Design and Analysis of Helical Coil Suspension using ANSYS

[1]Vikas Sahu, [2]Ashwini Bhoi, [3]Sudhir Singh Rajput

[1]Research Scholar, [2]Assistant Professor, [3]Head of Department
[1]Mechanical Engineering,
[1]Raipur Institute Of Technology, Raipur, Chhattisgarh, India.

*Abstract:*With increasing fuel prices and demand to reduce vehicle weight, automobile manufacturers are looking for lighter suspensions without compromising in strength.The current research investigates Aluminium alloy helical coil and compares it with structural steel 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.

Keywords: Helical coil suspension, Finite Element Analysis, Response Surface method, ANSYS.

I. INTRODUCTION

The suspension system is used to observe the vibrations from shock loads due to irregularities of the road surface. [1] 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. [2] Therefore, the suspension system performance of the vehicles should be maximized to reduce the damage and vibration. The main functions of suspension systems in vehicles are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension system requires elastic resistance to absorb the road shocks and this job is fulfilled by the suspension coil springs.

The primary functions for suspension systems are; [3]

- Provide vertical compliance so the wheels can follow the uneven road, isolating the chassis from roughness in the road.
- Maintain the wheels in the proper steer and camber attitudes to the road surface.
- React to the control forces produced by the tires longitudinal (acceleration and braking) forces.

II. LITERATURE REVIEW

Manish Dakhore et al [4], has examined estimation of stress saw as additional at the basic area of the spring as demonstrated by red shading. Thus probability of disappointment is more at that segment contrasted with other area of spring. This paper examines about train suspension loop springs, their key pressure dissemination and materials trademark. The investigation of train spring is done by thinking about cases, when the train at the straight way, bended way and on tough. This paper additionally talks about the Experimental investigation of a helical suspension spring by utilizing strain check. The pressure examination for the powers acquired and for modular and symphonious reaction has been completed by FEA utilizing ANSYS.

P.S.Valsange et al [5], have been introduced the survey of basic pressure circulation, normal for helical loop springs. A top to bottom dialog on the parameters impacting the nature of curl springs is likewise exhibited. Variables influencing quality of loop spring, FEA. Approaches by the specialists for loop spring examination are likewise contemplated. Decrease in weight is a need of car industry. Along these lines, the springs are to be intended for higher worries with little measurements. This requires basic plan of loop springs. This prompts basic material and assembling forms. Decarburization that was not a significant issue in the past now gets basic, to have better spring plan.

Tausif M. Mulla et al [6], contemplated versatile conduct and the pressure examination of springs utilized in the Three-Wheeler Vehicle's (TWV) front car suspension is considered. The outcomes got by a completely 3D Finite Element Analysis (FEA) additionally featured the poor exactness that can be given by the old-style spring model when managing these spring geometries. Generally little mistakes on most extreme shear pressure extending from 1.5 to 4 percent, regarding the applied burdens, are gotten when contrasted and the qualities determined by utilizing straightforward scientific model or equation. The pressure dissemination plainly shows that the shear pressure is greatest at the internal side of each curl. The dissemination of the pressure is likewise comparable in each loop. So the likelihood of disappointment of spring is the equivalent in each curl aside from end turns. In such case remaining worry in each curl might be significant factor which impact the disappointment.

Erol Sancakkar, and Mathieu Gratton et al [7], in their examination they watch composite leaf springs are effectively utilized in the suspension of the light vehicles. The strands utilized in these are unidirectional E-glass because of their high extensibility, durability and ease. The composite leaf spring is structured and examined utilizing ANSYS. The outcomes indicated that an ideal spring width diminishes hyperbolically and the thickness increments directly from the spring eye towards the hub seat. Contrast with steel springs the improved composite spring has quality that are a lot of lower, the characteristic recurrence is high and the spring weight is almost 80% lower. The utilization of composite materials can be reached out to regular car parts like, propeller shaft, drive shafts, guard pillar, side entryway sway bar, all-inclusive joints, heading, brakes.

III. PROPOSED WORK

The helical coil suspension contributes to a significant proportion of weight of vehicle. As automobile companies are demanding reduced weight of vehicle it has become imperative to reduce weight of helical coil suspension without much compromise in strength and integrity of suspension. The conventional steel material used in helical coil suspension is heavier and requires optimization in design parameters for weight reduction. Conventional methods of design optimization of design and analysis of multiple design mechanism is time consuming and hard and fails to give individual sensitivities of design parameters to output parameters. To overcome this problem an advanced statistical method of optimization is required which could generate specific design points and determine sensitivities of individual parameters to output parameters like equivalent stress, deformation and weight.The objective of this research is to develop optimized design of helical coil suspension using techniques of finite element method and response surface method. The CAD model of helical coil suspension design and analyzed ANSYS software.

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 as shown in figure 1 below. The model is meshed using tetra elements of appropriate size and shape. After meshing appropriate loads and boundary conditions are assigned.

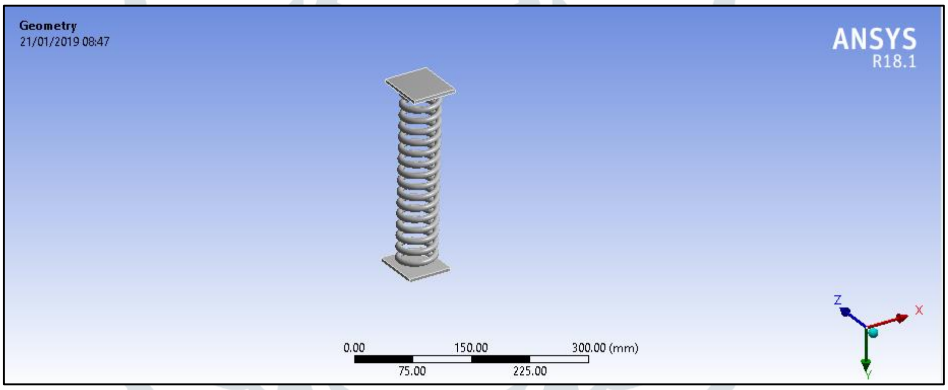

Fig 1: CAD Modelling suspension using ANSYS design modeler

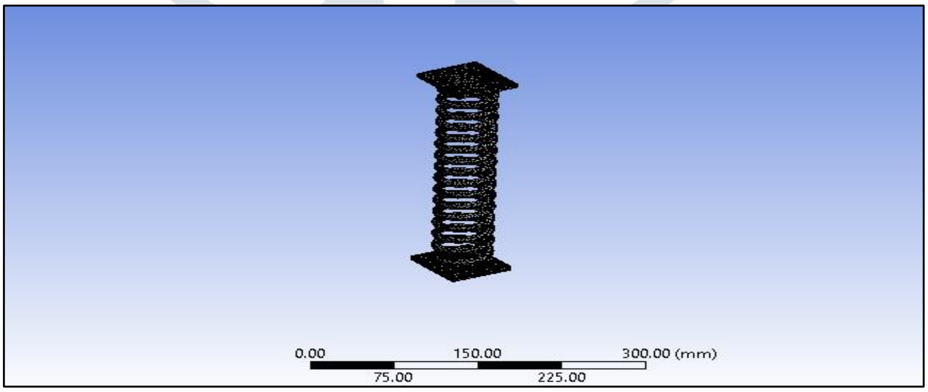

Fig 2: Meshing of suspension using ANSYS design modeler

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 2.CAD model of suspension after being meshed is applied with appropriate loads and boundary conditions. The bottom face of suspension is kept fixed and top face is applied with force of 1356.4N in downward direction as shown in figure 3.

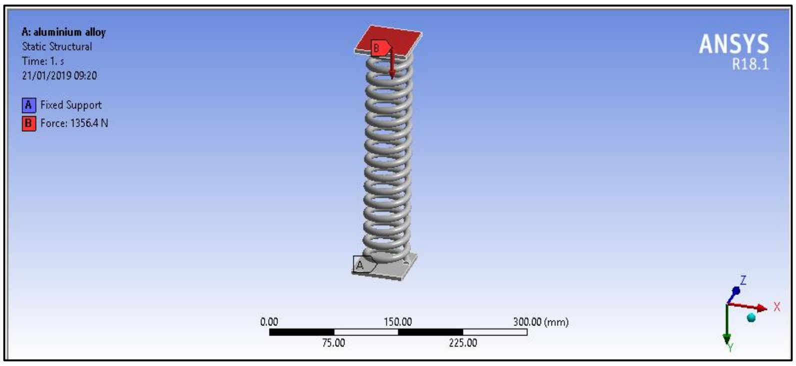

Fig 3: Applied loads and boundary conditions

In this stage software carries out matrix formulations, multiplications and inversions. Initially element stiffness matrix is formulated, the element stiffness matrix are assembled to form global stiffness matrix. When solver is set to run, the software calculates results at nodes and results are interpolated for entire element edge length.

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, the force and stresses are determined analytically.

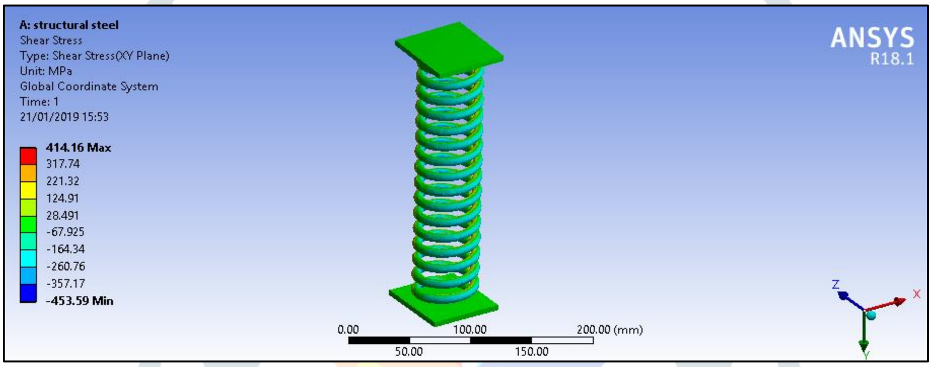

Figure 4: Shear Stress generated

Maximum Shear stress generated is denoted by red colour shown in figure 4 above with magnitude of 414.16MPa. The maximum shear stress is developed on inner surface of coil with value of 248.49MPa.

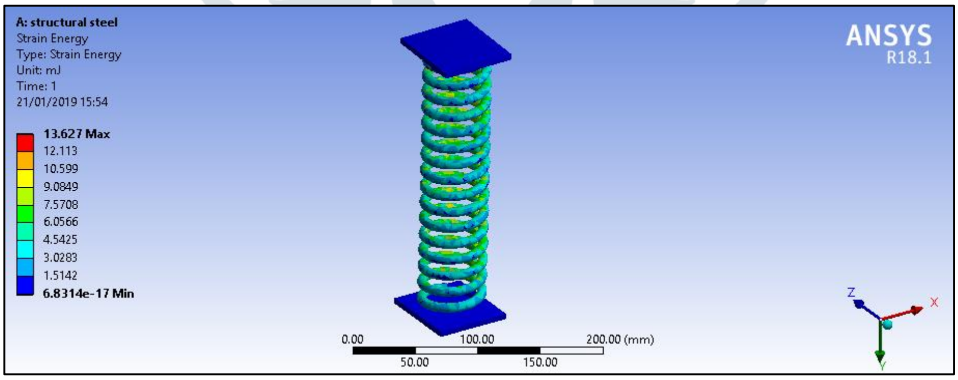

Figure 5: Strain energy

The maximum amount of strain energy developed is 13.62 mJ. Similar to shear stress this strain energy is developed on inner face of coil shown by dark red colour.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 as shown in figure 5 above.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.

Table1: Design Points generated and corresponding shear stress and strain energy

1	Name	P5 - radius (mm)	P6 - coil_dia (mm)	P7 - Shear Stress Maximum (MPa)	P9 - Strain Energy Maximum (mJ)	P10 - Solid Mass (kg)
2	1	25.067	7.4667	506.03	17.173	1.192
3	2	26.133	7.8222	488.31	23.898	1.3159
4	3	22.933	8.3556	349.76	36.194	1.3167
5	4	24.533	8.1778	383.08	8.8693	1.3412
6	5	22.4	7.2889	529.88	59.475	1.0644
7	6	23.467	7.6444	466.24	66.292	1.1759
8	7	24	8.7111	319.27	7.6712	1.4518
9	8	25.6	8.5333	347.39	5.1939	1.4784
10	9	21.867	8	410.85	38.195	1.1929

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. On the basis of design of experiments the maximum value and minimum value of output parameters are shown in table 2 below.

Table 2: Maximum and minimum values of shear stress and mass

	A	B	C
1	Name	Calculated Minimum	Calculated Maximum
2	P7 - Shear Stress Maximum (MPa)	315.72	613
3	P9 - Strain Energy Maximum (mJ)	-1.1759	66.292
4	P10 - Solid Mass (kg)	1.022	1.5884

Table 2 above shows maximum and minimum values of shear stress and strain energy obtained from response surface optimization. The maximum value of shear stress is 613MPa and strain energy is 66.292mJ while minimum values of shear stress is 315.72MPa and strain energy maximum is 1.17mJ. The mass range is from 1.022Kg to 1.588Kg.

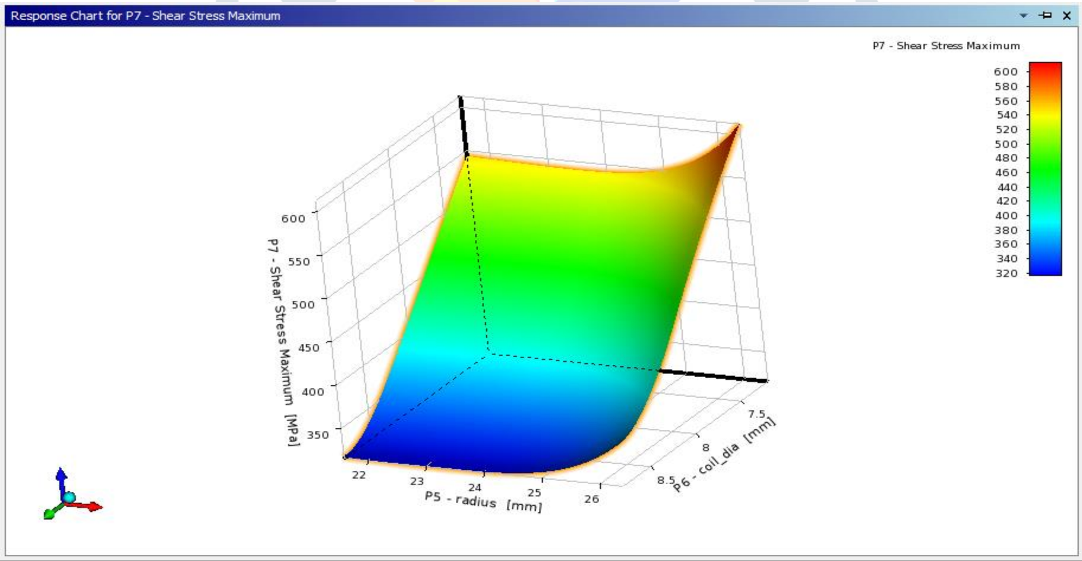

Fig 6: Response Surface for shear stress using Structural Steel material

The response surface plot of shear stress is shown in figure 6 above. The plot shows maximum value of shear stress of 598MPa for coil mean diameter less than 7.5mm and coil radius more than 25mm. The minimum value of shear stress is near to 320MPa for coil radius less than 22mm and coil mean diameter greater than 8.5mm.

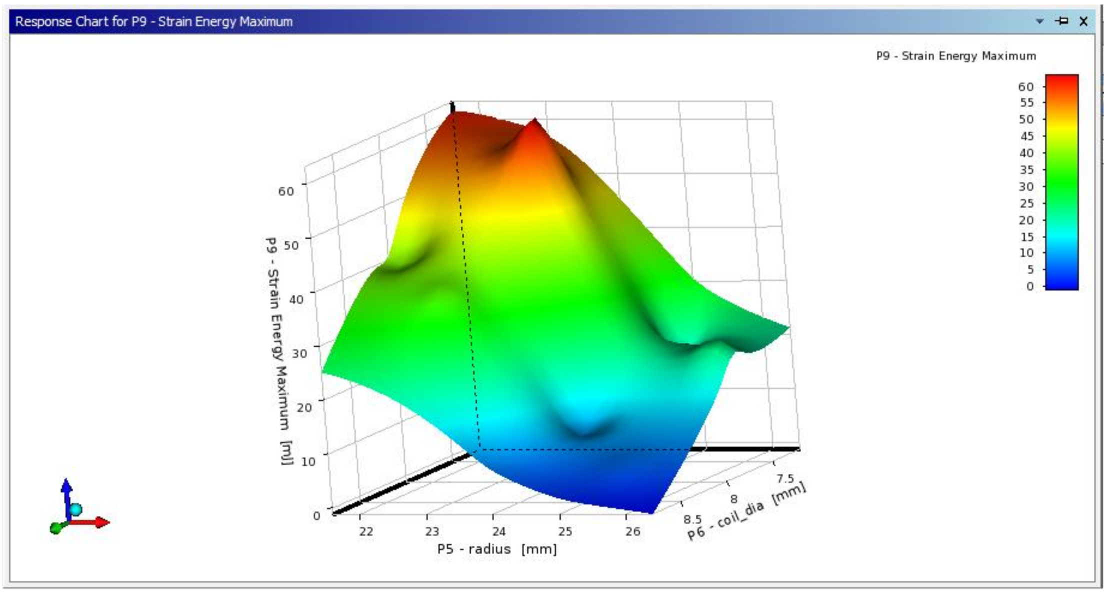

Fig 7: Response Surface for strain energy using Structural Steel material

The response surface plot for strain energy is shown in figure 7 above. The maximum value of strain energy is near to 62mJ for coil mean diameter less than 8mm and coil radius ranging from 21mm to 25mm. The minimum value of strain energy observed from radius ranging from 24mm to 26mm and coil mean dia ranging from 8mm to 9mm.

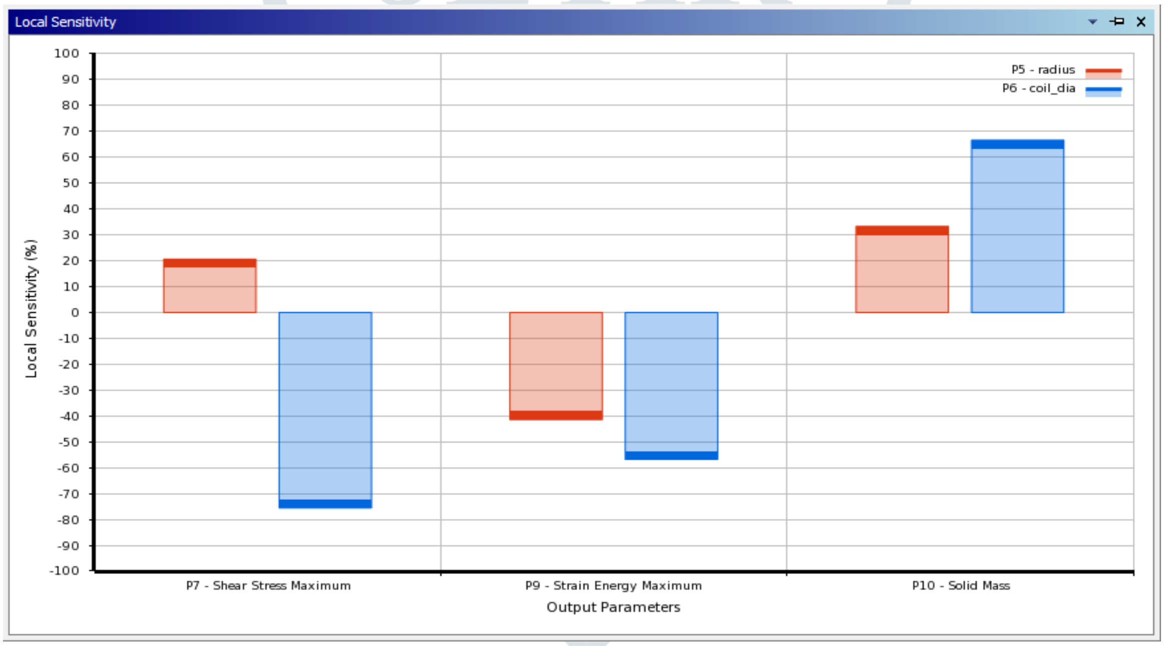

Fig 8: Local sensitivity graph using structural steel material

Local sensitivity plot of responses (shear stress and strain energy) is generated for input variables (coil radius and coil mean diameter) as shown in figure 8. The coil radius sensitivity percentage is 20.63(positive) and hence has positive effect on shear stress maximum while coil diameter has negative sensitivity of 75.58 (negative). Therefore, coil diameter has higher effect on shear stress maximum.For strain energy, the coil radius has 41.42(negative) sensitivity and coil diameter has 56.81(negative) sensitivity. Therefore, both coil radius and coil diameter has negative sensitivity on strain energy maximum. Coil mean diameter has higher effect on strain energy of helical coil suspension.For solid mass, both coil radius and coil diameter has positive sensitivity. The coil radius has 33.29(positive) sensitivity and coil mean diameter has 66.64 (positive) sensitivity. Coil mean diameter has higher effect on mass of helical coil suspension.

VI. CONCLUSION

FEA analysis of helical coil suspension is conducted and equivalent stresses and deformation are determined using ANSYS software. The FEA analysis is conducted using Structural Steel material and Aluminium Alloy material. After conducting FEA analysis design optimization of helical coil suspension is performed using Response Surface Method using structural steel and optimized mass is determined. The details of findings are:

1> The maximum shear stress generated using Aluminium alloy material is 404.23Mpa which is near to stress calculated from analytical method against 414.16Mpa obtained for structural steel, thereby the stress generated using Aluminium alloy material is lower than structural steel material.

2> The maximum amount of strain energy generated using Aluminium alloy material is 69.15mJ which shows good energy absorption characteristics whereas the maximum strain energy generated using structural steel is 13.627mJ, therefore Aluminium alloy absorbs more strain energy as compared to structural steel material

3> The design optimization of helical coil suspension using coil diameter and coil mean radius is performed using design of experiments for both structural steel material and sensitivities and responses of different input parameters are plotted.

4> From response surface analysis using structural steel material it was found that coil radius sensitivity percentage is 20.63(positive) while coil diameter has negative sensitivity of 75.58 (negative). Therefore, coil diameter has higher effect on shear stress maximum

5> From response surface analysis it was found that coil radius has 41.42(negative) sensitivity and coil diameter has 56.81(negative) sensitivity. Therefore, both coil radius and coil diameter has negative sensitivity on strain energy maximum. Coil mean diameter has higher effect on strain energy of helical coil suspension.

6> For solid mass, both coil radius and coil diameter has positive sensitivity. The coil radius has 33.29(positive) sensitivity and coil mean diameter has 66.64 (positive) sensitivity. Coil mean diameter has higher effect on mass of helical coil suspension.

7> The maximum obtained from response surface analysis is 1.588Kg using structural steel material and minimum mass obtained is 1.022Kg for structural steel material.

8> Using response surface method 14.2% weight reduction is possible with structural steel material.

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