Design and Material Optimization of Helical Coil Suspension

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Abstract:*The material selection of suspension is crucial for its proper functioning and should have good strength to weight ratio. The current research investigates the application of Aluminium alloy and SAE 1025 for helical coil suspension. The FEA analysis of suspension is conducted using ANSYS software to determine stresses and deformation. The results obtained from these materials are compared with conventional structural steel material. The design of suspension is further optimized using steel and aluminium material using Taguchi Response Surface Optimization method. The optimization parameters selected are wire diameter and coil mean diameter. The 3D response surface plots of optimization variables are generated along with sensitivity plots. The findings have shown that significant weight reduction of suspension is achieved using Aluminium alloy method and further design optimization.*

Key Words: Helical coil suspension, Finite Element Analysis, Response Surface method

1. INTRODUCTION:

Helical coil springs are simple forms of springs, commonly used for the suspension system in vehicles. They are generally used in automobile suspension system and industrial applications. Springs are crucial suspension elements and these are necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. Metal coils springs can be replaced by composite springs because of weight reduction and corrosion resistance. Composite coil springs can be manufactured using carbon/graphite/glass fibers and resin impregnation. These composite coil springs, compared to standard metal coil springs reduces weight.

2. LITERATURE REVIEW

Brita Pyttel, K.K. Ray, Isabell Brunner, Abhishek Tiwari and S. A. Kaoua et al. (2012) [1] conducted FEA analysis of helical coil suspension using ABAQUS software to determine fatigue life analysis. The results shown higher shear stress along spring length.

Priyanka Ghate , Dr. S. R Shankapal and M. H. Monish Gowda et al (2012) [2] conducted FEA analysis on helical coil suspension using ADAMS software in order to reduce stress level. The stress in generic design was 412MPa which reduced to 160MPa after using composite spring and case index was found to be 1.78.

Tausif M. Mulla et al (2012) [3] conducted review on material, failure causes and loading conditions of helical coil suspension. The study showed that most of suspension failures are caused due to fatigue cracks and market demands for lighter and newer material having good corrosion resistance and improved fatigue properties.

Manish Dakhore et al (2013) [4] investigate deformation and vibration characteristics of helical coil suspension using ANSYS 16.1 software package. The mode shapes and harmonic responses of helical coil suspension are obtained for forces of 4250N and 4500N for 100Hz frequency. The findings have shown that AISI 6150 is more durable as compared to structural steel.

N.Lavanya et al. (2014) [5] the author analyzes the safe load of the light vehicle suspension spring with different materials. The work is carried out on modeling the helical spring in Pro/E and analysis in ANSYS of primary suspension spring with two materials. The existing material is chrome vanadium and 60Si2MnA steel is a new material. The conventional steel helical spring 60Si2MnA is approved as best material for helical spring by reduction of deflection and overall stress.

Prince Jerome Christopher.J et al. (2014) [6] investigated the performance of helical coil suspension of 160cc bike using ANSYS software and CAD model is developed using Pro/e software. The analysis is conducted for different composite materials, bike weight and number of passengers.

P.R. Jadhav, N.P. Doshi, and U.D. Gulhane et al (2014) [7] right now coil spring is supplanted by composite material. Numerical outcomes have been contrasted with hypothetical outcomes and found with be in acceptable understanding in three distinctive composite helical springs. Contrasted with steel coil spring, the composite helical/coil spring has been found to have lesser pressure. Weight of spring has diminished and has been demonstrated that changing level of fiber, particularly at Carbon/Epoxy composite, doesn't influence spring weight.

Logavigneshwaran S. et al. (2015) [8] Author study the different boundaries affecting the pressure and distortion initiated. Subsequent to considering the different boundaries, displaying is finished by utilizing Pro/ENGINEER. For examination ANSYS programming is utilized. The examination is performed by considering the bicycle mass and with people situated on the bicycle. Study is finished by changing the wire distance across of the loop spring to check the best measurement for the spring in safeguard.

Logavigneshwaran S et al (2015) [9] conducted FEA analysis on helical coil suspension system by changing wire diameter. The CAD model of suspension was developed in Pro/E design software and FEA analysis is conducted using ANSYS FEA software. The best diameter is determined for which the suspension has higher strength and good vibration absorption characteristics.

3. OBJECTIVE

The objective of this research is to optimize the design of helical coil suspension using structural steel and aluminium alloy material using Taguchi design of experiments. The helical coil suspension is also tested using SAE 1025 material and chrome vanadium.

4. METHODOLOGY

The CAD modeling of suspension is done using ANSYS geometric modeler. The tools used for modeling is sweep and sketch. The sketch comprising of sweep profile and cross section is modeled and sweep operation is performed.

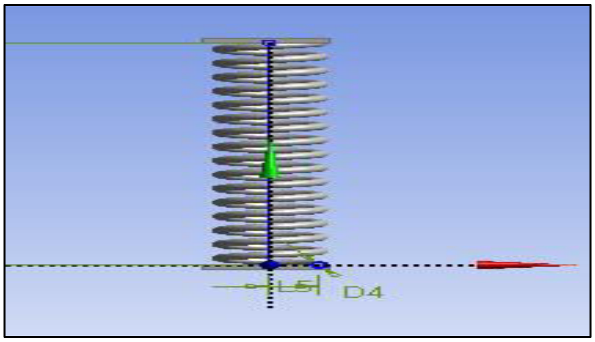

Figure1: Sweep profile

The static structural analysis is performed using ANSYS 18.1 software. The analysis comprises of 3 stages, namely pre-processing, solution and post-processing. 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.

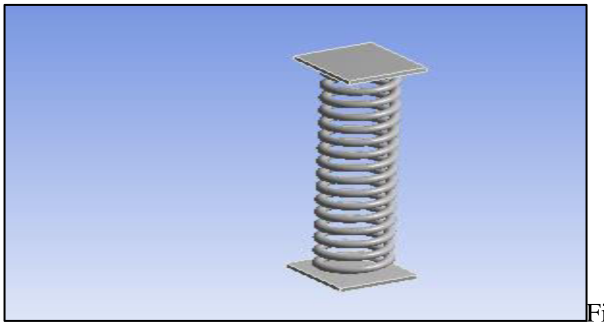

Fig 2: CAD Modelling suspension using ANSYS design modeler

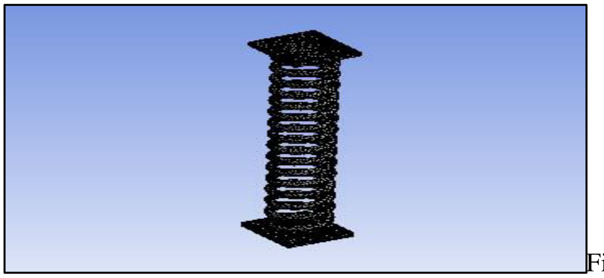

Fig 3: Meshing of suspension using ANSYS design modeler

The CAD model is meshed using tetrahedral elements and fine sizing with curvature effects on. The number of elements generated is 17432 and number of nodes generated is 34997. 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.

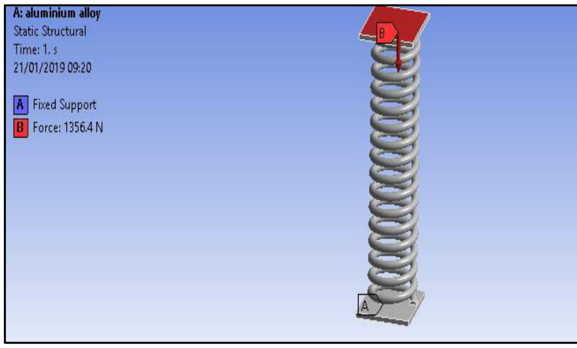

Fig 4: Applied loads and boundary conditions

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. The helical coil suspension is optimized using techniques of RSM and variables selected for optimization are wire diameter and coil mean diameter. These optimization variables influence output parameters i.e. stress, deformation and shear stress. The goodness of fit curves are developed for theoptimization and sensitivity plots are also generated.

5. RESULTS AND DISCUSSION

From the FEA analysis conducted on helical suspension, shear stress and deformation are evaluated which is discussed in the section. The model is formulated into spring matrix damper.

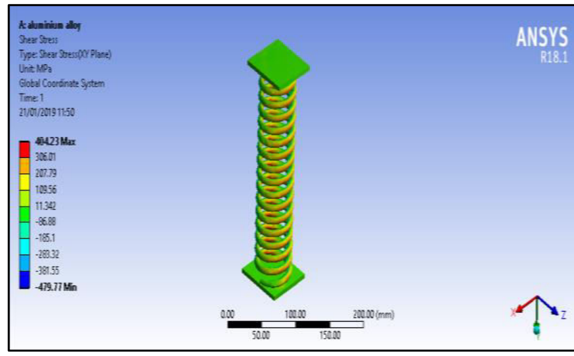

Figure 5: Shear Stress generated

The Maximum value of shear stress generated is 404.23MPa as shown in red colored zone on inner surface of coil. 404.23MPa. The other regions has stress value of 11.342MPa as shown by green colored regions.

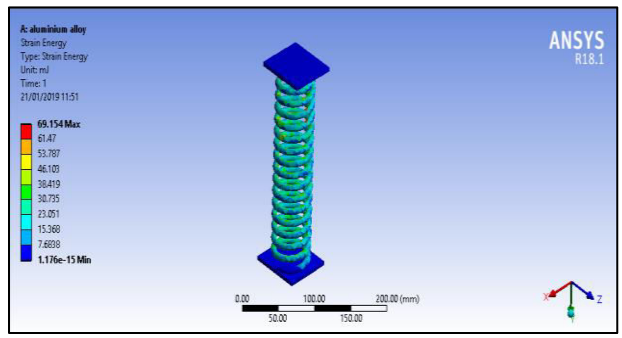

Figure 6: Strain energy

The figure 6 above shows strain energy generated in helical coil suspension. Themaximum magnitude of strain energy generated is 69.154mJ as shown by red colored zone. The strain is higher on inner face of coil as compared to outer face.The design points are generated using Taguchi Design of Experiments for optimization parameters (coil mean dia, coil radius) and output parameters are shear stress, strain energy and solid mass.

	A	B	C	D	E	F
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 DP 0	24	8	404.23	69.154	0.45056
3	2	21.6	8	375.61	116.33	0.41723
4	3	26.4	8	458.71	105.2	0.48404
5	4	24	7.2	564.24	197.58	0.38735
6	5	24	8.8	309.3	25.514	0.52035
7	6	21.6	7.2	513.96	162.6	0.36033
8	7	26.4	7.2	599.18	104.36	0.41443
9	8	21.6	8.8	278.98	49.824	0.48003
10	9	26.4	8.8	355.01	75.654	0.56085

Fig 7: Design Points generated and corresponding shear stress and strain energy

The design points generated are shown in figure 7 above on the basis of CCD (Central Composite Design) method. 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

Fig 8: Shear Stress, strain energy, mass Maximum and Minimum

On the basis of DOE , the minimum value of shear stress obtained is 278.98MPa , maximum value of strain energy obtained is 25.142mJ and solid mass is .36033Kg. On the basis of DOE , the maximum value of shear stress obtained is 599.18MPa , maximum value of strain energy obtained is 198.38mJ and solid mass is .56085Kg.

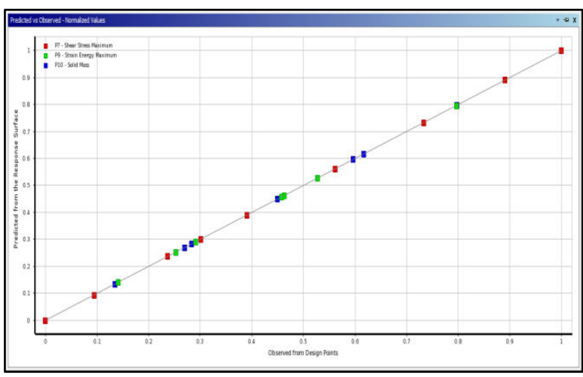

Fig 9: Goodness of fit curve

The deviation of expected values is shown by linear curve in figure 9 above while observed values are shown by colored boxes (red for shear stress, green for strain energy and blue for solid mass). The deviation observed is within the limit and minimal, hence the solution obtained from Taguchi DOE is nearly accurate as all points coincides with linear curve.

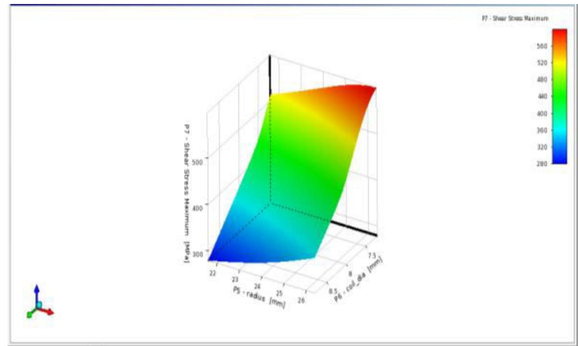

Fig 10: Response Surface for shear stress using Aluminium Alloy

The maximum magnitude of shear stress is observed for for coil mean dia. more than 7.48mm and coil radius more than 24.5mm with magnitude of 560MPa while minimum shear stress stress is observed for coil mean dia. less than 8.4mm and coil radius less than 24mm as shown in figure 10 above.

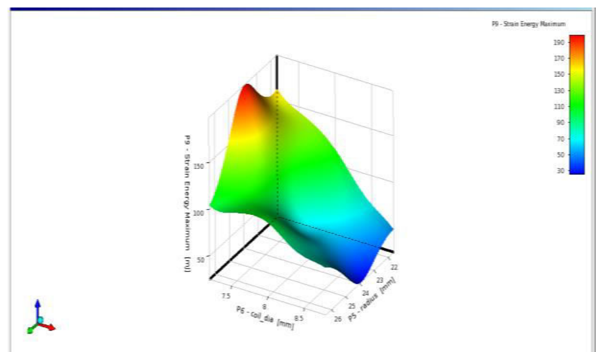

Fig 11: Response Surface for strain energy using Aluminium Alloy

The maximum strain energy is observed for coil mean dia. less than 7.6mm and coil radius ranging from 23.2mm to 24.5 mm with magnitude of 190mJ while the minimum strain energy is observed for coil mean dia. more than 8.4mm and coil radius ranging from 23mm to 25mm with magnitude of 30mJ.

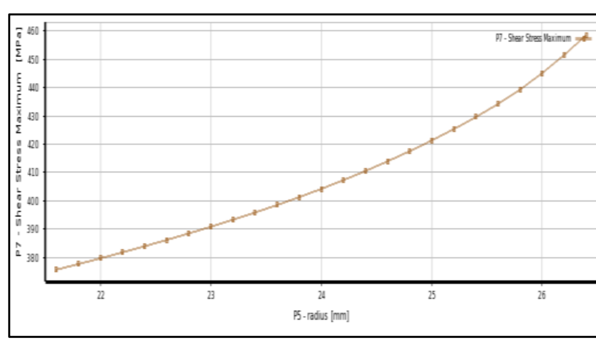

Fig 12: Shear stress variation with coil radius

The shear stress variation w.r.t radius shows quadratic polynomial curve with increase of shear stress attaining a maximum value of 460MPa at 28mm coil radius and minimum at 21mm coil radius.

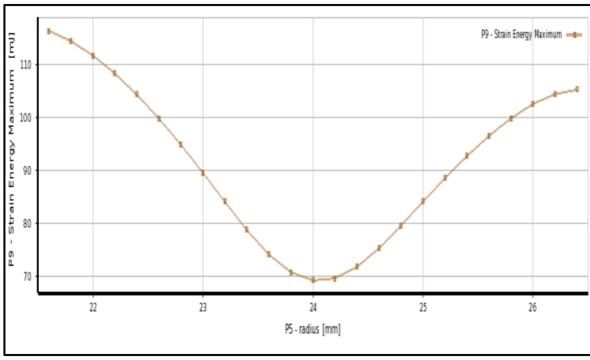

Fig 13: Strain energy variation with respect to coil radius

From the strain energy curve shown in figure 13 above, the minimal value of strain energy is observed for 24mm coil radius and highest for 21mm coil radius with magnitude of 68mJ. The value decreases and then increases upto 27mm coil radius and magnitude of maximum strain energy observed is 120mJ .

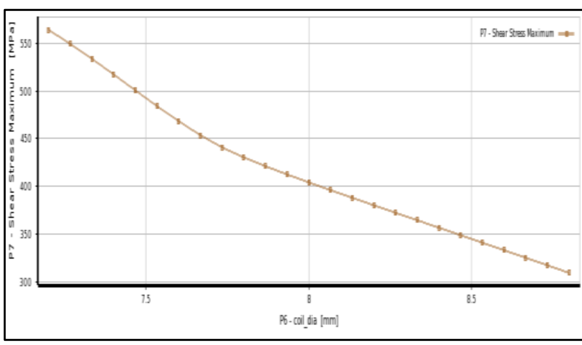

Fig 14: Shear stress variation with respect to coil diameter

Shear stress variation with respect to coil mean diameter is shown in figure 14 above. The graph shows almost decremental linear variation of shear stress. The highest value of shear stress is more than 550MPa and minimum value of shear stress is less than 320MPa.

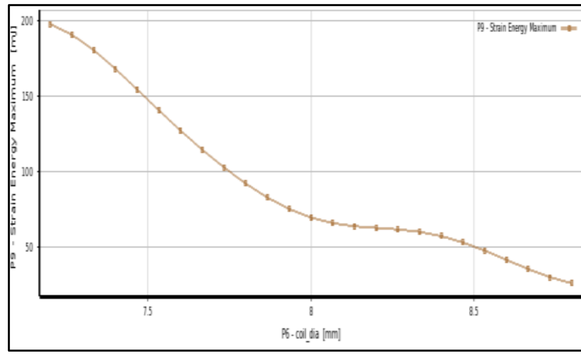

Fig 15: Strain energy variation with respect to coil diameter

The strain energy value decreases with increase in coil mean diameter. The maximum value of strain energy is little less than 200mJ and minimum value of strain energy is 15mJ. The decrement of strain energy shows steep curve, constant and again steep.

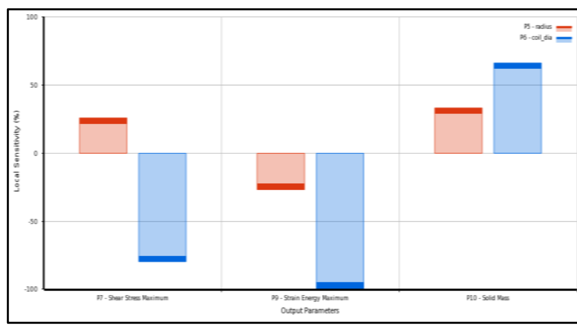

Fig 16: Local Sensitivity Analysis with coil radius and coil mean diameter

The sensitivities of different optimization variables are studied to determine its effect on output variables. This would enable designer/engineer to identify the optimization variable which could cause maximum variation in output variable (the one having higher sensitivity percentage). The sensitivities are generated for shear stress maximum, strain energy and solid mass.

6. CONCLUSION

The static structural analysis is conducted on helical coil suspension of 2-wheeler to determine shear stess, deformation and strain energy. The Finite Element Analysis has proved to be viable tool in investigating the feasibility of design and material used for manufacturing of helical coil suspension. The FEA analysis is conducted using Steel, aluminium alloy, SAE 1025 and chrome vanadium. The response surface optimization has provided certain set of optimum values for both design variables i.e. coil radius and coil mean diameter. The detailed conclusion are as :

1. The shear stress generated in aluminium alloy is lower than structural steel material by 2.39%. The stress generated from FEA results are validated with theoretical results available. The energy absorption characteristics of Aluminium alloy which is 69.15mJ is better than structural steel material having lower value of 13.627mJ.

2. The deformation obtained using structural steel is minimum as compared to other materials i.e. Aluminium alloy, chrome vanadium and SAE 1025. The shear stress obtained for SAE 1025 is maximum and strain energy absorption characteristics is highest for aluminium alloy material.

3. In case of aluminium alloy,for strain energy, the coil radius shows -26.699(negative) sensitivity while coil mean diameter shows -99.323(negative) sensitivity. Therefore, coil mean diameter has higher effect on strain energy generated due to higher sensitivity percentage in magnitude.

4. In case of aluminium alloy, for solid mass, coil radius shows 33.315(positive) sensitivity while coil mean diameter shown 66.337 (positive) sensitivity. Therefore, coil mean diameter has higher effect in mass of helical coil suspension.

5. For aluminium alloy, the maximum mass of helical coil suspension from response surface optimization .560kg and for structural steel is 1.589Kg. The weight reduction achieved using aluminium alloy is nearly 64% as compared to structural steel.

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