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MACHINE AND INDUSTRIAL DESIGN IN MECHANICAL ENGINEERING

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Politehnica University Timisoara, Faculty of Engineering, Hunedoara, Romania  
University of Szeged, Faculty of Engineering, Szeged, Hungary



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

*It is a real pleasure and great honor for us to greet You on behalf of the Organizing Committee of the Ninth International Symposium about machine and industrial design in mechanical engineering – KOD 2016. This year, symposium KOD, for the third time, takes place in Hotel Marina in Balatonfüred, Hungary on 9<sup>th</sup> and 12<sup>th</sup> June 2016, 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, industrial design and shaping, product development and management. 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.*

*Fifty articles are published in the Proceedings. It is the same number of papers as in last symposium. This means our colleagues and friends of KOD are always active. Of course, we believe that time for organizing symposium has not passed and we want to prove it. However, published papers are very interesting, contribute to the understanding of design building relationships across multidisciplinary design domains including engineering and product development, innovation, manufacturing, management, complexity, human behaviour and system design, so that means these topics have potentials and have to be further researched.*

*Thank You for coming in Balatonfüred to take part in symposium KOD 2016 and for Your interesting articles. I wish You success in Your further researching and great fortune and happiness in personal life.*

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## CONTENTS:

<b>1. DESIGN OF AUTOMOTIVE GEARBOX WITH TOP PROPERTIES BASED AT HYBRID AND CVT APPROACH</b>	
Milosav OGNJANOVIĆ, Dragan DŽODAN .....	1
<b>2. FORMATION OF A VIRTUAL DESIGN DEPARTMENT FOR DEVELOPMENT OF HIGH-TECH PRODUCTS IN AN SME</b>	
Gorazd HLEBANJA, Marjan JENKO .....	7
<b>3. COST ESTIMATION IN THE EARLY STAGE OF PRODUCT DEVELOPMENT</b>	
Dejan LUKIC, Mijodrag MILOŠEVIĆ, Jovan VUKMAN, Stevo BOROJEVIĆ, Mića ĐURDEV, Aco ANTIĆ .....	13
<b>4. IMPROVEMENT OF E-LEARNING PROCESS OF PACKAGING RAPID PROTOTYPING COMPUTER NUMERICAL CONTROL MACHINE SYSTEMS</b>	
Dragoljub NOVAKOVIĆ, Ivan PINČJER, Stefan ĐURĐEVIĆ, Gojko VLADIĆ, Nemanja KAŠIKOVIĆ, Uroš NEDELJKOVIĆ .....	19
<b>5. DEVELOPMENT OF IMPROVED WHEEL HUB PROTOTYPE THROUGH IDEALAB PLATFORM FOR STUDENTS'S CONTEST</b>	
Zoran ANIŠIĆ, Igor FÜRSTNER, Atila NAĐ, Nemanja SREMČEV, László GOGOLÁK .....	23
<b>6. TRANSFORMING PRODUCT-CONSUMER COMMUNICATION THROUGH AUGMENTED REALITY TECHNOLOGY</b>	
Gojko VLADIĆ, Dragoljub NOVAKOVIĆ, Nemanja KAŠIKOVIĆ, Ivan PINČJER, Stefan ĐURĐEVIĆ .....	29
<b>7. A NEW CONCEPT OF BICYCLE FRAME DESIGN</b>	
Marija MATEJIC, Milos MATEJIC, Marijana MILICEVIC, Lozica IVANOVIC .....	33
<b>8. 3D MODELLING OF CONSTRUCTION TOWER CRANE</b>	
Stefan ILIC, Nenad MILORADOVIC, Rodoljub VUJANAC .....	37
<b>9. STRUCTURAL SYNTHESIS OF THE MANIPULATOR OF THE THERMOFORMING MACHINE</b>	
Maja ČAVIĆ, Marko PENČIĆ, Miodrag ZLOKOLICA .....	41
<b>10. ANALYSIS OF THE CONCEPTUAL SOLUTIONS OF BIOMASS PELLET MILL</b>	
Marko PENČIĆ, Maja ČAVIĆ, Miodrag ZLOKOLICA .....	45
<b>11. DETERMINATION OF BASIC MECHANICAL PARAMETERS OF THE TRACTOR TYRE BY USING UNIVERSAL APPROACH</b>	
Boris STOJIC, Aleksandar POZNIC .....	49
<b>12. STRESS AND STRAIN STATE OF CYCLOID GEAR UNDER DYNAMIC LOADS</b>	
Mirko BLAGOJEVIĆ, Miloš MATEJIĆ .....	55
<b>13. USE OF SUN-AND-PLANET MECHANISM IN EDUCATIVE SYSTEM</b>	
Dušan JEŠIĆ, Pavel KOVAČ, Borislav SAVKOVIĆ, Marin GOSTIMIROVIĆ, Ivan SOVILJ-NIKIĆ .....	59

<b>14. EFFICIENCY AS AN EXPRESSION OF PLANETARY GEAR TRAIN ENERGY LOSSES</b>	
Jelena STEFANOVIĆ-MARINOVIĆ, Sanjin TROHA, Miloš MILOVANČEVIĆ .....	63
<b>15. LOAD CAPACITY OF CYLINDRICAL WORM GEARS ACCORDING TO DIN 3996-2012</b>	
Aleksandar MILTENOVIĆ, Milan BANIC, Đorđe MILTENOVIĆ .....	67
<b>16. ANALYSIS OF SELECTION PROCEDURES OF UNIVERSAL WORM GEAR UNITS</b>	
Siniša KUZMANOVIĆ, Milan RACKOV, Ivan KNEŽEVIĆ, Miroslav VEREŠ .....	73
<b>17. NUMERICAL ANALYSIS OF MOTORCYCLE SUSPENSION SYSTEM</b>	
Slavica MAČUŽIĆ, Jovanka LUKIĆ .....	79
<b>18. INFLUENCE OF VANES SHAPE ON FLOW VELOCITY OF VENTILATED DISC IN HEAVY TRUCK BRAKING</b>	
Nadica STOJANOVIC, Jasna GLISOVIC, Ivan GRUJIC .....	83
<b>19. A COMPUTER PROGRAM FOR THE VISUALIZATION OF IC ENGINE CRANKSHAFT MAIN BEARINGS LOAD</b>	
Nebojša NIKOLIĆ, Jovan DORIĆ, Mitar JOCANOVIĆ .....	89
<b>20. NONLINEAR KINEMATICS OF ENGINE CRANK-PISTON MECHANISM</b>	
Ivan GRUJIC, Danijela MILORADOVIC, Nadica STOJANOVIC .....	93
<b>21. DYNAMIC ANALYSIS AND PARAMETRIC OPTIMISATION OF THE CONNECTING ROD USING AUTODESK INVENTOR</b>	
Vasile George CIOATĂ, Imre KISS .....	99
<b>22. NEW INTERNAL COMBUSTION ENGINE</b>	
Jovan DORIĆ, Nebojša NIKOLIĆ .....	105
<b>23. STUDY ON BEHAVIOUR IN SERVICE OF DIESEL ENGINES AND ASPECTS CONCERNING THEIR MAINTENANCE</b>	
Olimpia COROIAN .....	109
<b>24. GASODYNAMIC STUDY OF THE INTAKE ROUTE AT A SPARK-IGNITION ENGINE</b>	
Sorin RAȚIU, Vasile ALEXA .....	113
<b>25. ON MAGNETORHEOLOGICAL BRAKE FEM MODELING</b>	
Aleksandar POZNIC, Danijela MILORADOVIC, Boris STOJIC .....	117
<b>26. THE INFLUENCE OF THE ECCENTRICITY ON SAFETY COEFFICIENT ON A BUTTERFLY VALVE BIPLANE DISC</b>	
Tiberiu Ștefan MĂNESCU, Cristian Marius MIMIȘ, Zeno-Iosif PRAISACH .....	123
<b>27. DIRECTIONAL DEFORMATION OF THE BIPLANE DISC BY MOVING THE ECCENTRICITY</b>	
Cristian Marius MIMIȘ .....	127
<b>28. GEOMETRY CHARACTERISTICS OF HUMAN BODY MODEL SUITABLE FOR SIMULATION OF THERMAL COMFORT IN AN AGRICULTURAL VEHICLE</b>	
Dragan RUŽIĆ, Mirko SIMIKIĆ .....	131

<b>29. DEVELOPMENT AND MANUFACTURING OF SENSOR CASES FOR MEMS INERTIAL MEASUREMENT UNITS</b>	
Florin CORCIOVA, Gheorghe-Daniel VOINEA, Andrei MARCU, Ivan KNEŽEVIĆ, Milan RACKOV .....	137
<b>30. AUTOMATIC TECHNOLOGY FOR GLUING CERAMIC HOBS</b>	
Gábor PINTYE, Gheorghe ACHIMAȘ, Csaba GYENGE .....	143
<b>31. COMPARISON OF DIFFERENT FLUIDIC MUSCLES</b>	
József SÁROSI .....	147
<b>32. LUBRICATION REGIME INFLUENCE ON COLD STAMPING PARTS</b>	
Silviu Dan AVRAM, Silviu Răzvan AVRAM, Tiberiu Ștefan MĂNESCU .....	151
<b>33. APPLICATION OF RAPID PROTOTYPING IN MAXILLOFACIAL SURGERY</b>	
Aleksandar DIMIC, Zarko MISKOVIĆ, Drago JELOVAC, Radivoje MITROVIC, Mileta RISTIVOJEVIC, Marija MAJSTOROVIC .....	157
<b>34. CAVITATION EROSION BEHAVIOR OF THE STEEL 17CrNiMo6</b>	
Ilare BORDEASU, Mircea Octavian POPOVICIU, Cristian GHERA, Laura Cornelia SALCIANU, Lavinia Madalina MICU, Corneliu Eusebiu PODOLEANU .....	163
<b>35. LINEAR ELECTRIC MOTORS – NEW POSSIBILITIES FOR SMART LINEAR MOTION</b>	
László GOGOLÁK, Igor FÜRSTNER .....	169
<b>36. ANALYSIS OF NEW TECHNICAL SOLUTION IN PROCESS OF DETOXIFICATION ELV FROM ENVIRONMENTAL ASPECT</b>	
Miroslav VULIĆ, Eleonora DESNICA, Aleksandar TOMOVIĆ .....	173
<b>37. ESTIMATION BY FUZZY LOGIC OF ABRASIVE WEAR PROPERTIES OF COATED VALVES SURFACES BY TIG WELDING</b>	
Hakan GÜRÜN, Uğur ARABACI .....	177
<b>38. END-MILLING FORCE CONTROL SYSTEM WITH SURFACE ROUGHNESS MONITORING</b>	
Uros ZUPERL, Franc CUS .....	181
<b>39. CLAMPING AND SUSPEND SYSTEMS TO MANIPULATIONS DOCKING RAMPS</b>	
Vasile ALEXA, Sorin RAȚIU .....	185
<b>40. EXTERNAL FACTORS INFLUENCE ON THE METAL COFFERDAM WALLS PROTECTING RIVERS IN CASE OF NATURAL DISASTERS</b>	
Silviu Răzvan AVRAM .....	189
<b>41. INNOVATIVE, SAFE AND COST-EFFICIENT LIGHT-WEIGHTING SOLUTIONS IN THE AUTOMOTIVE WHEEL MANUFACTURING</b>	
Imre KISS, Vasile George CIOATA .....	193
<b>42. COMPUTER-AIDED STRIP LAYOUT FOR PIERCING AND CUTTING DIES</b>	
Onur ÇAVUŞOĞLU, Gökhan KÜÇÜKTÜRK .....	199
<b>43. OPTIMIZATION OF PROCESS PARAMETERS OF SURFACE ROUGHNESS INAL-7075 DRILLING PROCESS</b>	
Ramazan ÇAKIROĞLU, Adem ACIR .....	203

44. DETERMINATION OF OPTIMUM PARAMETERS OF CUTTING FORCE IN DRILLING OF B <sub>4</sub> C ALUMINUM COMPOSITE WITH TAGUCHI METHOD Adem ACIR, Ramazan ÇAKIROĞLU, Yakup YURGUT, Selçuk YAĞMUR .....	207
45. EFFECTS OF CUTTING PARAMETERS ON THE CUTTING FORCE AND TORQUE IN DRILLING OF AISI D2 STEEL İsmail TEKAÜT, Halil DEMİR, Hacı Bekir ÖZERKAN, Ulvi ŞEKER .....	211
46. AN EXPERIMENTAL STUDY OF THE EFFECT OF ABRASIVE WATER JET AND LASER BEAM ON THE SURFACE INTEGRITY Duran KAYA, Gökhan KÜÇÜKTÜRK, H. Bekir ÖZERKAN .....	217
47. TIP-JET HELICOPTER PROPULSION SYSTEM TESTING Nenad KOLAREVIĆ, Nebojša KOSANOVIĆ, Marko MILOŠ .....	221
48. MODULAR CONSTRUCTION OF CIRCULAR MANIPULATOR AS A TEST BED FOR TESTING PNEUMATIC CONTROL Vule RELJIC, Dragan SESLIJA, Jovan SULC, Brajan BAJCI, Slobodan DUDIC, Ivana MILENKOVIC .....	225
49. INVESTIGATION OF MACHINING CARBON FIBER REINFORCED COMPOSITE MATERIALS WITH SOLID CEMENTITE CARBIDE TOOLS Selçuk YAĞMUR, Yafes ÇAVUŞ, Abdullah KURT, Hasan Basri ULAŞ, Ulvi ŞEKER .....	229
50. RISK ASSESSMENT EMISSION OF POLLUTION FROM ROAD TRANSPORT IN THE URBAN AREA CITY OF ZRENJANIN IN THE AIM OF ENVIRONMENT PROTECTION – USING THE SOFTWARE ADMS-ROADS Aleksandar ĐURIĆ, Miroslav VULIĆ, Una MARČETA, Bogdana VUJIĆ, Milan PAVLOVIĆ .....	235
INDEX .....	241



## NUMERICAL ANALYSIS OF MOTORCYCLE SUSPENSION SYSTEM

Slavica MAČUŽIĆ  
Jovanka LUKIĆ

**Abstract:** A shock absorber is the main part of a vehicle suspension system. This mechanical device has a role to reduce the bumpy road shocks and enable a more comfortable ride. In this study we investigated the behavior of a shock absorber, that is installed on the motorcycle, with three different material of helical springs. 3D model was created using Catia v5 r18. Numerical simulation was done by Ansys workbench 12.0. The results of von Mises stress, deformation and shear stress, in the case of three different materials of coil spring, are analyzed and presented.

**Key words:** shock absorber, suspension system, helical spring, finite element method

### 1. INTRODUCTION

A shock absorber presents a mechanical or hydraulic device that is designed to absorb the holes and bumps on the road. Kinetic energy of the shock is transformed into another form of energy, for example, in the heat, and then performs dissipation. A coil spring, as the main part of the shock absorber, is defined as an elastic body. Spring has a role to compress when loaded, and to return to the initial state, when the load disappears. In this study, we used three different materials of helical coil spring: structural steel, spring steel and chromium-vanadium steel. The last two materials are increasingly used in the suspension system. It is very important to determine which steel gives better results in real conditions.

### 2. LITERATURE REVIEW

A large number of researchers studying the suspension system of the vehicle. The goal is to design an optimal shock absorbers and using quality materials of helical coil, get better vehicle performance.

The authors [2] have presented an analysis of the shock absorber before and after optimization design. They executed the change in diameter of the coil and the use of

two materials showed how different loads affect the operation of the damper.

The author [3] observed the behavior of spring steel as the main material coils. It is a new material, invented by Japanese researchers, that has application in the suspension system. They concluded that spring steel having very high ultimate tensile strength.

Another author [4] has studied the behavior of the shock absorber when using two different materials coils. These materials are structural steel and aluminum alloy. A comparison was made for the same boundary conditions, and the result of research shows that best material for shock absorber is the steel.

As it is known, a composite material made from two or more constituent materials with significantly different physical or chemical properties. The resulting material has a better structure than the individual components. Recent research [5] studying composite materials. It was concluded that composite materials may find use in suspension systems because they have high strength, high stiffness and low weight.

### 3. MATERIALS AND METHODS

#### 3.1. Model definition

A 3D computer model of a shock absorber was developed using the CATIA v5 r18. The total height is 336 mm. Helical coil spring has the following physical characteristics:

- height 220 mm,
- diameter of wire 10 mm,
- total number of coils 10,
- outer diameter of spring coil 70 mm.

Figure 1 show 3D geometry of a shock absorber.

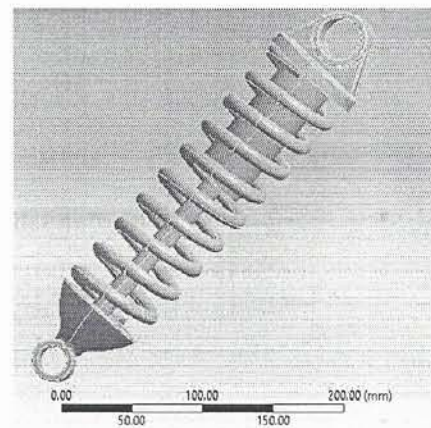


Fig.1. Geometry of shock absorber

Weight of motorcycle is 125 kg. In this study, it is assumed that a vehicle has two passenger of 75 kg. Rear suspension absorbs 60% of the total weight, and the force that acting on the shock absorber has a value of 1618 N. One end of the model is fixed, while at the other end acts mentioned value of the force.

#### 3.2. Material definition

Numerical simulations were conducted with three different materials of helical spring. The following

materials are used: structural steel, spring steel and chromium-vanadium steel. Table 1 shows main properties of used materials.

Table 1. Properties of materials[6], [7]

Properties	Structural steel	Spring steel	Chromium-vanadium steel
Young's Modulus (MPa)	2E+05	2.02E+05	2.1E+05
Density (kg/m <sup>3</sup> )	7850	7820	7800
Poisson's ratio	0.3	0.29	0.29
Tensile strength (MPa)	460	570	940
Yield Strength (MPa)	250	360	620

### 3.3. Finite element formulation

Finite element has become the most popular method for the investigation of the suspension system of the vehicle. This method solves a large number of differential equations to calculate von Mises stress and deformation of the model. The method has been widely used to predict mechanical behavior of shock absorber in various driving situations such as driving over rough road, or sudden braking.

Principle of virtual work is one of the basic principles of continuum mechanics. Applying the boundary conditions in the equilibrium equations [8] virtual work of internal and external forces can be equal, and we have

$$\delta W_{int} = \delta W_{ext} \quad (1)$$

Matrix form of virtual work of the previous equation can be written as

$$\delta W_{int} = \int_V \delta \mathbf{e}^T \boldsymbol{\sigma} dV$$

$$\delta W_{ext} = \int_V \delta \mathbf{u}^T \mathbf{F}^V dV + \int_{S^{\sigma}} \delta \mathbf{u}^T \mathbf{F}^S dV + \sum_i \delta \mathbf{u}^T \mathbf{F}^{(i)} \quad (2)$$

Applying the principle of virtual work and the constitutive relations for linear elastic material in matrix form, we have

$$\boldsymbol{\sigma} = \mathbf{C} \mathbf{e} \quad (3)$$

Applying the concept of isoparametric interpolation [9] in the finite element, we can write the equation of equilibrium finite elements

$$\mathbf{K} \mathbf{U} = \mathbf{F}_{ext} \quad (4)$$

where  $K$  is element stiffness matrix,  $U$  displacements at the nodes and  $F_{ext}$  - external forces in the element nodes. A basic assumption in the linear analysis of solids is that

the moving solids is infinitesimally small, the material is linearly elastic, and that the nature of the boundary conditions remain unchanged under the action of external loads. About that, last equation is related to the linear analysis of solids because the moving of the nodes is linear function of external forces.

## 4. RESULTS

Numerical simulation was done using Ansys workbench 12.0. Linear tetrahedral element was used as the final element. Finite element mesh consists of 138962 nodes and 77881 elements.

Numerical solutions of von Mises stress, deformations and shear stress are shown in the following figures. Figures 2, 3 and 4 shown result of simulations for the case when the material of helical spring is structural steel.

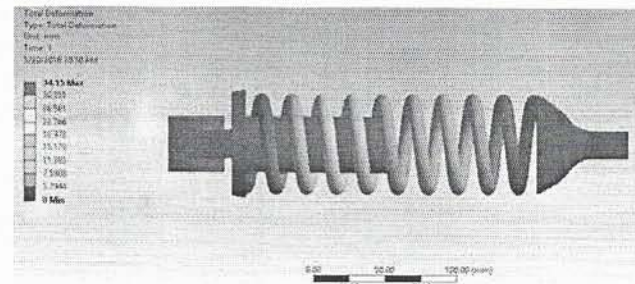


Fig.2. Total deformation of shock absorber for the first case

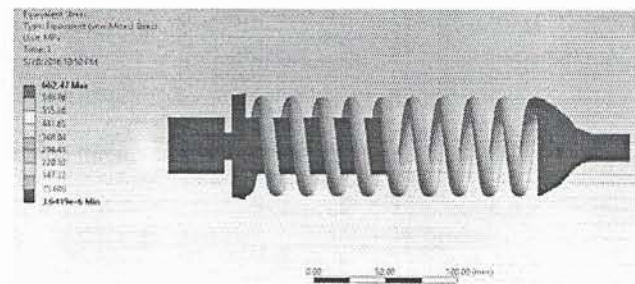


Fig.3. Von Mises stress of shock absorber for the first case

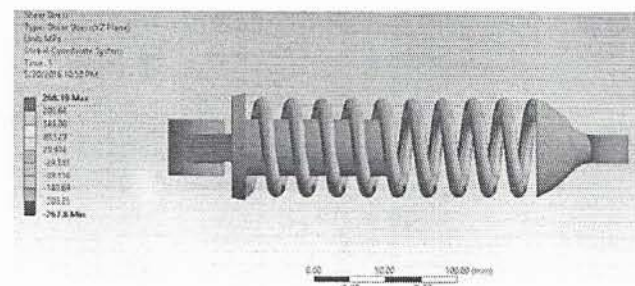


Fig.4. Shear stress of shock absorber for the first case

Figure 2 shows that the largest displacement appears in an area where the force is applied. The highest recorded value is 34.15 mm. Maximum von Mises stress (662.47 MPa) is developed at the inner side of the helical spring (Fig. 3). The maximum value of shear stress, 268.19 MPa, is recorded on a part of the helical spring which comes into contact with other parts of the coils during the compression process.

The simulation results for the second case, ie, when the material of coil is spring steel, are shown in the following three pictures.

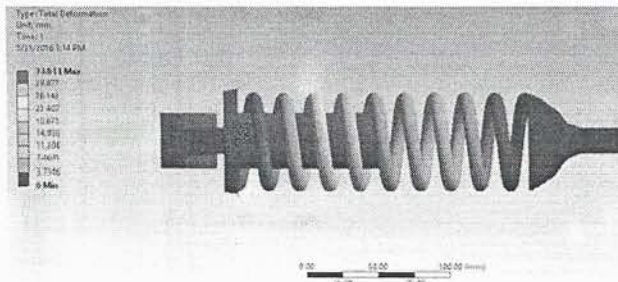


Fig.5. Total deformation of shock absorber for the second case

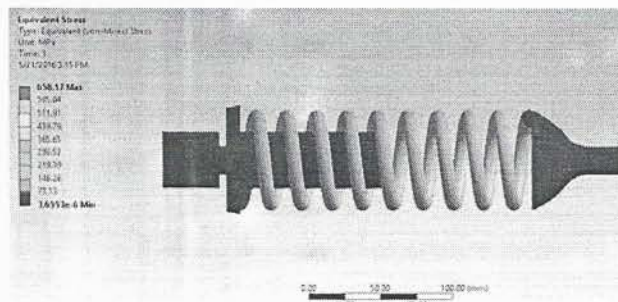


Fig.6. Von Mises stress of shock absorber for the second case

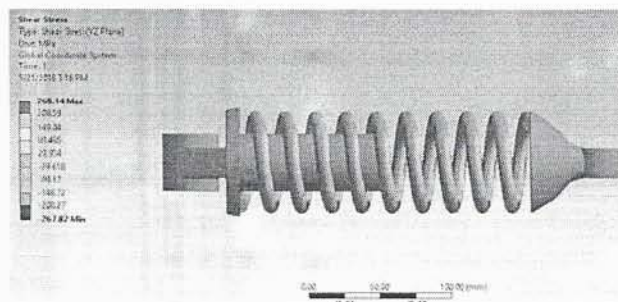


Fig.7. Shear stress of shock absorber for the second case

Results of the second case, show the same von Mises stress distribution, deformations and the shear stress. Maximum deformation is 33.61 mm, while von Mises stress has maximum value 658.17 MPa. Shear stress of shock absorber has maximum value 268.14 MPa. Finally, the third case involves the use of chromium-vanadium steel materials. The simulation results are shown in the following figures.

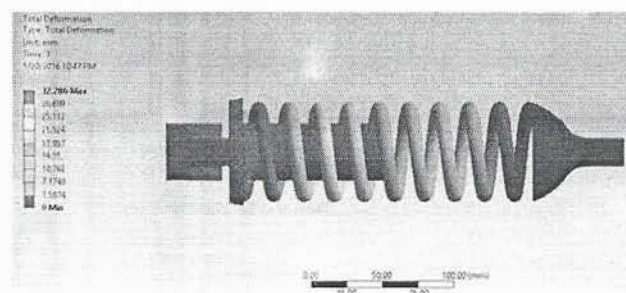


Fig.8. Total deformation of shock absorber for the third case

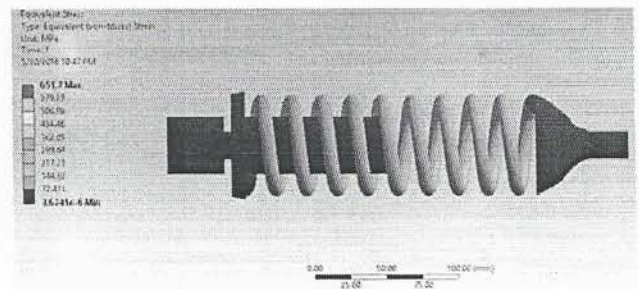


Fig.9. Von Mises stress of shock absorber for the third case

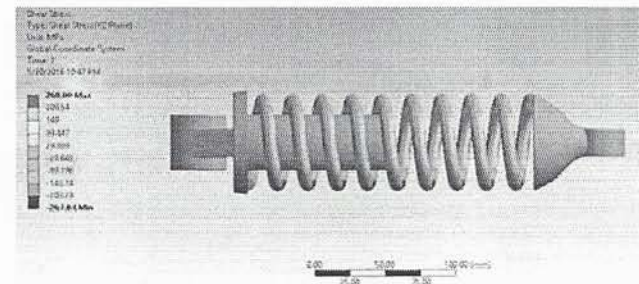


Fig.10. Shear stress of shock absorber for the third case

Fig. 8 shows that the deformations are smallest in this case, and have the maximum value of 32.28 mm. Also, the maximum value of von Mises stress (651.7 MPa) is smaller than in the previous two cases. Shear stress also has a lower maximum value (268.09 MPa). Next figure showed that the best solution, as the material of helical coils, is chromium-vanadium steel, because during the compression springs observed the smallest deformations (Fig. 11).

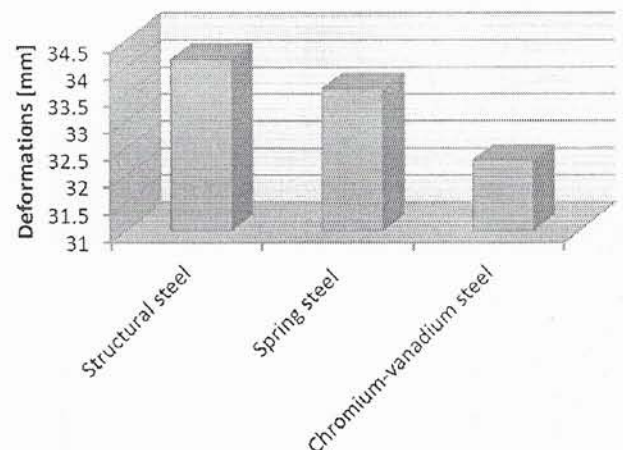


Fig.11. Comparison of the obtained deformations

## 5. CONCLUSION

In this study, we studied the behavior of the shock absorber in case loads its own weight and the weight of two passengers. In numerical simulations, we used three different materials spring: structural steel, spring steel and chromium-vanadium steel.

Results of the analysis showed that the best solution, as the material of helical springs, is chromium-vanadium steel, because during the compression springs observed the smallest deformations and von Mises stresses

Our future research will be in the direction of optimization design springs, and testing of dynamic loads. It would be interesting to find a solution by optimizing the design in order to find the application of materials that give a poor results during workloads.

## ACKNOWLEDGEMENT

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## INDEX

## A

1. Gheorghe ACHIMAŞ 143
2. Adem ACIR 203, 207
3. Vasile ALEXA 113, 185
4. Zoran ANIŠIĆ 23
5. Aco ANTIĆ 13
6. Uğur ARABAÇI 177
7. Silviu Dan AVRAM 151
8. Silviu Răzvan AVRAM 151, 189

## B

9. Brajan BAJCI 225
10. Milan BANIĆ 67
11. Mirko BLAGOJEVIC 55
12. Ilare BORDEAŞU 163
13. Stevo BOROJEVIĆ 13

## C, Č, Ć

14. Ramazan ÇAKIROĞLU 203, 207
15. Maja ČAVIĆ<sup>H</sup> 41, 45
16. Yafes ÇAVUŞ 229
17. Onur ÇAVUŞOĞLU 199
18. Vasile George CIOATA 99, 193
19. Florin CORCIOVA 137
20. Olimpia COROIAN 109
21. Franc CUS<sup>H</sup> 181

## D, Đ, DŽ

22. Halil DEMR 211
23. Eleonora DESNICA 173
24. Aleksandar DIMIC 157
25. Jovan DORIĆ 89, 105
26. Slobodan DUDIC 225
27. Mića ĐURĐEV 13
28. Stefan ĐURĐEVIĆ 19, 29
29. Aleksandar ĐURIĆ 235
30. Dragan DŽODAN 1

## F

31. Igor FÜRSTNER 23, 169

## G

32. Cristian GHERA 163
33. Jasna GLISOVIC 83
34. László GOGOLÁK 23, 169
35. Marin GOSTIMIROVIC 59
36. Ivan GRUJIC 83, 93
37. Hakan GÜRÜN 177
38. Csaba GYENGE 143

## H

39. Gorazd HLEBANJA 7

## I

40. Stefan ILIC 37
41. Lozica IVANOVIC 33

## J

42. Drago JELOVAC 157
43. Marjan JENKO 7
44. Dušan JEŠIĆ 59
45. Mitar JOCANOVIĆ 89

## K

46. Nemanja KAŠIKOVIĆ 19, 29
47. Duran KAYA 217
48. Imre KISS 99, 193
49. Ivan KNEŽEVIĆ 73, 137
50. Nenad KOLAREVIĆ 221
51. Nebojša KOSANOVIĆ 221
52. Pavel KOVAČ 59
53. Gökhan KÜÇÜKTÜRK 199, 217
54. Abdullah KURT 229
55. Siniša KUZMANOVIĆ 73

## L

56. Dejan LUKIC 13
57. Jovanka LUKIĆ 79

## M

58. Slavica MAČUŽIĆ 79
59. Marija MAJSTOROVIC 157
60. Tiberiu Ştefan MĂNESCU 123, 151
61. Una MARČETA 235
62. Andrei MARCU 137
63. Marija MATEJIC 33
64. Milos MATEJIC 33, 55
65. Lavinia Madalina MICU 163
66. Ivana MILENKOVIC 225
67. Marijana MILICEVIC 33
68. Danijela MILORADOVIC 93, 117
69. Nenad MILORADOVIC 37
70. Marko MILOŠ 221
71. Mijodrag MILOŠEVIĆ 13
72. Miloš MILOVANČEVIĆ 63
73. Aleksandar MILTENOVIC 67
74. Đorđe MILTENOVIC 67
75. Cristian Marius MIMIŞ 123, 127
76. Žarko MIŠKOVIĆ 157
77. Radivoje MITROVIC 157

## N

78. Atila NAD 23
79. Uroš NEDELJKOVIĆ 19
80. Nebojša NIKOLIĆ 89, 105
81. Dragoljub NOVAKOVIĆ 19, 29

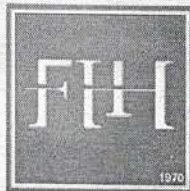
## O

82. Milosav OGNJANOVIĆ 1
83. Hacı Bekir ÖZERKAN 211, 217

## P

84. Milan PAVLOVIĆ 235

85.	Marko PENČIĆ	41, 45	107.	Boris STOJIC	49, 117
86.	Ivan PINČJER	19, 29	108.	Jovan SULC	225
87.	Gábor PINTYE	143	T		
88.	Corneliu E. PODOLEANU	163	109.	İsmail TEKAÜT	211
89.	Mircea Octavian POPOVICIU	163	110.	Aleksandar TOMOVIĆ	173
90.	Aleksandar POZNIĆ	49, 117	111.	Sanjin TROHA	63
91.	Zeno-Iosif PRAISACH	123	U		
R			112.	Hasan Basri ULAŞ	229
92.	Milan RACKOV	73, 137	V		
93.	Sorin RAȚIU	113, 185	113.	Miroslav VEREŠ	73
94.	Vule RELJIC	225	114.	Gojko VLADIĆ	19, 29
95.	Mileta RISTIVOJEVIC	157	115.	Gheorghe-Daniel VOINEA	137
96.	Dragan RUŽIĆ	131	116.	Rodoljub VUJANAC	37
S, Š			117.	Bogdana VUJIĆ	235
97.	Laura Cornelia SALCIANU	163	118.	Jovan VUKMAN	13
98.	József SÁROSI	147	119.	Miroslav VULIĆ	173, 235
99.	Borislav SAVKOVIĆ	59	Y		
100.	Ulvi ŞEKER	211, 229	120.	Selçuk YAĞMUR	207, 229
101.	Dragan SESLIJA	225	121.	Yakup YURGUT	207
102.	Mirko SIMIKIĆ	131	Z, Ž		
103.	Ivan SOVILJ-NIKIĆ	59	122.	Miodrag ZLOKOLICA	41, 45
104.	Nemanja SREMČEV	23	123.	Uros ZUPERL	181
105.	Jelena STEFANOVIĆ-MARINOVIĆ	63			
106.	Nadica STOJANOVIC	83, 93			



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