Design and performance testing of master leaf used for Mahindra pick-up

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***Abstract*—The project work deals with optimal design and analysis of composite material leaf spring made up from E-Glass fiber. In this work the four-leaf steel spring used in the rear suspension system of light vehicle having vehicle weight 2.5 to 5 ton is studied. The objective of the present work is weight reduction of the suspension system for prescribed stiffness which results in better fuel economy at present fuel crises environment. For the analysis of the leaf spring performance parameters used are as deflection, stress, strain energy storage capacity and weight. The Ansys 15.0 software is used for the structural, optimization and stress analysis. After the structural analysis result of the steel leaf spring, Optimization is done by using design surface optimization for the thickness reduction. The constant cross section mono-composite leaf spring is designed and analyzed for prescribed stiffness. The experimental validation is done by using Universal Testing Machine (UTM) . The comparison in between conventional and composite leaf spring shows the 30-50% weight reduction in the suspension system of an vehicle.**

Keywords-leaf spring, Weight reduction, E-Glass fiber, Fuel economy, Structural and stress analysis, , UTM

I. INTRODUCTION

Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. To improve the suspension system, many modifications have taken place over the time. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. Inventions of parabolic leaf spring, use of composite materials for these springs are some of these latest modifications in suspension systems. This seminar mainly focuses on the implementation of composite materials by replacing steel in conventional leaf springs of suspension system. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and

Stiffness. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi leaf steel springs are being replaced by mono-leaf composite springs.

II. LITERATURE REVIEW

1. J.J. Fuentes a, H.J. Aguilar, works on “Premature fracture in automobile leaf springs” In this paper, the origin of premature fracture in leaf springs, used in Venezuelan buses, is studied. To this end, common failure analysis procedures, including examining the leaf spring history, visual inspection of fractured specimens, characterization of various properties and simulation tests on real components, were used. It is concluded that fracture occurred by a mechanism of mechanical fatigue, initiated at the region of the central hole, which suffered the highest tensile stress levels. Several factors (poor design, low quality material and defected fabrication) have combined to facilitate failure. Preventive measures to lengthen the service life of leaf springs are suggested.

2. Basaran Ozmen, Berkuk Altiok, works on “A novel methodology with testing and simulation for the durability of leaf springs based on measured load collectives” In this study, the aim is to present the newly developed testing and simulation method for the durability of leaf springs in order to direct designers in the product development phase. The load spectra, which contain the variable amplitude loading to determine the fatigue life, were measured from different vehicles on rough road testing track. Afterwards, accelerated spectra were generated for testing and used in newly built fatigue test bench. Also, Finite Element Method (FEM) and Multi Body Simulation (MBS) calculations were performed and load spectra were processed with multichannel fatigue life calculation to generate a virtual test rig.

3. D.M. Brouwer, J.P. Meijaard, works on “Large deflection stiffness analysis of parallel prismatic leaf-spring flexures” In this study the support stiffness of a parallel leaf-spring flexure should ideally be high, but deteriorates with increasing displacement. This significant characteristic needs to be quantified precisely, because it limits the use of parallel leaf-spring flexures in precision mechanisms. We present new and refined analytic formulas for the stiffness in three dimensions

taking into account shear compliance, constrained warping and limited parallel external drive stiffness. The formulas are supplemented by a finite element analysis using shell elements to include anticlastic curving effects. Several approximation equations are presented for determining the drive force precisely. Even at relatively large deflections the derived formulas are in good agreement with the finite element results.

4. Y.S. Kong , M.Z. Omar, works on “Fatigue life prediction of parabolic leaf spring under various road conditions” In this work Parabolic leaf spring experiences repeated cyclic loading during operating condition. Fatigue life assessment of the parabolic leaf spring is a significant aspect during the component design stage. This paper serves to simulate the fatigue life of a parabolic leaf spring design under variable amplitude loading (VAL). VALs carry the road signal that provokes fatigue failure on leaf spring.

A).Research gap

By reviewing all research paper we found that some researchers worked on composite material to make a leaf spring but it is not possible practically to use composite materials like Epoxy fiber, because composite material gives maximum deflection. Composite materials definitely reduce a weight of leaf spring but stiffness and load carrying capacity of steel leaf spring is maximum. By overall analysis there is need of finding alternative steel material to overcome drawbacks of conventional steel material.

B).Problem statement

In case of MAHINDRA PICK-UP we identify some of the problems which generally occurs master leaf spring. The usual leaf spring has various problems identified which are listed as

1. Maximum deflection: because of continuous running of the vehicle there is a declination in the level of soothed offered by the spring.
2. Less strength: It is observed that the leaf springs be likely to break and deteriorate at the eye end segment which is extremely near to shackle and at middle.
3. High weight: The usual steel leaf spring having more weight, which influences the fuel efficiency.

III. PROBLEM FORMULATION

The problem identification, objective and hypothesis has been prepared in previous sections now to devise the problem the parabolic leaf spring taken into consideration is that of a mini loader truck (MAHINDRA PICKUP) having the following specifications as :

1. Kerb Weight : 815 kg

It is the definite weight of the truck exclusive of any cargo or passengers on it. It’s the basic weight that is used in exclusion to estimate the entire weight of the vehicle with cargo and passengers.

2. Loading Capacity : 1 Tons

It is the maximum load, which can be carried by the vehicle.

3. Max Gross Vehicle Weight : 1550 kg

It is the entire weight of the loaded vehicle. This comprises the vehicle itself and the cargo that is loaded inside that vehicle.

4. Load Calculations

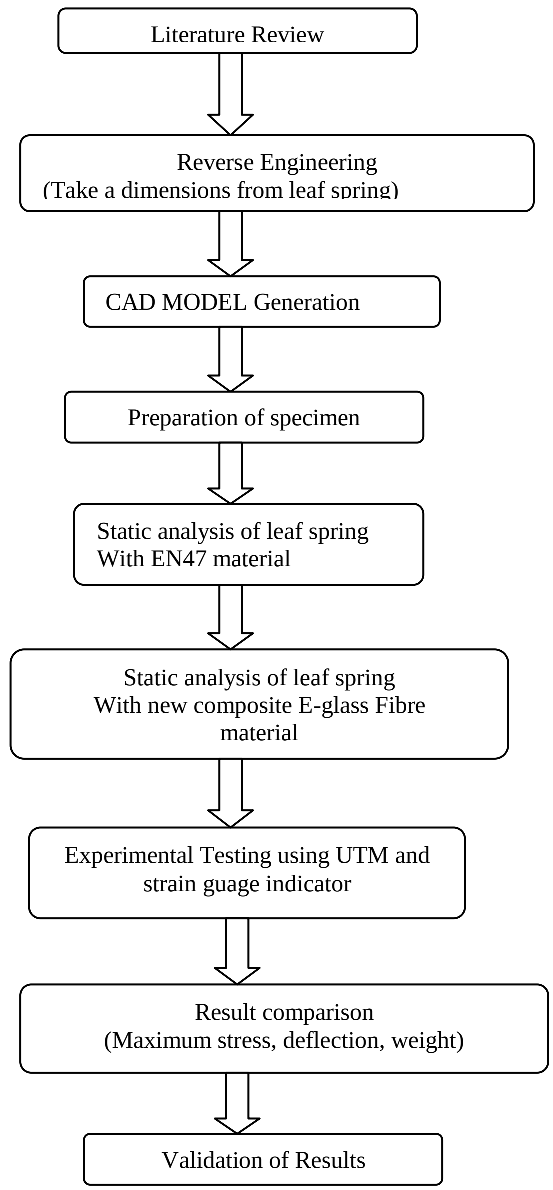
The parabolic leaf spring taken into consideration is of Mahindra Pickup having a Max Gross Vehicle Weight of 1550 kg.

Total weight acting downwards (i.e at full load)
= Gross Vehicle Weight × gravity
= 1550 x 9.81 = 15205.5 N.

There are four suspensions two at the front and two at the back. So, Load on one suspension = 15205.5/4 = 3801.4 N or 3800 N approx. For better safety spring should be design for 5000N load.

Factor of safety = Ranges (2 - 2.25) for leaf spring.

IV. METHODOLOGY



V. SELECTION OF MATERIAL

Materials of the leaf spring should be consist of nearly 60%-70% of the vehicle cost and contribute to the quality and the Performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact.

Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

C).Fiber Selection

The commonly used fibers are carbon, glass, keviar, etc. Among these, the glass fiber has been selected based on the cost factor and strength. The types of glass fibers are C-glass, S-glass and E-glass. Vertical vibrations and impacts are buffered by 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 capability of a leaf spring ensures a more compliant suspension system. The material used directly affects the quantity of storable energy in the leaf spring. The C-glass fiber is designed to give improved surface finish.S-glass fiber is design to give very high modular, which is used particularly in aeronautic industries. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

D).Mechanical properties of e-glass/epoxy

E-glass fibres has good mechanical, electrical and chemical properties at less cost. Mechanical properties of E-glass/epoxy composite materials are shown in Table

Table-I

Sr. No.	Properties	Value
1.	Density (Kg/mm^3)	2000
2.	Young's Modulus X direction (MPa)	45000
3.	Young's Modulus Y direction (MPa)	10000
4.	Young's Modulus Z direction (MPa)	10000
5.	Poisson's Ratio XY	0.3
6.	Poisson's Ratio YZ	0.4
7.	Poisson's Ratio XZ	0.3
8.	Shear Modulus XY (MPa)	5000
9.	Shear Modulus YZ (MPa)	3846.2
10.	Shear Modulus XZ (MPa)	5000
11.	Ultimate Tensile Strength (MPa)	1300

E).Cad model

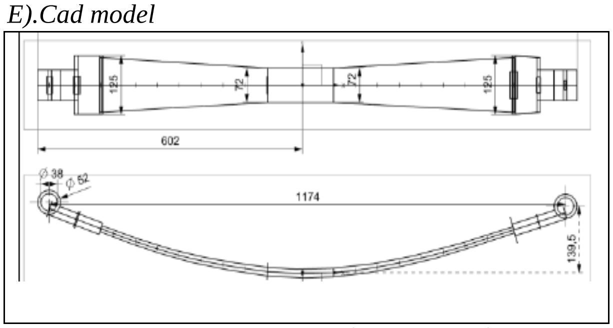


Fig.1 Overall Dimensions of Composite leaf spring

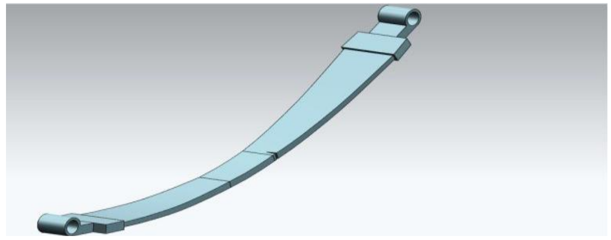


Fig.2 CAD Model of composite mono leaf spring

F). Static Analysis

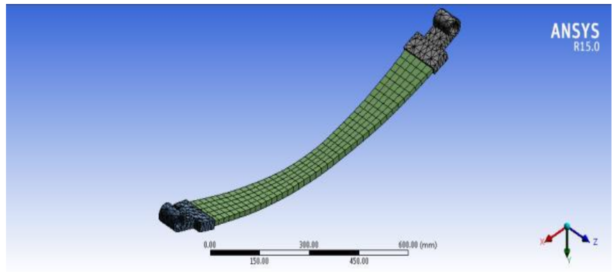


Fig.3 Meshing

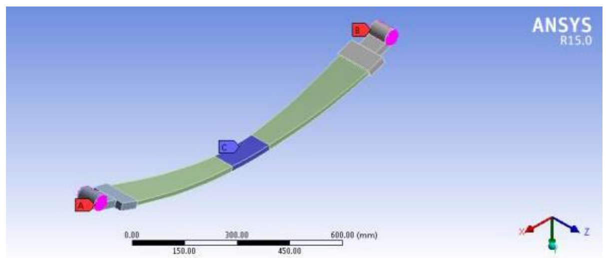


Fig.4 Application of boundary conditions

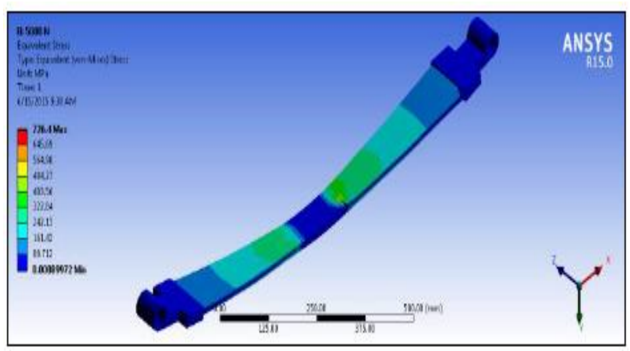


Fig.6 von-misses stresses

VI.EXPERIMENTAL SET-UP

Fig.7 Mechanical testing of EN47 leaf spring

Fig.8 Mechanical testing of E-glass material leaf spring

G). Observation Table

Table-II

Sr.No.	Load (KN)	Steel master leaf Deflection (mm)	Composite master leaf Deflection (mm)
1	50	12	8
2	100	22	10
3	150	35	12
4	200	48	16
5	250	64	22
6	300	80	28
7	350	92	35
8	400	112	40
9	450	N.A.	46
10	500	N.A.	52

During IS-1608-2005 mechanical testing, we found that as load on master leaf increases from 1000N to 5000N deflection in composite master leaf is less as compare to steel master leaf.In this test load is varying also deflection value changes.

H).Strain Measurement

Table-III

Sr.No.	Deflection (mm)	Load (KN)	Steel master leaf	
			$L_1 \times 10^{-6}$	$L_2 \times 10^{-6}$
1	10	40	6	56
2	20	85	8	57
3	30	130	9	58
4	40	150	10	59
5	50	200	10	61
6	60	250	12	66
7	70	270	32	74
8	80	300	33	76
9	90	340	36	76
10	100	370	43	81

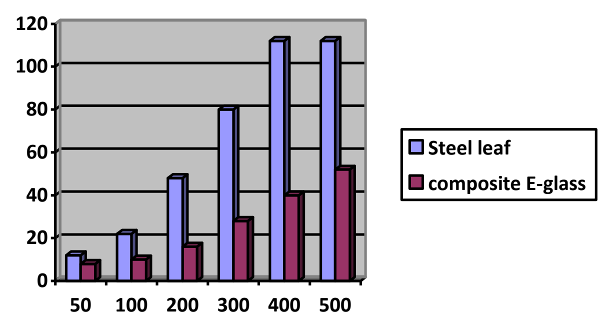
During IS-1608-2005 mechanical testing, we found that to achieve a particular deflection, load on master leaf increases from 1000N to 5000N.In this test we decide to place strain gauges at a distance L_1=150mm and L_2=350mm to check strain.During this test we found that strain at L_1 distance is less than strain at L_2 distance.

I).Observation table

Sr.No.	Deflection (mm)	Load (KN)	Composite master leaf	
			$L_1 \times 10^{-6}$	$L_2 \times 10^{-6}$
1	10	100	24	21
2	20	210	35	34
3	30	270	42	45
4	40	355	55	57
5	50	470	62	65
6	60	500	62	65
7	70	N.A	N.A	N.A
8	80	N.A	N.A	N.A
9	90	N.A	N.A	N.A
10	100	N.A	N.A	N.A

During IS-1608-2005 mechanical testing, we found that to achieve a particular deflection, load on master leaf increases from 1000N to 5000N.In this test we found that strain at $L_1$and L_2 is approximately same.

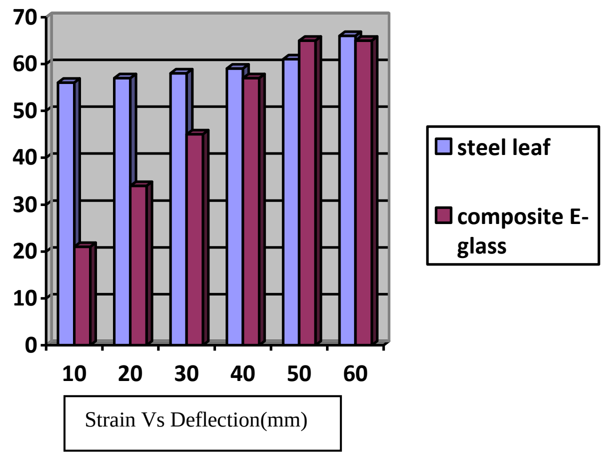
J). Load Vs Deflection chart



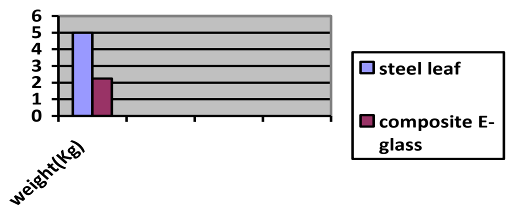
Deflection(mm) Vs Load (KN)

During IS-1608-2005 mechanical testing, we found that as load on master leaf increases from 1000N to 5000N deflection in composite master leaf is less as compare to steel master leaf. In this test load is varying also deflection value changes.

K). Deflection Vs strain chart



L). Weight comparison



VII.RESULTS

Sr. No	Load (N)	Deflection(mm)		Strain		Weight(kg)	
		steel	E-glass	steel	E-glass	Steel	E-glass
1	1000	22	10	55	21	2.25	5.0
2	2000	48	16	61	34	-	-
3	3000	80	28	76	51	-	-
4	4000	112	40	81	57	-	-
5	5000	112	52	N.A.	65	-	-

VIII.CONCLUSION

From results we can conclude that, reduction in un-sprung weight is possible due to use of composite material for fabrication of leaf spring. Almost 50% weight reduction is done. Composite master leaf does not gets rusted, so the performance will not get reduced after continuous use. The ultimate tensile strength of the composite leaf more than that of conventional master leaf ensuring good mechanical properties Stresses generated in the composite are much lower than that of conventional one. Stiffness of the composite leaf spring is nearly same as that of conventional steel master leaf. So we can replace conventional one by composite.

IX.ACKNOWLEDGMENT

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