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Development of a Composite Leaf Spring for a Light Commercial Vehicle (Tata Magic)

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ABSTRACT : Present time the main issue of automobile industry are weight reduction. The automobile industry has looking for any implementation or modification to reduce the weight of the vehicle. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for 10% to 20% of the unsprung weight. The introduction of composite leaf spring made of glass fiber rein forced plastic (GFRP) has made it to possible to reduce the weight of spring without any reduction on load carrying capacity and stiffness. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel spring. This work deals with the replacement of multi-leaf steel spring with mono composite leaf spring for the LCV. Suspension system in an automobile determines the riding comfort of passengers and the amount of damage to the vehicle. The main function of leaf spring assembly as suspension element is not only to support vertical load, but also to isolate road-induced vibrations. the behavior of leaf spring is complicated due to its clamping effects and inter-leaf contact etc. the objective of this paper is to replace the multi-leaf steel spring by mono composite leaf spring for the same load carrying capacity and stiffness. Since the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. It is possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. The design constraints were limiting stresses and displacement. Modeling and analysis of both the steel and composite leaf springs have been done using ANSYS software.

Keywords- Composite Materials, Leaf Spring, Material Property, FEA, ANSYS, and Pro-E.

I. INTRODUCTION

Leaf spring is a simple form of a spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. Just for the common form of its conception in Italian language a leaf spring suspension is called “balestra” (cross bow).an advantages of a leaf spring over a helical spring is that the end of the leaf spring may be guided along a definite path. Sometimes referred to as a semi elliptical spring or cart spring it takes the form of as lender arc-shaped length of spring steel of rectangular cross-section.the center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action .it is not well controlled and results in stiction in the motion of the suspension. For this reason manufactures have experimented with mono leaf spring.

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. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unstrung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. 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. The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. the leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of 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. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Fortunately, composites have these characteristics. Fatigue failure is the predominant mode of in-service failure of many automobile components. this is due to the fact that the automobile components are subjected to variety of fatigue loads like shocks caused due to road irregularities traced by the road wheels, the sudden loads due to the wheel traveling over the bumps etc. the leaf springs are more affected due to fatigue loads, as they are a part of the unstrung mass of the automobile. The fatigue behavior of glass fiber reinforced plastic (GFRP) epoxy composite materials have been studied in the past. Theoretical equation for predicting fatigue life is formulated using fatigue modulus and its degrading rate. This relation is simplified by strain failure criterion for practical application. A prediction method for the fatigue strength of composite structures at an arbitrary combination of frequency, stress ratio and temperature has been presented. These studies are limited to mono-leaf springs only. In the present work, a seven-leaf steel spring used in passenger cars is replaced with a composite multi leaf spring made of glass/epoxy composites. The dimensions and the number of leaves for both steel leaf spring and composite leaf springs are considered to be the same. The primary objective is to compare their load carrying capacity, stiffness and weight savings of composite leaf spring. Finally, fatigue life of steel and composite leaf spring is also predicted using life data

II. PREVIOUS RESEARCH

There are various researches for the comparison between composite leaf spring and laminated leaf spring for various types of vehicle.

V. Pozhilarasu and T. Parameshwaran Pillai [1] Comparison of Performance f Glass Fiber Reinforced Plastic Leaf Spring with Steel Leaf Spring. Dakshraj Kothari et al [2] Comparison of performance of two leaf spring steels used for light passenger vehicle. Kumar Krishan and Aggarwal M.L [3] a Finite Element Approach for Analysis of a Multi Leaf Spring using CAE tools. B.Vijaya Lakshmi and I. Satyanarayana [4] static and dynamic analysis on composite leaf spring in heavy vehicle. K. Devendra and T. Rangaswamy [5] Evaluation of Thermal Properties of E-Glass/ Epoxy Composites Filled By Different Filler Materials. Sorathiya Mehul et al [6] Analysis of composite leaf spring using FEA for light vehicle mini truck. M. Venkatesan and D. Helmen devaraj [7] Design and analysis of Composite leaf spring in light vehicle. Anil Kumar et al [8] Design Optimization of Leaf Spring Malaga. V. Lakshmi Narayana [9] Design and Analysis of Mono Composite Leaf Spring for Suspension in Automobiles. Vinkel Arora et al [10] Eye design analysis of single leaf spring in automotive vehicles using CAE tools. Bhushan B. Deshmukh and Santosh B. Jaju [11] Design and Analysis of Fiber Reinforce Polymer (FRP) Leaf Spring. K. K. Jadhao and R. S. Dalu [12] Experimental investigation & numerical analysis of composite leaf spring. M. M. Patunkar and D. R. Dolas [13] Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA. Gulur Siddaramanna Shiva Shankar and Sambagam Vijayarangan [14] Mono composite leaf spring for light weight vehicle - design, end joint analysis and testing.

III. DATA COLLECTION AND EXPERIMENTATION

A. 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.

FIBRES 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. 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.

RESINS SELECTION

In a FRP leaf spring, the Inter laminar shear strengths are controlled by the matrix system used. Since these are reinforcement fibers in the thickness direction fiber do not influences Inter Laminar Shear strength. Therefore, the matrix system should have good inter laminar shear strength characteristics compatibility to the selected reinforcement fiber. Many thermo set resins such as polyester, vinyl ester, Epoxy resins are being used for fiber reinforcement plastics (FRP) fabrication. Among these resin systems, epoxies show better inter laminar shear strength and good mechanical properties. Hence, epoxide is found to be the best resins that would suit this application. Different grades of epoxy resins and hardener combinations are classifieds, based on the mechanical properties.

Table1. Mechanical Properties of EN47

Properties	Value	Unit
Young's Modulus	200000-200000	MPa
Tensile Strength	650-880	MPa
Elongation	8-25	%
Fatigue	275-275	MPa
Yield Strength	350-550	MPa
Density	7700	Kg/M³

Table2. The mechanical properties of E-glass/epoxy

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

B. DESIGN PARAMETERS OF STEEL AND COMPOSITE LEAF SPRINGS

The dimensional specification of the steel leaf is given for the single plate. There are only three laminated plates used of same dimension.

Table3. Steel leaf spring specification

Length (L)	965 mm
Width (b)	45 mm
Thickness (t)	30 mm
Camber height	125 mm

The diagram below is showing the design of steel leaf spring and composite leaf spring have made in Pro-E wildfire 4.0 And the analytical parameters like deformation and von misses have done in ANSYS 12.1 software.

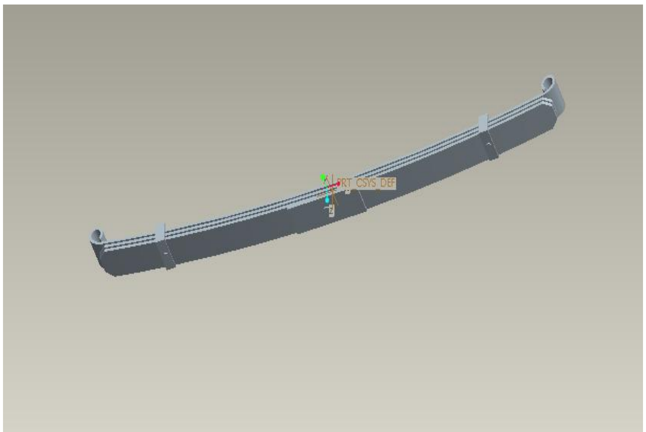

Fig.1 Design of steel leaf spring

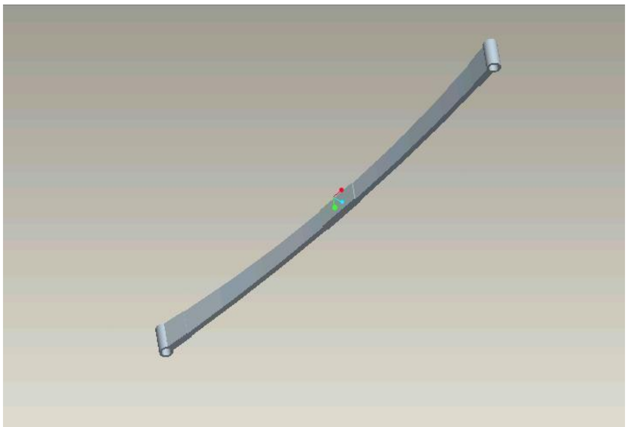

Fig.2 Design of composite leaf spring

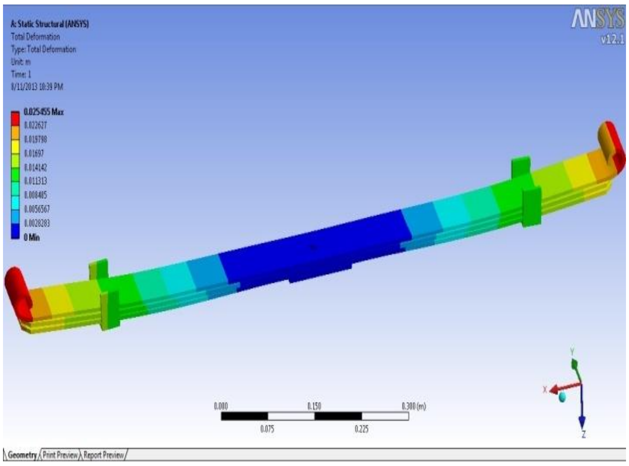

Fig.3 Deformation diagram of steel leaf spring

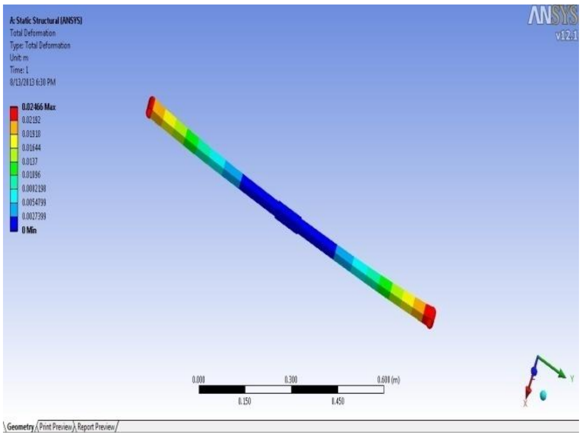

Fig.4 Deformation of composite leaf spring

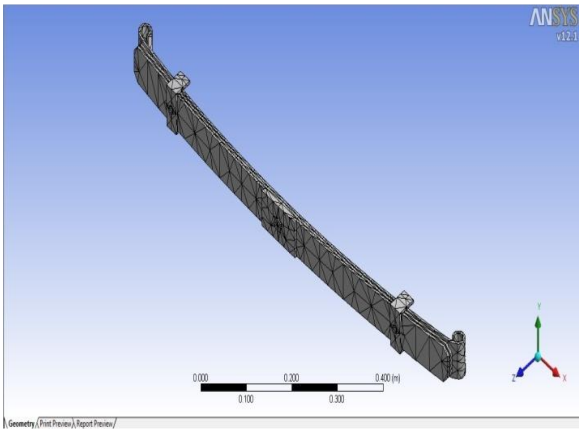

Fig.5 Meshing diagram of steel leaf spring

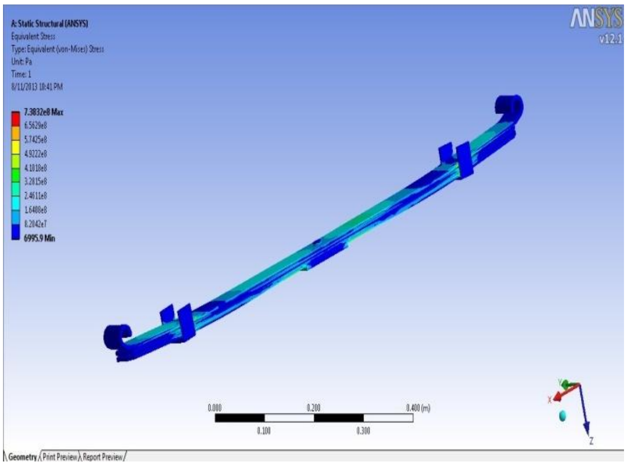

Fig.6 Von misses diagram of steel leaf spring

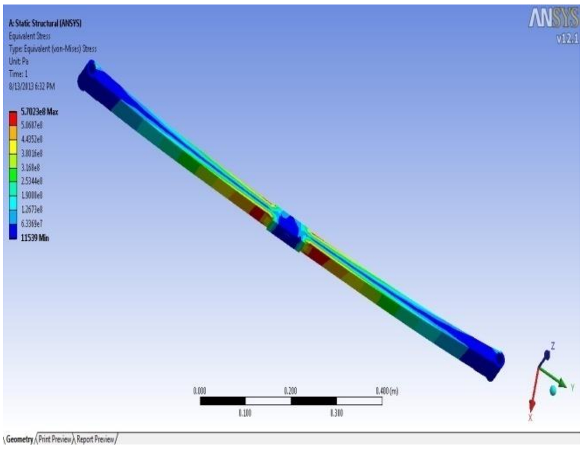

Fig.7 Von misses diagram of composite leaf spring

IV. RESULS AND DISCUSSION

On the basis of above analytical design data we have resulted out the table below.

Table4. FEA analysis

Parameters	EN47	Composite
Load (N)	2446	2446
Max. Stress (MPa)	738	570
Max. Deformation (mm)	25.4	24.6
FOS	1.15	1.57

V. CONCLUSION

These work involves the comparison of steel leaf material EN 47 and Composite material leaf spring under static loading conditions the model is preferred of in Pro-E 4.0 and then analysis is perform through ANSYS 12.1 from the result obtained it will be concluded that the development of a composite mono leaf spring has very effective than steel leaf spring.

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