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DESIGN AND ANALYSIS OF LEAF SPRING BY USING HYBRID COMPOSITE MATERIAL

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Abstract - *Highly important research issue in this modern world is the reduction of weight while increasing or maintaining strength of products. Composites are one among the material families which are attracting lot of researchers and is also a solution of such issues. This paper describe about design and analysis of composite leaf spring. For this purpose, a rear leaf spring for MAHINDRA "BOLERO" is considered. The objective also aims to compare the stresses, deformations and weight saving of composite leaf spring with that of conventional steel leaf spring, where stiffness is the design constraint. The Automobile Industry also shows great interest in replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. In this work an attempt is made to develop a natural and synthetic fiber reinforced hybrid composite material with optimum properties to replace the existing conventional steel leaf spring. The leaf spring was modeled in CATIA and the analysis was done using ANSYS 15.0 software.*

Key Words: Natural fibre, Hybrid Composite, Mono leaf spring,

1. INTRODUCTION

In now a day the fuel efficiency and emission gas regulation of automobiles are two important issues. To fulfil this problem the automobile industries are trying to make new vehicle which can provide high efficiency with low cost. The best way to increase the fuel efficiency is to reduce the weight of the automobile. The weight reduction can be achieved by the introduction of light weight material, design optimization as well as better manufacturing processes. The composites have less weight with very good mechanical properties, which made them a very good replacement for conventional steel. In automobiles components, one of the component which can be easily replaced is leaf spring. A leaf spring is commonly used for providing suspension in wheeled vehicles. The suspension of leaf spring is the area which needs to focus for comfort ride. The suspension leaf spring reduces 10 to 20% of unsprung weight. It is well known that springs are designed to absorb shocks. So the strain energy becomes a major factor in designing the springs. The introduction of composites will make it possible to reduce the weight of the leaf spring without reduction in load carrying capacity and stiffness, since it has high strength to weight ratio and more elastic strain energy storage capacity as compared with conventional steel. Composites offer high strength as well as light weight.

In this work, an attempt is made to develop a natural and synthetic fiber reinforced hybrid composite material with optimum properties to replace the existing conventional steel leaf spring. The Composite materials used for the analysis of leaf spring are E-glass, flax fibre and banana fibre.

1.1 DESIGN OF COMPOSITE LEAF SPRING

The leaf spring is considered of Mahindra Bolero (SUV), which is commonly used for carrying goods as well as passengers. High carbon steel leaf is generally used for rear suspension system and its properties are shown in Table 1.

Table -1: Properties of steel leaf spring

Parameter	Values
Material selected	55si2Mn90
Young's modulus	2.1×10^5
Poisson's ratio	0.3
Tensile strength yield	1470N/mm^2
Density	7850 kg/m^3

1.2 EXPERIMENTAL

Materials: The three types of materials employed in this study are Steel 65Si7 which is the most popular grade of spring steel being used in automobile leaf spring, E-Glass/Epoxy, E-Glass/banana/Epoxy and flax/E-Glass/Epoxy. In this research work Banana fibre and flax fibre is introduced in E-Glass/Epoxy to develop a hybrid composite material which can reduce the weight as well as cost of leaf spring.

1.3 Preparation of Composite specimens

Hybrid composite specimens of woven E-Glass and Banana fiber and E-glass and flax fiber with epoxy resin made by using Hand Lay-up technique. A mild steel mold of dimension 200x20x3 mm is used for the fabrication of composite specimen. The mold is coated with wax for the easy removal of the sample. At first the glass fiber banana fiber and flax fiber fabrics of required size are cut so that they can be deposited on the template layer by layer during fabrication. Epoxy L-12 resin of density 1.15-1.20 g/cm3, used as a matrix and mixed with hardener H407 of density 0.97-0.99 g/cm3, the solution was mixed with 10:1 by weight percentage. Two OHP sheets are used at the top and bottom of the mold to give smooth surface finish. Brush and roller are used to impregnate fiber fabrics and also to avoid air entrapped. Fiber fabrics are placed one over another with resin layer in between in the mold upto the required thickness of specimen. Brush and roller are used to impregnate fiber mats and also to avoid air entrapped. The fiber weight fraction is maintained at 40%. Now the mold is placed in the compression molding machine. Approximately 70 kgf pressure is applied on the mold and it is allowed to cure at room temperature for 24 hours.

Fig -1: Composite Preparation

Table -2: Material Properties

PROPERTIES	E-GLASS WOVEN	BANANA FIBER	FLAX FIBER
Density (g/cm^3)	2.55	1.35	1.4
Elastic Modulus (GPa)	50-73	27-32	60-80
Tensile Strength (MPa)	2400	529-914	800-1500

2. EXPERIMENTAL TESTS CONDUCTED

2.1 UTM Tensile Load Test

In UTM tensile load test, the specimen is fixed between the jaws of the testing machine before loading. The specimen used is uniform over the gauge length within which elongation measurements are done. Tensile test specimens are developed according to the ASTM standards. The cross section of the specimen is rectangular in shape. The change in gauge length of the sample is measured from an extensometer or by the stroke or overall change in length.

Fig -2: Tensile Load Test

2.2 Flexure (3 Point Bend) Test

The three point bending flexural test provides values for the bending modulus E_f, flexural strength σ_f, flexural strain ε_f and the flexural (bending) stress-strain response of the material. The ease of the specimen preparation and testing is main advantage of a three-point flexural test. However, the results of the testing method are sensitive to specimen and loading geometry along with strain rate which are certain disadvantages of this method.

Fig -3: Bending Load Test

3. TEST RESULTS

3.1 UTM Tensile Load Test Results

Tensile Load vs. Deflection

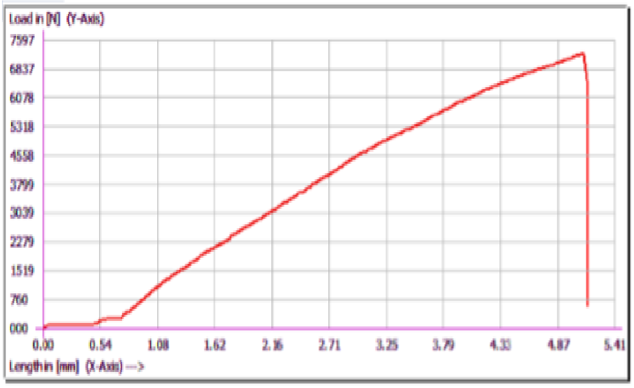

Chart -1: E-glass woven

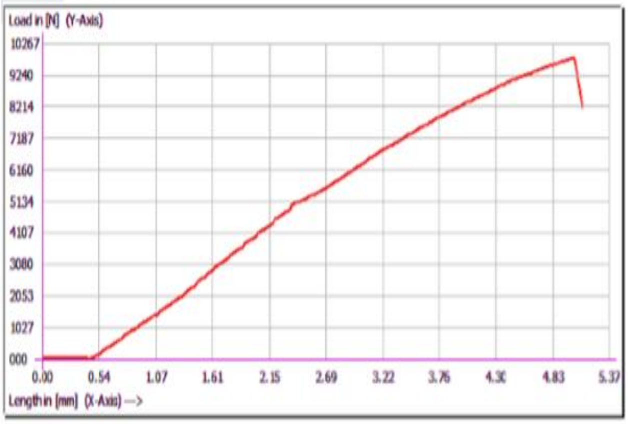

Chart -2: E-glass –Banana hybrid

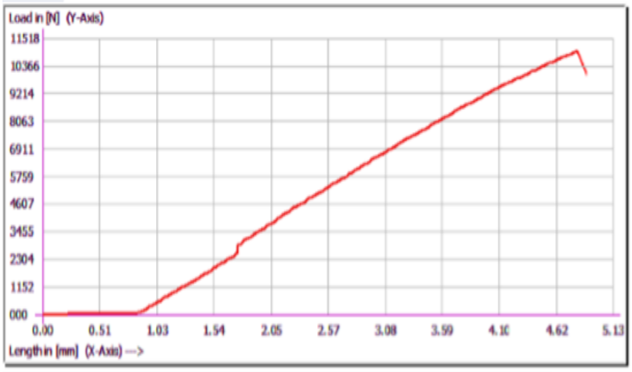

Chart -3: E-glass –flax hybrid

3.2 Flexure (3 Point Bend) Test Results

Bending Load vs. Deflection

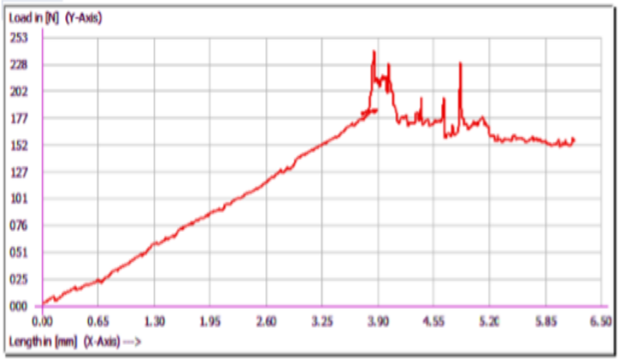

Chart -4: E-glass woven

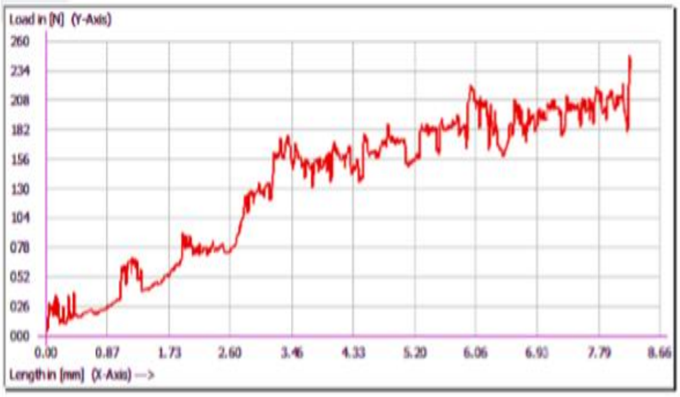

Chart -5: E-glass –Banana hybrid

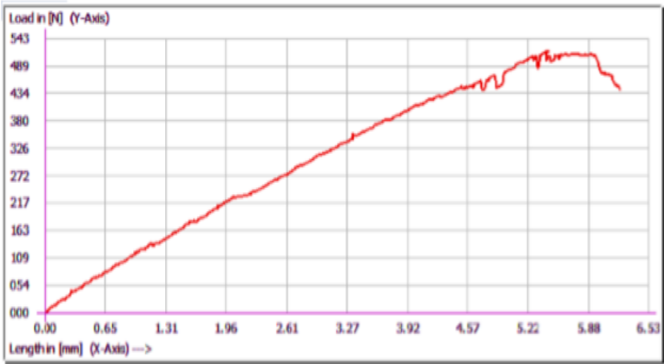

Chart -6: E-glass –flax hybrid

3.3 Results and Discussion

Table -2: UTM Tensile Test Obtained Parameters

Materials Used	Peak Load (N)	% elongation	UTS (MPa)	Yield Load @ 2 (N)
Woven E-glass	7234.78	3.96	120.58	3881
E glass-banana	9778.31	3.93	162.97	5405
E-glass-flax	10969.3	3.76	182.89	5425

Table -3: Flexure Test Obtained Properties

Materials Used	Peak Load (N)	σ_f (MPa)	σ_c (MPa)	E_b (MPa)
Woven E-glass	240.571	200.48	4.012	18137.04
E glass-banana	247.418	206.18	4.120	15558.41
E-glass-flax	517.576	431.32	8.623	1847.69

- Both tensile load test and flexure test shows hybrid composites have good properties than laminated composites.
- Both E-glass -banana and E-glass -flax hybrids have shown good strength properties, but E-glass -flax shows a bit higher value compared to E-glass –banana hybrid composite.
- Since the materials shows it can withstand higher stress values, it can be preferred as a replacement for materials used in high loading conditions.
- Also hybrids has a low density, which will help in creating overall light weight structure with better properties.
- So for the further analysis of composite leaf spring E-glass –flax hybrid material taken for the analysis and compare the results with conventional steel leaf spring

4. DESIGN CALCULATION OF LEAF SPRING

Basic data of Mahindra bolero is consider for design of leaf spring.

- Total length of the spring (Eye to Eye) = 1150mm
- No. of full length leaves (n_f) = 1
- No. of graduated leaves (n_g) = 4
- Thickness of leaf (t) = 8 mm
- Width of the leaf spring (b) = 65 mm
- Young's modulus (E)= 2×10^5 N/mm^2
- Central band 80 mm wide (Ineffective length)
- Tensile strength (σ_t) = 1962N/mm^2
- Yield strength (σ_y) = 1470 N/mm^2
- Total load = 2200Kg

1. Bending stress generated in the leaf spring

$$\sigma_b = \frac{6 \times w \times L}{n \times b \times t^2}$$

$$\sigma_b = \frac{6 \times 3657 \times 535}{5 \times 65 \times 8^2}$$

$$= 564 \text{ N/mm}^2$$

2. Deflection generated in the assembly of leaf spring

$$y = \frac{6 \times w \times L^3}{n \times E \times b \times t^3}$$

$$y = \frac{6 \times 3657 \times 535^3}{5 \times 210000 \times 65 \times 8^3}$$

$$= 100.06\text{mm}$$

4. CAD MODELING

CAD model designs with conventional and composite materials of mono leaf spring are created in CATIA V5 R20 which contains special tools in generating typical surfaces, which are later converted into solid models.

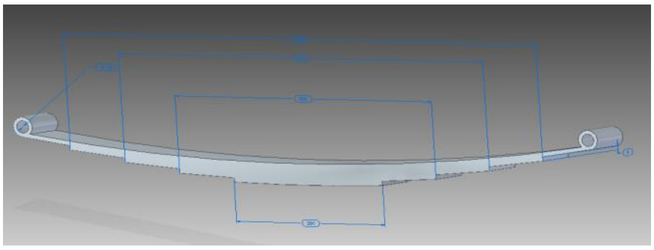

Fig -4: Conventional steel leaf spring

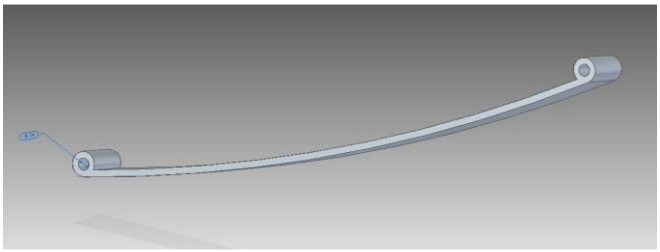

Fig -5: Composite mono leaf spring

Table -4: Properties of E-Glass/Flax/Epoxy hybrid composite

Sl No	properties	E-glass flax hybrid
1	Ex (Mpa)	1847.69
2	Ey (Mpa)	5397.42
3	Ez (Mpa)	5397.42
4	μ_{xy}	0.5
5	μ_{yz}	0.216
6	μ_{xz}	0.216
7	Gxy (Mpa)	3739.48
8	Gyz (Mpa)	3229.26
9	Gxz (Mpa)	3229.26
10	ρ (g/cm^3)	1.67

5. FINITE ELEMENT ANALYSIS USING ANSYS

The static analysis of conventional and composite leaf spring is carried out by ansys workbench15.0. The stress and deflection analysis is done for conventional and composite leaf spring using ANSYS software. The compared results of both composite and conventional leaf spring is given below.

Boundary Condition: one end remote displacement for component X free, Y and Z fixed and rotation Z free, X and Y fixed and other end remote displacement for component X, Y and Z fixed and rotation Z free, X and Y fixed. Loading conditions involves applying a load upper side at the Centre of the bottom leaf spring.

FEA Results: Structural analysis results which includes Stress (Von-misses), Deformation of steel E-Glass/flax/Epoxy, for the maximum load of 7315 N.

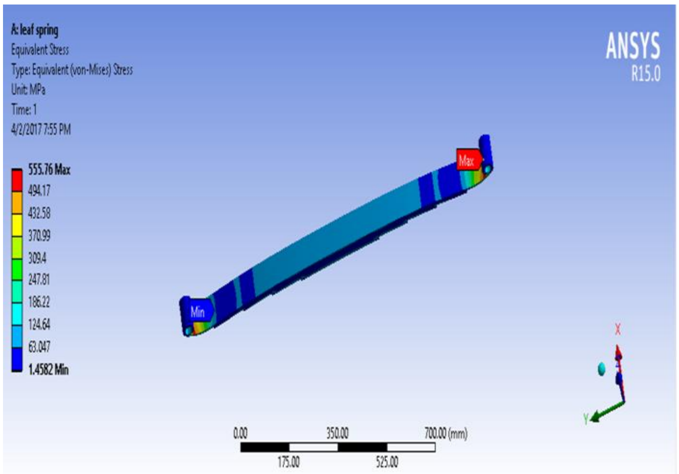

Fig -6: Von-Mises Stress (Steel)

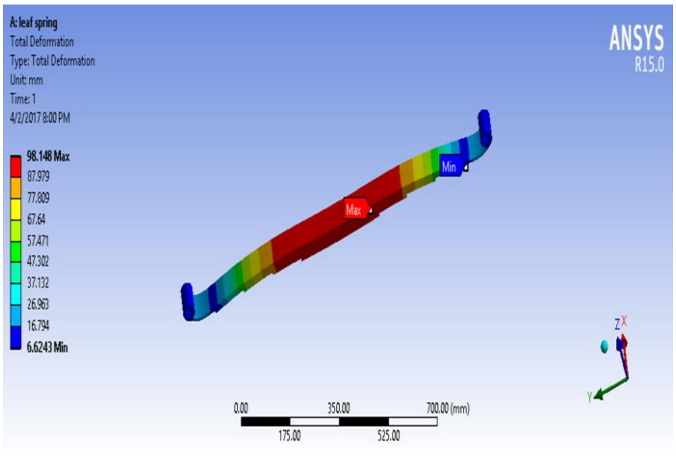

Fig -7: Deformation (Steel)

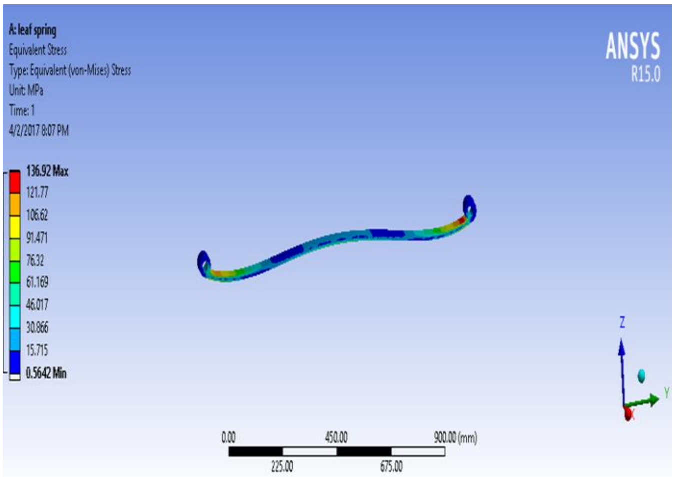

Fig -8: Von-Mises Stress (Composite)

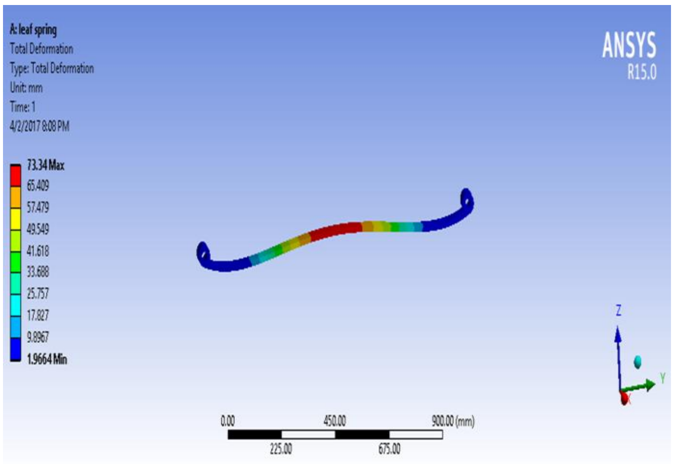

Fig -9: Deformation (Composite)

Table -5: Validation of steel leaf spring resuts

Parameters	Analytical results	Numerical results	Percentage variation
Von-misses stress (MPa)	564	555	1.59%
Maximum deflection (mm)	100.08	98.08	2%

Table -6: Comparison of results

Parameters	Conventional steel leaf spring	Composite leaf spring
Von-misses stress (MPa)	555	136.52
Maximum deflection (mm)	100.08	73.52

By the comparison of results between steel, and hybrid composite leaf spring it is found that, the maximum Von-Misses stress for steel leaf spring is 555 MPa which is higher than the stresses induced in E-Glass/Flax/Epoxy based hybrid composite leaf spring.

6. WEIGHT CALCULATION

For steel,

Weight of smallest leaf (leaf1)

= density × volume× acceleration due to gravity

= 294 × 8 × 65 × 0.00000786 ×9.81 =11.78 N

Weight of leaf2 = 508 × 8 × 65 × 0.00000786 ×9.81 =20.36N

Weight of leaf3 = 722 × 8 × 65 × 0.00000786 × 9.81 =28.94N

Weight of leaf4 = 936 × 8 × 65 × 0.00000786 × 9.81 =37.52N

Weight of leaf5 = 1150 ×8 × 65 × 0.00000786 × 9.81 =46.10N

Total weight of steel leaf spring = 144.7N

For E-glass/Flax/Epoxy,

Weight of mono leaf spring = 1150 × 14 × 65 × 0.000016 × 9.81 =16.42N

Weight saved = 144.7– 16.42 = 128.85

%weight saved = (128.85÷ 144.7) × 100 =88.49%

The conventional steel leaf spring weighs about 14.75Kg whereas d E-Glass/Flax/Epoxy weighs 1.67 Kg. Thus the weight reduction of 88.49% is achieved while using E-Glass/Flax/Epoxy hybrid composite leaf spring.

7. CONCLUSION

This research work provides comparative analysis between conventional steel, and E-Glass/Flax/Epoxy based hybrid composite leaf spring. The hybrid composite leaf spring is found to have lesser stresses and negligible higher deflection as compared to conventional steel leaf spring. Weight can be reduced by 88.49% if steel leaf spring is replaced by E- glass/Flax/Epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle.

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