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Design and Analysis of Leaf Spring Using Composite Materials and Prediction Using Artificial Neural Network

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ABSTRACT:

Leaf sprigs are crucial suspension elements used on light passenger vehicle necessary to minimize the vertical vibrations impacts and bumps due to road irregularities and to create a comfortable ride. Leaf springs are widely used for automobile and railroad suspensions. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly so increasing the energy storage capabilities of a leaf spring and ensures a more compliant suspension system. Three-dimensional finite element analysis of the leaf spring consists of a computer model or design that is stressed and analysed for specific results.

Keywords: Springs, Types, 3-D Modelling.

Introduction

A company that can verify a proposed design will be able to perform to the clients' specifications prior to manufacturing or construction. The external load applied upon the leaf spring induces bending stresses that are superimposed on the preliminary ones (i.e., created at assembly). In consequence, the maximum tensile stresses in the main leaf decrease, and those in the bottom leaf increase. Meanwhile, in the intermediate leaves, the stresses vary proportionally to the leaf location. Because the bottom leaves are subjected to a greater stress, the spaces between stay small, thus lessening the influence of the preliminary stresses.

Fig-2.1 Semi- elliptical leaf spring

NUMERICAL ON LEAF SPRING;

A truck spring has 10 leaves and is supported at a span of 1m with a central band of 80 mm width. A load of 6 kN is applied at the centre of spring whose permissible stress is 300 N/mm2. The spring has a ratio of total depth to width of about 2.5. Determine the width, thickness, deflection of leaves.

Given data

N = 10

2L = 1m = 1000 mm

W= $6 * 10^3$ N

σ =300 $\mathrm{n/mm^2}$

Load (p) = $\frac{w}{2}$ = $\frac{6*10^3}{2}$ = $3*10^3$ N

Effective length (L) = $\frac{2l*a}{2}$= $\frac{1000-80}{2}$ = 460 mm

Number of leaf spring (n) =n (full) + n (graduated)

i)Thickness of leaves:

$$\sigma = \frac{18pl}{bt^2(3*n(f)+2*n(g))}\frac{nt}{b} = 2.5$$

$$300 = \frac{18*3*10^3*460}{b(0.25)^2\,(3*2+2*8)}\frac{10*t}{b} = 2.5$$

b = 39.2 mm ≅ 40 mm t = 0.25b

ii)Deflection of springs:

$$\delta = \frac{12pl^3}{Ebt^3\,(3n(f)+2\,n(g))} \qquad E = 2*10^5\ \frac{\mathrm{n}}{\mathrm{mm}^2}$$

$$\delta = \frac{12*3*10^3*460^2}{2*10^5*39.2*(9.8)^3\,(3*2+2*8)}$$

$\delta = 21.5$ mm ≅ 22 mm

iii) Diameter of eye:

i) Bearing stress: $p = 8\,\frac{\mathrm{n}}{\mathrm{mm}^2}$

$p = \frac{p}{d*u}$ u = b

$8 = \frac{3*10^3}{d*39.2}$ $\sigma = 80\ \frac{\mathrm{n}}{\mathrm{mm}^2}$

d = 9.6 mm ≅ 10 mm c = 2mm

ii)Bending stress: $\sigma = \frac{32\,M}{\pi d^3}$

$M = \frac{p\vartheta}{4} = \frac{3*10^3*43.2}{4}$ = 32400 mm $\vartheta = u + 2c$

$80 = \frac{32*32400}{\pi d^3}$ = 39.2 + (2*2)

d = 16 mm = 43.2 mm

iv)Radius of leaves:

$R = \frac{l^2}{2*\delta} = \frac{500^2}{2*21.5}$ = 5813.9 mm

v)Length of leaves:

L (1) = $\frac{2l}{(n-2)}*1+a = \frac{2*460}{(10-2)}*1+80 = 150$mm

L (2) = $\frac{2l}{(n-2)}*2+a = \frac{2*460}{(10-2)}*2+80 = 185$mm

L (3) = $\frac{2l}{(n-2)}*3+a = \frac{2*460}{(10-2)}*3+80 = 295$mm

L (4) = $\frac{2l}{(n-2)}*4+a = \frac{2*460}{(10-2)}*4+80 = 395$mm

L (5) = $\frac{2l}{(n-2)}*5+a = \frac{2*460}{(10-2)}*5+80 = 525$mm

L (6) = $\frac{2l}{(n-2)}*6+a = \frac{2*460}{(10-2)}*6+80 = 688$mm

L (7) = $\frac{2l}{(n-2)}*7+a = \frac{2*460}{(10-2)}*7+80 = 700$mm

L (8) = $\frac{2l}{(n-2)}*8+a = \frac{2*460}{(10-2)}*8+80 = 785$mm

L (9) = $\frac{2l}{(n-2)}*9+a = \frac{2*460}{(10-2)}*8+80 = 895$mm

L(10) = $\frac{2l}{(n-2)}*10+a = \frac{2*460}{(10-2)}*8+80 = 1015$mm

Master leaf:l = 2l + $\pi\,(d+t)^2$

l = 500 + $\pi\,(39.2+9.8)^2$

= 1120.9mm

Resulting dimensions:

b = 39.2 mm ≅ 40 mm

t = 9.8 mm $\cong$ 10 mm

$\delta = 21.5$ mm $\cong$ 22 mm

d = 16 mm

R = 2698 m

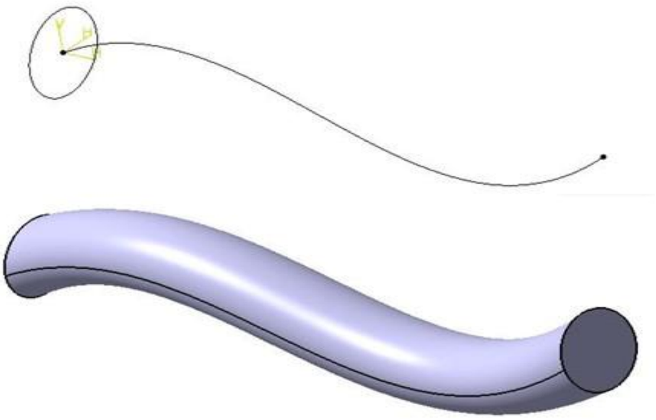

FIG:3.2.8

SLOT command:

SLOT removes the material along a guide curve. Here is an example of slot. While using SLOT, I have used the same guide curve that was used for RIB. This ensures that the cross section will be uniform throughout.

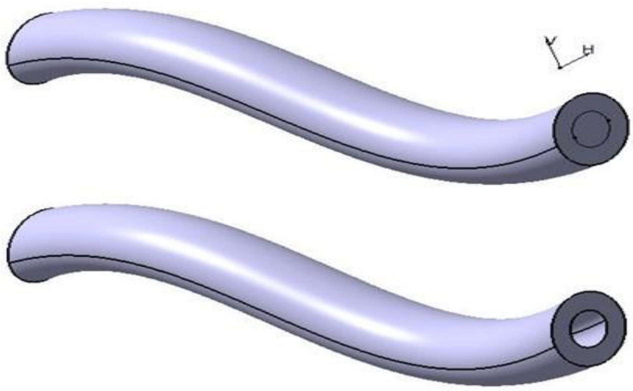

FIG: 3.2.9

Step 4: Assembly Module:

Assembly environment is used to provide mating to two or more part models to from complete assembly

Structural Steel:

Geometry:

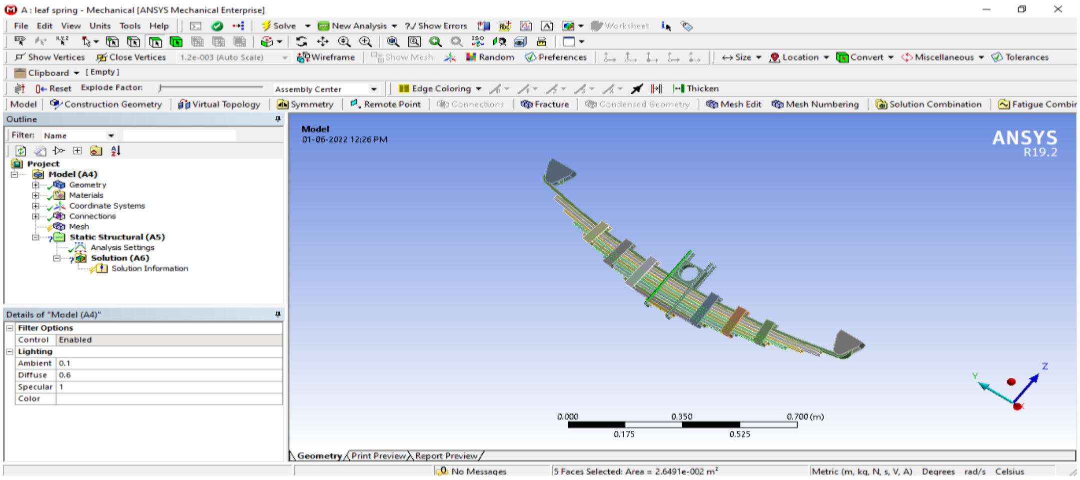

Fig-4.2.1 Ansys Workbench

MESH:

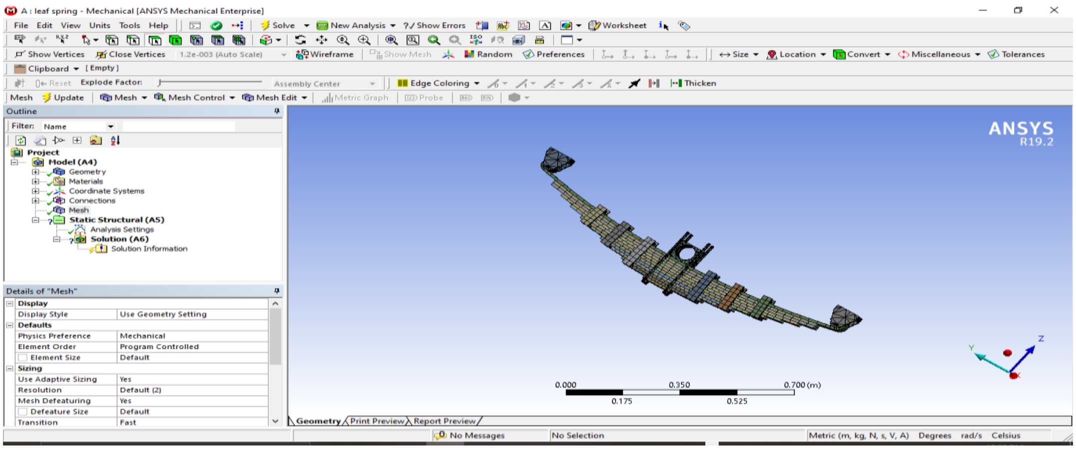

Fig-4.2.3 Meshing

FIXED SUPPORTS:

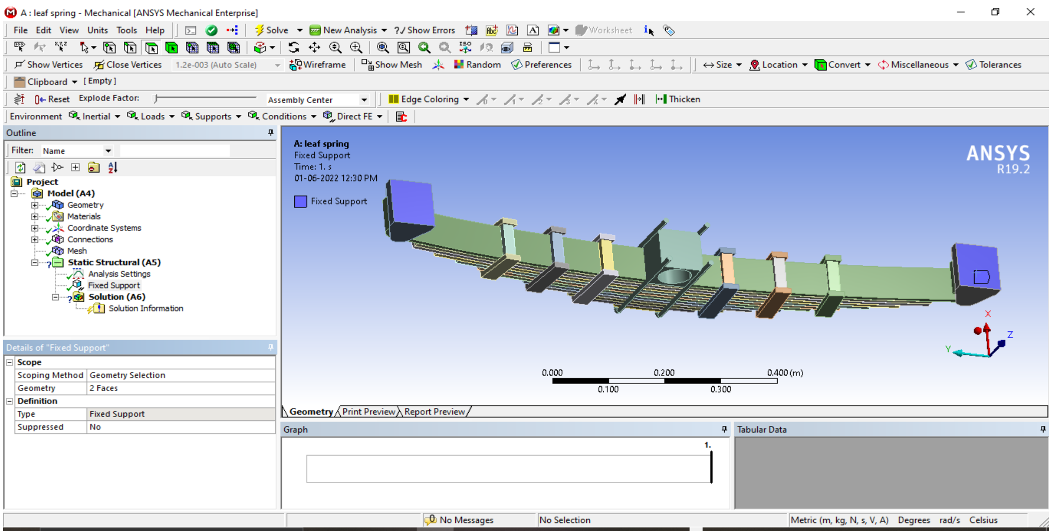

Fig-4.2.4 Fixing supports

LOADING:

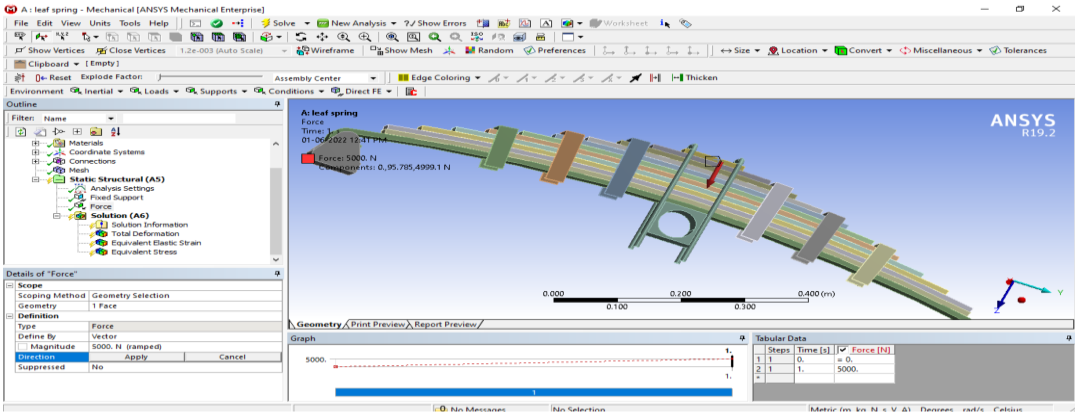

Fig-4.2.5 Applying load

Literature Review

1. Mahmood M. shokrieh and DavoodRezaei[1] presented work on design, analysis and optimization of leaf spring .The aim of this review paper was steel leaf spring was replaced with an optimized composite one.

   Main objective of this paper was to obtain a spring with minimum weight that is capable of carrying given static external forces without failure. Here the work is carried out of a four-leaf steel spring which used in the rear suspension system of light vehicles & heavy duty vehicles. The four-leaf steel spring is analyzed by using ANSYS V5.4 software.

   The finite element results showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main consideration is given to the optimization of the spring geometry. In this study stress and displacements were used as design constraint.

   The experimental results are verified with the analytical data and the finite element solutions for the same dimensions. Result shows that stresses in the composite leaf spring are much lower than that of the steel leaf spring. Compared to the steel leaf spring the optimized composite leaf spring without eye units weights nearly 80% less than the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance.

2. E. Mahdi a, O.M.S. Alkoles[2] etc presented work on light composite elliptic springs for vehicle suspension. They worked on based study marries between an elliptical configuration and the woven roving composites. In this paper, the influence of ellipticity ratio on performance of woven roving wrapped composite elliptical springs has been investigated both experimentally and numerically.

   A series of experiments was conducted for composite elliptical springs with ellipticity ratios (a/b) ranging from one to two. Here they were also presented history of their failure mechanism. Both spring rate and maximum failure increase with increasing wall thickness. In general, this present investigation demonstrated that composites elliptical spring can be used for light and heavy trucks and meet the requirements, together with substantial weight saving. The results showed that the ellipticity ratio significantly influenced the spring rate and failure loads. Composite elliptic spring with ellipticity ratios of a/b 2.0 displayed the highest spring rate.

3. Y. N. V. Santhosh Kumar, M. VimalTeja[3] etc presented work on design and analysis of composite leaf spring . They also discussed the advantages of composite material like higher specific stiffness and strength, higher strength to weight ratio. This work deals with the replacement of conventional steel leaf spring with a Mono Composite leaf spring using E-Glass/Epoxy. For this they selected design parameters and analysis of it. Main objective of this work is minimizing weight of the composite leaf spring as compared to the steel leaf spring. For this they selected the composite material was E-Glass/Epoxy.

   The leaf spring was modeled in Pro/E and the analysis was done using ANSYS Metaphysics. From results they observed that the composite leaf spring weighed only 39.4% of the steel leaf spring for the analyzed stresses. So from result they proved that weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %, and it was also proved that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. It was found that the longitudinal orientations of fibers in the laminate offered good strength to the leaf spring.

4. Pankaj Saini, Ashish Goel, Dushyant Kumar[4] etc. studied on design and analysis of composite leaf spring for light vehicles. Main objective of this work is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring.

   Here the three materials selected which are glass fiber reinforced polymer(E-glass/epoxy),carbon epoxy and graphite epoxy is used against conventional steel. The design parameters were selected and analyzed with the steel leaf sprinFrom results, they observed the replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction and also the composite leaf spring has lower stresses compared to steel spring.

From the static analysis results it is found that there is a maximum displacement of in the steel leaf spring. From the result, among the three composite leaf springs, only graphite/epoxy composite leaf spring has higher stresses than the steel leaf spring. From results its proved that composite mono leaf spring reduces the weight by 81.22% for E-Glass/Epoxy, 91.95% for Graphite/Epoxy, and 90.51 % for Carbon/Epoxy over steel leaf spring. Hence it is concluded that E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view.

5. Manas Patnaik, Narendra Yadav, [5] etc worked on study of a parabolic leaf spring by finite element method & design of experiments. Main objective of this study was the behaviour of parabolic leaf spring, design of experiment has been implemented.

For DOE, they selected input parameters such as Eye Distance & Depth of camber. This work is carried out on a mono parabolic leaf spring of a mini loader truck, which has a loading capacity of 1 Tonnes. The modelling of the leaf spring has been done in CATIA V5 R20. Max Von Mises stress and Max Displacement are the output parameters of this analysis. In DOE Eye Distance & Depth of camber have been varied and their affect on output parameters have been plotted. The variation of bending stress and displacement values are computed. From design of experiments they observed following

a) If The camber is increased there is a decrease in the average amount of displacement.

b) If the eye distance is increased there is an increase in the average amount of displacement.

c) If the camber is increased there is an increase in the average amount of von misses stress.

d) If the eye distance is increased there is an increase in the average amount on von misses stress.

Hence from results it is conclude that the optimum setting of dimensions pertaining to parabolic leaf spring can be achieved by studying the various plots obtained from Design of Experiments.

RESULTS:

Object Name	*Total Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	1.4882e-013 m/m	2.7663e-002 Pa
Maximum	7.9993e-005 m	5.4608e-004 m/m	1.0433e+008 Pa
Average	6.474e-005 m	1.1486e-005 m/m	2.0125e+006 Pa
Minimum Occurs On	FINAL LEAF SPRING 1-FreeParts[13]	FINAL LEAF SPRING 1-FreeParts[25]	
Maximum Occurs On	FINAL LEAF SPRING 1-FreeParts[25]	FINAL LEAF SPRING 1-FreeParts[13]	

TABLE: 6

DEFORMATION:

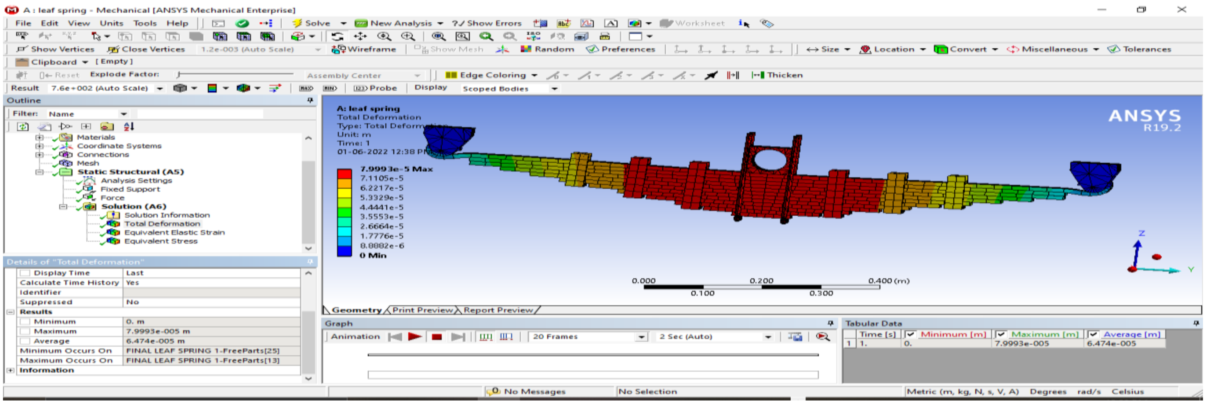

Fig-4.2.6 Deformation

STRESS:

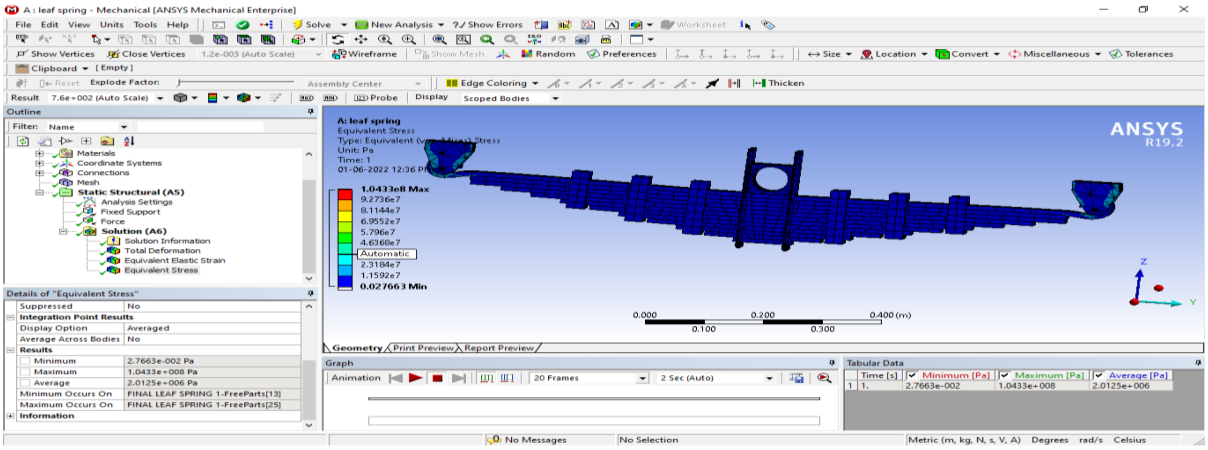

Fig-4.2.7 Stress

STRAIN:

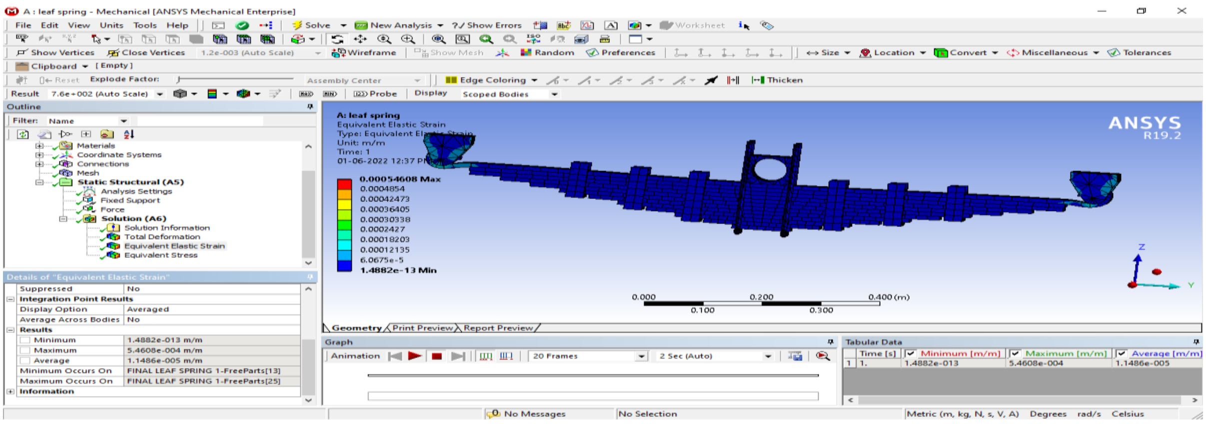

Fig-4.2.7 Strain

MATERIAL:

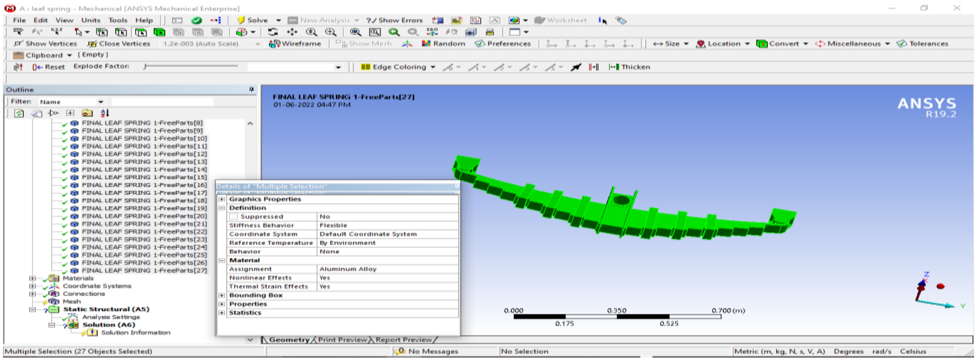

Fig-4.3.1 Applying Material

MESH:

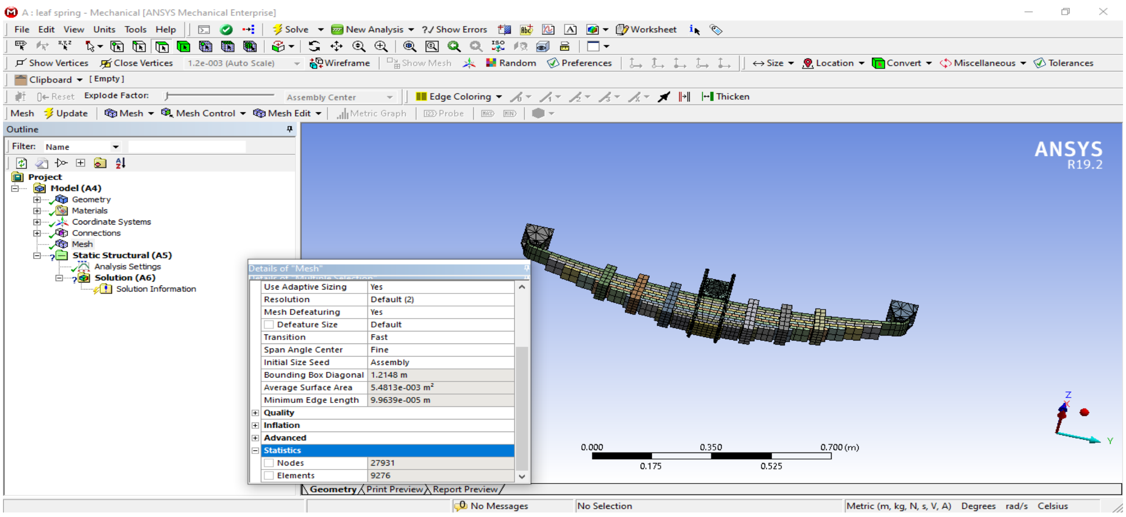

Fig-4.3.2 Meshing

FIXED SUPPORTS:

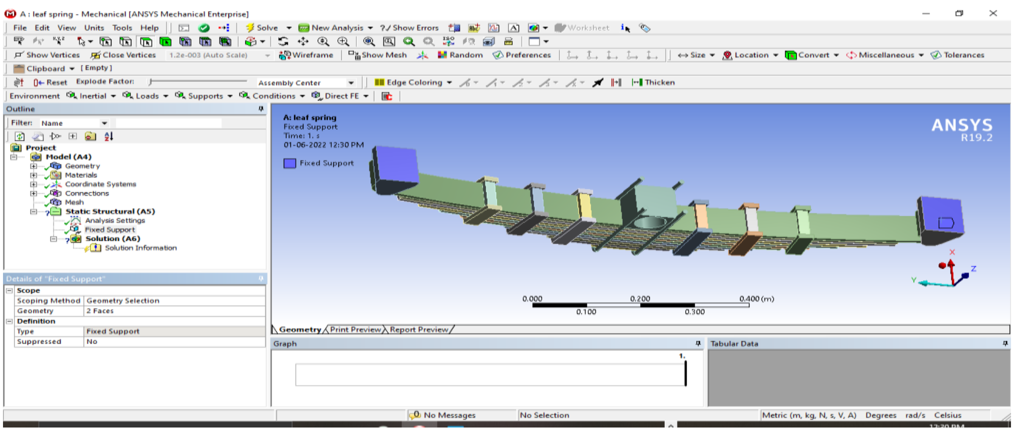

Fig-4.3.3 Fixing supports

LOADING:

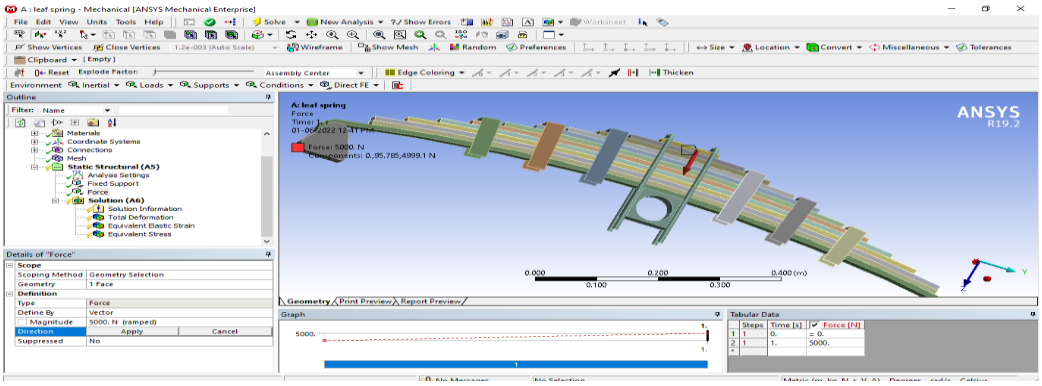

Fig-4.3.4 Loading

RESULTS:

Object Name	*Equivalent Elastic Strain*	*Equivalent Stress*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation
Results			
Minimum	5.1198e-013 m/m	3.4246e-002 Pa	0. m
Maximum	1.5236e-003 m/m	1.0356e+008 Pa	2.2477e-004 m
Average	3.2459e-005 m/m	2.0207e+006 Pa	1.8183e-004 m
Minimum Occurs On	FINAL LEAF SPRING 1-FreeParts[13]		FINAL LEAF SPRING 1-FreeParts[25]
Maximum Occurs On	FINAL LEAF SPRING 1-FreeParts[13]		FINAL LEAF SPRING 1-FreeParts[25]

TABLE: 11

DEFORMATION:

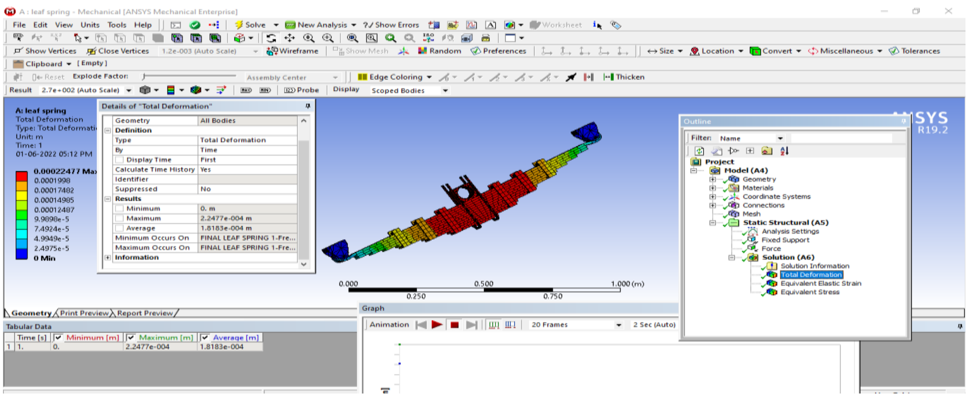

Fig-4.3.5 Deformation

STRESS:

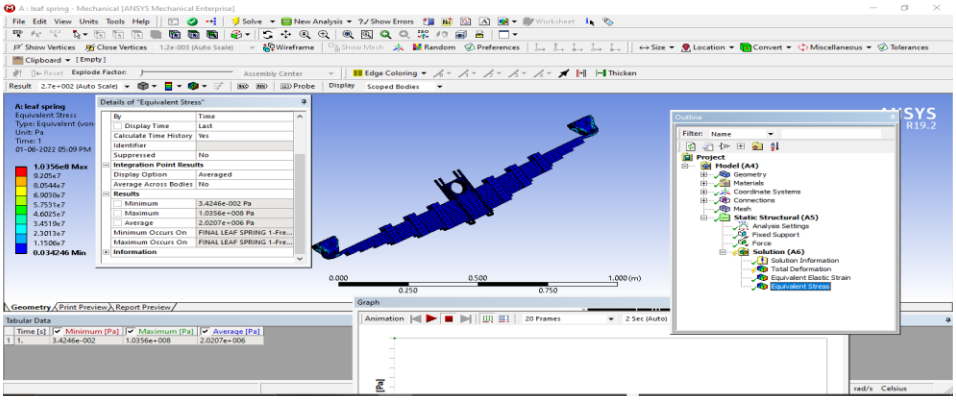

Fig-4.3.6 Stress

STRAIN:

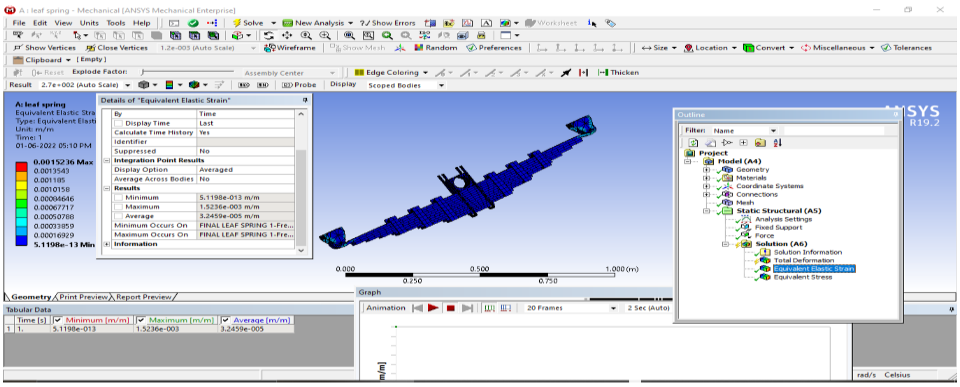

Fig-4.3.7 Strain

COMPARISON OF ANSYS AND THEROTICAL RESULTS:

STRESS:

$$\sigma = \frac{18pl}{bt^2(3*n(f) + 2*n(g))}$$

$$\sigma = \frac{18*25*510}{40(10)^2(3(3)+2(8))} = 2.295N/m^2$$

DEFLECTION:

$$\delta = \frac{12pl^3}{Ebt^3\ (3n(f) + 2\,n(g))}$$

$$\delta = \frac{12*25*(510)^3}{2*10^5\ *40*(10^3)(3(3)+2\,(8))} = 198.97*10^{-3}$$

$$E = \frac{\delta l}{l} = \frac{198.97*10^{-3}}{1100} = 1.80*10^{-4}m/m$$

ANSYS RESULTS:

TABLE: 42

Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	1.4882e-013 m/m	2.7663e-002 Pa
Maximum	7.9993e-005 m	5.4608e-004 m/m	1.0433e+008 Pa
Average	6.474e-005 m	1.1486e-005 m/m	2.0125e+006 Pa
Minimum Occurs On	FINAL LEAF SPRING 1-FreeParts[13]	FINAL LEAF SPRING 1-FreeParts[25]	
Maximum Occurs On	FINAL LEAF SPRING 1-FreeParts[25]	FINAL LEAF SPRING 1-FreeParts[13]	

Conclusion

1. From the above analysis reports the **EPOXY E GLASS** is best material for the manufacturing the leaf spring.
2. Static analysis of leaf spring for different material combination under similar loading condition has been done for all design cases.
3. Total deformation, equivalent elastic strain, equivalent (Von-Mises) stress, results have been analyzed for different material combination in different design cases of leaf spring.
4. Results for selected parameters are obtained for all design cases of leaf spring
5. Prediction of deformation using MATLAB.

Future Scope

- Dynamic analysis of leaf spring may be done and obtained results could be compared with software and experimental results.
- Improve the Design Of Leaf Spring By Reducing The Frictional Stress.
- Fatigue Life Prediction of Leaf Spring used in the Suspension System of Light Commercial Vehicle.
- Analysis of the Vibration Characteristics of a Leaf Spring System Using Artificial Neural Networks.
- Experimental analysis may be conducted and obtained results could be compared with software result.
- Carry out the fatigue analysis for the vibration of a leaf spring suspension system to predict the life.
- Carry out the random analysis with PSD data.
- Carry out the fatigue analysis to determine the life.
- Use alternate materials for the leaf spring and study the result

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