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THE 9TH INTERNATIONAL SYMPOSIUM
MACHINE AND INDUSTRIAL DESIGN IN MECHANICAL ENGINEERING

# KOD

Konstruisanje • Oblikovanje • Dizajn

# 2016

# PROCEEDINGS

9

9 - 12 June 2016, Hotel Marina, Balatonfüred, Hungary

University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
Politehnica University Timisoara, Faculty of Engineering, Hunedoara, Romania
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The Ninth International Symposium

# KOD 2016

## Machine and Industrial Design in Mechanical Engineering

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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 $9^{th}$ and $12^{th}$ 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.*

*Prof. D.Sc. Siniša Kuzmanović, Eng.*
*Prof. D.Sc. Imre Kiss, Eng.*
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# 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 motocycle, 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 syspension 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.

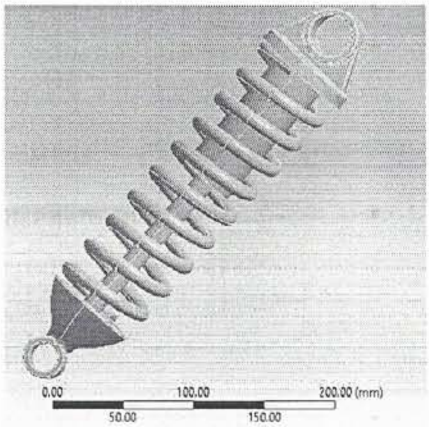


*Fig. 1. Geometry of shock absorber*

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$^3$) | 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 syspension 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

$$\delta W_{\text{int}} = \delta W_{ext} \tag{1}$$

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

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

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

$$\boldsymbol{\sigma} = \mathbf{Ce} \tag{3}$$

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

$$\mathbf{KU} = \mathbf{F}_{ext} \tag{4}$$

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.

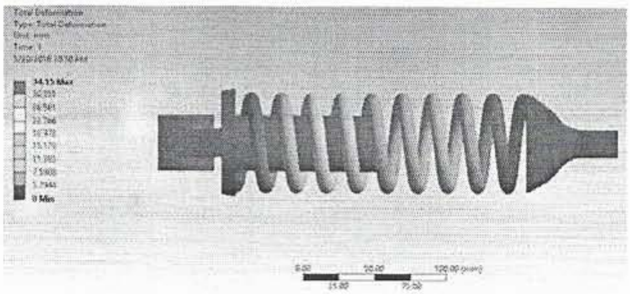

*Fig.2. Total deformation of shock absorber for the first case*

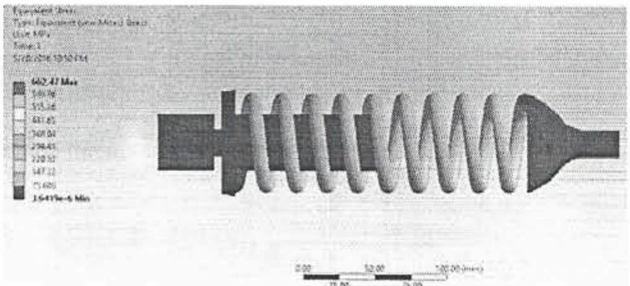

*Fig.3. Von Mises stress of shock absorber for the first case*

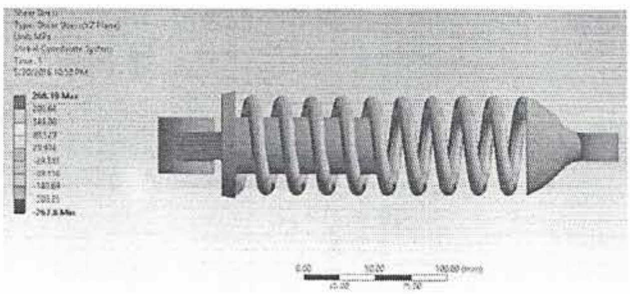

*Fig.4. Shear stress of shock absorber for the first case*

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.

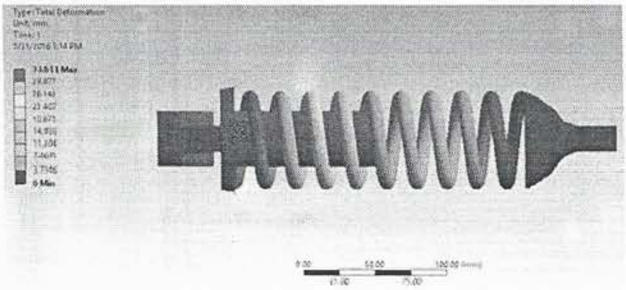

*Fig.5. Total deformation of shock absorber for the second case*

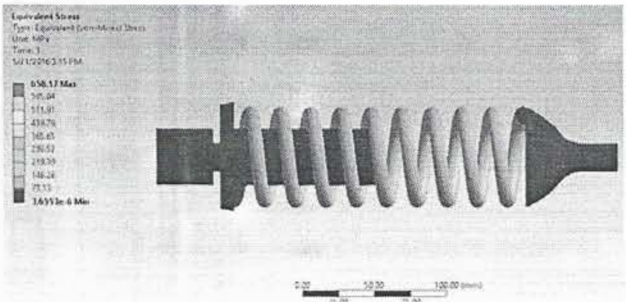

*Fig.6. Von Mises stress of shock absorber for the second case*

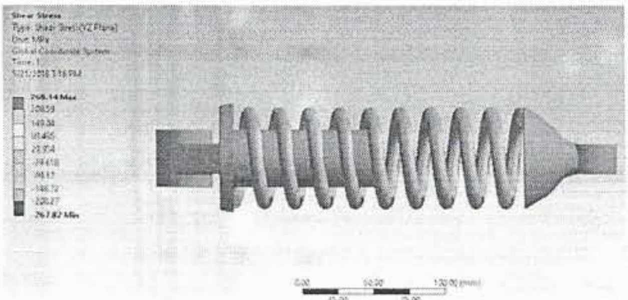

*Fig.7. Shear stress of shock absorber for the second case*

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.

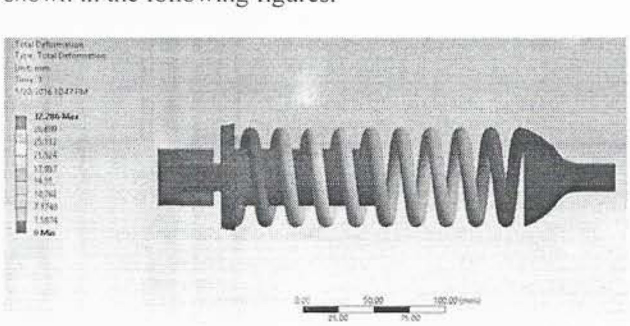

*Fig.8. Total deformation of shock absorber for the third case*

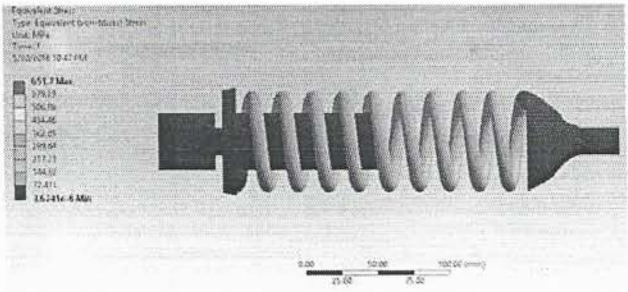

*Fig.9. Von Mises stress of shock absorber for the third case*

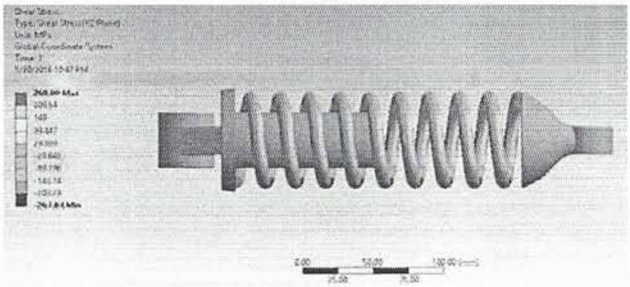

*Fig.10. Shear stress of shock absorber for the third case*

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).

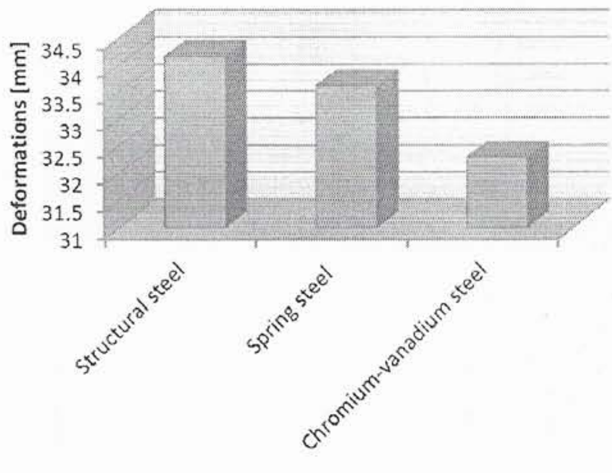


*Fig.11. Comparison of the obtained deformations*

## 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.

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# INDEX

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