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Design Analysis and Fabrication of Composite Leaf Spring

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Abstract- Leaf springs are the main suspension elements in an automobile system. This paper represents comparison of conventional leaf spring with composite leaf spring. It describes the design, experimental testing and numerical analysis of a composite leaf spring prepared by Epoxy Resin and E-glass fibre of Unidirectional and Bidirectional laminates. A 3D modelling of the leaf spring is created in CATIA V5.Static and fatigue analysis has done in ANSYS 17.0 WORKBENCH for both conventional leaf spring and composite leaf spring. Static load testing of both composite and conventional leaf spring is performed. The leaf spring made of glass fibre reinforcement polymer show higher strength and life when compared to conventional leaf spring.

Index Terms- Composite materials, Leaf spring, Composite beam, Suspension system, Steel leaf spring.

1. INTRODUCTION

The application of leaf spring is used in heavy weight vehicles where it plays a vital role of absorbing shocks that are transmitted to the vehicle due to gravity or sudden impacts resulting in smooth functioning of the vehicles with out any damage to engine and increases the efficiency of the vehicle, the application of the leaf spring has now a days also being used in light motor vehicles but the cost and weight of the vehicles increases, in order to overcome these problems, The automobile industries are looking for weight reduction in the automobiles to increase the efficiency of the vehicle. The best way of countering the weight reduction process is by using composites materials. These materials are used for the fabrication process by enhancing their properties by the means of mixing of the one or more materials in order to achieve high strength, less corrosive, lighter weight basically achieving the positive properties of an individual materials by merging the material into each other, Conventional leaf springs are particularly taken into consideration for replacing it with composites leaf spring as it contains lesser weight than steel and high stress carrying capacity moreover the hybrid composites are also being considered for the fabrication of leaf springs, hybrid composites are the mixture of two composites by roving them together but this will make the composite leaf springs costlier.

The idea of design & fabrication of composite leaf spring is taken from the existing conventional leaf spring of Maruti Omni car; moreover researchers have been studying how to replace the shock absorber with leaf spring in light weight vehicles. Composites are the best material that can be used for the fabrication of leaf springs for example carbon fiber, Kevlar…etc as shown in figure 1 and 2.


Fig.1.Carbon Fiber Leaf Spring


Fig.2. GFRP Leaf Spring

2. LITERATURE REVIEW

H.A Al-Qureshi.et.al [1]; in this research paper he expertise how the composites leaf spring is a perfect replacement for the conventional leaf springs in light motor vehicle and also a revolution in making more use of composites in manufacturing vehicle parts in order to get less weight to increase the efficiency of the vehicle. The publisher fabricated the composites leaf spring along with experimental testing as well as on road testing on Jeep by using glass fibers reinforced polymer (GFRP) as the composites and has done static testing via hydraulic testing machine, confirms that the composites leaf springs are the perfect replacements for the conventional leaf springs in light weight motor through the results and suggested to use the hybrid composites for future work.

Erol Sancaktar and Matheiu Gratton.et.al [2]; in this published paper Mr. Sancaktar used the composites leaf spring for his solar powered light weight vehicles as the replacement for the front suspensions, the material he used in the fabrication of leaf spring is unidirectional roving Glass fiber reinforcement polymer, which is a bit weak in holding the polymer and he has done complete finite element analysis, but according to his design of the vehicle the composite leaf spring was perfectly compatible and it met all the targets of his design and the publisher shows a possibilities for the future changes and improvements of the composites leaf springs.

After doing the literature survey on the leaf spring we have come to an conclusion that all the publishers has successfully fabricated the composite leaf spring by using GFRP and carbon fiber and they have also tested the leaf spring by attaching it to a vehicle and they have also done static testing and analysis on the conventional and composite leaf springs but they have not yet done the fatigue analysis of composite leaf spring in comparison to conventional leaf spring.

3. DESIGN AND CALCULATION

The sample selected, for the fabrication of the composite leaf spring is Glass Fiber Reinforced Polymer and its properties are mentioned in table.3,and the dimensions to prepare the composite leaf spring has been designed through the specifications of an existingleaf spring of maruti omni car, the dimensions of the conventional leaf spring is mentioned in table .1. below and same dimensions are being used for fabrication of the composite leaf spring by using E Glass as reinforment and Ploysiter resin as the matrix agent, The specifications of the composite material used for the fabrication process is mentioned below in table .2.

Table 1. Dimensions of Conventional Leaf Spring

Specifications	Dimensions
L- Length (mm)	939.8
W-Width (mm)	55
T- Thickness (mm)	6.35

Table.2. Specifications of Composite

Material	Specifications
E Glass	10 gsm
Ployster Resin	2.5 kgs

Table.3. Properties of Glass Fiber Reinforced Polymer

S. No	Material Properties	Values
1	Density (ρ)	1850 kg/m^3
2	Young Modulus (E)	8.9x10^{10} N/m^2
3	Poisson's Ratio (μ)	0.1
4	Bulk Modulus	3.7x10^{10} N/m^2
5	Shear Modulus	4.04x10^{10} N/m^2

3.1. *Design of conventional leaf spring*

The design of a leaf spring is inspired by the existing leaf spring of the Maruti Omni and calculations are done by using the dimensions of the conventional leaf spring as mentioned in table.1

3.1.1. *Bending Stress*

$$\sigma b = \frac{6PL}{nbt^2} \qquad \text{...3.1}$$

Where, **P** = Load acting on a leaf. **L** = Length of the spring. **n** = no. of leaves. **b** = width of a leaf. **t** = thickness of a leaf.

3.1.2. Deflection of a Spring

$$\delta = \frac{6PL^3}{Enbt^3} \qquad \text{...3.2}$$

Where, **P** = Load acting on a leaf. **L** = Length of a spring. **E** = Young Modulus. **n** = no. of leaves. **b** = Width of a leaf. **t** = Thickness of a leaf

3.2. *Values*

Weight of the leaf (P) = 7848N**.** Width (b) = 55mm Thickness (t) = 6.35mm Young Modulus (E) = 2.1 × 10^5 N/mm^2

3.3. *Calculations*

3.3.1 Bending Stress

$$\sigma b = \frac{6 \times 7848 \times 939.8}{1 \times 55 \times (6.35)^2}$$

$$= 19954.25\ N/mm^2$$

3.3.2 Deflection of a Spring

$$\delta = \frac{6 \times 7848 \times 939.8^3}{2.1 \times 10^5 \times 1 \times 55 \times 6.35^3}$$

$$= 13216.40\ mm$$

4. FABRICATION

The fabrication of the composite leaf spring is done by using the dimensions of existing conventional leaf spring of a Maruti Omni car and material used in fabrication is E Glass as a reinforcement and Polyester Resin as the matrix in it.

The specification of E Glass used in fabrication is 10 gsm of fiber sheet, polyester resin and hardener, and the procedure which is followed to fabricate the composite leaf spring is by hand layup method

Fig.3. Final Achieved Composite Leaf Spring

5. STATIC TESTING OF LEAF SPRING

Static testing is done on a leaf spring in order to measure the deflection and deformation of a leaf spring, in this method single strip conventional leaf spring of a Maruti Omni car has been take for testing procedure, the procedure of testing and measurement of a leaf springs that is both conventional and composite are as follows,

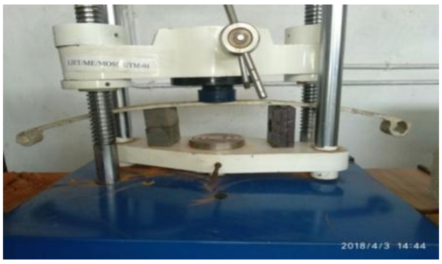

Fig.4. Universal Testing Machine

Fig. 5. Machine Operating Inputs

(1) The position of the leaf springs was kept in between the both jaw seat and load is applied on it.

(2) As the load is applied the readings of deformation of the leaf springs are recorded as shown in table.4. And in table.5.

(3) The graphs of load v/s deflection have plotted based on the table.4. and 5 as shown in fig.6. And fig.7.

Table.1. Deflection of Composite Leaf Spring

S. No	Load Applied (KN)	Deflection (mm)
1	0	0
2	5	3
3	7	5
4	9	7
5	11	9
6	13	11
7	15	13
8	17	15
9	21	20
10	23	25
11	24	50
12	25	55

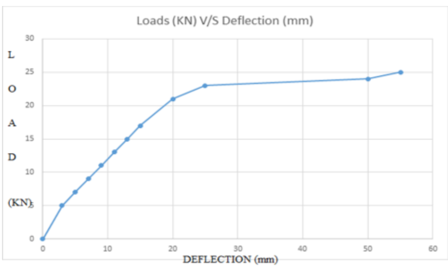

Fig.6. Load v/s Deflection Plotted Graph

Table.5. Deflection of Conventional Leaf Spring

S. No.	Load Applied (KN)	Deflection (mm)
1	0	0
2	5	10
3	7	15
4	10	20
5	16.5	25
6	21	30
7	24	35
8	26	40
9	27	45
10	27.5	50
11	29	55
12	34	60
13	38	65
14	43.5	70
15	50	75
16	55	80
17	63.5	85

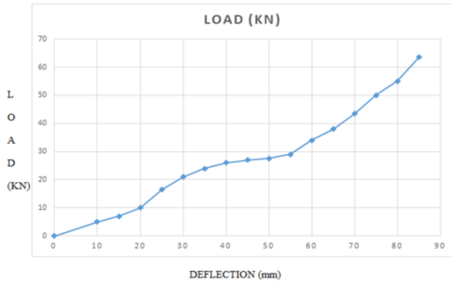

Fig.7. Load v/s Deflection Plotted Graph Based on The Readings of Conventional

6. Finite elements Analysis

6.1. *Geometric model in Ansys*

Geometric model has been created in CATIA V5 and imported in ANSYS WORKBENCH 17.0. as shown in fig.8.

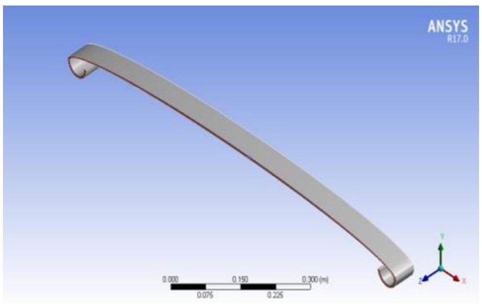

Fig.8.Imported Geometrical Model

6.2. *Finite Element Meshed Model*

Geometric model created is an CATIA V5 has imported in Ansys workbench 17, the model is discretized by using static structural as shown in Fig. 9.
TYPE OF ELEMENT: Shell Element 188
Number of element: 684

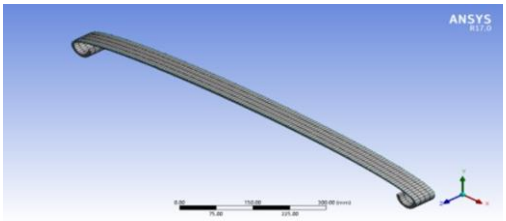

Fig.9.Finite Element Analysis Model

6.3. *Boundary Conditions*

In static analysis both the ends are fixed as shown in fig.10.

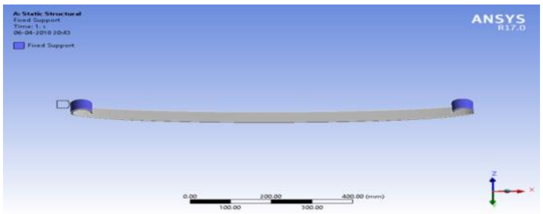

Fig.10.Boundary Condition of a Static Analysis

In fatigue analysis the one end is fixed while the other end is given a displacement of 0.3 m to x – direction as shown in fig.11.

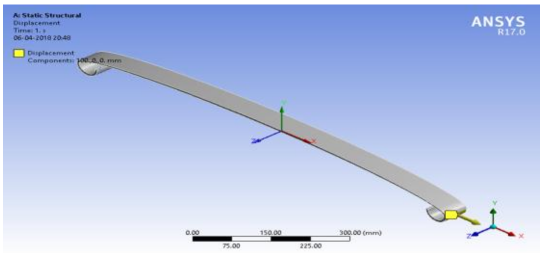

Fig.11.Boundary Condition of a Fatigue Analysis

6.4. *Loading Conditions*

In both static and fatigue analysis the point load of 7848 N is acting in the center of the leaf spring as shown in fig.12.

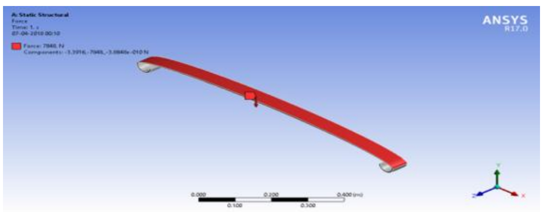

Fig.12.Static & Fatigue Loading

6.5. *Results & Discussion*

The finite element modeling for static and fatigue models are solved with considering boundary and loading conditions as mentioned above and post processing results are discussed in details.

6.5.1. Static analysis of conventional leaf spring

(1) Total Deformation

Figure.13. shows the Maximum deformation of 12.978mm at the center of the leaf spring.

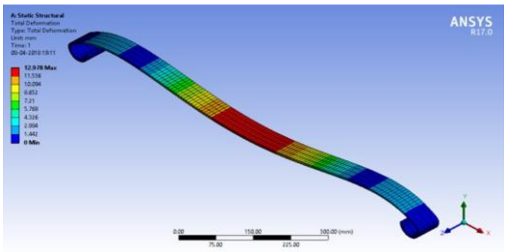

Fig.13. Total Deformation of Conventional Leaf Spring

(2) Equivalent Stress

Figure.14. shows the maximum stress of 845.51 MPa at the ends of the leaf spring.

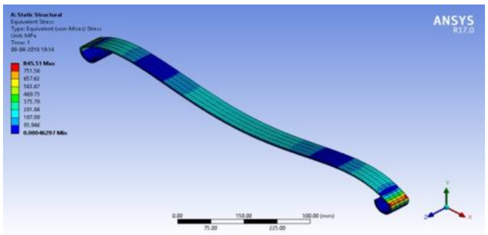

Fig.14. Equivalent Stress Acting on Conventional Leaf Spring.

6.5.2. Static analysis of composite leaf spring

(1) Deormation

Figure.15. shows the Maximum deformation of 29.67 mm at the center of the leaf spring.

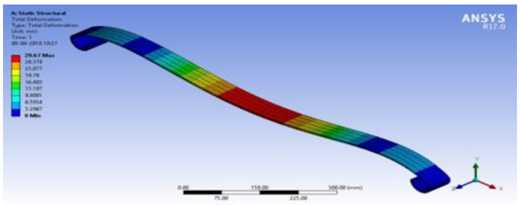

Fig.15. Total Deformation of Composite Leaf Spring.

(2) Equivalent Stress

Figure.16. shows the maximum stress of 850.32 MPa at the ends of the leaf spring.

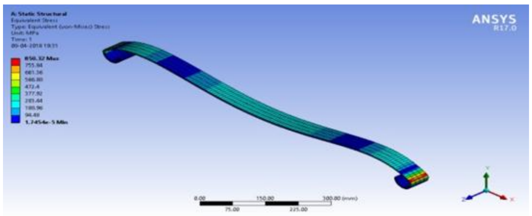

Fig.16. Equivalent Stress Acting on Composite Leaf Spring

Table.6. Static Analysis Results of Conventional and Composite Leaf Springs

S. No.	Materials	Total Deformation (mm)		Stresses (MPa)	
		Minimum	Maximum	Minimum	Maximum
1	Conventional	0	12.978	0.00046297	845.51
2	Composite	0	29.67	1.745e-5	850.32

6.5.3. Fatigue analysis of conventional leaf spring

S-N Fatigue Analysis

(1) Deformation

Figure.17. shows the Maximum deformation of 6904.6 mm at the center of the leaf spring.

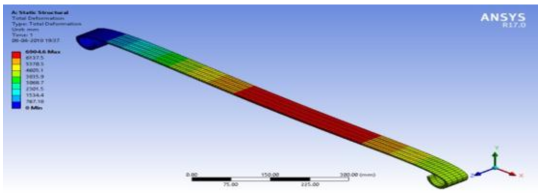

Fig.17, Total Deformation of Conventional Leaf Spring

(2) Equivalent Stress

Figure.18. shows the maximum stress of 1.3183e5 MPa at the ends of the leaf spring.

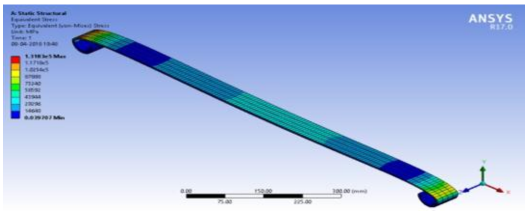

Fig.18. Equivalent Stress Acting on Conventional Leaf Spring.

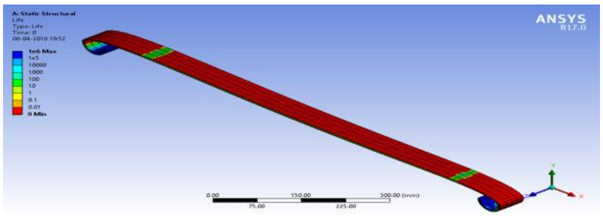

Fig.19. Life of a Conventional Leaf Spring.

6.5.4. Fatigue analysis of composite leaf spring

S-N Fatigue Analysis

(1) Deformation

Figure.20. shows the Maximum deformation of 4762 mm at the center of the leaf spring.

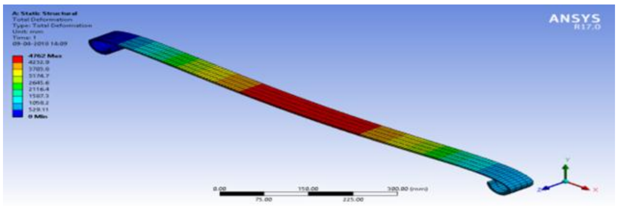

Fig.20. Total Deformation of Composite Leaf Spring

(2) Equivalent Stress

Figure.21. shows the maximum stress of 49506 MPa at the ends of the leaf spring.

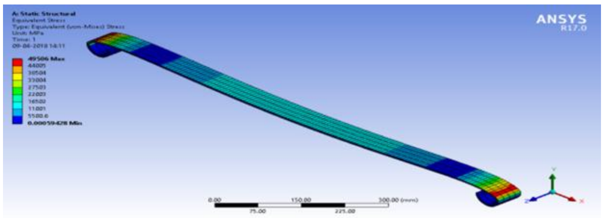

Fig.21. Equivalent Stress Acting on Composite Leaf Spring

(3) Life

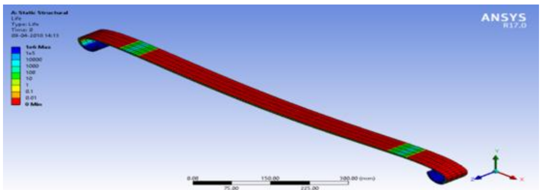

Fig.22. Life of a Composite Leaf Spring

.(A.1)

7. CONCLUSION AND FUTURE WORK

The composite leaf is designed, fabricated, tested experimentally and numerically using ANSYS WORKBENCH 17.0 for static and fatigue analysis.

The leaf spring made of glass fiber reinforcement polymer material shows higher strength and life when compared to conventional leaf spring. The leaf spring is tested for Goodman's Curve, Soderberg's Curve, and Gerber's Curve. The result shows Gerber's curve as best suitable parameter for selecting the life of composite leaf spring. The achievement of the tests and analysis on composite leaf spring indicates that the composite leaf spring is significantly better alternate to conventional leaf spring.

Based on the studies of literature survey and the on going work we have come across to various ideas which can be explored in several methods to fabricate the composite leaf spring, by using different hybrid materials like carbon/glass fiber, carbon/aramid fiber, glass/nylon fiber…. etc. and it has been observed that fatigue testing has not been done experimentally in any of the previous work and it should be done in future work. The leaf springs can also replace the rear shock absorbers in light weight vehicles.

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