An Numerical Investigation of Open Coil Helical Compression Spring Using Different Alloys Materials for Light Duty Vehicle

Samuel Tilahun*, P. Velmurugan
Department of Mechanical Engineering, School of Mechanical and Automotive Engineering, College of Engineering and Technology, Dilla university, Dilla, Ethiopia.

* Corresponding author: samueltl@du.edu.et

Abstract. The main purposes of automobile open coil suspension systems are to isolate the chassis of the vehicle and the passenger from shocks and vibrations caused by irregularities of the road surface. The main objective of this work is to concentration on the stress and deflection of open coil helical spring used in light vehicle suspension spring with different materials. Finite Element Analysis of open coil helical spring has been carried out. In FEA 3D modeling is done in SOLIDWORKS and analysis is in ANSYS software. From the ANSYS results, it is observed that the maximum deflection in the Chrome Vanadium spring is 217.47 mm and in Chrome Silicon and Hard drawn steel springs are 212.83 mm and 212.36 mm respectively. From the ANSYS results, it also seen that the shear stress in the Chrome Vanadium spring is 757.21 MPa and in Chrome Silicon and Hard drawn steel springs are 753.65 MPa and 761.32 MPa respectively. From ANSYS results the maximum shear stress of Chrome Silicon alloy steel spring is less compared to Chrome Vanadium and Hard Drawn alloy steel spring.

Keywords: coil spring; finite elements analysis; stress analysis; Chrome Silicon alloy steel; Chrome Vanadium alloy steel; Hard Drawn alloy steel.

1. Introduction
Mechanical springs are used in machines to exert forces, to afford elasticity, and to store or absorb energy. In general, open coil helical springs is classified as coil springs, leaf springs or special shaped springs. Most of the vehicles have open coil helical compression spring as one of the main elastic members in their suspension systems. They act as an energy absorbing machine element. The prime aim of a vehicle suspension system is to connect the wheel to the body. Suspension system of automotive vehicle is very needful part, they are responsible to absorb road shock and isolated passenger curb to road shock, comfort, safety, handling, road holding and ride quality. Investigated on springs design as the determination of the geometry, dimensions, and stiffness of a spring needed to satisfy the force-deflection requirements [1, 2]. The analyzed reduction of overall stress and deflection of Chrome Vanadium and 60Si₂MnA steel. It is observed that the 60Si₂MnA [3, 4, 5]. Stress and deflection of existed steel helical compression spring and new material. It is observed that reduction of stress and deflection in new material [6]. The modal and structural analysis was done on spring steel and Phosphor Bronze. Finally authors conclude that steel material for spring is best [7]. The open coiled helical compression materials has been used for Chrome Vanadium steel material, Chrome
Silicon steel and Hard Drawn steel [8, 9]. Based on the dimensions obtained from the conventional helical compression spring was created with the help of the 3D modeling SOLIDWORKS software. The main objectives of this work are to reduce the overall deflection and stresses of the open coil helical compression spring by finite element approach.

2. Materials and Methods

In this Finite Element Analysis model is prepared in SOLID WORK 15 and save as in IGES file format. Then its IGES format file is imported in ANSYS WORKBENCH 15.0. In ANSYS 15.0 material properties, meshing and boundary condition is given. In this solution deformation and stress are simulated. These calculations carried out for the chosen materials for spring steels such as Chrome Vanadium, Chrome Silicon and Hard Drawn alloy steel. The results obtained for various considerations are compared for the three materials chosen. The open coil helical compression spring which is used in Nissan patrol/safari 2010 front suspension. This spring is made up of ASTM A231 material with square ends.

Length of the vehicle: 5080 mm
Width of the vehicle: 1940 mm
Height: 1855 mm
Wheel Base of the vehicle: 2970 mm
Curb Weight: 2465 kg
Seating Capacity (Persons): 7

The material properties and boundary conditions of helical compression spring are carried out in static analysis. This analysis involves meshing, boundary and loading conditions. Figure 1 is shown as meshed 3D model of helical compression spring. The loading and boundary conditions of helical compression spring is shown in Figure 2.

- Mesh statics: Fine mesh
- Number of nodes: 4681
- Number of elements: 1785

3. Results and discussions

The simulated results of deformation and stress are discussed. These calculations carried out for the chosen materials for spring steels, viz., Chrome Vanadium, Chrome Silicon and Hard Drawn alloy steel for minimum and maximum load conditions. The results obtained for various considerations are compared for the three materials chosen.
3.1. Static Analysis of Chrome Vanadium Steel

From the FEA, the maximum deflection and shear stress under 3234 N are 108.73 mm and 378.6 MPa respectively shown in Figure 3a and Figure 3b.

![Figure 3](image1.png)

Figure 3. (a). Deformation in xy Plane under 3234N Load (b). Stress in xy Plane under 3234N Load

From the FEA, the maximum deflection and shear stress under 4312 N are 144.98 mm and 504.8 MPa respectively shown in Figure 4a and Figure 4b.

![Figure 4](image2.png)

Figure 4. (a). Deformation in xy Plane under 4312N Load (b). Stress in xy Plane under 4312N Load
From the FEA, the maximum deflection and shear stress under 5390 N are 181.22 mm and 631.0 MPa respectively shown in Figure 5a and Figure 5.b.

From the FEA, the maximum deflection and shear under 6468 N are 217.47 mm and 757.21 MPa respectively shown in Figure 6a and Figure 6.b. The area of maximum deflection and maximum shear stress are indicated by red color and the area of minimum deflection and minimum shear stress are indicated by blue color. From the FEA, the maximum stresses are occurred at inner side of the helical compression spring.
3.2. Static Analysis of Chrome Silicon Steel

From the FEA, the maximum deflection and shear stress under 3234 N are 106.41 mm and 376.82 MPa respectively shown in Figure 7a and Figure 7b.

![Figure 7](image)

**Figure 7.** (a) Deformation in xy Plane Under 3234N Load (b) Stress in xy Plane Under 3234N Load

From the FEA, the maximum deflection and shear stress under 4312 N are 141.89 mm and 502.43 MPa respectively shown in Figure 8a and Figure 8b.

![Figure 8](image)

**Figure 8.** (a) Deformation in xy Plane Under 4312N Load (b) Stress in xy Plane Under 4312N Load
From the FE analysis, the maximum deflection and shear stress under 5390 N are 177.36 mm and 628.04 MPa respectively shown in Figure 9a and Figure 9b.

From the FE analysis, the maximum deflection and shear stress under 6468 N are 212.83 mm and 753.65 MPa respectively shown in Figure 10a and Figure 10b.

3.3. Static Analysis of Hard Drawn Steel
From the FE analysis, the maximum deflection and shear stress under 3234N are 106.18 mm and 380.66 MPa respectively shown in Figure 11a and Figure 11b.
From the FEA, the maximum deflection and shear stress under 4312 N are 141.57 mm and 507.55 MPa respectively shown in Figure 12a and Figure 12b.

Figure 11. (a). Deformation in xy Plane Under 3234N Load (b). Stress in xy Plane Under 3234N Load

Figure 12. (a). Deformation in xy Plane Under 4312N Load (b). Stress in xy Plane Under 4312N Load
Figure 13. (a). Deformation in xy Plane Under 5390N Load (b). Stress in xy Plane Under 5390N Load

From the FEA, the maximum deflection and shear stress under 5390N are 176.97 mm and 634.43 MPa respectively shown in Figure 13a Figure 13b.

Figure 14. (a). Deformation in xy Plane Under 6468N Load (b). Stress in xy Plane Under 6468N Load
From the FEA, the maximum deflection and shear stress under 6468 N are 212.36 mm and 761.32 MPa respectively shown in Figure 14a Figure 14b. Consolidated Results of Finite Element Analysis are presented for maximum load conditions in Table 1 and for minimum load conditions in Table 2.

Table 1. FEA Results under Maximum Load Conditions

| Sl.No. | Parameters       | Materials          | Chrome Vanadium | Chrome Silicon | Hard Drawn |
|--------|------------------|--------------------|-----------------|----------------|------------|
| 1      | Deflection (mm)  |                    | 217.47          | 212.83         | 212.36     |
| 2      | Shear Stress (MPa) |                  | 757.21          | 753.65         | 761.32     |

Table 2. FEA Results under Minimum Load Conditions

| Sl.No. | Parameters       | Materials          | Chrome Vanadium | Chrome Silicon | Hard Drawn |
|--------|------------------|--------------------|-----------------|----------------|------------|
| 1      | Deflection (mm)  |                    | 108.73          | 106.41         | 106.18     |
| 2      | Shear Stress (MPa) |                  | 378.60          | 376.82         | 380.66     |

3.4. Comparison of Finite Element Analysis Results

The comparison of FEA results for deflection and shear stress under different loads on Chrome Vanadium, Chrome Silicon and Hard Drawn spring are shown in Table 1 and Table 2. When applied loads are increased the deflection and shear stress also increased.

Figure 15. Graphical representation of stress vs. Load

Figure 16. Graphical representations of deflection vs. Load
The maximum deflections for the three materials of helical compression spring under different loads are shown in Figure 15.

4. Conclusions
The helical coil spring of chrome silicon, chrome vanadium and hard drawn spring steel are studied using FE analysis. The shear stress and deflection values are have been calculated using finite element analysis for Chrome Silicon, Chrome Vanadium and Hard Drawn spring steel. It is observed the maximum deflection in the Chrome Vanadium spring is 217.47 mm and in Chrome Silicon and Hard drawn steel springs are 212.83 mm and 212.36 mm respectively. From the ANSYS results, it also seen that the shear stress in the Chrome Vanadium spring is 757.21 MPa and in Chrome Silicon and Hard drawn steel springs are 753.65 MPa and 761.32 MPa respectively. The FEA results proves that even though the maximum deflection are almost close the value but the maximum shear stress of Chrome Silicon steel spring is less and comparative to the Chrome Vanadium and Hard Drawn steel spring value is high. The above result shows that the Chrome Silicon is best replacement for chrome vanadium and Hard Drawn steel.

5. References
[1] Mott R. C. (1989),”Machine Elements in Mechanical Design”, Maxwell Publishers, New York.
[2] K Pavan Kumar, S Praveen Kumar and G Guru Mahesh (2013), “Static analysis of a primary suspension spring used in locomotive” International Journal of Mechanical Engineering and Robotic Research, IJMERR, Vol. 2(4), pp. 430-436
[3] P.S.Valsange (2012), “Design of Helical Coil Compression Spring”, International Journal of Engineering Research and Application (IJERA), Vol. 29(6), pp.513-522
[4] N.Lavanya, P.Sampath Rao, M.Pramod Reddy (2014), “Design and Analysis of A Suspension Coil Spring For Automotive Vehicle”, International Journal of Engineering Research and Applications, Vol. 4(9), pp.151-157
[5] Mehdi Bakhshesh and Majid Bakhshesh (2012), “Optimization of Steel Helical Spring by Composite Spring”, International journal of multidisciplinary science and engineering, vol.3 (3), pp. 47-51.
[6] C.Madan Mohan Reddy, D.Ravindra Naik, M.Lakshmi Kantha Reddy (2014), “Analysis And Testing Of Two Wheeler Suspension Helical Compression Spring”, International organization of Scientific Research, Vol. 04, Issue 06 , pp. 55-60.
[7] Achyut P, Banginwar , Nitin D. Bhusale, Kautuk V. Totawar (2014), “Design and analysis of shock absorber using FEA tool”, International Journal of Engineering Research and Development, Vol. 10, Issue 2 , pp.22-28.
[8] Samuel Tilahun, Velmurugan,P. Senthil Kumaran S (2020), some study on fatigue life of open coil suspension springs, Journal of Critical Reviews, Vol 7, Issue 13, pp 139-143.
[9] Velmurugan, P.,Kumaraswamidhas, L.A. and Sankaranarayanasamy, K. (2011) ‘Investigation on influence of stiffness and hydro-pneumatic suspension for dynamic analysis of a heavy truck using ADAMS simulation’, Int. J. Human Factors Modelling and Simulation, Vol. 2, No. 3, pp.204–221.