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FEM Analysis and Weight Optimization of Composite Leaf Spring

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Abstract—*As the natural resources are depleting day by day it is important to conserve them and reduce the amount of consumption of these resources. The leaf springs in the automobiles comprise almost 10-20% unsprung mass this includes wheel assembly, axles, shock absorbers and part of the weight of suspension spring. By reducing the weight of the spring, we can increase the efficiency and reduce the fuel consumption in the vehicles. This paper deals with the analysis and optimization of leaf springs made of composite materials. There are various composite materials which can be replaced with steel such as carbon/epoxy, S-glass/epoxy, and E-glass/Epoxy. In which E-glass/Epoxy is considered due to the high strength to weight ratio and low cost over others. The objective is to reduce the material usage by replacing the conventional multi steel leaf spring with the mono leaf of glass fiber reinforced polymer(E-glass/Epoxy) for a light commercial vehicle without any reduction in the strength and the stiffness in the leaf spring. For this purpose firstly we optimize the parameters of the spring in MATLAB in which the design constraints are bending stresses and deflection and the design variables are width and thickness , then the modeling work is done in SolidWorks and static stress analysis using the finite element method has been done in Ansys 15.0 in order to find out the detailed stress distribution and the displacement of the spring. A comprehensive study has been carried out and compare the results for both the materials and it was found that the overall weight of the spring has been reduced significantly.*

Keywords*: Multi Steel leaf Spring, Composite mono leaf spring, E-glass/Epoxy, Static Analysis.*

1. INTRODUCTION

With the rising energy and environmental concerns, weight reduction has been the main focus of automobile manufactures in the present scenario. The industries are attempting to reduce the weight of the leaf spring as it takes around 10-20% unsprung mass of the vehicle [1] and by reducing the unsprung mass there is reduction in the fuel intake and increases the ride comfort. It can be achieved by introducing advance materials, optimization in the design of the leaf spring or adapting a better manufacturing process.

The amount of elastic energy that can be stored by a spring is

$S = \frac{\sigma^2}{2E}$ Eq -1

Where σ is the maximum allowable stress induced into the spring and E is the modulus of elasticity in both directions. The most suitable material for leaf springs in which there is higher strength and minimum modulus of elasticity in longitudinal as well as in transverse direction. By introducing composite materials, it can be possible to reduce the weight of the leaf spring without compromising the load carrying capacity or the stiffness of the spring because of its properties like high strength to weight ratio, high stiffness to weight ratio, good thermal conductivity, low coefficient of thermal expansion and improved corrosion resistance[2] but high fabrication cost and difficulty in rework and repair are some of the limitations of the composite materials[3] .

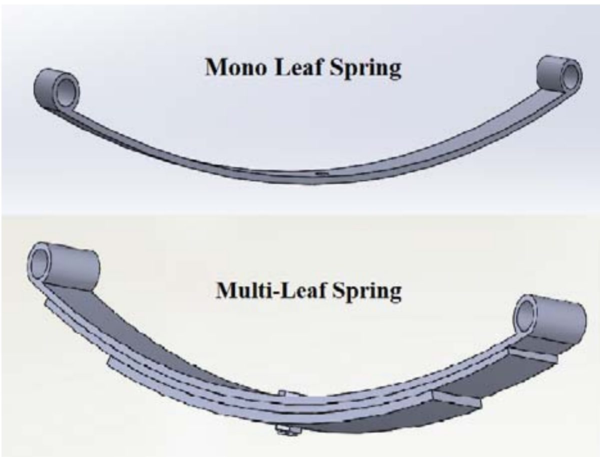
Composite materials are now using extensively in the replacement of leaf springs. Some of these papers are reviewed here, which mainly uses composite leaf spring. Thippesh[4] manufactured and tested a mono leaf hybrid composite of unidirectional glass fibers and fly ash in epoxy resin and there is less deflection and bending stresses for the same load. Jadhaol[5] compared the dynamic behavior of steel and composite leaf spring using theoretical method and FEA and concluded that it can sustain the sudden impact force of a large magnitude. Sureshkumar[6] have done Experimental Investigation, it has been observed that deformation and strain energy is higher but not much variation in stress for composite leaf spring. Kamaleldin Gaffar[7] conducted Design and Numerical analysis of leaf springs by the FEA analysis, it can be concluded that there is a decrease in the deflection and the stresses in the composite spring and also reduction in weight. M. Kamaleldin Gaffar Abbas [11] conducted Design and Numerical analysis of leaf springs using Composite materials in which the material selection is E-glass/epoxy reinforced polymer. By the FEA analysis, it can be concluded that there is a decrease in the deflection and the stresses in the composite spring. Also, the wight is reduced by 67.7%. The stress in the composite material is less than the compressive strength and ultimate strength, so the design is safe. Harshit [12] conducted Design and Simulation analysis of Leaf Spring for light weight commercial vehicle Using FEM. By the static analysis, it can be concluded that the stresses linearly increase with the applied load maximum also the deformation is slightly higher than the steel leaf spring, but the stiffness is higher in the steel as compared to the composite material. Also, the material is safe according to the maximum principal stress criterion and von-mises stress criterion.

In optimization of design, the objective is to reduce the weight of the leaf spring. There are various optimization software's in which we can optimize the parameters such as MATLAB, AIMMS, CPLEX etc.

In the present work the three-leaf steel spring of Tata Ace Commercial Vehicle is considered and all the design parameters of existing three-leaf spring is considered for this work.

2. LEAF SPRING

There are various types of springs available for the suspension system. Now a day's extensively used suspension systems in automotive are the Leaf springs. It is also called by its shape as a semi-elliptical spring or cart spring, which is similar to an arc-shaped length of a steel spring with a rectangular cross-section. We can fasten a leaf spring directly at both ends (eyes) of the frame or directly to the one end usually the front end, whereas the other end is attached with the shackle, a short swinging arm. For the smooth riding in very heavy vehicles, a leaf spring prepared out of multiple leaves in multiple layers stacking at the top of each other often started with gradually shorter leaves in the end and is used to provide ease in riding in very heavy vehicles as shown in figure. By replacement of steel leaf, spring with composite leaf spring will minimize spring mass in addition to resistance increase under the effect of applied loads. Increasing opposition and innovations in the automotive field tend to alter existing products or replacing old products through new and sophisticated material products.



"Figure 1: Types of Leaf Spring"

3. STEEL LEAF SPRING

The material conventionally used in leaf springs are 65Si7 consisting of the Chromium Vanadium, Chromium, Nickel, Molybdenum, and Silicon. The leaves are heat treated after the manufacturing forming process. The heat treatment of spring steel produces improved strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

"Table 1. Material Properties of Conventional Leaf Spring"

1	Yeild Strength	1158 Mpa
2	Tensile Strength	1272 Mpa
3	Poison Ratio	0.26
4	Density	7850 Kg/m^3
5	Behaviour	Isotropic
4	Young Modulus	2.1 x 10^5

4. SELECTION OF MATERIAL

The material cost of the leaf spring almost takes 60-70% cost in the automobile and responsible for the comfort and the efficiency of the vehicle. Even a small reduction in weight in the vehicle may have a huge economic and environmental impact. Composite materials are proved as suitable replacement for steel in reference with a weight reduction of the vehicle. There are various types of composite fibres are available such as Carbon fibers, E-Glass, S-Glass, etc. in which E-glass/Epoxy composite material is selected for high strength to weight ratio and cost-effective as compared to others fiber such as carbon fiber is not feasible because of its high cost.

"Table 2. Material Properties of E-glass/Epoxy Composite"

Properties	Values
Tensile modulus along X-direction (Ex), MPa	34000
Tensile modulus along Y-direction (Ey) MPa	6530
Tensile modulus along Z-direction (Ez), MPa	6530
Poisson ratio along XY-direction (NUxy)	0.217
Poisson ratio along YZ-direction (NUyz)	0.366
Poisson ratio along ZX-direction (NUzx)	0.217
Compressive strength of the material, MPa	450
Tensile strength of the material, MPa	900
Shear modulus along XY-direction (Gxy), MPa	2433
Shear modulus along YZ-direction (Gyz), MPa	1698
Shear modulus along ZX-direction (Gzx), MPa	2433
Mass density of the material (ρ), kg/mm3	2.6106
Flexural modulus of the material, MPa	40000
Flexural strength of the material, MPa	1200

5. MODELLING AND DESIGN OF LEAF SPRING

The modelling and design of three-leaf steel spring of Tata Ace Commercial Vehicle is considered and all the design parameters are shown in table 3. In the modelling of leaf spring the design parameters are width, thickness and length of leaf spring.

"Table 3. Design Parameters of Tata Ace Commercial Vehicle"

Sr. No.	Design Parameters	Values
1	Total Length (eye to eye)	860mm
2	Width of leaves	60mm
3	Thickness of each leaves	8mm
4	Spring rate	23.1N/mm
5	No. of full-Length leaves	01
6	No. of graduated leaves	02
7	Arc height of axle seat(camber)	90mm
8	Full Bump Loading	4169
9	Young's Modulus of Elasticity	2.1 x 10^5 N/mm^2
10	Available space for spring width	40-45 mm

5.1 Design Parameters

In this work the design constraints are bending stress and deflection.

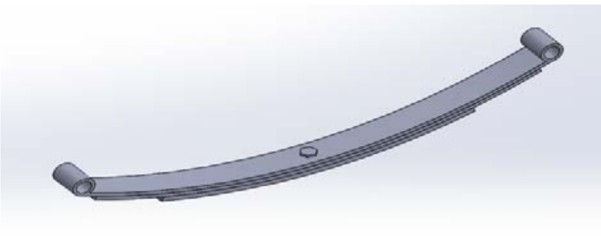
$$\sigma_b = \frac{6FL}{nbt^2}$$

$$\delta = \frac{12\,FL^3}{Ebt^3(2n_G + 3n_f)}$$

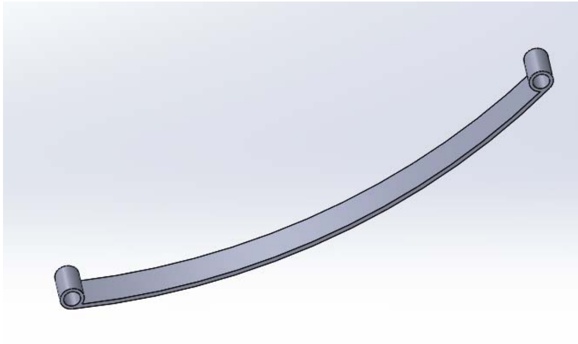
Where σ_b is the bending stresses, δ is the deflection, F is the force acting on the leaf spring, L is length of the leaf spring, b is the width of leave, t is the thickness of each leave, n_G is number of graduated leaves and n_f is the number of full loading leaves.

5.2 Modelling of Leaf Spring

The diagram below is showing the design of steel leaf spring and composite leaf spring have made in Solid Works and the analytical parameters like deformation and von misses have done in ANSYS 15.0 and 17.0 software.



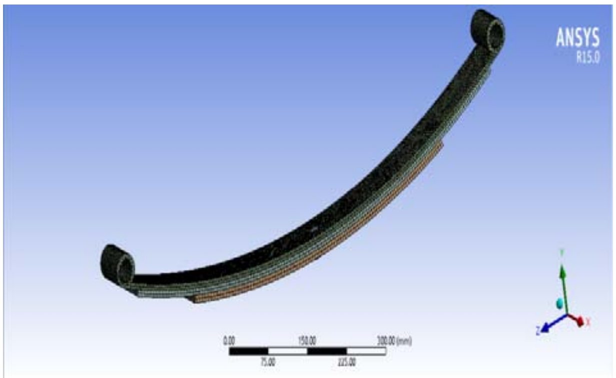
"Figure 2 Design of steel leaf spring"



"Figure 3 Design of composite leaf spring"

5.3 Meshing

Meshing involves division into small pieces of the entire model and these elements are called elements. This is done by meshing tool available in any FEA software. It is desirable to select the free mesh because the leaf spring has sharp curves so that the shape of the object will not alter. Here, the element size of 5mm and number of nodes are 95209.

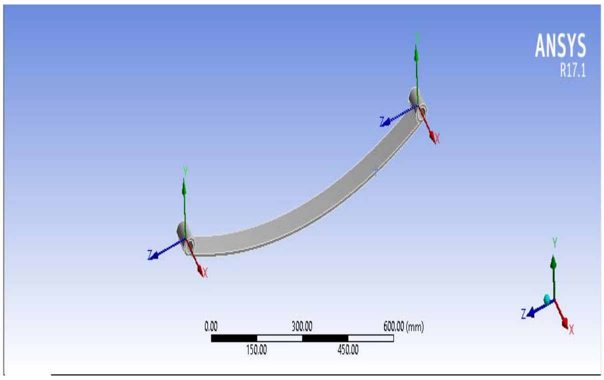


"Figure 4 - Meshing diagram of steel leaf spring"

5.4 FEM Analysis

Finite Element Analysis (FEA) is a computer based numerical technique to solve complex and to calculate the behaviour of the mechanical structure. FEA can be used to calculate many phenomena for instant, vibration, stress, deflection, and bulking behaviour. FEA is widely used these days in many companies and disciplines due to the low cost of the modern computers [8]. The method of FEA is to break the structure to many small simple elements then use mathematics tool to link the solutions. The behaviour of each element can be described with a relatively simple set of equations. Those element equations joined into a large set of equations, which is describing the behaviour of the whole structure then the computer solving the whole set of equations simultaneously [9]. The procedure starts with creating the geometry of the model. Then the meshing is implementing to the model.

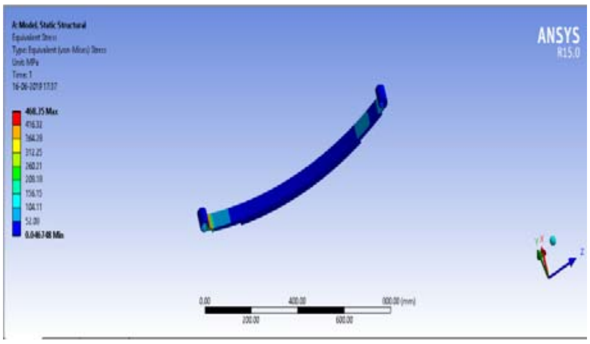
Boundary condition applying to the model in order to define the displacement and load applied to the leaf spring. Finally, the result obtained to get the stress and deflection of the model. The model solution only processed when all definitions are done. Within the limits of the physical problem, the processing of the data is usually done. While the post processing offers information for acceptance or rejecting of the data analysis of the model [10].



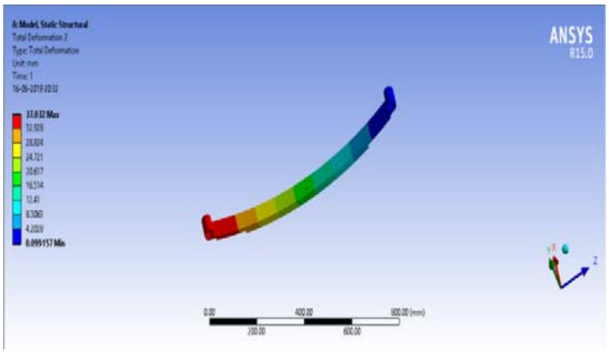
"Figure 5- Boundary Conditions in Composite Leaf Spring"

6. RESULT AND DISCUSSION

In the leaf springs obtained in Figure 5, and Figure 6, below, the outcomes for the maximum deflection and tress for steel leaf spring are 37.38 mm and 496.12 MPa respectively. The concentration of Maximum deflection was seen in the middle of the leaves as well as in the top of left eye end. Maximum stress was found in the left eye of leaf spring.



"Figure 6 -Von misses Stress diagram of steel leaf spring"



"Figure 7- Deflection contour in Steel leaf spring"

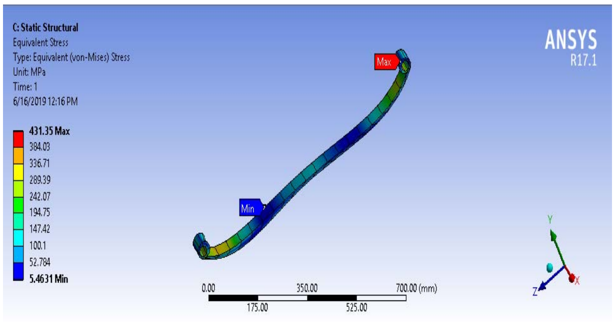
The design of leaf spring, deflection and stress analysis was implemented using a method of the finite element that is done by using ANSYS 15.0 and 17.0. The analysis of leaf spring carried out for steel spring. The comparison between the theoretical and finite element analysis result of steel leaf spring as shown in Table 4.

"Table 4. Theoretical and Finite Element Analysis Result of Steel Leaf Spring"

Parameters	Theoretical	FEA (Steel)	Validation
Load [N]	2145.937	2145.937	-
Deflection [mm]	35.33	37.032	5.8%
Stress [MPa]	508.61	468.35	7.91%

The analysis of composite material spring carried out for E-glass/Epoxy in which mono leaf selected. The static analysis is done for von-mises stresses and displacement. In the leaf springs obtained in Figure 8, and Figure 9, below, the outcomes for the maximum deflection and tress for composite leaf spring are 33.618 mm and 431.68 MPa respectively. The concentration of Maximum deflection was seen in the middle of the leaf and decreases from the end. Maximum stress was found in the right eye of leaf spring.

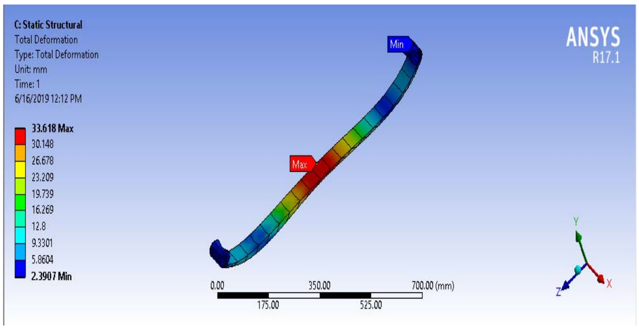
The comparative finite element analysis of composite and steel leaf spring are shown in table 4. From the results there is reduction of stresses and the deflection in the composite leaf spring as compared to multi-leaf steel leaf spring.



"Figure 8 -Von misses Stress diagram of composite leaf spring"

"Table 4. FEA results in comparison of steel and Composite leaf spring"

Parameters	Steel Leaf Spring	Composite Leaf Spring
Deflection [mm]	37.38	33.618
Stress [MPa]	468.35	431.35
Weight [Kg]	81.75	10.57



"Figure 9- Deflection contour in Composite leaf spring"

7. CONCLUSION

In this work the static analysis is done for E-glass/Epoxy composite material from which the mono leaf spring is designed and von-mises stress and deflection are calculated and the conventional three leaf composite material is also analyzed for the comparison and it was found that there is a reduction of 87.06% as conventional leaf spring. It is also observed that the station deflection and the stresses are less in composite leaf spring as compared to the conventional leaf spring. Therefore, we can conclude that the replacement of the leaf spring with composite material can be made.

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REFERENCES

[1] Lukin, Pavel Petrovič, Grant Arutûnovič Gasparânc, and Vasilij Fedorovič Rodinov. Automobile Chassis: Design and Calculations. Mir Publishers, 1989.

[2] Al-Qureshi, H. A. "Automobile leaf springs from composite materials." Journal of materials processing technology 118.1-3 (2001): 58-61.

[3] Bhandari V B, Design of machine elements, {Tata McGraw- Hill Publishing Company, Limited, New Delhi, 1998.

[4] Thippesh L.Fabrication of Hybrid Composite Mono-Leaf Spring with Unidirectional Glass Fibers.5 (1) 2980–2984, 2018.

[5] K. K. Jadhao1 and R. S. Dalu. Impact Analysis of Steel and Composite Leaf Spring for Light Commercial Vehicle. 5(3) 896-899, 2017.

[6] M.Sureshkumar, Dr.P.Tamilselvam, and G.Tharanitharan.Experimental Investigation of Hybrid Fiber Mono Composite Leaf Spring for Automobile Applications. 5(1) 89-93, 2015.

[7] M. Kamaleldin Gaffar Abbas, Aliasghar Niakan, Chia Chee Ming, Ramesh Singh, and Patrick Teo.Design and Numerical analysis of leaf springs using Composite materials. Vol. 723, 305-310, 2016.

[8] Amrute, Ashish V., Edward Nikhil Karlus, and R. K. Rathore. "Design and assessment of multi leaf spring." International journal of research in aeronautical and mechanical engineering 1.7 (2013).

[9] T. R. Chandrupatla, A. D. Belegundu, Introduction to Finite Elements in Engineering, Pearson Education, New Jersey, 2002.

[10] Mac Donald, Bryan J. Practical stress analysis with finite elements. Glasnevin publishing, 2007.

[11] M. Kamaleldin Gaffar Abbas, Aliasghar Niakan, Chia Chee Ming, Ramesh Singh, and Patrick Teo.Design and Numerical analysis of leaf springs using Composite materials. Vol. 723, 305-310, 2016.

[12] Harshit, Sanjiv Kumar, and Antariksha Verma.Design and Simulation of Leaf Spring for TATA-ACE mini Loader Truck Using FEM. 2(10) 1421-1427, 2016.