

FINITE ELEMENT ANALYSIS OF LEAF SPRINGS

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Abstract— A leaf spring is a simple form of spring, generally employed for the suspension in automobiles. It is one of the important forms of springing techniques. An accurate modelling of the leaf spring is necessary for rider comfort, breaking performance, vibration characteristics, and stability. Substituting composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. The automobile industry has shown increased interest in the replacement of steel spring with fiber glass 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 of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modeled by CATIA and analysis was analyzed by using ANSYS 11.0 Multi physics software.

Keywords— leaf spring, ANSYS, CATIA, E-glass, Epoxy

I. INTRODUCTION

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. Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device.

The automotive industry is exploring composite material technology for structural components construction in order to obtain the reduction of weight without decrease in vehicle quality and reliability. To conserve the natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. Actually, there is almost a direct proportionality between the weight of the vehicle and its fuel consumption, particularly in city driving. The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density). Advanced composite materials seem ideally suited for suspension (leaf spring) applications. Their elastic properties can be tailored to increase the strength and reduce the stresses induced during application.

II. LITERATURE REVIEW

Energy conservation is one of the most important objectives in any vehicle design and reduction of weight is one of the most effective measures for energy conservation as it reduces overall fuel consumption of the vehicle [1]. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unsprung weight. The leaf spring should absorb vertical vibrations, shocks and bump loads by means of spring deflection so that the potential energy is stored in the leaf spring as strain energy and then released slowly. Thus elastic strain energy storage capacity is an important criterion while selecting the material for leaf spring [2]. The specific elastic strain energy is inversely proportional to the density and young's modulus. The automobile industry has shown increased interest in the replacement of steel leaf spring with fiber glass composite leaf spring because FRP composites possess lower young's modulus, lower density and lesser weight as compared to steel [3-5]. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity [7,8]. Research has indicated that EGlass/ Epoxy has good characteristics for storing specific strain energy

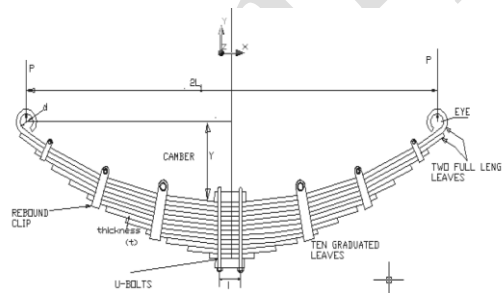
as E-glass has lower young's modulus and lower density than steel. Hence, E-Glass/Epoxy is selected as the composite material [6]. This research is an innovation in this field as it finds the suitability of natural fiber based hybrid composite material in leaf spring application. Recently natural fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements such as glass in plastics due to their low cost, low density, acceptable specific strength, fairly good mechanical properties, eco friendly and biodegradability characteristics [9]. In this work, an attempt is made to develop a natural and synthetic fiber reinforced hybrid composite material with optimum properties so that it can replace the existing synthetic fiber reinforced composite material in automobile leaf spring application. Three dimensional models of mono leaf spring are prepared in Unigraphics NX4. Static structural analysis of leaf spring models is performed in ANSYS 14.5 considering three different materials i.e. steel, composite (E-glass/Epoxy) and hybrid composite (Jute/E-glass/Epoxy). The leaf spring analysis is done in a range of 1KN to 5KN.

III. MODELING AND ANALYSIS

- Modeling of Steel leaf spring and E-Glass/Epoxy composite leaf spring using CATIA V5
- Static analysis of Steel leaf spring, E-Glass/Epoxy composite leaf spring, using ANSYS software.
- Modal analysis of Steel and E-Glass/Epoxy composite leaf spring to find the natural frequency so as to investigate the ride quality

A. Construction of leaf spring

A leaf spring commonly used in auto mobiles is of semi-elliptical form as shown figure. It is built up of a number of plates (known as leaf). The leaves are usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaves are held together by means of a band shrunk around them at the center or by a bolt passing a center.



IV. DESIGN PARAMETERS OF LEAF PRING

A. SPECIFICATION OF THE PROBLEM:

Objective of present work is to consider an existing automobile leaf spring model TATA SUMO EZRR PARABOLIC REAR and to design and analyze a composite leaf spring with upturned eye without changing stiffness in order to replace the existing steel leaf spring with a composite leaf spring.

B. ASSUMPTIONS

1. The leaf spring has a uniform, rectangular cross section.
2. All non- linear effects are excluded.
3. The stress-strain relationship for composite material is linear and elastic; hence Hooke's law is applicable for composite materials.

4. The load is distributed uniformly at the middle of the leaf.

Table 1.Parameters of steel leaf spring

PARAMETER	VALUE
Material selected – Steel	55Si2Mn90
Tensile strength (N/mm ²)	1962
Yield strength (N/mm ²)	1470
Young’s modulus <i>E</i> (N/mm ²)	2.1e5
Total length (mm)	1232
Arc height at axle seat (mm)	138
Normal static loading (N)	6000
Available space for spring width (mm)	70
Spring weight (kg)	16.4
Thickness at the centre of leaf(mm)	12
Spring arc diameter (mm)	1443.8406

C. FINALIZATION OF COMPOSITE MATERIAL

Based on the advantages discussed earlier, the E-Glass/Epoxy material is selected. The table shows the properties of the E- glass/Epoxy material used for the design of composite leaf spring.

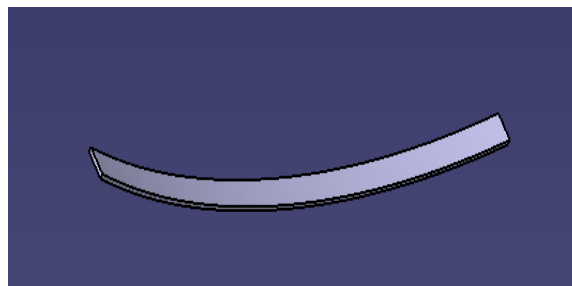
V. LOADS APPLIED

- On the area where the axle seat comes in contact with the leaf spring is fixed
- At both the extreme ends of steel leafs and composite leaf loads are applied

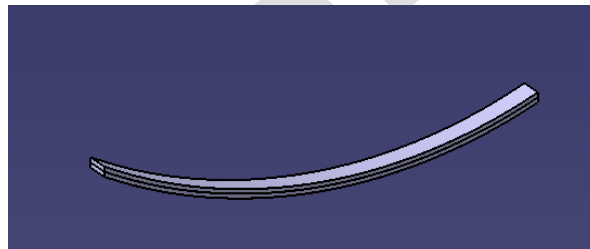
S.NO	SYMBOL	UNIT	VALUE
1	E_x	Mpa	34000
2	E_y	Mpa	6530
3	E_z	Mpa	6530
4	S_t	Mpa	900
5	S_c	Mpa	450
6	G_{xy}	Mpa	2433
7	G_{yz}	Mpa	1698
8	G_{xz}	Mpa	2433
9	ν_{xy}	NU _{xy}	0.217
10	ν_{yz}	NU _{yz}	0.366
11	ν_{xz}	NU _{xz}	0.217
12	ρ	Kg/mm ³	2.6e-6

S.NO	LEAF	LOAD (N)
1	STEELMASTER LEAF	6000
2	STEEL SECOND LEAF	6000
3	NO OF LEAFS	6000
4	COMPOSITE LEAF	6000

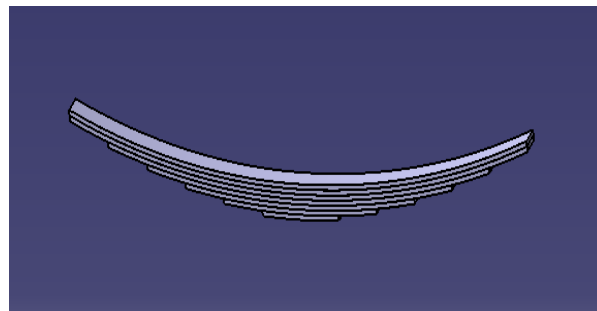
The following parts were modeled in CATIA V5



Master leaf spring(steel)



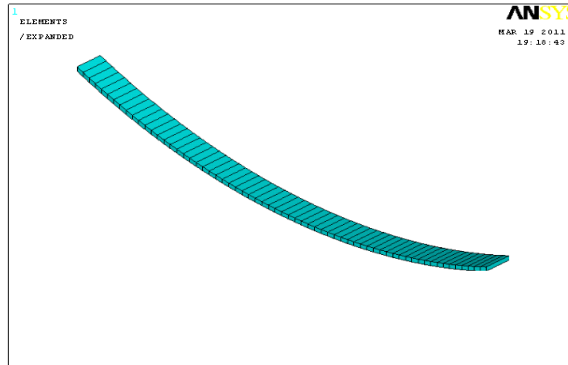
second leaf spring(steel)



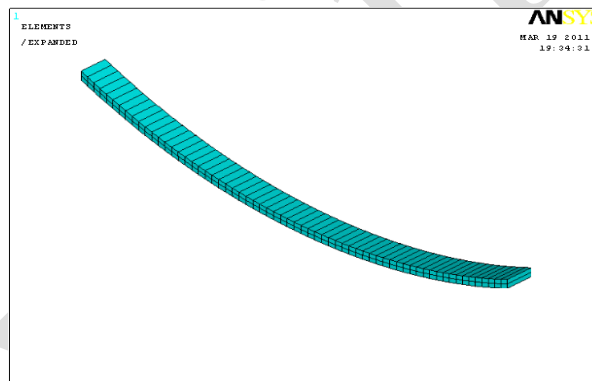
No of steel leaf springs

Above three type of springs is modeled in CATIA as per dimensions.

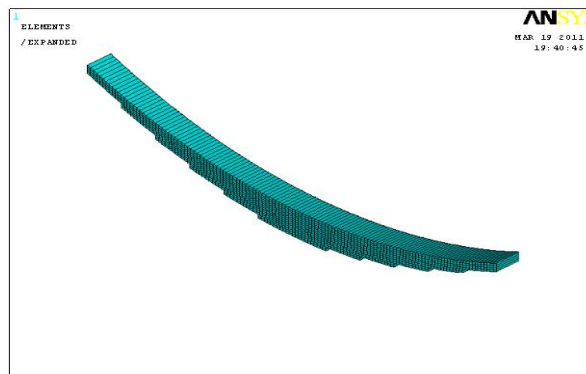
- CATIA part file is saved as IGES file.
- Master leaf (steel) IGES file is imported to ansys
- In the preferences, structural mode was selected.
- Element type selected was SOLID 42
 - master leaf designed in CATIA
 - Material properties selected in material model were structural – linear –elastic – isotropic and the values of Young’s modulus and Poisson’s ratio for steel were entered.
 - In the mesh section the volume was meshed with solid tetrahedral elements



Meshed master leaf designed in CATIA



Meshed second leaf designed in CATIA.



VI. CONCLUSION

- The stresses in the composite leaf spring are much lower than that of the steel spring.
- The composite spring can be designed to strengths and stiffness much closer to steel leaf spring by varying the layer
- The E-Glass/Epoxy composite leaf spring was modeled and analyzed to replace the conventional steel leaf spring in the suspension system of automobiles.
- It was observed that the stress in the composite leaf spring was almost equal so we can say that composite spring had the same stiffness as that of steel spring.
- It was observed that the composite leaf spring weighed only ----- of the steel leaf spring for the analyzed stresses. Hence the weight reduction obtained by using composite leaf spring as compared to steel was **65.78%**.
- By analyzing the design, it was found that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. To reduce the deflections we have to increase width or thickness of leaf spring.

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