Experimental Analysis and Design of Leaf Spring

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Abstract— Leaf spring is a simple form of suspension Spring used to absorb vibrations induced during the Motion of a vehicle. The automobile industry has shown Increased interest in the replacement of steel leaf spring (55 Si 7) with composite leaf spring (E-glass/Epoxy) and Jute/ glass epoxy due to high strength to weight ratio, Higher stiffness, high impact energy absorption and lesser Stresses. This research is aimed to investigate the suitability of natural and synthetic fiber reinforced hybrid composite material in automobile leaf spring application. By using natural fibers efforts have been made to reduce the cost and weight of leaf spring. In this work an attempt is made to develop a natural and synthetic fiber enforced hybrid composite material with optimum properties so that can replace the existing synthetic fiber reinforced composite material n automobile leaf spring. Jute and E-glass woven roving mats are used as reinforcements and epoxy resin LY556 is used as the matrix material. The CAD models of Leaf spring are prepared in CATIA V5 and imported in static structural analysis work bench of Ansys14.5 where ignite element analysis (FEA) is performed. The design constraints are stresses and deflections. This study gives a comparative analysis between steel leaf spring and Jute/E glass reinforced Epoxy leaf spring. The hybrid composite leaf spring is found to have lesser weight, lesser cost, lesser stresses and higher stiffness.

Key words: Analysis of Leaf Spring, Design of Leaf Spring

I. INTRODUCTION

A leaf spring is a long, flat, thin, and flexible piece of spring steel or composite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple, and leaves have been used in various capacities since medieval times. Most heavy duty vehicles today use two sets of leaf springs per solid axle, mounted perpendicularly to the axle and supporting the vehicle's weight. This system requires that each leaf set act as both a spring and a horizontally stable link. Because leaf sets lack rigidity, such a dual-role is only suited for applications where load-bearing capability is more important than precision in suspension response. Older transverse leaf spring arrangements mounted the a single leaf set running parallel to a live axle, but used it both as a suspension link and a spring element in a similar manner to the traditional arrangement. In vehicles with independent suspension and a transverse leaf spring arrangement the leaf is not used to control the wheel's location and acts only as a spring element. In this arrangement double wishbones act to locate the wheel, while a single leaf or leaf set connected to the front or rear sub-frame in the middle of the vehicle and the lower wishbone on each side provides the spring element. In some applications two transverse leaf springs are used on a single axle with each providing separate springing action to each wheel. In the past most transverse leaf springs arrangements used multiple steel elements in a set similar to their traditional longitudinal counterparts, but most modern Applications use a composite (generally fiberglass) mono leaf element.

Originally called laminated or carriage spring a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is one of the oldest forms of springing, dating back to medieval times.

Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender 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 systematically shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions.

II. LITERATURE SURVEY

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

Kumar Krishna and Aggarwal M.L carried out on a multi leaf spring having nine leaves used by a commercial vehicle. The finite element modeling and analysis of a multi leaf spring has been carried out. It includes two full length leaves in which one is with eyed ends and seven graduated length leaves. The material of the leaf spring is SUP9.The FE model of the leaf spring has been generated in CATIA V5 R17 and imported in ANSYS-11 for finite element analysis, which are most popular CAE tools. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining the under defined boundary condition. Bending stress and deflection are the target results. A comparison of both i.e. Experimental and FEA results have been done to conclude.

Pankaj Saini, Ashish Goel and Dushyant Kumar reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this paper we describe design and analysis of composite leaf spring. The objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. The design constraint is stiffness. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is used against conventional steel. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modeled in Auto-CAD 2012 and the analysis was done using ANSYS 9.0 software.

Shishay Amare Gebremeske Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this project reducing weight of vehicles and increasing or maintaining the strength of their spare parts is considered. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials considering static loading only. The constant cross section design of leaf springs is employed to take advantages of ease of design analysis and its manufacturing process. And it is shown that the resulting design and simulation stresses are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life. This particular design is made specifically for light weight three wheeler vehicles. Its prototype is also produced using hand lay-up method.

Jadhav Mahesh, Zoman Digambar B, Y R Kharde and R R Kharde efforts have been made to reduce the cost of composite leaf spring to that of steel leaf spring. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very replacement material for convectional steel. Material and manufacturing process are selected upon on the cost and strength factor. The design method is selected on the basis of mass production. From the comparative study, it is seen that the composite leaf spring are higher and more economical than convectional leaf spring. After prolonged use of conventional metal Coil Spring, its strength reduces and vehicle starts running back side down and also hits on the bump stoppers (i.e. Chassis). This problem is entirely removed by our special purpose Composite leaf Springs.

Santhosh Kumar and Vimal Teja composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials is discussed. The automobile industry has shown increased interest in the replacement of steel spring with fiberglass composite leaf spring due to high strength to weight ratio. This work deals with the replacement of conventional steel leaf spring with a Mono Composite leaf spring using E-Glass/Epoxy. The design parameters were selected and analyzed with the objective of minimizing weight ofthe composite leaf spring as compared to the steelleaf spring. The leaf spring was modeled in Pro/E and the analysis was done using ANSYS Metaphysics software

Manas Patnaik, L.P. Koushik and Manoj Mathew has been carried out on a parabolic leaf spring of a mini loader truck. The spring has been analyzed by applying a load of 3800 N and the corresponding values of stress and displacement are computed. In this work, Design of experiments has been applied under various configurations of the spring (i.e by varying camber & eye distance). Camber and Leaf span of a Parabolic Leaf Spring was found for Optimized Stress and Displacement value using Artificial Neural Networks. Various networks with different architecture were trained and the network giving the best performance was used for optimization. Baviskar A. C.1, Bhamre V. G.2, Sarode S. S.3 (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 6, June 2013. The aim of this review paper is to represent a general study on the design, analysis of leaf spring.

The suspension system in a vehicle significantly affects the behavior of vehicle, i.e. Vibration characteristics in Cludingride comfort, stability etc. Leaf springs are commonly used in the vehicle suspension system and are subjected to millions of varying stress cycles leading to fatigue failure .A lot of research has been done for improving the performance of leaf spring. Now the automobile industry has shown interest in the replacement of steel spring with composite leaf spring.

In general, it is found that fiberglass material has better strength characteristic and lighter in weight as compare to steel for leaf spring. In this paper there is reviewed some papers on the design and analysis leaf spring performance and fatigue life prediction of leaf spring. There is also the analysis of failure in leaf spring. Also the analysis of leaf spring with Ansys is done. The automakers can reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing.

Bhushan, Deshmukh, Dr. Santosh and B. Jaju Int J Engg Techsci.Weight reduction is now the main issue in automobile industries. 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. The composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, so multi-leaf steel springs are being replaced by mono-leaf composite springs. The paper gives the brief look on the suitability of composite leaf spring on vehicles and their advantages. The objective of the present work is design, analysis and fabrication of mono composite leaf spring. The design constraints are stress and deflections. The finite element analysis is done using ANSYS software. The attempt has been made to fabricate the FRP leaf spring economically than that of conventional leaf spring.

III. MODELLING OF A LEAF SPRING

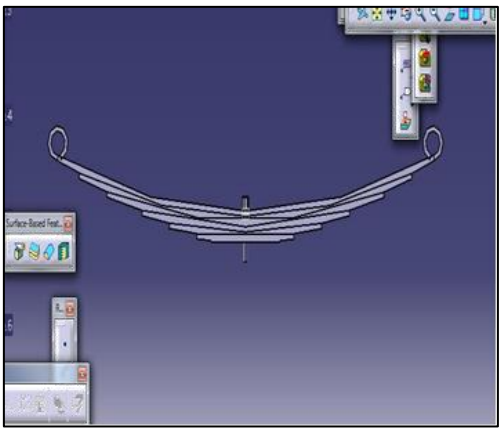

Fig. 2: modeling of leaf spring

Total Length of Leaf Spring (Eye to Eye)	1100 mm
Arc Height at Axle Seat	170 mm
Thickness of Leaf Spring	6 mm
Width of Leaf Spring	56 mm
Outer Diameter of Eye	50 mm
Inner Diameter of Eye	44 mm

Table 1: Design Parameters of Steel Leaf Spring

IV. RESULTS AND DISCUSSION

A semi-elliptical leaf spring may be considered as two cantilever leaf springs, and a full-elliptical leaf spring. Let

F= force applied at the end of the leaf spring b = width of each leaf spring t = thickness of each leaf

n = number of graduated leaves

l = length of the spring

σb = bending stress

Maximum bending movement, Mmax 6l

Bending stress where σb = 2 = 260.23 N/mm^2 6^3

Maximum deflection, δ max = $_2$ max = 238.75 mm

Strain energy = 0.0009 MJS

A. Comparison of 55 Si 7 Steels With Theoretical and Simulation Results

	Total Deformation (mm)		Stress (N/mm^2)		Strain energy (MJ)	
Load (N)	Theoretical Values of steel	Ansys values of steel	Theoretical Values of steel	Ansys values of steel	Theoretical Values of steel	Ansys values of steel
500	238.75	194.56	260.23	167.05	0.0009	0.00 07
1000	477,50	389.12	520.46	334.11	0.0019	0.00 15
1500	716.25	583.68	780.699	501.16	0.0028	0.00 23
2000	955.00	778.25	1040.93	668.21	0.0036	0.00 31
2500	1193.76	972.81	1301.165	835.26	0.0046	0.00 39

Table 2: Comparison between Theoretical and Simulation results of 55Si7

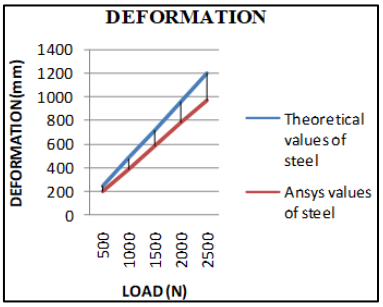

Fig. 3: Load Vs Deformation

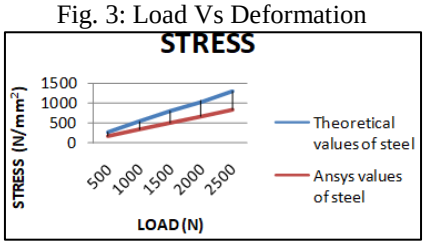

Fig. 4: indicates Load Vs Stress

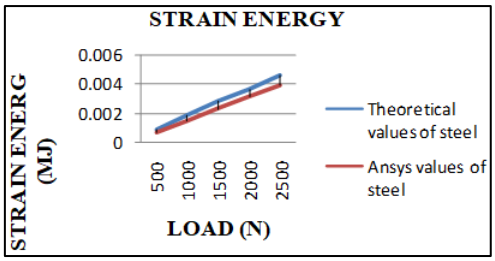

Fig. 5: Load Vs Strain energy

	Total Deformation (mm)		Stress (N/mm^2)		Strain energy (MJ)	
Load (N)	[A]	[B]	[A]	[B]	[A]	[B]
1000	10.39	11.88	12.822	12.822	0.00053	0.00061
2000	20.78	23.76	25.644	25.645	0.00106	0.00122
3000	31.19	35.65	38.466	38.467	0.00160	0.0018
4000	41.59	47.53	51.287	51.289	0.0021	0.0024

Table 3: Comparison between E-Glass/Epoxy and Jute/E-Glass/Epoxy results

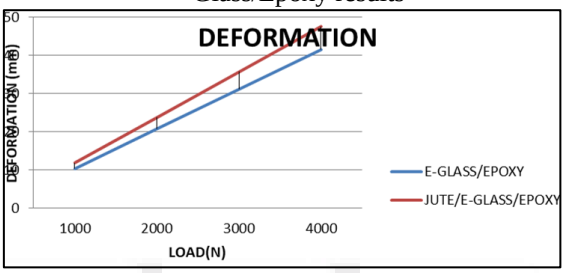

Fig. 6: Load Vs Deformation

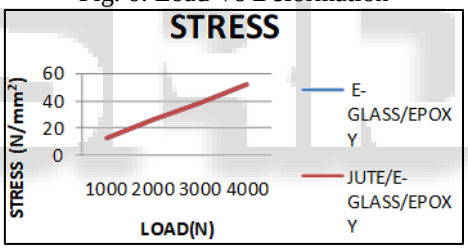

Fig. 7: Load Vs Stress

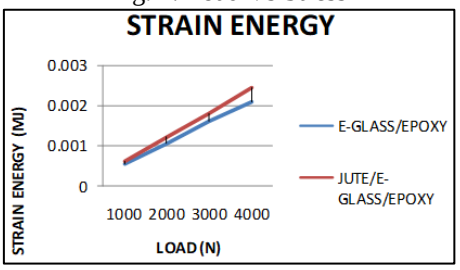

Fig. 8: Load Vs Strain

B. Comparison of Weights

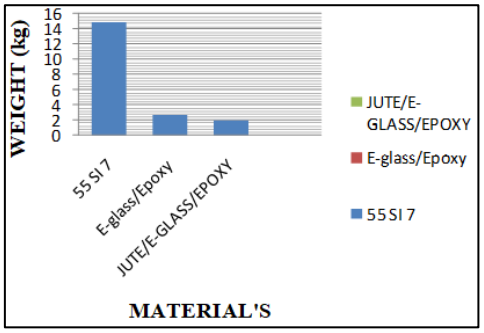

Fig. 9: Indicates Weight Vs Material

Bar- Chart drawn for the comparison of weight of both steel and composite leaf springs. The bar chart drawn below shows the comparisons in leaf spring weight (Kg) in case of steel and composite material. From this comparison of bar chart it is easily observed that the weight reduction in leaf spring. For steel leaf spring weight is 15kg and for composite leaf springs it is 2 & 2.8 kg.

V. CONCLUSIONS

The 3-D modeling of both steel and composite leaf spring is done and analyzed A comparative study has been made between composite and steel leaf spring with respect to Deflection , strain energy and stresses. From the results

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