International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 7, Issue 8, August 2018, ISSN: 2278 -7798

Optimization of a shock absorber using Finite Element Analysis

Sitangshu Chatterjee, Subhas Nandy

***Abstract*— Shock absorbers form an essential part of most modern vehicles. For proper functioning of the shock absorbers without failure, prior analysis of the stresses developed and the resulting deformation is required. The modern approach is to use Finite Element Analysis because of its cost-effectiveness and time-efficiency. In this study, we use two different commercial FEA packages to carry out the simulation of shock absorbers subjected to load and its variation of performance based on various parameters like material of spring used, profile of spring wire and number of coils in the spring. This study is a first-of-its-kind approach aimed at multi-parameter optimization of the spring used in a shock absorber.**

***Index Terms*—Shock absorber, Finite Element Analysis, Abaqus, Ansys, Optimization.**

1. Introduction

Most modern vehicles are equipped with shock absorbers to dampen the vibrations caused to the vehicle body when travelling over uneven roads. They form an integral part of the vehicle suspension system and aids in limiting body movement of the vehicle, stabilizing the ride and tires as well as limit the damage caused to the vehicle chassis. Another major function of the shock absorber is to keep the vehicle tire in contact with the ground at all times, even on a bumpy road. Keeping these essential functions in mind, stresses developed in the shock absorber and the resulting deflection are the two most important parameters to be taken care of while designing a shock absorber for any vehicle.

A particular area of interest among researchers has been the design of a mono-tube shock absorber used in motorcycles. It essentially consists of an upper mount with a piston-rod extension, which fits inside the inner walls of the lower mount. The lower mount has hydraulic oil which acts as a damper and dissipates the energy absorbed by the shock absorber. A helical compression spring lies outside the outer wall of the lower mount, and is ground at the ends to maintain contact with the flat ends of the upper and lower mounts. The major stresses developed in the helical spring of a shock absorber; and hence, researchers have worked on analysing the stresses and deformation in the spring due to the forces applied on the shock absorber. Reference [1] carried out the structural and modal analysis of a two wheeler suspension systems using two different materials-spring steel and beryllium copper, of varying wire diameters, and concluded that spring steel of lesser diameter is a better choice. Reference [2] made a comparative study of the shear stresses and deflection in spring wires made of carbon steel, brass and Monel metal. It was found that carbon steel exhibited the least deflection. The effects of increasing wire diameter were studied by [3], who came up with a modified design to reduce the resulting stresses in the spring. Reference [4] used spring steel, beryllium copper and carbon fibre and studied the effects of changing spring materials on the resulting stresses and deflection. Structural steel and aluminium alloy were used by [5] as materials to compare their effects for the same loading conditions, who concluded that structural steel is the preferred material. Reference [6] did structural and modal analysis using FEA tool to verify the best material for spring in shock absorber, and concluded that spring steel is better than phosphor bronze due to the comparatively lesser stresses and deformation. Reference [7] analysed the effects of varying speed on the spring of a mono-suspension system used in motorcycle.

While most of the aforementioned researchers studied the effects of varying materials of the spring on the performance of the shock absorber, no comprehensive study was done to compare the effects of the varying the cross section of the spring wire itself. In this paper, we carry out the Finite Element Analysis of a helical spring for varying cross-section of spring wires, and further optimize it by varying the materials used. To the best of the authors' knowledge, no previous study has been done to optimize the performance of a shock absorber taking into consideration both the materials and the cross-sectional shape of the spring wire.

2. Design

The parts of the shock absorber were created using the commercial CAD software Solidworks. The major components of the shock absorber assembly made were the upper mount, the lower mount and the helical spring. The CAD model of the final assembly of the shock absorber has been shown in Fig. 1.

The essential dimensions of the spring were taken from a commercial automobile shock absorber and were found to be:

Eye to eye distance=306 mm
Free length of spring=250 mm
Diameter of spring wire=8 mm
Mean diameter of helix=55 mm
Number of turns=10,15

Manuscript received July 2018
***Sitangshu Chatterjee**, Department of Mechanical Engineering, National Institute of Technology, (e-mail: sitangshugk95@gmail.com). Durgapur, India, +918436525281*
***Subhas Nandy**, Department of Mechanical Engineering, National Institute of Technology, (e-mail: subhas.nandy72@gmail.com). Durgapur, India, +919547200825*

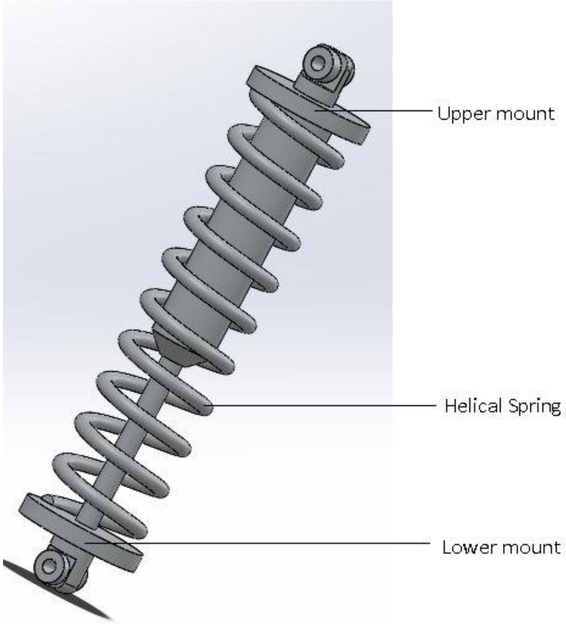

Fig. 1: CAD model of shock absorber

3. Analysis of the model

The analysis of the Shock Absorber was carried out on two different commercial Finite Element Analysis softwares: Abaqus and Ansys. The model simulated using Abaqus had 15 turns and the one simulated using Ansys had 10 turns in the spring.

Steps in Abaqus

Importing the Model

Each of the parts was imported as a 'Single Body' with 'Deformable' characteristics.

Assigning Materials

The material properties of the spring, upper and lower mounts were defined. Stainless Steel was selected as the material of choice for the lower and upper mounts, and a variety of materials were chosen one at a time for the spring. The essential material properties defined were the modulus of elasticity, density and Poisson's ratio.

Section Assignments

A solid, homogeneous section was specified individually for each part and the respective materials were associated with the sections.

Meshing

The meshing of the parts was carried out individually, and different global seed values were assigned to each part, with finer mesh being applied to the parts where stresses are expected to be more. Consequently, a moderately coarse mesh was assigned to the upper and lower mounts, and a finer mesh was assigned to the helical spring.

Assembly

The instances were brought together in the Assembly module, and assembled according to the physical orientation of the real-life shock absorber. A reference point was assigned to the upper mount, which represents the point where the concentrated load was applied.

Definition of Interaction Properties

The nature of contact existing between the different instances, as well as among themselves, was defined.

A mechanical "Hard" contact property was defined with normal pressure load attribute, with "separation of contact" selected so as to enable the rebound of the spring during unloading.

Definition of Self-Contact in the spring

In order to ensure no-penetration of the spring coils into each other during the analysis, "Self-contact" was defined in the turns of the spring, excluding the top and bottom flattened surfaces of the spring where it is in contact with the mounts.

Defining the Constraints

Two different constraints were defined in the model to replicate the real-life physical state of the shock absorber:

Coupling Constraint between point of loading and upper surface of spring: This constraint connects the upper surface of spring to the point of loading (as defined in Assembly module), ensuring that the upper flat surface of the spring moves along with the upper mount, and compresses the spring during loading.

Tie Constraint between lower mount and the lower surface of spring: The lower mount of the shock absorber is fixed, and the lower surface of spring which is in contact with the lower mount should not undergo any motion. This is ensured by the Tie constraint.

Application of Load

A concentrated load was applied at the point of loading and its orientation was specified.

Imposition of Boundary Conditions

The lower mount of the Shock Absorber is fixed, and thus, an "Encastre" boundary condition was imposed on the lower mount instance. Due to "Tie" constraint, the lower surface of spring was essentially tied with the lower mount, and was ensured to behave as fixed.

Submission of Job

The job was created, checked and then submitted for analysis. The resulting shear stresses and deflection in the axial direction were computed for further study and verification.

Steps in Ansys

Importing the Model

The assembled model was imported. The contacts between the surfaces are automatically detected in Ansys.

Assigning Materials

The material properties of the spring, upper and lower mounts were defined. Stainless Steel was selected as the material of choice for the lower and upper mounts, and a variety of materials were chosen one at a time for the spring. The essential material properties defined were the modulus of elasticity, density and Poisson's ratio.

Meshing

The meshing of the parts was carried out using hex elements, with finer mesh being applied to the parts where stresses are expected to be more. Consequently, a moderately coarse mesh was assigned to the upper and lower mounts, and a finer mesh was assigned to the helical spring.

Defining the Contacts

Contacts were defined in the model to replicate the real-life physical state of the shock absorber. Two such surfaces of contact exist- one between one ground end of the spring and the lower mount, and the other between the other ground end of the spring and the upper mount. Both these surface pairs are essentially always in contact, and hence the contacts between them were defined as "Bonded".

Application of Load

An axial compressive load was applied at the point of loading.

Imposition of Boundary Conditions

The lower mount of the Shock Absorber is fixed, and thus, a "Fixed Support" boundary condition was imposed on the lower mount. Due to its "Bonded" contact with the upper ground surface of spring, the upper mount was designed to move along with the spring when compressed, while the lower mount remained fixed in its position.

Solve

The model was submitted for analysis, and the resulting shear stresses and deflection in the axial direction were computed for further study and verification.

4. RESULTS

The undeformed state of the shock absorber with 15 coils in its helical spring has been shown in Fig. 2 and the resulting maximum shear stresses and deformation have been analysed using Abaqus and shown in Fig. 3 and Fig. 4 respectively.

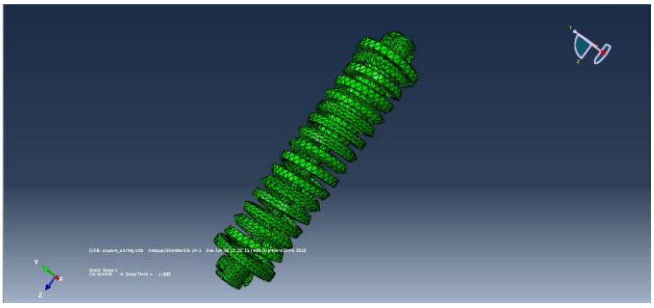

Fig. 2 Undeformed shock absorber

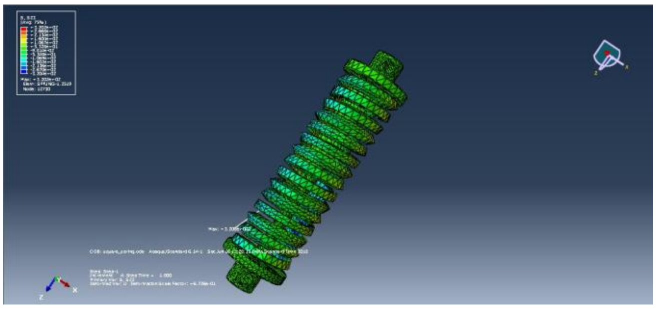

Fig. 3 Visualization of maximum shear stresses in Abaqus

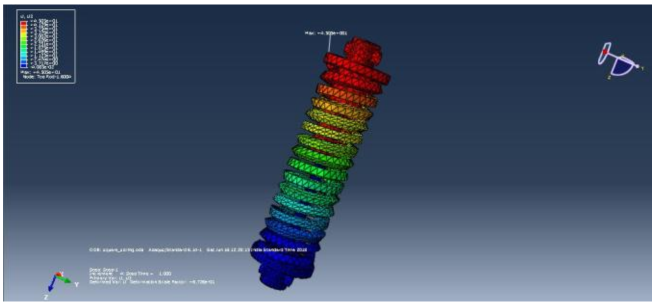

Fig. 4 Visualization of deformation in Abaqus

The undeformed state of the shock absorber with 10 coils in its helical spring has been shown in Fig. 5 and the resulting maximum shear stresses and deformation have been analysed using Abaqus and shown in Fig. 6 and Fig. 7 respectively.

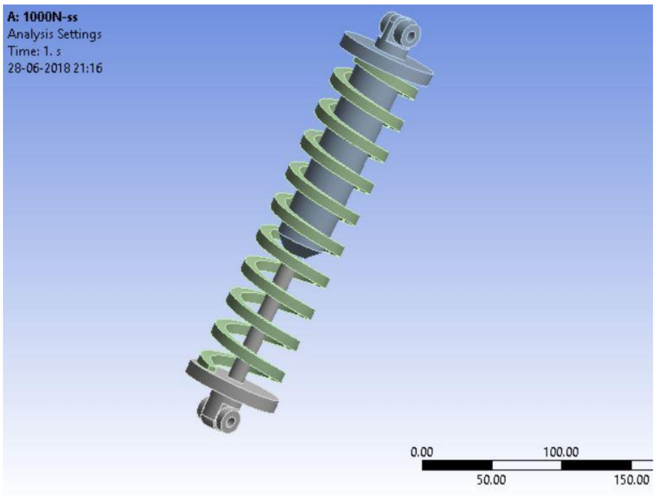

Fig. 5 Undeformed shock absorber

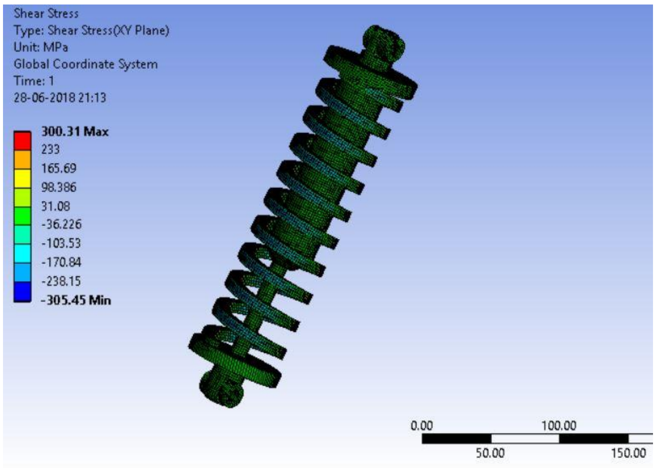

Fig. 6 Visualization of maximum shear stresses in Ansys

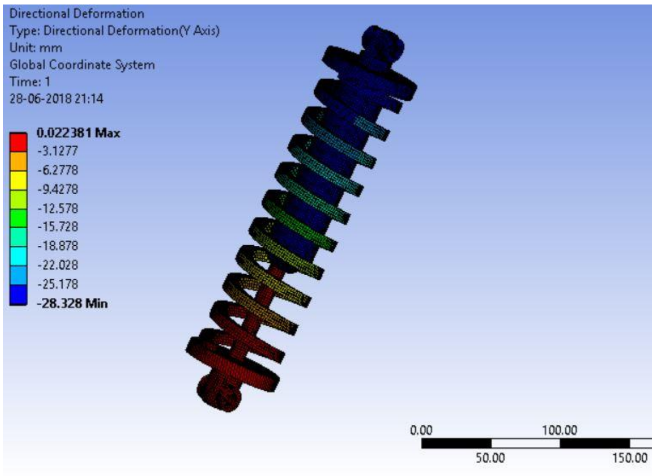

Fig. 7 Visualization of maximum shear stresses in Ansys

The main aim was to find the most optimum material among a set of three most commonly used materials, and then to optimize the preferred cross-sectional shape of a spring wire made of the optimized material by studying the stresses and deformation developed in the spring. Thereafter, a comparative study was made to study the effect of the number of turns in the spring on the spring of optimized material and cross-section. The comparative study between theoretical and FEA values showing the variation in shear stresses and deflection for square and round profile springs for different materials with the number of turns of spring has been shown in Fig. 8 and Fig. 9 respectively.

Optimization of Material

Three different materials were chosen for analysis- ASTM A227, ASTM A679 and Monel K metal. It was found that the results of simulation were quite close and within the limits of numerical errors to the theoretical values obtained by analytical relationship. According to the results obtained for stress and deflection values, ASTM A679 spring steel was found to be the most suitable material for usage in shock absorbers, complying with the optimal stress and deformation values. Further, optimization of cross-sectional shape of the spring wire was done by selecting ASTM A679 as the most optimum material.

Optimization of cross-sectional shape of spring wire

The analysis was further performed on two different profiles of springs-round and square. It was seen that for ASTM A679 spring steel, the spring made of square cross-section showed lesser stress and deformation compared to round profile springs.

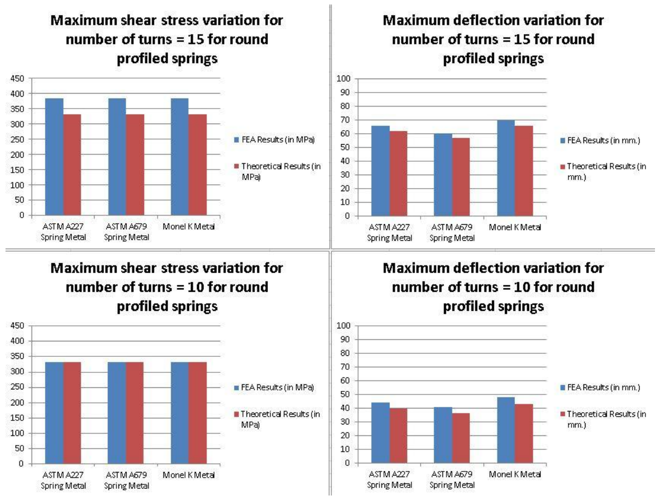

Fig. 8 Variation of shear stress and deflection in round profile springs with number of turns

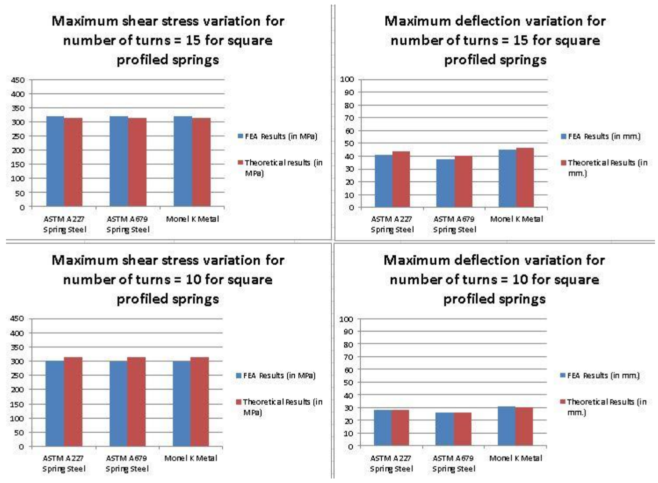

Fig. 9 Variation of shear stress and deflection in square profile springs with number of turns

Load Applied (in N)	Material	Number of turns in spring	Stress developed (in MPa)				Deflection of spring (in mm.)			
			Round Profile (FEA Results)	Round Profile (Theoretical Results)	Square Profile (FEA Results)	Square Profile (Theoretical Results)	Round Profile (FEA Results)	Round Profile (Theoretical Results)	Square Profile (FEA Results)	Square Profile (Theoretical Results)
1000	ASTM A227 Spring Metal	10	384.701	332.805	320.167	313.787	65.965	62.254	40.913	44.044
		15	332.89	332.805	300.31	313.787	44.309	39.713	28.328	28.096
	ASTM A679 Spring Metal	10	384.701	332.805	320.167	313.787	60.599	57.185	37.584	40.458
		15	332.9	332.805	300.29	313.787	40.981	36.733	26.2	25.989
	Monel K Metal	10	384.701	332.805	320.167	313.787	69.912	65.982	44.985	46.682
		15	332.92	332.805	300.27	313.787	48.107	43.133	30.758	30.516

5. CONCLUSION AND FUTURE WORK

A comparative study showing the results of the analysis study and theoretical values has been shown in Table 1.Based on the results obtained from the finite element analysis of the model, it was found that square profiled springs made of ASTM A679 spring steel is more suitable for application is shock absorbers of motorbikes, as compared to round profile springs. It was also established that reduction in the number of turns of the spring resulted in a reduction in maximum axial deformation, though the stress induced in the spring material did not change by a significant amount. However, if the number of turns is reduced drastically, the spring would become excessively stiff, thus inhibiting compression during loading, and this would undermine the very purpose of usage of springs in shock absorbers. Hence, a trade-off is essential and optimal number of turns of spring should be applied.

Further enhancements to this work may include: introduction of a damping fluid between the piston rod of the lower mount and the hole in the upper mount, usage of advanced materials like composites as spring materials and study of the changes introduced in stresses and deflections

REFERENCES

[1] Rameshbabu, K. and Rao, T.B., 2013. Design Evaluation of a two wheeler suspension system for variable load conditions. International Journal of Computer Engineering Research, 3(4), pp.279-283.

[2] Lade, A.V., Paropate, R.V., Choube, A.M. and Wakulkar, R.E., Analysis of mono suspension spring with different materials. International Journal of Research In Science & Engineering e-ISSN.

[3] Logavigneshwaran, S., Sriram, G. and Arunprakash, R., 2015. Design and Analysis of Helical Coil Spring in Suspension System. International Journal For Trends In Engineering & Technology.

[4] Chavhan, G.R., Burande, S.W. and Dhole, L.P., 2014. ANALYSIS OF SHOCK ABSORBER USING DIFFERENT MATERIAL OF SPRING.Int J AdvEngg Tech/Vol. V/Issue IV/Oct.-Dec, 19, p.21.

[5] Raddy, S. and ThontarajUrs, T.S., 2014. Comparative Study of Static Structural Analysis of a Shock Absorber for Different Material.IJESIT, vol3, (6).

[6] Banginwar, A.P., Bhusale, N.D. and Kautuk, V.T., 2014. Design and analysis of shock absorber using FEA tool.International Journal of Engineering Research and Development, 10(2), pp.22-28.

[7] Jadhav, P.R., Doshi, N.P. and Gulhane, U.D., 2014. Analysis of Helical Spring in Monosuspension System Used in Motorcycle. International Journal of Research in Advent Technology, 2(10).

Sitangshu Chatterjee pursued his B.Tech in Mechanical Engineering from the National Institute of Technology, Durgapur, India. He is currently pursuing his M.Eng degree from Texas A&M University, College Station, USA

Subhas Nandy pursued his B.Tech in Mechanical Engineering from the National Institute of Technology, Durgapur, India. He is currently working as a Graduate Engineering Trainee (GET) in BALCO India – Vedanta Resources, Korba, Chhattisgarh, India.

.