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Analysis of Helical Joint Suspension System with 6 Sigma Tool

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Abstract: Conventional helical coil suspensions are heavier and have lower energy absorption characteristics. To improve vehicle mileage and ensure a smoother ride there is a need to develop a new design of helical coil suspensions that are lighter in weight and possesses better energy absorption characteristics. Structural analysis using the FEA method on new design of helical coil (varying cross-section) suspension is performed using ANSYS software and composite material is employed to achieve better performance of helical coil suspensions. The CAD model of helical coil suspension is developed using ANSYS design modeller software and structural analysis is conducted in workbench. The optimization variables are selected to respond to the surface optimization of suspension. The design points are generated using Taguchi DOE (Design of Experiments) and stresses, deformation, mass are evaluated for each design point. The 3D response surface plots, sensitivity plots are generated and the component is further subjected to 6 sigma evaluation for robust designing. The 6-sigma evaluation of suspension would provide us sigma value for each design point with a probability distribution and parts that are likely to fail.

Key Words: Helical Coil Suspension, FEA, optimization, 6-sigma analysis

1. INTRODUCTION

The suspension system is used in vehicles for absorbing shocks due to uneven road surfaces. Another purpose of suspension is to obtain constant contact between tyre and road surface irrespective of uneven road conditions. The suspension system comprises of arm rods, ball joints, axles and part springs. The light coil springs are used in modern light weight passenger vehicles. For commercial vehicles, the helical suspensions are used in the front and rear wheels can have leaf springs.

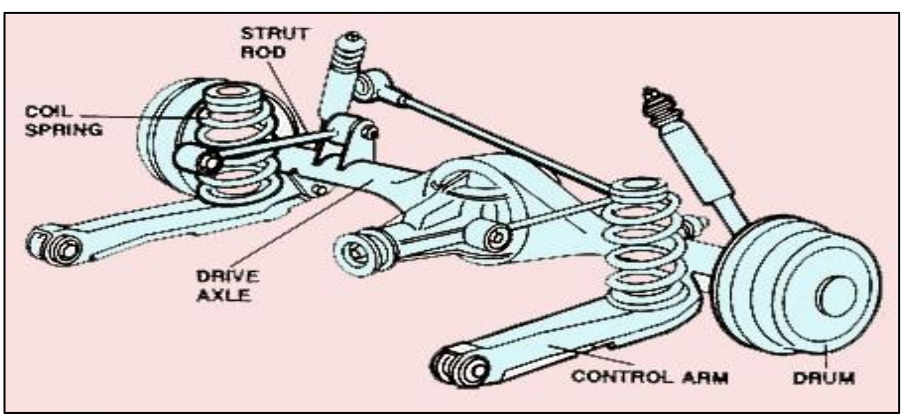

Figure 1: Automobile suspension system

2. LITERATURE REVIEW

Numerical investigations have been conducted on mono suspension of unicorn bike using techniques of FEA. The static structural analysis of suspension is conducted using 1095, 5160, Carbon steel, Cobalt chrome, Chrome vanadium, Beryllium copper materials. The wire diameters taken for the analysis are 12mm and 14mm. The stresses are determined for static and dynamic loading conditions and best material is determined [1]. Investigations on Alto K10 suspension were carried out using techniques of Finite Element Analysis. The 3D model is developed using CATIA V5 software and fatigue life assessment is conducted. The results from experimental testing are in close agreement with numerical results. The experimental testing apparatus for determining stresses and strain of helical coil suspension is shown in figure 2 below [2].

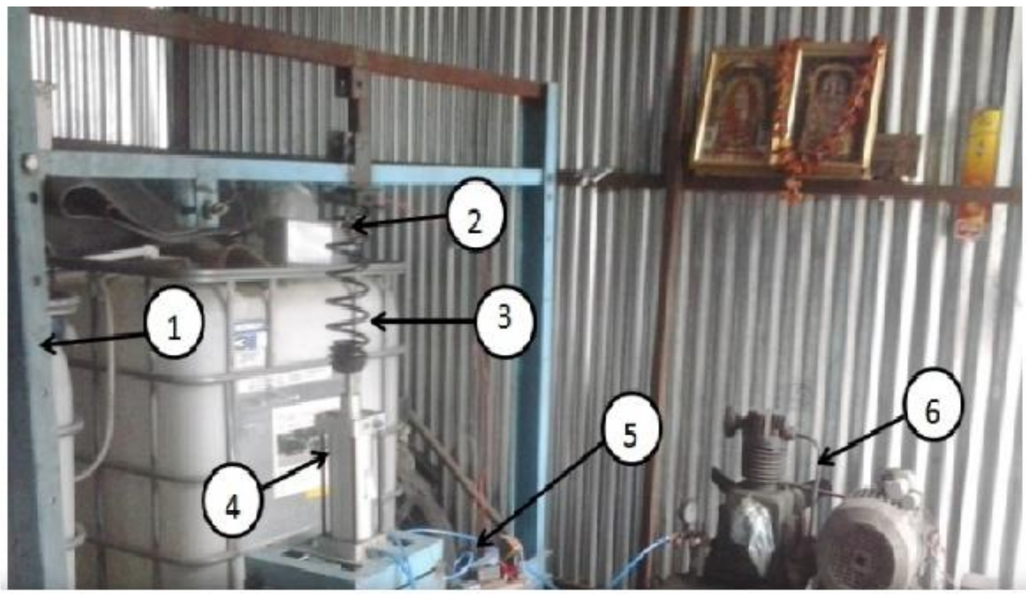

Figure 2: Experimental set up of helical coil suspension [2]

Numerical analysis of light weight vehicle suspension is done using ANSYS software. The 3D model of suspension was developed in Pro/E design software and material used for the analysis is $60Si_2MnA$ steel. From the structural analysis conducted in ANSYS software, the research findings have shown that $60Si_2MnA$ is the best suited material for the same [3]. Investigations of suspension coil have been carried out using ANSYS software. The research was intended to determine the parameters affecting stress generation and deformation developed on suspension. The research findings have shown that suspension coil diameter has significant effect on suspension stress and deformation [4]. The experimental testing apparatus for determining compressive strength of helical coil suspension is shown in figure 3.

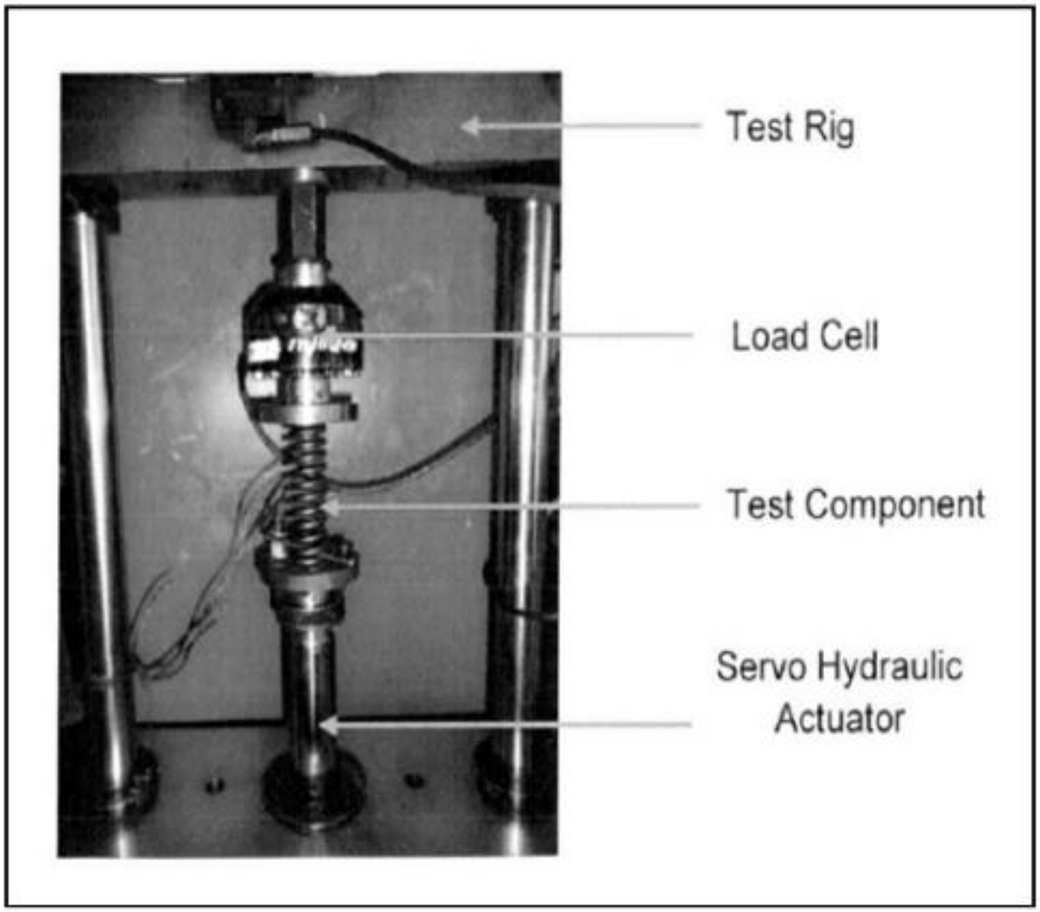

Figure 3: Servo Hydraulic Experimental Setup [4]

Experimental analysis on automobile suspension is performed for investigating the fatigue failure of suspension and surface imperfections using SEM (scanning electron microscope). The research findings have shown that premature failure of suspension is caused due to material in homogeneity [5]. Analysis of shock absorber of helical coil profile was carried out using a 160cc bike. The existing design of shock absorber was improved by minimizing the diameter. The 3D CAD design of suspension was developed using Pro/E software and FEA simulation is conducted using ANSYS software [6]. Evaluation and analysis of the coil spring suspension performance of a motorbike prepared using different materials of fiber is performed by applying diverse loads pertaining to motorcycle payload for determining the total deformation loss, stress as well as strain analysis of suspension under the static conditions [7]. The functionality and utility of a helical spring coil can be enhanced by increasing its strain energy. Various design parameters like spring wire diameter, coil spring diameter and number of spring turns etc. were optimized using the multi-objective optimization formulation technique [8].

3. METHODOLOGY

The FEA analysis is conducted on helical coil suspension to determine stresses and deformation. Different steps of analysis are shown in flowchart as shown in figure 4 below.

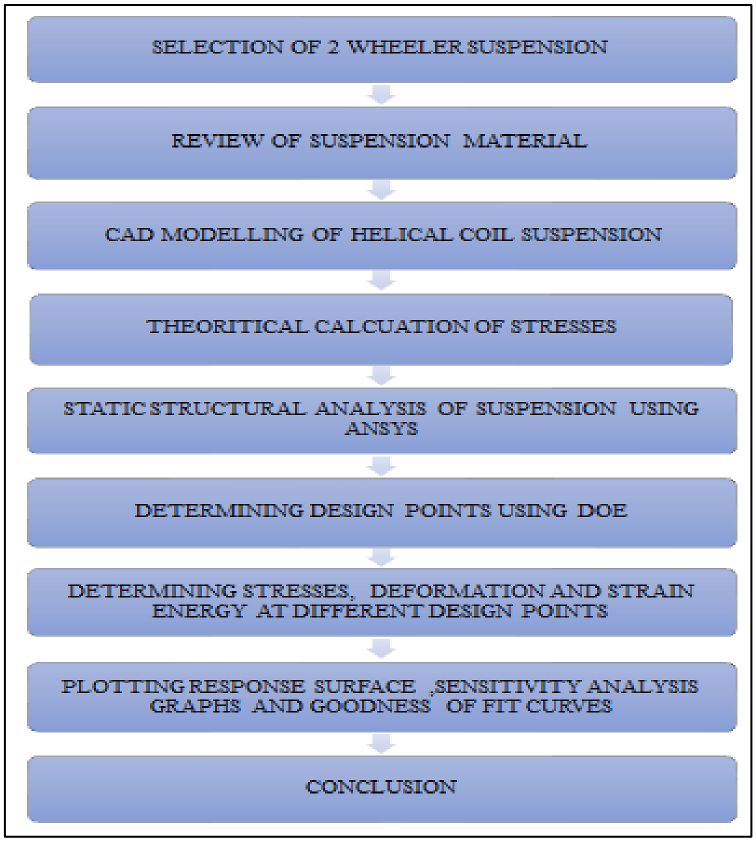

Figure 4: Methodology Flow Chart

The model of helical suspension is developed in ANSYS design modeler using sweep and sketch tool. The dimensions of helical coil suspension are taken as shown below [9]:

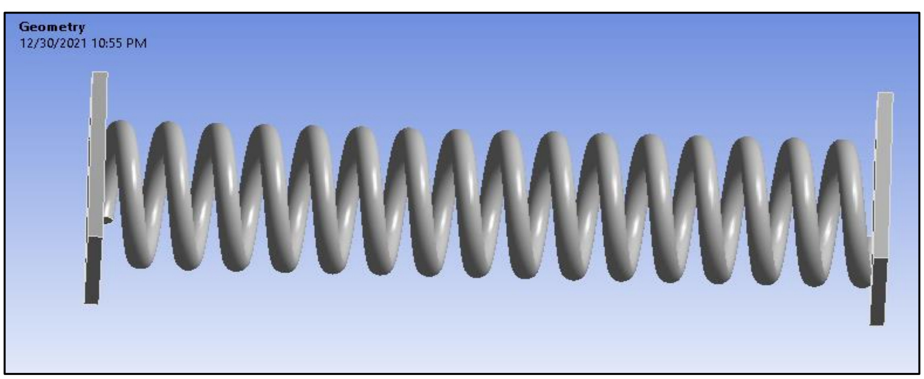

Figure 5: Design of helical coil suspension

The suspension model is discretized using tetrahedral element type with fine relevance setting. The growth rate is set to 1.3 and inflation set to normal with smooth transition. The number of elements generated is 20054 and number of nodes generated is 9263.

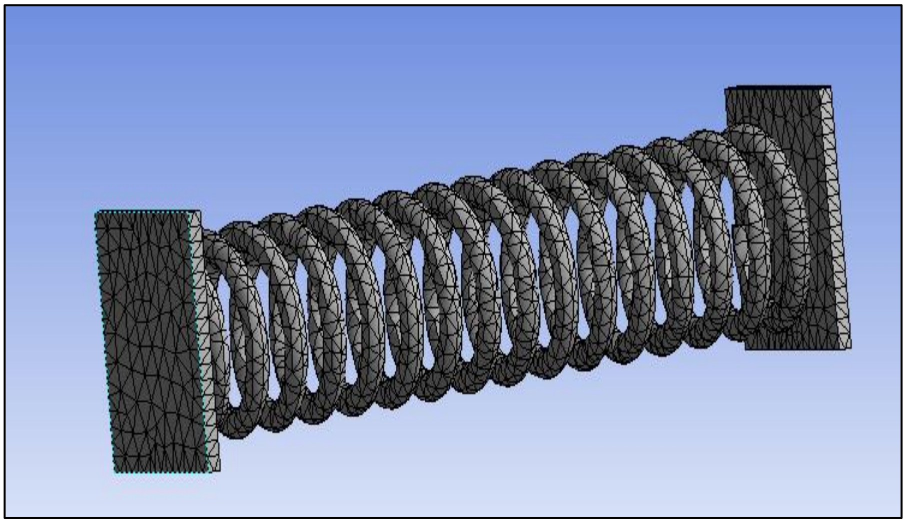

Figure 6: Discretized model of suspension

The static structural loading conditions are applied on helical coil suspension as shown in figure 7. The bottom face is applied fixed support.

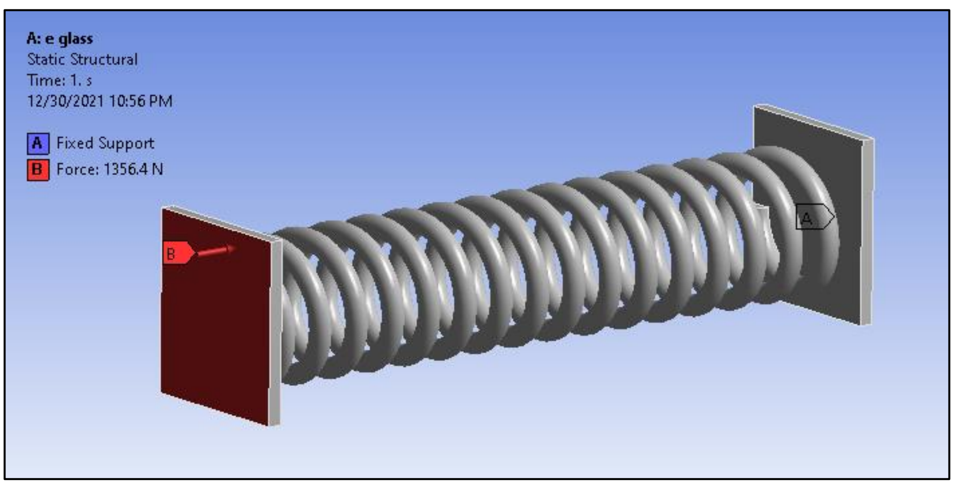

Figure 7: Applied loads and boundary condition

After applying boundary conditions, the sparse matrix iteration solver is invoked. The stiffness matrix is formulated and nodal calculations are performed. The nodal displacement values are determined from computation.

4. RESULTS AND DISCUSSION

The numerical simulation is conducted on helical coil suspension to determine deformation, equivalent stress and strain energy.

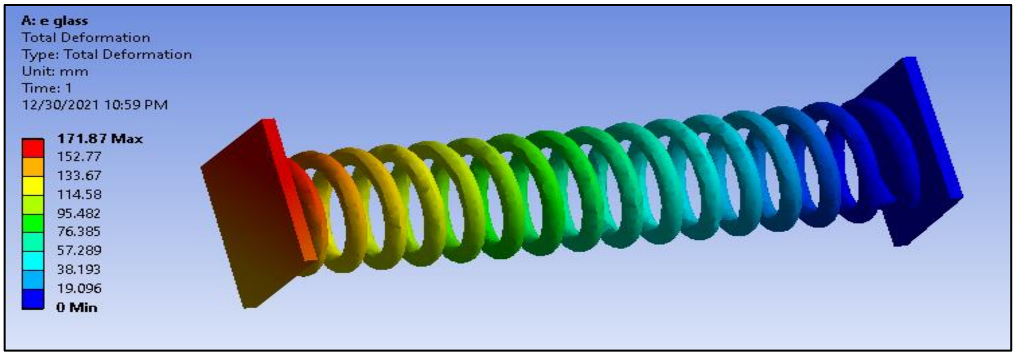

Figure 8: Total deformation plot

The deformation plot is obtained for helical coil suspension as shown in figure 8. The bottom face of suspension has minimal deformation and top end of suspension shows maximum deformation with magnitude of more than 152mm.

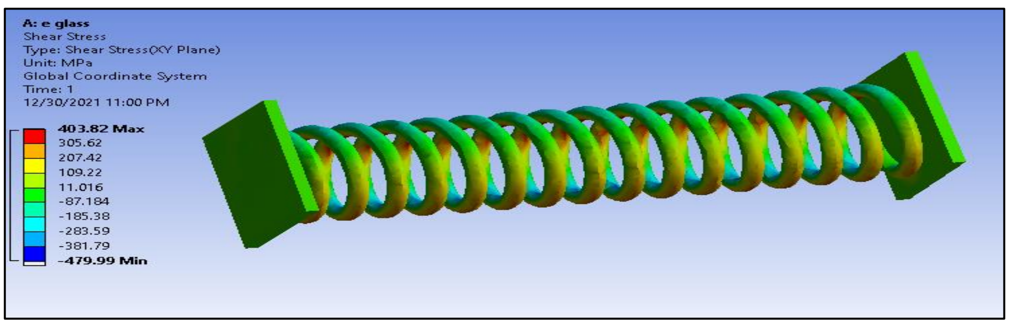

Figure 9: Shear stress plot

The shear stress plot is generated for helical coil suspension as shown in figure 9. The inner surface of helical coil has higher shear stress as compared to outer surface of coil.

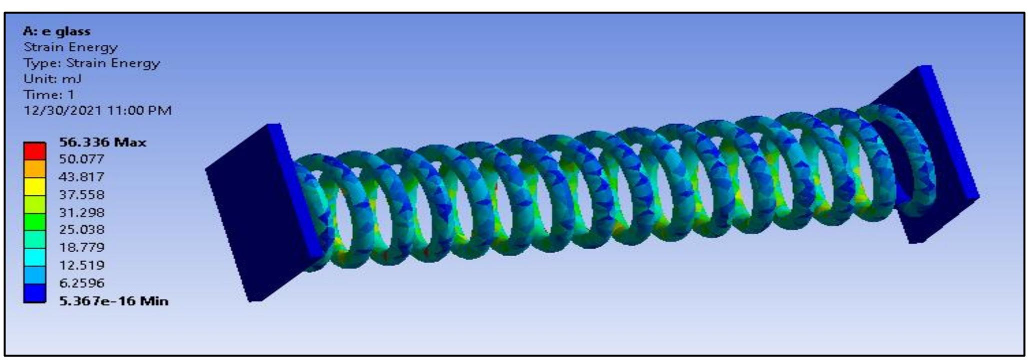

Figure 10: Strain energy plot

The strain energy plot is generated for helical coil suspension. The maximum strain energy obtained from analysis is more than 50.077mJ.

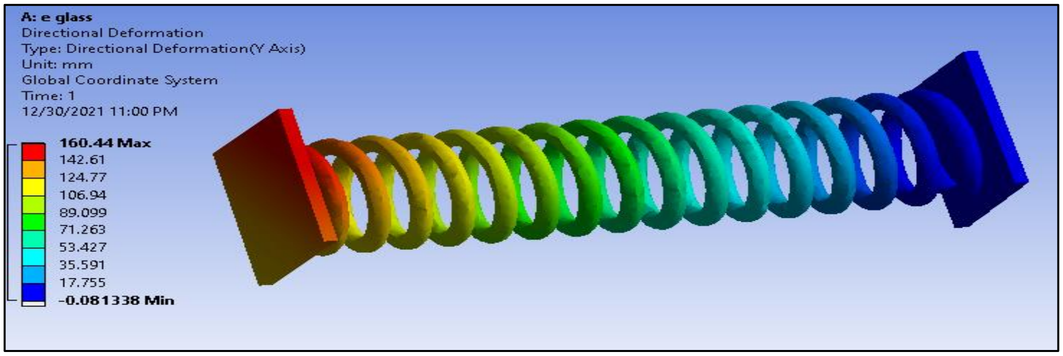

Figure 11: Directional deformation

The directional deformation plot is obtained and maximum value of deformation obtained is more than 142mm. The variation of shear stress with respect to coil radius is investigated using optimization technique.

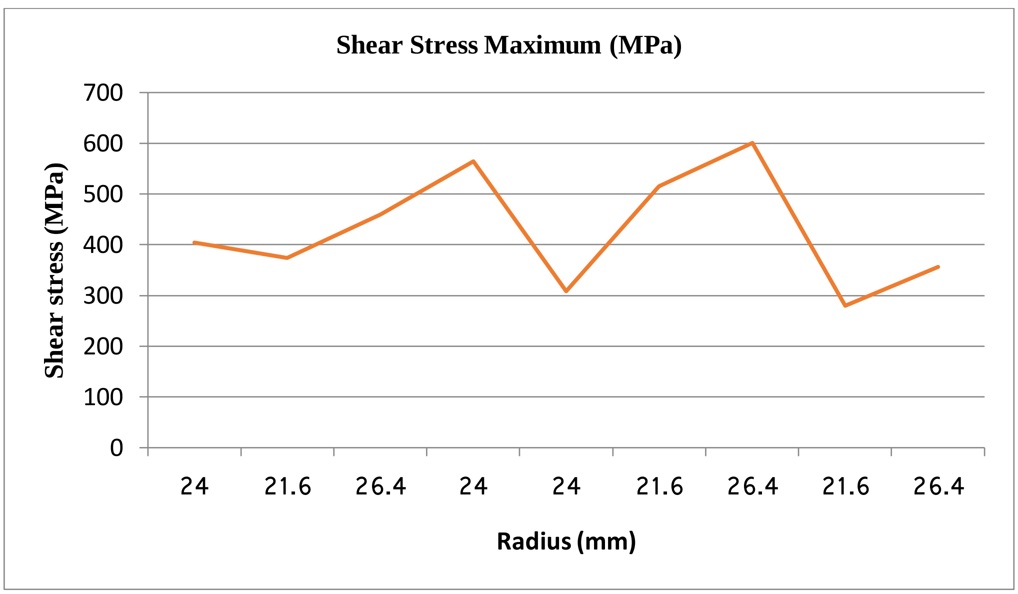

Figure 12: Shear stress Vs coil radius

The variation of shear stress with respect to coil radius is obtained from optimization results as shown in figure 12. The maximum shear stress is obtained for coil radius value of 26.4mm and minimum shear stress is obtained for coil radius of 21.6mm.

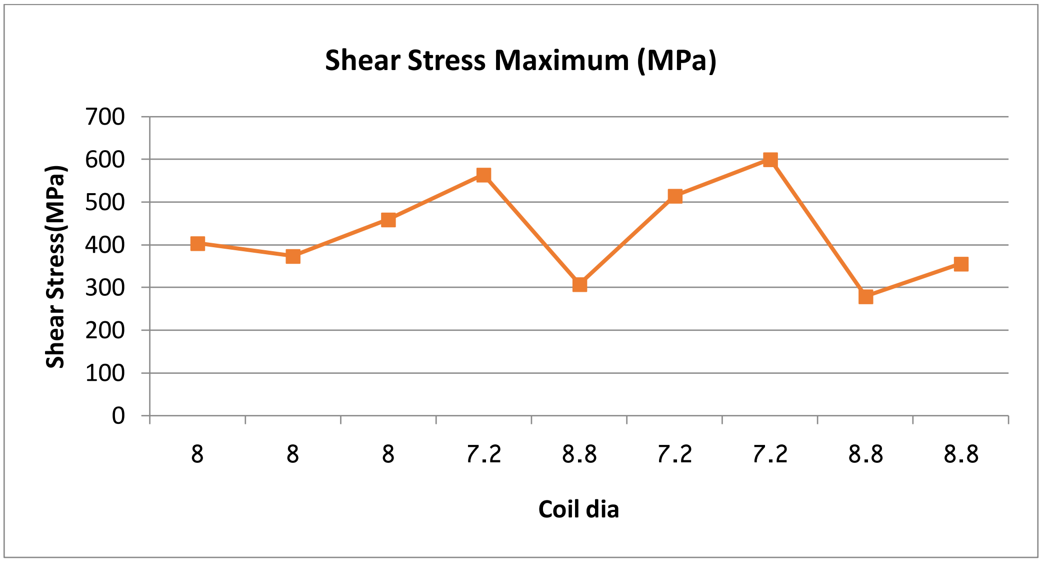

Figure 13: Shear stress Vs coil diameter

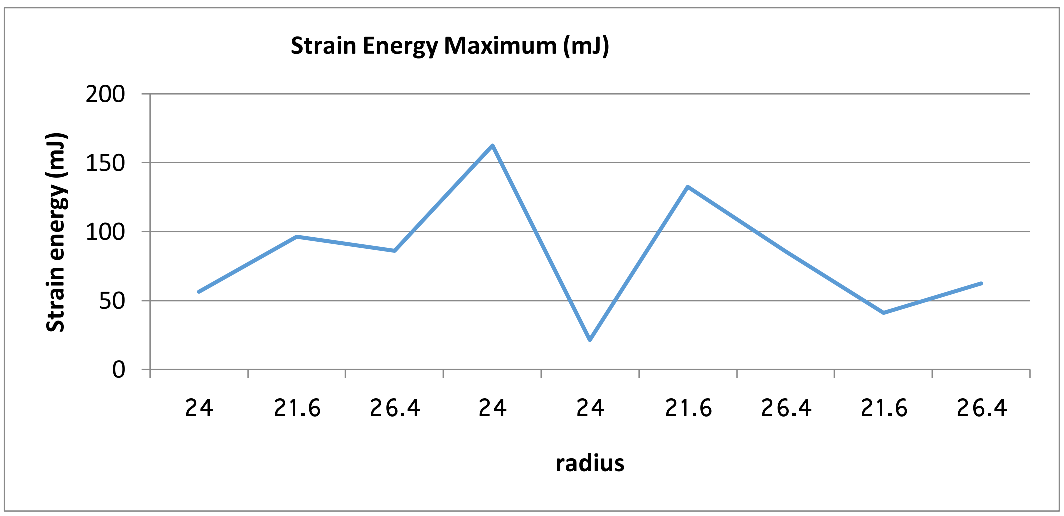

Figure 14: Strain energy Vs radius

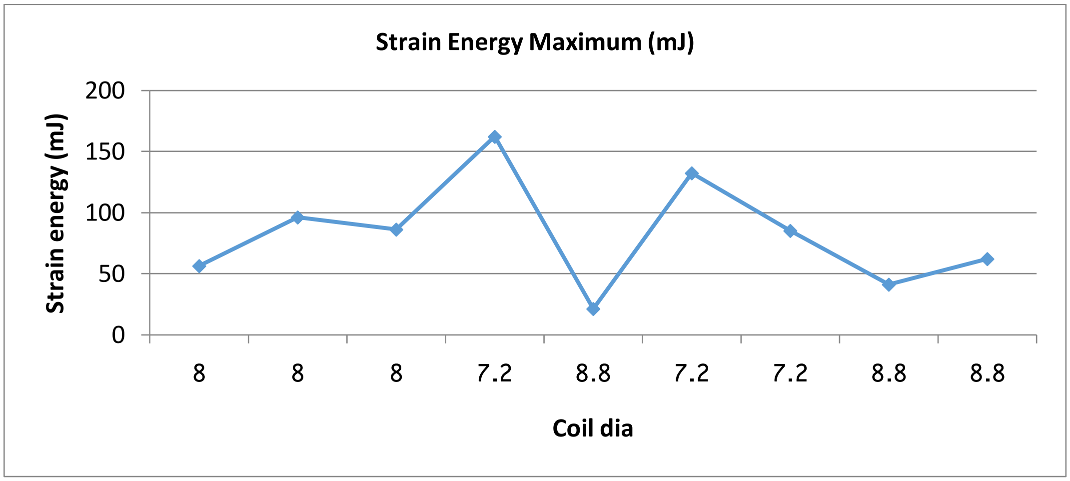

Figure 15: Strain energy Vs coil diameter

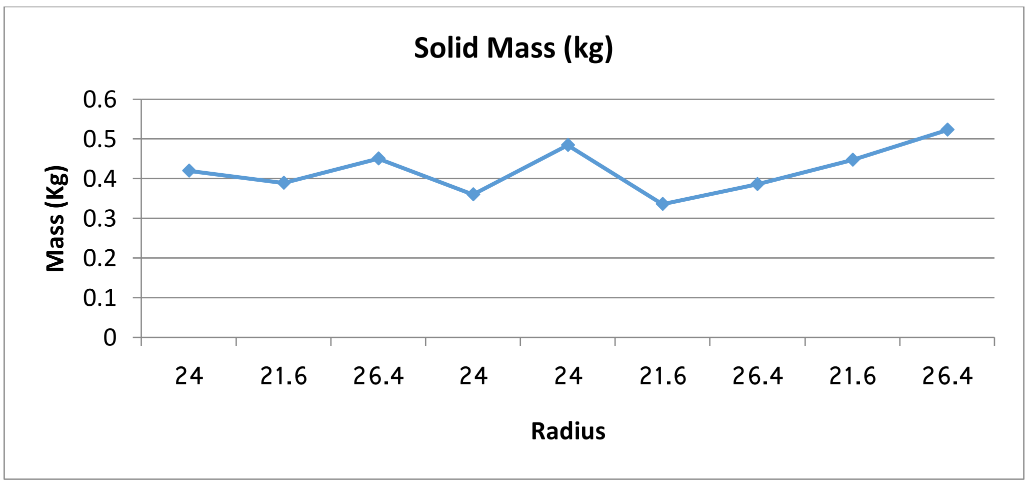

Figure 16: Solid mass Vs radius

The variation of output parameters with respect to each optimization variable are shown in figures 13 to 16. The maximum shear stress is obtained for coil diameter value of 7.2mm. Similarly, the maximum strain energy is obtained for radius of 24mm. The maximum strain energy is obtained for coil diameter value of 7.2mm and is minimum for coil diameter value of 8.8mm coil diameter.

6-SIGMA EVALUATION

Table 1: 6-sigma design evaluation for different radius

Table of Outline A5: Statistics for P5 - radius

	A	B	C
1	P5 - radius (mm)	Probability	Sigma Level
2	19.449	6.9312E-05	-3.8106
3	19.823	0.00025219	-3.4784
4	20.197	0.00080929	-3.1525
5	20.571	0.0021481	-2.8556
6	20.945	0.0054578	-2.5454
7	21.319	0.012775	-2.233
8	21.693	0.027322	-1.9217
9	22.067	0.053619	-1.6107
10	22.441	0.096973	-1.299
11	22.815	0.16179	-0.98713
12	23.189	0.24963	-0.67565
13	23.563	0.35796	-0.36391
14	23.937	0.47919	-0.052186
15	24.311	0.60243	0.25965
16	24.686	0.7161	0.57129
17	25.06	0.81139	0.88303
18	25.434	0.88391	1.1947
19	25.808	0.93397	1.506
20	26.182	0.96545	1.8178
21	26.556	0.98337	2.1289
22	26.93	0.99269	2.4416
23	27.304	0.99703	2.7513
24	27.678	0.9989	3.0627
25	28.052	0.99963	3.3768
26	28.426	0.99985	3.6115
27	28.8	0.9999	3.7111
28	29.174	0.99993	3.8106

The sigma level shows the robustness of design i.e. higher the sigma level more robust is the design and minimum the sigma level less is the robustness. The sigma level is evaluated for different values of radius which is shown in table 1.

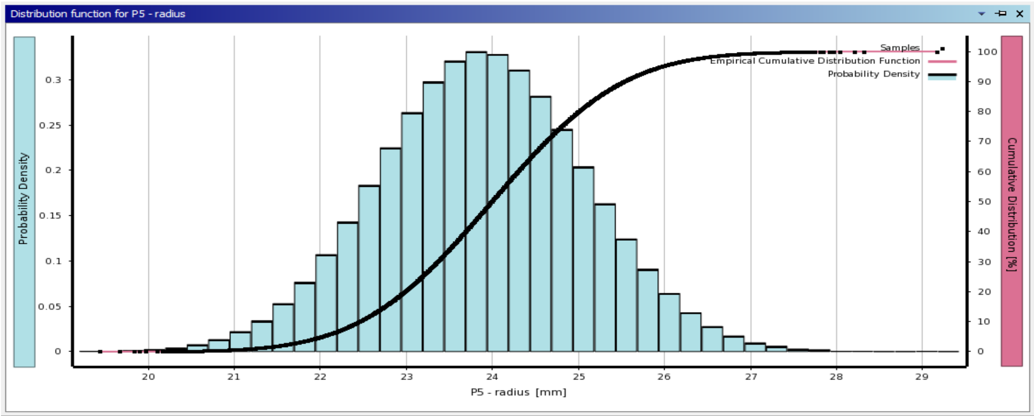

Figure 17: Probability density curve for radius

The variation of different radius with respect to sigma level is shown in figure 17. From probability density and sigma level the most robust value for radius is 28.426mm, 38.8mm and 29.174mm. These values have shown sigma level higher than 3.4.

Table 2: 6-sigma design evaluation for different coil diameters

Table of Outline A6: Statistics for P6 - coil_dia

	A	B	C
1	P6 - coil_dia (mm)	Probability	Sigma Level
2	6.3162	6.9312E-05	-3.8106
3	6.4448	0.00011001	-3.6949
4	6.5735	0.00018791	-3.5565
5	6.7022	0.00062896	-3.2254
6	6.8309	0.0017453	-2.9209
7	6.9596	0.0046839	-2.5983
8	7.0883	0.01135	-2.2785
9	7.217	0.025136	-1.9576
10	7.3457	0.050984	-1.6354
11	7.4744	0.094406	-1.3141
12	7.6031	0.16053	-0.99227
13	7.7318	0.25122	-0.67065
14	7.8605	0.36356	-0.34895
15	7.9891	0.48919	-0.027099
16	8.1178	0.61586	0.29463
17	8.2465	0.73115	0.6163
18	8.3752	0.82585	0.93791
19	8.5039	0.89609	1.2596
20	8.6326	0.94309	1.5812
21	8.7613	0.97147	1.9029
22	8.89	0.98694	2.2243
23	9.0187	0.99457	2.547
24	9.1474	0.99795	2.8709
25	9.2761	0.99927	3.1841
26	9.4048	0.99976	3.4964
27	9.5334	0.99989	3.691
28	9.6621	0.99993	3.8106

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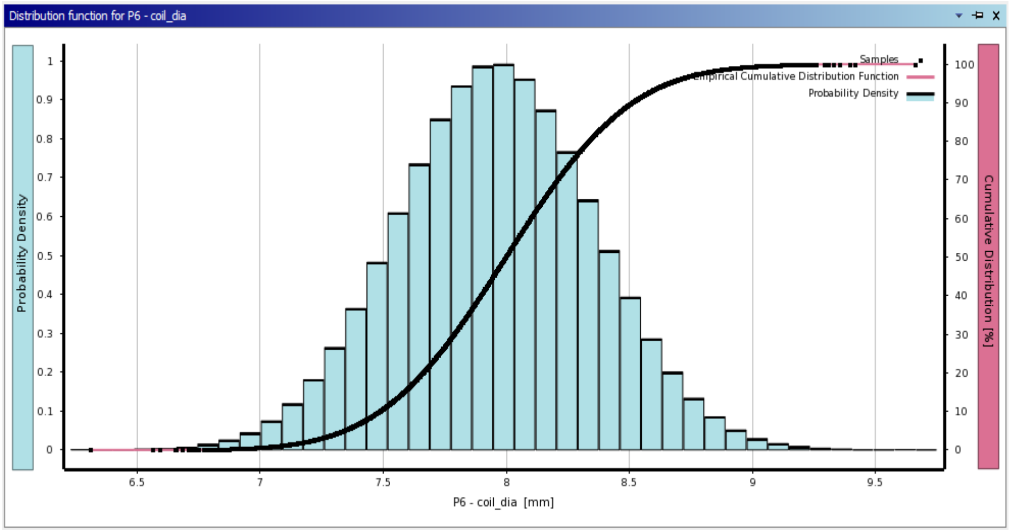

Figure 18: Probability density function for different coil diameters

The variation of different coil diameter with respect to sigma level is shown in figure 18. From probability density and sigma level the most robust value for coil diameter is 9.4048mm, 9.5334mm and 9.6621mm. These values of coil diameter have shown sigma level higher than 3.4.

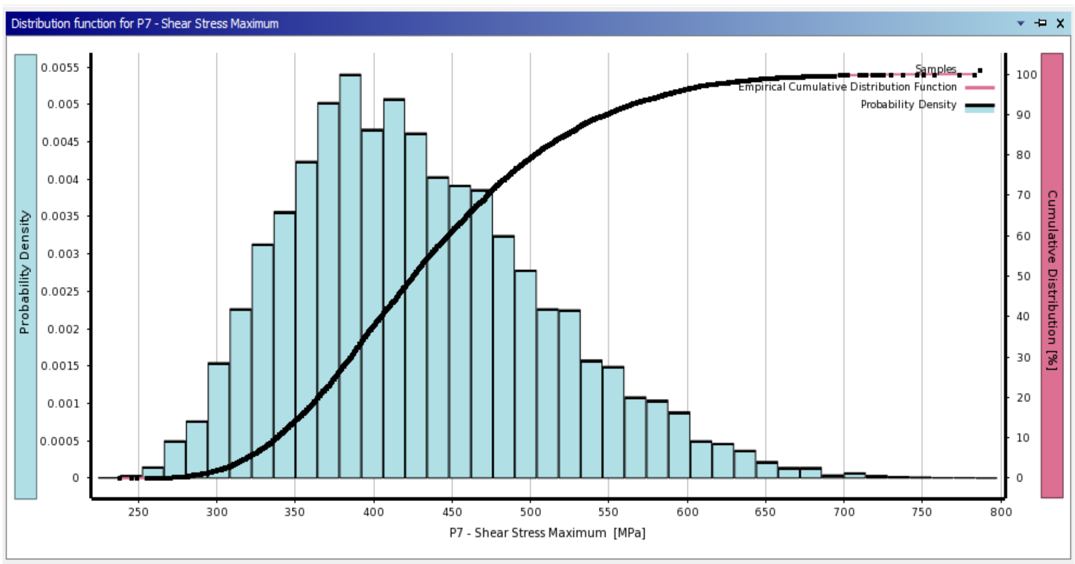

Figure 19: Probability density function for shear stress

The probability density function curve is obtained for shear stress as shown in figure 19. From the probability density curve, the occurrence of 385.05MPa shear stress is maximum due to high probability density of 0.0005407.

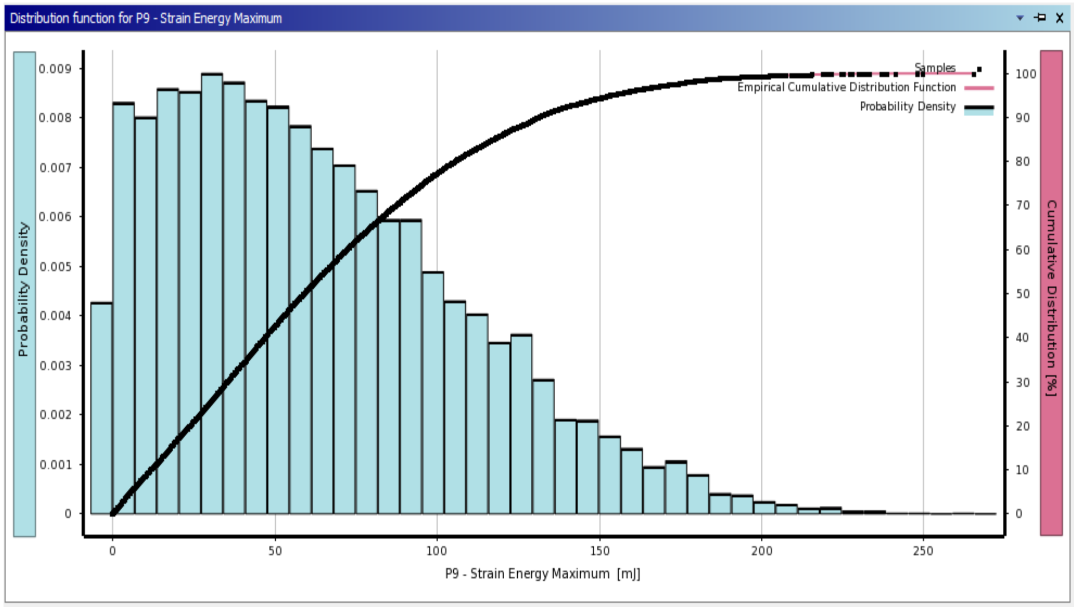

Figure 20: Probability density function for strain energy

The probability density function curve is obtained for strain energy as shown in figure 20. From the probability density curve, the occurrence of 30.573mJ strain energy is maximum due to high probability density of 0.0088968

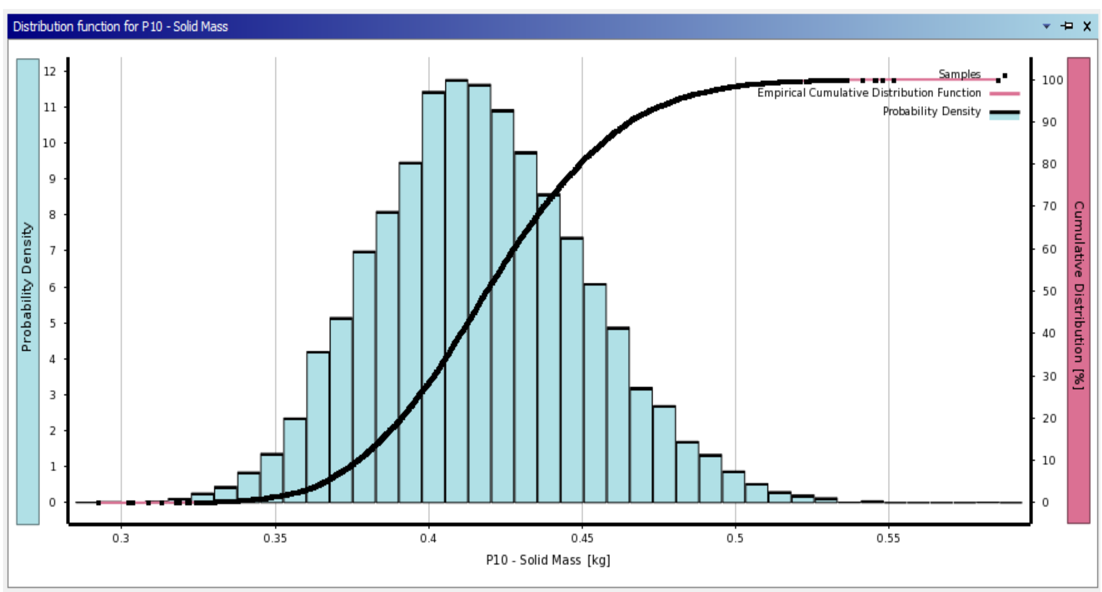

Figure 21: Probability density function for solid mass

The probability density function curve is obtained for solid mass as shown in figure 21. The maximum occurrence is observed for solid mass of 0.409Kg with probability density of 11.763.

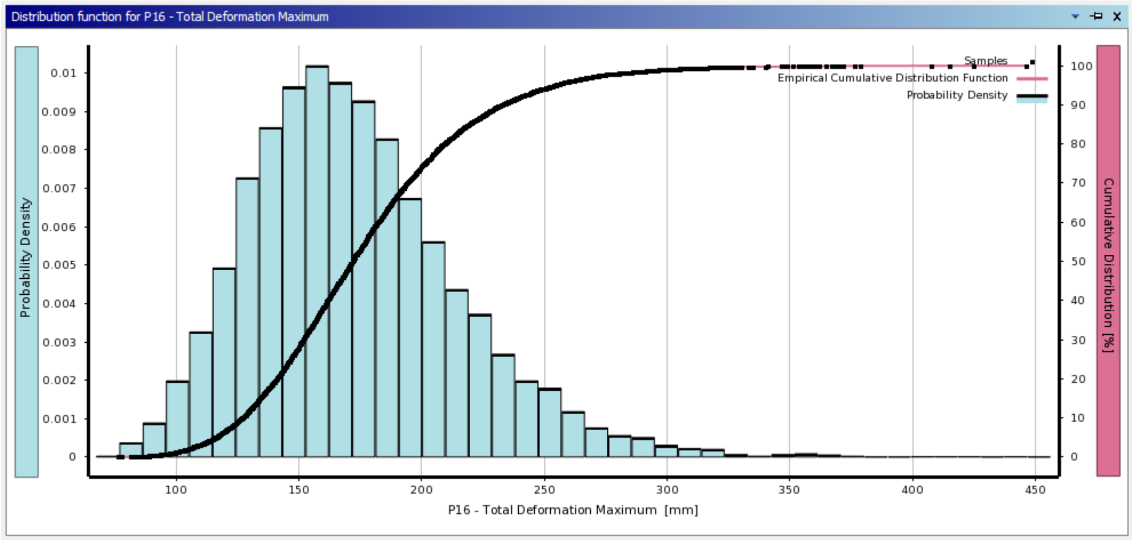

Figure 22: Probability density function for total deformation

The probability density function curve is obtained for total deformation as shown in figure 22. The maximum occurrence is observed for total deformation of 157.49mm having probability density of 0.0101.

6. CONCLUSION

The use of computer simulation package is a viable tool in determining structural characteristics of helical coil suspension subjective to compressive loads. The critical regions of helical coil suspension are determined having high shear stress and deformation. From the optimization results, it is evident that coil radius has significant effect on shear stress generated on helical coil suspension. The maximum shear stress is obtained for coil radius value of 26.4mm and minimum shear stress is obtained for coil radius of 21.6mm.

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