



**The Sixth International Symposium**  
**about forming and design in mechanical engineering**

**KOD 2010**

**PROCEEDINGS**

**29-30 September 2010, Palić, Serbia**

*Naziv izdanja: Proceedings – the Sixth International Symposium “KOD 2010”*

*Izdavač: Faculty of Technical Sciences – Novi Sad, Serbia*

*Štampa: FTS, Graphic Center – GRID, Novi Sad, Serbia*

CIP – Katalogizacija u publikaciji  
Biblioteka Matice srpske, Novi Sad

658.512.2 (082)

7.05:62 (082)

INTERNATIONAL Symposium about Forming and Design in  
Mechanical Engineering (6; 2010; Palić)

Proceedings / The Sixth International Symposium about  
Forming and Design in Mechanical Engineering, KOD 2010,  
29–30 September 2010, Palić, Serbia. – Novi Sad: Faculty of  
Technical Sciences, 2010 (Novi Sad: Graphic Center GRID). –  
V, 376 str.: ilustr.; 30 cm

Slike autora. – Tiraž 110. – Bibliografija uz svaki rad. – Registar.

ISBN 978–86–7892–278–7

- a) Industrijski proizvodi – Konstruisanje – Zbornici
- b) Industrijski dizajn – Zbornici

COBISS.SR-ID 255525127



*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<sup>th</sup> and 30<sup>th</sup> 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*

A handwritten signature in black ink, appearing to read 'Siniša Kuzmanović' with a stylized flourish at the end.

*Palić, 29 September 2010*

# ORGANIZERS

*Honorary Chairman of the Symposium KOD 2010:*

Kosta KRSMANOVIĆ  
Faculty of Applied Arts and Design, Belgrade

*Chairman of Organizing Committee:*

Siniša KUZMANOVIĆ  
Faculty of Technical Sciences, Novi sad

*Chairman of Scientific Committee:*

Vojislav MILTENOVIĆ  
Faculty of Mechanical Engineering, Niš

ADEKO – Association for Design, Elements and Constructions

WITH SUPPORT OF THE JOURNAL:

**MACHINE DESIGN**, ISSN 1821–1259

WITH SUPPORT OF:

Ministry of Science and Technological Development

Provincial Secretariat for Science and Technological Development

## SCIENTIFIC COMMITTEE

Zoran ANIŠIĆ	Novi Sad	Slobodan NAVALUŠIĆ	Novi Sad
Kyrill ARNAUDOW	Sofia	Peter NENOV	Rousse
Branimir BARIŠIĆ	Rijeka	Vera NIKOLIĆ-STANOJEVIĆ	Kragujevac
Radoš BULATOVIĆ	Podgorica	Dragoljub NOVAKOVIĆ	Novi Sad
Ilija ĆOSIĆ	Novi Sad	Milosav OGNJANOVIĆ	Belgrade
Lubomir DIMITROV	Sofia	Miroslav PLANČAK	Novi Sad
George DOBRE	Bucharest	Suzana SALAI	Subotica
Vlastimir ĐOKIĆ	Niš	Maria Felicia SUCALA	Cluj Napoca
Milosav ĐURĐEVIĆ	Banjaluka	Momir ŠARENAC	E. Sarajevo
Milosav GEORGJIJEVIĆ	Novi Sad	Rastislav ŠOSTAKOV	Novi Sad
Janko HODOLIĆ	Novi Sad	Slobodan TANASIJEVIĆ	Kragujevac
Sava IANICI	Resita	Radivoje TOPIĆ	Belgrade
Miomir JOVANOVIĆ	Niš	Lucian TUDOSE	Cluj Napoca
Svetislav JOVIČIĆ	Kragujevac	Miroslav VEREŠ	Bratislava
Imre KISS	Hunedoara	Simon VILMOS	Budapest
Zoran MARINKOVIĆ	Niš	Dragiša VILOTIĆ	Novi Sad
Nenad MARJANOVIĆ	Kragujevac	Jovan VLADIĆ	Novi Sad
Štefan MEDVECKY	Žilina	Aleksandar VULIĆ	Niš
Radu-Florin MIRICA	Bucharest	Miodrag ZLOKOLICA	Novi Sad
Radivoje MITROVIĆ	Belgrade		

## ORGANIZING COMMITTEE

Vojislav MILTENOVIĆ, Niš  
Milosav OGNJANOVIĆ, Belgrade  
Milan RACKOV, Novi Sad

## REVIEWERS COMMISSION

Branimir BARIŠIĆ, Rijeka	Vojislav MILTENOVIĆ, Niš
Milosav ĐURĐEVIĆ, Banjaluka	Milosav OGNJANOVIĆ, Belgrade
Sava IANICI, Resita	Miroslav VEREŠ, Bratislava
Kosta KRSMANOVIĆ, Belgrade	Simon VILMOS, Budapest

# CONTENTS:

1. EFFORTS AND ACTIONS IN PRODUCT DEVELOPMENT AND DESIGN CHALLENGES Milosav OGNJANOVIĆ .....	1
2. CONCEPT OF VIRTUAL PRODUCT DEVELOPMENT Vojislav MILTENOVIĆ, Miroslav VEREŠ, Milan BANIĆ .....	7
3. ROLLING BEARING LOAD RATING CAPACITIES AND RATING LIFE Lucian TUDOSE .....	13
4. MACHINE ELEMENTS: OVERVIEW AS CONCEPT AND ACADEMIC DISCIPLINE George DOBRE, Milosav OGNJANOVIĆ, Siniša KUZMANOVIĆ, Vojislav MILTENOVIĆ, Radu Florin MIRICA .....	23
5. E-LEARNING IN AUTOMATION TEACHING Peter KOŠŤÁL, Andrea MUDRIKOVÁ .....	31
6. ENERGY OUTPUT OF TRACKED PV SYSTEMS WITH BI-MOBILE LINKAGES Maria-Monica VĂTĂȘESCU, Dorin DIACONESCU, Ion VISA, Bogdan BURDUHOS .....	35
7. RESEARCH AND DEVELOPMENT OF CARRYING STRUCTURE OF RADIAL-AXIAL BEARING OF CONSTRUCTION AND TRANSPORT MECHANIZATION MACHINES Milomir GAŠIĆ, Mile SAVKOVIĆ, Goran MARKOVIĆ, Nebojša ZDRAVKOVIĆ .....	41
8. INVESTIGATION AND COMPARISON OF STATIC AND DYNAMIC LOAD IN THE MAIN MACHINE TOOLS SPINDLE Branko PEJOVIĆ, Vladan MIĆIĆ, Bogdan ĆIRKOVIĆ .....	49
9. CHOOSING THE OPTIMAL ROBOT CONSTRUCTION Ljubinko JANJUŠEVIĆ, Miroslav RADOSAVLJEVIĆ, Zlatan MILUTINOVIĆ .....	57
10. MULTI-OBJECTIVE OPTIMIZATION OF ROBOT GRIPPERS Cornel ȘTEFANACHE, Cristina STĂNESCU, Lucian TUDOSE .....	63
11. JAWS OF CLAMPING FIXTURES Jarmila ORAVCOVÁ, Peter KOŠŤÁL, Erika HRUŠKOVÁ .....	69
12. STRESS CONCENTRATION IN PLATES WITH ONE HOLE Nada BOJIĆ, Zvonimir JUGOVIĆ .....	73
13. FEM ANALYSIS OF TEMPERATURE FIELDS BY WELDING APPLYING VOLUME HEAT SOURCES Maria BEHULOVA, Eva BABALOVA, Daniel ŠVRČEK .....	79
14. A VORTEX LATTICE METHOD APPLICATION IN AERODYNAMIC ANALYSIS AND DESIGN OF LIGHT AIRCRAFT Zoran STEFANOVIĆ, Ivan KOSTIĆ .....	85
15. APPLICATION OF DIGITAL HUMAN MODEL IN THE DESIGN OF TECHNICAL SYSTEMS Slavko MUŽDEKA, Aleksandar KARI, Dragan BOROVIČANIN .....	93
16. DAMAGE TOLERANCE OF AIRCRAFT SANDWICH STRUCTURE – PRINCIPLE «FAIL-SAFE» Darko TUMANOV, Biljana MARKOVIĆ .....	99

17. FORWARD SWEPT ROTOR BLADES OF TURBOJET ENGINES AXIAL COMPRESSORS Emil BANJAC, Dubravka BANJAC .....	107
18. DESIGN OF LINK-DRIVE MECHANISM IN DEEP DRAWING PRESSES Karl GOTLIH, Ivo PAHOLE .....	113
19. POWER TOOLS PNEUMATIC IMPACT MECHANISM MODELLING AND ROBUST ANALYSIS Georgi TODOROV, Velichko PEIKOV, Konstantin KAMBEROV, Nikolay NIKOLOV .....	119
20. CONTRIBUTION TO DESIGNING BY WORKPIECE SOLID MODELLING Eva RIEČIČIAROVÁ, Marcela CHARBULOVÁ .....	125
21. EVALUATION AND EXPLOITATION OF A TOOL SHAPE ACQUIRED BY THE 3D SCANNING PROCESS Ivo PAHOLE, Mirko FICKO, Jože BALIČ, Jernej ŠENVETER .....	129
22. MODELLING THE CONECTION BETWEEN END-PLATE AND STEEL STRUCTURE USING FEM Tale GERAMITCIOSKI, Ilios VILOS, Vangelce MITREVSKI .....	133
23. FRICTION PLANETARY TRANSMISSIONS FOR EXTREME CONDITIONS Elena MARDOSEVICH .....	137
24. SOME PECULIARITIES OF DESIGN AND CALCULATION OF PLANETARY ECCENTRIC GEAR TRANSMISSIONS OF COMPOSITE MATERIALS Viktor STARZHINSKY, Elena MARDOSEVICH .....	145
25. WEIGHTED COEFFICIENTS METHOD APPLICATION IN PLANETARY GEAR TRANSMISSIONS OPTIMIZATION Jelena STEFANOVIĆ-MARINOVIĆ, Miloš MILOVANCEVIĆ .....	151
26. DYNAMIC ANALYSIS OF THE DOUBLE HARMONIC TRANSMISSION (D.H.T.) Draghita IANICI, Dorian NEDELCU, Sava IANICI, Liviu COMAN .....	155
27. ANALYSIS OF INFLUENCE OF AXIAL LOAD OF OUTPUT SHAFT OF UNIVERSAL MOTOR GEAR REDUCER ON THEIR OPERATING LIFE Siniša KUZMANOVIĆ, Milan RACKOV .....	159
28. EFFECT OF LUBRICANTS AT EFFICIENCY COEFFICIENT OF WORM GEAR TRANSMITTERS Đorđe MILTENOVIĆ, Milan BANIĆ, Aleksandar MILTENOVIĆ .....	163
29. MICRO PITTING, ITS ORIGINS AND MEASURES OF PREVENTION Gorazd HLEBANJA .....	167
30. EXPERIMENTAL DETERMINATION OF DYNAMICAL CHARACTERISTICS OF STEERING WHEEL JOINT SHAFT Andreja ILIĆ, Danica JOSIFOVIĆ, Lozica IVANOVIĆ .....	173
31. SHAFT DESIGN FOR WINDING PULLEYS OF WINDING INSTALLATIONS OF MK 5x2 TYPE WINDING ENGINE Vilhelm ITU, Iosif DUMITRESCU, Wilhelm W. KECS, Răzvan Bogdan ITU .....	177

32. FEM MODEL FOR CALCULATION OF HYDRO TURBINE SHAFT Ivana ATANASOVSKA, Radivoje MITROVIĆ, Dejan MOMČILOVIĆ .....	183
33. DESIGN AND BASES FOR ASSEMBLING PREFABRICATED INDUSTRIAL OBJECTS Radomir ĐOKIĆ, Jovan VLADIĆ, Dragan ŽIVANIĆ .....	189
34. MODELLING AND DYNAMIC ANALYSIS AS BASIS FOR ELEVATORS DESIGN Jovan VLADIĆ, Radomir ĐOKIĆ .....	193
35. SHAPING MACHINERY ELEMENTS EXPOSED TO CYCLIC LOAD Svetislav Lj. MARKOVIĆ, Aleksandar MARINKOVIĆ, Nada BOJIĆ .....	199
36. THE LIFE CYCLE OF PROJECTS Livia HUIDAN .....	207
37. RESEARCH FOR WORK TIME STRUCTURES FEATURES IN INDUSTRIAL PRODUCTION ENTERPRISES Miroslav CAR, Tomislav KOLAČNY, Goran LULIĆ, Ivan RAJKO .....	211
38. DESIGN FOR PRODUCT VARIETY Nikola SUZIĆ, Milovan LAZAREVIĆ, Nemanja SREMČEV .....	219
39. AESTHETIC DEMANDS IN INDUSTRIAL DESIGN Klara RAFA .....	223
40. SHAPING AND DESIGN OF GRAPHIC PRODUCTS Slađana MATOVIĆ, Svetislav Lj. MARKOVIĆ, Danijela BABANIĆ, Dobrila VESKOVIĆ .....	227
41. PRINCIPLES OF MODULE BASED DESIGN OF WOODEN PACKING Sonja BRSTINA, Dragoljub NOVAKOVIĆ .....	235
42. CUSTOMISATION OF MODULAR PRODUCTS BY INTERNET-BASED APPLICATION, APPLIED TO THE PET BOTTLE DESIGN Gojko VLADIĆ, Nemanja KAŠIKOVIĆ .....	239
43. PACKAGING ELEMENTS FOR IDENTIFICATION AND CONFIRMATION OF AUTHENTICITY OF PRODUCTS Dragoljub NOVAKOVIĆ, Gojko VLADIĆ, Nemanja KAŠIKOVIĆ .....	243
44. ANALYSIS OF HALFTONE DOTS DEFORMATION IN THE PROCESS OF PACKAGING AND EXPLOITATION OF CARDBOARD PACKAGE Ivan PINČJER, Magdolna APRO .....	249
45. PARAMETRIC MODELING APPLIED IN WOOD FURNITURE MANUFACTURING Milan RADOJEVIĆ, Dragan MILČIĆ, Miroslav MIJAJLOVIĆ .....	253
46. DESIGN OF MODERN ORDER PICKING SYSTEMS Dragan ŽIVANIĆ, Anto GAJIĆ, Vuk BOGDANOVIĆ .....	261
47. STEP ORIENTATION SYSTEM FOR A SOLAR THERMAL PLATFORM Veronica-Elvira DOMBI, Macedon Dumitru MOLDOVAN, Bogdan Gabriel BURDUHOS .....	265
48. DEFORMATION BEHAVIOUR OF BOARDS LOPREFIN WITH PRESS ON TEXTILE Pavel BRDLÍK .....	269

49. ENHANCEMENT OF MATERIAL PROPERTIES BY ECAP PROCESS Miroslav PLANČAK, Dragiša VILOTIĆ, Milentije STEFANOVIĆ, Plavka SKAKUN, Ognjan LUŽANIN .....	273
50. WELDING ERGONOMICS: PRINCIPLES AND APPLICABILITY Mihaela POPESCU, Emilia Georgeta MOCUTA, Carmen OPRIS .....	277
51. MANUFACTURING PROCESS WELDED FROGS BUILT IN TURNOUTS Vlastimir DJOKIC, Sonja STEVANOVIC .....	283
52. WHEEL WEAR AND RIDING QUALITY AT SERBIAN RAILWAYS Dušan STAMENKOVIĆ, Miroslav ĐURĐANOVIĆ, Milan NIKOLIĆ .....	287
53. CONSTRUCTION OF NONCONVENTIONAL INTERNAL COMBUSTION ENGINE Jovan DORIĆ, Ivan KLINAR .....	293
54. MOBILE MONITORING OF TECHNICAL CONDITION OF HYDRAULIC DRIVES OF TRACTORS Ivan OUSS, Uladzimir BASINIUK, Mirko RADUSINOVICH, Driss El MESSAOUDI .....	297
55. ONE METHOD FOR DETERMINING THE LIMIT VALUES OF DIAGNOSTIC PARAMETERS OF I.C. ENGINE PISTON - CYLINDER ASSEMBLIES Ivan KLINAR, Jovan DORIĆ .....	305
56. ANALYSIS OF WORKING AND STRUCTURAL PARAMETERS OF THE MOTOR MEMBER HYDRAULIC CYLINDERS LEVER MECHANISM Radovan PETROVIĆ, Jože PEZDIRNIK, Ljubiša ĐURIČIĆ .....	311
57. MONITORING OF CHANGES IN SERVICE PROPERTIES OF LUBRICANTS IN TRANSMISSIONS OF TECHNOLOGICAL EQUIPMENT Uladzimir BASINIUK, Lyubov MARKOVA, Driss EL MESSAOUDI, Mirko RADUSINOVICH .....	317
58. ADJUSTABLE INTERMITTENT MOTION MECHANISMS – WORKING COEFFICIENT STUDY Milan KOSTIĆ, Maja ČAVIĆ, Miodrag ZLOKOLICA .....	323
59. STEP MOTION LAW OF A PSEUDO-EQUATORIAL OPEN LINKAGE USED FOR A TRACKED CPV SYSTEM Ioana HERMENEAN, Ion VISA, Anca DUTA, Dorin DIACONESCU .....	327
60. APPLICATIVE CHARACTERISTICS OF VIBRATION MONITORING SYSTEM BASED ON PIC MICROCONTROLLER Miloš MILOVANČEVIĆ, Jelena STEFANOVIĆ MARINOVIĆ .....	333
61. REMOTE CONTROL OF COMPRESSOR UNIT AND PNEUMATIC SUPPLY SYSTEM DESIGN Uros ZUPERL .....	337
62. ACCELERATED GEAR TESTING FOR CONTACT ENDURANCE Nikolai ISHIN, Arkadi GOMAN, Victor STARZHINSKY .....	341
63. INTERLAMINAR STRENGTH-TESTS DURING RENEWALS BY COLD METAL SPRAYING METHODS Lajos FAZEKAS, Zsolt TIBA .....	345



64. THE TECHNOLOGICAL DOMAINS IN AREA OF HALF-HARD NODULAR CAST-IRON ROLLS – IN SOME GRAPHICAL ADDENDA Imre KISS .....	349
65. CONSIDERATIONS ON THE EFFECT OF HEAT TREATMENTS APPLIED ON A TITANIUM ALLOY ON ITS RESISTANCE TO CAVITATION STRESS Marcela Elena DIMIAN, Ion MITELEA, Ilare BORDEAȘU .....	353
66. POLYCARBONATES - PROPERTIES AND APPLICATIONS Gheorghe Radu Emil MĂRIEȘ .....	357
67. PLASMA NITRIDING TREATMENT FOR IMPROVEMENT OF FATIGUE STRENGTH OF STEEL ENGINE PARTS Radinko GLIGORIJEVIĆ, Jeremija JEVTIĆ, Djuro BORAK .....	361
68. PROGRAMMABLE DYNAMIC TESTS OF ELEMENTS AND COMPLEX STRUCTURES BY MECHATRONIC SYSTEMS Milomir MIJATOVIĆ, Dragan GOLUBOVIĆ .....	367
69. ENERGY SAVINGS FOR BUILDINGS USING PHOTOVOLTAIC PANELS IOAN SÂRBU, CĂLIN SEBARCHIEVICI .....	371
INDEX .....	375



## 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 virtual 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:  $\nu$  (presented as rotational velocity of the drive shaft).

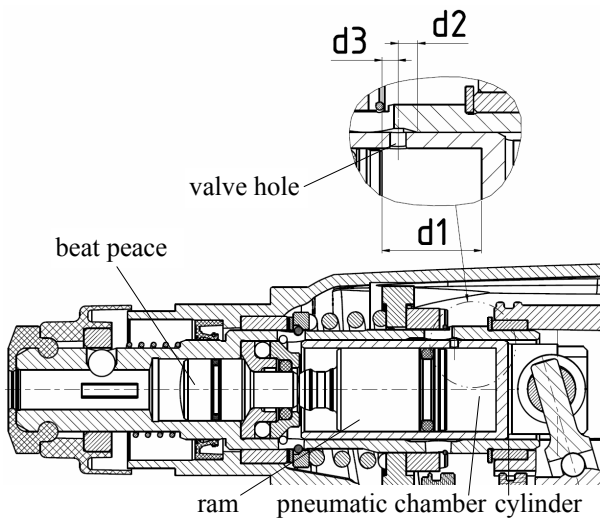


Fig. 1. Geometry dimensions explored and valve in the cylinder wall

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].

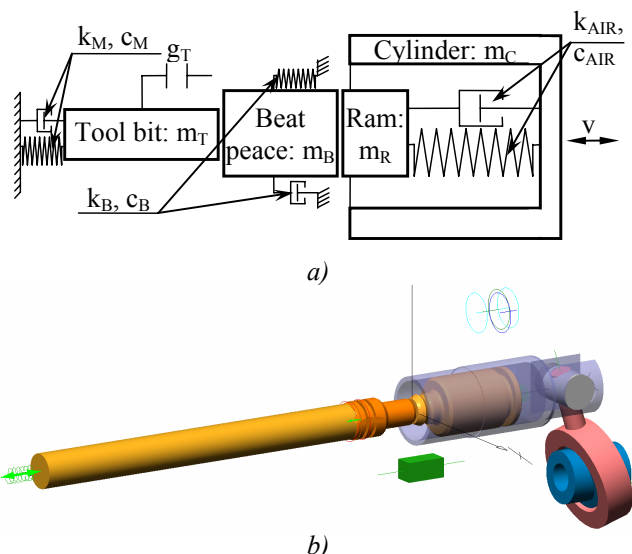


Fig. 2. A mechanical model and virtual prototype of the pneumatic impact mechanism with moving cylinder

### 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
$d_1$	$10.8 \cdot 10^{-3}$ m	$11.8 \cdot 10^{-3}$ m	$12.8 \cdot 10^{-3}$ m
$d_2$	$1.6 \cdot 10^{-3}$ m	$2.6 \cdot 10^{-3}$ m	$3.6 \cdot 10^{-3}$ m
$d_3 / d_2^*$	$1.8 \cdot 10^{-3} / 3.6 \cdot 10^{-3}$ m	$2.8 \cdot 10^{-3} / 2.6 \cdot 10^{-3}$ m	$3.8 \cdot 10^{-3} / 1.6 \cdot 10^{-3}$ m
$\nu$	4350 min <sup>-1</sup>	4550 min <sup>-1</sup>	4750 min <sup>-1</sup>

\* 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.

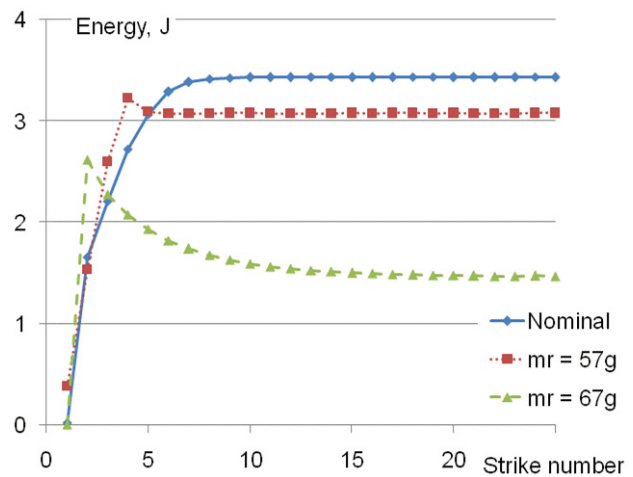


Fig. 3. Influence of ram mass over the impact energy

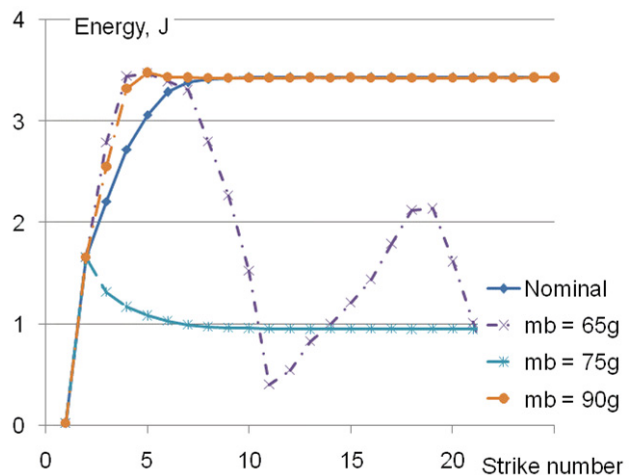


Fig. 4. Influence of beatpiece mass over the impact energy

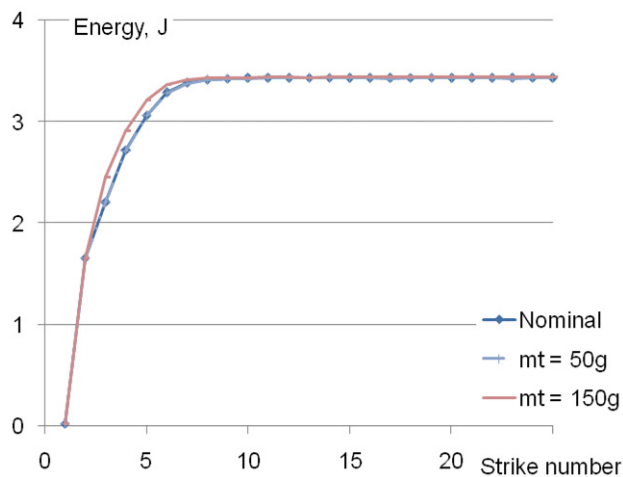


Fig.5. Influence of tool mass over the impact energy

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.

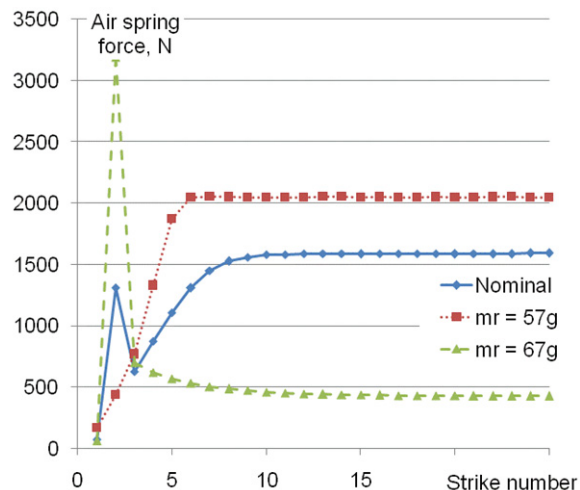


Fig.6. Influence of ram mass over reaction force in the air spring

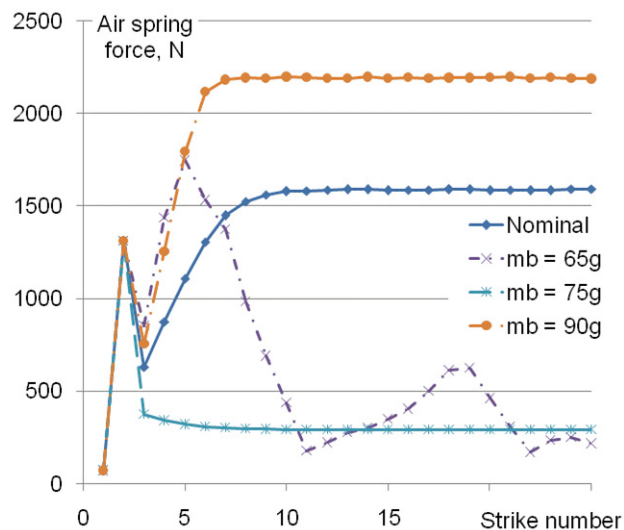


Fig.7. Influence of beatpiece mass over reaction force in the air spring

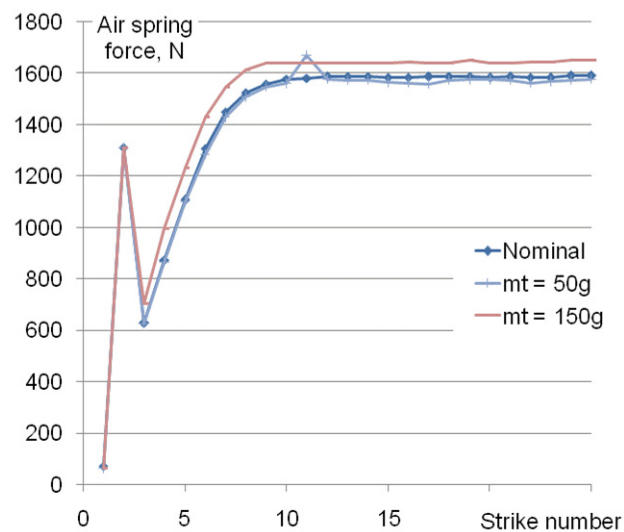


Fig.8. Influence of tool mass over reaction force in the air spring

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.

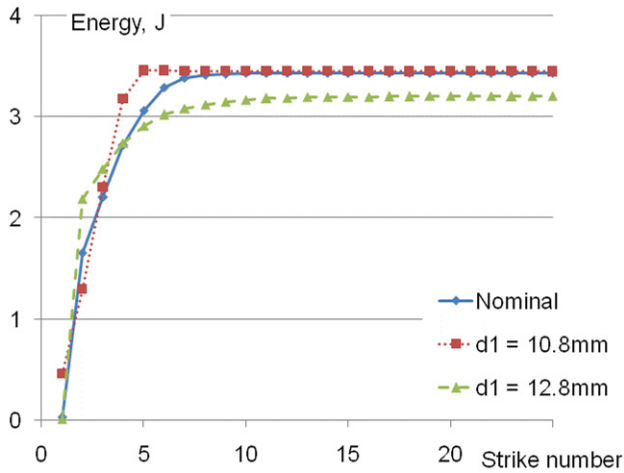


Fig.9. Influence of dimension  $d_1$  over impact energy

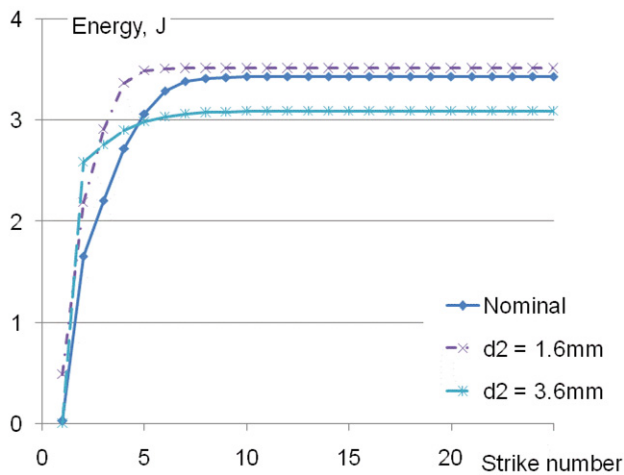


Fig.10. Influence of dimension  $d_2$  over impact energy

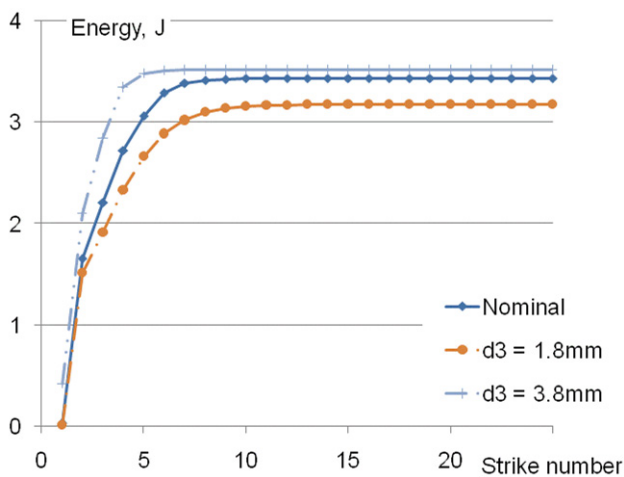


Fig.11. Influence of dimension  $d_3$  over impact energy

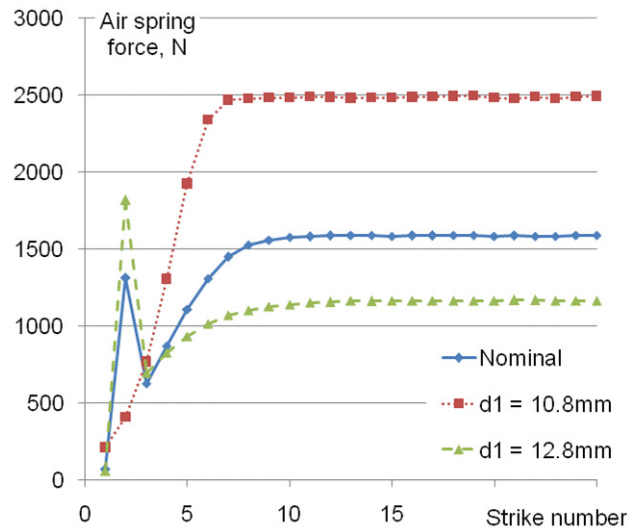


Fig.12. Influence of dimension  $d_1$  over reaction force in the air spring

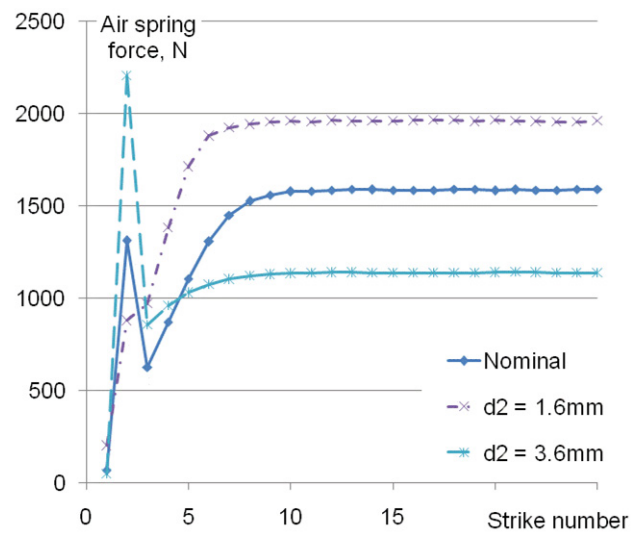


Fig.13. Influence of dimension  $d_2$  over reaction force in the air spring

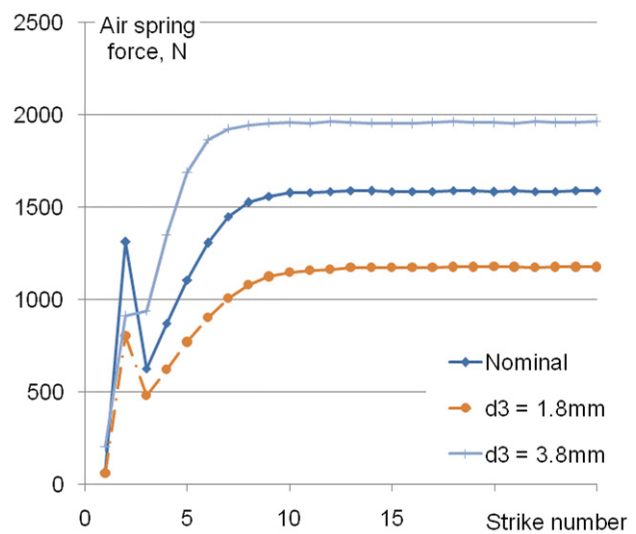


Fig.14. Influence of dimension  $d_3$  over reaction force in the air spring



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.

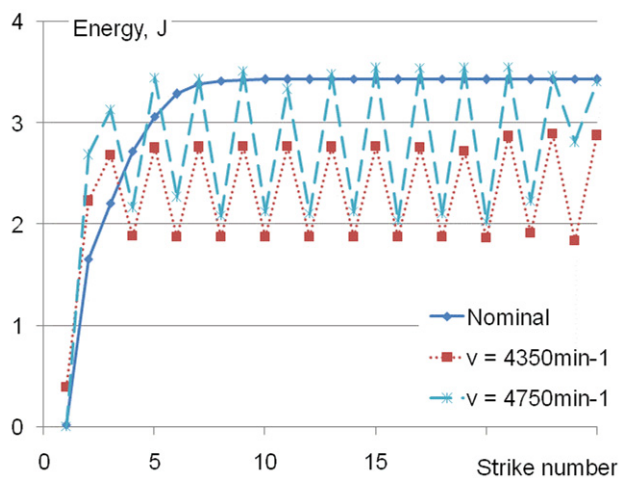


Fig.15. Influence of drive shaft rotational velocity (impact frequency) over impact energy

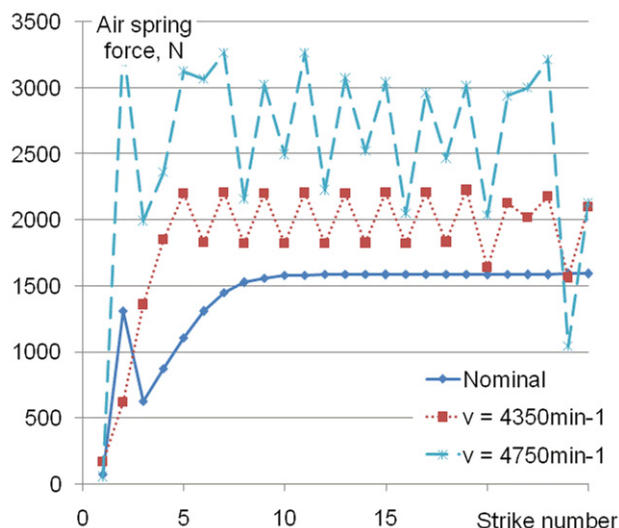


Fig.16. Influence of drive shaft rotational velocity (impact frequency) over reaction force in the air spring

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.

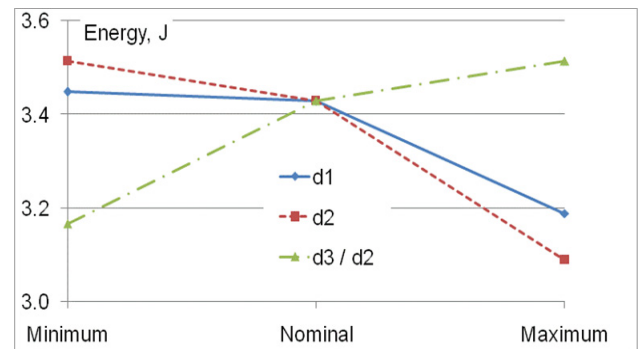


Fig.17. Sensitivity of impact energy to change of pneumatic chamber dimensions

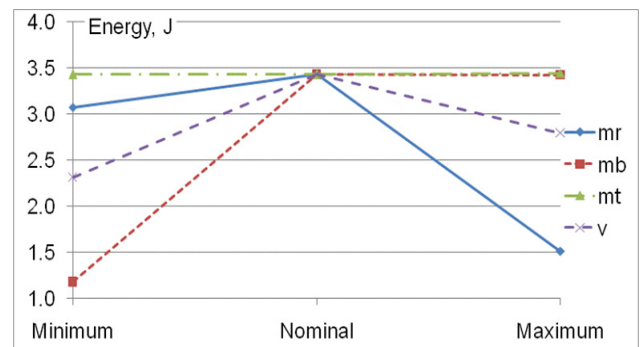


Fig.18. Sensitivity of impact energy to change of ram, beatpiece and tool masses

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.

## ACKNOWLEDGMENTS

This research study is performed by the support of billiteral Bulgarian-Chinese project D002-11/05, National Science Fund, Ministry of Education, Youth and Science, Bulgaria.

## 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., VEPRİK, 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

## CORRESPONDENCE



Georgi TODOROV, Prof. PhD Eng.  
Technical University – Sofia, MTF,  
TMMM, Laboratory “CAD/CAM/CAE in  
Industry”  
8, “Kl. Ohridski” Blvd.  
1797 Sofia, Bulgaria  
gdt@tu-sofia.bg



Velichko PEYKOV, M. Sc. Eng.  
Sparky Eltos AG  
Design Department  
Kubrat Str. 9, Lovech, Bulgaria,  
velichko.peykov.se@sparkygroup.com



Konstantin KAMBEROV, M. Sc. Eng.  
Technical University – Sofia, MTF,  
TMMM, Laboratory “CAD/CAM/CAE in  
Industry”  
8, “Kl. Ohridski” Blvd.  
1797 Sofia, Bulgaria  
kkamberov@3clab.com



Nikolay NIKOLOV, Prof. PhD Eng.  
Technical University – Sofia, MTF, TMM,  
Laboratory “CAD/CAM/CAE in Industry”  
8, “Kl. Ohridski” Blvd.  
1797 Sofia, Bulgaria  
nickn@tu-sofia.bg