Experimental & Finite element Analysis of Composite Mono Leaf Spring

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Abstract – In order to economize energy and conserve natural resources, weight reduction has been the main focus of automobile manufacturers in the present scenario. The increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced materials. More efforts have taken in order to increase the comfort of user. The aim of this paper is to present a low cost fabrication of complete mono composite leaf spring. Single leaf, variable thickness, variable width spring of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf steel spring, was designed, fabricated and tested. The finite element analysis of composite spring carried using ANSYS software. The experimental test is carried to verify the FEA result. Comparison between the performance of the GFRP and the multi leaf steel springs is presented.

Keywords: *- leaf spring, static analysis, stress analysis, finite element analysis.*

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I. INTRODUCTION

Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The introduction of FRP material has made it possible to reduce the weight of spring without any reduction on load carrying capacity. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel. Selection of material is based on cost and strength of material.

Shokriehet.al (2003), in their paper [1] made the optimization of the composite leaf spring. The results were verified by the existing analytical and experimental solutions. Then shape and the weight optimization were carried out. It has been observed that composite leaf spring saves the 80% of the weight comparing the conventional spring by increasing the thickness linearly and decreasing the width hyperbolically.

H. A. Al-Qureshi (2001), in this [2] discussed leaf spring from composite material. A single leaf spring, variable thickness spring of GFRP, with similar mechanical & geometrical properties to the multileaf steel leaf spring, was designed fabricated and tested.

Kainulainen (2011) had [3] studied the analysis of the parabolic leaf spring failure. It has been observed that for static loading the stress is concentrated at the middle portion of the spring but for the impact loading the stress concentration takes place near to the eye end along the driving direction. But for stresses in driving conditions there is not much difference in the stresses.

Patunkar et. al (2011) in their research paper [4] done the analysis of composite mono leaf spring made of glass fiber reinforced plastic. It has been observed that there is large deflection in the conventional spring than composite spring. Conventional leaf spring also possesses more weight than composite leaf spring.

Krason and Wysocki (2011) in his research [5] have made the vibration analysis of the simplified model of the suspension system. The subject of the paper deals with the forced vibrations of the rear suspension of the biaxial vehicle fitted with the double spring spatial shell model and the viscous damper, under the force pulse input with the given transient response.

Venkatesan and Devraj (2012) in their paper [6] have discussed the analysis of the composite leaf spring in light commercial vehicles. The objective of the work was to compare the load carrying capacity, stiffness and the weight reduction. The development of a composite leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring has been considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective

II. DESIGN & FABRICATION OF COMPOSITE LEAF SPRING

Mahindra Bolero is sport utility vehicle commonly used for carrying goods and passengers, specification of vehicle given in Table 1. Carbon steel leaf is used for rear suspension system and its specification is shown in Table 2. Number of leaves used in leaf spring depends on load coming on the system. For low load mono leaf is used, but for full load another graduated leaf is used. For avoiding number of graduated leaf springs there is scope for application of composite mono leaf spring.

Selected vehicle: - Mahindra Bolero

Table 1 Specification of Vehicle

Laden weight	2200 kg
Unladen weight	1615 kg
Wheel track	1346 mm
Wheel base	2794 mm

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Conventional Leaf material Composition-

Table 2 Specification & Properties of Existing Multi Leaf Spring

Sr. No.	Parameter	Value
1	Material selected – Steel	$55Si_2Mn_{90}$
2	Tensile strength (N/mm2)	1962
3	Yield strength (N/mm2)	1470
4	Young's modulus E (N/mm2)	2.1·105
6	Total length (mm)	1050
7	spring width (mm)	63
8	Spring weight (kg)	15.370
9	No. of full length leave	5
10	Thickness of leaf (mm)	6
11	Maximum Load given on spring (N)	6000

Composite Material

After full study on composite material & its properties; it has been found that E-glass epoxy having good properties to that of other material, but main reason to selection of this material is cost. The cost of E-glass epoxy is one third of Graphite/epoxy and Kevlar/epoxy. E-glass epoxy gives better material properties compared to other material with respect to cost of each material.

Properties of E-Glass/Epoxy

Table 3 Properties of E-Glass/Epoxy

Sr. No	Properties	Value
1	Tensile modulus along X-direction(Ex), MPa	34000
2	Tensile modulus along Y-direction(Ey), MPa	6530
3	Tensile modulus along Z-direction (Ez), MPa	6530
4	Tensile strength of the material, MPa	900
5	Compressive strength of the material, MPa	450
6	Shear modulus along XY-direction (Gxy), MPa	2433
7	Shear modulus along YZ-direction (Gyz), MPa	1698
8	Shear modulus along ZX-direction (Gzx), MPa	2433
9	Poisson ratio along XY-direction (NUxy)	0.217
10	Poisson ratio along YZ-direction (NUyz)	0.366
11	Poisson ratio along ZX-direction (NUzx)	0.217
12	Mass density of the material (ρ),Kg/mm3	2.6e3
13	Flexural modulus of the material, MPa	40000
14	Flexural strength of the material, MPa	1200

Specific Design Data:

Here we considered weight and initial measurements of "Mahindra Bolero".

Weight of vehicle = 1615 kg
Maximum load carrying capacity = 585 kg
Total weight = 1615 + 585 = 2200 kg;
Acceleration due to gravity (g) = 10 m/s$_2$
There for; Total Weight (W') = 22000 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight. As shown in Figure 1.

F = 22000/4

F = 5500 N

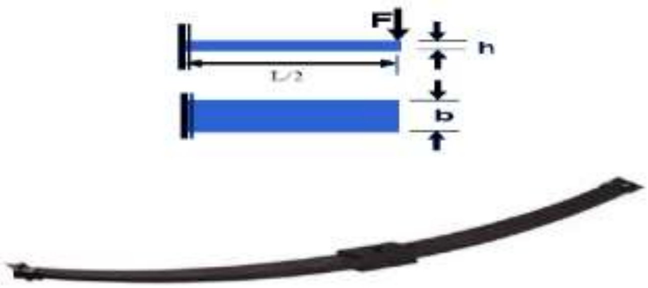

Fig. 1 Load acting on spring

III. Modelling & Finite Element Analysis

Modeling of multi leaf steel & composite leaf spring is done in Catia as shown in Fig. 2 & Fig. 3 and processed in ANSYS 15.0 as shown in Fig. 4 & Fig. 5

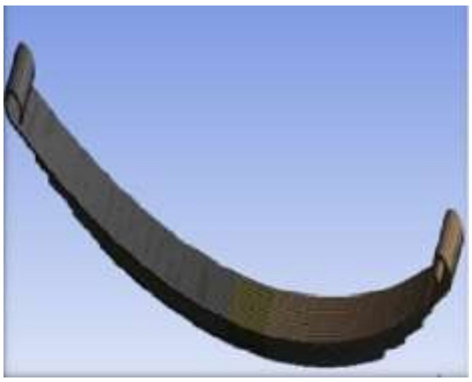

Fig. 2 Model of conventional leaf spring

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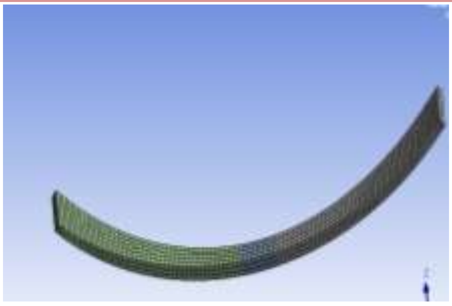

Fig. 3 Model of composite leaf spring

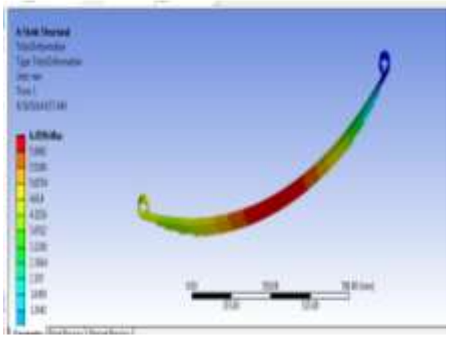

Fig. 4 FEA result of steel leaf spring deflections & stresses

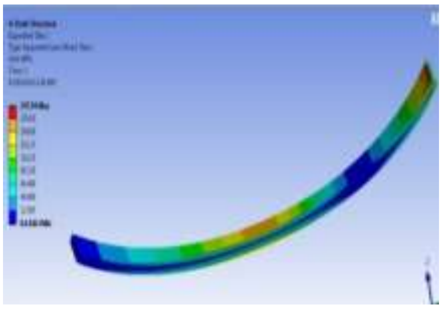

Fig. 5 FEA result of composite leaf spring deflections & stresses

The result of deflection for conventional & composite leaf spring for various loads is shown in Table 4.

Table 4 FEA result of deflections for steel & composite leaf spring

Sr. No.	Load (N)	Deflections (mm)	
		Steel	Composite
1	0	0	0
2	500	5.383	4
3	1000	10.766	8
4	1500	16.1	12.1
5	2000	21.5	16.1
6	2500	26.9	20.19
7	3000	32.2	24.2
8	3500	37.68	28.2
9	4000	43	32
10	4500	48.44	36.5
11	5000	53.8	40.38
12	5500	59.2	44.42
13	6000	64.5	48.4

The stresses of both springs are shown in Table 5 below and it shows the stresses for composite material are far below than steel for same load.

Table 5 FEA result for steel & composite leaf spring

LOAD (N)	VON-MISES STRESS (Mpa)	VON-MISES STRESS (Mpa)
	Steel	Composite
0	0	0
500	30.768	16.95
1000	61.53	32.989
1500	92.304	49.48
2000	123	65.979
2500	153.84	82.473
3000	184.61	98.968
3500	215.38	115.46
4000	246.14	131.96
4500	276.91	148.45
5000	307.68	164.95
5500	338.45	181.44
6000	368.9	197.94

The graph of comparison of FEA results of conventional multi leaf spring & mono composite leaf spring as shown in Fig. 6 below

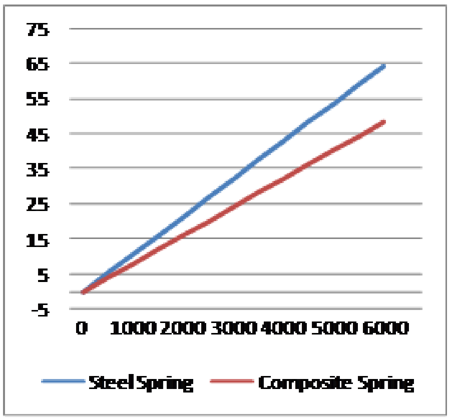

Fig. 6 Comparison graph of conventional & composite leaf spring deflections

IV. EXPERIMETAL TESTING

The steel and composite leaf springs are tested by using universal testing machine as shown in Figure 7. The leaf springs are tested by following standard procedures. The spring to be tested is examined for any defects like cracks, surface abnormalities, etc. The load is applied at the centre of spring; the vertical deflection of the spring centre is recorded in the load interval and it is shown in Table 6 & Table 7 for conventional & composite spring respectively.

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Fig. 7 Experimental Set Up

Table 6 Experimental Results for Conventional Multi Leaf Spring

Sr. No.	Load (N)	Displacement (mm)
1	0	0
2	500	5.6
3	1000	11.2
4	1500	17.3
5	2000	22.8
6	2500	28.1
7	3000	34.7
8	3500	39.15
9	4000	45.3
10	4500	51.6
11	5000	57.4
12	5500	63.2
13	6000	69.5

Table 7 Experimental Results for Composite Spring

Sr. No.	Load (N)	Displacement (mm)
1	0	0
2	500	4.15
3	1000	8.27
4	1500	13.2
5	2000	17.3
6	2500	22.53
7	3000	26.2
8	3500	30.8
9	4000	35.1
10	4500	41.2
11	5000	45.3
12	5500	50.2
13	6000	56.2

The comparison graph of experimental results of conventional multi leaf spring & mono composite leaf spring as shown in Fig. 8 below

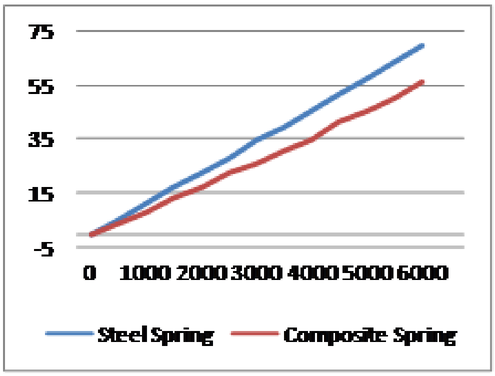

Fig. 8 Comparison graph of steel & composite leaf spring deflections

V. CONCLUSION

A mono composite leaf spring for the vehicular suspension system was designed using E-Glass/Epoxy with the objective of minimization of weight of the leaf spring subjected to constraints such as type of loading and laminate thickness.

The weight of composite leaf spring is 63.27 % less than the conventional leaf spring; also the stresses in composite leaf spring are much lower than the conventional leaf spring.

The finite element result shows good agreement to the experimental results.

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