

Design Optimization of Helical Coil Suspension using Aluminium Alloy

¹Chandrakant Khare, ² Dr. Suman Sharma

¹Research Scholar, ²Head of Department

¹Automobile Engineering,

¹ SAGE University, Indore, India

Abstract: With increasing fuel prices and demand to reduce vehicle weight, automobile manufacturers are looking for lighter suspensions without compromising in strength. This research investigates Aluminium alloy helical coil suspension using finite element method by ANSYS software and later subjected to design optimization using response surface optimization considering coil diameter and coil mean radius as optimization parameters. Sensitivities of both input parameters are plotted for equivalent stress and deformation. Considerable weight reduction of helical coil suspension is achieved using response surface method.

Keywords: Helical Coil Suspension, Finite Element Analysis, Response Surface Method

I. INTRODUCTION

Vehicles generate vibration while passing through irregularities or bumps on roads which are absorbed by suspensions. The vehicles must have a good suspension system that can deliver a good ride and good human comfort. Suspension system separate the axle from the vehicle chassis, so that any road irregularities are not transmitted directly to the driver and the load on the vehicle. To reduce damage to vehicles and shocks to passengers it becomes imperative to improve suspension systems. The suspension system isolates vehicle structure and occupants from vibrations caused due to uneven road surface. This is achieved by elasticity property of helical coil suspension which is made up of spiral wire coil with constant cross section diameter and pitch. Suspension systems are made from both compression as well as tension spring. The important criteria in the design of suspension system is strength of steel which determines the acceptable stress level and desired spring rate.



Figure 1: Helical Coil Suspension

II. LITERATURE REVIEW

Anil Antony Sequeira, Ram Kishan Singh, and Ganesh K Shettiet al [1] has conducted static structural analysis to study the behavior of carbon and Kevlar composite helical suspension and comparison is made from steel helical spring using ANSYS software. The properties investigated are load carrying capacity, stiffness along with weight reduction using FRP composite spring. The optimization design parameters are inner coil diameters, pitch length, height. Their researches show that the specific modulus (young's modulus (E) upon mass density of the material (ρ)) of CFRP composite spring is the highest and Kevlar FRP (KFRP) is lowest. Load and deflection characteristics of steel spring have been found better than composite ones. However, mass of the KFRP helical spring has been determined less than CFRP and steel ones. A good percentage of weight reduction is achieved using CFRP against steel suspension.

Nijssen, R.P.L et al [2] has investigated the effect of Fiber volume fraction on properties of composite materials used in analysis of helical coil suspension. A schematic of variation in fiber reinforced composite with amount of fiber volume fraction is shown in figure 2-1. Typically, fiber share 30% to 75% of volume of composites. At low fiber volume fraction, matrix properties are dominant while at high fiber volume percentage, behavior of composite is controlled by the fiber properties. Tensile strength increases with increase the fiber contents while compressive strength is high at low fiber contents and decreases with increasing fiber volume fraction.

Mehdi Bakhshesh et al [3] conducted comparative study using steel spring with composite helical spring and results have shown that composite helical spring is found to have lower stresses and performs best when fiber position has been considered to be in direction of loading. The spring weight is also reduced by changing fiber percentage of Carbon/Epoxy composite.

P.R. Jadhav, N.P. Doshi, and U.D. Gulhane et al [4] in this research steel coil spring is replaced by three different composite material. The results obtained from numerical method are in close agreement with results from analytical method. The stress generated in composite helical coil spring is found to be lower as compared to steel suspensions and considerable weight reduction is also achieved by changing fiber percentage.

III. PROPOSED WORK

The objective of this research is to optimize design of helical coil suspension to reduce weight using response surface methodology. The material used for analysis is Aluminium Alloy and sensitivities of input parameters (coil diameter and coil radius) are determined along with response surfaces.

IV. METHODOLOGY

In this stage the CAD model is developed using ANSYS software. ANSYS design modeler is specific tool used for designing and editing operation. The model is meshed using tetra elements of appropriate size and shape. After meshing appropriate loads and boundary conditions are assigned

Table 1: Dimensions of Helical Coil Suspension [5]

Free Length (lf)	256mm
Mean dia. (D)	48mm
Wire Dia (d)	8mm
No. of turns (n)	16
Pitch (p)	16mm
Spring index (D/d)	6

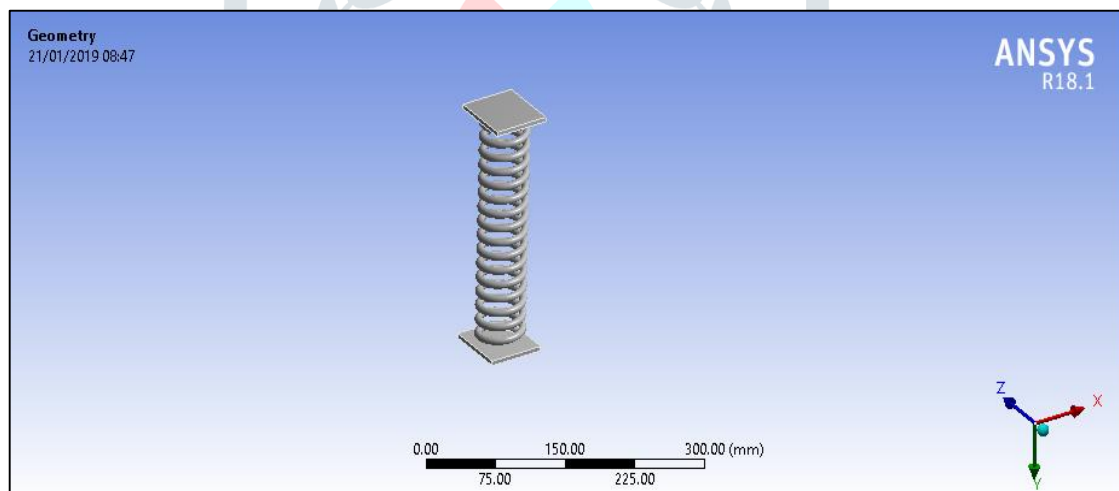


Figure 2: CAD modeling of helical coil suspension

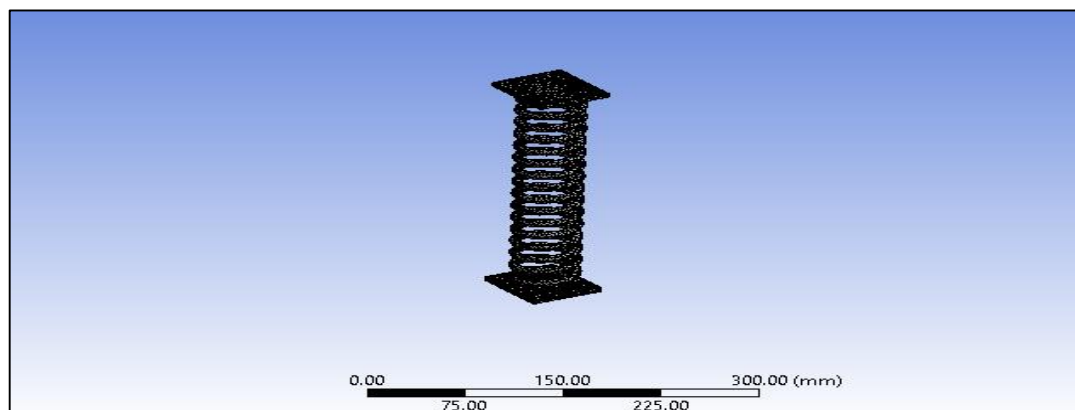


Figure 3: Meshed model of helical coil suspension

The CAD model is meshed using tetrahedral elements and fine sizing with curvature effects on. The number of elements generated is 17431 and number of nodes generated is 34996 as shown in figure 3 above. The element shape of tetrahedral element is shown in figure 3 below. It consists of 4 nodes connected to each other by tetrahedral shape. CAD model of suspension after being meshed is applied with appropriate loads and boundary conditions.

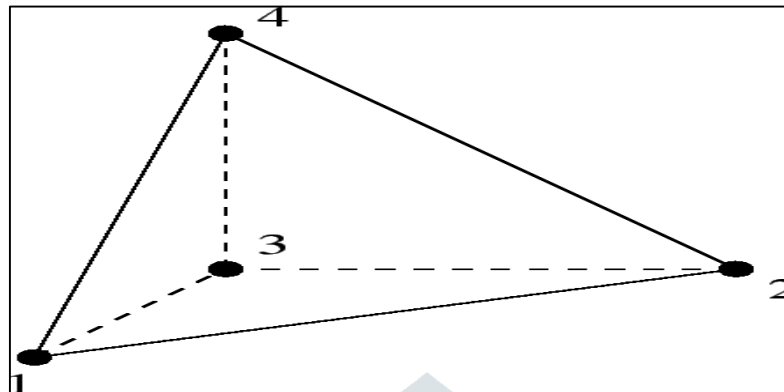


Figure 4: Tetrahedral element

The bottom face of suspension is kept fixed and top face is applied with force of 1356.4N in downward direction.

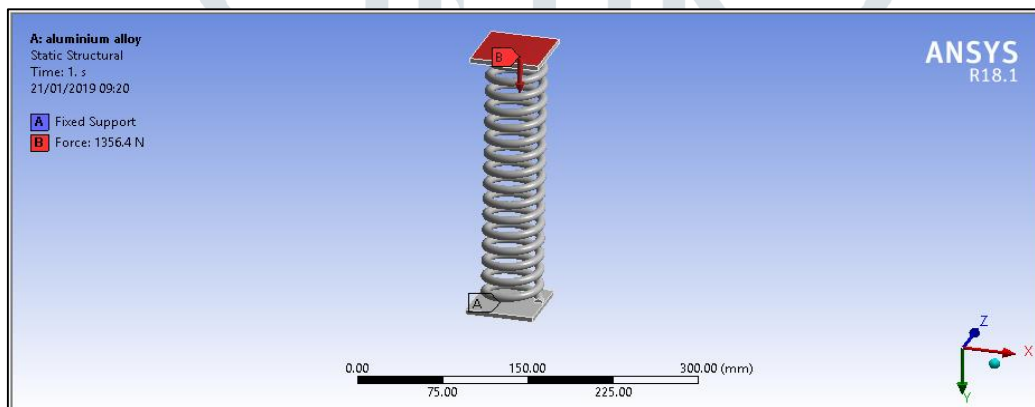


Figure 5: Loads and Boundary conditions

The vehicle has mass of 300kg. The suspension system has a spring constant (spring rate) of 46714.2N/m and here we consider a damping ratio of $\xi = 0.5$. The road surface varies with an amplitude of $Y = 50\text{mm}$. Calculation made for 1km/hr to 40 km/hr & deflection & stresses value determine at various speed. The frequency ω of the base excitation can be found by dividing the vehicle speed v km/hr by the length of one cycle of road roughness.
or 3Km/hr

$$\omega = 2\pi f = 2\pi (V \times 1000) / 3600 \times (1/1) = 1.74 \text{ v rad/s}$$

$$\omega = 1.74 \times 3 = 5.22 \text{ rad/s}$$

The natural frequency of the vehicle is given by
 $\omega_n = \sqrt{k/m} = \sqrt{46714.2/300} = 12.4 \text{ rad/s}$

Frequency ratio: $r = \omega / \omega_n = 5.22 / 12.4 = 0.42$

Amplitude ratio: -(Displacement transmissibility)

$$X/Y = \{1 + (2\xi r)^2 / (1 + r^2)^2 + (2\xi r)^2\}^{1/2} \quad X/Y = \{1 + (2 \times 0.5 \times 0.42)^2 / (1 + 0.42^2)^2 + (2 \times 0.5 \times 0.42)^2\}^{1/2}$$

$$X/Y = 1.17$$

Thus the displacement of vehicle at 3 km/hr is given by
 $X = 1.17 \times Y = 1.07 \times 0.05 = 0.0586 \text{ m} = 58.6 \text{ mm}$

This indicates that a 50mm bump in the road is transmitted as a 58.6mm deflection to the chassis.

$$\text{Forces (F)} = \frac{\delta G}{8} \frac{d^4}{d^3 n} = (58.6 \times 42 \times 10^3 \times 84) / (8 \times 483 \times 6)$$

F= 1356.4 N

$$\text{Stresses}(\tau) = K \frac{8FD}{\pi d^3}$$

$$\tau = (1.25 \times 8 \times 1356.4 \times 48) / (\pi \times 8^3)$$

$\tau = 404.8 \text{ N}$

V. RESULTS AND DISCUSSION

The static structural analysis is performed using techniques of Finite Element Method used by ANSYS software. The problem is formulated into spring matrix damper system as discussed in previous chapter, the force and stresses are determined analytically.

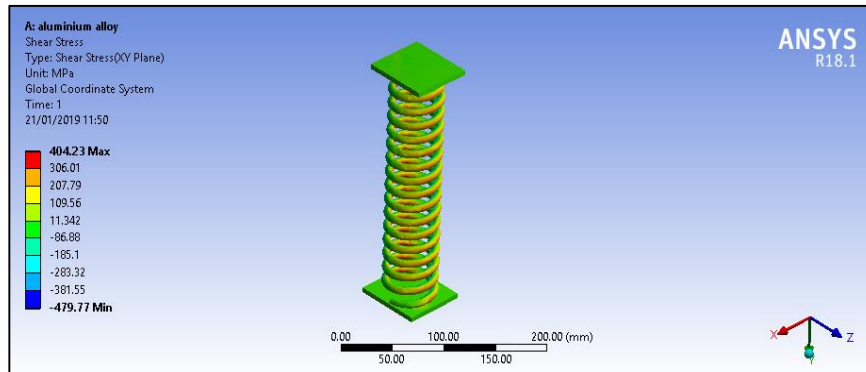


Figure 6: Shear Stress generated

Maximum Shear stress generated is denoted by red color shown in figure 5.1 above with magnitude of 404.23MPa. The maximum shear stress is developed on inner surface of coil with value of 109.5MPa.

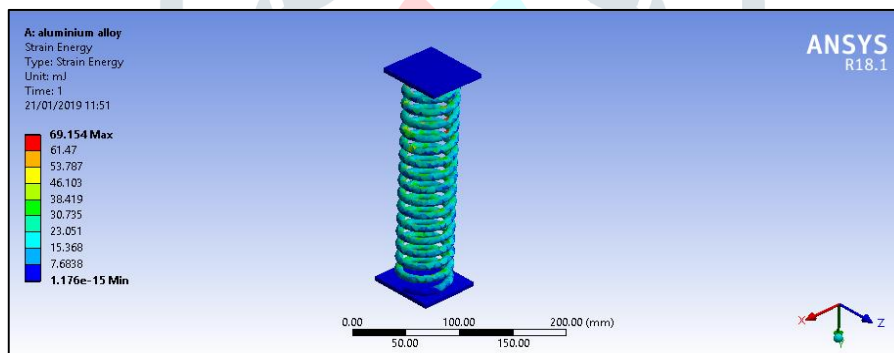


Figure 6: Strain energy

The maximum amount of strain energy developed is 69.15mJ. Similar to shear stress this strain energy is developed on inner face of coil shown by dark red colour. After conduction of Finite Element Analysis and determination of stresses, on the basis of input variables for optimization i.e. coil radius and mean diameter, design points are generated using design of experiments.

	A	B	C	D	E	F	G
1	Name	Update Order	P5 - radius (mm)	P6 - coil_dia (mm)	P7 - Shear Stress Maximum (MPa)	P9 - Strain Energy Maximum (mJ)	P10 - Solid Mass (kg)
2	1 DP 0	5	24	8	404.23	69.154	0.45056
3	2	2	21.6	8	375.61	116.33	0.41723
4	3	8	26.4	8	458.71	105.2	0.48404
5	4	4	24	7.2	564.24	197.58	0.38735
6	5	6	24	8.8	309.3	25.514	0.52035
7	6	1	21.6	7.2	513.96	162.6	0.36033
8	7	7	26.4	7.2	599.18	104.36	0.41443
9	8	3	21.6	8.8	278.98	49.824	0.48003
10	9	9	26.4	8.8	355.01	75.654	0.56085

Figure 7: Design Points generated and corresponding stresses and strain energy at these points

These design points are generated on the basis of 2nd order polynomial function. On the basis of these design points software calculates response i.e. shear stress and strain energy which is shown in figure 7 above. The results are generated on the basis of

central composite design scheme. On the basis of design of experiments the maximum value and minimum value of output parameters are shown in figure 8 below.

1	Name	Calculated Minimum	Calculated Maximum
2	P7 - Shear Stress Maximum (MPa)	278.98	599.18
3	P9 - Strain Energy Maximum (mJ)	25.142	198.38
4	P10 - Solid Mass (kg)	0.36033	0.56085

Figure 8: Maximum and Minimum Value of Shear Stress and Strain Energy

Figure 8 above shows maximum and minimum values of shear stress and strain energy obtained from response surface optimization. The maximum value of shear stress is 599.18MPa and strain energy is 198.38mJ while minimum values of shear stress is 278.98MPa and strain energy minimum is 25.142mJ and maximum strain energy is 198.38mJ.

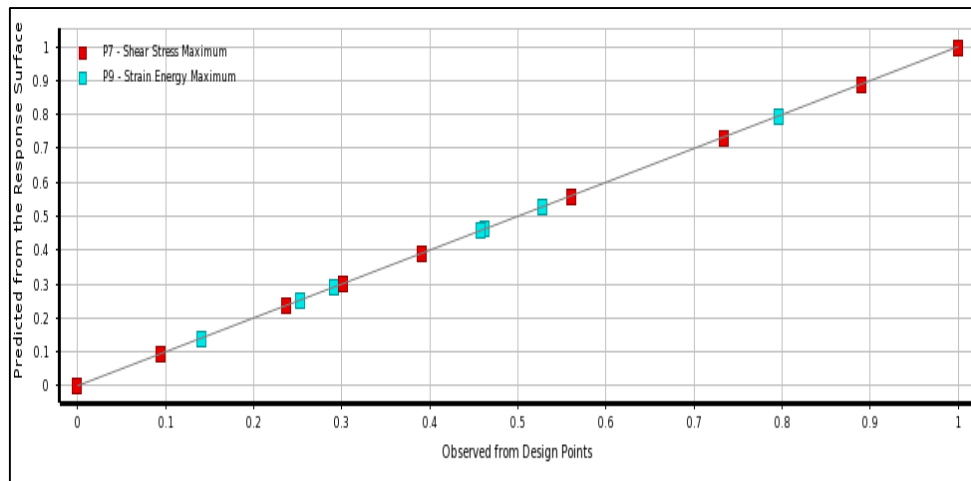


Figure 9: Goodness of Fit Curve

The goodness of fit curve plotted in figure 9 above shows deviation between observed values and expected values of shear stress and strain energy. Both shear stress and strain energy values doesn't show much deviation from expected values as can be seen in figure above both parameter values coincide with the linear curve.

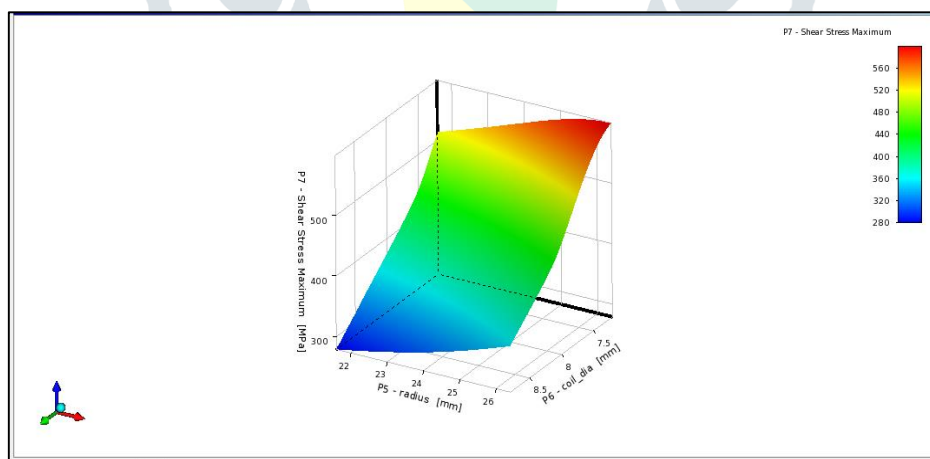


Figure 10: Response Surface for shear stress using Aluminium Alloy

The response surface plot for shear stress is plotted in figure 10 above shows maximum magnitude of shear stress with red plots with magnitude of 560MPa and more for coil mean dia. more than 7.5mm and coil radius more than 25mm. The minimum value of shear stress is below 280MPa is shown by dark blue colour for coil mean dia. less than 8.5mm and coil radius less than 22mm.

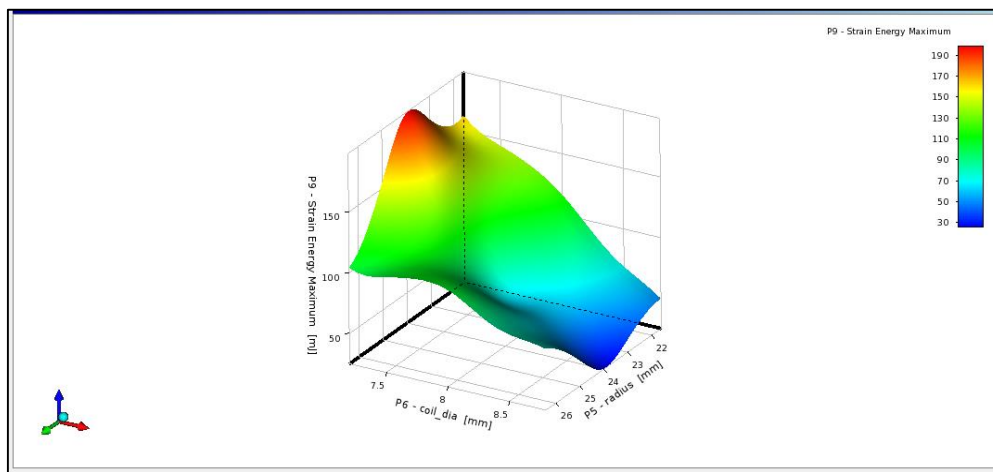


Figure 11: Response Surface for strain energy using Aluminium Alloy

The response surface plot for strain energy is plotted in figure 11 above shows maximum magnitude of strain energy with red plots with magnitude of 190mJ and more for coil mean dia. less than 7.5mm and coil radius ranging from 23mm to 24mm. The minimum value of strain energy is below 30mJ is shown by dark blue colour for coil mean dia. more than 8.5mm and coil radius near to 24mm.

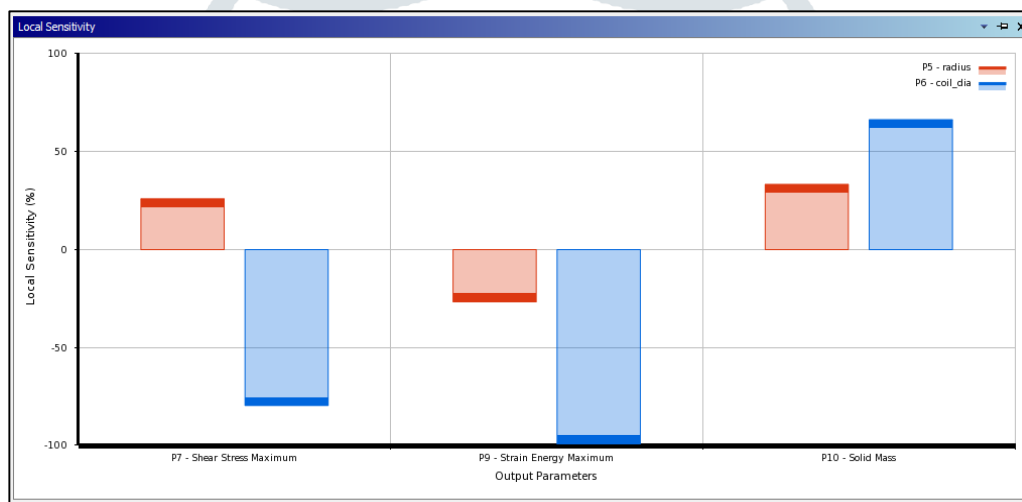


Figure 12: Sensitivity Charts

Figure 12 above shows sensitivity chart for both response (shear stress and strain energy) considering input variables (coil radius and coil mean diameter). Coil radius shows positive response of 25.5% for shear stress and coil mean diameter shows negative response of -79.61% for shear stress. The positive response of coil radius signifies increase of shear stress with increase of coil radius while negative response of strain energy signifies decrease in shear stress with increase of coil mean diameter.

6. CONCLUSION

The FEA analysis is conducted to determine shear stress and deformation using Aluminium material in helical coil suspension design. Along with FEA analysis design optimization is also performed to determine the sensitivities of parameters in stress generation, deformation and mass of helical coil suspension. The sensitivity graph has shown that coil diameter has higher contribution in weight as compared to coil mean radius. The response surface analysis has shown that considerable amount of weight reduction is possible.

REFERENCES

- [1]. Anil Antony Sequeira, Ram Kishan Singh, and Ganesh K Shetti, "Comparative Analysis of Helical Steel Springs with Composite Springs using Finite element method," St Joseph Engineering College-Vamanjoor,Mangaluru , pp. 63-70, 2016.
- [2] R. Nijssen, "Fatigue Life Prediction and Strength Degradation of Wind Turbine Rotor Blade Composites," TU Delft, Netherlands, 2006.
- [3] Mehdi Bakhshesh, and Majid Bakhshesh, "Optimization of Steel Helical Spring by composite spring," International Journal of Multidisciplinary Sciences And Engineering, Vol. 3, No. No.6 , Pp. 47-51, June 2012.

[4] P.R. Jadhav, N.P. Doshi, and U.D. Gulhane, "Analysis of Helical Spring in Dual Suspension System Used in Motorcycle," International Journal of Research in Advent Technology, vol. 2, October 2014.

[5] Anil Agarwal, Vaibhav Jain, "Design and Analysis of Helical Spring in Two Wheeler Suspension System using Finite Element Method" International Research Journal of Engineering and Technology (IRJET) , Volume: 04 Issue: 09 | Sep -2017

[6] Settey Thriveni, G. Ranjith Kumar, Dr.G. Harinath Gowd (2014), "Design, Evaluation & Optimization of A Two- Wheeler Suspension System", International Journal of Emerging Technology and Advanced Engineering, August 2014, Volume 4, Issue 8, pp 370-374.

[7] Niranjana Singh (2013), "General Review of Mechanical Springs used in Automobile Suspension System", International Journal of Advanced Engineering Research and Studies, October-December 2013, Volume 3, Issue 1, pp 115-122.

