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about forming and design in mechanical engineering

KOD 2010

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Dear Ladies and Gentlemen, respectable Colleagues and Friends of KOD,

It is a real pleasure and great honor for me to greet You on behalf of the Organizing Committee of the Sixth International Symposium about forming and design in mechanical engineering – KOD 2010. This year, symposium KOD takes place in Hotel Prezident in Palić, Serbia on 29^{th} and 30^{th} September 2010, and I would like to thank You for participating in it.

As we all know, the basic goal of this event is to assemble experienced researchers and practitioners from universities, scientific institutes and different enterprises and organizations from this region. Also, it should initiate more intensive cooperation and exchanging of practical professional experiences in the field of shaping, forming and design in mechanical and graphical engineering. Having always present need for making more effective, simpler, smaller, easier, noiseless, cheaper and more beautiful and esthetic products that can easy be recycled and are not harmful for environment, the cooperation between specialists of these fields should certainly be intensive.

Sixty nine articles, by authors from thirteen countries, are published in this Proceedings. It could be more papers, but the recession is everywhere, so also in publishing papers and proceedings. However, published papers are very interesting, so that means these topics have potentials and have to be further researched.

Thank You for coming in Palić to take part in symposium KOD 2010 and for Your interesting articles. I wish You success in Your further researching and great fortune and happiness in personal life.

Prof. D.Sc. Siniša Kuzmanović, Eng.
Chairman of the Organizing Committee of KOD

Palić, 29 September 2010

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POWER TOOLS PNEUMATIC IMPACT MECHANISM MODELLING AND ROBUST ANALYSIS

Georgi TODOROV
Velichko PEIKOV
Konstantin KAMBEROV
Nikolay NIKOLOV

Abstract: *This study aims to overview different possibilities for optimization of pneumatic impact mechanisms of handheld power tools (demolition hammers and rotary hammers) at the stage of their design on the base of virtual prototypes. The study is focused on impact mechanisms basic parameters variations and optimization based on Design of Experiments (DoE). Three main groups of parameters are examined – masses, geometry dimensions and input rotational speed. The target is to evaluate parameters influence over major output characteristic of the power tool – impact energy, i.e. power tool overall performance. Key factor for realization of multiple experiments is virtual engineering technology used. Its application allows not only evaluation of output parameters but also close look over physics of the explored process.*

Key words: *Power tools, Analysis, Virtual Engineering, CAD, CAE*

1. INTRODUCTION

The development of hand-held percussion machines is an important area of mechanical engineering. Drilling of man-made or natural rocks in mining, tunnelling, petroleum exploration, road and construction engineering requires large input of power. This is supplied by proper impact mechanisms, having design depending mainly on their size. Wide varieties of designs have been used during years, resulting in modern design usage of pneumatic impact mechanisms mainly. Generally, they include of impact mass (ram), connected to the drive by pneumatic chamber (cylinder/piston group), which acts as spring. Prior analyses and researches allows to group impact mechanisms in two categories – with moving piston and with moving cylinder. Moving cylinder category is applied in low to middle range rotary hammers and is in the focus of the presented research. [1, 5].

Performed research aims to study the influence of different important parameters over the major power tool performance characteristic – impact energy of the tool. A modern engineering tool – virtual prototyping – allows performing multiple tests without manufacturing physical prototype, for relatively short period of time. Instead of cost optimization, another major advantage is achieved – the possibility to explore the nature of physics of analyzed processes. This allows engineers to have better view, evaluated during the virtual tests as well as to collect know-how database for future design. [2, 5]

2. VIRTUAL PROTOTYPE DEVELOPMENT

As it was mentioned above – two categories of pneumatic impact mechanisms are used in the contemporary hand-held power tools – with moving piston and with moving cylinder. This has major influence over pneumatic chamber formation and divides in general the approach for design of these mechanisms.

Virtual prototyping has one very important stage – development of correct conception for the virtual prototype. This could allow performing multiple variants simulation with high level of detail as well as evaluation of variants and choice of optimal one with high adequacy to the real physical product.

The process of simulation of impact mechanism could be divided in the next several main stages:

Conception of the mechanics and definition of kinematic structural model of the examined impact mechanism;

- Definition of the major parameters to be explored;
- Building of a virtual prototype of the impact mechanism;
- Evaluation of major parameters influence over power tool performance, i.e. its impact energy;
- Selection of optimal variant for realization and verification. [6]

The research is focused over the evaluation of major parameters influence over the impact mechanism with moving cylinder (refer to figure 1). This type of mechanism is selected for research because of its wide use (low to middle range power tools) as well as because of the complexity of ongoing physical processes inside the pneumatic chamber.

The mechanism design consists of moving cylinder, ram and beatpiece, which are positioned inside the spindle of the power tool. The pneumatic chamber is developed inside the cylinder, between its frontal surface and the surface of the ram. This chamber connects the ram to the cylinder and transmits cylinder's linear movement to the ram. The pneumatic chamber is replaced in the virtua prototype by a spring with dynamically update of parameters, depending on relative positions of ram/cylinder during examined work cycles. Major role of the spring is to collect and accumulate the backwards energy of the ram that is to be used for the next impact as additional acceleration [3]. Normally, the ram linear velocity does not exceed 10 m/s and is not less than 8 m/s. Generated impulse of impact energy is transferred to the tool by the beatpiece. This leads to stability and independence of the power tool performance from the applied by the user hand axial load, from the type of work material or from the weight of the used tool.

Typical design characteristic of this category of pneumatic impact mechanism is the usage of a valve in the cylinder that is opened or closed at certain conditions (refer to figure 1). It is closing acts to seal the chamber and thus – to define the "free length" of the air spring L_{ini} – current distance between side surfaces of the cylinder and the ram.

Three groups of parameters are examined in the current study:

- masses: tool weight m_t, beatpiece weight m_b and ram weight m_r;
- pneumatic chamber dimensions: d_1, d_2, d_3;
- impact frequency: v (presented as rotational velocity of the drive shaft).

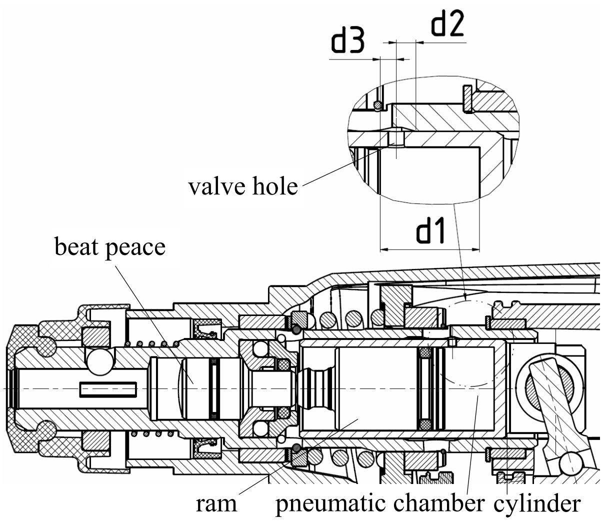

Fig.1. Geometry dimensions explored and valve in the cylinder wall

The mechanical model and the developed virtual prototype are shown together on figure 2. The virtual prototype is generated using software for numerical simulations – MSC visualNASTRAN. Detailed information for the built virtual model and its specifics could be found in [4].

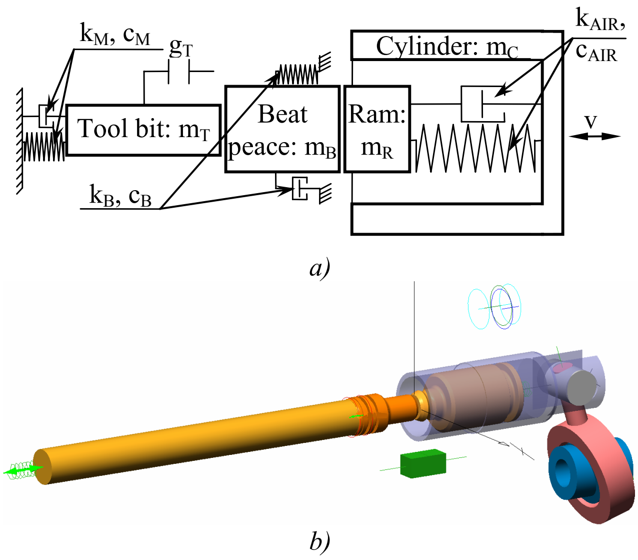

Fig.2. A mechanical model and virtual prototype of the pneumatic impact mechanism with moving cylinder

3. ANALYSIS RESULTS

Each of the examined parameters includes three variants – nominal value, lower value and higher value of the certain parameter. The target is to evaluate the robustness of the parameters and this is performed separately for each parameter at nominal values of the other parameters. Used values for the parameters are shown in table 1 bellow.

Table 1. Robust analysis – used parameters values

Parameter	Min. value	Nom. value	Max. value
m_R	0.057 kg	0.062 kg	0.067 kg
m_B	0.065 и 0.075 kg	0.085 kg	0.090 kg
m_T	0.050 kg	0.100 kg	0.150 kg
d_1	$10.8*10^{-3}$ m	$11.8*10^{-3}$ m	$12.8*10^{-3}$ m
d_2	$1.6*10^{-3}$ m	$2.6*10^{-3}$ m	$3.6*10^{-3}$ m
d_3 / d_2*	$1.8*10^{-3}$ / $3.6*10^{-3}$ m	$2.8*10^{-3}$ / $2.6*10^{-3}$ m	$3.8*10^{-3}$ / $1.6*10^{-3}$ m
v	4350 min^{-1}	4550 min^{-1}	4750 min^{-1}

* corresponds to changed position of the valve without changing position of the rear edge of spindle cavity

The influence of the masses of ram, beatpiece and tool over the impact energy is shown for a sequence of 25 strikes of the tool on figures 3, 4 and 5.

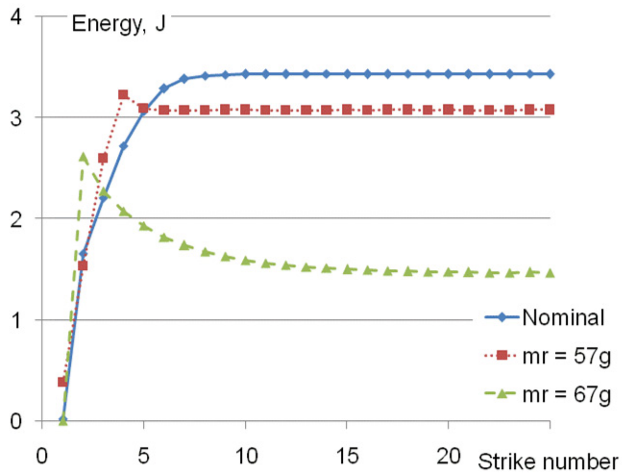

Fig.3. Influence of ram mass over the impact energy

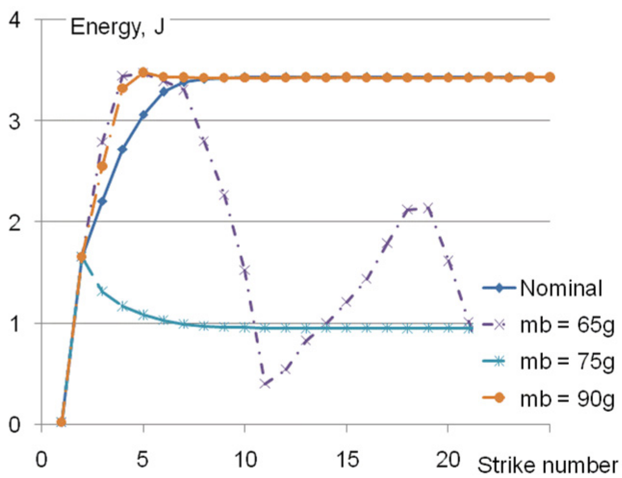

Fig.4. Influence of beatpiece mass over the impact energy

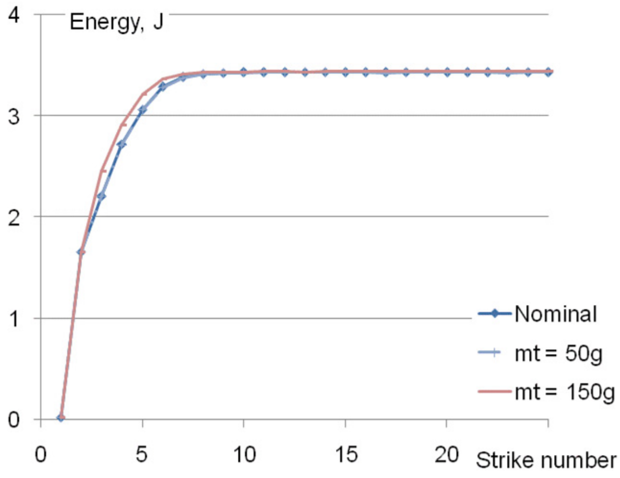

Fig.5. Influence of tool mass over the impact energy

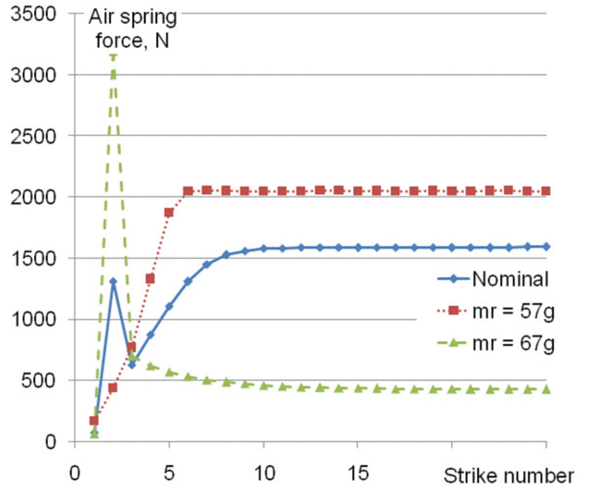

Fig.6. Influence of ram mass over reaction force in the air spring

The first several impacts should not be included in further analysis as they are highly influenced by the transition "idle" to "work" function of the power tool. The results show that changing masses of the ram and of the beatpiece – either increasing or decreasing it – the impact energy decreases. Also, high decrease of beatpiece mass leads to high deviation in output energy as it is changed from about 0.4J difference between consecutive impacts to 3.3J and the cyclic recurrence is about 10-12 strikes. Such deviation in power tool performance could have negative effect on the user comfort and will decrease the product efficiency. The mass of the tool has no influence over the impact energy at all. This fact guarantees that using different tools will not influence output characteristic of the power tool and it will work uniformly, with constant energy.

Besides the impact energy, another important output parameter is the maximal value of the backwards reaction force in the air spring. It has major influence over the hand vibrations of the demolition hammers and is of great importance for work conditions and comfort of the user.

Some results for the change of this parameter are shown on the graphics on figures 6, 7 and 8. Tendency of the results is that even the impact energy is not changed significantly (as by changing masses of ram and beatpiece), the max value of reaction spring force is changed. An example is the comparison between examined variants with 0.057kg and 0.09kg mass of the ram and of the beatpiece. Thus, lower force – and lower vibrations – could be achieved by increasing ram mass or slightly increasing the mass of the beatpiece. High rate of beatpiece ram increase will also increase the vibrations. These examinations could be used to develop product variant with lower vibrations, nevertheless of lower level of impact energy.

As the mass of the tool does not influence the impact energy, the reaction force in the spring is not changed also. This is clearly seen by the presented variants results on figure 8.

Generally, the performed analysis over masses influence shows that the examined nominal design has optimal performance – as by its maximal impact energy values, as by the stability of work parameters and independence of used tool.

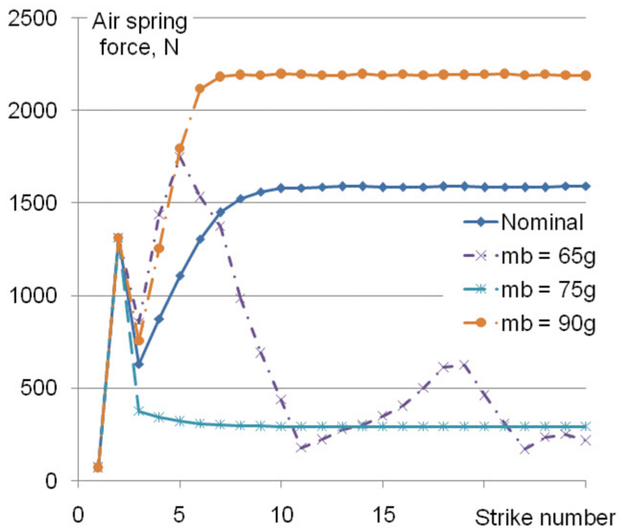

Fig.7. Influence of beatpiece mass over reaction force in the air spring

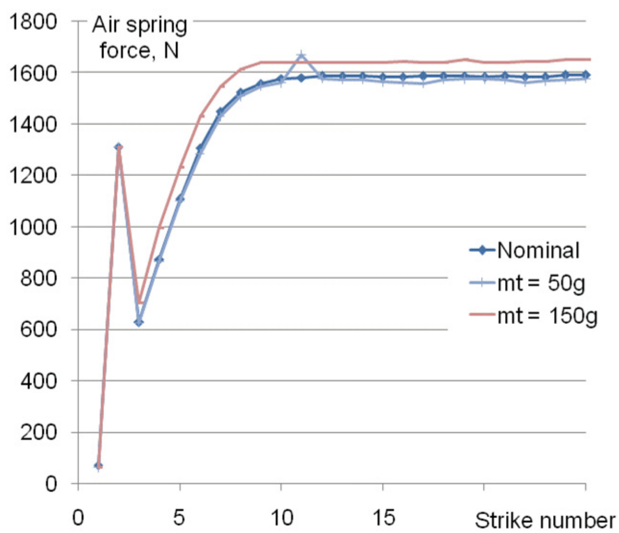

Fig.8. Influence of tool mass over reaction force in the air spring

The changes in the pneumatic chamber dimensions are the subject of separate set of analyses, where the results are shown on figures 9, 10 and 11. They shows that there are not great change of the major parameter – impact energy, and again the change is more raised for the reaction force in the air spring – figures 12, 13 and 14. The decrease of d_1 leads to increased reaction force by 1000N and to significantly increased work vibrations.

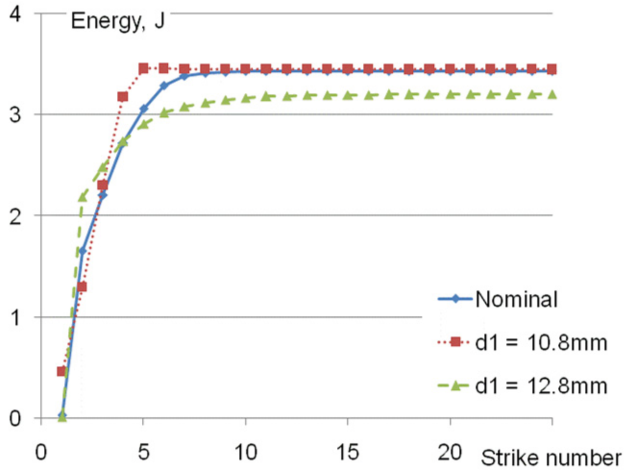

Fig.9. Influence of dimension d_1 over impact energy

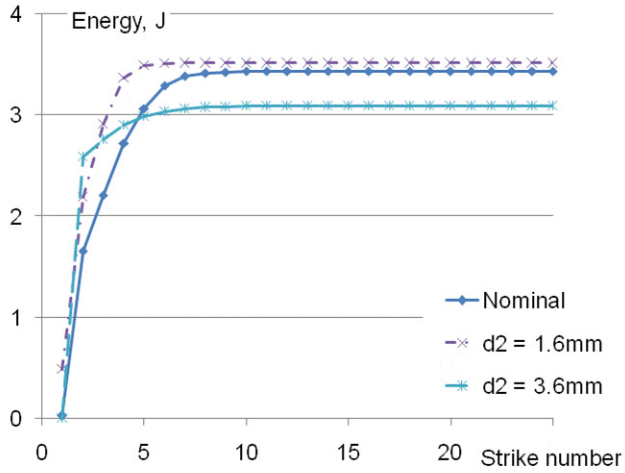

Fig.10. Influence of dimension d_2 over impact energy

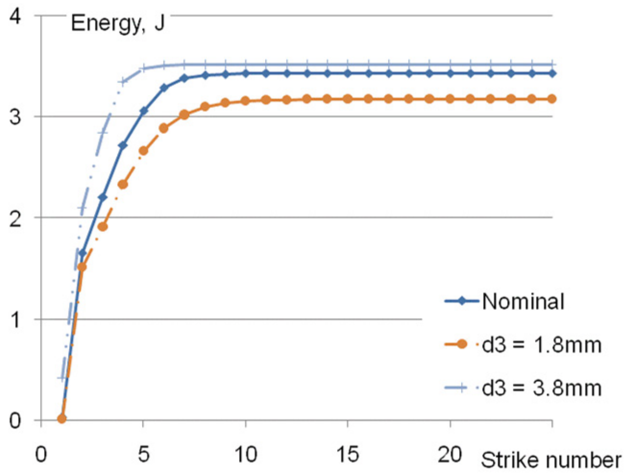

Fig.11. Influence of dimension d_3 over impact energy

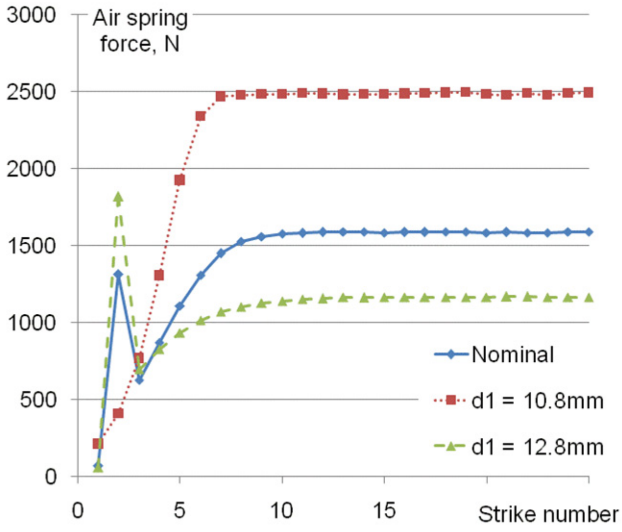

Fig.12. Influence of dimension d_1 over reaction force in the air spring

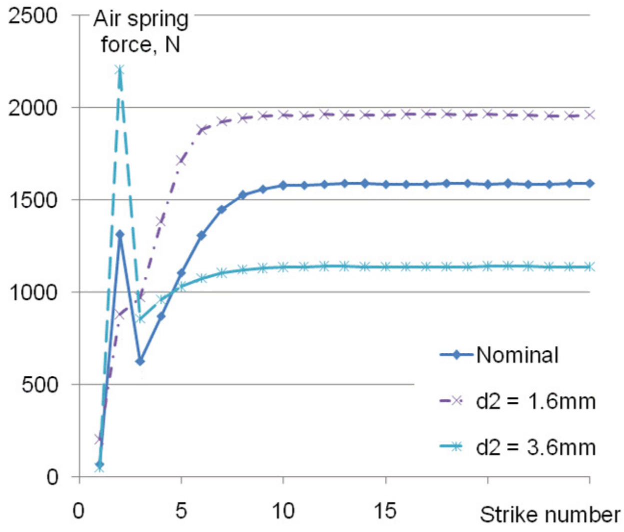

Fig.13. Influence of dimension d_2 over reaction force in the air spring

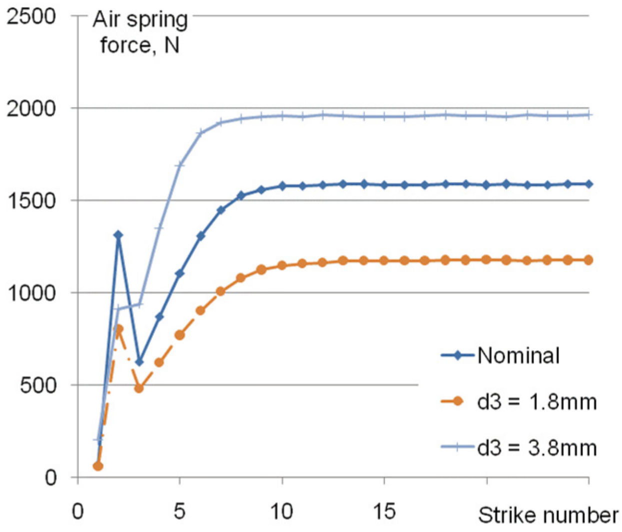

Fig.14. Influence of dimension d_3 over reaction force in the air spring

Another examined variable is the impact frequency, defined through the rotational velocity of the drive shaft. It is observed that changing impact frequency results in deviations of the impact energy output – high differences between two impacts energies (refer to figure 15). Additionally, the mean value of the energy decreases when rotational velocity of the drive shaft is changed. The effect of high deviation is amplified when examining reaction force in the air spring. Values are dispersed almost twice more than similar effect for the energy (refer to figure 16).
This is an indicative that certain design of pneumatic impact mechanism has its optimal value for impact frequency. Changing this value leads to deviations in output and irregularity of loads, generally to increased vibrations. It could be resumed that certain design has its optimal impact frequency for highest efficiency.

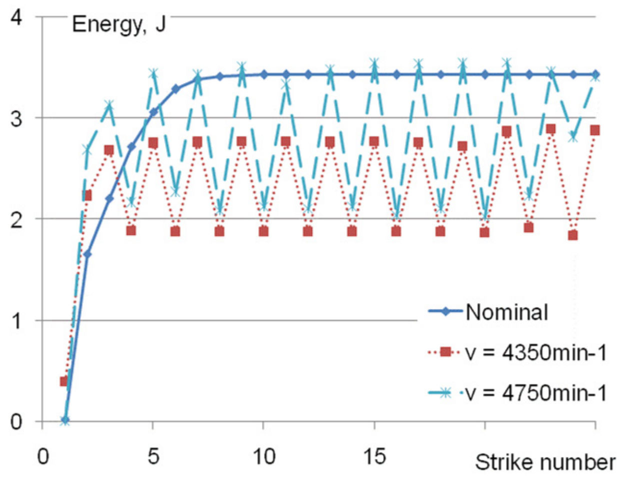

Fig.15. Influence of drive shaft rotational velocity (impact frequency) over impact energy

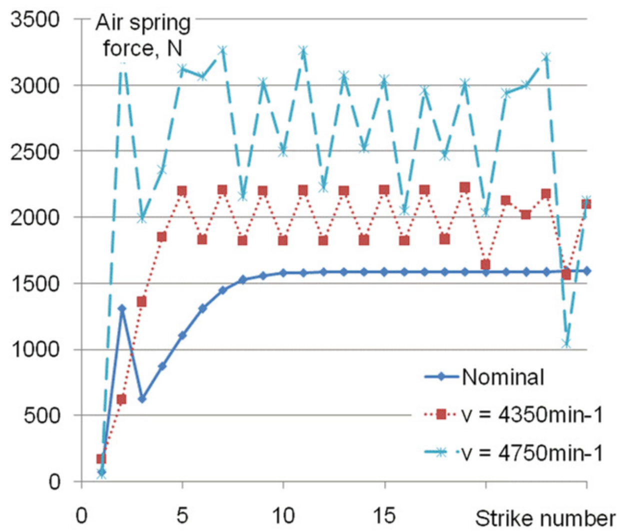

Fig.16. Influence of drive shaft rotational velocity (impact frequency) over reaction force in the air spring

A robust analysis of examined parameters is presented on figures 17 and 18 – concerning the variations of the pneumatic chamber dimensions and masses of acting bodies (ram, beatpiece and tool). Values for each variant shown on these figures are mean for the last 18 impacts and are extracted from previously shown results on figures 3, 4, 5, 9, 10 and 11. The energy mean value is formed by impacts No8 to No25, as the first 8 impacts are generated when the system is in transition to work condition.

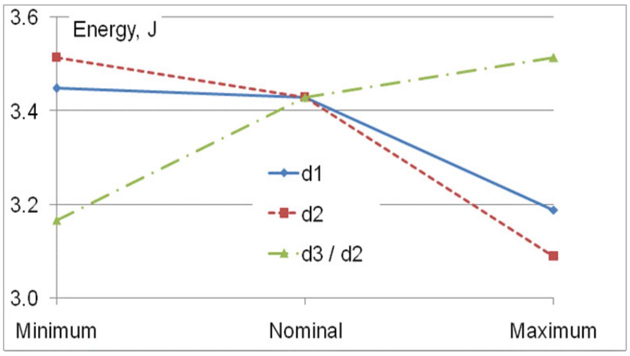

Fig.17. Sensitivity of impact energy to change of pneumatic chamber dimensions

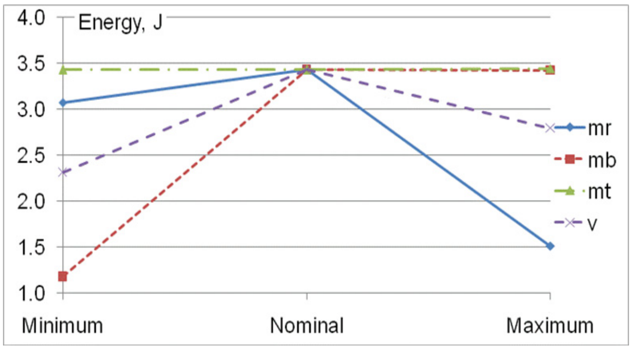

Fig.18. Sensitivity of impact energy to change of ram, beatpiece and tool masses

An analysis of the graphics data shows that each change of the examined parameters will decrease the output performance of the impact mechanism, i.e. the nominal dimensions of the pneumatic chamber and masses of the acting bodies are with optimal values.
As it was mentioned, the most indicative is the analysis of the change in the impact frequency. It is observed that the maximum of the energy corresponds to minimum reaction force in the air spring – at nominal impact frequency. This is an indicative for well optimized parameters set up of the explored impact pneumatic mechanism as well as for correct set up of the virtual simulation model.

4. CONCLUSION

The build simulation model on virtual prototype basis uses the design of well-known and tested mechanism of existing power tool – a product of leading world manufacturer. The target of this research is to build correct simulation model, which will allow to vary different parameters of the examined pneumatic impact mechanism with moving cylinder. Used virtual prototype includes the movement and relations between mechanism's components as well as allows substitution of the pneumatic chamber with nonlinear spring member,

which has adequate characteristic. Complete mechanical simulation model with included components relations is built and tested – ready for further examinations.
Robust analysis results indicate most sensitive parameters. Overview of these results shows certain nonlinearity in the relation between impact energy and reaction force in the air spring – vibrations in the handle. The relation between explored parameters of the pneumatic impact mechanism and output performance (impact energy) is also nonlinear.
High influence over power tool performance has the masses of the ram and of the beatpiece. The change of pneumatic chamber geometry dimensions has greater influence over reaction force in the air spring. Another important parameter is the impact frequency. It could be stated that for certain mechanism exists optimal impact frequency when the output productivity is highest and vibrations are lowest. All other impact frequencies will cause higher deviations in the impact energy and higher vibrations.
Major result of current study is the generated simulation model, based on virtual prototype, which will be used in future examinations. Information, obtained from the model, is sufficient for better understanding of the ongoing processes and a good basis for design considerations.

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REFERENCES

Books
[1] RESHENTSEV, N., ALABUJEV, P., NIKISHIN, N, TIMOSHENKO, E., BATUEV, N., *Electrical hand held power tools with hammering action*, Moscow, Nedra, 1970

Journal articles
[2] GOLYCHEVA, E., BABITSKY, V., VEPRIK, a., *Dynamic correction of excitation in handheld electro-pneumatic percussion machines*, Journal of Sound and Vibration, 2003 r., Vol. 259
[3] SOUNDRANAYAGAM, S., *Investigation of Nonlinear Transformation of Impulses in Impact Units for Improvement of Hammer Drill Performance*, Ph. D. Thesis, Loughborough University, 2000

Conference articles
[4] TODOROV, G., PEYKOV, V., KAMBEROV, K., NIKOLOV, N., LAI, Y., DAI, Y., *Parameters analysis of pneumatic vacuum mechanism with moving cylinder*, Proceedings of the International Scientific Conference, Sozopol 2010 (in press)
[5] TODOROV, G., KAMBEROV, K., PEYKOV, V., *Possibilities for controlled resonance application in impact mechanisms of demolition and rotary hammers – Part I*, Proceedings of the International Conference on Automation and Informatics, Sofia, October 2009, pp. II-17 – II-20, ISSN 1313-1850
[6] TODOROV, G., KAMBEROV, K., PEYKOV, V., *Possibilities for controlled resonance application in impact mechanisms of demolition and rotary hammers – Part II*, Proceedings of the International Conference on Automation and Informatics, Sofia, October 2009, pp. II-21 – II-24, ISSN 1313-1850

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