMEs have dedicated no part of their innovation budget for Open Innovation activities, have no dedicated employees for open innovation and also have no product developed in the last three years which is based on the open innovation principles. 19.4 percent of all respondents spent 0-5 percent of their innovation budget on open innovation activities, resulting in 0-10 percent of their new products developed implementing open innovation concept.

According to the answers provided by the SMEs presented on Table 6, the key constraints regarding Human Resources are the scarcity of skilled employees in their companies (93.3 percent) and the high level of the wages which is burden for their financial condition (36.7 percent).

Table 6: *Key Constraints in Implementing Open Innovation in SMEs.*

Key Constraints	n	Response rate [%]
Recruiting Constraints (Human Resources)		
Scarcity of skilled employees	28	93.3
Wages of the skilled employees are too high, it is a great burden for us	11	36.7
General Constraints		
Lack of knowledge in implementing new technology	18	54.5
Lack of quality managers in the country	18	54.5
The labor market lacks skilled workers	17	51.5
Competition Constraints		
Increase quality of product/service	24	72.7
Increase marketing activity	22	66.7
Policy Constraints		
Government policies, laws and regulations	19	73.1
Unfavorable business climate	17	65.4

The main general constraints are the lack of knowledge to implement new technology (54.5 percent) and the lack of skilled workers on the Macedonian labor market (51.5 percent). In an era of globalization and enormous influence that Internet technologies have on people's private and professional life, the competitiveness constraints to adoption of the open innovation competition constraints, or activities that should be undertaken to compensate the barriers related to competition. The first one is to increase the quality of the products/services (72.7 percent) and to increase the marketing activities (66.7 percent). The last aspects of the constraints for implementing Open innovation in SMEs are the so called policy constraints.

Table 7: *Factors Affecting Success of Implementing Open Innovation Concept in SMEs.*

Open Innovation Success Factors for SMEs	n	Response rate [%]
Support by the top management	19	57.6
Collaborators' training for Open Innovation	18	54.5
Allocate enough resources (employees, time and budget)	14	42.4
Managing an idea generation process (selection and prioritization of the ideas)	11	33.3
Managing the intellectual property (protection and valorization)	11	33.3
Ability to measure Open Innovation success in Enterprises	9	27.2
To have a corporate culture that promotes idea-sharing	7	21.2
Support by the middle management	3	9.1
Existence of systematic and organized approach for acceptance of external ideas	3	9.1
Proper selection and encouraging of partnerships	3	9.1

The last aspects of the constraints for implementing Open innovation in SMEs are the so called policy constraints. Macedonian SMEs have identified the following two key constraints: 1) problems with the government policies, laws and regulations that are not in favor of the open innovation concept, and 2) the unfavorable business climate presence in the country.

Results presented on Table 7 shows that according to the SMEs themselves three main factors important for successful implementation and practice of Open Innovation concept in SMEs are: Support by the top management, Collaborators' training on Open Innovation and Allocation of enough resources (including employees, time and budget) dedicated to Open Innovation.

4. Conclusion

SMEs on their innovation path can follow two possible approaches. The first one is to perform the innovation activities fully in-house (so called close innovation), but for small firms this is a big challenge because they typically struggle with lack of financial resources, scant opportunities to recruit specialized workers, poor understanding of advanced technology, and so on. The second approach is to adopt an innovation model to use ideas and knowledge from outside the firm's boundaries, so called open innovation concept.

The awareness of Macedonian SMEs on Open Innovation is not satisfactory. It is evident from the research results that in general they do not pay proper attention on innovation activities (both closed and open), but the fact that they do not have even idea and information on good SMEs open innovation practices and strategies should raise a 'red flag' among all innovation stakeholders in the country.

The research finds that the two main constraints for the low level of open innovation adoption rate by the SMEs are the problem related to the scarcity of skilled employees and the problem with the government policies, laws and regulations that are not supportive to the open innovation paradigm.

Despite overcoming both key constraints depend more on innovation policy makers, the SMEs themselves could make some actions to improve as well. The research suggests that the most obvious measures are to build a strong commitment and support for open innovation concept by the SME's top management (in most cases the owners of the firms), and to take joint activities with firm's collaborators and partners with focus on promotion and training on Open Innovation concept.

5. Literature

[1] Zimmermann Volker (2014), KfW SME Panel 2013: How German SMEs finance their innovations, KFW Economic Research, pg. 1-3.

[2] Gassmann Oliver & Enkel Ellen (2004), Towards a Theory of Open Innovation: Three Core Process Archetypes, Institute of Technology Management, University of St. Gallen, Switzerland, pg. 1-2.

[3] Chesbrough Henry (2006), "Open Innovation: The New Imperative for creating and Profiting from Technology", Harvard Business School Press, United States, pg. 2.

[4] State Statistical Office of Republic of Macedonia. 2015a. Number of active business entities, 2014. News Release No: 6.1.15.14. Available at: http://www.stat.gov.mk/pdf/2015/6.1.15.14.pdf [Accessed 18 May 2015].

[5] State Statistical Office of the Republic of Macedonia. 2015b. MAKStat Database. Available at http://makstat.stat.gov.mk/pxweb2007bazi/Dialog/Saveshow.asp [Accessed 18 May 2015].

[6] European Commission (2014), Innovation Union Scoreboard 2014. European Commission, Brussels.

[7] Josimovski Sasho (2011), "Thematic Report 2011 under Specific Contract for the Integration of INNO Policy Trend Chart with ERAWATCH", Pro Inno Europe, pg. 9-15.

[8] Rahman Hakikur & Ramos Isabel (2013), "Challenges in Adopting Open Innovation Strategies in SMEs: An Exploratory Study in Portugal", Issues in Informing Science and Information Technology, Volume 10, pg. 435.

[9] Chesbrough Henry & Bogers Marcel (2014), "Clarifying an Emerging Paradigm for Understanding Innovation, Explicating Open Innovation", Explicating Open Innovation, ISPIM, Dublin.

[10] Chesbrough Henry (2015), "From Open Science to Open Innovation", Institute for Innovation and Knowledge Management, ESADE, Science Business Publishing.

[11] ANNAIN, VDC & INNONET (2011), "Open Innovation: Benefits for SMEs", EURIS, Brussels.

[12] Baruch, Yehuda & Holtom C. Brooks (2008), "Survey response rate levels and trends in organizational research", Human Relations vol. 61 no. 8, pg. 1139-1160.

ЛЕСОПИЛЬНЫЕ РАМЫ С НОВОЙ КИНЕМАТИКОЙ РЕЗАНИЯ

FRAME SAW THE NEW KINEMATICS OF CUTTING

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Аннотация: *Рассматриваются вопросы создания лесопильных рам нового поколения с установкой пильной рамки в шарнирно-рычажной подвеске и качанием пил по самопересекающейся замкнутой кривой типа восьмерки. В результате улучшаются условия работы пил и снижается энергоемкость процесса пиления на 40...50%. При этом производительность лесопильных рам можно увеличить в 1,5…2 раза.*
КЛЮЧЕВЫЕ СЛОВА: *ЛЕСОПИЛЬНАЯ РАМА, ПИЛЬНАЯ РАМКА, ЗАГОТОВКА, МЕХАНИЗМ КАЧАНИЯ, КИНЕМАТИКА РЕЗАНИЯ*

Abstract: *The question of creating a new generation of log frames with the installation of the saw frame in hinged - arm suspension and swing saws on self-intersecting closed curve such as the Group of Eight. As a result of improved working conditions and reduced energy consumption saws sawing process by 40 ... 50 %. This performance saw- frames can be increased in 1.5 ... 2 times.*
KEYWORDS: *FRAME SAW, THE SAW FRAME, BLANK, ROCKING MECHANISM, KINEMATICS OF CUTTING*

1. Введение

Лесопильные рамы используются в качестве головного оборудования в линиях изготовления пиломатериалов. Поэтому качество пиломатериалов, а также производительность и эффективность этих линий в основном определяется работой лесопильных рам. В связи с этим в прошлом столетии был выполнен ряд работ по изучению, исследованию и совершенствованию следующих проблемных вопросов дальнейшего развития лесопильных рам [7]:

1) Кинематика процесса пиления;
2) Уравновешивание сил инерции;
3) Замена направляющих и установка пильной рамки в шарнирно-рычажные механизмы;
4) Силовые и качественные показатели процесса пиления;
5) Конструктивные особенности узлов и механизмов;
6) Повышение надежности и долговечности.

Следует отметить, что кинематика процесса пиления на лесопильных рамах достаточно основательно была изложена в работах М.А. Дешевого [5]. Было отмечено, что при пилении древесины с равномерной скоростью подачи во время рабочего хода величина подачи на зуб (толщина срезаемого слоя древесины зубом пилы) существенно изменяется, а в начале холостого хода продолжается взаимодействие зубьев пилы с дном пропила и наблюдается даже смятие древесины. В результате возникают дополнительные силы – силы скобления, которые препятствуют продвижению заготовки в этот период времени. При этом ошибочно отмечалось, что это скобление можно уменьшить или даже исключить путем установки пил с большим уклоном. Исследования В.Я. Филькевича [6] показали, что в начале холостого хода, в результате взаимодействия зубьев пилы с древесиной, заготовка (пиловочник) останавливается или даже совершает возвратное перемещение. Эти силы скобления, действуют на полотно рамной пилы, вызывают боковое отклонение их и обуславливают преждевременную потерю устойчивости. С целью уменьшения сил скобления зубьев пилы о дно пропила в начале холостого хода А.Л. Бершадский [4] рекомендовал задний угол зубьев рамных пил увеличить и принять его равным 28° вместо 18°. Это отрицательно повлияло на процесс резания во время рабочего хода, так как с увеличением угла резания на 10° сила резания возросла, а качество поверхности пропила ухудшилось.

2. Научный поиск совершенствования кинематики резания

В связи с этим начались поиски улучшения и совершенствования кинематики процесса пиления на лесопильных рамах. Предлагалось дополнительно осуществлять качание пил в плоскости пиления по эллиптической или каплевидной кривой. Однако исследования В.Ф. Фонкина [8] показали, что в этом случае смятие древесины зубьями пилы в начале холостого хода можно не только уменьшить, но и полностью исключить. Но при этом происходит еще большая неравномерность подачи на зуб во время рабочего хода, чем при пилении без качания пил. Это обуславливает увеличение максимальных нагрузок на пилы и ухудшение качества поверхности пропила. Создание опытных образцов с такой кинематикой резания не увенчалось успехом, так как качество поверхности пропила ухудшалось, а производительность в связи с этим снижалась.

Предлагалось так же осуществлять перемещение заготовки с переменной скоростью (толчками) с циклом за рабочий или холостой ходы, а также с циклом за рабочий и холостой ход или за оборот. Исследования показали [1,2], что в том случае, когда подача заготовки осуществляется с переменной скоростью с циклом за рабочий или холостой ходы, скобление зубьями пилы дна пропила в начале холостого хода можно исключить, но во время рабочего хода возрастают максимальные значения подачи на зуб и, следовательно, максимальные значения силы резания увеличиваются, а качество поверхности пропила ухудшается. При подаче заготовки с переменной скоростью с циклом за рабочий и холостой ходы или с циклом за оборот исключить скобление зубьями пилы дна пропила не представляется возможным. При опережении или запаздывании цикла переменных подач наблюдается рост подачи на зуб во время рабочего хода и ухудшение качества поверхности пропила. Таким образом, создание лесопильных рам с предложенными ранее переменными скоростями подачи заготовки не эффективно, так как производительность снижается, а качество поверхности обработки пиломатериалов ухудшается. Несмотря на эти научные выводы ученых, промышленность продолжает иногда выпуск лесопильных рам с такими переменными скоростями подачи.

3. Решение рассматриваемой проблемы. Основные научные положения по синхронизации движений пил и заготовки

Работами автора [2] было установлено, что для синхронизации движений рамных пил и заготовки качание пил необходимо осуществлять за рабочий ход по кривой, представляющей собой половину восьмерки, а за холостой ход - по кривой, представляющей собой половину капли. Причем оказалось, что рамные пилы в начале рабочего хода необходимо отводить от дна пропила, затем в средней части хода пил надвигать их на заготовку, а в конце хода пил снова отводить от дна пропила. В начале холостого хода необходимо продолжить отвод пил от дна пропила, а затем переместить их в верхнее крайнее положение пильной рамки. Такие полученные математические модели перемещения пил осуществить на практике довольно трудно, так как математическая модель движения пил за рабочий ход существенно отличается от математической модели движения пил за холостой ход. Проблема осуществления полной синхронизации движений пил и заготовки оказалась противоречивой и сложной. Таким образом, создание лесопильных рам с полной синхронизацией движений пил и заготовки трудно выполнимо, так как разработка механизма качания пил с получением за рабочий ход подачи на зуб пилы S_z=*const* и в то же время исключить скобление зубьями пилы дна пропила в начале холостого хода – довольно сложная задача. Поэтому на первом этапе предлагаются упрощенные математические модели перемещения пил, в которых непременным (первостепенным) условием ставится исключение скобления зубьями пилы дна пропила в начале холостого хода, а подача на зуб пилы во время рабочего хода может изменяться, достигая максимального значения в 1,2...1,3 раза от ее среднего значения. Такого результата можно достигнуть, если перемещение пил осуществлять по самопересекающейся замкнутой кривой типа восьмерки. Еще лучшие результаты получаются в том случае, когда перемещение пил осуществляется по самопересекающейся замкнутой кривой, у которой узловая точка смещена в сторону верхнего положения пильной рамки, а размах качания в нижней части хода пил больше в 2,0 раза, чем размах качания в верхней части хода пил.

В том случае, когда синхронизация движений пил и заготовки осуществляется с переменной скоростью подачи, перемещение заготовки необходимо производить с возвратным движением в начале холостого хода. Причем скорости движений заготовки во время рабочего и холостого ходов должны быть различными, при этом скорость перемещения заготовки во время холостого хода пил больше, чем во время рабочего хода. Такую математическую модель выполнить довольно сложно, в виду того, что математическое описание перемещения заготовки во время рабочего хода отличается от математического описания перемещения заготовки во время холостого хода. В связи с этим предлагаются упрощенные варианты перемещения заготовки. За рабочий и холостой ходы перемещение заготовки необходимо осуществлять с остановками или возвратными перемещениями в моменты, когда пильная рамка находится в верхнем и нижнем крайних положениях. В этом случае скобление зубьями пилы дна пропила во время холостого хода исключается, а максимальное значение подачи на зуб во время рабочего хода может достигать значения S_z=(1,2...1,3) от средней её величины, что вполне допустимо.

Таким образом научно разработаны математические модели перемещения пил и заготовки, при которых можно обеспечить полную или частичную синхронизацию.

4. Реализация научных положений в промышленности

Вариант качания пил по самопересекающейся замкнутой кривой типа восьмерки [2] был впервые реализован на одноэтажной лесопильной раме мод. Р63-4. Даниловский ЗДС в 1983 году по предложению ВятГУ изготовил опытно-промышленный образец, который подтвердил научные положения автора [2] и показал положительные результаты и работоспособность образца в промышленных условиях. Фактическая траектория движения пил с высокой степенью точности совпадает с расчетной теоретической траекторией перемещения пил.

В дальнейшем по исходным данным автора [2] Вологодское ГКБД разработало рабочий проект одноэтажной лесопильной рамы мод. Р63-7, в которой была реализована такая же траектория движения пил, как и на опытно-промышленном образце лесопильной рамы мод. Р63-4. Испытания опытного образца лесопильной рамы мод. Р63-7, изготовленного Тарбагатайским ЗДС (Читинская область) в 1992 году показали, что производительность возросла в 1,5 раза, а энергоемкость процесса пиления снизилась на 37%. Такая модель лесопильной рамы изготавливалась 6 лет. Несмотря на положительную реализацию научных положений в промышленном масштабе, дальнейший выпуск и совершенствование лесопильных рам с улучшенной кинематикой резания в настоящее время приостановлен.

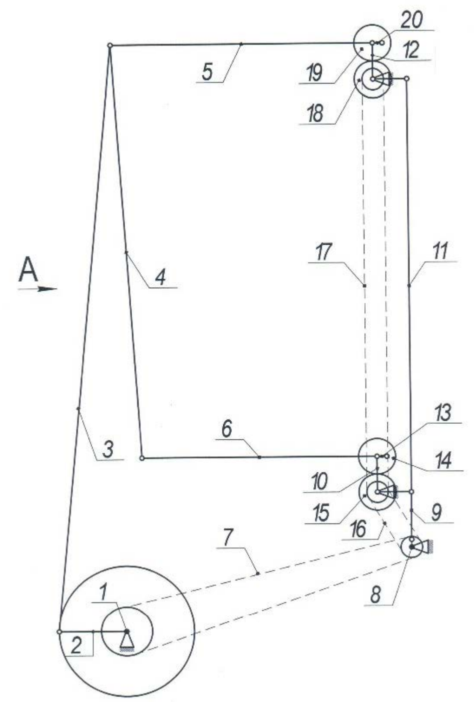
5. Опыт использования шарнирно-рычажной подвески пильной рамки

Заслуживают внимания и одобрения также работы по установке пильной рамки в шарнирно-рычажные механизмы. Для этого рекомендовалось использовать четырехзвенные шарнирно-рычажные механизмы Уатта, Робертса, Эванса, Чебышева и других ученых. В этом случае трение скольжения в паре ползун-направляющие заменяется на трение качения в шарнирно-рычажном механизме. Опытные образцы лесопильных рам с шарнирно-рычажной подвеской пильной рамки были изготовлены в СССР в лабораторных условиях и показали свою работоспособность. Зарубежными фирмами были предложены опытно-промышленные образцы лесопильных рам с шарнирно-рычажной подвеской пильной рамки. Но специалистами промышленности признания эти образцы лесопильных рам не получили. Предлагаемые шарнирно-рычажные механизмы достаточно сложны и проблемы с их использованием не были достаточно глубоко изучены и апробированы в промышленности. К тому же на этих образцах лесопильных рам производительность не повышалась, а энергоемкость процесса практически оставалась на прежнем уровне, так как кинематика процесса пиления не изменялась.

Следует также отметить, что качание пильной рамки вместе с ползунами и направляющими представляет собой такую систему, в которой трудно добиться выполнения требуемой точности теоретической траектории движения пил. К тому же стабильность и жесткость пильной рамки в боковом направлении при качании ее снижается. Следовательно, только совместное использование этих двух направлений – установка пильной рамки в шарнирно-рычажной подвеске и синхронизация движении пил и заготовки позволит обеспечить создание надежных и более эффективных лесопильных рам нового поколения.

6. *Предлагаемый вариант лесопильной рамы с новой кинематикой резания*

Предлагается вариант лесопильной рамы с новой кинематикой резания и установкой пильной рамки в шарнирно-рычажной подвеске (фиг. 1, фиг. 2).



Фиг. 1 *Принципиальная схема лесопильной рамы с качанием пил (вид в поперечном направлении).*

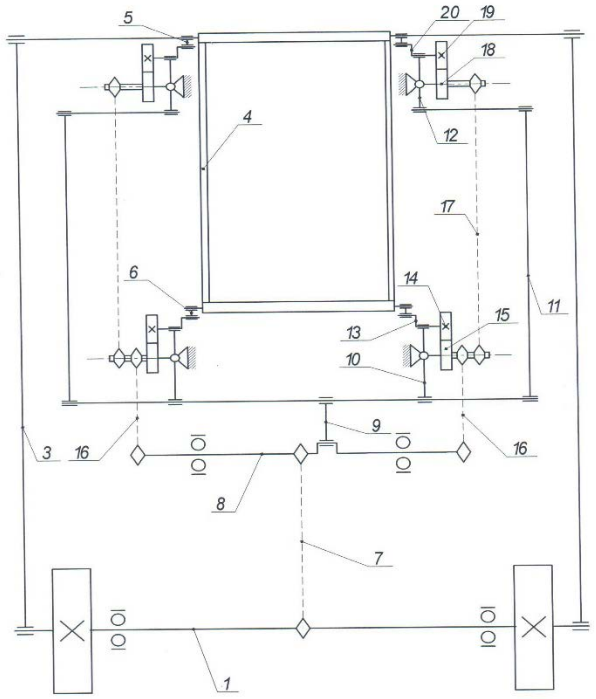
Лесопильная рама состоит из коленчатого вала 1, кривошипов 2, шатунов 3, соединенных с пильной рамкой 4, которая установлена в верхних 5 и нижних 6 рычагах. На коленчатом валу 1 установлена звездочка цепной передачи 7 с передаточным отношением 2:1. Цепная передача 7 передает движение на промежуточный вал 8, на котором расположены дополнительные кривошипно-шатунные механизмы 9, которые шарнирно соединены с одним из концов нижнего двуплечего рычага 10 и с помощью тяги 11 кинематически связаны с одним из концов верхнего двуплечего рычага 12. На другом конце нижнего двуплечего рычага 10 установлен эксцентриковый вал 13 с радиусом r. На этом же валу установлено зубчатое колесо 14, которое находится в зацеплении с зубчатым колесом 15 и вращается вместе со звездочкой цепной передачи 16, установленной на промежуточном валу 8. Эксцентриковые валы 13 шарнирно соединены с нижними рычагами 6 пильной рамки. На валу зубчатого колеса 15 установлена звездочка цепной передачи 17, которая связана с верхней звездочкой и зубчатым колесом 18, находящимся в зацеплении с другим зубчатым колесом 19, расположенным на другом конце двуплечего рычага 12. На валу зубчатого колеса 19 расположен верхний эксцентриковый вал 20 с радиусом r, который связан шарнирно с верхним рычагом 5 пильной рамки 4.

Качание пильной рамки по самопересекающейся замкнутой кривой осуществляется от дополнительного кривошипно-шатунного механизма 9, а выравнивание оси симметрии этой кривой производится эксцентриковыми механизмами 13 и 20.

Величина амплитуды качания пил по самопересекающейся замкнутой кривой типа восьмерки осуществляется от дополнительного кривошипно-шатунного механизма 9 и определяется уравнением

$$x_к = r_к \cdot \sin 2\alpha, \tag{1}$$

где $r_к$ – радиус дополнительного кривошипно-шатунного механизма качания пил; α – угол поворота кривошипа.



Фиг. 2 *Принципиальная схема лесопильной рамы с качанием пил (вид по направлению скорости движения заготовки).*

Величина радиуса дополнительного кривошипно-шатунного механизма качания пил рассчитывается с учетом хода пильной рамки R, подачи на один оборот коренного вала S_0, шага зубьев пил $t_з$, а также соотношений плеч двуплечего рычага по обычным методикам [3].

Для обеспечения движения пильной рамки (перемещение пил) по самопересекающейся замкнутой кривой типа восьмерки, имеющей прямолинейную вертикальную ось симметрии необходимо установить эксцентриковый вал таким образом, чтобы законы перемещения эксцентрикового вала и пильной рамки были идентичными. Движение пильной рамки по вертикали описывается уравнением

$$y = R \cdot (1 - \cos \alpha) + L \cdot (1 - \cos \beta), \tag{2}$$

где R – радиус кривошипа привода пильной рамки; L – длина шатуна; β – угол между шатуном и вертикалью.

Угол поворота шатуна относительно вертикали можно определить по формуле

$$\beta = arcsin \frac{R \cdot \sin \alpha}{L}. \tag{3}$$

При перемещении пильной рамки поворачиваются и рычаги, с которыми она связана шарнирами. При повороте шарнира рычага по дуге окружности пильная рамка получает смещение по горизонтали x_p, которое можно компенсировать эксцентриком. При этом эксцентрик необходимо расположить таким образом, чтобы начало рабочего хода пил совпадало с началом отвода их по горизонтали. В данном варианте лесопильной рамы эксцентрик необходимо расположить в крайнее левое положение, когда пильная рамка будет находиться в начале рабочего хода в верхнем крайнем положении. Только в этом случае будет происходить выравнивание дуги окружности движения шарнирного соединения рычага с пильной рамкой за счет получаемого перемещения от эксцентрикового вала.

Движение эксцентрика по горизонтали будет осуществляться по уравнению

$$x_э=r\cdot(1-\cos 2\alpha), \quad (4)$$

где r – радиус эксцентриков 13 и 20.

За половину рабочего хода пильной рамки (y=R) пилы необходимо отвести по горизонтали на максимальную величину искривления оси движения рычага по горизонтали, которое должно быть равно 2r. В этом случае за половину хода пил (α=90°) эксцентрик должен повернуться на 180° и тогда перемещение по горизонтали будет равно 2r. За вторую половину рабочего хода пил эксцентрик снова повернется на 180° и обеспечит возврат пильной рамки в исходное положение на величину 2r. Следовательно, угловая скорость вращения эксцентрика должна быть в 2 раза больше, чем угловая скорость вращения кривошипа привода пильной рамки.

При использовании эксцентрика перемещение пильной рамки по горизонтали определится по формуле

$$X_p=l_p\cdot(\cos\varphi_B-\cos\varphi)-r\cdot(1-\cos 2\alpha), \quad (5)$$

где l_P – длина рычага шарнирно-рычажной подвески пильной рамки; φ_B – угол наклона рычага шарнирно-рычажной подвески пильной рамки определяющей верхнее крайнее положение; φ – текущий угол поворота этого рычага пильной рамки относительно горизонтали.

Угол φ_B можно определить по формуле

$$\varphi_B = arc\sin\frac{R}{lp}. \quad (6)$$

Текущий угол поворота рычага шарнирно-рычажной подвески пильной рамки можно определить по формуле

$$\varphi = arc\sin\frac{R-y-r\sin 2\alpha}{lp}. \quad (7)$$

Следовательно, необходимо, чтобы при работе такого механизма обеспечивалось равенство

$$l_p\cdot(1-\cos\alpha)=r\cdot(1-\cos 2\alpha). \quad (8)$$

Используя это равенство и подставляя численные значения в это равенство при φ=0 и α=180°, получим величину радиуса эксцентрика, при котором обеспечивается прямолинейная ось симметрии перемещения пилы по самопересекающейся замкнутой кривой типа восьмерки. В этом случае радиус эксцентрика определится по формуле

$$r = 0{,}5\cdot(l_p-\sqrt{l_p^2-R^2}). \quad (9)$$

Таким образом, выравнивание оси движения пильной рамки по самопересекающейся замкнутой кривой типа восьмерки в прямую линию будет наблюдаться только лишь в том случае, когда радиус эксцентрика будет определяться по формуле (9).

7. Выводы и предложения

Таким образом имеются научные и практические предпосылки для создания лесопильных рам с шарнирно-рычажной подвеской пильной рамки и новой кинематикой резания. Рациональной траекторией качания пил является самопересекающаяся замкнутая кривая типа восьмерки, которая позволяет исключить скобление зубьями пилы дна пропила в начале холостого хода и уменьшить максимальные нагрузки на пилы во время рабочего хода. Для получения такого перемещения пильной рамки необходимо чтобы угловая скорость качания пил была в 2 раза больше чем угловая скорость движения коренного вала лесопильной рамы. При синхронизации движений пил и заготовки путем использования переменной скорости подачи заготовки необходимо, чтобы перемещение заготовки осуществлялось с циклом за рабочий и холостой ходы с остановками или с возвратными перемещениями этой заготовки в моменты, когда пильная рамка находится в верхнем и нижнем крайних положениях. На лесопильных рамах с новой кинематикой резания рекомендуется использовать пилы с углом резания 60° вместо 75°. При этом задний угол рекомендуется принимать равным 13° вместо 18°. Улучшение условий работы пил позволяет увеличить производительность лесопильных рам в 1,5…2,0 раза, снизить энергоемкость процесса пиления на 40...50% и уменьшить потери древесины в опилки.

8. Литература

1.Агапов, А. Кинематика процесса пиления древесины на лесопильных рамах. – Горький: Изд-во ГГУ, 1981. – 99 с.

2.Агапов, А. Кинематика лесопильных рам. – М.: Лесн. пром-сть, 1987. – 144 с.

3.Агапов, А. Лесопильные рамы нового поколения. – Актуальные проблемы машиностроения. Изд-во Самарского научного центра РАН, том 16, №1(2), 2014. – С. 340-345.

4.Бершадский, А. Резание древесины (Бершадский, А., Цветкова, Н.) – Минск: Выш. шк., 1975. – 304 с.

5.Дешевой, М. Механическая обработка дерева. – Л.,М.: Главная редакция литературы по машиностроению и металлообработке, 1936. – 429 с.

6.Филькевич, В. Динамика лесопильных рам. – М.: Лесн. пром-сть, 1968. – 230 с.

7.Фонкин, В. Современные лесопильные рамы. – М.: ЦИНТИАМ, 1964. – 66 с.

8.Фонкин, В. Лесопильные станки и линии. – М.: Лесн. пром-сть, 1979. – 320 с.

INFLUENCE OF PARAMETERS BY ELECTRONIC RAY ON PROPERTIES OF SUPERFICIAL LAYERS OF OPTICAL ELEMENTS OF EXACT INSTRUMENT-MAKING

ВЛИЯНИЯ ПАРАМЕТРОВ ЭЛЕКТРОННОГО ЛУЧА НА СВОЙСТВА ПОВЕРХНОСТНЫХ СЛОЕВ ОПТИЧЕСКИХ ЭЛЕМЕНТОВ ТОЧНОГО ПРИБОРОСТРОЕНИЯ

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Abstract: *In the article are presented the results of researches of action of electronic ray on optical elements. The analysis of surfaces of elements before and after a beam-processing the method of atomic-force microscopy shows that in first case the height of microburries makes 50…60 nm, and in second case goes down to the level of 0,5…1 nm. Influence of parameters of electronic ray is set on the height of microburries: the increase of closeness of thermal influence of ray in 6 times results in diminishing of height of microburries in 3…4 time, diminishing of rate of movement of ray in 5 times results in diminishing of height of microburries in 5…6 times. It is shown that by optimization of the modes of beam-processing of elements it is possible substantially to improve (to 50…60%) properties of its superficial layers and basic operating descriptions of devices. Thus probability of destruction of elements and death devices in the conditions of intensive external thermal influences, devices can undergo that at their storage, portage and application, diminishes in 1,5…2 time.*
***KEYWORDS**: OPTICAL GLASS, ELECTRONIC RAY, SURFACE LAYERS, ELEMENTS OF PRECISION INSTRUMENTS*

1. Introduction

Application expanding conditions (higher heating temperature, external pressure, thermal shock effects, etc.) devices with optical elements for measurement and control of thermal objects of different physical nature (laser modules for fiber optics, sights to observe in the visible and the infrared of the spectrum, IR-devices targeting and tracking of different objects, etc.) make high demands on their technical and operational characteristics (resistance to external heat and mechanical stress, sensitivity, reliability, etc.) [1-3]. This is because in these conditions there is a deterioration of the surface layers of the optical elements up to their destruction (cracking, chipping and other defects), leading to failure of the devices based on them.

That is the anticipation of these adverse events at the stage of design and manufacture of devices considered to optical elements is urgent. In a number of studies conducted by different authors in this direction [4-6] was found that one of the most promising directions in the elimination of undesirable changes in the properties of the surface layers of the optical elements is their finishing moving electron beam. In particular, the possibilities of an electron beam method in the formation of surface layers on the elements of optical glass with altered physic and chemical properties were shown [7].

2. Results and discussion

Systematic studies on the effects of the electron beam on the surface layers of the elements are very limited nowadays. Therefore, in this paper the results of studies on the influence of the main parameters of thermal effects (heat flux density, its speed), low-energy electron beam ($E \leq 10$ keV) in the surface layers of the elements of optical glass (K8, K108, K208, BK10, TF110) are presented.

In order to find the regularities of thermal influence of the electron beam on the elements of optical glass and mode control processing it is necessary to know changes in the structure of the modified layers of materials, the height of the residual microscopic irregularities on the treated surfaces of the glass and the depth of their melting depending on implemented in practice processing modes: heat flux density from electron beam $F_n = 7 \cdot 10^6 ... 5 \cdot 10^8$ Wt/m^2, the speed of its movement according to the optical elements $V = 8 \cdot 10^{-3} ... 5 \cdot 10^{-2}$ m/s. Characteristics of the studied glasses, methods of preparation of their surfaces, as well as modern methods of studies of the properties of the surface layers of glass are standard and well-known [2].

The research results of the surface elements of optical glass by scanning electron microscopy method showed that on the surface of the machined glass (K108, K208, etc.), the presence of various micro roughnesses are the most characteristic: tiny cracks of 0,1...1,5 mm depth, as well as "hillocks", bubbles, dots etc., those sizes are $3 \cdot 10^{-3} ... 2 \cdot 10^{-2}$ microns. After the electron beam treatment on the surface of the glass bubbles and points sizes (diameters) decrease in 3...5 times, the "bumps" and other unevenness smaller than 1..3 microns are not detectable, i.e. by treating the surface with an electron beam glasses they "cleared" and minor defects disappear. Surface analysis of optical glasses before and after electron beam treatment by AFM shows that in the first case, the height of asperities is 50...60 mm, and in the second case it reduces to 0,5...1 nm level. That is why the following effect parameters of the electron beam at the height of the residual microscopic irregularities (fig.1, 2) were established: the increase of the density of heat exposure to the beam up to 6 times reduces the height of the residual microscopic irregularities in 3...4 times. Reducing the speed of the beam is 5 times reduces the residual height of asperities in 5...6 times.

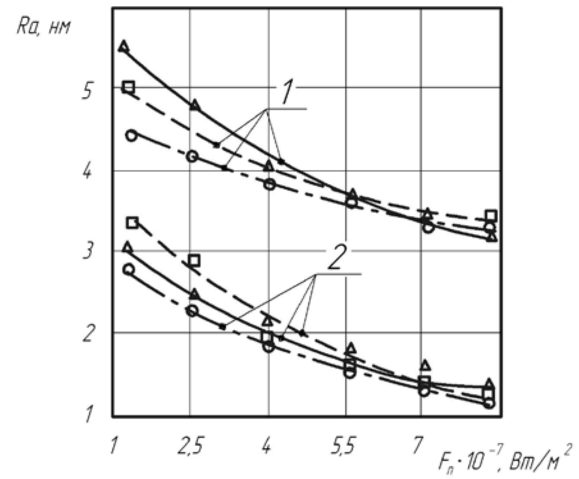

***Fig.1.** The dependence of the height of the residual surface roughness of the optical elements of glass on the density of the electron beam exposure to heat: 1 – $V = 5 \cdot 10^{-2}$ m/s; 2 – $V = 8 \cdot 10^{-3}$ m/s; ——— – K8 glass element; – – – – – TF110 glass element; – · – · – – BK10 glass element; Δ, ○, □ – experimental points.*

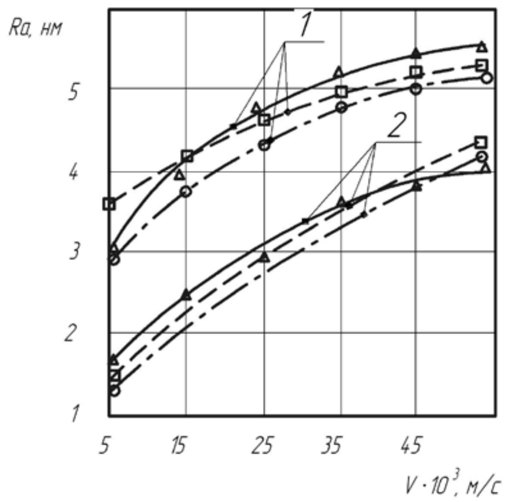

Fig.2. *The dependence of the height of the residual surface roughness of the optical elements of glass on the velocity of the electron beam: 1 – F_n = 7·10⁶ m/s; 2 – F_n = 5·10⁸ m/s;* ——— *– K8 glass element; – – – – – TF110 glass element; – · – · – – BK10 glass element; Δ, ○, □ – experimental points.*

Study of fractogram surface layers of the optical elements of glass before and after electron beam treatment showed that the depth of the main-heat zone or the thickness of the fused layer can reach 250..300 microns and substantially depend on of the density of the heat exposure to the beam and its speed (fig.3-6): an increase in the heat exposure to the beam from $7 \cdot 10^6$ Wt/m^2 to $5 \cdot 10^8$ Wt/m^2 leads to an increase in the depth of melting of the optical element from 50 microns to 300 microns; an increasing the velocity of the beam from $8 \cdot 10^{-3}$ m/s to $5 \cdot 10^{-2}$ m/s, on the contrary, leads to the reduction in the depth of melting from 150 microns to 30 microns.

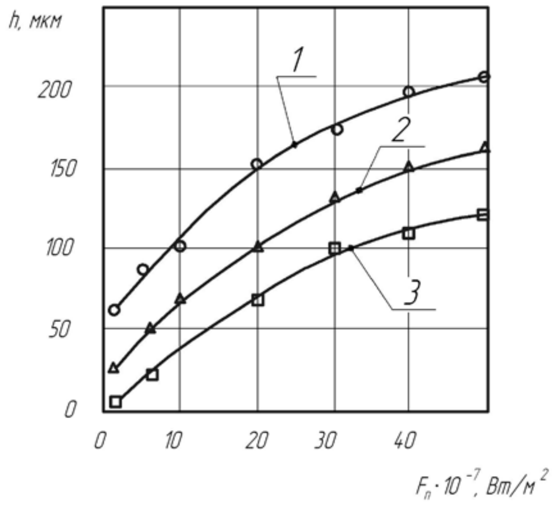

Fig.3. *The dependence of the thickness of the melted layer of the optical elements of glass on the density of the electron beam exposure to heat (V = $5 \cdot 10^{-3}$ m/s): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ, ○, □ – experimental points.*

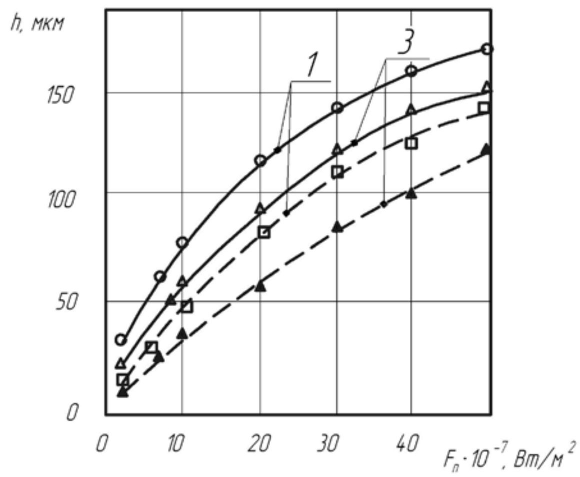

Fig.4. *The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the density of the thermal effect of the electron beam:* ——— *– V = $5 \cdot 10^{-3}$ m/s; – – – – – V = $4 \cdot 10^{-2}$ m/s; Δ, ○, □ – experimental points.*

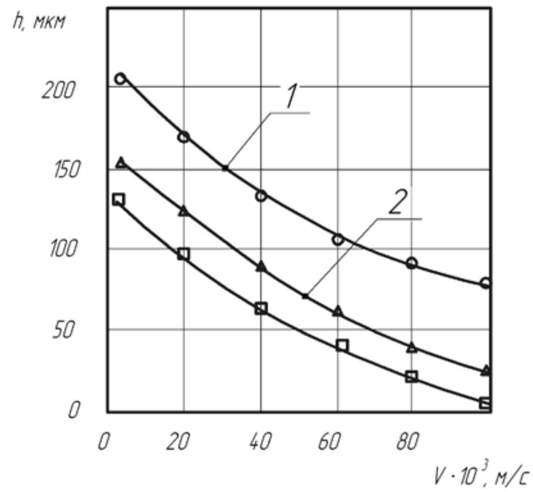

Fig.5. *The dependence of the thickness of the melted layer of the optical elements of glass on the speed of the electron beam (F_n = $6 \cdot 10^8$ Wt/m^2): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ, ○, □ – experimental points.*

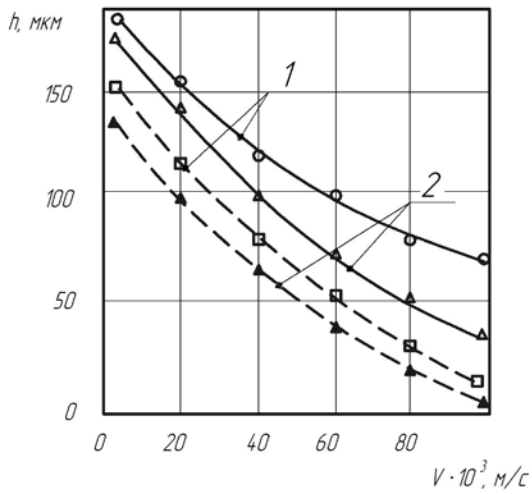

Fig.6. *The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the speed of the electron beam:* ——— *– F_n = $6 \cdot 10^8$ Wt/m^2; – – – – – F_n = $3 \cdot 10^8$ Wt/m^2; Δ, ○, □ – experimental points.*

A detailed study of sections of scans surfaces of the optical elements of glass after the electron beam treatment points to the local smoothing irregularities, significant dependence on the surface shape of the processing modes. So that, with a deep melting (250...300 mm) there is a clear undulating surface of the section. That is why this modified layer has a clearly melted oriented structure depth reflow.

Thus, the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

Spectra analysis of the concentration dependence of element distribution in the treated and untreated surfaces of the electron beam optical glass (e.g., glass K8, K108 and BK10) also indicate on the instability of K_2O and Na_2O on the depth of the electron beam exposure.

In the study of the elements of optical glass by ultra-soft X-ray reflexometer method was found that the electron beam in the treated cell the surface structure corresponds to the crystalline state, in which a violation of coordination of silicon atoms is virtually nonexistent.

It is also established that the electron beam treatment of the optical elements of glass reflow leads not only to homogenization of the surface but also to the surface oriented rearrangement in silicon-oxygen network of the glass, close to that of quartz glass, which has a high heat resistance to external-heat.

3. Conclusion

It was found that the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

It is also established that the electron beam treatment of the optical elements of glass reflow leads not only to homogenization of the surface but also to the surface oriented rearrangement in silicon-oxygen network of the glass, close to that of quartz glass, which has a high heat resistance to external-heat.

Thus, by optimization of electron-beam processing of elements of optical glass (up to 50...60%) the properties of their surface layers and the basic technical and operational characteristics of the devices can be significantly improved. The probability of failure of elements and the failure of the devices under intense external-heat, which the units during storage, transport and use may be exposed, decreases in 1,5...2 times.

4. Literature

1. Vashhenko V.A. Teplovye processy pri jelektronnoj obrabotke opticheskih materialov i jekspluatacii izdelij na ih osnove (*Thermal processes at electronic treatment of optical materials and exploitation of wares on its basis*) / V.A.Vashhenko, D.I.Kotel'nikov, Ju.G.Lega, D.M.Krasnov, I.V.Jacenko, O.V.Kirichenko – K.: Nauk.dumka, 2006. – 368 s.
2. Vashhenko V.A. Osnovi elektronnoї obrobki virobiv z optichnih materialiv (*Bases of electronic treatment of wares are from optical materials*) / V.A.Vashhenko, I.V.Jacenko, Ju.G.Lega, O.V.Kirichenko – K.:Nauk.dumka, 2011. – 262 s.
3. Dudko G.V. Formirovanie predel'no gladkih poverhnostej opticheskih stekol / G.V.Dudko, A.A.Kravchenko, D.I.Cherednichenko (*Forming maximum of smooth surfaces of optical glasses*) // Fizika i himija stekla, 1987. – t.13. – №5. – S.740-746.
4. Vashhenko V.A. Opticheskie svojstva podlozhek OIS iz stekla posle nizkojenergeticheskoj jelektronno-luchevoj obrabotki (*Optical properties of plates of OIS from glass after a low-energy beam-processing*) / V.A.Vashhenko, G.N.Dubrovskaja, G.V.Kanashevich, S.V.Pozdeev // Trudy III Mezhdunarodnogo simpoziuma «Vakuumnye tehnologii i oborudovanie». – Har'kov, 1999.
5. Dubrovskaja G.N. Poluchenie funkcional'nyh sloev v opticheskom stekle i keramike metodom jelektronnoj obrabotki (*Receipt of functional layers in optical glass and ceramics the method of electronic treatment*) / G.N.Dubrovskaja, G.V.Kanashevich, V.A.Vashhenko // Sb.dokladov Mezhdunarodnogo nauchno-prakticheskogo simpoziuma «Funkcional'nye pokrytija na steklah». – Har'kov: NTC HFTI «Konstanta», 2003. – S.135-137.

„Подредено производство” (Lean manufacturing) за повишаване ефективността на конвейерно машинно електронно производство в условия на Тотално управление на качеството(ТУК)

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Резюме: В доклада се разглежда конвейерен машинен електонен монтаж и необходимостта от прилагане на съвременни модерни методи за повишаване на ефективността в условията на тотално управление на качеството. Чрез използване на метода „Lean manufacturing” е показано реално повишаване на ефективността на машинно производство при високо качество. Дадени са конкретни примера за повишаване на ефективността на машинно производство в модерно електронно предприятие чрез въвеждане на високотехнологично машинно оборудване. Конкретизирани са основните ползи от прилагането на описания метод с реални икономически резултати.

Ключови думи: - lean manufacturing, циклично време за производство, производителност, качество.

1. Въведение

Ефективното производство и качеството отдавна са елементи на стандарти от общ характер[1], [2], така и на специфични стандарти за конкретни области[3], [4]. В областта на електронния монтаж качеството и ефективността в много от случаите е водещи за успешното съществуване на дадена бизнес единица и за възможностите и за реализация на висококонкурентни пазари. Процесите в електронния монтаж са съпроводени с високи скорости и съответно малки операционни циклични времена. Горното предразполага за използване на различни методи за подобрение на ефективността и намаляване на риска от лошо качество[5]. За да е устойчиво, предсказуемо и рентабилно, всяко производство вече се стреми да използва автоматизация чрез машинна обработка, която е решаваща за определяне такта на линията. Все повече човекът участва в настройката и подготовката на линията или най-много в обслужването и, което позволява да се получат нула дефекти.

2. Процеси в машинния електронен монтаж

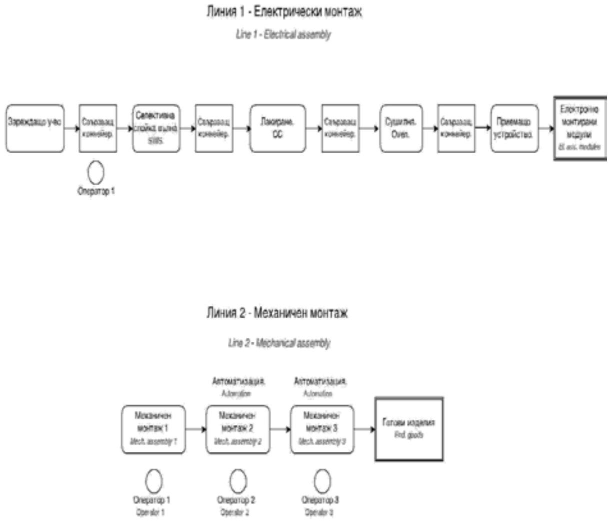
Основните процеси в машинния електронен монтаж са:

- електрически монтаж чрез спойка вълна[8];
- конвейерен автоматизиран механичен монтаж;
- параметрично и функционално тестване.

В настоящия материал е описан модел на машинно електронно производство, включващ част от цялостния процес(фиг.1), за който е приложен метода за подобрение „Lean manufacturing” във фирма Унипост ООД, който обхваща следните процеси:

- електрически монтаж на обемни компоненти със селективна спойка вълна[9] и спрей нанасяне на защитно лаково покритие[10];

- автоматизиран механичен монтаж на крайни изделия.



Фиг.1 - Автоматизирана линия за монтаж

3. Разбирането за метода “Lean manufacturing”

„Lean manufacturing”[6] е метод за подобрение на ефективността на производствения процес, при който чрез изучаване, измерване, пресмятане, анализиране и промяна се осъществява нова организация на производство с цел намаляване на операционните циклични времена за производство на даден продукт и максимално използване на ресурсите.

Създаден е в Япония през 50-те години на миналия век от Тайичи Оно и силно развит в TOYOTA. Благодарение и на него тази фирма става водеща в автомобилостроенето в света и символ за високо качество на добра цена.

Основните производствени принципи при него са:

- теглене от страна на клиента, а не бутане от производството;
- минимизиране на всички загуби и излишъци;
- перфектно качество от първия път;
- непрекъснато подобрение;
- гъвкавост.

Той е приложим за всички процеси и е най-силно използван за подобрение на ефективността на производството в момента.

Този метод е с възможност за постоянно подобрение и е съществен елемент на тоталното управление на качеството.

Съществуват различни форми за улесняване на прилагането му, но в крайна сметка целта е да се разпределят ресурсите така, че да се използват еднакво и максимално и се премахнат загубите.

Започва се с детайлно изучаване на стъпките на процесите. Снемат се операционните времена и цикличното време за производство. Прави се анализ и чрез пренареждане, запаралелване на процеси и намаляване на транспортните пътища се организира нов начин на движение и обработка с цел намаляване на цикличното време за производство и елиминиране на условията за грешка.

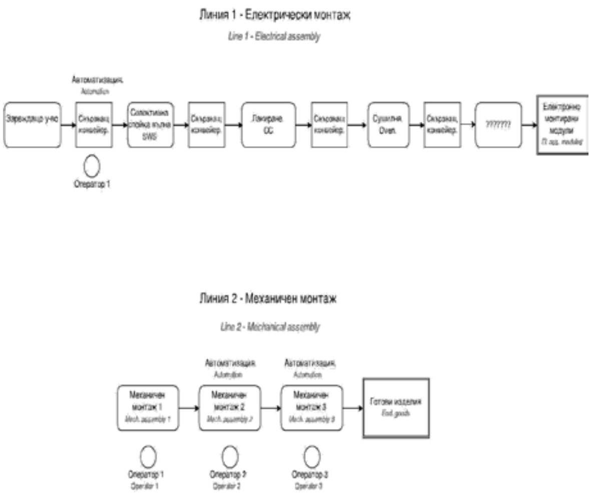
4. Прилагане на „Lean manufacturing”

В производствената линия на фирма „УниПОС” беше продължено прилагането на метода „Lean manufacturing”[7] с цел намаляване на производствените разходи и подобрение на качеството чрез намаляване на ремонта. Основното развитие продължи с инвестиране и въвеждането в експлоатация на съврememнни машини за запояване и монтаж.

На фиг. 1 е показана автоматизираната производствена линия преди прилагането на метода. Основните процеси по електрически и механичен монтаж се извършваха на машинни линии от оператори по показаната схема. Резултатите бяха:

- циклично време за производство – 11 секунди;
- производителност – 2600 изделия на смяна;
- разход на труд – 0,73 минути;
- ремонт – 0,57 %.

След прилагане на метода се стигна до решението за въвеждане на допълнителна автоматизация за ускоряване работата на машинния конвейер за електрически монтаж и за стабилизиране на работата му от гледна точка на късия цикъл на работа на оператора, както е показано на фиг.2. Част от сглобяването на втората линия беше интегрирано в работата на първата.



Фиг.2 - Автоматизирана линия за монтаж с автоматизации на ръчно зареждане.

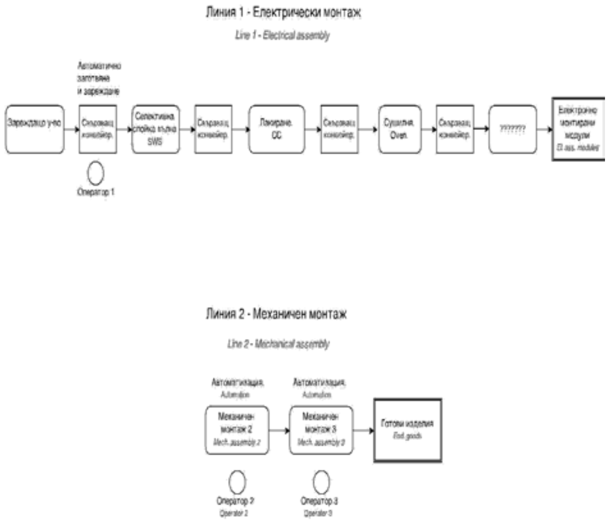
Получиха се следните резултати при експлоатацията на описаната линия:

- циклично време за производство – 10 секунди;
- производителност – 2880 изделия на смяна;
- разход на труд – 0,67 минути;
- ремонт – 0,42 %.

Имаше сериозно подобрение, което работеше устойчиво. Производителността се увеличи с 10%, разхода на труд се намали с 8% и ремонта намаля с 26%.

Вече беше ни ясно, че стъпките за подобрение ще стават все по-трудни, но тъй като обемите разстяха, благодарение на намалените цени от по-ефективно производство ние продължихме.

След детайлното наблюдение и анализ на работата на машинните линии се стигна до извода, че трябва да се интегрират повече операции в една, използвайки допълнителна автоматизация, позволяваща операторът да манипулира веднъж, при което да се получава продукт в по-голямо развитие или с монтирани в паралел повече компоненти от допълнителна машина. Това беше внедрено в линията за електрически монтаж и то доведе до ускоряване работата на линията и намаляване на броя на операциите в механичния монтаж. Допълнително беше стабилизирано сглобяването на чувствителния елемент на произвежданото изделие, което даде възможност по-късно да се опрости настройката му. Стигнахме и до решението, че трябва да се промени основно линията за механичен монтаж, която в съществуващия си дизайн не отговаряше на възможностите на линията за електрически монтаж. Всичко описано доведе до нова опростена организация на захранване с материали. Организционната схема на тази линия е показана на фиг.3.



Фиг.3 - Автоматизирана линия за монтаж с автоматично заготвяне и зареждане от оператор.

Постигнахме следните резултати при експлоатацията на тази линия:

- циклично време за производство – 9 секунди;
- производителност – 3150 изделия на смяна;
- разход на труд – 0,45 минути;
- ремонт – 0,3 %.

Производителността се увеличи с 10%, разхода на труд се намали с 33% и ремонта намаля с 29%.

намали разходите за труд и материали.

Работата продължи, като анализите показват, че трябва да се редизайнва работата на линията за механичен монтаж и да се намали ръчния труд. Насочваме се към инвестиране в център за автоматичен механичен монтаж, който трябва да е гъвкав, с обслужване от един оператор и с възможности за непркъсната работа. При тези бързи процеси, ремонта трябва да е 0.

5. Заключение

Инвестирането в подобряване на организацията на производство и в машинни автоматични конвейерни линии се налага задължително при обеми на производство над 200000 изделия годишно и особено, ако изделията са крайни. Намаляването на себестойността при отлично качество е основата за конкурентна способност и разширение на пазарни възможности. Постигането му е невъзможно без устойчиво прилагане на съвременни методи за ефективно производство и тотално управление на качестото.

6. Литература

[1] ISO 9000.

[2] ISO TS 16949.

[3] QS 9000.

[4] IPC –A - 650 E.

[5] IPC – A - 610 E

[6] James P. Womack, Daniel T. Jones и Daniel Roos, The Machine That Changed the World: The Story of Lean Production(1991).

[7] MacInnes, Richard L.The Lean Enterprise Memory Jogger(2002)

[8] Biocca, Peter, Lead-free wave soldering(2005)

[9] ERSA VERSAFLOW 3/45 (2014)

[10] NORDSON ASYMTEK SL-940E(2014)

Данни за автора:

Валентин Петров Ценев. Инженер – електронна техника (1986 г.). Доктор (2010 г.). Директор Нови Технологии в “УниПОС” ООД, гр. Плевен. Научни интереси в областта на технологиите за електронен монтаж, организация на производство и управлението на качество.

Lean manufacturing applying for increasing the efficiency of conveyor machine electronic production in the condition of Total Quality Managing

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Abstract: The report presents a certain example of using lean manufacturing for increasing the efficiency of machine production in TQM environs. The approach, the application and the final results of TQM lean manufacturing are shown.

Key-Words: - lean manufacturing, production cyclical time, productivity, quality.

A NEW APPROACH TO AUTOMATED DESIGN OF A MINIMUM MASS CARDAN COUPLING

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Abstract: *While designing a Cardan coupling it is necessary to assess the assembly-ability of its components as well as to ensure that they do not interfere with each other during normal operation. In practice, this is done by use of prebuilt sample models, where everything is checked by experimenting. The authors share herewith their idea for developing a new approach to designing Cardan couplings, where all operations are performed in an automated way as early as the design stage,*

Keywords: CARDAN COUPLING, AUTOMATED DESIGN, ASSEMBLY

1. Introduction

One of the most substantial applications of Cardan couplings is to connect rotating shafts arranged at an angle to each other, and to transfer torque from one shaft to the other. Various designs are used in practice, the most common joint to connect the shafts is the Hooke's joint, where two forks are connected by a crosspiece with perpendicular axes, through needle roller bearings.

While designing a Cardan joint, it is necessary to assess the assembly-ability of its components, as well as the manufacturability of such a connection. In effect, this comes down to ensuring non-interference of the components in any possible positional relationship within the chosen range of intersection angles of the shafts, as well as during the components' assembly. So far such checks have been commonly carried out by pre-building several sample models of the design, and using them for simulated checks, since 2D mapping only cannot provide sufficiently reliable compatibility.

In this publication the authors propose a new method and algorithm for automated checking of the assembly-ability of individual components of a Hooke's joint in the course of designing a minimum mass coupling.

2. Current state

The rotation of the two forks with different angular velocities not only complicates the interference check but also affects in a complex manner the forks' instantaneous velocity values. This makes it difficult to carry out a correct strength estimate of the forks. The estimate is realized with some reserve, basing on the forces and the corresponding torque and bending moment values in two limit positions [1, 2 and 6]. This makes the strength estimate to a great extent conditional. At higher speeds of rotation, the dynamic load on the components of the Cardan coupling substantially increases, and the design is required to take this factor into account too [4, 7].

The foregoing necessitates an optimization of the Cardan coupling design, and calls for a new design approach which requires the solving a sequence of problems:

1. A parametric description of the mathematical model representing the base design for modelling a minimum size Cardan transmission;
2. Development of a method for accurate determination of the tangential and axial forces acting on the joints for an arbitrary rotation angle of the drive fork;
3. Development of an algorithm for determining the conditions allowing assemblability of the fork and crosspiece for a specified size as early as the design stage;
4. Development of an algorithm for determining the size of the forks under the condition of non-interference in motion, with an accurate 3D spatial model of the joint, at various shaft intersection angle values, and in arbitrary relative positions of the fork legs;
5. Checking the state of tension of the components of the Hooke's joint for each specific position.

The present article is focused mainly on solving task №3.

3. Problem solution

The mathematical model adopted in [3, 5] was adopted here as the mathematical model for describing the fork shape.

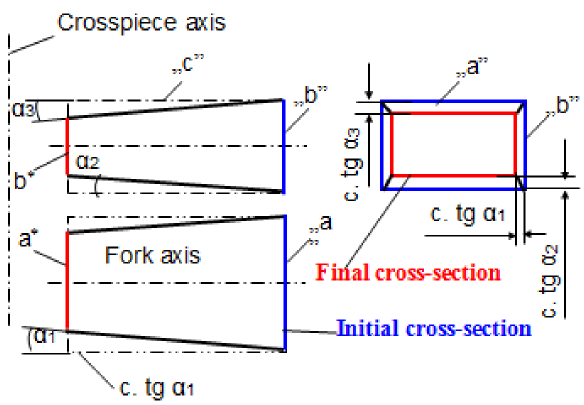

Fig. 1 *Parametric model of the fork legs a x b, a* x b* – initial and final cross-section values; c – leg length;* α_1*,* α_2*,* α_3 *– angles defining the final cross-section*

For convenience in compiling the mathematical model of the design, the values ($a^* \times b^*$) of the final cross-section – the one nearer the fork's eye – are to be represented via the α_1, α_2 and α_3 angles (Fig. 1). Different angle values result in rectangular or trapezoidal shape of the final and intermediate cross-sections, with different size.

3.1 Determining the conditions for assemblability of the fork and the crosspiece

The assemblability conditions are examined for two cases: for non-chamfered and for chamfered (chamfer angle β) fork eyes.

To determine the assemblability conditions for non-chamfered fork eyes, the limit position of the crosspiece is examined (Fig. 2), determined by the following:

Point A of the upper journal lies on the border line of the upper eye bore; point G of the lower journal lies in the internal plane of the lower eye; point D lies on the right border line (or the extension thereof) of the upper eye bore; the geometric axes of the crosspiece and the bore are at an angle of 45° with respect to each other.

Thus the horizontal straight line FD determines the limit position of the upper eye relative to the lower eye. In this position, the crosspiece touches the three points A, D, and G. On displacement of point A upward, the touching point of the crosspiece will move away from point D. Then the distance between FD and the lower eye will correspond to the minimum distance between the eyes at which assembly is possible.

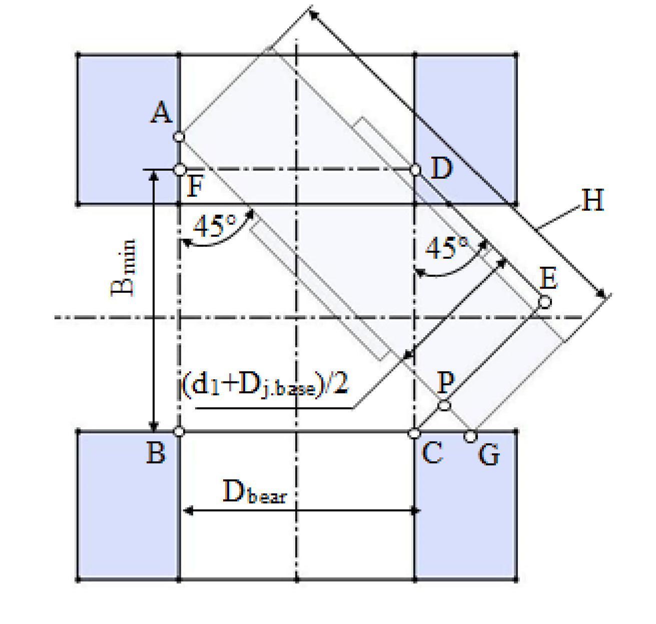

Fig. 2 *Diagram for determining the assemblability conditions for the fork and crosspiece for non-chamfered fork eyes.*

From the isosceles right-angled Δ ABG, the side

(1) $BG = H/2^{½}$ is determined.

Segment CG is determined along ⇒

(2) $CG = BG - D_{bear}$

From the isosceles right-angled Δ CPG, the side

(3) $CP=PG=CG/2^{½} =(BG - D_{bear})/2^{½} =(H/2^{½} - D_{bear})/2^{½}$ is determined;

where: H – crosspiece height, mm.

Segments PE and CE are determined through (4).

(4) $PE = (d_1+D_{i.base})/2;$
$CE= PE+CP = (d_1+D_{j.base} + H- D_{bear}2^{½})/2;$

where: $D_{j.base}$ – diametre of the base of the crosspiece journal, mm.

From the isosceles right-angled Δ DCE, the following is determined:

(5) $B_{min} = CD =2^{½}/2. (d_1+D_{j.base} + H- D_{bear} 2^{½})$

The condition which guarantees assemblability is: $B \geq B_{min}$.

If the eyes are chamfered at an angle β (Fig. 3), the distance B_{min} determined for non-chamfered eyes must be increased by the difference between the enlargement of the upper eye (segments KM and NP) and the lower eye.Then for $B^{β}_{min}$, (6) can be written.

(6) $B^{β}_{min} = B_{min} + (KM- NP)$

Since KM = D_{bear}.tgβ, and NP = tgβ. $(D_{bear} +D_{eye})/2$ for $B^{β}_{min}$ obtains the value ⇒

(7) $B^{β}_{min} = B_{min} + tgβ (D_{bear} - D_{eye})/2;$

where: D_{eye} – outer diameter of the eye, mm.

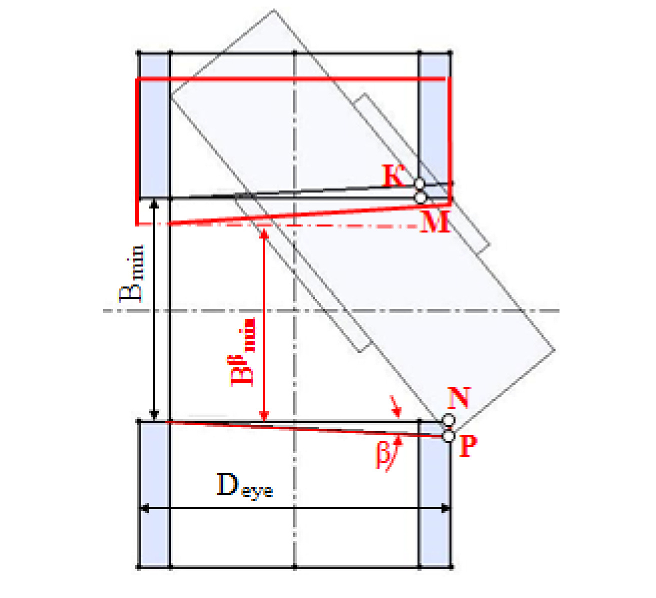

Fig. 3 *Diagram for determining the assemblability conditions for the fork and crosspiece for fork eyes chamfered at angle β.*

Due to strength considerations, in order not to reduce too much the eye height L_{eye} and affect the integrity of the bore, the value of angle β may have to be restricted: the chamfered part should not exceed 1/3 of the eye height.

3.2 Determining the minimum fork dimensions

The components comprising the fork design are: a hub, connected with two identical legs, each ending with an eye. The main geometric parameters characterizing the design are (Fig.4):

hub – a cylinder with an outer diameter D_{hub}, inner diameter d_{hub}, and length L_{hub};

eye – a cylinder with an outer diameter D_{eye}, inner diameter d_{eye}, and length L_{eye};

leg – a prismatic geometric base shape with dimensions **a** x **в** x **c,** with an initial cross-section representing a rectangle with dimensions **a** x **в** touching the hub face and displaced relative to the geometrical axis of the fork by a distance of $\mathbf{R_0}$**.**

Through varying the $\boldsymbol{\alpha_1}$, $\boldsymbol{\alpha_2}$, and $\boldsymbol{\alpha_3}$ angles, the geometric base shape can morph into a right or skewed pyramid with a square or rectangular base.

The following parameters for relative position of the individual components have been defined in relation to the geometric axis of the fork:

- Parameter B – the distance between the eyes positioned symmetrically with respect to the fork's geometric axis.
- Parameter R_0 – determines the position of the leg in relation to the hub and eye.
- The distance between the eye and the hub is determined through the **c** dimension of the leg.

Geometrical and design characteristics of the bearing:

Four versions of design implementation have been assumed, namely I, II, III, and IV. Outer and inner bearing diameter D_{bear}, d_{bear};

- diameter and length of the needle d_n , l_n
- thickness of the bearing housing base b_{bear};
- inner bearing shoulder: m=0 mm for versions I and III; m=3 mm for versions II and IV;
- clearance between the journal face and the bearing base when assembled: c=0.5 mm.

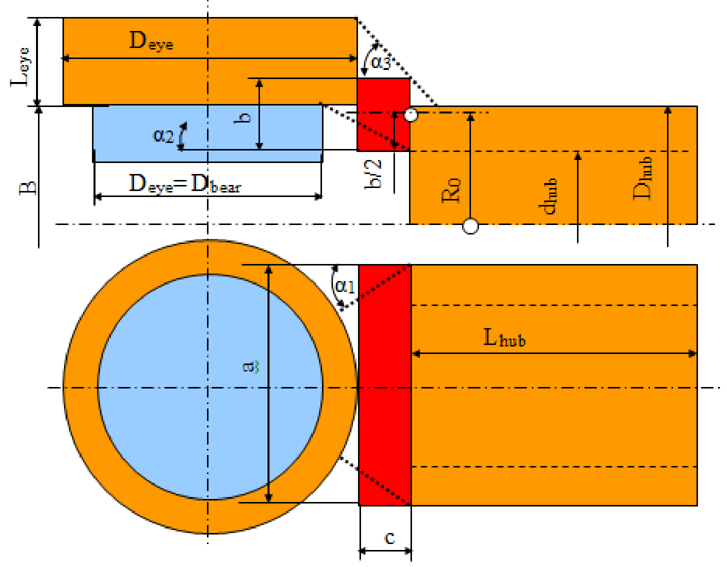

Fig. 4 *Main fork components. Relative positions and geometrical characteristics defining the design.*

Basing on the values defined above, the geometrical characteristics of the crosspiece, eye, and hub are defined by use of mathematical expressions. The minimum dimensions of the crosspiece have been specified during the selection and dimensioning of the bearing. The minimum eye thickness value can be assumed to be equal to the thickness of the bearing case. The minimum **c** value (Fig. 4) can be assumed to be equal to zero, where the eye will touch the hub. Such a leg can be implemented only if the intersection angle γ between the geometric axes of the forks is equal to zero. In the other cases the initial value of c_{min} is assumed to be 1 mm, and subject to additional correction.

Relative position of the leg with respect to the eye

The assumed spatial shape of the leg is a right or skewed pyramid with a rectangular base (or, as a special case, square), can also have negative values. The initial cross-section (base of leg) lies in the face plane of the hub and represents a rectangle with dimensions a x b. The final cross-section, with dimensions a* x b*, is located at a distance **c** from the initial cross-section, and can be either a rectangle or a trapezium, depending on the α_1, α_2, and α_3 angle values. A conditional cross-section is also introduced, representing a transitional geometric shape between the eye and the leg. It sets the conditional limit beyond which the leg protrudes inside the eye.

When the leg is located between the eye and the hub, certain general limitations are in order (Fig.5).

a) If $\alpha_2 > 0$, then the conditional part of the leg (where the transition between leg and eye occurs) must not protrude inside the bearing, i.e. the minimum distance at which the conditional final cross-section of the leg should be located in

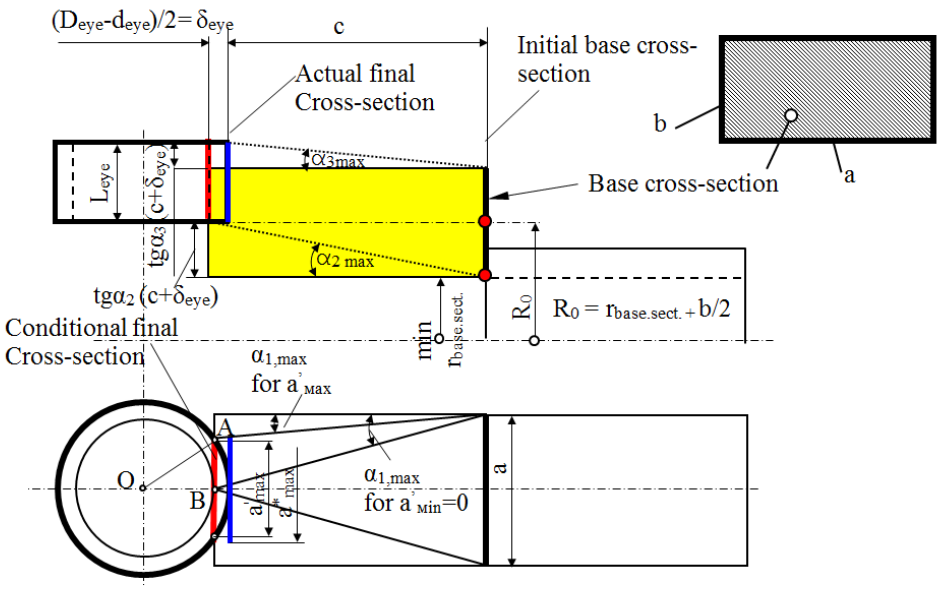

Fig. 5 *Defining the position of the leg in relation to the fork eye and hub, through the initial base cross-section, the displacement of the final cross-section with relation to the initial one, and the admissible displacement of a conditional cross-section in relation to the final one.*

resulting from the prism base shape (where the three angles α_1, α_2, and α_3 have a value of zero). The spatial shape can be modified into a pyramid, depending on the assumed values of the three angles. The α_1 and α_2 angles can only have positive values (≥ 0) while α_3

b) relation to the geometric axis of the eye, is equal to ½ D_{bear}, while the distance between the conditional and actual final cross-sections is δ_{eye}.

c) If $\alpha_2 = 0$, the maximum displacement of the conditional final cross-section of the leg coincides with the eye's geometric axis, and the distance between the conditional and actual final cross-sections is equal to δ_{eye}.

d) If $\alpha_2 > 0$, then the minimum limit value for the location of the initial base cross-section $\mathbf{r}^{min}_{\mathbf{base.sect}}$ is determined by the condition that the leg must not protrude inside the hub bore: $\mathbf{r}^{min}_{\mathbf{base.sect}} = \mathbf{d_{hub}/2}$ **.**

e) If $\alpha_2 = 0$, then the inner surface of the leg cannot be positioned under the inner face surface of the eye. Then the initial base cross-section must be located outside of the hub thickness, which necessitates supplementing the leg with a new geometric shape similar to the assumed one, to serve as a material bridge between the initial cross-section and the hub. These conditions determine also the location of the starting point of the base cross-section $\mathbf{r}^{min}_{\mathbf{base.sect}} \geq B/2$.

f) The highest part of the base cross-section may be located at the level of the outer face surface of the eye. Then $\mathbf{r}_{\mathbf{base.sect,max}} \leq B/2 + L_{eye}$-b.

g) Dimension b of the initial cross-section of the leg must be located within $d_{hub}/2$ (lower limit) and $B/2 + L_{eye}$ (upper limit), which means that its maximum overall dimension in this direction must be $b_{max} \leq B/2 + L_{eye} - d_{hub}/2$. Its minimum value can be assumed to be $b_{min} \geq L_{eye}/2$.

h) The final cross-section should be located within the thickness of the eye.

i) The maximum value (a_{max}) of parameter **a** of the base cross-section may not exceed the eye diameter $a_{max} = D_{eye}$, while the minimum value can be assumed to be $a_{min} = d_1$ (journal) $= d_{in.dia}$ (bearing inner diameter).

j) Angle α_3 is only related to the strength characteristics of the final cross-section. No specific limitations need to be introduced for it, as it is dependent on the two limitations described above.

4. Conclusion

- The applied approach for designing a Cardan coupling can serve as the initial stage of software development. 3D imaging combined with automated computation of certain parameters would reduce the duration of the design phase and provide greater certainty in the final result via suitable visualization.

- Characteristic for the examined approach is the intent of the authors not to focus on any specific case, but rather to develop the algorithm to cover all possible design variations resulting from the variety of input data, in a way such that the mass of the designed Cardan coupling is minimal.

References

[1] Ненов П., Д. Андреев, П. Стаматов, И. Спасов. Курсово проектиране по машинни елементи. София, Техника, 2007

[2] Ненов П., Е. Ангелова, А. Добрева, В. Добрев. Машинни елементи (с алманах). РУ "Ангел Кънчев" , 2010.

[3] Ненов П., Е. Ангелова, и др., Генериране на математичен модел за изследване характеристиките на шарнир на Хук, Сборник доклади НК ЕМ'12, Русе, 2012, 49-52

[4] Писарев А. Динамика на машини с карданни предавки. София, Техника, 1974.

[5] Ронкова В. Проектиране на карданови съединители, насочено към минимизиране на габаритните им размери. сп. Българско списание за инженерно проектиране, 2013, брой 19, стр. 79-86, ISSN 1313-7530.

[6] Nenov P., Ronkova V., Angelova E., Trifonov T., Almanac of Information Materials, 3D Images, Animations and Other Visualizations As An Aid in Studying Machine Elements. IN: IRMES 2011, The 7th International Scientific Conference, Research and Development of Mechanical Elements and Systems, Zlatibor, Serbia, 2011, pp. 119-126.

[7] Živković K., Ivanović L., Stojanović B., The effect geometry on the stress distribution of cross shaft. IRMES 2011, The 7th International Scientific Conference, Research and Development of Mechanical Elements and Systems, Zlatibor, Serbia, 2011.

ИЗСЛЕДВАНЕ НА ЕЛЕКТРОЗАДВИЖВАНИЯ ЗА ШПИНДЕЛА НА КЛАС МЕТАЛОРЕЖЕЩИ МАШИНИ

STUDY OF ELECTRIC DRIVES FOR THE SPINDLE OF A CLASS OF MACHINE TOOLS

ИССЛЕДОВАНИЕ ЭЛЕКТРОПРИВОДОВ ДЛЯ ШПИНДЕЛЯ ОДНОГО КЛАССА МЕТАЛЛОРЕЖУЩИХ СТАНКОВ

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Abstract: *This paper examines the features of spindle electric drives for a class of milling machines with digital program control. The requirements that should be met with these electric drives are formulated. Practical settings of the represented DC and AC electric drives have been carried out. Experimental studies have been conducted showing that the selected AC drive with vector control satisfies the necessary requirements. The research held and the results obtained can be used in the development of such electric drives for the studied class of machine tools.*

KEYWORDS: *MILLING MACHINES, SPINDLE ELECTRIC DRIVE, DUAL-ZONE SPEED CONTROL*

1. Въведение

Съвременните металорежещи машини с цифрово-програмно управление (ЦПУ) поставят високи изисквания към системите за задвижване. Ролята на електрозадвижванията нараства все повече и понастоящем те влияят дори на конструкциите на самите задвижвани механизми и машини [1], [2], [3], [4].

В металорежещите машини електрозадвижването на шпиндела участва в процеса на механичната обработка, влияейки съществено върху качеството на детайлите и производителността. Основните изисквания, които се поставят към това електрозадвижване, може да бъдат формулирани по следния начин:

- двузонно регулиране на скоростта (съответно при постоянен момент и при постоянна мощност);
- висока максимална скорост;
- реверсиране по скорост;
- ориентирано спиране с висока точност.

При разработването на електрозадвижвания за шпиндела е необходимо да бъдат отчетени редица съществени фактори, такива като: особеностите на технологичния процес, вида на обработваните материали, параметрите на използваните инструменти и избраните механични предавки.

Изборът на подходящо електрозадвижване за главното движение преминава през следните няколко етапа:

- разработване на методика на базата на изискванията;
- провеждане на съответните изчислителни процедури;
- технико-икономически анализ на възможните варианти;
- синтез на системата за управление;
- анализ чрез моделиране и компютърно симулиране;
- провеждане на експериментални изследвания в съответните режими на работа и оценка на показателите.

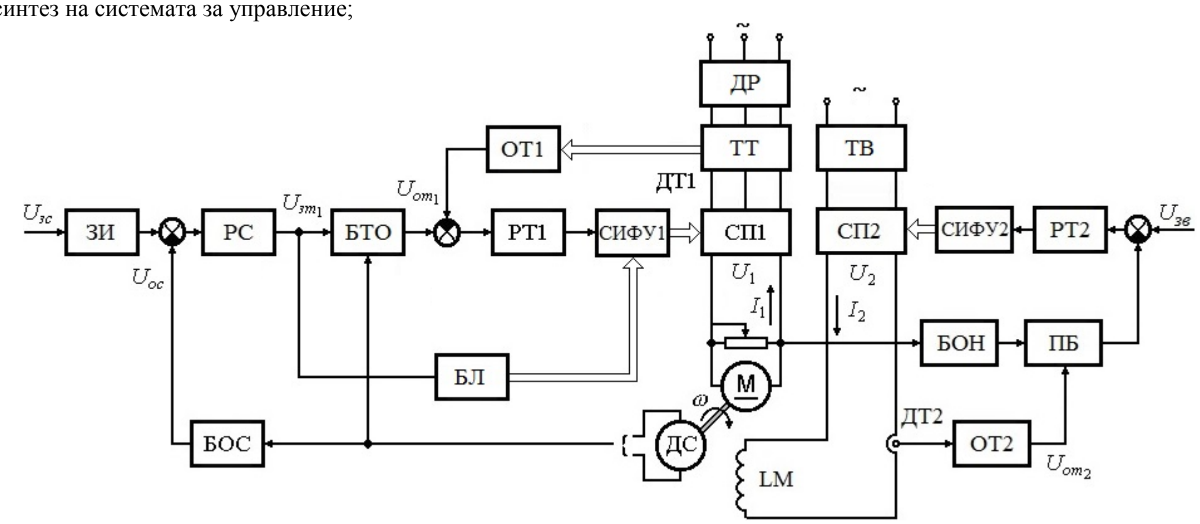
Методика за избор на електрозадвижвания за шпиндела, приложима както за постояннотокови, така и за променливотокови системи е описана в [6].

Математическото моделиране и компютърното симулиране предлагат ефективни начини за изследване на системите за задвижване при различни динамични и статични режими на работа, особено когато не е възможно или е неудобно да се извършват такива тестове в лабораторни или промишлени условия. Резултати от изследване посредством компютърно симулиране на адаптивна система за двузонно регулиране на скоростта са отразени и анализирани в [5]. Модел на електрозадвижване, обслужващо шпиндела на фрезови машини е представен в [7].

В тази статия са представени резултати от изследвания на двузонни електрозадвижвания с двигатели за постоянен и променлив ток, предназначени за шпиндела на един вид фрезови машини с ЦПУ. Направен е и сравнителен анализ по основни показатели.

2. Постояннотоково електрозадвижване

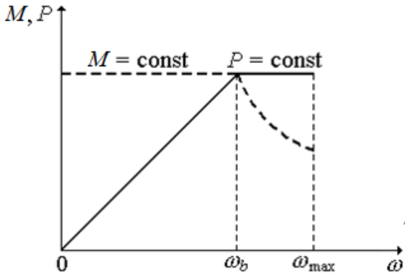
На фиг. 1 е представена блоковата схема на едно двузонно електрозадвижване за главното движение на разглеждания клас фрезови машини, реализирано с двигател за постоянен ток (ДПТ).



Фиг. 1. *Електрозадвижване на шпиндела с двигател за постоянен ток.*

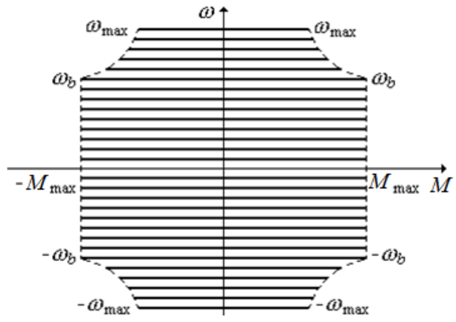
Използваните означения са следните: ЗИ – задатчик на интензивност; РС – регулатор на скорост; БТО – блок за токоограничение; РТ1 – регулатор на котвения ток; СИФУ1 – система за импулсно-фазово управление за силовия преобразувател на котвената верига; БОС – блок за обратна връзка по скорост; ОТ1 – блок за обратна връзка по котвения ток; БЛ – блок логика; ДР – дросел; ТТ – токов трансформатор; СП1 – силов преобразувател за котвената верига; ДТ1 – датчик на котвения ток; ТВ – трансформатор на възбудителната верига; РТ2 – регулатор на възбудителния ток; ОТ2 – блок за обратна връзка по възбудителния ток; СП2 – силов преобразувател за възбудителната верига; ДТ2 – датчик на възбудителния ток; ПБ – превключващ блок; LM – възбудителна верига на двигателя за постоянен ток М; БОН – блок за обратна връзка по котвено напрежение. Системата за управление включва две взаимосвързани подсистеми, като свързващият параметър е котвеното напрежение на двигателя:

На фиг. 2 са представени диаграмите, съответстващи на двете зони за регулиране на скоростта. С ω_b е означена базовата скорост, при която се превключват зоните. Обикновено се приема $\omega_b = \omega_{nom}$.



Фиг. 2. *Зони на регулиране с постоянен момент и постоянна мощност.*

Механичните характеристики на четириквадрантно двузонно електрозадвижване са представени на фиг. 3, където ω_{max} е горната граница на диапазона на регулиране, а M_{max} е максималният момент на двигателя.

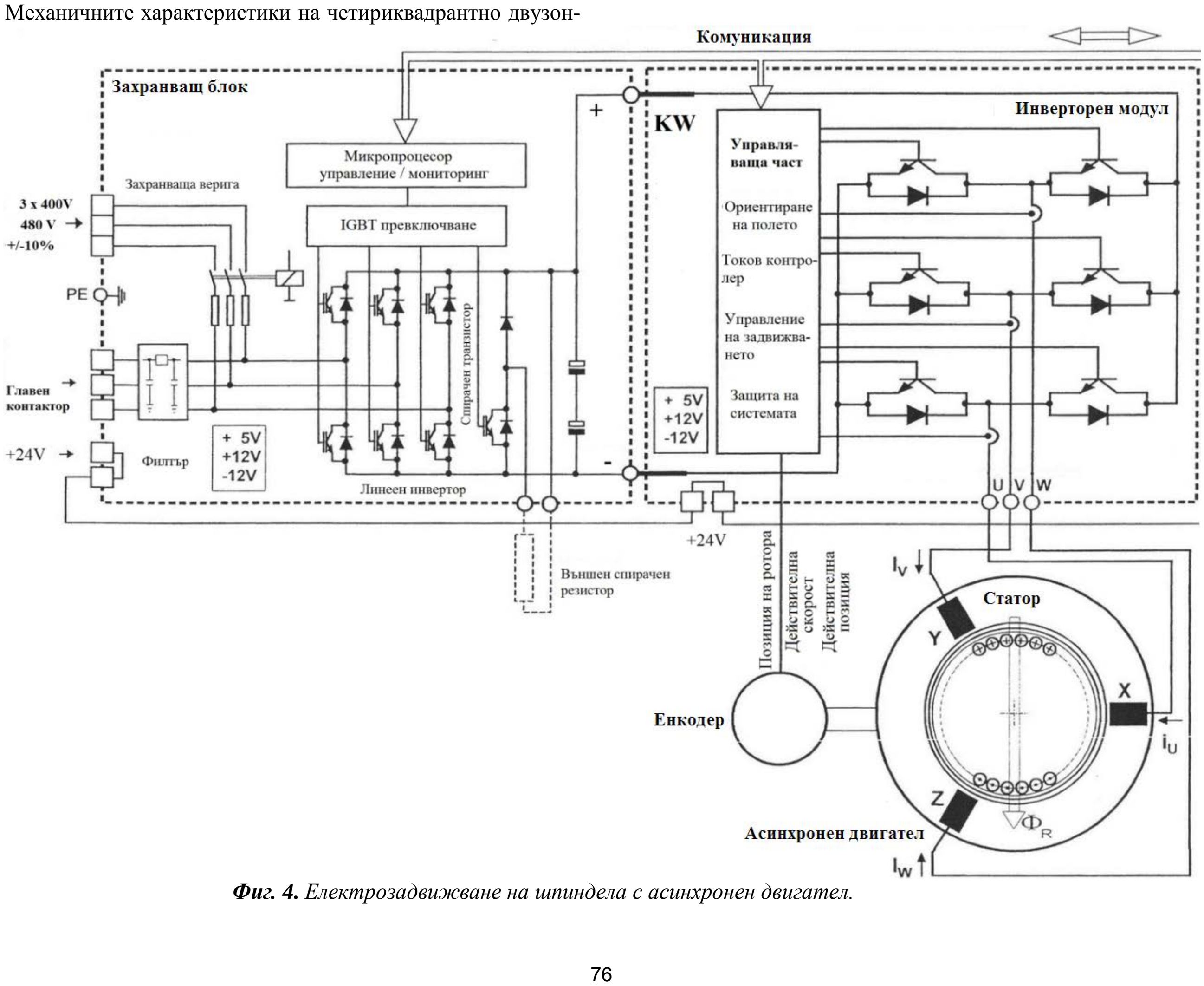


Фиг. 3. *Механични характеристики при двузонно задвижване.*

Електрозадвижванията с двигатели за постоянен ток притежават много добри регулировъчни качества, но същевременно имат и редица съществени недостатъци, свързани с наличието на колекторно-четков апарат. По тази причина напоследък постояннотоковите електрозадвижвания се заменят с променливотокови, на базата на асинхронни двигатели (АД) с векторно управление. При такова управление може да се използват аналогични структури с подчинено регулиране на координатите, както при постояннотоковите системи.

3. Променливотоково електрозадвижване

На базата на формулираните изисквания, с отчитане на необходимостта от двузонно регулиране на скоростта, посредством осъществените изчислителни процедури по разработената методика [5], е избрана и внедрена променливотокова система за електрозадвижване на шпиндела.

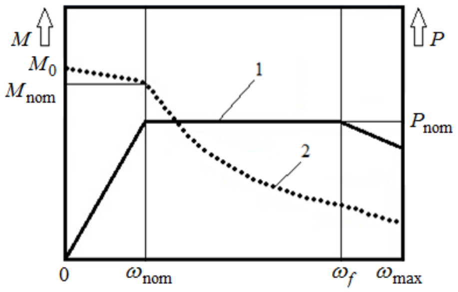


Фиг. 4. *Електрозадвижване на шпиндела с асинхронен двигател.*

Функционалната схема на изследваното променливотоково електрозадвижване с асинхронен двигател [8], [9] е дадена на фиг. 4.

Поради използваните значително по-мощни двигатели за главното задвижване в сравнение с подавателното, в случая е избрана система с управляем изправител, при която има възможност за връщане на енергия в захранващата променливотокова мрежа.

Управлението е изцяло цифрово и се осъществява със задаване на необходимите параметри от база данни. Указват се типа на използваните двигател и съответен преобразувател, входни/изходни компоненти и на тази база се извършва необходимата настройка за конкретната система.



Фиг. 5. *Характеристики на електрозадвижването с АД.*

На фиг. 5 са представени съответните характеристики на това електрозадвижване, където използваните означения са следните: 1 – крива на мощността; 2 – крива на въртящия момент; ω_f - ограничение на скоростта при постоянна номинална мощност.

4. Експериментални изследвания и анализ

За осъществяване на необходимите експериментални изследвания е разработен стенд за настройка и изследване на електрозадвижванията.

Провеждане на експериментално изследване и настройка на едно електрозадвижване за шпиндела на разглежданите металорежещи машини е илюстрирано на фиг. 6.

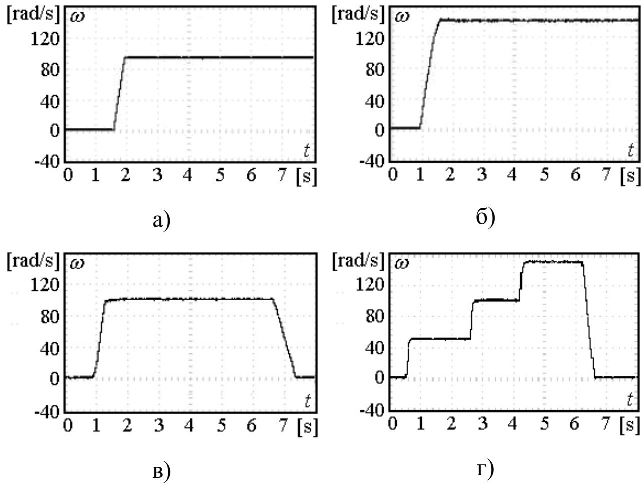
Фиг. 6. *Настройка на електрозадвижване за шпиндела.*

На фиг. 7 са представени някои осцилограми $\omega(t)$ от изследването на двузонно постояннотоково електрозадвижване, получени експериментално при различни настройки на регулиращите контури.

Траекторията, показана на фиг. 7*а* е снета при работа под основната скорост на въртене на шпиндела. Зададената скорост е $\omega_з = 100$ rad/s и се намира в първата зона.

На фиг. 7*б* е представена траектория при зададена скорост $\omega_з = 140$ rad/s, което в този случай отговаря на работа във втората зона.

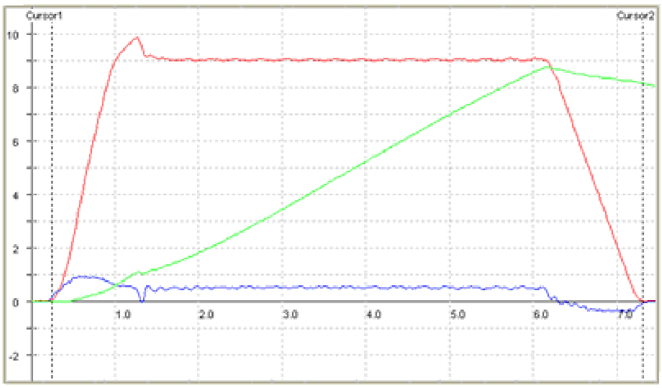
На фиг. 7*в* е дадена траектория, включваща ускоряване, въртене със зададената скорост $\omega_з = 100$ rad/s и плавно ориентирано спиране.



Фиг. 7. *Осцилограми на електрозадвижване с ДПТ.*

На фиг. 7*г* е представена осцилограма на траектория $\omega(t)$, включваща три зададени скорости на въртене: $\omega_{з_1} = 52$ rad/s, $\omega_{з_2} = 90$ rad/s, $\omega_{з_1} = 150$ rad/s и следващо бързо спиране.

На фиг. 8 са представени осцилограми, получени експериментално при изследване на променливотокова система за електрозадвижване на шпиндела. За снемането на съответните характеристики е използван програмният продукт AIPEX PRO, който е специализиран и дава възможност за подробни изследвания, с високо качество на резултатите.



Фиг. 8. *Осцилограми на електрозадвижване с АД.*

По абсцисната ос е представено времето за извършване на изследванията в секунди, а по ординатната – съответните сигнали, като скалата е във волтове. С червена линия е илюстрирана скоростта на въртене, със синя – момента, а със зелена – натоварването на инвертора. При това изследване зададената скорост е 53.41 rad/s.

Избраният променливотоков двигател е от серията DH на фирмата AMK с вграден енкодер за обратна връзка [8]. Това са високо-динамични трифазни двигатели, които са особено подходящи за главни електрозадвижвания на металорежещи машини. Предимствата на използвания асинхронен двигател са следните:

- висока претоварваща способност;
- възможности за скоростно, позиционно и синхронизирано управление;

- вграден вентилатор за охлаждане.

Направеният сравнителен анализ показва, че съответните динамични и статични показатели на изследваното променливотоково електрозадвижване са високи и напълно съизмерими с тези на постояннотоковото електрозадвижване. Същевременно трябва да се отбележи значително по-лесната експлоатационна поддръжка на това електрозадвижване, поради липсата на колекторно-четков апарат. Като недостатък, на този етап може да се посочи неговата по-висока цена.

Част от резултатите от направено проучване на различни фирми производители на електрозадвижвания за главното движение [8], [9], [10], са представени в табл. 1.

Табл. 1. *Някои резултати от направеното проучване.*

КОМПЛЕКТ ДПТ И ПРЕОБРАЗУВАТЕЛ		
Модел	**Параметри**	**Цена (€)**
MP 112L/5EOA	7.5 kW, 104.67 rad/s	1382
MP 132M/8EOA	11 kW, 104.67 rad/s	1650
MP 132L/12EOA	15 kW, 104.67 rad/s	1820
КОМПЛЕКТ АД И ПРЕОБРАЗУВАТЕЛ		
Модел	**Параметри**	**Цена (€)**
DH 10-40/KW 8	6.3 kW, 157 rad/s	2342
DH 10-55/KW 10	10 kW, 188.4 rad/s	2856
DH 13-100/KW 20	15 kW, 157 rad/s	3839

Както се вижда, цената на променливотоковия двигател с включения съответен преобразувател, се увеличава значително с нарастването на мощността на двигателя. Въпреки това, съществува устойчива тенденция към постепенна замяна на постояннотоковите електрозадвижвания с променливотокови, на базата на асинхронни и синхронни двигатели с векторно управление.

5. Заключение

Формулирани са изискванията към електрозадвижването на шпиндела на един вид фрезови машини с цифрово-програмно управление.

Извършена е практическа настройка на използваните електрозадвижвания за постоянен и променлив ток. Направен е сравнителен по основни показатели.

Проведени са експериментални изследвания, показващи, че представеното променливотоково асинхронно електрозадвижване с векторно управление напълно удовлетворява поставените изисквания.

Проведените изследвания и получените резултати от тях може да се използват при избор на електрозадвижвания за главното движение на разглеждания клас металообработващи машини.

Литература

[1] Altintas Y., A. Verl, C. Brecher, L. Uriarte, G. Pritschow, Machine Tool Feed Drives, *CIRP Annals - Manufacturing Technology*, Vol. 60, No. 2, pp. 779 -796, 2011, ISSN: 0007-8506.

[2] Moriwaki T., Trends in Recent Machine Tool Technologies, *NTN Technical Review*, No. 74, pp. 2-7, 2006, ISSN 0915-0528.

[3] Crowder R., *Electric Drives and Electromechanical Systems*, Elsevir, Oxfort, 2006, ISBN 978-0-7506-674091.

[4] Soshi M., S. Yu, S. Ishii, K. Yamazaki, Development of a High Torque–High Power Spindle System Equipped with a Synchronous Motor for High Performance Cutting, *CIRP Annals - Manufacturing Technology*, Vol. 60, No. 1, pp. 399-402, 2011, ISSN: 0007-8506.

[5] Mikhov M., M. Zhilevski, A. Spiridonov, Modeling and Performance Analysis of a Spindle Electric Drive with Adaptive Speed Control, *Journal Proceedings in Manufacturing Systems*, Vol. 7, No. 3, pp. 153-158, 2012, ISSN 2067-9238.

[6] Mikhov, M., M. Zhilevski, Methodology for Selection of Spindle Drives for Milling Machines, *International Journal of Engineering and Computer Science*, Vol. 3, No. 5, pp. 5948-5953, 2014, ISSN 2319-7242.

[7] Жилевски М, М. Михов, Подавателно електрозадвижване за шпиндела на фрезови машини, *Научни известия на НТС по машиностроене*, т. 23, № 6, 50-53, София, 2015, ISSN 1310-3946.

[8] AMKASYN, AC-Servo- and Main Spindle Motors, *AMK Catalogue*, 2014.

[9] AMKASYN, Servo Drives KE/KW, *AMK Catalogue*, 2014.

[10] SERVOMOTORS, *GAMA MOTORS Catalogue*, 2014.

THE DEPENDENCE OF THE PHYSICAL AND MECHANICAL PROPERTIES OF TOOL STEEL ALLOYS FROM THE TYPE OF MACHINING

ЗАВИСИМОСТЬ ФИЗИКО-МЕХАНИЧЕСКОГО СОСТОЯНИЯ ИНСТРУМЕНТАЛЬНЫХ ЛЕГИРОВАННЫХ СТАЛЕЙ ОТ ВИДА МЕХАНИЧЕСКОЙ ОБРАБОТКИ

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The results of studies of the influence of the type of machining and tool material to the structural state of the surface layer and the fatigue strength of ХВСГsteel during machining are shown. Processing with the composite-10 tool in a surface layer for α - and γ - phases is accompanied only by compressing residual pressure while abrasive processing promotes occurrence of stretching pressure of an I-type. Increasing of cutting speed of the composite-10 tool from 50 to 200 m/min does not lead to significant changes in fatigue strength.

KEYWORDS: CUTTING, TOOL STEEL, GRINDING, TURNING, AUSTENITE, MARTENSITE, MICROHARDNESS, RESIDUAL STRESSES, FATIGUE STRENGTH

Introduction.. The impact of high temperatures and pressures in the cutting zone has a decisive influence on the formation of surface layers in the machining tool alloy steel. Structural changes occurring during this process depend on the value of the factors above, as well as the chemical composition and structure of the original material. Unlike conventional heat treatment, this changes happens in the course of plastic deformation caused by high contact pressure, speed of heating and cooling the surface layers of metal [1].

In the case of the machining of high-strength structural steels two zones of the structural state are formed in the surface layers: directly at the surface - area of secondary hardening and the surrounding area, corresponding to the structure of the quick high-temperature release. Depth of zones of structural changes in the surface layers of the steel at various machining types is determined by various combinations of temperature and pressure contact pairs [2, 3]. Machining of tool alloy steel with cutter has little effect on the strength and ductility of both soft and hardened steels, but has a significant influence on their resistance to cyclic stresses [4]. This is explained by the development of fatigue failure, usually from the surface and in a small volume; while every local weakening of the material causes a shift with tears and thus fatigue cracks later [5].

The grinding of tool steel alloys usually leads to a decrease in fatigue resistance, which is conditioned by the occurrence of tensile residual stress during processing [6]. The rough turning also reduces the fatigue resistance of structural and tool steels because of worst microgeometry of the surface. However, different types of turning have different effects on endurance, and more rougher the machining, the lower endurance will be in the details made of structural steel [7]. Therefore, fine turning with small feeds provides a surface with good microgeometry, a smaller number of defects (gaps, cracks, torns) and reinforcing effect. The most significant effect of turning on endurance of alloy steels have the rate of feed, the radius of the rounding of the cutting edge, the rake angle and the cutting speed [8]. The changing the depth of cut has little influence on the fatigue resistance of steels, since the microgeometry of the machined surface has no significant dependence of this parameter; and some increase in work hardening by increasing the depth of cut is offset by the growth of residual tensile stresses [9].

Usage of superhard cutting materials based on wurtzite boron nitride –composite-10, which has a high thermal conductivity, contributes to shift of the level of residual stresses and, consequently, improves the strength properties of the material [10, 11]. However, the question of using nitride ceramics in the processing of tool alloy steel by turning and grinding isn't studied enough.

Objective. Study the effect of the type of tool material and machining conditions on the strength characteristics and structural condition of the surface layers of tool steel alloy 107WCR5.

Study methodology. To study the effect of the type of tool material on the structural state of the surface layers of the studied steel 107WCR5 obtained by grinding abrasive wheels and turning cutters of composite-10. Technological process of manufacturing the samples consists of cutting round bars for workpiece, pre-turning, semifinished and finish machining. To study the effect of the grinding process of steel 107WCR5, hardness HRC 54 ... 56 samples were prepared in the form of cylinders of 10 mm height and 50 mm in diameter, and effects of turning - 250 mm long, which were hardened at a temperature of 850 ^{0}C (with cooling in oil) and tempered at a temperature of 200 ^{0}C in air.

Grinding was carried out on cylindrical grinding machines 3Б12 with abrasive wheel: 1А1 250x16x76 63С 6 СМ1К and wheel 1А1 250x16x5x76 ГА 125/100 100% БСТ from composite-10.

Turning was performed on a turning machine 16К20 with cutters of composite-10 and different processing rates - the cutting speed V = 20, 40, 80, 160 and 250 m/min, feed s = 0,07 mm/rev and depth of cut t = 0,25 mm. X-ray studies were conducted by stratified analysis on a diffractometer ДРОН-3 in Fe K α-radiation. The amount of residual austenite (fγ) in the samples was determined from measurements of the integrated intensity of X-ray lines (110) and (111) α and γ-phases in view of repeatability factor:

$$f_\gamma = \frac{S_\gamma}{0{,}66 \cdot S_\alpha + S_\gamma} \cdot 100\% \qquad (1)$$

where S_α; S_γ – the integrated intensity of X-ray lines α and γ-phases, respectively. The numerical values of $S\alpha$ and $S\gamma$ are determined by computation of respective lines. I-type stresses in the surface layers were evaluated by X-ray diffraction as the sum of the principal stresses (σ1 + σ2) by the formula:

$$\sigma_1 + \sigma_2 = \frac{E}{\mu} \cdot ctg\Theta \cdot \Delta\Theta \qquad (2)$$

where E - modulus of elasticity; μ - Poisson's ratio; $\Delta\Theta = \Theta - \Theta_0$ - angle difference, K_α - components of α and γ phases after machining (Θ) and the original (Θ_0).Research of microhardness of the surface layers of samples was performed on microhardness tester ПМТ-3 with a load of 0.2 N and 0.5 N.

Fatigue test of samples were performed as a cantilever bend with rotation. The frequency of load changes was – 15.0 Hz, the test base – 10 million cycles. For curve fatigue plotting at least 15 samples were tested, machined according to the regimen. The resulting calculation of averages $\bar{\sigma}$, $\lg \bar{N}_p$, mean-squared departure of σ_i and $\lg N_{p_i}$ the correlation coefficient and others are the initial data to correlation equation - fatigue curve equation:

$$\lg N_p = A + M\sigma \quad (3)$$

where N_p - the average number of cycles to failure of the sample with stress σ; A, M - factors.

Evaluation. Studies of microhardness depending on the depth of the layer during grinding with abrasive wheel and turning with cutters of composite-10 showed that the depth of the zone of the secondary quenching decreases with increasing thermal conductivity of the tool material processing. In this case area of high-temperature tempering have a depth of 30-650 microns for grinding wheel, , and 8-12 mm in the case of turning cutters of composite-10. Thus, when the temperature drop in the processing zone, the depth of the damaged layer is reduced and becomes a minimum for the surface processed with turning by cutter of composite-10.

The results of measurements of residual austenite after grinding by abrasive wheels and after turning by cutter of composite-10 shown in Table 1. As seen from Tables depth of austenite impaired concentration is by several times less than the depth of impaired microhardness and when processing with abrasive wheel is equal to 120 microns by cutter of composite-10– 80 microns. Noticeable changes in the concentration of retained austenite during the turning by cutters of composite-10 occur in the range of V = 20-80 m/min. It can be associated with the process of adhesion of the processed material on the cutter as described in [5, 7].

The structural state of the surface layer of the studied steel during turning with cutter composite-10 (Fig. 1, a-d) is characterized by compressive stress area during α- and γ-phases, maximal at the sample's surface. The subsequent behavior of the stresses in depth for the α- and γ -phase varies and depends on the cutting speed. To investigate the rate of the minimum in γ-phase is reduced to zero at a depth of 60 micron. A characteristic feature of the process of grinding with abrasive wheel is the occurrence of tensile stresses of I-type during α-phase of structure of the high-speed release (Fig. 1, h). Their maximum value according to (σ1 + σ2) is achieved at a depth of 30-50 micron below the surface. During γ-phase small compressive stress takes place, extending to a depth of 40 micron.

Table 1 *The amount of residual austenite, f_γ% in 107WCR5 steel after grinding by abrasive wheels and after turning by cutters of composite-10*

№	Type of processing	Depth, (mm)						
		10	20	30	40	80	120	160
		f_γ, %						
1	Grinding by abrasive wheel	23	27	28	28	29	30	30
2	Turning by cutters of composite-10, 20 m/min	25	28	30	31	31	31	31
3	Turning by cutters of composite-10, 40 m/min	25	27	29	30	35	36	38
4	Turning by cutters of composite-10, 80 m/min	31	32	33	33	36	37	37
5	Turning by cutters of composite-10, 160 m/min	36	37	38	39	41	41	41
6	Turning by cutters of composite-10, 250 m/min	31	31	31	32	32	33	34

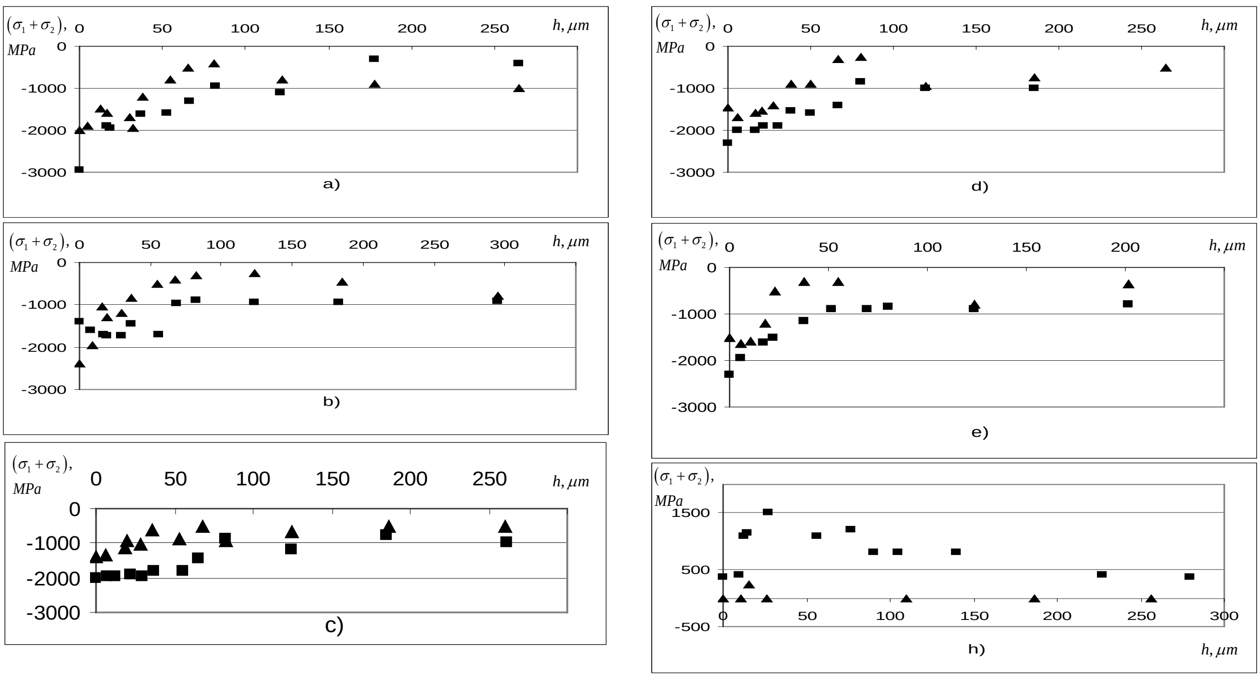

Fig. 1 *- Distribution of residual stresses of the first kind in depth of the surface layer at V = 20 (a); 80 (b); 160 (c); and 250 m/min (d), grinding with abrasive wheel (h), (■ –γ-phase, ▲– α-phase)*

For the fatigue test four batches of samples were made. First – machined by grinding wheel according to the following routine: RPM range - 2800 rotations/min, number of revolutions of the sample - 400 rev/min; second, third and fourth - composite-10 at a cutting speed *V* = 50, 100 and 200 m/min. respectively; depth of cut and delivery rate for the last three parties remained constant and equal to t = 0,25 mm S = 0,07 mm/rev. The results of fatigue testing of the above 107WCR5 steel batches of samples are presented in Fig. 2.

Data for stress-cycle diagram, correlation coefficients and limited fatigue strength are shown in Table 2. The analysis of the test results shows that, on the basis of approved testing, fatigue resistance of the material is characterized by a sloped fragment of a diagram – beginning of stress-cycle diagram is shifted towards longevity. The stress-cycle diagram of the fourth installment sample (200 m/min.) is located below the 2nd and 3rd parties curves and the limited endurance limit is 10% lower than for the 2nd batch.

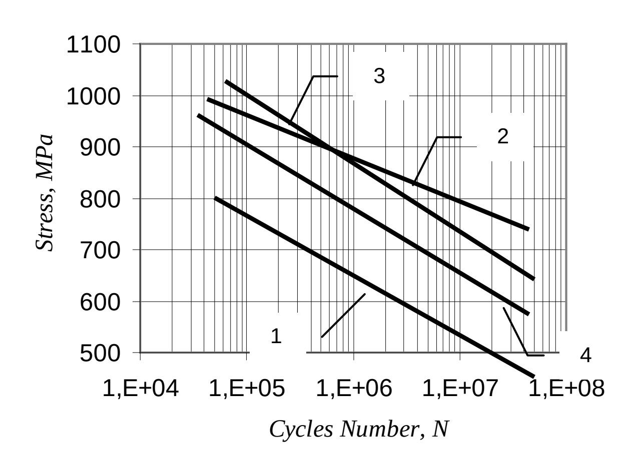

Fig. 2. *- Stress-cycle diagram of 107WCR5 steel samples: grinding with abrasive wheel - (1); turning with cutter of composite-10 at a speed V = 50 (2), 100 (3) and 200 (4), m/min.*

Table 2. *The results of fatigue tests of 107WCR5 steel samples in a cantilever bending*

№	Type of processing	Correlation coefficients		Limited fatigue strength σ_{-1}, MPa
		A	*M*	
1	Grinding by abrasive wheel	12,09	-0,0089	660
2	Turning by cutters of composite-10 R, 50 m/min	16,07	-0,01126	827
3	Turning by cutters of composite-10, 1000 m/min	12,76	-0,00776	770
4	Turning by cutters of composite-10, 200 m/min	12,27	-0,00775	735

Endurance of grinded test samples is significantly lower than endurance of samples turned with cutter of composite-10. Narrow endurance limit for the first batch (560 MPa) is by 32% lower than for the 2nd batch. This is due to the fact that in the process of cutting with composite-10 fast tempering in the surface layers of steel goes under stress, this causes compressive residual stress of the 1st type in α- and γ-phase, slowing the decay of residual austenite. The combination of evenly spaced brittle and ductile structural components in the surface layer enhances endurance of 107WCR5 steel. While grinding with abrasive wheel is causing tensile stresses of the 1st kind in the γ-phase, partially decomposes retained austenite and increases the degree of its hardening.

Conclusion. Thus, studies of the process of grinding with abrasive wheels and turning with cutters of composite-10 a tool steel alloy 107WCR5 showed the following:

- the increase of thermal conductivity of the tool material is narrowing the area of the structural changes occurred in the surface layer of the processed material, it is minimal for turning with cutters of composite-10;
- the amount of residual austenite in the process of turning with cutter of composite-10 is lowest within the limits of cutting speed 40-80 m/min;
- the joint effect of pressure and temperature in high-speed cutting reduces the degree of strain hardening γ- phase in the surface layer;
- machining by composite-10 tool for α- and γ-phases in the surface layer is only accompanied by compressive residual stresses, while grinding with abrasive wheels contributes to the tensile I-type stress in α-phase structure of tempering speed;
- turning by cutters of composite-10 increases on 30% the endurance limit, compared with the grinding by abrasive wheels, wherein the increasing of cutting speed from 50 to 200 m/min does not cause the substantial change of resistance to fatigue.

Literature

1. Ящерицин П. И. Теория резания. Физические и тепловые процессы в технологических системах / П.И. Ящерицын, М.Л. Еременко, Е.Э. Фельдштейн. Минск.: Вышейшаяшкола, 1990, 512 с.
2. Nizhnik S.B. Formation of secondary structures in steels at high pulsed temperature and pressureRussian metallurgy // Metally. 2006. T. 2006. № 4. С. 314-322.
3. Нижник С.Б. К вопросу формирования вторичных структур в сталях при импульсном действии высоких температур и давлений // Металлы. 2006. № 4. С. 42-53.
4. Обработка инструментом сталей резцами из Гексанита-Р / Г.Г. Карюк, М.С. Пивоваров, В.П. Барабан и др. // Гексанит и Гексанит-Р и изделия на их основе инструментального назначения.– Киев.ин-т пробл. материал. АН УССР, 1975.– С. 14-17.
5. Постнов, В. В. Процессы на контактных поверхностях, износ режущего инструмента и свойства обработанной поверхности / В. В. Постнов, Б. У. Шарипов, Л. Ш. Шустер. Свердловск: Изд-во Уральского ун-та, 1988.-224 с.
6. Кагаев В.П., Дроздов Ю.Н. Прочность и износостойкость деталей машин.- М: Высшая школа, 1991, 320 с
7. Суслов, А. Г. Качество поверхностного слоя деталей машин Текст. / А. Г. Суслов. М.: Машиностроение, 2000.– 318 с
8. Сулима, А. М. Поверхностный слой и эксплуатационные свойства деталей машин / А. М. Сулима, В. А. Шулов, Ю. П. Ягодкин. М.: Машиностроение, 1988. - 238 с.
9. Терентьев В.Ф. Усталость металлических материалов, Изд-во: Наука, 2003, 257 с.
10. Приймачук В.Л., Божко А.В. Овенесян А.О. Теплофизические свойства разных модификаций нитрида бора // Порошковая металлургия.–1983.–№ 8.– . 80-82.
11. Волкогон В.М., Котляр Д.А., Аврамчук С.К., Кравчук А.В., Антонюк В.С. ВпливпопередньоїпідготовкипорошківBNв до спікання на основні характеристики процесуобробкисталі ШХ15 в режимібезперервногорізання // Високітехнології в машинобудуванні: Зб. науковыхпраць.- Харків НТУ «ХПІ», 2010- Вип. 1.- С. 35-44.

METHOD OF CUTTING OF THIN-WALLED PIPES ON THE DETAILS AND SEMI-FINISHED DETAILS

СПОСОБ РАЗРЕЗКИ ТОНКОСТЕННЫХ ТРУБ НА ДЕТАЛИ И ПОЛУФАБРИКАТЫ

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Abstract: *The main issues are considered in this topic: new structural diagram of the device for cutting the tubular billet with through shear and torsion; the geometric parameters and characteristics of the cut surface; analytical dependences for determining the shear force and torque cutting of thin-walled pipes on the details and semi-finished details; performed modelling physical process.*

KEYWORDS: *SHIFT, TORSION, WASTE-FREE CUTTING, HOLDER, CUTTING, PIPE BLANKS, THE STRESS-STRAIN STATE, KNIFE*

1. *Введение*

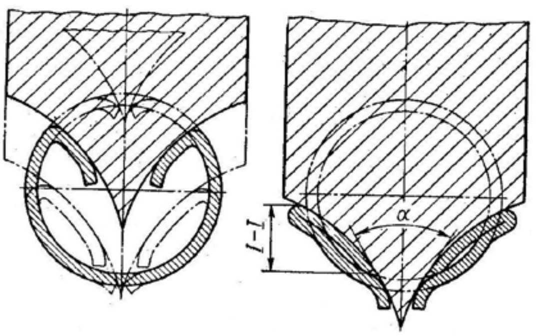
Известно много способов отрезки деталей или полуфабрикатов от тонкостенной трубчатой заготовки: механические на отрезных станках различными стальными или керамическими инструментами, отрезкой гидроабразивной струей, термическим разделением, в т.ч. излучением лазера [1, 2].

Наряду с преимуществами, каждому из упомянутых способов присущи определенные недостатки: потери металла на прорезной слой, энергоемкость, наличие зоны термического влияния, недостаточная производительность, что особенно проявляется в крупносерийном и массовом производстве (изготовление элементов втулочно-роликовых цепей, заготовок для холодного выдавливания осесимметричных деталей, защитных экранов от элекромагнитного и радиационного излучений).

Перспективной представляется резка в штампах чистым сдвигом на прессах.

При чистом сдвиге объем очага деформации минимальный (теоретически он ограничен плоскостью сдвига), а, следовательно, и минимальная энергоемкость процесса, отсутствуют потери на прорезной слой, простыми средствами механизации обеспечивается высокая производительность процесса.

Однако, при резке в штампах чистый сдвиг наблюдается только в начальной стадии процесса с образованием на поверхности среза участка с незначительной шероховатостью (<0.32μ). После чего сдвиг сопровождается изгибом, искривлением поверхности среза, что приводит в конечном итоге к разрушению сколом. В результате поверхность разделения имеет характерную сигмаобразную форму не перпендикулярную оси заготовки. Для исключения или минимизации влияния изгибающего момента при разделении профильных заготовок в штампах применяют резку с дифференцированным прижимом, с осевым сжатием, а для разрезки тонкостенных трубчатых заготовок (ТТЗ) - применяют специально спрофилированные пуансоны (Рис. 1.).



а б

Рис. 1. Разрезка ТТЗ профильным пуансоном:
а) - начальная стадия; б) - конечная стадия.

Однако отрезка в первых двух случаях сопровождается искажением профиля поперечного сечения, нанесением повреждений на поверхности, а в третьем случае низкой стойкостью пуансона.

2. *Постановка задачи и решение проблемы*

Альтернативным методом, лишенным отмеченных недостатков, может служить разрезка тонкостенных трубчатых заготовок (ТТЗ), заключенных в двух парах оправок [3, 4]. Зазор между наружными и внутренними оправками равен толщине стенки ТТЗ с учетом допуска на толщину и соосность внутреннего и наружного контура поперечного сечения.

Оправки шлифованными торцами прижаты в процессе разделения в плоскости среза, чем исключается изгиб отрезаемой части заготовки. Конструкция экспериментального устройства для исследования процесса разрезки ТТЗ показана на Рис. 2.

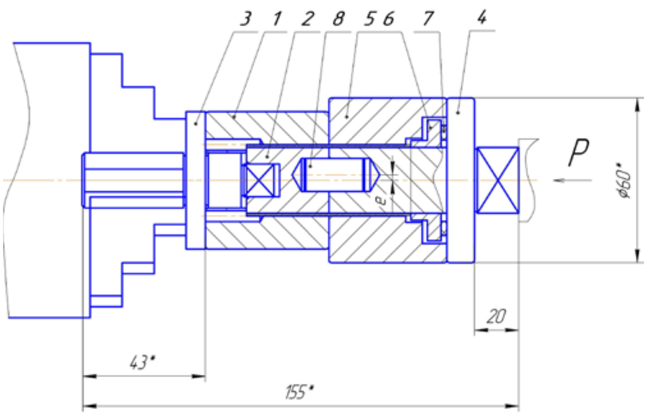


Рис. 2. Конструктивная схема экспериментального устройства для исследования разрезки ТТЗ в оправках.
1, 2 - наружная и внутренняя оправки, вращающиеся вокруг фиксированной оси; 3, 4 - опорные кольца; 5, 6 - наружная и внутренняя оправки, совершающие плоскопараллельное движение; 7 - упор; 8 – палец (эксцентрик).

Как видно из рисунка, внутренние оправки 2 и 6 соединены пальцем 8, ось которого эксцентрична оси вращения левой пары оправок 1 и 2. Процесс разделения ТТЗ в оправках происходит следующим образом: при вращении оправок 1 и 2 вокруг фиксированной оси, являющейся осью симметрии ТТЗ, оправки 5 и 6 с отделяемой деталью смещаются параллельно плоскости среза [5]. Существенно, что направление смещения (сдвига) непрерывно изменяется в процессе вращения оправок 1, 2, что предотвращает накопление микротрещин и разрушение сколом при фиксированных линиях скольжения, характерных в случае неизмененного направления сдвига.

Изменение направления показывает годограф максимального смещения (Рис. 3).

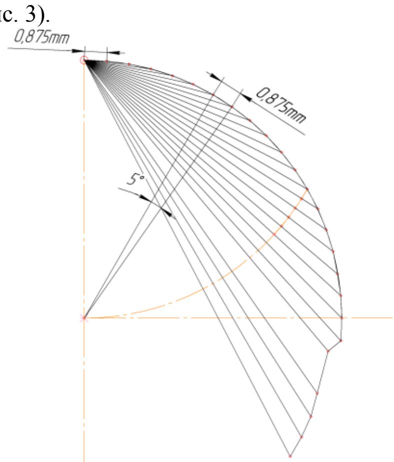


Рис. 3. Годограф максимального смещения оправок 5, 6 в зависимости от угла поворота оправок 1, 2.

В результате смещения оправок 5, 6 на заготовке образуются два серповидных надреза, форма и размеры которых зависят от угла поворота (Рис.4): с наружной стороны образуется надрез A_1M $A^1{}_1$K A_1 с внутренней - B_1L_1 $B^1{}_1K_1$ B_1.

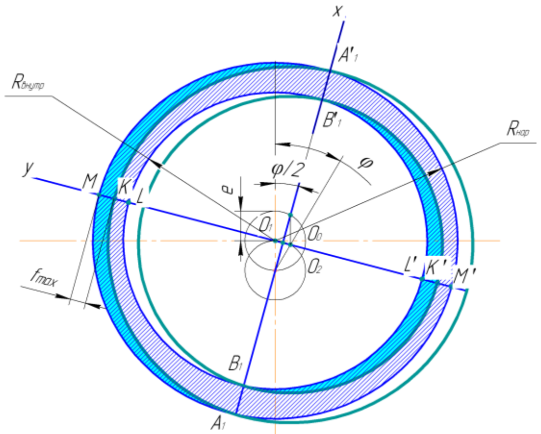


Рис. 4. Начальная стадия разделения ТТЗ в оправках при угле поворота эксцентрика φ<45^0

С увеличением угла поворота площадь срезанных участков возрастает, в точках L, L^I стенка заготовки прорезается, а участки непрорезанной стенки уменьшаются (Рис. 4.)

В конечный момент участки смыкаются, и происходит разделение заготовки. При смыкании происходит скол [6].

С увеличением угла поворота площадь срезанных участков возрастает, в точках L, L^I стенка заготовки прорезается, а участки непрорезанной стенки уменьшаются (Рис. 5.)

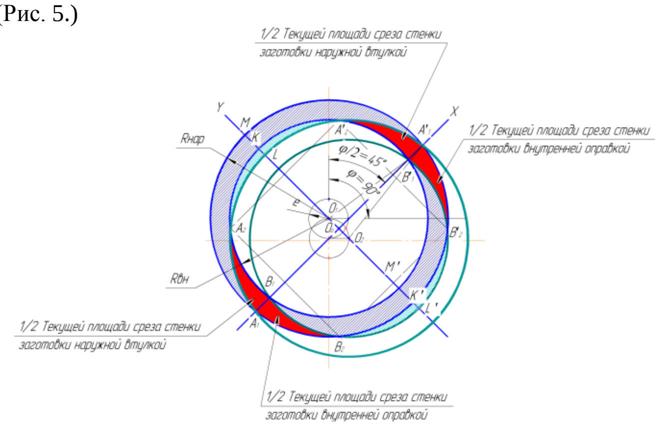


Рис. 5. Непрорезанные участки стенки ТТЗ при угле поворота φ=45^0

В конечный момент участки смыкаются, и происходит разделение заготовки. При смыкании происходит скол и на поверхности среза образуется «вырыв» (Рис.6). Избежать нежелательного скола можно при условии реверса смещения оправок 5 и 6 при неизменном направлении вращения оправок 1 и 2. Для этого используем свойство кинематики движения кривошипа, роль которого в нашем случае выполняет эксцентрик 8. Например, если ось эксцентрика в исходный момент будет находиться выше горизонтального диаметра оправок, то при вращении оправок 1, 2 по часовой стрелке она будет смещаться вправо и вниз, как показано на Рис. 7 и Рис. 8.

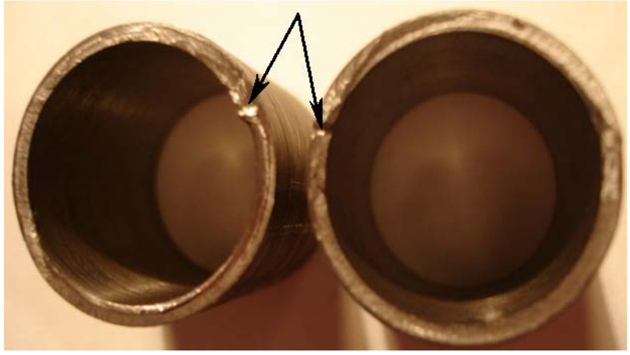


Рис. 6. Вид поверхности среза в месте смыкания надрезов без изменения направления смещения оправок 5, 6 в заключительной стадии разделения ТТЗ.

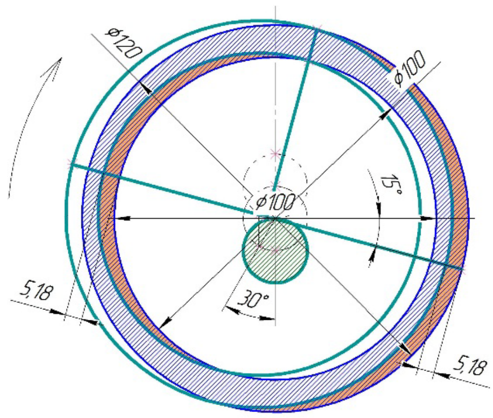


Рис. 7. Направление смещения оправок 5, 6 в зависимости от исходного положения оси эксцентрика и вращения оправки 1 по часовой стрелке.

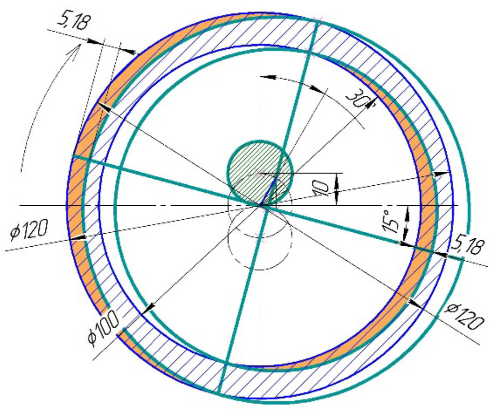


Рис. 8. Направление смещения оправок 5, 6 в зависимости от исходного положения оси эксцентрика и вращения оправки 2 по часовой стрелке.

Для реверса смещения оправок 5, 6 внутренние оправки 2 и 6 соединены коленчатым пальцем. Оси каждого из колен расположены эксцентрично относительно оси вращения оправок 1 и 2, и находятся по разные стороны диаметра перпендикулярно прямой, соединяющей оси указанных колен (Рис. 9.)

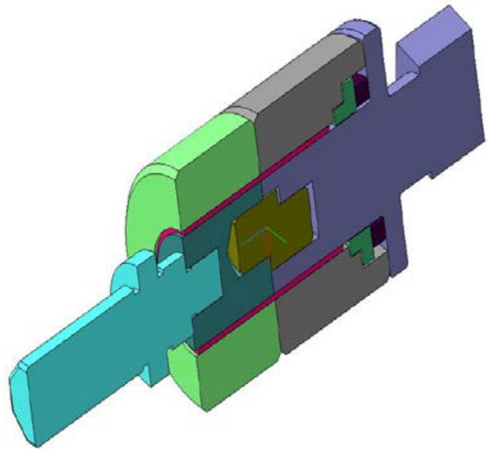


Рис. 9. 3D-модель экспериментального устройства для разделения ТТЗ в оправках, две из которых (внутренние) соединены коленчатой осью [7].

При реверсе смещения оправок на заключительной стадии разделения ТТЗ скол не происходит, а на поверхности среза «вырывы» отсутствую. (Рис 10).

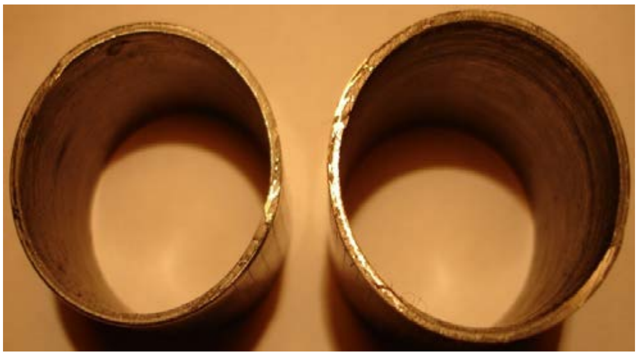


Рис. 10. Вид на поверхности среза при реверсе смещения оправок в заключительной стадии разделения ТТЗ.

Поскольку величиной зазора между стенками ТТЗ и оправками можно пренебречь, то границами текущей площади среза будут дуги окружностей, являющиеся контурами поперечных сечений оправок (режущих кромок). Тогда легко установить аналитические зависимости для определения максимального сдвига, текущей площади среза, усилия на каждой стадии разделения.

Первая стадия сдвига при условии, что максимальный сдвиг удовлетворяет условию:

$$f_{\max} = 2e\sin\frac{e}{2} \le R_{нар} - R_{вн}$$

Текущую площадь сдвига соответствующей углу поворота φ эксцентрика с внешней стороны поверхности заготовки найдем как разность площадей криволинейных трапеций ограниченных дугами $y_1(x)$ и $y_3(x)$ в пределах ($-A_1$ - A'_1):

$$S_{нар}(\varphi) = \int_{X_{A_1}}^{X_{A_1^1}} y_1(x)dx - \int_{X_{A_1}}^{X_{A_1^1}} y_3(x)dx =$$

$$= \int_{-\sqrt{R_{нар}^2-(e\sin(\varphi/2))^2}}^{\sqrt{R_{нар}^2-(e\sin(\varphi/2))^2}} 2e\cdot\sin(\varphi/2)dx =$$

$$= 4e\cdot\sin(\varphi/2)\cdot\sqrt{R_{нар}^2 - (e\cdot\sin(\varphi/2))^2}$$

Текущую площадь сдвига соответствующей углу φ поворота эксцентрика с внутренней стороны поверхности заготовки найдем как разность площадей криволинейных трапеций ограниченных дугами $y_2(x)$ и $y_4(x)$ в пределах ($-A_1$ - A'_1):

$$S_{вн}(\varphi) = \int_{X_{A_1}}^{X_{A_1^1}} y_2(x)dx - \int_{X_{A_1}}^{X_{A_1^1}} y_4(x)dx = \int_{-\sqrt{R_{вн}^2-(e\sin(\varphi/2))^2}}^{\sqrt{R_{вн}^2-(e\sin(\varphi/2))^2}} 2e\cdot\sin(\varphi/2)dx =$$

$$= 4e\cdot\sin(\varphi/2)\cdot\sqrt{R_{вн}^2 - (e\cdot\sin(\varphi/2))^2}$$

Общая площадь сдвига:

$$S(\varphi) = S_{нар}(\varphi) + S_{вн}(\varphi);$$

Эту величину следует рассматривать как абсолютное значение уменьшения площади поперечного сечения при внедрении оправок в заготовку:

$$\Delta F(\varphi) = S(\varphi),$$

или

$$S(\varphi) = 4e\cdot\sin(\varphi/2)\left[\sqrt{R_{нар}^2 - (e\cdot\sin(\varphi/2))^2} + \right.$$

$$\left. + \sqrt{R_{вн}^2 - (e\cdot\sin(\varphi/2))^2}\right]$$

Относительная площадь сдвига (среза):

$$\psi(\varphi) = \frac{F(\varphi)}{F_0} = \frac{S(\varphi)}{F_0};$$

где F_0 – площадь поперечного сечения ТТЗ:

$$F_0 = \pi\left(R_{нар}^2 + R_{вн}^2\right).$$

$$\psi(\varphi) = \left[\frac{\pi\left[(R_{вн}+s)^2 - R_{вн}^2\right] - 4e\cdot\sin(\varphi/2)}{\pi\left[(R_{вн}+s)^2 - R_{вн}^2\right]}\right.$$

$$\left.\frac{\sqrt{R^2 - (e\cdot\sin(\varphi/2))^2}}{\pi\left[(R_{вн}+s)^2 - R_{вн}^2\right]}\right]$$

Учет упрочнения выполним по уравнению кривой упрочнения второго рода предложенному С.И. Губкиным:

$$\sigma_s = \frac{\sigma_в}{1-\psi_ш}\left(\frac{\psi}{\psi_ш}\right)^{\frac{\psi_ш}{1-\psi_ш}}$$

Учитывая то, что разделение трубы происходит в условиях близких к условиям чистого сдвига, сопротивление сдвигу принимаем по теории максимальных касательных напряжений:

$$\tau_s = \frac{\sigma_s}{2};$$

$$\tau_s = \frac{\sigma_в}{2(1-\psi_ш)}\left(\frac{\psi}{\psi_ш}\right)^{\frac{\psi_ш}{1-\psi_ш}}$$

Текущая площадь среза после сдвига на величину $S(\varphi)$ равна:

$$F_{\text{ср}}(\varphi) = F_0 - S(\varphi);$$

Тогда текущее усилие среза на первой стадии разделения заготовки можно определить по формуле:

$$P_{\text{ср}}(\varphi) = \tau_s(\varphi) \times F_{\text{ср}}(\varphi)$$

или с учетом формул

$$P_{\text{ср}}(\varphi) = \frac{\sigma_{\text{в}}}{2(1-\psi_{\text{ш}})}\left(\frac{\psi}{\psi_{\text{ш}}}\right)^{\frac{\psi_{\text{ш}}}{1-\psi_{\text{ш}}}} \times \left\{F_0 - \left[4e\cdot\sin(\varphi/2)\right.\right.$$
$$\left.\left.\cdot\left[\sqrt{R_{\text{нар}}^2 - (e\cdot\sin(\varphi/2))^2} + \sqrt{R_{\text{вн}}^2 - (e\cdot\sin(\varphi/2))^2}\right]\right]\right\}$$

Момент силы относительно оси эксцентрика:

$$M(\varphi) = P_{\text{ср}}(\varphi) \times L(\varphi),$$

где

$$L(\varphi) = 2e\cdot\cos\frac{\varphi}{2}.$$

С учетом формул, получим:

$$M(\varphi) = \frac{\sigma_s}{2(1-\psi_{\text{ш}})}\left(\frac{\psi}{\psi_{\text{ш}}}\right)^{\frac{\psi_{\text{ш}}}{1-\psi_{\text{ш}}}} \times \left\{F_0 - \left[4e\cdot\sin\frac{\varphi}{2}\cdot\left[\sqrt{R_{\text{нар}}^2 - \left(e\cdot\sin\frac{\varphi}{2}\right)^2} + \sqrt{R_{\text{вн}}^2 - \left(e\cdot\sin\frac{\varphi}{2}\right)^2}\right]\right]\right\}$$
$$\times 2e\cdot\cos\frac{\varphi}{2}$$

Параметры резки на второй стадии, когда $f_{\max} \geq R_{\text{нар}} - R_{\text{вн}}$.

Текущая площадь среза на второй стадии разделения:

$$S_{\text{ср}}(\varphi) = 4\left(-\left\{e\sin\frac{\varphi}{2}\sqrt{R_{\text{нар}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2} + e\sin\frac{\varphi}{2}\sqrt{R_{\text{вн}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2} - 2\sqrt{R_{\text{нар}}^2 - \left(\frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{4e\sin\frac{\varphi}{2}} + e\sin\frac{\varphi}{2}\right)^2}\right\} + \right.$$
$$+\frac{1}{2}\left\{\left[\sqrt{R_{\text{нар}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2} \times \left(e\sin\frac{\varphi}{2}\right) + R_{\text{нар}}^2 \arcsin\frac{\sqrt{R_{\text{вн}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2}}{R_{\text{вн}}} - \sqrt{R_{\text{нар}}^2 - \left(\frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{e\sin\frac{\varphi}{2}} + e\sin\frac{\varphi}{2}\right)^2} + \right.\right.$$
$$R_{\text{нар}}^2 \arcsin\frac{\sqrt{R_{\text{нар}}^2 - \left(\frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{4e\sin\frac{\varphi}{2}} + e\sin\frac{\varphi}{2}\right)^2}}{R_{\text{нар}}}$$
$$-\left[\sqrt{R_{\text{вн}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2} \times \left(e\sin\frac{\varphi}{2}\right) + R_{\text{вн}}^2 \arcsin\frac{\sqrt{R_{\text{вн}}^2 - \left(e\sin\frac{\varphi}{2}\right)^2}}{R_{\text{вн}}}\right] -$$
$$-\left[\sqrt{R_{\text{нар}}^2 - \left(\frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{4e\sin\frac{\varphi}{2}} + e\sin\frac{\varphi}{2}\right)^2} \times \sqrt{R_{\text{нар}}^2 - R_{\text{вн}}^2 - \left(\frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{4e\sin\frac{\varphi}{2}} + e\sin\frac{\varphi}{2}\right)^2} + \right.$$
$$\left.\left.\left.\left. R_{\text{вн}}^2 \arcsin\frac{\sqrt{R_{\text{нар}}^2 - \frac{R_{\text{нар}}^2 - R_{\text{вн}}^2}{4e\sin\frac{\varphi}{2}} + \left(e\sin\frac{\varphi}{2}\right)^2}}{R_{\text{вн}}}\right]\right]\right\}\right)$$

Площадь каждого из них найдем как разницу интегралов:

$$F'_{\text{ср}}(\varphi) = \left(\int_{X_{A_2'}}^{X_{A_1'}} y_2(x)dx - \int_{X_{B_2'}}^{X_{B_1'}} y_3(x)dx\right)$$

3. Выводы

По приведенным формулам программным методом построены диаграммы $P_{\text{ср}}(\varphi)$ и $M(\varphi)$ необходимые для определения энергосиловых параметров резки. Различия расчетных и экспериментальных значений не превышают 10-12%.

Использованная литература:

1. Соловцев С.С. Безотходная разрезка сортового проката в штампах / С.С.Соловцев - М.: Машиностроение, 1985.-176 с.
2. С.И. Веселовский Разрезка материалов. - М.: Машиностроение, 1985.-360 с.
3. №46319 B21D37/00 Спосіб одержання короткої трубчастої заготовки; Автори: Стеблюк Володимир Іванович, Савченко Дмитро Миколайович, Розов Юрій Георгійович, Азарх Ілля Павлович, 10.12.2009р. Бюл.№23.
4. Стеблюк В.И., Савченко Д.Н., Розов Ю.Г. Методы совершенствования способов резки труб на короткие заготовки// Вестник НТУУ «КПИ». - 2009. - №57.
5. Стеблюк В.И., Савченко Д.Н., Шкарлута Д.Б. Последовательность резки тонкостенной трубчатой заготовки сдвигом вращающихся оправок // Вестник национального технического университета Украины «Харьковский политехнический институт». Сборник научных трудов. – Харьков: ХТУ «ХПИ» - 2010. - №43. – с. 141-146.
6. Стеблюк В.И., Савченко Д.Н., Розов Ю.Г. Холявик О.В. Экспериментальные исследования усовершенствованного метода резки трубчастых заготовок одновременным сдвигом и кручением // Вестник Донбасской государственной машиностроительной академии: сборник научных трудов. – Краматорск: ДГМА, 2010. -№1(22). – с. 179-182.
7. Стеблюк В.И., Савченко Д.Н., Розов Ю.Г. Холявик О.В. Исследование процесса резки одновременным сдвигом и кручением на усовершенствованном устройстве // Вестник национального технического университета Украины «Киевский политехнический институт». Машиностроение. - К.: НТУУ «КПИ». - 2010. - 58. – с.208-211.

DEVELOPMENT OF A CANTILEVER PLATE’S MODEL AS A COMPONENT OF THE METHOD OF LOCAL APPROXIMATIONS

РАЗВИТИЕ МОДЕЛИ КОНСОЛЬНОЙ ПЛАСТИНЫ КАК КОМПОНЕНТА МЕТОДА ЛОКАЛЬНЫХ АППРОКСИМАЦИЙ

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Abstract: *The paper contains a numerical-analytical solution for deflections and force factors in a cantilever plate of infinite length due to a concentrated load, which is obtained using modern data about optimal quadrature integration. The aspect of optimality is the main feature that distinguished the present solution. The formulas provide high accuracy, which is examined through comparison of the results with the finite elements method and another numerical-analytical solution. The paper also contains formulas for deflections for different laws of load distribution and ideas for their application.*
KEYWORDS: *THEORY OF ELASTICITY, STRESSED STATE, THE METHOD OF LOCAL APPROXIMATIONS, KIRCHHOFF PLATE, DEFLECTIONS, GEAR MODELING*

1. Introduction

Due to rapid development of technologies and materials usable in mechanical engineering, the need of strength calculations’ clarification rises for innovative purposes. In this context, theoretical studies of stress concentration in complex-shaped bodies with loaded ledges (such as gearings, for example), which are based on separate analysis of force factors due to an applied load, are extremely valuable. As it is noticed in [1], the standardized methods for calculating numerous sets of details of different mechanisms and machines with loaded ledges (e.g., the Russian GOST - State Standard №21354-87 “Cylindrical Involute Gear Transmissions: Strength Calculations”, 1987) for bending strength of the ledges are guided by simplified conceptions. They provide neither information about force factors’ distribution laws nor ways for modeling different materials with complex properties. On the other hand, there is a very effective tool – the finite elements method, which has high prevalence among engineers and researchers. However, it demands much of constructing the model properly, and has some specific disadvantages such as the locking effect, for example, which can give troubles if you desire to compute the result with high accuracy. Other reasons for building analytical solutions in parallel with improvement of the FEM modeling are, of course, urge towards having comparative results and general regularities, which could be made more precise with the FEM.

The present paper contains some basic ideas about the method of local approximations (the MLA) – a method of investigation of the stressed state of complex-shaped bodies with loaded ledges. G. A. Zhuravlev proposed it in [2, 3] in the context of modernization of a gearing’s geometry accordingly to the actual stress concentration, which takes into account origin of every stress component. The method is based on two plane problems, to which the three-dimensional one is being reduced. Thus, we calculate the force factors on a cantilever plate (using classic or improved theories of plate bending) in order to use them in calculation of the respective stress components in the model of a rod with two deep symmetric hyperbolic recesses. In this connection we consider, that the contour of the hyperbolic recess approximates the contour of the ledge, and take into account the depth of the plate’s sealing. It is shown in the paper [4], how the first requirement can be satisfied for a tooth of a spur pinion. The question about the depth of the sealing is observed, for example, in [3].

The problem of stress concentration in a rod with two deep symmetric hyperbolic recesses is solved in [5]. As for the problem of a cantilever plate calculation, the number of papers, which contain analytical or numerical-analytical solutions, is not big. The present paper describes a comparatively simple solution, which corresponds to a model of an infinitely long plate, clamped along one of its long sides. T. J. Jaramillo described this problem in [6] and gave an exact solution in terms of improper integrals for the deflections and moments due to a transverse concentrated load acting at an arbitrary point of the plate. It was proposed in [6] to calculate the respective integrals using residue theory, but as it was shown in the papers [7, 8] and in the Proceedings of 2015 International Conference on “Physics and Mechanics of New Materials and Their Applications” (PHENMA 2015), the residue solution of [6] gives a big error for some calculation points. The present paper continues the course of [7] and presents a numerical-analytical solution for deflections (which is basic for calculating force factors and stresses), built with applying modern ideas about optimal quadrature integration.

We also introduce formulas for deflections, suitable for different laws of load distribution, such as uniformly distributed over a segment and over a rectangle loads, a distributed over a segment accordingly to the parabolic law load and a load, distributed over an ellipse.

2. Deflections

2.1. A numerical-analytical solution for deflections

On the analogy of [6], the plate is considered in the form of an infinitely long strip of width A and thickness h, fixed along one of its long edges. The transverse load F is applied at an arbitrary point $P(c,0)$ of the plate, where the Cartesian coordinate system $Oxyz$ is located such that xy is the middle plane of the plate, Oy belongs to the fixed side and the line of F belongs to the xz plane. Let the plane $x=c$ divide the plate and the functions, which are determined in the areas $0 \le x \le c$ and $c \le x \le A$, have the indexes 1 and 2 respectively. Then, if the weight of the plate isn’t considered the deflections $W_j(x,y)$, $j=1,2$, satisfy the biharmonic equation

$$\nabla^4 W_j(x,y)=0,\quad j=1,2,$$

which is valid everywhere except the point P.

It is proposed in [7] to define the functions $W_j(x,y)$, $j=1,2$, as

$$W_j(x,y)=\int_0^\infty f_j(x,\alpha)\cos(\alpha y)\,d\alpha,$$

where

$$f_j(x,\alpha)=\left(A_j+B_j\alpha x\right)\cosh(\alpha x)+\left(C_j+D_j\alpha x\right)\sinh(\alpha x),$$

A_j, B_j, C_j, D_j are assumed functions of the α variable.

Then the boundary conditions can be written as

$$\left.\begin{array}{l} f_1(0,\alpha)= f_{1,x}(0,\alpha)=0; \\ f_{2,xx}(A,\alpha)-\alpha^2\,\mu\, f_2(A,\alpha)=0; \\ f_{2,xxx}(A,\alpha)-\alpha^2(2-\mu)\, f_{2,x}(A,\alpha)=0; \\ f_1(c,\alpha)- f_2(c,\alpha)=0; \\ f_{1,x}(c,\alpha)- f_{2,x}(c,\alpha)=0; \\ f_{1,xx}(c,\alpha)- f_{2,xx}(c,\alpha)=0; \\ f_{2,xxx}(c,\alpha)- f_{1,xxx}(c,\alpha)=\dfrac{F}{\pi D}, \end{array}\right\}$$

where $D=\dfrac{E\,h^3}{12\left(1-\mu^2\right)}$ is the flexural rigidity of the plate (E is Young's modulus, μ is Poisson's ratio).

Being solved for A_j, B_j, C_j, D_j, $j=1,2$, the system provides the following functions:

$$f_1(x,c,\alpha)=\frac{F}{2\pi A D\gamma}\left[-x\alpha\cosh(x\alpha)\sum_{i=1}^{4}a_i k_i+\sinh(x\alpha)\sum_{i=4}^{8}a_i k_i\right],$$

$$f_2(x,c,\alpha)= f_1(c,x,\alpha),$$

$$\gamma=\alpha^3\left[5+2(A\alpha)^2(\mu-1)^2+(2+\mu)\mu-\left(\mu^2+2\mu-3\right)\cosh(2A\alpha)\right]$$

i	k_i	a_i
1	$5+2A(A-c)\alpha^2(\mu-1)^2+(2+\mu)\mu$	$\cosh(c\alpha)$
2	$-\left(\mu^2+2\mu-3\right)$	$\cosh\left[(c-2A)\alpha\right]$
3	$\alpha(\mu-1)(2A-c)(\mu-1)$	$\sinh(c\alpha)$
4	$\alpha c(\mu-1)(\mu+3)$	$\sinh\left[(c-2A)\alpha\right]$
5	$5+\left(2A^2-2Ac+cx\right)\alpha^2(\mu-1)^2+(2+\mu)\mu$	$\cosh(c\alpha)$
6	$-\left(1+cx\alpha^2\right)\left(\mu^2+2\mu-3\right)$	$\cos\left[(c-2A)\alpha\right]$
7	$\alpha\left[\begin{array}{l}-c(\mu-1)^2+2A^2x\alpha^2(\mu-1)^2- \\ -2A\left(cx\alpha^2-1\right)(\mu-1)^2+4x(\mu+1)\end{array}\right]$	$\sinh(c\alpha)$
8	$c\alpha\left(\mu^2+2\mu-3\right)$	$\sinh\left[(c-2A)\alpha\right]$

Thus,

$$W_j(x,y,c)=\int_0^\infty f_j(x,c,\alpha)\cos(y\alpha)\,d\alpha,\quad j=1,2,$$

and for numerical calculation of the deflections we have proposed in [10] the following formula:

$$W_j(x,y,c)=\frac{\pi}{2n}\sum_{k=1}^{n}F_j\left[x,y,c,\tan\frac{(2k-1)\pi}{4n}\right],\quad j=1,2 \qquad (1)$$

where

$$F_j(x,y,c,\alpha):=\left(1-\alpha^2\right)f_j(x,c,\alpha)\cos(\alpha y),\quad j=1,2,$$

and the error of (1) is $\dfrac{\pi}{4n}$.

Due to the behavior of the respective functions it is proposed to use different values of n for $j=1$ and for $j=2$. The main feature of the formula (1) is that it can be called an almost optimal one, because we use the respective result from theory of optimal quadrature integration in order to build it. However, some additional assumptions, which take into account the behavior of the integrands and substantiate selection of n values, have to be made. It is convenient to use dimensionless coordinates

$$\xi=\frac{x}{A},\ \eta=\frac{y}{A},\ \zeta=\frac{c}{A}.$$

Computational experiments show that the values of deviation between the results of the FEM modeling and the formula (1) become more than 1% if η approach 1,00. Here we consider the following parameters of the model in ANSYS:

Length of the plate L, m	h, m	A, m	F, N	Finite elements type	Multiplicity of splitting: the side of L, the side of h, the side of A
0,2	0,002	0,01	2000	SHELL63	400
					4
					40

It is obvious that the results directly depend on the ratios of $\dfrac{L}{A}$ and $\dfrac{y}{L}$ in the FEM model; thus, we have to consider a sufficiently long plate and calculation points, which are sufficiently removed from the side edges of the plate.

2.2. Different laws of load distribution

The following formulas in terms of improper integrals correspond to different cases of a distributed load, such as uniformly distributed over a segment and over a rectangle loads, a distributed over a segment accordingly to the parabolic law load and a load, distributed over an ellipse. Hereinafter we suppose, that r is a ratio of a distance between the sealing line of the plate and the center of a loaded area to the size A, F_Σ is a distributed load, q_0 is intensity of loading in the center point of a loaded area and $\varphi_j(\xi,\zeta,\mu)=\dfrac{f_j(\xi,\zeta,\mu)}{F}\mu^3\kappa(\mu)$, $j=1,2$, where $\mu=\alpha A$, $\kappa(\mu)=\mu^2+\theta^2+(2\theta+1)\cosh^2(\mu)$, $\theta=\dfrac{1+\nu}{1-\nu}$. The following formulas are proposed on the base of [8].

If the load is uniformly distributed over an interval of length 2ρ, which is parallel to the sealing line, than

$$W_j(\xi,\eta,\zeta)=\frac{F_\Sigma}{q_0}\int_0^\infty\frac{\varphi_j(\xi,r,\mu)}{\mu^4\kappa(\mu)}\cos(\mu\eta)\sin(\mu\eta)\,d\mu.$$

If the load is distributed over the same segment, divided into k elementary segments of equal lengths ΔS, accordingly to the parabolic law

$$q=\frac{3F_\Sigma\left(\rho^2-\varepsilon^2\right)}{4\rho^3},$$

where ε is the distance between the center of the segment and the calculation point, then

$$W_j(\xi,\eta,\zeta)=\frac{3F_\Sigma}{q_o^3}\int_0^\infty\frac{\varphi_j(\xi,r,\mu)}{\mu^6\kappa(\mu)}\cos(\mu\eta)\left[\sin(\mu\rho)-\mu\rho\cos(\mu\rho)\right]d\mu.$$

If a load of intensity q is uniformly distributed over a rectangle $\zeta_1\le\xi\le\zeta_2$, $\eta_1\le\eta\le\eta_2$, then

$$W_j(\xi,\eta,\zeta)=4q\int_0^\infty\frac{\cos\left[(\eta-\overline{\eta})\mu\right]\sin(\mu v)}{\mu^5\kappa(\mu)}\overline{\varphi}(\xi,\mu)\,d\mu,$$

where

$$\overline{\varphi}(\xi,\mu)=\sum_{j=1}^{2}\left\{\begin{array}{l}\sinh(\mu u_j)\varphi_j\left(\xi,\overline{\xi}_j,\mu\right)+ \\ \quad+\left[\mu u_j\cosh(\mu u_j)-\sinh(\mu u_j)\overline{\varphi}_j\left(\xi,\overline{\xi},\mu\right)\right]\end{array}\right\},$$

$$\overline{\varphi}_j(\xi,\zeta,\mu)=(1+2\theta)\left(2\mu\xi C_2+S_2-S_1\right)-2\mu(1-\xi)C_4-S_4+2\mu C_5+t_jS_5,$$

$$t_1=1+4\mu^2\xi,\ t_2=(1+2\theta)^2+4\mu^2(1-\xi),$$

$$S_1=\sinh\left[(2-\zeta+\xi)\mu\right],\qquad S_2=\sinh\left[(2-\zeta-\xi)\mu\right],$$

$$S_4=\sinh\left[(\zeta+\xi)\mu\right],\qquad S_5=\sinh\left[(\zeta-\xi)\mu\right],$$

$C_2 = \cosh\left[\left(2-\zeta-\xi\right)\mu\right]$, $\quad C_4 = \cosh\left[\left(\xi+\zeta\right)\mu\right]$,

$C_5 = \cosh\left[\left(\zeta-\xi\right)\mu\right]$, $v = \dfrac{\eta_2-\eta_1}{2}$, $\bar{\eta} = \dfrac{\eta_1+\eta_2}{2}$,

$$u_1 = \begin{cases} \dfrac{1}{2}\left[\zeta_2 - \max\left(\xi,\zeta_1\right)\right], & \xi \le \zeta_2; \\ 0, & \xi > \zeta_2, \end{cases}$$

$$u_1 = \begin{cases} \dfrac{1}{2}\left[\min\left(\xi,\zeta_2\right) - \zeta_1\right], & \xi \ge \zeta_1; \\ 0, & \xi < \zeta_1, \end{cases}$$

$$\bar{\xi}_1 = \frac{1}{2}\left[\zeta_2 + \max\left(\xi,\zeta_1\right)\right],\ \bar{\xi}_2 = \frac{1}{2}\left[\min\left(\xi,\zeta_2\right) + \zeta_1\right].$$

At last, if the load is applied accordingly to the law of semi-ellipsoid over an ellipse with dimensionless semi-axes a and b, which is inclined by an angle Λ, it is proposed in [8] to use a method, based on reduction of the problem to the case of the parabolic law of load distribution. Thus, we divide the ellipse into elements with a system of equidistant chords, parallel to the free edge. The intensity of the load inside every element is

$$q\left(\varepsilon,\zeta\right) = q_0\left\{1 - -\frac{\left[\varepsilon\cos\left(\Lambda\right)+\left(\zeta-r\right)\sin\left(\alpha\right)\right]^2}{a^2} - -\frac{\left[\varepsilon\sin\left(\Lambda\right)-\left(\zeta-r\right)\cos\left(\alpha\right)\right]^2}{b^2}\right\}^{\frac{1}{2}},$$

where $q_0 = \dfrac{3}{2}\dfrac{F_\Sigma}{\pi ab}$, and we replace it with an equivalent one, which is distributed accordingly to the parabolic law over the chord, which contains the application point of the resultant force of the element. We introduce the following notation:
NN' is the diameter of the ellipse, connected with the chosen system of dividing chords; $S_0 = \dfrac{NN'}{2}$; S is a linear coordinate, which is counted off the center of the ellipse along the diameter NN'; n_e is a number of parts, into which the ellipse is divided; λ_i, $i = 1,2,...,n+1$, are the coordinates of points of dividing chords' intersection with NN'; F_k, $k = 1,...,n$, is the value of the resultant force on the element between λ_k and λ_{k+1}; l_k is the coordinate of the point of the resultant force acting; ρ_k is one-half of the chord, along which the equivalent load is distributed; β is the angle between NN' and $O\xi$.
The following relations link all of the introduced parameters:

$$\lambda_0 = \sqrt{\frac{a^4\sin^4\left(\Lambda\right)+b^4\cos^2\left(\Lambda\right)}{a^2\sin^2\left(\Lambda\right)+b^2\cos^2\left(\Lambda\right)}};$$

$$\lambda_i = -\lambda_0 + \left(i-1\right)\frac{2\lambda_0}{n_e},\ i = 1,2,...,n_e+1;$$

$$F_k = \frac{\pi abq_0}{3n_e\lambda_0^{\ 2}}\left[3\lambda_0^{\ 2} - \left(\lambda_{k+1}^{\ 2} + \lambda_k\lambda_{k+1} + \lambda_k^{\ 2}\right)\right],\ k = 1,2,...,n_e;$$

$$l_k = -\frac{Aabq_0}{4\pi nF_k\lambda_0^{\ 2}}\left(\lambda_{k+1}+\lambda_k\right)\left(\lambda_{k+1}^{\ 2}+\lambda_k^{\ 2}-2\lambda_0^{\ 2}\right),$$

$$\rho_k = \frac{ab}{\lambda_0}\sqrt{\frac{\lambda_0^{\ 2}-l_k^{\ 2}}{a^2\sin^2\left(\Lambda\right)+b^2\cos^2\left(\Lambda\right)}},$$

$$\cos\left(\beta\right) = \frac{a^2\sin^2\left(\Lambda\right)+b^2\cos^2\left(\Lambda\right)}{\sqrt{a^4\sin^2\left(\Lambda\right)+b^4\cos^2\left(\Lambda\right)}}.$$

Thus, the method provides the following:

$$W_j = 3\sum_{k=1}^{n}\frac{F_k}{\rho_k^{\ 3}}\int_0^\infty\frac{\varphi_j\left(\xi, r-l_k\cos\left(\beta\right),\mu\right)}{\mu^6\kappa\left(\mu\right)}\cos\left[\left(\eta+l_k\sin\left(\beta\right)\right)\mu\right]\cdot \cdot\left[\sin\left(\mu\rho_k\right)-\mu\rho_k\cos\left(\mu\rho_k\right)\right]d\mu.$$

2.3. Practical recommendations for calculation

The problem of the deflections' calculation for the observed cases of load distribution consists in calculation of the respective improper integrals, which contain complex integrands. We suppose that the most effective way is building highly accurate approximate formulas, which take into account not only behavior of the integrands, but also correctly reflect the influence of the respective derivatives. The latter is very important for creation calculation algorithms for force factors and stresses.
Some approximate formulas can be found in [8]. Though they include strict limitations for calculation points and are not universal concerning material properties, they provide satisfying accuracy for steel plates within the limits of their application.
It is also useful to notice, that for deflections at the points located in the area of loading it is not hard to reduce the problem to consecutive repeated application of the formula (1). This is shown in the paper [1], where an algorithm for the case of the parabolic law of load distribution is represented.

3. Force factors due to a concentrated load

In the proceedings of PHENMA 2015 we have proposed the following formulas for the force factors due to a concentrated load – respectively, shearing force, bending and twisting moments:

$$Q_{jx}\left(x,y,c\right) = -\frac{\pi D}{2n}\sum_{k=1}^{n}F_j^{Q_x}\left[x,y,c,\tan\frac{\left(2k-1\right)\pi}{4n}\right],$$

$$M_{jx}\left(x,y,c\right) = -\frac{\pi D}{2n}\sum_{k=1}^{n}F_j^{M_x}\left[x,y,c,\tan\frac{\left(2k-1\right)\pi}{4n}\right],$$

$$M_{j\,xy}\left(x,y,c\right) = -\frac{\pi D\left(1-\mu\right)}{2n}\sum_{k=1}^{n}F_j^{M_{xy}}\left[x,y,c,\tan\frac{\left(2k-1\right)\pi}{4n}\right],$$

where

$$F_j^{Q_x}\left(x,y,c,\alpha\right) = \left\{\begin{array}{l}\left[f_j\left(x,c,\alpha\right)\cos\left(\alpha y\right)\right]_{xxx} + \\ \quad +\left[f_j\left(x,c,\alpha\right)\cos\left(\alpha y\right)\right]_{xyy}\end{array}\right\}\left(1-\alpha^2\right),$$

$$F_j^{M_x}\left(x,y,c,\alpha\right) = \left\{\begin{array}{l}\left[f_j\left(x,c,\alpha\right)\cos\left(\alpha y\right)\right]_{xx} + \\ \quad +\mu\left[f_j\left(x,c,\alpha\right)\cos\left(\alpha y\right)\right]_{yy}\end{array}\right\}\left(1-\alpha^2\right),$$

$$F_j^{Q_x}\left(x,y,c,\alpha\right) = \left[f_j\left(x,c,\alpha\right)\cos\left(\alpha y\right)\right]_{xy}\left(1-\alpha^2\right).$$

This solution was compared with one, which could be found in [9] for a steel plate. It is shown, that the results of [9] are qualitatively improved.

References

[1] G. A. Zhuravlev, Y. E. Drobotov, *Dependence of Displacements on Elastic Properties in Solids of Complex Shaped*, Advanced Materials, Springer Proceedings in Physics, Vol. 152, 2014, pp. 231 – 246

[2] G. A. Zhuravlev, R.B. Iofis, *Gipoidniye Peredachi. Problemi i razvitie*, Rostov State University Press, Rostov-on-Don (1978) (in Russian)

[3] G. A. Zhuravlev, P.S. Prokopiev, in Proceedings of the International Conference on Motion and Power Transmissions, The Japan Society of Mechanical Engineers, Tokyo. 23–26 November 1991, p. 866–870

[4] Y. E. Drobotov, *Opisanie kontura zuba cilindricheskogo pryamozubogo kolesa v ramkah metoda lokalnyh approksimacij*, Innovacionnaya nauka, №5, 2015, pp. 63 – 68 (in Russian)

[5] G. Neueber, Stress Concentration (State Publishers of Technical and Theoretical Literature, Moscow, 1947
[6] T. J. Jaramillo, J. Appl. Mech. 17(1), 67 (1950)
[7] Y. E. Drobotov, G. A. Zhuravlev, in Modern Problems of the Theory of Machines: Sovremennye problemy teorii mashin, Novokuznetsk. 2015, p. 224 – 231 (in Russian)
[8] G.A. Zhuravlev, V.M. Onishkova, VINITI, Moscow, No 6266-B87, 17.07.1987 (in Russian)
[9] Zhuravlev G. A., Onishkova V. M., *Momenti i pererezyvayushchie sily v konsolnoj plastine beskonechnoj dliny*, VINITI, Moscow, No 46-B, 2.01.1986 (in Russian)

ОРГАНИЗАЦИОННЫЕ ИННОВАЦИИ И ИХ ИНФОРМАЦИОННОЕ СОПРОВОЖДЕНИЕ В ОСНОВНЫХ ЦЕХАХ МАШИНОСТРОИТЕЛЬНОГО ПРОИЗВОДСТВА

ORGANIZATIONAL INNOVATIONS AND INFORMATION SUPPORT AT THE MAIN SHOPS OF ENGINEERING PRODUCTION

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Резюме. На основе обобщения теории и практики организационных изменений в статье представлен подход к совершенствованию системы оперативно-производственного планирования, заключающийся в организационной трансформации, регламентации и синхронизации работ по планированию и стимулированию. Предложенный инструментарий апробирован в основном производстве новосибирской организации литейного машиностроения. Как результат – на основе сокращения трудоемкости обработки информации и продолжительности выполнения работ по планированию и учету производственного процесса уменьшилось сопротивление персонала технологическим инновациям.

Abstract. On the basis of generalization of the theory and practice of organizational changes presents an approach to the improvement of operational and production planning, which consists in organizational transformation, regulation and synchronization of planning and promotion. Proposed instruments tested in the main production of foundry engineering organization. (Novosibirsk). The staff resistance to technological innovation based on reducing the complexity of information processing and duration of work on the planning and integration of the production process to reduce. As a result as resistance to technological innovation personnel decreased by reducing the complexity of information processing and duration of work on planning and accounting of the production process.

Ключевые слова. Организационные инновации, оперативно-производственное планирование, CASE-технологии, специалист по организации трудовых и производственных процессов, машиностроительное производство.

Keywords. Organizational innovation, operational and production planning, CASE-technology specialist in the organization of labor and production processes, machinery production.

1. Introduction / Введение

Согласно статистическим данным, по уровню инновационной активности организаций Россия значительно отстает от большинства стран Евросоюза, США и других зарубежных стран. Более того, наметилась тревожная тенденция снижения удельного веса организаций, осуществляющих технологические инновации в обрабатывающих производствах [1].

К числу проблем, на наш взгляд, относится, наряду с другими, отсутствие должного внимания к организационным инновациям: доля организаций, осуществляющих инновации в этой области, в три раза ниже, чем тех, кто реализовал технологические инновации.

В составе организационных инноваций значительную долю занимает внедрение современных методов управления на основе информационных технологий. В связи с этим выполненная тема исследования является актуальной.

Целью исследования явилась разработка инструментария внедрения современных методов оперативного управления производством на основе информационных технологий.

Для реализации поставленной цели решен ряд задач: теоретическое обоснование внедрения организационных инноваций и методов оперативного управления производством на основе информационных технологий;

анализ предметной области (литейное производство) и исследование объекта внедрения информационных технологий (чугунолитейный цех ОАО «Сиблитмаш» [2]);

локализация объекта и выявление существующих проблем и ограничений в решении задач;

анализ методов и путей решения поставленной задачи и разработка системы оперативно-производственного планирования.

2. Preconditions and means for resolving the problem / Предпосылки и средства для решение проблемы

Классическое определение системы оперативно-производственного планирования мы находим в учебнике, актуальном для IV технологического уклада, когда под нею понимались методика и техника плановой работы, определяемые степенью централизации плановой работы, выбором планово-учетной единицы, дифференциацией плановых периодов, составом и точностью календарно-плановых нормативов, а также составом, порядком оформления и движения планово-учетной документации [3].

Современные словари включают термин «оперативное планирование» (англ. Operative planning) как текущее производственно-финансовое и исполнительское планирование, ориентированное на дополнение, детализацию, внесение корректив в намеченные ранее планы и графики работ [4]. Конкретизируя эту систему на уровне отдельных производственных единиц, ее называют системой оперативно-производственного планирования.

Главной задачей оперативно-производственного планирования является организация слаженной работы всех подразделений предприятия для обеспечения равномерного, ритмичного выпуска продукции в установленном объеме и номенклатуре при полном использовании производственных ресурсов.

Современное оперативно-производственное планирование имеет следующие особенности, которые

необходимо учитывать в ходе постановки задач информационного обеспечения:
объектом планирования выступает производственный процесс как совокупность операций, требующая их строгой увязки в пространстве и во времени;
плановыми показателями являются конкретные измерителями (детале-операции);
ресурсное обеспечение определяется плановым объемом выпуска на основе сальдовой модели;
детализация периода оперативного планирования (от месяца до одного часа в зависимости от изменчивости факторов и требуемой скорости реагирования на эти изменения);
воздействие на ход производственного процесса осуществляется путем доведения планов-графиков хода процесса до линейных руководителей и непосредственного приведения системы в равновесие в соответствии с заданными параметрами [5];
тесная взаимосвязь технико-технологического и трудового процессов предопределяет увязку плановых и фактических показателей производства с производительностью труда и заработной платой основного производственного персонала.
Анализируя предмет и объект приложения информационных технологий, нами выявлен ряд барьеров, препятствующих внедрению технологических инноваций (литейное производство). Основным подразделением, ответственным за оперативно-производственное планирование на уровне цеха, является планово-диспетчерское бюро, функционал которого достаточно разнообразен (нами выявлено 16 функций). В исходном варианте в цехе в качестве самостоятельного подразделения функционировало также бюро труда и заработной платы, в зону ответственности которого входил учет выполняемой работы и начисление заработной платы основным производственным рабочим. Организационная трансформация на микроуровне цеха заключалась в объединении экономических функций планирования производства и стимулирования труда (расчёта заработной платы основным производственным рабочим). При сокращении объемов производства каждое из подразделений было представлено одним специалистом, поэтому было принято решение об их объединении в планово-диспетчерскую службу. В ее состав включены ведущий инженер-экономист и специалист по организации трудовых и производственных процессов.
Опираясь на отработанные авторами алгоритмы проведения подобных исследований, выполненных ранее [6, 7, 8], в качестве основополагающей предложено использовать методологию функционального моделирования (CASE-технологии) [9]. Описание действующего документооборота в данном подразделении представлено в нотации DFD (рис.1).

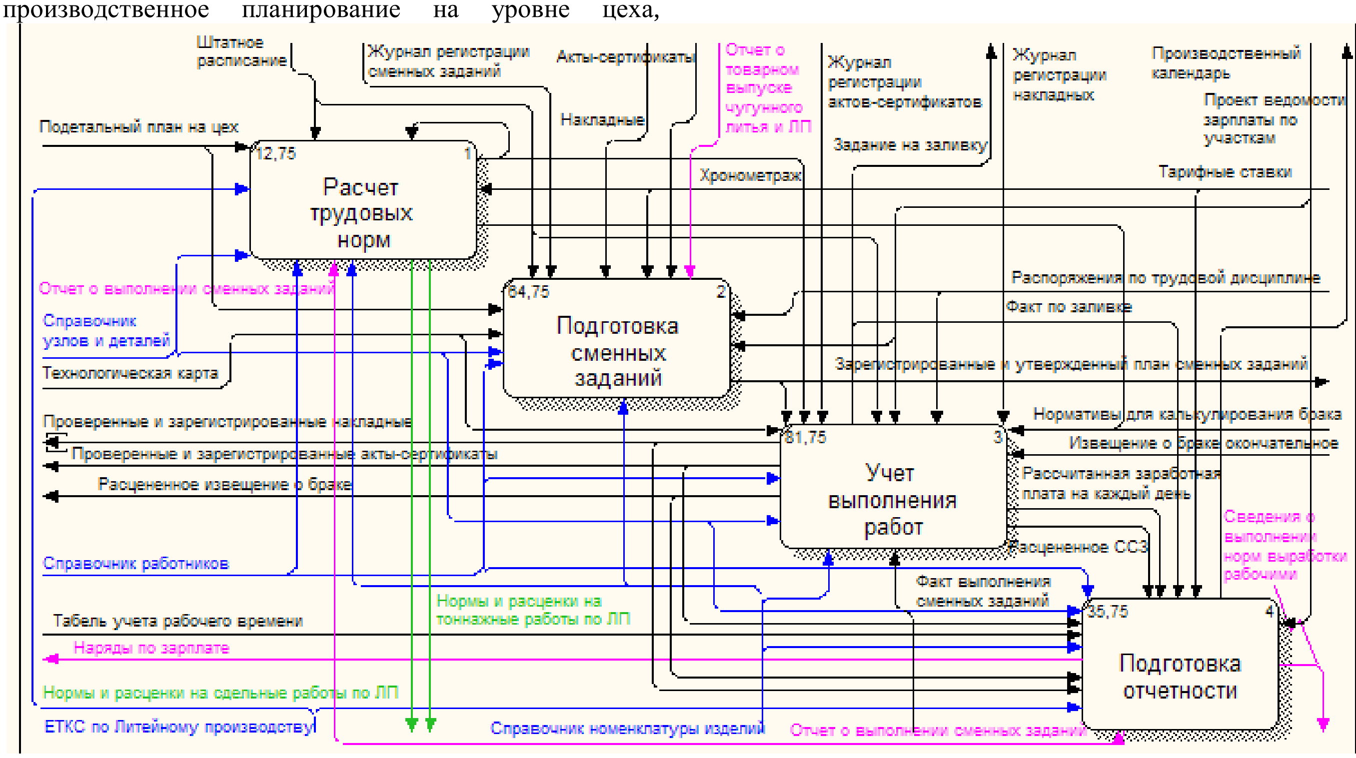

***Рис. 1** – Модель DFD AS-IS рабочего места специалиста по организации трудовых и производственных процессов (составлено авторами)*

Особое внимание было уделено ABC-анализу (Activity Based Costing), или стоимостному анализу, с целью определить общую стоимость процесса ОПП на основе наблюдения и фиксации затрат рабочего времени специалистов, связанных с выполняемыми операциями.
При рассмотрении всей совокупности DFD-диаграмм были выявлены следующие недостатки существующего документооборота: большинство документов составляется вручную, расчеты производятся на обычном калькуляторе, некоторые отчеты ведутся в тетрадях.
В настоящее время на предприятии обходятся простым способом передачи информации. При этом необходимы колоссальные затраты времени для поиска необходимой информации, для формирования отчетности руководству цеха и заинтересованным подразделениям заводоуправления. Возникает постоянная проблема – потеря важных документов.

Результаты проведенного АВС-анализа показали, что часть времени специалиста по организации трудовых и производственных процессов уходит на дублирование действий инженера-экономиста и постороннюю, не относящуюся к данному рабочему месту работу; также достаточно большое количество времени тратится на заполнение текущей и ежедневной документации, подготовку отчетов и проведение необходимых расчетов вручную. Как результат, сверх нормативных 166,25 часа в месяц в среднем по году переработка по времени составляет 19 часов в месяц.

Существенным фактом является то, что специалист по организации трудовых и производственных процессов выполняет не только свои, но и несвойственные функции, не относящиеся к данному подразделению и к данному рабочему месту. Также часть функций выполняется им совместно с ведущим инженером-экономистом. В таком случае необходимо перераспределение выполняемых на данном рабочем месте функций.

В работе проанализирован ряд релевантных программных продуктов, реализуемых на рынке, а именно:

система календарного планирования и диспетчерского контроля Zenith SPPS;

автоматизированная система оперативно-календарного планирования и диспетчеризации производства СПРУТ-ОКП (функционально – программный комплекс для создания и внедрения системы автоматизации управления предприятием);

интегрированная система оперативного управления производством (англ. MES – Manufacturing Execution Systems) «ФОБОС»;

MES-система для машиностроения PolyPlan;

IRIUS MES – платформа, предназначенная для создания автоматизированных систем управления производством на промышленных предприятиях различных отраслей;

система управления производством Omega Production (компания Omega Software);

«1С: Управление производственным предприятием 8.0», позиционируемое как комплексное прикладное решение, охватывающее основные контуры управления и учета на производственном предприятии.

Выявлены их особенности и условия реализации.

Выполненный анализ позволил обосновать выбор собственного подхода к организационному совершенствованию процесса оперативно-производственного планирования.

3. Solution of the examined problem / Решение рассматриваемой проблемы

В качестве решения выявленных проблем в области оперативного управления производством в части планирования в среде MS Access разработан прототип программного обеспечения по формированию и распределению сменных заданий по участкам цеха и подготовке отчетности по выполненным в цехе работам на конец смены и на конец месяца.

Для реализации прототипа программного обеспечения в работе также составлены информационная модель системы и спецификация информационных потоков, структура описания таблиц внутренней информационной базы, схема базы данных разрабатываемой информационной системы, а также схемы рабочих мест. Фрагмент представлен на рис.2.

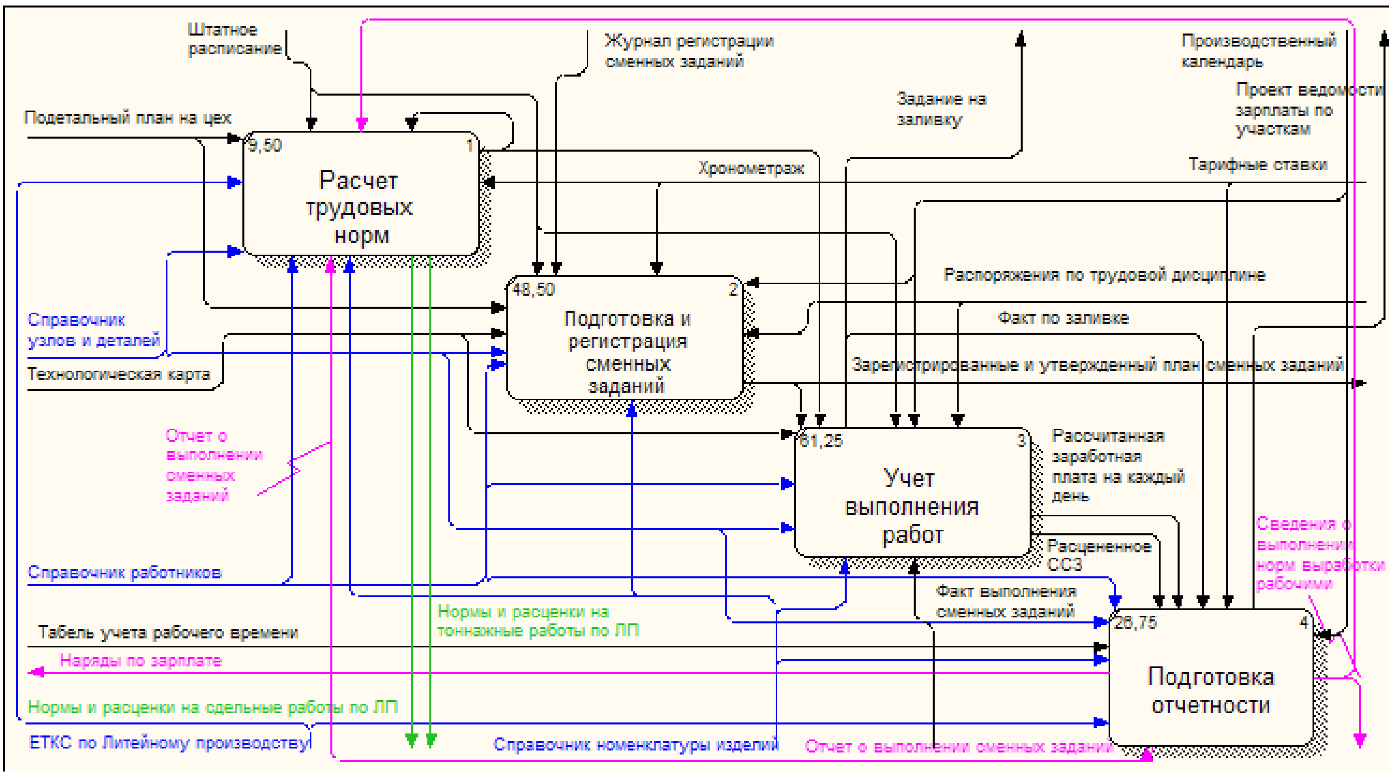

Рис. 2 *– Модель DFD TO-BE рабочего места специалиста по организации трудовых и производственных процессов (составлено авторами)*

При использовании данного программного обеспечения достигается снижение трудоемкости обработки информации и повышение качества расчетов.

4. Results and discussion / Результаты и дискуссии

Разработанная система позволит значительно сократить трудовые и временные затраты на подготовку и расчет необходимых показателей по отчетности.

Помимо изменений в функционировании рабочих мест планово-диспетчерской службыв в случае увеличения объемов производства (при загрузке производственных мощностей более чем на 50%) предложено выделить отдельное рабочее место специалиста по планированию, который будет на автоматизированном уровне составлять план работ на час, день, месяц, а также заниматься нормированием труда рабочих и составлением (своевременным обновлением) норм и расценок на сдельные работы.

5. Conclusion / Заключение

Отметим, что организационная трансформация, регламентация и синхронизация работ по планированию и стимулированию труда основного производственного персонала ускорили адаптацию и к технологическим инновациям, о чем свидетельствовали результаты опроса: индекс сопротивления персонала значительно сократился.

6. Literature / Литература

1. Индикаторы инновационной деятельности: 2015. Статистический сборник / Национальный исследовательский университет «Высшая школа экономики». М., 2015. 321 с.
2. Официальный сайт ОАО «Сиблитмаш». URL: www.siblitmash.com (дата обращения: 03.03.2015).
3. Ковальский В.И. Организация и планирование производства на машиностроительном предприятии: Учеб.пособие для машиностроительных техникумов. М.: Машиностроение, 1986. 288 с.
4. Словарь по экономике и финансам Глоссарий.ру. URL:http://www.glossary.ru/cgi-bin/gl_fors.cgi?ROvlwgyoitul!zvwgirltol (дата обращения: 03.07.2015).
5. Планирование на предприятии: конспект лекций / И. Дрогомирецкий, Кантор Е., Г. Маховикова М.: Юрайт, 2014. 140 с.
6. Адова И.Б. Стратегия и тактика управления вознаграждением персонала организации. Новосибирск: САФБД, 2010. 298 с.
7. Милёхина О. В., Адова И. Б. Подходы к управлению людьми в организации: генезис в условиях непрерывных изменений // Проблемы современной экономики. 2014. № 1. С. 91-95.
8. Милёхина О.В., Черявко С.В. Процессный подход на машиностроительном предприятии // Реинжиниринг бизнес-процессов на основе современных информационных технологий. Системы управления знаниями: материалы XIV научно-практическойконференции. (МЭСИ), Институт компьютерных технологий. М., 2011. С. 257-258.
9. Информационные системы: теоретические предпосылки к построению : учеб. пособие / О. Милёхина, В. Титова, Е. Захарова. Изд. 2-е. Новосибирск: Изд-во НГТУ, 2014. 283 с.

ВЛИЯНИЕ ВНЕШНЕЙ СРЕДЫ НА РАБОТОСПОСОБНОСТЬ ЗАПОМИНАЮЩИХ УСТРОЙСТВ В УСЛОВИЯХ КРИТИЧЕСКОГО ПРИМЕНЕНИЯ

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Аннотация: *В статье исследованы факторы и условия, влияющие на безотказную работу элементов памяти в системах критического применения. Установлено, что наибольшее влияние на точность запоминающих устройств (ЗУ) имеют следующие факторы внешней среды: температура, вибрации и электростатическое поле. Автором предложен способ испытания с помощью которого возможно исследование совместного влияния негативных факторов на элементы памяти. Установлено, что наиболее существенное влияние на работоспособность имеет именно комплексное влияние вышеперечисленных факторов, а эксплуатация ЗУ в оптимальных режимах разрешает увеличить вероятность безотказной работы. Кроме того, установлено, что современные элементы памяти типа DDR4 имеют большую помехоустойчивость по сравнению с устаревшими (DDR2).*
КЛЮЧЕВЫЕ СЛОВА*: ЗАПОМИНАЮЩЕЕ УСТРОЙСТВО, ПОМЕХОУСТОЙЧИВОСТЬ, ВЛИЯНИЕ ТЕМПЕРАТУРЫ, ЭЛЕКТРОСТАТИЧЕСКОГО ПОЛЯ, ВИБРАЦИЙ*

1. Введение

Наноэлектроника – относительно новая отрасль науки, занимающаяся разработкой физических и технологических основ создания интегральных электронных схем с характерными топологическими размерами элементов менее 100 нанометров. С появлением современных субмикронных технологий, которые обеспечивают высокий уровень интеграции, возрастает производство разнообразных средств компьютерной техники. Большинство таких средств основаны на универсальных компонентах, которые содержат разные виды запоминающих устройств, а при их изготовлении используется технология «устройство на одном кристалле» (System-on-Chip, SOC). Это позволяет значительно увеличить быстродействие работоспособность, а также уменьшить габариты таких систем, чем улучшается их оперативность и снижается энергозатраты.

Однако, использование средств компьютерной техники в системах критического применения (систем управления стратегическими энергетическими объектами, аэрокосмическими объектами, системами жизнеобеспечение и т.д.), которые требуют высокой надежности, точности вычислений, скорости обработки и обмена информацией, приводит к значительному уменьшению времени на проведение расчетных операций. Как результат, это ведет к повышению интенсивности отказов и появлению сбоев, что вызывает задержку в работе и может привести к искажению результатов. Особенно критическим явлением считается отказ запоминающих устройств.

В тоже время известно [1], что наибольшее влияние на работоспособность запоминающих устройств оказывают условия окружающей среды, а именно: влажность, вибрации и электростатические поля, а уменьшение воздействия этих факторов ведет к увеличению срока надежной эксплуатации устройства. Однако элементы памяти критического применения требуют высокой надежности работы именно в жестких условиях окружающей среды [2]. Поэтому целью работы является изучение влияния факторов окружающей среды (температуры, влажности, вибраций и электростатических полей) на работоспособность памяти и предоставление рекомендаций по использованию памяти в критических условиях.

2. Порядок проведения эксперимента

В качестве исследуемого образца использовались планки памяти SDRAM DDR2 и DDR4 S, которые устанавливались в специально разработанное автором диагностическое оборудование (рис. 1), где образцы испытывались в широком диапазоне температур, вибраций и электростатических полей.

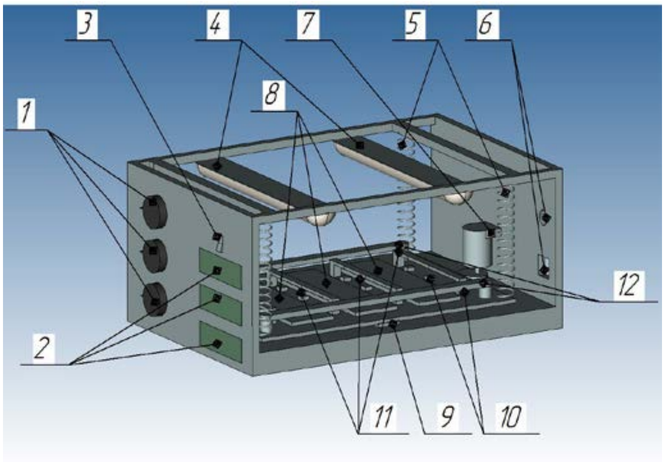

Рис. 1. *Внешний вид диагностического стенда: 1 – ручки регулирования параметров; 2 – индикатор состояния работы стенда; 3 – кнопка включения-выключения; 4 – кварцевые лампы КГ-1000; 5 – пружины виброподвеса; 6 – разъемы для подключения ПК и электросети; 7 – электродвигатель; 8 – разъемы для установления ЗУ; 9 – тензодатчик; 10 – термопары; 11 – коротрон-разрядник; 12 – датчик напряженности электростатического поля.*

Рабочие режимы диагностического стенда, при которых испытывались ЗУ следующие: температура: +20…+70 °С; поверхностная плотность электростатического заряда: 0,1…2,2 мкКл/мкм^2; вибрационные колебания: 0…0,45 мм/с.

Суть эксперимента заключалась в следующем. Запоминающее устройство устанавливалось в специальные разъемы, и подвергалось тепловому, вибрационному и электростатическому воздействию. При этом диагностический стенд подключался к ПК, а отказоустойчивость элементов памяти проверялись набором специальных компьютерных тестов в реальном времени [3].

3. Обсуждение результатов исследований

В результате экспериментов были получены зависимости надежности (вероятности возникновения сбоев), помехоустойчивости от совместного влияния температуры, влажности, амплитуды вибрационных колебаний и поверхностной плотности электростатического заряда. Результаты исследований на примере элементов памяти SDRAM DDR2 и DDR4 представлены на рис. 2.

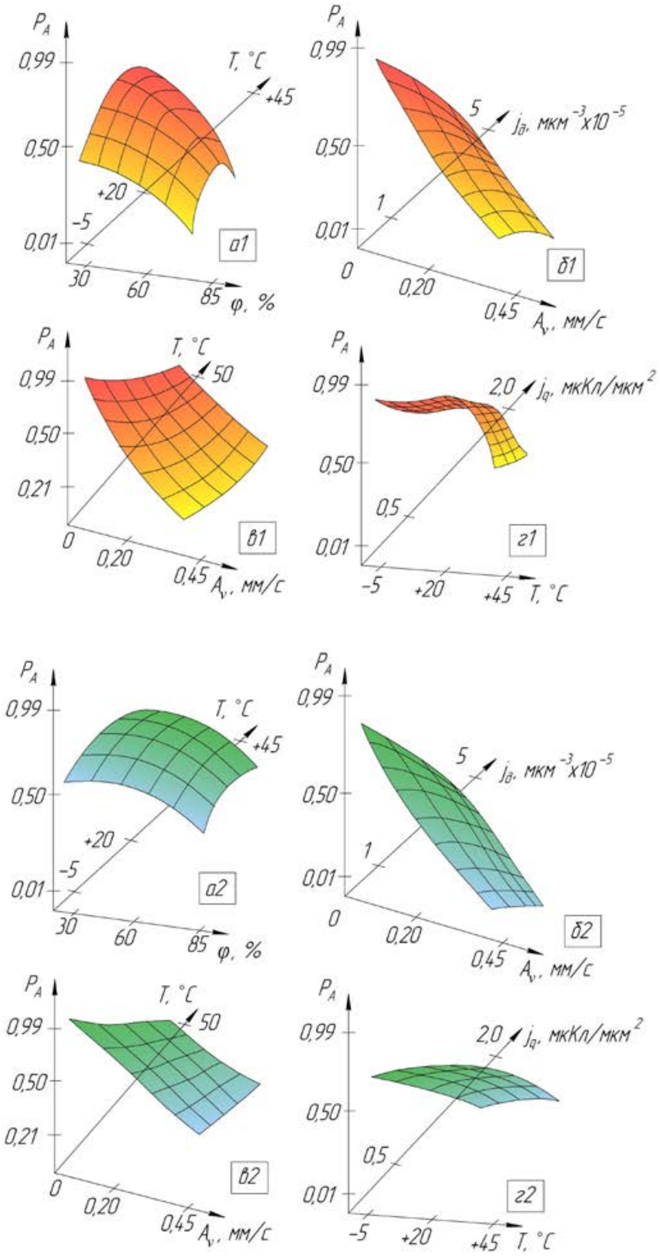

Рис. 2. *Экспериментальные зависимости влияния внешних факторов на вероятность безотказной работы ЗУ разных типов памяти*

Экспериментальные исследования позволили установить, что наибольшее влияние на безотказную работу ЗУ типа DDR2 и DDR4 имеет именно комбинированное действие температуры, влажности, вибраций и электростатического поля. Так, пониженная температура при низкой влажности (рис.2.а1, а2) приводит к уменьшению помехоустойчивости элементов памяти. Это может быть связано с уменьшением электродинамических свойств как проводников, так и полупроводниковых кристаллов с одновременным накоплением электростатического заряда на поверхности этих элементов, что негативно влияет на качество сохранения информации в элементах памяти. С другой стороны (рис.2.в1, в2), температура, которая превышает оптимальные значения, с одновременным влиянием вибрационных колебаний с амплитудой более 0,27 мкм/с приводит к уменьшению вероятности безотказной работы ЗУ на 3-8%. По мнению автора, такое комбинированное влияние вызывает увеличение микро- и нанодефектов в кристалле ЗУ, чем уменьшает его способность накапливать и сохранять информацию (рис. 3) [4].

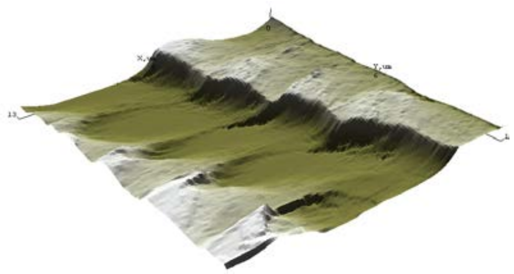

Рис. 3. *АСМ-изображение топограммы участка поверхности элемента памяти с отслоившейся шиной данных вследствие совместного термического и вибрационного действия со стороны внешней среды*

В тоже время, как можно установить из зависимости, приведенной на рис.2.б1, б2, на надежную работу ЗУ большее влияние оказывает высокая плотность поверхностного распределения электростатического заряда, чем вибрации, действующие на элемент памяти. При этом (рис.2.г1, г2) в оптимальном диапазоне температур 20-25 °С наблюдается уменьшение плотности распределения заряда, чем на 2-6 % повышается надежность работы ЗУ.

Проведя сравнение между элементами памяти DDR2 и DDR4, установлено, что влияние вышеперечисленных внешних факторов больше сказывается на элементах памяти первого типа (DDR2), что связано с большей технологичностью и помехоустойчивостью элементов памяти второго типа (DDR4). Это лишний раз подчеркивает факт необходимости применения в системах критического применения именно современных элементов памяти.

4. Заключение

В ходе проведенных исследований было изучено влияние факторов окружающей среды (температуры, влажности, вибрация и электростатических полей) на работоспособность элементов памяти, которая работает в критических условиях, и показано:

1. Наибольшее влияние на работоспособность ЗУ имеет комбинация таких внешних факторов, как: температура, влажность, вибрации и электростатические поля, однако подбор оптимальных условий позволяет повысить вероятность безотказной работы ЗУ.

2. Показано, что современные элементы памяти, например, типа DDR4 имеют преимущества по сравнению с устаревшими (DDR2), а также большую работоспособность и помехоустойчивость, чем повышают время надежной эксплуатации систем критического применения в 1,5-2 раза.

5. Список литературы

1. Техническая механика микросхем / В.Н. Тимофеев // М.: БИНОМ. Лаборатория знаний, 2011. – 176 с.
2. ГОСТ Р 52567-2007 Автомобили скорой медицинской помощи. Технические требования и методы испытаний.
3. Регламентирование проведения многоверсионного диагностирования запоминающих устройств с учетом полупериодов деградации / В.А. Андриенко, В.Г. Рябцев, Т.Ю. Уткина // Радіоелектронні і комп’ютерні системи. – 2008. – №7. – С. 135-140.
4. Перспективи використання методу атомно-силової мікроскопії при комплексному контролі елементів приладів точного приладобудування / В.С. Антонюк, Ю.Ю. Бондаренко, М.О. Бондаренко, С.О. Білокінь, В.О. Андрієнко // Перспективні технології та прилади. Збірник наукових праць. – 2014. – Вип. 5. – С. 5-9.

VIRTUAL FULL FACTORIAL EXPERIMENT IN THE SIMULATION OF A CONTINUOUS PROCESS SPD COMMERCIALLY PURE TITANIUM WITH THE INFLUENCE OF FRICTION FACTOR

ВИРТУАЛЬНЫЙ ПОЛНЫЙ ФАКТОРНЫЙ ЭКСПЕРИМЕНТ ПРИ МОДЕЛИРОВАНИИ НЕПРЕРЫВНОГО ПРОЦЕССА ИПД ТЕХНИЧЕСКИ ЧИСТОГО ТИТАНА С УЧЕТОМ ВЛИЯНИЯ ФАКТОРА ТРЕНИЯ

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Abstract: *With the use of computer modeling in the environment of the DEFORM-3D software, a virtual full factorial experiment has been conducted for the processing of commercially pure titanium by equal-channel angular pressing (ECAP) via the Conform scheme. In the course of the modeling, the effect of independent parameters (the rotation velocity of the working wheel, the friction factor on the lateral surfaces of the working wheel and the friction factor between the billet and the die) has been evaluated. As a result of the experiment, a regression equation has been obtained and the most important individual factors and their mutual combinations that influence the response parameter (strain intensity) have been identified.*

KEYWORDS: *COMPUTER MODELING, COMMERCIALLY PURE TITANIUM, VIRTUAL FULL FACTORIAL EXPERIMENT, FRICTION FACTOR, STRAIN INTENSITY.*

1. Introduction

Currently, there is interest in research aimed at enhancement of the strength of metals by microstructure refinement to a submicrocrystalline (SMC) size using severe plastic deformation (SPD) processing [1]. One of the SPD processing techniques is equal-channel angular pressing (ECAP) [2, 3] and its advanced modification - ECAP-Conform [4], which was developed to produce long-length billets with a bulk SMC structure and enables creating preconditions for practical implementation of SPD processing. Fig. 1 illustrates the principle of the ECAP-Conform process.

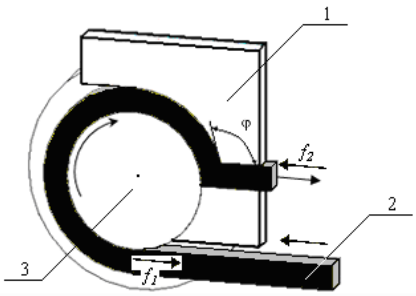

Fig. 1. *Principle of an SPD technique - equal-channel angular pressing - Conform (ECAP-Conform): 1 – stationary die; 2 - billet; 3 – working wheel - punch*

This process, based on structure refinement by SPD processing and implemented on an ECAP-Conform setup, is an effective way to increase the strength of metals and alloys. However, to produce long-length semi-products using this process, it is necessary to solve the problem caused by a revealed contradiction. This contradiction lies in the fact that to feed the billet in the deformation zone, it is necessary to use active friction force on the lateral surfaces of the working wheel, i.e. to have the maximum friction coefficient (f_1). At the same time, to implement directly the deformation process and produce high-quality semi-products with a defect-free surface, it is required to ensure the lowest value of the friction coefficient (f_2) in the deformation zone.

The use of fragmentary application of a lubricant only on those surfaces where it is necessary to have a low friction coefficient leads to lower productivity and mechanization of SPD processing. The processing, which is already not cheap, becomes even more expensive. Thus, to improve the efficiency of SPD processing by the ECAP-Conform technique is necessary to find a compromise solution, which would enable the use of one option of preparation of the billet surface prior to deformation processing, able to ensure the feeding of the billet in the deformation zone and fabrication of semi-products of the required quality in the deformation process.

In scientific and practical activities, in particular, in the analysis of tribological systems, of significant importance are numerical methods for the study of complex processes, including computer modeling using the latest software products [5, 6]. The efficiency of the methods applied for modeling and solving of engineering problems grows significantly, if at the stage preceding the design of the actual manufacturing process, conditions are created to assess the influence of the most important independent parameters.

The application of mathematical methods is one of the most rational approaches to solving problems related to assessing the effectiveness of non-standard metal forming processes. In this regard, it seems reasonable to conduct numerical simulation using the planning of a virtual full factorial experiment (FFE) [7].

The advantage of FFE is the ability to describe the process in full compliance with the algorithm of physical experiment, taking into account the established assumptions. FFE is the most easily implementable method among the numerous methods of physical experiment. The aim of conducting the FFE is to obtain a linear mathematical model of the process, which will allow defining the future strategy for conducting a real experiment.

Thus, the purpose of modeling is to perform a virtual SPD processing by ECAP-Conform with the use of FFE, and to identify the rational processing velocity in combination with a universal preparation of the billet surface in the conditions of fabrication of long-length SMC semi-products.

2. Research procedure

In order to obtain more complete information about the studied dependencies, the authors used FFE when performing modeling. Experiment planning is a procedure of selecting the number and conditions of the experiments, which are necessary and sufficient to obtain a mathematical model of the process [8]. It is important to consider the following: a tendency to minimize the number of experiments; simultaneous variation of all variables that determine the process; the choice of a clear strategy that allows making grounded decisions after each series of experiments. Prior to planning a full-scale experiment, it is necessary to gather additional information about the object under study, employing the skills and knowledge obtained in previous studies, or described in literature [9].

The planning of the experiment was conducted on the basis of the modeling of the processing of long-length semi-products from commercially pure titanium, using the ECAP-Conform technique. The principle of the device for ECAP-Conform is presented in Fig. 1.

The object of study is commercially pure titanium VT1-0, the rheological properties of which were entered when developing the numerical model [10].

For the purposes of numerical simulation, the standard application software package (ASP) *DEFORM-3D* was applied.

To perform the simulation and factorial experiment with the *DEFORM-3D* software, three-dimensional models were preliminarily created with the *Kompas-3D* software.

Assumptions

1) The material of the billet in the initial state is isotropic and has no initial stresses and strains;

2) The temperature of deformation is assumed to be 200°C;

3) The angle of the channels intersection is 120°;

4) The tool is absolutely rigid, and the geometry of the tool is taken into account automatically;

5) The initial billet material is assumed ductile;

6) The selected number of modeling steps is 100, taking into account a full passage of the billet through the die and obtaining a stable result;

7) The billet is divided into 43553 trapezoidal elements.

We believe that at the stage of preparation of the modeling task, the most significant factors influencing the fabrication of defect-free semi-products in the conditions of severe deformation at a temperature of 200° C are factors of friction (contact parameters) of the billet with different parts of the tool and the deformation velocity, conditioned by the rotation velocity of the working wheel. In this connection, it was decided to perform a virtual FFE using a two-level model with three unknown variable factors, followed by the formalization of the results in the form of a regression equation and the optimization of the selected factors.

Thus, as independent variables in the process of drawing with shear, characterizing the running of the process and its effectiveness from the point of view of the deformation force, we chose the friction factor from the upper and lower surfaces of the working wheel, which determines the efficiency of feeding of the billet in the deformation zone, f_1 (X_1), the friction factor from the forming tool parts, f_2 (X_2), the deformation velocity (the rotation velocity of the working wheel) V (X_3). The deformation force P (Y) was determined as the response parameter (dependent parameter).

The factors were varied at two levels. The variation intervals of the variable factors and their real-scale values are shown in table 1.

Table 1. Factor levels

Factors	X_1	X_2	X_3 (*V, m/min.*)
Basic level (X_i)	0.50	0.50	20
Variability interval (ΔX_i)	0.25	0.25	10
Upper level ($x_i = 1$)	1	1	30
Lower level ($x_i = -1$)	0	0	10

The number of experiments N was determined from the number of factors k in accordance with the formula:

$$N = 2^k = 2^3 = 8 \qquad (1)$$

It is required to determine such values of f_1, f_2, V, at which the lowest deformation force P is ensured.

3. Experimental results and discussion

The mathematical model after the implementation of the full factorial experiments takes the following form:

$$y=b_0+b_1x_1+b_2x_2+\ldots+b_{12}x_1x_2+b_{13}x_1x_3+ +b_{23}x_2x_3\ldots+b_{123}x_1x_2x_3, \qquad (2)$$

where b_i is the regression coefficient.

For calculating the coefficients of this model, the extended matrix of experiment planning and results has been used (table 2).

Table 2. *Extended matrix of plan 2^3 and results of experiments*

Experiment No.	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	*Y (kN)*
1	+	+	+	+	+	+	+	+	13.3
2	+	-	+	+	-	-	+	-	16.5
3	+	+	-	+	-	+	-	-	10.7
4	+	-	-	+	+	-	-	+	12.7
5	+	+	+	-	+	-	-	-	23.2
6	+	-	+	-	-	+	-	+	19.8
7	+	+	-	-	-	-	+	+	13.5
8	+	-	-	-	+	+	+	-	12.9

Fig. 2 *illustrates the solution of the problem of numerical simulation of the ECAP-Conform process, as a result of which the minimum deformation force has been obtained.*

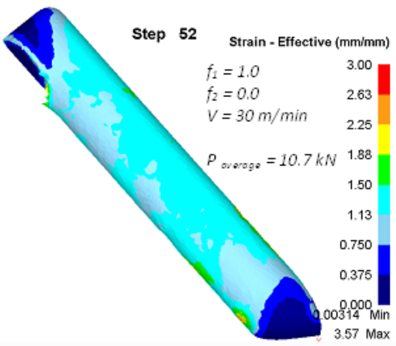

Fig. 2. *The result of the simulation of the ECAP-Conform process: distribution fields of accumulated strain. Deformation force $P_{average}$ = 10.7 kN*

The regression coefficients were calculated using the formula:

$$b_i = \frac{\sum_{i=1}^{N} x_i y_i}{N}, \qquad (3)$$

where $i = 0, 1, 2, \ldots, 8$.

On the basis of the calculations, the following general form of a linear regression equation has been obtained:

$$y=15.33X_0-0.15X_1+2.88X_2-2.03X_3+0.20X_1X_2-1.15X_1X_3-1.28X_2X_3-0.50X_1X_2X_3 \qquad (4)$$

Equation (4) shows that the most significant influence on the deformation force is exerted by the friction factor in the sliding contact between the billet and the tool f_2 (X_2) and the deformation velocity V (X_3). Moreover, it can be seen from the coefficients of the regression equation that the deformation force will decrease with an increase of both factors. A much smaller influence on the deformation force is exerted by the active friction factor f_1 (X_1) from the upper and lower surfaces of the working wheel which feeds the billet in the deformation zone. While the greatest and unidirectional influence is extered by the factors X_2 and X_3, it becomes possible to select the option of universal preparation of the billet surface. It should be noted that double and triple mutual interactions have ambiguous interpretations, and therefore complex interactions should be analyzed separately and with reference to the specific operating conditions of a multicomponent system.

A priori, it can be stated that in the considered conditions the minimum value of the deformation force can be obtained at the optimal combination of the independent parameters adopted in this study.

It is of practical interest to solve the optimization problem dealing with defining the actual values of the independent parameters considered in the virtual experiment of numerical simulation and providing the minimum value of the deformation force when implementing ECAP-Conform. This task is solved by the "steepest ascent" method [6].

Steps in the variation of the factors were calculated in the real scale. For this purpose, we first identified the product of the coefficients with the corresponding intervals of factor variation, i.e. $b_i \Delta X_i$, then in proportion to these products steps were assigned. Using the values of $b_i \Delta X_i$, the steps in the variation of the factors were determined as follows. From the technological considerations, the step in the variation of the factor of friction from the upper and lower surfaces of the working wheel was selected (Δ_1 = 0.05). The steps for the other factors were derived from the following proportions:

$$\frac{b_1 \Delta X_1}{b_2 \Delta X_2} = \frac{\Delta_1}{\Delta_2}; \frac{b_1 \Delta X_1}{b_3 \Delta X_3} = \frac{\Delta_1}{\Delta_3}, \tag{5}$$

The sequence of the stages of the steepest ascent is presented in table 3.

Table 3. Steepest ascent

Factors	X_1 (the factor of friction from the upper and lower surfaces of the working wheel, f_1)	X_2 (the factor of friction from the forming tool parts, f_2)	X_3 (the deformation velocity V, m/min)	Y (the deformation force P, kN)
b_i $b_i \Delta X_i$ Step Step after rounding	0,25 0,125 0,05 0,05	-0,8 -0,4 -0,16 -0,2	-0,2 - 4,0 - 1,6 - 5,0	
Basic level (X_i)	0,5	0,5	20	
Mental experiment Practical experiment Mental experiment	0,45 0,45 0,55	0,3 0,3 0,7	15 20 15	13,20
Mental experiment Practical experiment Mental experiment	0,55 0,55 0,45	0,3 0,7 0,7	25 15 20	17,90
Mental experiment Practical experiment Practical experiment	0,55 0,55 0,55	0,3 0,3 0,3	20 30 10	 12,20 14,50

Some of the mental experiments were implemented in a computer model (Table 3). Experiment planning using the steepest ascent showed that under these conditions the deformation force will be minimum at high friction from the upper and lower surfaces of the working wheel ($f_1 \approx 1.00$), at the friction, tending to the minimum values, from the forming tool parts ($f_2 \approx 0.00$), as well as at a high deformation velocity ($V \approx 25$ m/min). If the indicated values of independent parameters are observed, it is possible to ensure the deformation force $P \approx 10.7$ kN (Fig. 2). However, the objective of the study was to provide SPD processing by ECAP-Conform with the minimum possible deformation force under the condition of a universal preparation of the billet surface.

By solving the inverse problem we were able to choose such an option of universal surface preparation and deformation force, at which the value of the deformation force $P \approx 12.5$ kN, which is quite acceptable, is achieved.

Here, it is necessary to ensure $f_1 = f_2 = 0.3$ and the deformation velocity $V \approx 30$ m/min.

Fig. 3 shows the simulation results for the above values of variable factors in the context of the stated task of the study.

Thus, a universal preparation of the billet surface is possible, ensuring the minimum value of the deformation force. On this basis, for a practical implementation of processing of commercially pure titanium by ECAP-Conform, an option of preparing the billet surface can be proposed, combining a sub-lubricant layer and a technological lubricant.

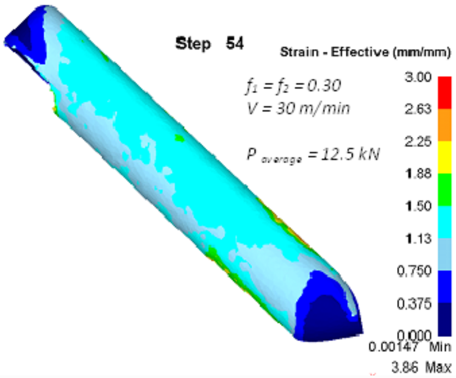

Fig. 3. *The result of the simulation of the ECAP-Conform process after solving the inverse problem: the distribution field of accumulated strain. Deformation force $P_{average}$ = 12.5 kN.*

The rheological properties of such a combination would correspond to a material with a high shear stress in the area of the sliding contact. This assumption requires further research.

4. Practical implementation of the obtained dates

To assess the correctness of the obtained simulation results and their possible use in a real process were made long length semi-finished products of commercially pure titanium. Installation for the implementation of SPD by scheme ECAP-Conform represented in Fig. 4.

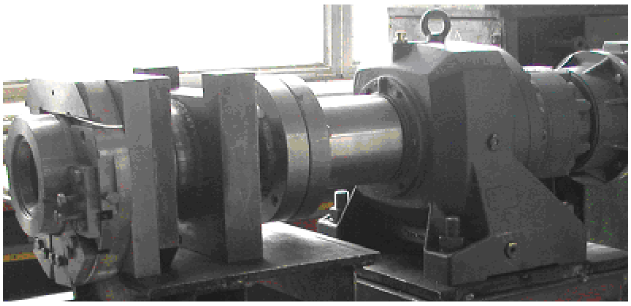

Fig. 4. *The machine for continuous sever plastic deformation.*

For practical implementations use sub-lubricant coating trinitraftorborate in combination with a graphite lubricant on the basis of the polymer and isopropyl spirit for practical implementations use sub-lubricant coating trinitrotoluene in combination with a graphite lubricant on the basis of the polymer and isopropyl spirit. This combined preparation of the billet surface allows providing a coefficient of friction in the region of 0.25 - 0.3 and high shear stress in the lubricating layer in the process according to the scheme of ECAP-Conform. The deformation velocity was 30 m/min.

In Fig. 5 show the semi-finished products of commercially pure titanium after ECAP-Conform. Analysis of semi-finished products showed that the proposed preparation of the workpiece surface ensures the production of defect-free products with the desired surface quality.

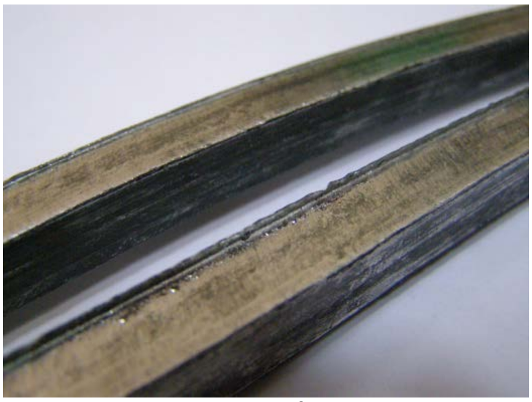

Fig. 5. *Produced semi-finished products*

Conclusions

1. As a result of a virtual full factorial experiment, it has been established that the most significant influence on the deformation force is exerted by the friction factor in the sliding contact between the billet and the tool f_2 (X_2) and the deformation velocity V (X_3). It has also been found that the active friction factor f_1 (X_1) from the upper and lower surfaces of the working wheel, which feeds the billet in the deformation zone, has a much smaller influence.

2. The virtual full factorial experiment, conducted using the steepest ascent method in the process of numerical simulation, has allowed us to determine the numerical values of friction factors from the upper and lower surfaces of the working wheel, f_1 and from the forming parts of the tool, f_2, which are universal for the SPD processing of commercially pure titanium by the ECAP-Conform technique.

3. For a practical implementation of processing of commercially pure titanium by ECAP-Conform, an option of preparing the billet surface can be proposed, combining the application of a sub-lubricant layer and a technological lubricant.

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References

[1] R.Z. Valiev, *Bulk Nanostructured Metallic Materials: Production, Structure and Properties.* Moscow: Akademkniga Pub, 2007. – 398 p. (in Russian).

[2] V.M Segal, V.I. Reznikov, V.I. Kopylov, et al. *Processes of Plastic Structure Formation in Metals/*Minsk: Nauka i Tekhnika, 1994. 232 p. (in Russian).

[3] Segal V.M. *Engineering and commercialization of equal channel angular extrusion*//Mater. Sci. Eng. A. – 2004; V. 386.P. 269 – 276.

[4] G.I. Raab, R.Z. Valiev, *Equal-channel angular pressing//*Izvestya Vuzov. Tsvetnaya Metallurgiya -2000 – Vol. 5, p.50-53 (in Russian).

[5] S. Petrović Savić, D. Adamović, G. Devedžić, B. Ristić, A. Matić *Contact Stress Generation on the UHMWPE Tibial Insert*//Tribology in Industry, Vol. 36, No. 4 (2014) 354-360.

[6] A. Belhocine, A.R. Abu bakar, M. Bouchetara *Numerical Modeling of Disc Brake System in Frictional Contact*//Tribology in Industry, Vol. 36, No. 1 (2014) 49-66.464

[7] F.S. Novik, Ya.B. Arsov, *Optimization of Processes in Technology of Metals by Experiment Planning Methods.* Moscow: Mashinostroenie; Sofia: Tekhnika. 1980. 304 p. (in Russian).

[8] Yu.P. Adler, *Pre-planning of Experiments*. Moscow: Znanie. 1978. 72 p. (in Russian).

[9] Yu.P. Adler, *Introducton to Experiment Planning*. Moscow: Metallurgiya. 1969. 158 p. (in Russian).

[10] P.I. Polukhin, G.Ya. Gun, A.M Galkin, *Resistance to Plastic Deformation of Metals and alloys.* Moscow: Metallurgiya. 1976. 486 p. (in Russian).

MECHANICS OF TECHNOLOGICAL INHERITANCE

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Abstract: *Increasing demands for the quality and longer service life of machine parts require methods of strengthening treatment with plastic deformation of the surface (PDS). The PDS processes become significantly more efficient when technological inheritance is taken into consideration. The mechanics of technological inheritance was developed by the author and exemplified by the life cycle of a part, including processes of cutting and PDS as well as fatiguing, which occurs during the operation stage. Theoretical and experimental findings include key patterns of technological inheritance and can be applied to engineering of efficient strengthening processes.*

Keywords: TECHNOLOGICAL INHERITANCE, DEFORMATION SITE, DEGREE OF SHEAR DEFORMATION, PLASTICITY RESERVE

1. Introduction

One of the crucial challenges of contemporary machine engineering is to make sure using processing methods that machine parts have a longer service life. The service life of machine parts is, in many ways, determined by the behavior of the surface layer. Its parameters are formed throughout the entire design process. Among the processing methods which improve the service life of a part at final stages of the processing route are the methods of plastic deformation of the surface (PDS) that are widely applied to manufacture. Practical application has proven that with the correctly assigned modes of PDS the service life of a part can increase 5 times or more. At the same time, the incorrectly assigned PDS modes and disregard of properties accumulation occurring prior to PDS can cause the rupture of the surface during the manufacture or premature failure of the part during operation.

When designing a route for strengthening machining and when evaluating the service life of a machine part technological inheritance (TI) has to be taken into account. This means exposing and applying the functional dependencies between the parameters of the surface behavior and performance parameters. That, in its turn, requires an analysis of that behavior initiation at all stages of the life cycle of a part. In most cases, the dependency between the surface layer and technology, on the one hand, and the surface layer and the part service life, on the other hand, is established empirically. That, in its turn, contradicts to the practical application needs because new materials, new articles and new operation conditions require a whole new set of time-consuming and labor-intensive experiments.

The author underlines four crucial aspects.

1. Manufacturing engineering is developed to the point when the accumulation of scientific facts and findings do not generate new knowledge any more.
2. High rates of machine engineering development, occurrence of new materials and more complicated machine operation environment require a shorter period for design-to-manufacture facility by reducing experiments and increasing design work. That, in its turn, generates the necessity in more complex but also more accurate models of metal behavior under loading. It is especially critical for strengthening treatment.
3. A plethora of specific data, unfortunately, can not always make the basis for contemporary automated process engineering techniques. That requires the exposure and description of physical dependencies between the phenomena and processes under study. It also requires making the information obtained systematic and structured to be further used in contemporary information technologies.
4. The patterns of technological inheritance are too complex to be exposed as various stages of surface stressing (e.g., cutting, plastic deformation of the surface, operation fatiguing) are currently studied by means of various methodologies and definitions.

Despite the complexity of the phenomena that develop in the surface layer, the author has described them from a phenomenological perspective using the fundamentals of the mechanics of deformable environments. The core of this approach is that the physical behavior of the surface layer is interpreted as a result of the plastic flow of metal within the deformation site, with the plastic flow developing under the conditions of complex stress-strain behavior. This approach includes not only the conventional parameters of surface layer behavior such as roughness, waviness, hardness, residual stresses but also the degree of shear deformation, degree of plasticity reserve depletion, which are well-known in strain theory.

The life cycle of a part is seen as a continuous process of depletion by the metal surface layer of plasticity reserve. The stages and steps of such process are controlled by stressing programs.

The models of formation and transformation of the surface layer during cutting, plastic deformation of the surface (PDS) and operation fatiguing were developed and patterns of such phenomenon were studied. The end-to-end analysis and computations of hereditable deformation parameters of the surface layer during machining and operation of parts were carried out.

In addition to the above, the processes occurring in the surface layer were described in a way adapted to the use by engineers.

1. Problem solution: prerequisites and aids

Technological inheritance is one of the key areas of research study in machine engineering, which has been done in the Soviet Union and Russia since 1930s.

When analyzing how accurate metalcutters can process machine parts, Sokolovsky A.P. found that inaccuracies copy themselves throughout the entire design process [1]. Kovan V.M. suggested a dimensional analysis from the final (assembly) to the initial (workpiece) manufacturing stages [2]. At that time the part to be manufactured carried hereditary information and its accuracy characteristics were getting “copied” (inherited) throughout the entire design process.

By early 1960s demands for reliability of machine parts increased and that, in its turn, required a new approach to evaluating engineering procedure. After performing a set of studies researching the accuracy and quality of the surface of parts of bearings Yatsheritzyn P.I. established that the properties of treated surfaces had to be studied in relation to the whole set of performed operations [3]. Together with Ryzhov E.V. and Averchenkov V.I. he showed that a design process includes certain “barriers” that disrupt some parameters describing the surface layer of a product [4]. There are positive and negative factors of technological inheritance. During process engineering the structure of a process should involve operations, which would generate more obstacles for negative factors to reach the final operation.

A.M. Dal’skiy proved that inheritance played a role in making sure that high-precision parts of machines are reliable [5]. Together with A.S. Vasilyev and A.I. Kondakov, he gained new knowledge about process environments [6]. Primary forms of inheritance were established such as parametric and structural and, also, the inheritance of interaction characteristics between a workpiece and its external environment, which are found in process environments at various levels. The prevalent opinion is that hereditary information is carried by the thin surface layer, which is getting formed throughout the entire design process.

A.G. Suslov believes that technological inheritance is represented by various structural models [7].

The author of this article developed the scientific foundation for the mechanics of technological inheritance. Its fundamentals are shown below [8].

1. The conceptual foundation of technological inheritance is formed by the fundamentals of the strain and fracture mechanics.
2. The TI mechanics is based on the categories of life cycle (LC) and continuous processes of deformation accumulation and depletion of plasticity reserve in the metal surface layer of a part during machining and operation that follows.
3. The fundamentals of TI mechanics are exemplified by the life cycle of a part, including cutting, plastic deformation of the surface and operation fatiguing affected by cyclic loading.
4. Each machining or operation step is seen as a stressing stage. Stressing stages are interpreted through stressing programs and how complete they are. They are described in terms of the phenomenology of deformation accumulation and plasticity reserve depletion.
5. Stressing stages are divided into a set of steps of quasimonotonous deformation, which determine the patterns of deformation accumulation in the surface layer of a part.
6. Operation fatiguing, in its turn, involves two stages. The first one begins with cyclic loading and ends with the point of the complete depletion of plasticity reserve and the occurrence of visible faults (cyclic life stage). The second stage begins with the point of surface material discontinuity and ends with the complete failure of a part (separation into fragments) and is described with the cyclic crack growth diagram (cyclic crack growth stage).
7. Interrelated deformation processes occur in the surface at each stressing stage and step. According to the ideas of mechanics, during stressing at each stage there occurs a deformation site (DS), plastic deformations accumulate, plasticity reserve of metal is gradually depleted, residual stresses occur and transform. Thus, the surface layer is getting formed with specific hereditable properties.
8. Ontological models of processes are based on the patterns of formation and transformation of the deformation site at the stages of life cycle.
9. At each stage the deformation site forms under the exposure to stressing. The behavior of the DS reflects the surface behavior. The DS is the carrier of hereditary information; its form, dimensions and behavior are fully and adequately determined by the properties accumulated (inherited) prior to that.
10. TI is seen as a common pattern when deformation accumulation at a certain quasimonotonous stage is determined by stressing program and its history. The evaluation of stressing programs is made on the basis of the computation of DS stress and strain state (SSS).
11. Stressing history is described in terms of stressing programs within the prior time periods. Stressing history affects the stressing programs at a certain stage by altering the intensity of deformation accumulation and plasticity reserve depletion.
12. TI is exemplified by the terms of non-hereditable (reversible) and hereditable (irreversible) damage or by the terms of depleted and residual plasticity reserve.
13. The TI mechanics governs engineering techniques of new design of strengthening treatment by means of PDS, of plasticity control and of efficient control for the surface behavior at each stage of stressing by means of physical methods.

3. Solution to the problem under discussion

We are discussing the life cycle of a machine part undergoing the stages of cutting, plastic deformation of the surface and stressing with the exposure to operation cyclic loading. A more characteristic type of fatiguing is multicycle stressing of a machine part, which, in its turn, includes two stages such as cyclic life and fatigue crack growth.

Parameters known as terms of mechanics of deformable solids are used for TI mechanics problem solving:

- Stress state index:

(1) $$\Pi = \frac{\sigma}{\mathrm{T}} = \frac{1/3(\sigma_1+\sigma_2+\sigma_3)}{1/\sqrt{6}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}};$$

- Degree of shear deformation:

(2) $$\Lambda = \\ = \langle \frac{2}{\sqrt{3}} \int_0^t \sqrt{\frac{1}{2}\left[\left(\xi_x-\xi_y\right)^2+\left(\xi_y-\xi_z\right)^2+(\xi_z-\xi_x)^2\right]++\frac{3}{4}(\eta_{xy}^2 + \eta_{yz}^2+\eta_{zx}^2)}\rangle\, dt;$$

- Residual stress tensor:

(3) $$[\mathrm{T}\sigma_{\text{ост}}]_{ij} = \left[\mathrm{T}\sigma_{\text{деф}}\right]_{ij} + \left[\mathrm{T}\sigma_{\text{раз}}\right]_{ij} + [\mathrm{T}\sigma_t]_{ij};$$

- Degree of plasticity reserve depletion [9]:

(4) $$\Psi = \Psi_1+\Psi_2 = \Psi_1 + (\Psi_{21}+\Psi_{22}) = \\ = n\varphi_0 \int_0^{\Lambda_k} \Lambda_i^{n-1} d\Lambda + \left(\int_0^{\Lambda_k} \frac{d\Lambda}{\Lambda_p} - \varphi_0 \int_0^{\Lambda_k} \Lambda_p^{n-1} d\Lambda\right),$$

where σ – average normal stress; T – shear stress intensity; $\sigma_1, \sigma_2, \sigma_3$ – principal components of a stress tensor; $\xi_x, \xi_y, \xi_z, \eta_{xy}, \eta_{yz}, \eta_{zx}$ – components of a deformation rate tensor; $\left[\mathrm{T}\sigma_{\text{деф}}\right]_{ij}$ – load stress tensor; $\left[\mathrm{T}\sigma_{\text{раз}}\right]_{ij}$ – unloading stress tensor; $[\mathrm{T}\sigma_t]_{ij}$ – thermal stress tensor; Ψ_1– component dependent on flow stress or on accumulated deformation; Ψ_2 – component dependent on metal plasticity with $\Pi = const$; Λ and Λ_p – accumulated and maximum permissible degree of shear deformation with a certain stress state index Π; n – strain-hardening coefficient; φ_0 – coefficient determined by plasticity tests. In unstrengthened metal $\Psi = 0$, when plasticity reserve is completely depleted, $\Psi = 1$.

The TI mechanics is based on continuous deformation accumulation and plasticity reserve depletion in the surface of a part affected by stressing programs.

Strengthening curve $\sigma_s = \sigma_s(\Lambda)$, ultimate plasticity curve $\Lambda_p = \Lambda_p(\Pi)$ and fatigue crack growth diagram $V = V(K)$ in the coordinates «stress intensity coefficient K– fatigue crack growth rate V» are used as initial metal characteristics.

It is assumed that the surface behavior is known and is described in terms of deformation mechanics for the case of annealed work material as

(5) $$\begin{cases} \Lambda_{ij|i=0,j=0} = 0; \\ \Psi_{ij|i=0,j=0} = 0; \\ \Lambda_p = \Lambda_p(\Pi); \\ [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=0,j=0} = 0, \end{cases}$$

where i stands for the number of a stressing stage and j – for the number of a quasimonotonous step at this stage.

It is established that machining by cutting and by plastic deformation of the surface comprises three steps of quasimonotonous deformation. Deformation alternates where these steps approach each other and plasticity reserve partially recovers.

The first stage – cutting – starts with initial (zero) values of deformation and of degree of plasticity reserve depletion (fig. 1).

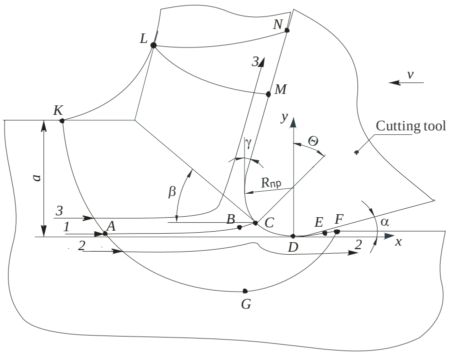

Fig. 1. *Orthogonal cutting model:*
α – rear angle; γ – front angle; ρ – tool edge radius; Θ – indentation angle; a – cutting depth; S – feed

According to the flow pattern, deformation site *KLMCDEFGAK* is seen to comprise two areas: higher and lower than some current line 1, which overlaps with line *ABC*.

The deformation site contour during cutting is described with a set of points and lines: KL – non-contact swarf edge; LM – end line of metal plastic flow; point M stands for the end of plastic contact of swarf with the cutting tool and point N – point of separation of swarf from the cutting tool front surface, it stands for the end of elastic contact of swarf with the cutting tool; KAG – starting line of metal plastic flow (front boundary of deformation site); point G stands for inmost depth of plastic deformation growth; GF – end line of metal flow (back boundary of deformation site); ABC – critical current line, which separates metal flows into those turning into swarf and those going under the tool; $MCDE$ – cutting tool contour line; EF – back non-contact edge; point E – point of separation of the cutting tool from the treated surface.

The metal plastic flow occurs along current lines with some of them (e.g. current line 3-3) being displaced into swarf and the others (e.g. current line 2-2) being displaced under the tool. Some critical current line 1 (ABC) is the boundary between them.

Deformation accumulates and plasticity reserve is depleted along current lines under the conditions of a certain state of stress with the swarf creating additional hydrostatic stress and altering the nature of SSS in the area of *ABCDEFG*.

Depending on the stressing diagram and degree of plasticity reserve depletion metal flows may split at point *A*, along current line *ABC* (1-1) or at point *C*, which will generate miscellaneous kinds of swarf.

Within the three stages of quasimonotonous deformation: deformation $\Lambda_{\text{рез}}$ accumulates, plasticity reserve is partially depleted by the value of $\Psi_{\text{рез}}$, residual stresses described by tensor $[\mathrm{T}\sigma_{\text{ост}}]_{\text{рез}}$occur in the surface:

$$(6)\quad \begin{cases} \Lambda_{\text{рез}} = \Lambda_{ij|i=1,j=3} = \sum\limits_{j=1}^{j=3} \Lambda_j\,; \\ \Lambda_p = \Lambda_p(\Pi); \\ \Psi_{\text{рез}} = \Psi_{ij|i=1,j=3}; \\ \Psi_{\text{рез}} = \int\limits_0^{\Lambda_{\text{рез}}} \left[n\varphi_0\Lambda_j^{n-1} + \left(1 - \varphi_0\Lambda_p^n\right)\dfrac{1}{\Lambda_p} \right] d\Lambda; \\ [\mathrm{T}\sigma_{\text{ост}}]_{\text{рез}} = [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=1,j=3}. \end{cases}$$

The surface behavior after the treatment by cutting is initial for the stage of PDS (fig. 2).

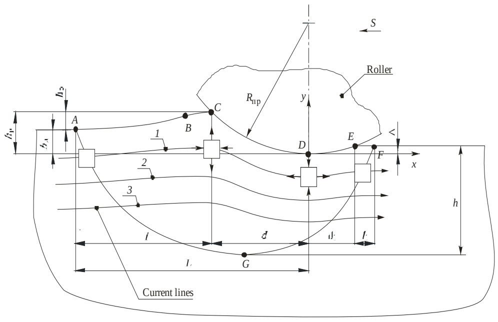

Fig. 2. *PDS model: S – feed; $R_{\text{пр}}$ – contour radius of deforming tool (roller)*

The PDS process is viewed in the axial section of the shaft where the plane of principal deformations is located. The following points, lines and areas were specified in the DS cross-section: $h_{\text{д}}$ – active preload, equal to the depth of the tool indentation; $h_{\text{в}}$ – height of elastic and plastic wave prior to the deforming tool; $h_{\text{р}} = h_{\text{д}} + h_{\text{в}}$– estimated preload, equal to the elevation view of the contact front arch; Δ – height of elastic and plastic metal recovery following the deforming tool; Δd– length of the bottom view of the contact front arch (length of the DS contact front zone); d_1 – length of the bottom view of the contact rear arch DE (length of the DS contact rear zone); l – wave length preceding the deforming tool (length of the DS front non-contact area); $L = l + d$ – length of the DS front area; l_1– length of the DS secondary area. Along the DS cross-section plastic deformation occurs at point A and ends at point F. The DS cross-section includes front non-contact area ABC, contact area CDE and rear non-contact area EF. The front non-contact area, in its turn, comprises concave line AB and convex line BC.

When the surface layer is exposed to stressing, material particles move into the DS along current lines 1, 2 and 3, plastic deformation reaches depth h. It results into the surface layer characterized with a various depth for shear deformation, plasticity reserve utilization and residual stress tensor.

Close enough interrelation exists between the DS geometric parameters. Moreover, close interrelation is found between the DS parameters, on the one hand, and segments of treatment modes and surface quality parameters, on the other [8].

The interrelation specified above is used to describe boundary and initial conditions for TI mechanics problem solution.

Residual stresses as a result of cutting are removed during the PDS stage, involving stressing and creation of plastic deformation site. Within the three steps of quasimonotonous deformation: plastic deformation keeps accumulating and plasticity reserve keeps getting depleted. It results in a new behavior of the surface characterized by a specific degree of shear deformation, of plasticity reserve depletion and residual stress tensor:

$$(7)\quad \begin{cases} \Lambda_{ij|i=2,j=0} = \Lambda_{\text{рез}}; \\ \Psi_{ij|i=2,j=0} = \Psi_{\text{рез}}; \\ \Lambda_{ij|i=2,j=3} = \sum\limits_{j=1}^{j=3} \Lambda_j = \Lambda_{\text{ППД}}; \\ \Lambda_p = \Lambda_p(\Pi); \\ \Psi_{\text{ППД}} = \Psi_{ij|i=2,j=3} = \\ = \int\limits_{\Lambda_{\text{рез}}}^{\Lambda_{\text{ППД}}} \left[n\varphi_0\Lambda_j^{n-1} + \left(1 - \varphi_0\Lambda_p^n\right)\dfrac{1}{\Lambda_p} \right] d\Lambda; \\ \Lambda_{\text{мех}} = \Lambda_{\text{рез}} + \Lambda_{\text{ППД}}; \\ \Psi_{\text{мех}} = \Psi_{\text{рез}} + \Psi_{\text{ППД}}; \\ [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=2,j=0} = [\mathrm{T}\sigma_{\text{ост}}]_{\text{рез}}; \\ [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=2,j=1} = 0; \\ [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=2,j=3} = [\mathrm{T}\sigma_{\text{ост}}]_{\text{ППД}}. \end{cases}$$

Value $\Psi_{\text{ППД}}$ stands for a degree of plasticity reserve depletion during PDS, involving the stressing history. Within two machining stages such as cutting and PDS degree of shear deformation $\Lambda_{\text{мех}}$

has been accumulated and plasticity reserve $\Psi_{мех}$ has been depleted. In addition, the residual stress tensor depends on the total accumulated deformation.

The mechanics models for multicycle fatiguing such as cyclic life and fatigue crack growth during operation were introduced.

The initial state for cyclic life is described with values $\Lambda_{мех}$, $\Psi_{мех}$ and $[T\sigma_{ост}]_{ППД}$. This stage is characterized by further accumulation of deformation occurring when tensors of operation (fatigue) $[T\sigma_{уст}]$ and residual $[T\sigma_{ост}]_{ППД}$ stresses go in with each other. Compressive residual stresses after the exposure to PDS result in more favorable fatiguing diagrams.

In each fatiguing cycle the degree of shear deformation continues to accumulate and plasticity reserve continues to deplete itself where there is quasimonotonous deformation. Residual stresses partially get partial relaxation. At the completion moment of cyclic life the residual stress tensor equals to 0.

During cyclic life, deformation $\Lambda_{ЦД}$ has accumulated and plasticity reserve $\Psi_{ЦД}$ has been depleted. As a result, within the three stages of cutting, of PDS and of cyclic stressing ultimate deformation has accumulated and plasticity reserve has completely been depleted at a point of probable surface metal failure. That behavior is denoted by value $\Psi = 1$; there appears a visible crack in the surface.

Further fatiguing (stage of fatigue crack growth) is described in terms of fatigue crack growth diagrams $V = V(K)$ in the coordinates «stress intensity coefficient K– fatigue crack growth rate V». The crack development begins with threshold coefficient of stress intensity K_{th} and ends with the ductile failure of a part specimen corresponding to critical coefficient of stress intensity K_{fc}.

Fatiguing ends with a complete fragmentation of a part, which is described by the parameters of failure damping.

At various stages and steps of the life cycle of a strengthened part any exposure can be applied to an extent that will increase their duration. First of all, we are speaking of thermal exposure that will enable complete or partial recovery of initial properties (metal plasticity reserve). This can be a mechanical action altering the character of load application and generating a new mechanical state of a product and so on. The structure of process model and kinetic equations incorporates other thermal and mechanical stressing stages.

4. Findings and discussion

Theoretical and experimental study of the mechanics of technological inheritance was performed. It is found that the surface properties formation is affected by stressing programs $\Lambda = \Lambda(\Pi)$, which are shown in the coordinates «stress state index Π – degree of shear deformation Λ».

The stressing program-based TI patterns, which have been specified, are shown below.

1. Technological inheritance exposes itself in the formation of hereditary stressing programs in relation to hereditary deformation sites, which act as a set of initial and boundary conditions for problem solution occurring in the strain mechanics.
2. Stressing history is described in terms of the programs occurring at the prior stressing stages.
3. At each following stage technological inheritance manifests itself through the transformation of stressing programs compared to the stressing programs of the material lacking such strain history.
4. Inherited stressing program «fades out» and deformation accumulation rate reduces at each following stage subject to the exponential hereditary law.
5. Residual stress state in terms of inheritance depends on total (accumulated) values of deformation degree and degree of plasticity reserve depletion.
6. Residual stress state together with the stresses caused by external loading forms an index and, thus, forms a stressing program at the stage of cyclic life.
7. Technological inheritance is a pattern. It is a characteristic feature of prior stressing programs to affect the formation of stressing programs at the following stages, which are also the results of specific stressing history of the metal surface of a product.

5. Conclusion

The description of technological inheritance is, first of all, the description of the impact of the complex alternate character of plastic deformation flow within the prior time periods on the formation of properties during the stressing stage under study.

Solving problems by means of terms and concepts of the mechanics of strain does not mean denying conventional beliefs about the surface quality of machine parts. At the same time, it means that in order to study technological inheritance more completely and profoundly, primary (ontological) patterns of surface formation, which have been accumulated throughout science advancement, can be applied as boundary and initial conditions to the solution of problems arising in mechanics.

6. References:

1. A.P. Sokolovskiy, Science behind manufacturing engineering, Mashgiz, Moscow, 1955, 515pp.
2. V.M. Kovan, Calculating machining allowance in machine engineering, Mashgiz, Moscow, 1953, 208pp.
3. P. I. Yashcheritsyn, Technological inheritance and performance properties of parts, Science and technology, Minsk, 1971, 210 pp.
4. P. I. Yashcheritsyn, E.V. Ryzhov, V.I. Averchenkov, Technological inheritance in machine engineering, Science and technology, Minsk, 1977, 256pp.
5. A.M. Dal’skiy, Engineering support of the reliability of high-precision machine parts, Mashinostroyeniye, Moscow, 1975, 223 pp.
6. Technological inheritance in machinery manufacturing, A.M. Dal'skiy, B.M. Bazrov, A.S. Vasilyev and others; in: A.M. Dal'skiy (Ed.), Moscow Aviation Institute Publishers, Moscow, 2000, 364 pp.
7. A.G. Suslov, Quality of the surface layer of machine parts, Mashinostroenie Publishers, Moscow, 2000, 320 pp.
8. V.Yu. Blumenstein, Mechanics of technological inheritance during treatment and operation of machine parts / V.Yu. Blumenstein, V.M. Smelyanskiy, Mashinostroyeniye-1, Moscow, 2007, 400 pp.
9. Yu.K. Filippov, Evaluation criterion for the quality of parts produced by cold forging//Forging and stamping production, 1999, № 2, P. 3-9.

BASIC FINANCIAL CALCULATIONS USING INFORMATION SYSTEMS FOR SOLVING BUSINESS TASKS

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An Introduction

A detailed study of the financial concepts fundamentals certainly is to give some idea on the concepts of finance. The investment world can be confusing for the investors. The investors need to go through some finance theories which will help them to understand the market behavior in a better way. There are a number of factors that influence the functioning of the investment market. The individual investor's choice of investment may vary from one person to another. While some investors go for investing in the risky securities, some investors tend to play safe in the market by investing in the less risky environment.

The finance theory concept including studying the various ways by which businesses and individuals raise money, as well as how money are allocated to projects while considering the associated with them risk factors.

1. The concept of finance theory

The concept of finance also includes the study of money and other assets, managing and profiling project risks, control and management of assets, and the science of money managing. Simply, 'financing' also means provision and allocation of funds for a particular business module or project. There are a number of finance theories that offer separate approaches to the finance hypotheses. Some of the major popular finance theories of the world are: Arbitrage Pricing Theory, Rational Choice Theory, Prospect Theory, Cumulative Prospect Theory, Monte Carlo Option Model, Binomial Options Pricing Model, Gordon Model, International Fisher Effect, Black Model, and Legal Origins Theory

2. Financial Services Company

The finance industry provides to the clients a number of services. There are different types of financial services which company can provide to different commercial sectors as well as to the individuals. Some of that types of financial services are lending money for different purposes, insurances, depository services, mortgage services, investment services, credit rating services and many more. The different types of financial services jointly create one of the largest industries of the world. Every individual as well as institution has a definite income source and a particular way of expenditure. These particular sources of income, habit of investment and expenditure habit, all come under the domain of finance. Several important finance concepts have been developed through close study of all these things [2].

3. Financial Goal - Profit versus Wealth

Every firm has a predefined goal or an objective. Therefore the most important goal of a financial manager is to increase the owner’s economic welfare. Here economics welfare may refer to profit maximization or maximization of shareholders wealth. Therefore Shareholders wealth maximization (SWM) plays a very crucial role as far as financial goals of a firm are concerned. Profit is the remuneration paid to the entrepreneur after deduction of all expenses. Maximization of profit can be defined as maximizing the income of the firm and minimizing the expenditure. The main responsibility of a firm is to carry out business by manufacturing goods and services and selling them in the open market. The mechanism of demand and supply in an open market determine the price of a commodity or a service. A firm can only make profit if it produces a good or delivers a service at a lower cost than what is prevailing in the market. The margin between these two prices would only increase if the firm strives to produce these goods more efficiently and at a lower price without quality compromising. The demand and supply mechanism plays a very important role in determining the price of a commodity. A commodity which has a greater demand commands a higher price and hence may result in greater profits. Competition among other suppliers also effect profits. Tendency is manufacturers to move towards production of those goods which guarantee higher profits. As result comes a time when equilibrium is reached and profits are saturated.

According to Adam Smith – business man while are fulfilling the own goals for profit in turn benefits the whole society. Obviously when a firm tends to increase profit it eventually makes use of its resources in a more effective manner. Profit is regarded as a parameter to measure firm’s productivity and efficiency. Firms which tend to earn continuous profit eventually improvise their products according to the consumers demand. Bulk production due to massive demand leads to economies of scale which eventually reduces production cost. Lower production cost directly impacts the profit margins. Profit maximization objective is a little vague in terms of returns achieved by a firm in different time period. When measuring profit the time value of money is often ignored. It leads to returns uncertainty. Two firms which use same technology and same factors of production may eventually earn different returns. It is due to the profit margin. It may not be legitimate if seen from a different stand point [5], [6].

4. Importance of Cash Flow

In case of both personal and business finance, cash flow is an important concept. It is more important with regard to solvency. Cash flow is used as a documentation of past investments and earnings. It is also used by the business entities in order to represent the direction where they want to take their company. In the present competitive world the business cash flow becomes an important phenomenon. It is assumed that people like creditors and brokers that the person or business entity that has a decent cash flow record is in a better position to make his payments at the right time. Thus it becomes easier for such parties to obtain finance for various purposes.

Equational Representation of DCF

The Discounted Cash Flow could be represented through the following equation:

$$\mathbf{DCF = CF1/(1+r)^1+CF^2/(1+r)^2+ \ldots +CF^n/(1 + r)^n}$$

In this formula CF stands for cash flow and r represents the rate of discount.

Discounted Cash Flow in Mathematics

The method of Discounted Cash Flow is used in Mathematics as well. The formula for discounted Cash Flow has been deduced from the future value formula. The future value formula is used to calculate the following:

*** Compounding Returns**

*** Time Value of Money**

5. Basic principles of finance

It is a basic principle of finance that separate amounts of money cannot be equated, added or subtracted if they are at different times. Interest is present in all of the problems we consider. This means that, looking backward a dollar today is worth less yesterday, or, looking forward, it is worth more tomorrow. The principle of bringing all amounts to a common point, usually called a pivot point, is absolutely fundamental when solving finance problems. Complete freedom of choice is available for the pivot point, as the correct answer to a finance problem does not depend on the chosen pivot point. Therefore, the pivot point is usually chosen for convenience of calculation.[4],[10]

The basic principles and equations are developed for elementary finance, based on the concept of compound interest. The five quantities of interest in such problems are present value, future value, also amount of periodic payment, number of periods and the rate of interest per period.

The fundamental mathematical topics on which elementary finance is based are the arithmetic and geometric sequences. Other terms in use are AP and GP, where the "P" stands for progression, an older term for sequence. Arithmetic sequences correspond to problems where simple interest is used, and geometric sequences to those involving compound interest. We do not consider arithmetic sequences and simple interest here.

A sound understanding of basic finance is a very important and useful skill for life, even if a career in finance is not the ultimate goal. At least in western societies, everyone needs at least a basic understanding of the implications of borrowing or investing money in a compound interest environment. With the advent of the modern electronic spreadsheet, as exemplified by Microsoft Excel, it is now not only possible, but rather easy to improve drastically on this approach to the teaching of basic finance.

In the spreadsheet environment, we advocate a three-pronged approach, and it is tacit that all three approaches must yield the same result for any given problem. The approaches are:

- Traditional algebraic formulas, sometimes supplemented with the powerful Goal Seek
- Linear recursive schedule, also sometimes with Goal Seek
- Excel intrinsic financial functions

6. The basic equation

$$FV = PV(1+I)^N$$

FV = future value
PV = present value
I = interest
N = number of periods

7. Excel Spreadsheets. Financial Functions [1], [3], [7], [8], [9], [11]

Below is the list of the 5 most useful ones:

Functions	What it Does
FV	Returns the future value of an investment
NPER	Returns the number of periods for an investment
PMT	Returns the periodic payment for an annuity
RATE	Returns the interest rate per period of an annuity
IRR	Rreturn the Internal Rate of Return for a supplied series of periodic cash flows

7.1. The RATE Function

The question to which RATE brings an answer to is:

- What is the real interest rate if they ask me for a certain amount each period to pay a loan?

	A	Descriptions
1	48	Number of periods (years, months, weeks..etc)
2	$550	Periodic payment
3	$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end of the period (0). If you omit this argument Excel uses "0" saying that the payment is made at the end of each period which is usually the reality when you borrow money.
6	5.00%	The result with the formula using the RATE function. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2

Here is the formula in cell A6:

=RATE(A1,-A2,A3,A4,A5)*12

Notes on the formula: The payment argument is negative (-A2); If you use months as periods and you want an annual rate you multiply by 12, if you use a years as periods and you want an annual rate you don't multiply......; If you don't use the "Percentage" format in cell A6 the result of this example will be 0.05; The formula could also be **=RATE(A1,-A2,A3)*12** the arguments in A4 and A5 being optional

7.2. The PMT Function

The question to which PMT brings an answer to is:
- If I borrow a certain amount of money and I want it repaid at the end of a certain period of time what will be the periodic payment?

	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic payments (years, months, weeks)
3	$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end of the period (0). If you omit this argument Excel uses "0" saying that the payment is made at the end of each period which is usually the reality when you borrow money.
6	-$550.41	The result with the formula using the PMT function.

Here is the formula in cell A6:

=PMT(A1/12,A2,A3,A4,A5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4)and if the payment is annual you don't divide the rate argument (A1) ; The formula could also be **=PMT(A1/12,A2,A3)** the arguments in A4 and A5 being optional; If you want the payment to show as a positive value add a minus sign before the equal sign (**=-PMT(A1/12,A2,A3,A4,A5)**)

7.3. The FV Function (Future value)

The question to which **FV** brings an answer to is:
- If I put a certain amount of money in the bank each month, how much money I will have saved at the end of a certain period of time?

	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic deposits (years, months, weeks)
3	$550	Amount of periodic deposits
4	$0	Beginning balance. If you omit this argument Excel uses "0".
5	1	Deposits made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0". In the case of the FV function make sure that you enter "1".
6	-$29,279.68	The result with the formula using the FV function.

	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic deposits (years, months, weeks)
3	$550	Amount of periodic deposits
4	$0	Beginning balance. If you omit this argument Excel uses "0".
5	1	Deposits made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0". In the case of the FV function make sure that you enter "1".
6	-$29,279.68	The result with the formula using the FV function.

Here is the formula in cell A6:

=FV(A1/12,A2,A3,A4,A5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4)and if the payment is annual you don't divide the rate argument (A1) ; The formula could also be **=FV(A1/12,A2,A3)** the arguments in A4 and A5 being optional; If you want the RESULT to show as a positive value add a minus sign before the equal sign (**=-FV(A1/12,A2,A3,A4,A5)**)

7.4. The NPER Function

The question to which **NPER** brings an answer to is:
- How many months would it take me to repay a certain loan at a certain interest rate if I pay a certain amount each month?

	A	Descriptions
1	5.0%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	$550	Periodic payment

3	$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0".
6	48.26	The result with the formula using the NPER function.

Here is the formula in cell A6:

=NPER(D1/12,-D2,D3,D4,D5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; The second argument MUST BE NEGATIVE; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4)and if the payment is annual you don't divide the rate argument (A1) ; The formula could also be

=NPER(A1/12,A2,A3) the arguments in A4 and A5 being optional;

7.5. The IRR Function (Internal Rate of Return)

The Internal Rate of Return (IRR) indicates the profitability of an investment and therefore is commonly used in business, when choosing between investments.

This measurement uses a series of cash flows (including an initial investment, along with the net income) over a number of periods, to calculate the compounded return, assuming the Net Present Value of the investment is zero.

The value of the IRR is calculated as the value of ***r*** that satisfies the following equation:

$$\sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

where the series of cash flows provide the values for ***Cn*** and ***N*** is the number of periods over which the returns have been made.

The Excel IRR function returns the Internal Rate of Return for a supplied series of periodic cash flows (ie. a set of values, which includes an initial investment value and a series of net income values).

The syntax of the function is :

IRR(values, [guess]),

where the arguments are as follows:

values - A reference to a range of cells containing the series of cash flows (investment and net income values) - must contain at least one negative and at least one positive value

[guess] - An initial guess at what you think the IRR might be. This is an optional argument, which, if omitted, takes on the default value of 10% (=0.1) - This is only a value for Excel to start off working with - Excel then uses an iterative procedure to converge to the IRR.

Conclusion

Each company main goal is to achieve profit, which goal requires additional operations and solving many financial problems. By optimal valuation of the cash flows, applying mathematical financial models and using the capabilities of free software - spreadsheets, management experts of the companies will be able to successfully optimize the company's activities and maximize profits.

Literature

1. Славов Здр., Брусева М, Къновски Р., Анализ на пазари и вземане на икономически решения в условия на неопределеност, ВСУ, Варна, 2012
2. Славов Здр., Брусева М, Анализ на риска при вземане на финансови решения, ВСУ, Варна, 2011
3. Брусева М., Управление на риска, ВСУ, Варна, 2010
4. Асват Дамодаран, Инвестиционная оценка. Инструменты и методы оценки любых активов, изд. ‘Альпина Бизнес Букс’, 2004, ISBN 978-5-9614-0802-7
5. Bergeron B. Essentials of Knowledge Management, John Wiley & Sons, Inc., Hoboken, New Jersey 2003
6. Mertins, K., P.Heisig, J.Vorbeck, Knowledge Management – Concepts and Best Practices, Springer Verlag, Berlin-Heidelberg, 2003
7. http://www.excel-examples.com/annex-4-excel-financial-functions.htm
8. http://www.get-digital-help.com/2012/01/27/free-school-schedule-template/
9. http://epublications.bond.edu.au/ejsie/vol4/iss2/1
10. http://pages.stern.nyu.edu/~adamodar/

THE PROCESSING OF ELECTROCHEMICAL COATINGS THROUGH SURFACE PLASTIC DEFORMATION (SPD)

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Abstract: *Because of the surface oxide film’s presence, a negative electric potential and formation of the disadvantageous residual strains under the galvanic film’s putting on soft metals and alloys, there are the coming of considerable technological complications. This is obstructive to the good interaction between the films and main metal. In this case it is expedient the technological combination the galvanic film of the surface with surface plastic deformation. In this case, the surface plastic deformation is realized by the tools with radial feed of the deforming elements.*
Key words: *surface plastic deformation, electrochemical covers, quality, roughness, precision.*

1. INTRODUCTION

The operating characteristics of the details and their work’s time limit in considerable stage are defined by their roughness.

The applying of the surface plastic deformation (SPD) as a method for finished processing provides the improvement of the relief of the roughness and its parameters [5]. From its side it proofs the operating characteristics of the surface. It can be applied in combination with other technological methods for finished processing. The realized combination proofs physic and mechanicals characteristics of the surface layer metal [1].

The galvanic cover of the metal surfaces is one of the most applied methods for its finished processing. With this their corrosion stability and stability of the wear are rising [2].

With the making of the galvanic covers on soft metals and alloys, there are considerable technological complications which appear, because of the presence the surface oxidized layer, negative electrical potential and forming of the unfavorable remaining voltages. These complications disturb the good interactions between the surface and the main metal [2]. In this case its expedient the technological combination of the galvanic cover of the surface and SPD [1].

On a mass scale in the practice the instruments for SPD with axis feeding found their application. However they are non- applicable with the processing of thin galvanic covers. The reason is the presence of the edge defect and getting of wave in front of the deformation rollers [4].

In this case it’s expedient to be used instruments with radial feeding of the deformation elements which has respective priorities [3].

2. PURPOSE AND OBJECT OF THE RESEARCH

Purpose of the present work is to be examined the technological opportunities for combining of the finished processing with galvanic soft cover and surface plastic deformation in case of recovery of the aluminum pistons for internal-combustion engines.

The objects of the research are the surfaces of the apertures for the piston pins of the diesel engines ЯМЗ-238 НБ и СМД-62.

The pins of this kind of engines are made of aluminum alloy Al25 with high contents of Si. Their hardness after heat-treating is HB 90-130.

There are presented some requirements according to the apertures for the piston pin:

- The precision of the piston’s aperture ЯМЗ-238 НБ is $Ø\ 50^{-0,006}_{-0,015}$ mm; the precision of the piston’s aperture СМД-62 is $Ø45^{-0,005}_{-0,010}$ mm;
- Aperture’s roughness is ***Rz*** = 0,4μm;
- The mutually beating of the apertures is maximum to 0,015mm.

3. EXPOSE

With work the piston is put under considerable mechanical and heat loadings from gases and inertia forces. The high maximum pressures of the gases and high frequency of the working cycles determine the accelerated character of the piston’s loading.

With rendering the technological characteristics of the processing surfaces (presence of grooves and apertures) and the contact interaction of the deform elements with the surfaces, a tool with radial feeding is chosen for the surface plastic deformation [3] – Fig.1.

The tool for surface plastic deformation has two line deformation rollers. It has possibility for simultaneously machining of two apertures in the piston’s tabs.

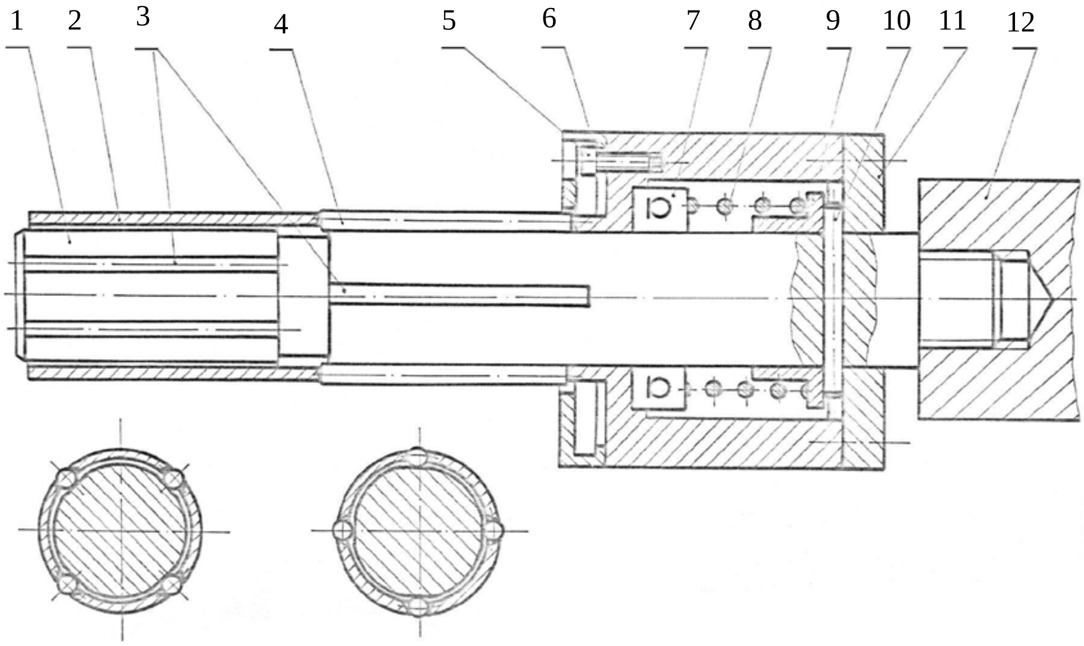

Figure 1: *A tool for surface plastic deformation has two line deformation rollers*

The tool has tubular bearing shaft 1 with chords 3, which made over it; a separator 2 (it carries two line cylindrical rollers 4), which is bearing through the thrust bearing 7 on the bearing shaft 1; a screw 5, a guide insertion 9, a finger 10 (which serve as a fixer), a cap 11 and a tail-end 12.

When the tools is not work situation the fixer 10 ensure establishment of the rollers 4 over the chords 3 and it go into the grooves of the cap 11. In this case the separator 2 and the bearing shaft 1 are immovable together. The tool has diametric size smaller than the diameter of the machining aperture. This allows free tool's movement – in and out of the aperture което позволява свободното му въвеждане и извеждане. The working of the tool is the following: through the tail-end 12, the tool is moved in axis direction till to contact the fulcrum 6 with the front of the detail. The continuing of the movement causes a flexion of the spring 8 from the guide insertion 9 and release the finger 10 from the grooves of the cap 11. In this way the separator 2 gives the possibility for a relatively turning with the rollers 4 round about the bearing shaft 1.

The machining scheme with such tools ensures the galvanic cover from outflow in the two apertures' ends [4].

As deformation elements are used cylindrical rollers from a steel SchCh15 (BDS 12731).They turn over a bearing shaft with chords. The rollers are polished to ***Ra*** = 0,06 – 0,07µm.

The machining by the surface plastic deformation is going on the vertically - boring machine PK-32 with turning frequency 63min^{-1}. The pistons are fixed in an appliance. This prevents their rotating toward to the machine. In this case the fixture is provided from the tool's jam.

Before the process of the piston's recovery it is made measuring, which is necessary for the conclusive valuation of the done. It is measured 16 pistons of the diesel engines АМЗ 238 НБ and 18 pistons of the diesel engines СМД-62. The measuring is made to the following parameters:

- The precision of the apertures' shapes for the piston pin, which is measured with an apparatus „TALYROND 200";
- The apertures' diameters for the piston pin, which is measured with an universal apparatus for a length with a precision 0,0002mm;
- The apertures' roughness, which is measured with an apparatus „TALYSURF-6".
- The dimension's wear of the apertures' diameters for the piston pin is dispersing in a field 0,0636 mm for Ø 45mm and 0,0534mm for Ø 50mm. This is over that the apertures' limit.

The measured roughness is ***Rz*** = 4,27 – 14,58µm for Ø 45mm and ***Rz*** = 3,98 – 7,99µm for Ø 50mm. This is over repeatedly the requirements for roughness ***Rz*** = 0,4µm which is necessary in the documentation.

The recovery cover for the piston pin's aperture is Fe-Zn alloy. The technological process is the following:

- become lighter in a nitrogen and fluorine-hydrogen acids;
- contact zinc-coating with a room temperature;
- become lighter and contact zinc-coating for the second time;
- stratification with temperature 42° and electricity force from 3 to 5A/gm^2.

A planned experiment is carried out on a plan B_4 (table 1) and statistic analysis. As an object of the examination before and after surface plastic deformation are the roughness and the precision of the dimensions and the shape of the machined surfaces.

Table 1: *A plan of the experiment*

Factors and levels of a variance					
$F_l = N/mm$;	Naturals Coding	$x_1 \equiv F_l$	$x_2 \equiv m$	$x_3 \equiv n$	$x_4 \equiv l_z$
m – number;	-1	100	1	11,2	6
n – min^{-1};	0	150	3	31,5	29
Rz - µm	+1	200	5	63	52

Steerable factors, which are acceptable: the deform force in a unit of length $\boldsymbol{F_l}$, the turning frequency of the bearing shaft ***n***, the starting roughness ***Rz*** and the rate frequency of the deformation influence ***m*** (which is performed by number the separator's turning).

The following parameters are measured:

Ra is the average absolute deviation of the roughness of the section, µm;

Rz is the height of the roughness of the section, µm;

tp is the relatively bearing length of the section, %

Δ is the maximum diversion of a circle, µm;

E is the dislocation of the real aperture's axis toward the geometric axis of the aperture, µm;

$\boldsymbol{\Delta_r}$ is the radial beating toward the geometric axis of the aperture, µm.

The controlled parameter's data for each model are received from two mutually perpendicular plains.

The precision of the dimensions and the shape before and after surface plastic deformation is presented by their dispersing field and the respective theoretical and experimental distribution. The last is illustrated with the following numeral characteristics:

R is the range;

$\bar{x}$ is the chosen measure of central tendency of the data set;

$\sigma[x]$ is the standard deviation;

$\sigma^2[x]$ is the variance;

γ_1 is the asymmetry;

γ_2 is the excess.

The theoretical frequency of the distribution is determinate thought characteristics of the appropriate law, which is confirmed by the Pirson criterion. In the case the hypotheses for normal, logarithmic-normal and exponential distribution are examined. The curves of the distribution are built (Fig.2).

The statistical characteristics of the distribution for the apertures' diameters show preservation of its normal character before and after surface plastic deformation. It is observed decrease of the average value of the diameter's dimension $\bar{x}$, remarkable narrowing of the probable field ω (20 – 60%), sharpened of the theoretical curve of a distribution, which is conditioned by the excess value $\gamma 2$ and displacement of $\bar{x}$ toward medium of the distribution's field. It is evident from the asymmetry value γ_1.

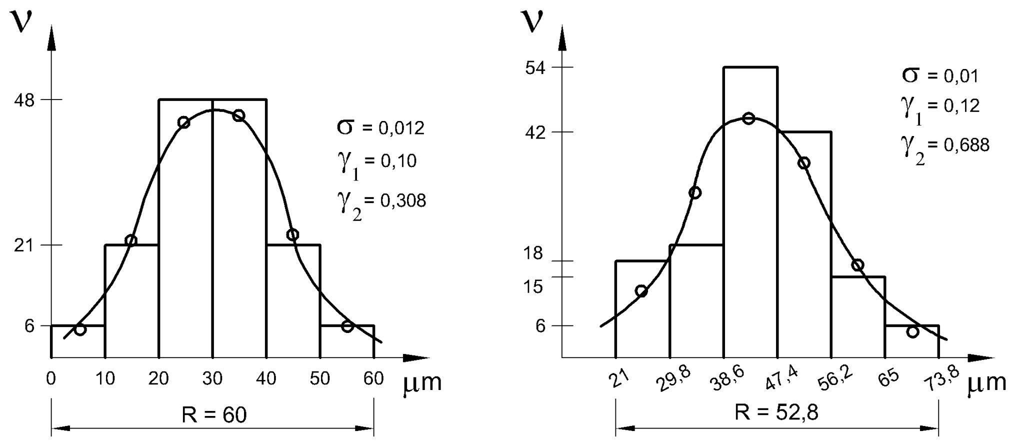

Figure 2: *Curves of the distribution*

The values of the three parameters for the shape's precision are determinate as a result of double measuring in exactly definitely section of the models. The graphs (Fig.3) are using for evaluation of the diversions of the right geometrical shape. The comparison of the statistical distribution characteristics of the parameters and the reading of the distribution laws, which are confirmed by the Pirson criterion (Fig.3), enable to establish the following changing in the shape's precision:

- the value of the probable distribution's field after surface plastic deformation decrease with all three controlled parameters;
- the mathematical expectance of the parameters, which characterized the shape's precision after c surface plastic deformation is less than that before surface plastic deformation;
- the percentage notability of the decrease is graded accordingly the rising line: a radial beating toward the geometric axis and the diversion of a circle;
- the grouping of the diversions' values round about the mathematical expectance evidence for presence of a calibration effect once more.

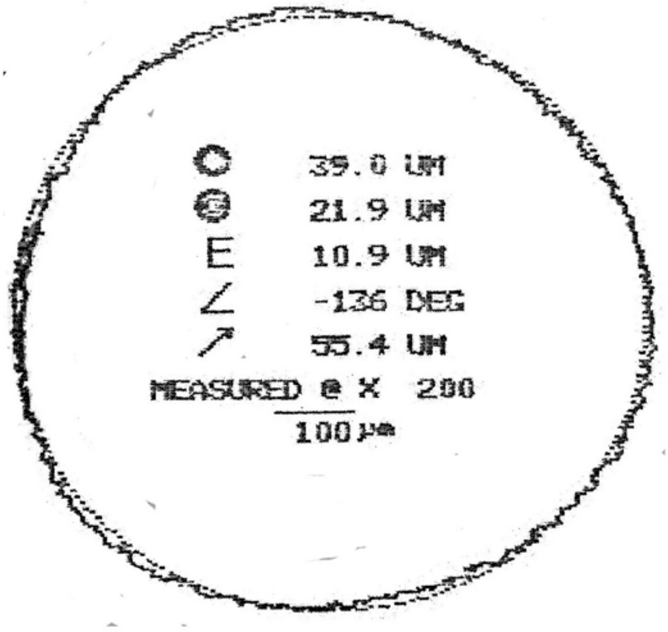

Figure 3: *A graph for control the shape's precision*

The received data of the planned experiment for the roughness parameters (Ra, Rz и tp) and the analyzing of the coefficients of the members in the equations of the regression show, that the greatest influence over the roughness have F_l and outgoing Rz.

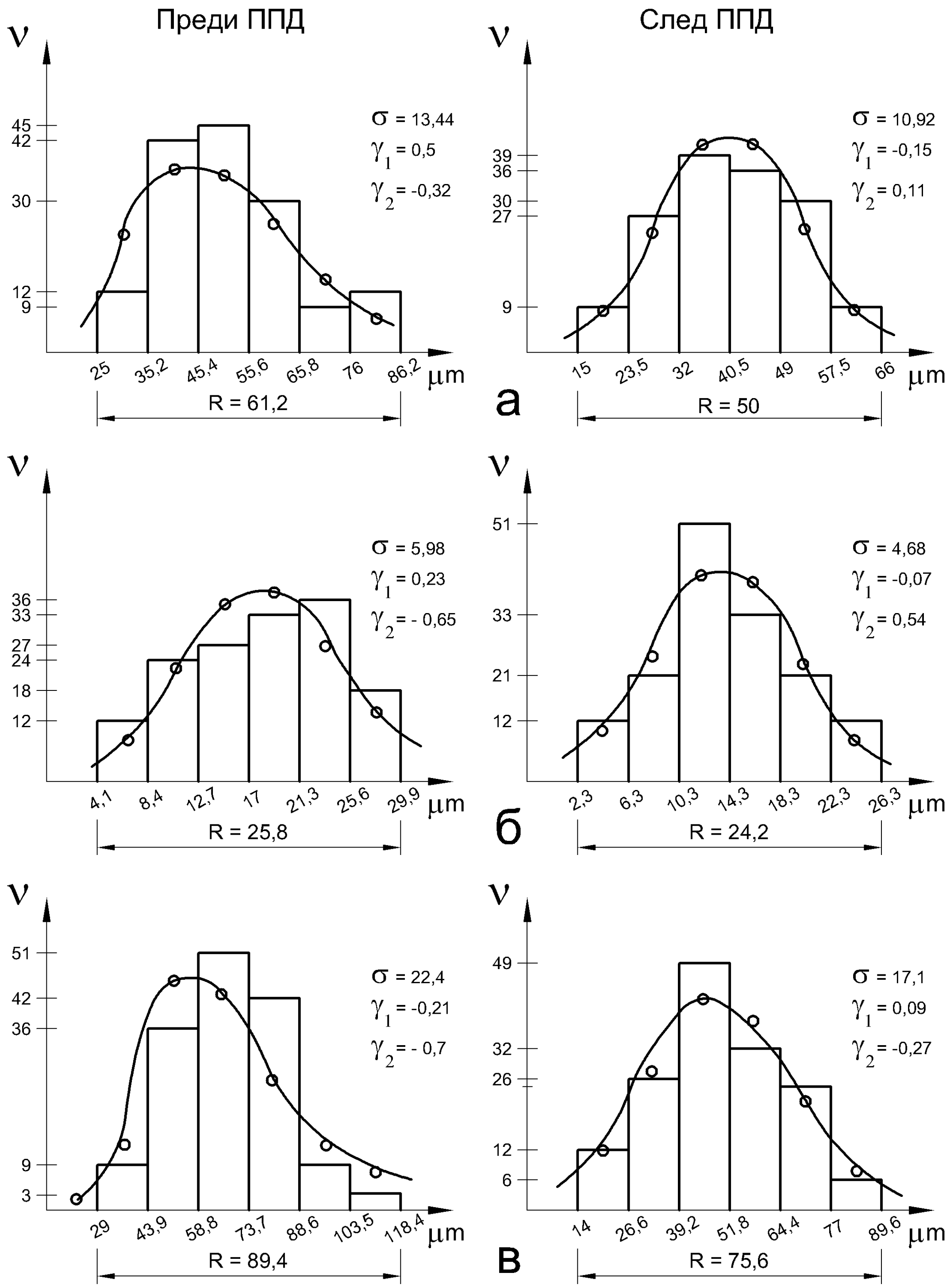

Figure 4: *A distribution of the shape's diversions:*
*a – diversion from a circle (**Δ**); b – off-centered; (**E**) ; c – radial beating (Δ_r)*

It is received adequate equations of the regression. Their comparing shows that the plasticity of the processing metal determines their structural diversity. The equations' analyse with the two levels of the outgoing roughness shows that the decrease outgoing roughness increase the influence of other steerable factors. Fig.4 shows the out-rigger curve of the roughness profile. The favorable shapes of the curves after surface plastic deformation are obvious – the parameter ***tp*** increase vastly, respectively the carrying ability of the processing surfaces.

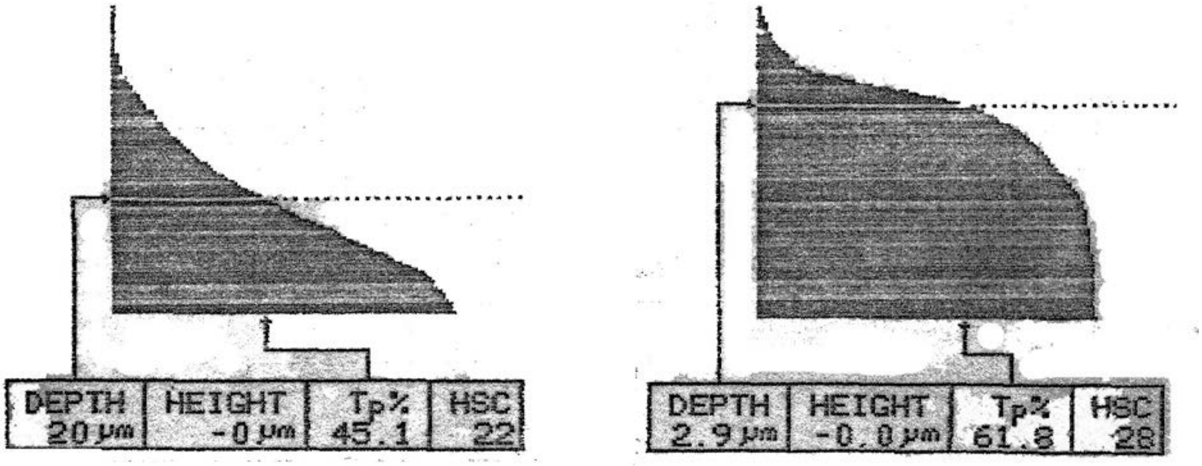

Figure 5: *Out-rigger curve of the profile*

4. CONCLUSION

As a result of the made research it can do the following conclusions:

- the finishing machining through surface plastic deformation of the apertures for the piston pin of the diesel engine's pistons in combination with the discussing technology for the recovery through galvanic cover ensures the necessary precision parameters;
- it is satisfied the technical requirements to the processing surfaces according the constructive documentation in reference to the received qualitative indices of the surface (***Ra***, ***Rz***, diversion from a circle, diversion from a cylinder);
- the application of the surface plastic deformation over galvanic recovery surfaces allows to increase the resource for using of the internal-combustion engine's pistons and to expand the technologic possibilities of the method.

BIBLIOGRAPHY

[1] Baranov E.A. Engineering galvanic techniques in instrument-building. Moskva, Machine building, 1977, in Russian.

[2] Kostadinov V.S. About the ending effect for surface plastic deformation tools with radial feed. Scientific works of High technical school, Rousse, volume XXVIII, 1986, in Bulgarian.

[3] Suchkov A.G., V.S.Kostadinov, M.K.Karchakov. BG Patent № 29758, 1979, in Bulgarian.

[4] Suchkov A.G. and other. Finishing processing by surface plastic deformation. Sofia, Techniques, 1984, in Bulgarian.

[5] Karchakov M.K., N.Georgieva, S. Kostadinov. Tool for combined machining of apertures, magazine “Mechanics of the machines”, Technical University - Varna, volume 6, 2005, page 86-89, in Bulgarian.

ASPECTS OF RISK MANAGEMENT IN LOGISTICS ACTIVITIES OF ENTERPRISES. APPLICATION OF FAULT TREE ANALYSIS (FTA)

НЕКОТОРЫЕ АСПЕКТЫ УПРАВЛЕНИЕ РИСКАМИ В ЛОГИСТИЧЕСКОЙ ДЕЯТЕЛЬНОСТИ ПРЕДПРИЯТИЙ. ПРИМЕНЕНИЕ АНАЛИЗ ДЕРЕВА ОТКАЗОВ (FTA)

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Abstract: *Risk management in logistics enterprises is one of the important topics in the management of supply. In today's global reality characterized by constant and rapid changes that make high degree of uncertainty and risk, make the logistics activity critical.*
The purpose of this article is to present the main aspects of risk management including the construction of the risk profile in logistics activity in enterprises and demonstrate the applicability of the FTA, which was developed conditional example. This will considerably facilitate efforts directed at risk management in logistics activity in enterprises.
***KEYWORDS**: RISK MANAGEMENT, LOGISTICS, LOGISTIC ACTIVITY, FTA*

1. Introduction

For many enterprises, the traditional operational strategies directed to "stock" setting up and investments in buffer capacities, that will take the high initial demand, cannot match the business environment and to be competitive. That motivates the enterprises to direct their efforts to search and apply strategies that will create an opportunity for quick and adequate reaction of the changes in the business environment and at the same time the expenses are reduced to a minimum [1].

The risk assessment in any activity as well as in the logistic management is a key element and has a determinant role for the way of functioning and the competitive power in particular and for the enterprise as a whole.

2. Presentation

2.1. Key role of logistics in business management in the dynamics of the modern business environment

The modern dynamics of the business environment, considerably exalted in result of the world crisis, places new outlines in the global world. New economic sectors are formed as a result of new demands and preferences as well as different consumer values. The adaptation of the enterprises to all these changes is turning to be a critical stage in their management. The growing variability of the business environment is getting so big that it is impossible to predict. In addition to that the new risks coming into existence create huge risk for the enterprises as well as high insecurity in their operations.

Keeping the dynamic balance between the way of functioning of the enterprises and the requirements and characteristics of the business environment as well as creating of competitive privileges is getting more and more difficult goal [2].

Along with the already mentioned above, another two factors for the modern business cannot be skipped, and they are time and space where the connection between them is the logistics.

The logistic itself is defined as one of the main competitive privileges. For instance – Martin Christopher, [5] defines the effective management of logistics and chain of supply as a main resource of competitive privilege – which means the position of having a long upper hand of the consumer's preference among the competitors can be achieved by better logistic management and chain of supply.

On figure1 is presented a simplified model of the enterprise, consumers and competitors or the so called the 3 C's – the three ways of interdependence between them [5].

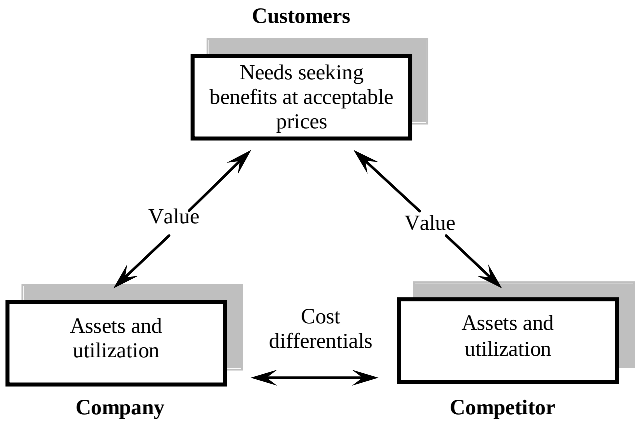

***Fig.1** Competitive advantage and the "Three Cs" (Source: Ohmae, K., The Mind of the Strategist, Penguin Books, 1983)*

According to Martin Christopher [5] the resource of competitive privilege is detected in first place in the ability of the enterprises to determine themselves from the consumers and the competitors and in second place – operating by less expenses to generate higher profit.

Gleissner and Femerling [6] define the logistics as a competitive instrument and means for rationalization.

In that way the logistic services can generate different opportunities for strategical competitive privilege. On the other hand, the good organization of the logistic systems can develop the potential of rationalization that can give a stable competitive privilege of the enterprise.

According to Harrison and van Hoek, [7], you need to clearly set the goals and their essentiality and measurability so you can clearly define the logistic privileges. Basically three "firm goals" are dissociated - quality, time and price. Later on they determine two main ways of logistic privilege formation and the variability in the logistic process and managing the vagueness - they are called "supportive capabilities".

The goal and achieving of competitive priorities are in the basis of the enterprises competitive power that is assessed as inner value for any of them and it is connected with certain characteristics. The competitive priorities and all factors of the same character are very dynamical and the way of getting them stable in the modern dynamics of the business environment must be directed to searching a broad complex of different processes and activities connected to quality, reliability, price, speed including manufacturing and distribution.

Logistic management as a management of the whole flow of products, information, people, financial resources etc… must keep close connection with the whole complex of activities and processes. The high coordination and harmonization in management of the logistic process together with the rest of the activities and processes in the enterprises is in the basis of high loyalty creation to the customers and in the basis of achieving stable competitive privileges.

2.2. Risk profile and risk profiling in management of the logistic activity.

The large and quick changes in the business environment put in central stage the topic of risk and risk management. The risk management is an essential key element exerting extreme influence on the activity of the enterprises. They cause different risk situations because of their complicated nature.

The possibility of identifying and evaluating the risk situations is in the basis of adequate reaction and respectively adequate management that can minimize the risk results e.g. decreasing the loss amount, opening new opportunities etc. This means it decreases the potential negative risks and increases the potential of the positive risks and the buffer effect when you can't avoid the risk situation. In that way "taking the risk" creates an environment for the enterprise to cope with the negative influence (fig.2).

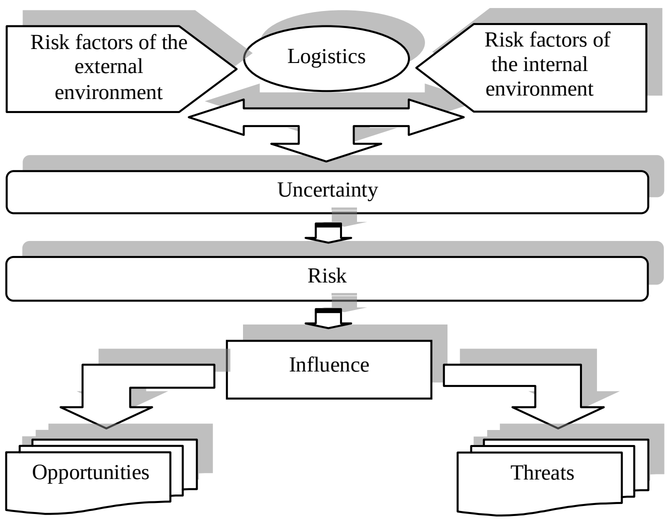

Fig.2 *Risk resource and influence*

The global factor and the permanent development of the information technologies constantly change and create a completely different way of functioning of the logistics and the logistic systems. They create new structures of competition, communication, manufacturing locations etc…

Risk management in the logistic activity in the enterprises has a huge impact on the way of functioning and the competitive power. In 2011 Aon Global Risk Management Survey [4] records „supply chain failure" as one of the top three risks shown by the respondents in the industries – biotechnologies, pharmaceuticals, consumer's goods, machinery and equipment and non-aviation transport.

The large risk variety in different types of business are typical in the logistic activity as well , like financial risks, transport risks, outsourcing risk, political risks etc...

Determining of the risk profile that has an effect on the "risk exposition" in certain period of time is of a great significance for reaching an effective risk management. Defining the separate risk groups, specific risks as well as their potential effect – their probability and consequences connected with the logistic activity, afford an opportunity for defining the target risk profile or the so called "desired" risk profile. This determining will be connected with the risk appetite, the set goals, the method of management etc… For instance, if we look at logistic macro-model that consists of three main components – supply, manufacturing and distribution, we can define the four main group risks – business environment, consumers, products and services , raw material suppliers(fig.3).

Based on the risk analysis we can create a risk profile where the accent will be directed to all key risks and risk areas of this activity, strengths and weaknesses, opportunities, risk tolerance guideline, priority set up etc… It is important to be highlighted that forming of a significant risk profile is a major step to forming of an integrated risk management.

In that way the risk management in the logistic activity will be connected with "constant" correction in the current risk profile, i.e. risk defining (risk groups, specific risks etc…) that has high influence and effects and will be directed to different ways of decreasing. This will form the so called "desired" risk profile.

In result of development and defining of the risk profile the threats will be identified as well as the logistic activity possibilities and guidelines for building of effective risk management strategies.

2.3. Application of Fault Tree Analysis (FTA) for risk rating in the logistic activity

Fault tree is a graphic method that can make a quantitative risk analysis in different stages of the activity e.g. in the process planning stage, in the operation stage etc… Here this method will be applied in a different way and it is risk analysis in the logistic activity.

On the basis of presenting the separate reasonable factors and logic connection along with the identified event ("top" event) a quantification can be done for the possibility that it will be realized (fig.4). This allows thorough understanding of the logistic activities and revealing of the events that lead to risk realization.

FTA application consists of consecutive stages and is exemplified by model example. The example illustrates some possible situations related to the raw material supply.

First stage. Determination of the main event

In the example the main event related to the raw material supply is "Delay of delivery". On this basis a graphic model of the lowest level events is built up and it is showing the link between the separated elements related to the main event.

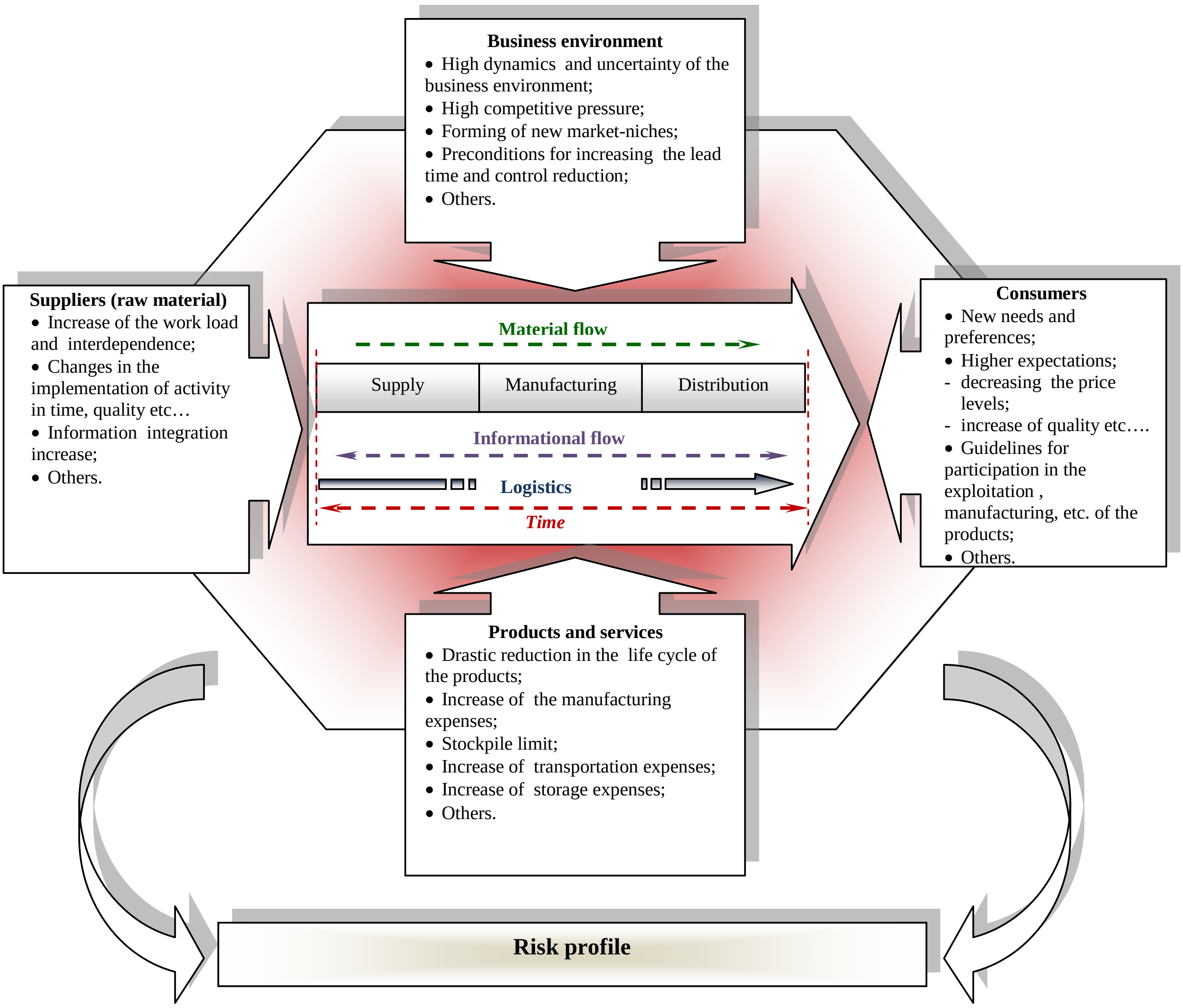

Fig.3. *Risk profile set up in the logistic activity*

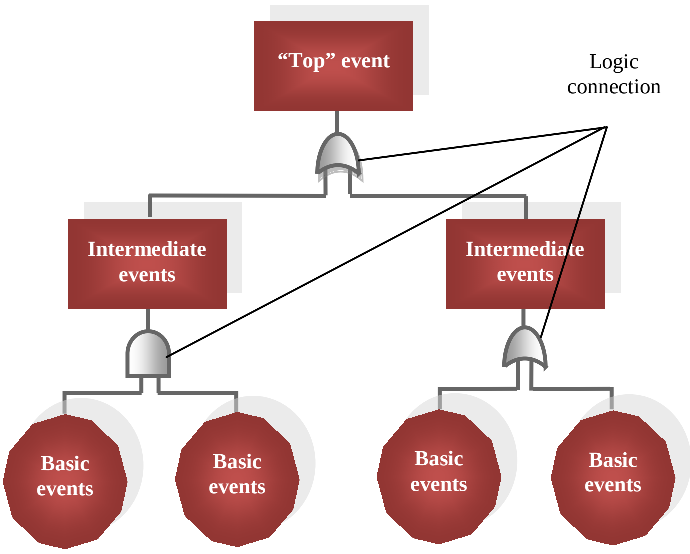

Fig.4. *Fault tree*

Second stage. Identifying the reasons leading to the main event

A few possible reasons are shown (possible situations) that are related to the main event realization, like:

- *Incorrect specification of the raw materials – inaccuracy in the raw material description, inaccuracy in the date of order;*
- *Incorrect determination of the time between initiation and realization of the order or the so called “lead time” – determination of unreal time of delivery, omission in lead-time delivery overview;*
- *“Problem” with invoicing - incorrect invoicing, invoicing delay.*

On the basis of these two stages we can set up a graphic model showing the links between the separate “elements” with the main event (fig.5).

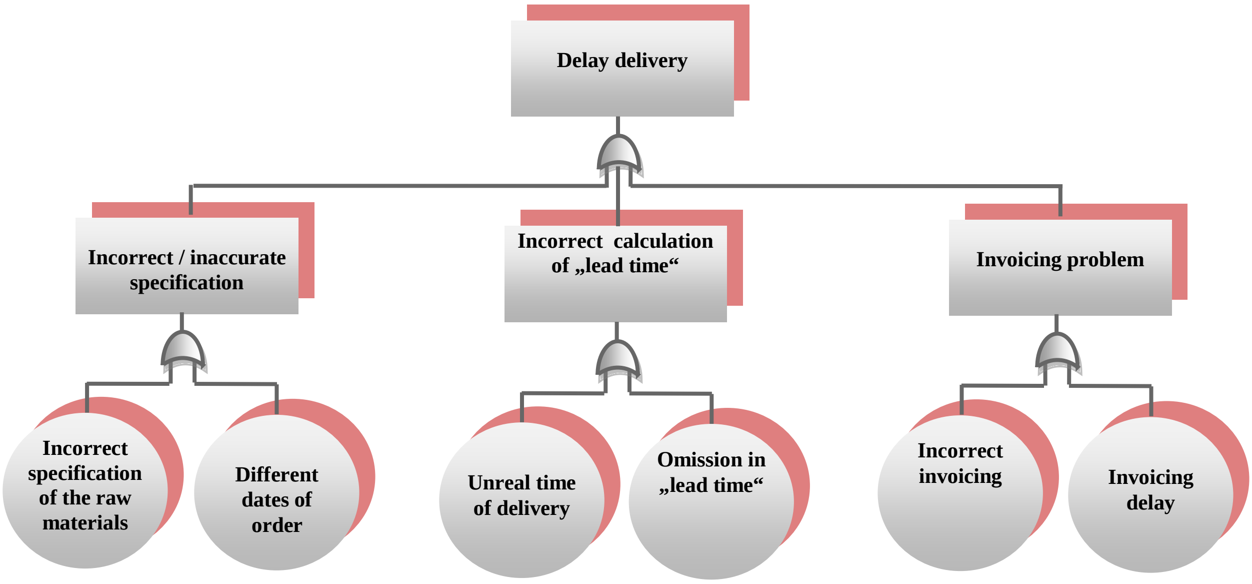

Fig.5 *Fault tree of delay delivery*

In this case the logistic operation between the separate "elements" will be "or" because every separate activity will lead to risk realization at higher level.

Third stage. Determination of the possibility of every separate event

The possibility determination begins with the main event and in the example given it can be determined on the basis of statistic data for certain period of time.

For example, if we have "inaccuracy" in the raw material inventory in a month for 10 out of 50 orders, the possibility for accuracy is 0.8, respectively the possibility for inaccuracy is 0.2. For the rest of the parameters::

Different dates of order – 0.55 (0.45);

Unreal time of delivery – 0.45 (0.55);

Non-inspection of lead time – 0.35 (0.65);

Wrong invoicing – 0.90 (0.10);

Delay invoicing – 0.70 (0.30).

Forth stage. Determination of the possibility for delivery delay

To determine the possibility of delivery delay we need to determine the possibilities for any of the intermediate events on the basis of the main events. Having in mind the logistic operation "or" and determination of the separate event's possibility, the possibility of delay delivery event can be determined by calculation of "negative event" from one:

$$P = 1 - \prod_{i=1}^{n} (1 - P_i) \qquad (1.1)$$

Where:

P – in this case – possibility that the delivery will not be delayed;

P_i – in this case – possibility of accuracy of the examined situations, $i=1,\ldots,n$,

In the first case we will begin with calculation of the possibility that there is no "incorrect" specification of the raw materials where the intermediate event eventuates from two main events: inaccuracy in the raw material specifications and inaccuracy of the date of order. Using formula 1.1 we have:

$$P = 0{,}91$$

Respectively for the possibility that there is no "incorrect" calculation of lead time where the intermediate event eventuates from two main events: unreal time of delivery and omission in lead time we have:

$$P = 0{,}64$$

For the possibility that "there is no" problem with the invoice, where the intermediate event eventuates from two main events: wrong invoicing and delay invoicing, we have:

$$P = 0{,}97$$

Therefore, in this example, on the basis of the calculations made, the possibility that *there will be no delivery delay is*: 0,99, i.e. the risk is 0,01.

The demonstrated method of risk evaluation in the logistic activity has many priorities like high flexibility and this gives opportunities for analysis of many factors and possible situations. The realization of top-down method allows us to focus our attention to all negative events connected to the main event.

3. Conclusion

Risk management is of main importance and a key stage of the activity of any enterprise. The few aspects that are examined are connected with the risk and its evaluation. They affect the risk profile and the risk profiling and are in the basis of effective risk management in the logistic activity of the enterprises. This gives opportunities for the enterprises in the logistic departments and this leads to construction of effective strategies and their management. The demonstrated method of risk evaluation by adapting the FTA technique in the logistic activity gives an opportunity for considerably deeper analysis and evaluation of the risks in the examined sphere.

Bibliography:

1. Димитракиева С., ”Управление на финансовите ресурси”, Варна, България, 2013г., ISBN 978-954-2912-41-5.
2. Димитракиева С., Ралчева Д., “Възможности на системата за управление на взаимоотношенията с клиентите за ефективно управление на бизнес стратегията на организацията”, Девета международна научна конференция ”Мениджмънт и инженеринг”, гр.Созопол, 2011г., стр. 678-684,ISSN 1313-7123.
3. Николов Б., Управление на риска в производствените системи (Класически и алтернативни решения), Кинг, 2012, ISBN 978-954-9518-70-4
4. Aon, Global Logistics Practice: World-Class Global Logistics Risk Management, 2012.
5. Christopher M., 2013. Logistics and Supply Chain Management ePub eBook, Pearson UK, 2013, http://www.aon.com/attachments/risk-services/Marine-World-Class-Global-Logistics-Risk-Management.pdf
6. Gleissner H., J. Christian Femerling, 2013.Logistics: Basics – Exercises – Case Studies, Springer International Publishing Switzerland 2013, ISBN 978-3-319-01768-6.
7. Harrison A., van Hoek R.,2008., Logistics Management and Strategy Competing through the supply chain, Third edition, Prentice Hall, 2008, ISBN: 978-0-273-71276-3
8. Langevin A., Riopel D.,2005. Logistics Systems: Design and Optimization, Springer Science+Business Media, Inc.,2005, ISBN 0-387-24971-0, e-ISBN 0-387-24977-X