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DESIGN AND MATERIAL OPTIMIZATION OF HELICAL COIL SUSPENSION USING ANSYS

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Abstract:*The helical coil suspensions are used in most of the 2 wheelers. The design and material of suspension has significant effect on its shock absorption characteristics. The current research investigates the feasibility of E-glass material for helical coil suspension. The design of suspension is then optimized using optimal space filling scheme of response surface method. The effect of optimization variables on output parameters is also evaluated using sensitivity plot along with 3D response surface plots. By response surface optimization, nearly 26% weight reduction of helical coil suspension is achieved which is satisfactory.*

Key Words: Helical Coil Suspension, FEA, Response Surface Optimization

1. INTRODUCTION:

The primary purpose of helical coil suspension is to absorb shocks on roads due to uneven road surfaces. These shocks are absorbed in the form of strain energy which is later released gradually. The helical coil suspensions are made of helical springs as shown in figure 1 below.

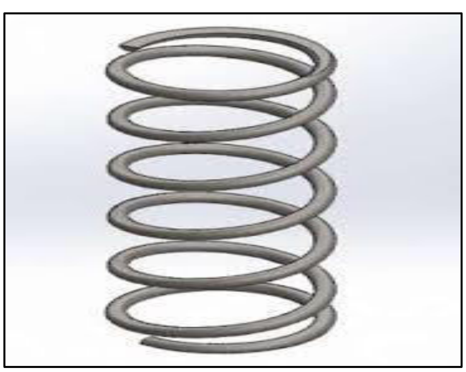

Figure 1: Spring used in helical coil suspension

The important design parameter of helical coil suspensions are wire diameter and coil diameter which has significant effect on stiffness of suspension [11].

2. LITERATURE REVIEW

Singh Pankaj et al [1]conducted FEA analysis on helical coil suspension using ANSYS FEA software. The materials investigated are steel, Cobalt chrome, Chrome vanadium, Beryllium copper. The conclusion is made on the basis of stress, deformation.

Dhiraj V. Shevale[2] conducted FEA analysis on MARUTI SUZUKI Alto K10 suspension using ANSYS software. The fatigue life prediction is done for suspension using experimental and analytical techniques and FEA results are validated.

N.Lavanya[3] conducted analysis of light weight vehicle suspension using chrome vanadium and 60Si2MnA steel. The CAD model is developed using Pro/E design software and FEA analysis is conducted using ANSYS software.

Logavigneshwaran S. [4] investigated the design parameters affecting the shock absorption characteristics of helical coil suspension of bike using ANSYS FEA software. The findings have shown that wire diameter of coil has significant effect on strength of suspension.

YogeshChoubey[5] investigated the premature failure in suspension system by using SEM images. The findings have shown that failure of suspension is due to imperfection in the materials.

J. C. Hendry and C. Probert [6] explained about replacement of steel coil spring used in the suspension system of a passenger car by a coil spring in fiber reinforced plastics. Author proposed CFRP (Carbon Fiber Reinforced Plastics) spring design which gives more than 50% saving in weight against the steel coil spring. This could have been achieved but gives a slight relaxation in volume of coil spring specification to allow a bigger coil diameter. Author also found that cost of the final carbon fiber spring is three times than that of the steel coil spring

Chang Hsuan Chiu et al [7] investigated suspensions made from unidirectional laminates and rubber core unidirectional laminates. The rubber core helical coil suspension gas 12% higher load carrying capacity and unidirectional laminate helical coil suspension has 18% higher load carrying capacity.

P. K. Mallick [8] has suggested the concept of fiber reinforced composite elliptic springs for automotive suspension system. Due to higher strength-to-weight ratio for unidirectional fiber reinforced plastics, the composite elliptic springs can be saved approximately 50 percent weight over steel coil springs.

Mathieu Gratton et al [9] has investigated composite leaf spring using ANSYS FEA software. The thickness of unidirectional E glass fibres are varied and findings have shown that composites have high extensibility, durability and ease. The e-glass composites can be used for suspensions, joints and other automotive parts.

3. OBJECTIVE

The objective of this project is to investigate the feasibility of E glass in helical coil suspension for mass minimization. The design of helical coil suspension is then optimized using optimal space filling scheme of response surface method. The sensitivity of each variable on output parameter is generated. The variables selected for optimization are wire diameter and coil diameter.

4. METHODOLOGY

The FEA analysis of helical coil suspension is conducted using ANSYS FEA software. The design of suspension is modeled as per dimensions of Hero Honda CBZ. The CAD model is shown in figure 2 below. The dimensions of helical coil suspension are taken from reference [10]

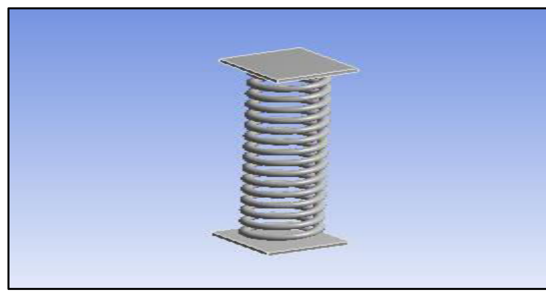

Figure 2: CAD model of helical coil suspension

The model is meshed using fine relevance setting and with curvature effects. The mesh quality for skewness and other defects is also checked. The magnitude of force caused due to 50mm is 1356.4N and this load is applied on top face of helical coil suspension while bottom end is fixed [11]. The loading conditions are shown in figure 3 below.

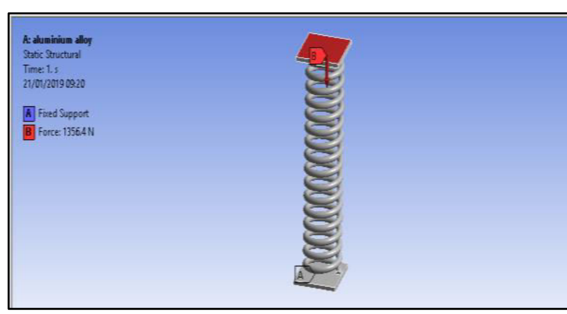

Fig 3: Applied loads and boundary conditions

The simulation is then solved using sparse grid solver. The results are generated are many iterations. After running FEA simulation the optimization variables i.e. wire

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diameter and suspension diameter is selected for optimization. Similarly, the output parameters selected for optimization is strain energy, mass and total deformation.

5. RESULTS AND DISCUSSION

The static structural analysis is conducted on helical coil suspension using E glass material. The shear stress and strain energy plots are generated and discussed in this section.

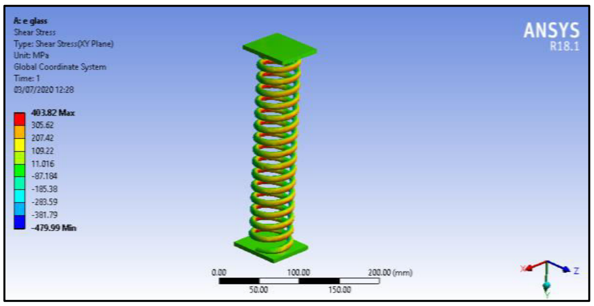

Figure 4: Shear Stress generated using E-glass material

Maximum Shear stress generated is generated on inner regions of suspension as denoted by red color shown in figure 4 above with magnitude of 403.82MPa while the outer regions of coil develops lower shear stress as shown by green colored regions. The shear stress generated on inner region is tensile in nature while shear stress developed on outer region is compressive in nature.

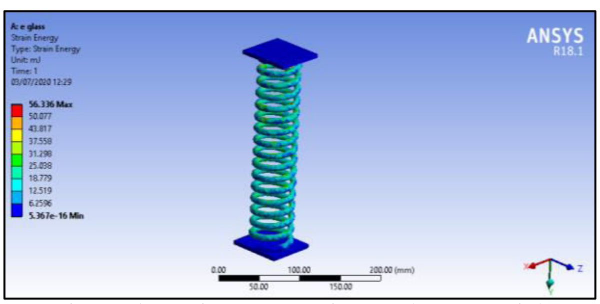

Figure 5: Strain energy using E-glass material

As can be observed in figure 5 above, the shock experienced by helical coil suspension is absorbed in the form of strain energy. This energy is high on inner face of coil as shown by red, yellow colored regions while outer regions of coil has lower magnitude as shown by dark blue color. 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	P5 - radius (mm)	P6 - coil_dia (mm)	P7 - Shear Stress Maximum (MPa)	P9 - Strain Energy Maximum (mJ)	P10 - Solid Mass (kg)	P16 - Total Defor... Maximum (mm)
2	1	25.067	7.4667	506.04	40.336	0.39178	254.33
3	2	26.133	7.8222	486.57	56.166	0.43249	233.62
4	3	22.933	8.3556	348.89	84.996	0.43275	123.58
5	4	24.533	8.1778	382.29	20.833	0.4408	166.56
6	5	22.4	7.2889	532.69	139.72	0.34983	203.67
7	6	23.467	7.6444	467.34	156.46	0.38646	190.65
8	7	24	8.7111	318.58	18.021	0.47714	121.91
9	8	25.6	8.5333	346.82	12.189	0.4859	156
10	9	21.867	8	411.14	90.237	0.39207	132.05

Fig 6: Design Points generated and corresponding shear stress and strain energy

After DOE, total 9 design points are generated with corresponding values of shear stress, strain energy, mass and total deformation. These design points are generated using optimal space filling design scheme. The maximum and minimum values of output parameters are shown in table 1 below.

Table 1: Maximum and minimum values

	A	B	C	D
1	Name	Calculated Minimum	Calculated Maximum	Maximum Predicted Error
2	P7 - Shear Stress Maximum (MPa)	317.12	615.49	5.5964
3	P9 - Strain Energy Maximum (mJ)	-2.8751	156.46	65.099
4	P10 - Solid Mass (kg)	0.33588	0.52206	1.1018E-08
5	P16 - Total Deformation Maximum (mm)	90.178	323.02	2.5879

Table 1 above shows maximum and minimum values of shear stress and strain energy obtained from response surface optimization.

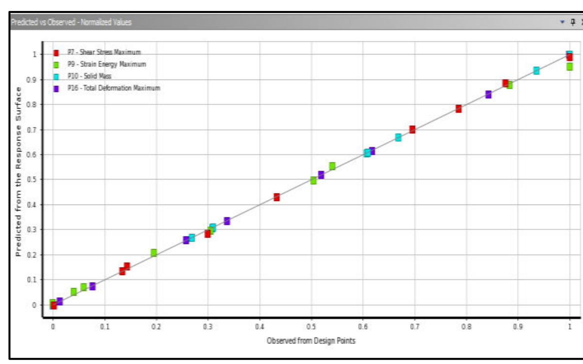

Fig 7: Goodness of fit curve

The 3D response surface plot of different variables are generated which includes shear stress, strain energy and mass.

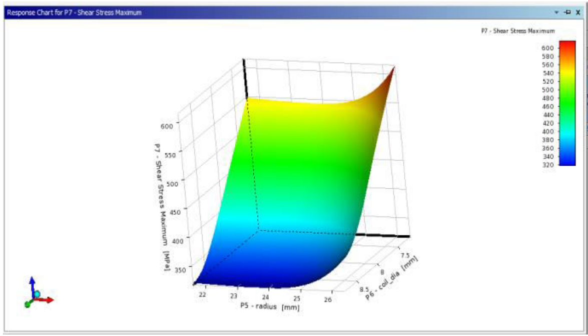

Fig 8: Response Surface for shear stress using E glass

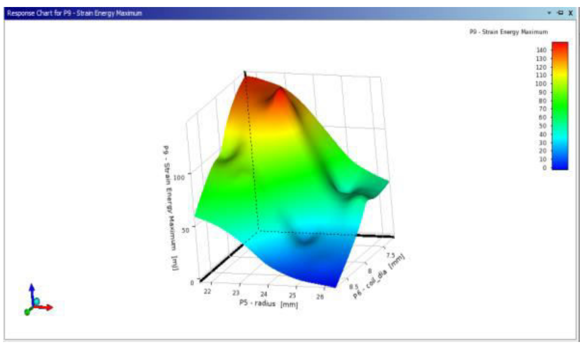

Fig 9: Response Surface for strain energy using E glass

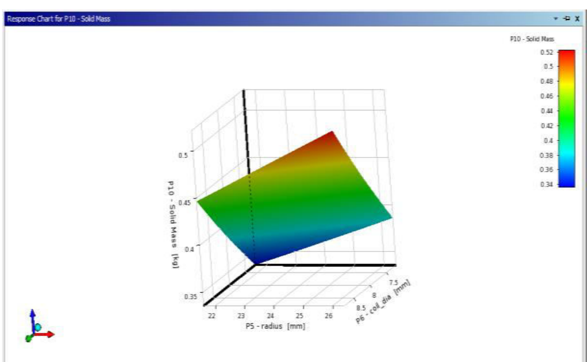

Fig 10: Response Surface for mass using E glass

The response surface plot for mass is plotted in figure 10 above shows maximum magnitude of mass with red plots with magnitude of .47kg and more for coil mean dia. more than 8.5mm and coil radius ranging from 24mm to 26mm. The minimum value of mass is below .4Kg is shown by dark blue color for coil mean dia. less than 8mm and coil radius ranging from 22mm to 26mm. The linearized behavior of shear stress, strain energy and solid mass are evaluated by generating 2 dimensional curves.

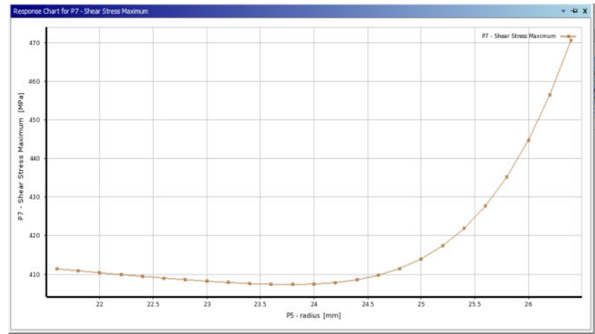

Fig 11: Shear stress variation with coil radius

From shear stress curve obtained in figure 11 above, the shear stress value increases parabolically with increase in radius. The minimum shear stress is observed for 21.6mm radius while maximum shear stress is observed for 26.4mm radius. The rate of increase is higher after 26mm radius.

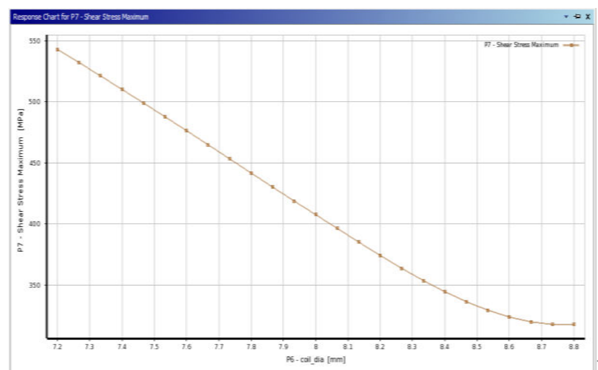

Fig 12: Shear stress variation with coil diameter

From shear stress curve obtained in figure 12 above, the shear stress value decreases with increase in coil diameter. The minimum shear stress is observed for 8.8mm coil diameter while maximum shear stress is observed for 7.2mm coil diameter. The rate of shear stress decrement is higher for coil diameter ranging from 7.2mm to 7.65mm and then decrease is linear.

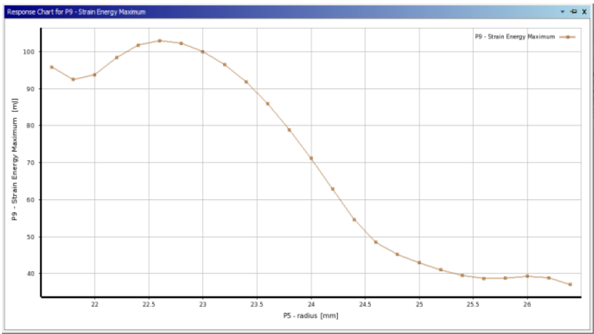

Fig 13: Strain energy variation with respect to radius

The strain energy curve is shown in figure 13 above. The strain energy values increases upto 22.7 and then decreases linearly upto 26mm.

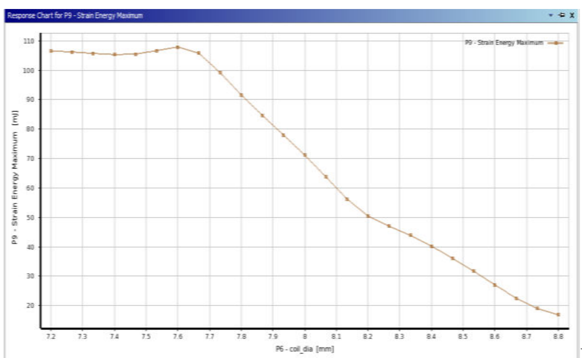

Fig 14: Strain energy variation with respect to coil diameter

The strain energy deceases with increase in coil diameter which is quadratic in nature as shown in figure 14 above. The maximum strain energy is observed for 7.6mm coil diameter and minimum strain energy is observed for 8.8mm coil diameter.

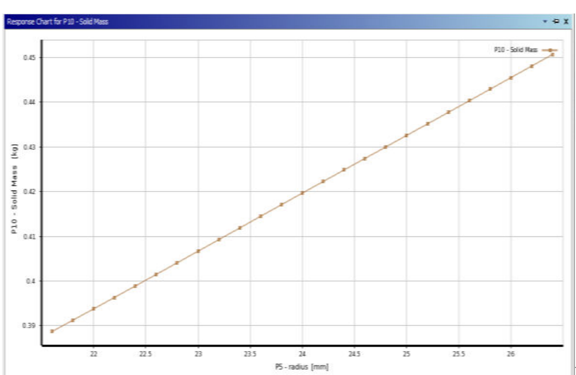

Fig 15: Solid mass variation with respect to radius

The solid mass increases linearly with increase in radius as can be seen in figure 15 above. The minimum solid mass is observed for radius 21.6mm and maximum solid mass is observed for radius 26.4mm .

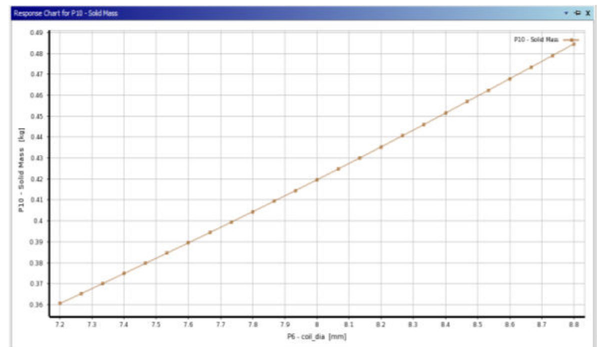

Fig 16: Solid mass variation with respect to coil dia

The solid mass increases linearly with increase in radius as can be seen in figure 16 above. The minimum solid mass is observed for radius 7.2mm and maximum solid mass is observed for radius 8.8mm.

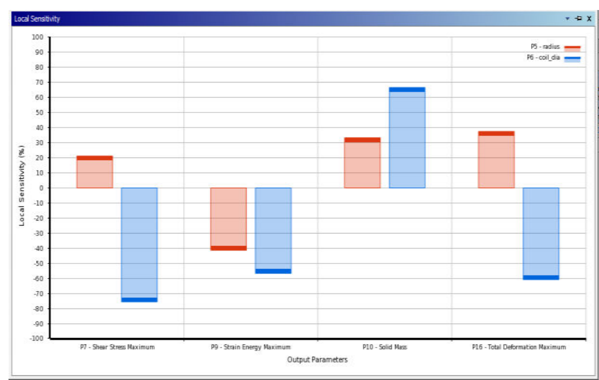

Fig 17: Sensitivity plot of different design parameters

The sensitivity plot is generated for different design parameters which shows the effect of each design variable on output parameter along with sensitivity percentage. Sensitivities obtained are either positive or negative. The positive sensitivity signifies that increasing the variable value would increase output parameter and reducing variable value will reduce parameter value. The negative sensitivity signifies that increasing the variable value would decrease output parameter and reducing variable value would increase parameter value.

6. 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 carbon Steel material and E glass material. After conducting FEA analysis design optimization of helical coil suspension is performed using Response Surface Method with E glass material.

The details of findings are:

1> For shear stress, radius shows positive sensitivity of 21.209% and coil diameter shown negative sensitivity of 75.605%. Therefore, coil diameter has higher effect on shear stress as compared to radius.

2> For strain energy, radius shows negative sensitivity of 41.35% and coil diameter shown negative sensitivity of 56.68%. Therefore, coil diameter has higher effect on strain energy as compared to radius.

3> For solid mass, radius shows positive sensitivity of 33.29% and coil diameter shown positive sensitivity of 66.64%. Therefore, coil diameter has higher effect on solid mass as compared to radius.

4> For total deformation, radius shows positive sensitivity of 37.486% and coil diameter shown negative sensitivity of 60.84%. Therefore, coil diameter has higher effect on solid mass as compared to radius

5> The mass of carbon steel suspension is 1.273Kg while mass of E glass suspension is .419Kg which is 67.08% less.

6> The weight of generic design is .52Kg and weight obtained after optimization using design is .32Kg which is nearly 26% reduction.

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