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Fatigue Analysis of Leaf Spring by Using ANSYS Workbench

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ABSTRACT: This paper describes design and fatigue analysis of mono leaf spring. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle is taken for modelling and analysis of mono leaf spring with two materials namely, steel and Carbon/Epoxy subjected to the same load. The design constraints were stresses, deflections, damage, and life and safety factor. The two different leaf springs have been modelled by considering uniform cross-section, with unidirectional fibre orientation angle for each lamina of a laminate. Fatigue analysis of a 3-D model has been performed using ANSYS workbench. Keywords: Composite leaf spring (CLS), Fatigue analysis, Steel, Carbon/Epoxy. The fatigue analysis is performed under different repetition loads 250 and 397.27 with different time 10, 20, 30 and 40sec respectively.

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. 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 the 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 laminated 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 vibrations 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. In the present work, an attempt is made to replace the existing mono steel leaf spring used in maruti 800 passenger car with a laminated composite mono steel leaf spring made of three different composite materials viz., E-glass/epoxy, S-glass/epoxy and Carbon/epoxy composites. Dimensions and the number of leaves for both steel leaf spring and laminated composite leaf springs are considered to be the same.

The review mainly focuses on replacement of steel leaf spring with the composite leaf spring made of glass fibre reinforced polymer (GFRP) and majority of the published work applies to them. Mouleeswaran et al. [1] describes static and fatigue analysis of steel leaf spring and composite multi leaf spring made up of glass fibre reinforced polymer using life data analysis. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken and are verified by design calculations. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 7.1 and compared with experimental results.

Al-Qureshi et al. [2] has described a single leaf, variable thickness spring of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated and tested.

Rajendran I, et al.[3] investigated the formulation and solution technique using genetic algorithms (GA) for design optimization of composite leaf springs. Gulur Siddaramanna et al. [4] explain the automobile industry has shown interest in the replacement of steel spring with fibreglass composite leaf spring due to high strength to weight ratio. Peiyong et al. [5] describes that the leaf spring design was mainly based on simplified equations and trail and error methods. The simplified equation models were limited to the three-link mechanism assumption and linear beam method. This work presents detailed finite element modelling and analysis of a two stage multi leaf spring, a leaf spring assembly Gulur Siddaramanna et al. [4] explain the automobile industry has shown interest in the replacement of steel spring with fibreglass composite leaf spring due to high strength to weight ratio.

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LEAF SPRINGS

Leaf springs also known as flat spring are made up of flat plates. Leaf springs are designed in two ways: 1. Multi leaf 2. Mono leaf. The importance of leaf spring is to carry bump loads (i.e due to road irregularities), break torque, driving torque, etc… in addition to shocks. The multi-leaf spring is made up of several steel plates of different length stacked together, while mono-leaf spring is made up of single steel plate. During normal operation, the spring compresses to absorb road shock. The leaf spring bends and slide on each other allowing suspension movement.

Materials for Leaf springs:

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. After the heat treatment process spring steel products gets greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

COMPOSITE MATERIALS:

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds. Composites are combinations of two materials in which one of the material is called the “matrix phase” is in the form of fibres, sheets, or particles and is embedded in the other material called the “reinforcing phase”. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any rational metallic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of metallic materials. The fatigue strength weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries. Another unique characteristic of many fibre reinforced composites is their high interal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighbouring structures. High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort.

II. MATERIALS AND METHODOLOGY:

Table 1 shows the specifications of a mono leaf steel spring of a maruti 800 passenger vehicle. The typical chemical composition of the material is 0.565C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S.

S.No	Parameters	Value
1	Total length of the spring(Eye to Eye)	482.5mm
2	No. Of full length leave (Master Leaf)	01
3	Thickness of leaf	10 mm
4	Width of leaf spring	50 mm
5	Maximum load given on spring	397.27 N
6	Young’s Modulus of leaf spring	2.1e5 N/mm2

III.RESULTS AND DISCUSSIONS:

FINITE ELEMENT ANALYSIS OF LAMINATED COMPOSITE LEAF SPRING

Dimensions of composite leaf spring (CLS) are taken as that of the conventional steel leaf spring(SLS). Composite leaf spring (LCLS) is assumed to have 4 lamina of 0_0 degree fibre orientation angle (thickness of each lamina of 2.5mm). Width of the leaf is 50mm. Since the properties of CLS vary with directions of fibre, a 3-D model of leaf spring is used for analysis in ANSYS Workbench. The loading conditions are assumed to be static. The element chosen for the analysis is SHELL 99, which is a layered version of the 8-node structural shell model. The element has six degrees of freedom at each node : translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The element allows up to 250 layers. The finite element analysis is carried out on mono steel leaf spring as well as on three different types of laminated composite mono leaf spring. From the analysis the equivalent stress (Von-mises stress) and displacements damage, life and safety factor. were determined and are shown in figure.

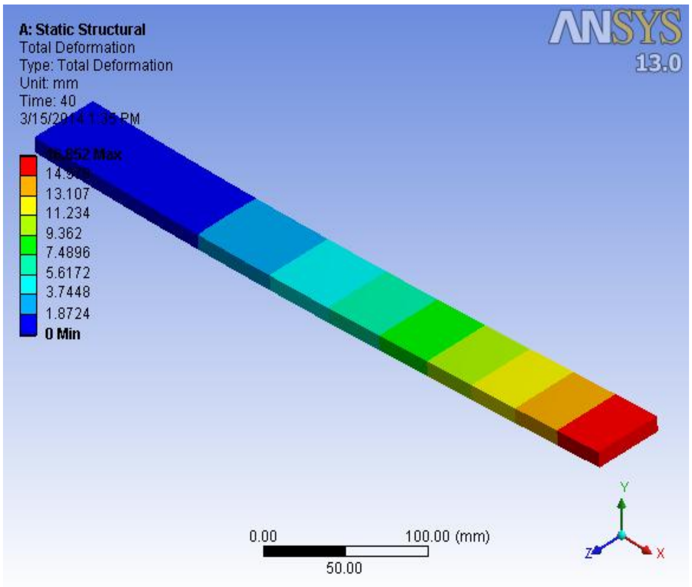

Fig1:Total deformation of steel

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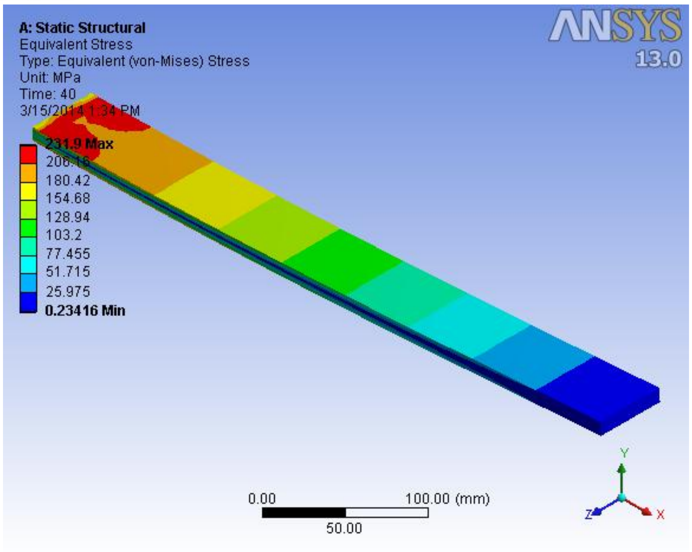

Fig2:Equalent Stress of steel

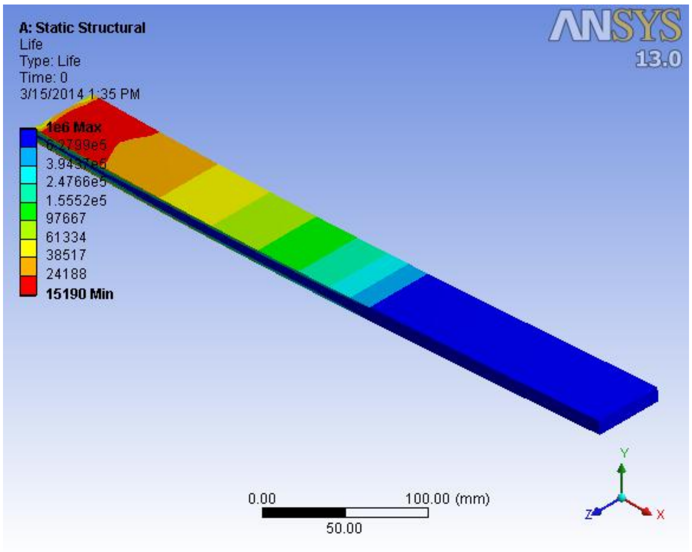

Fig5:Life factor of steel

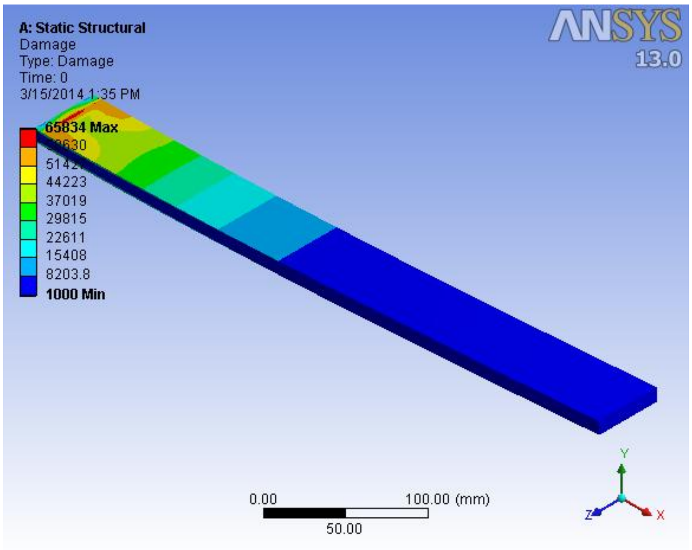

Fig3:damage of steel

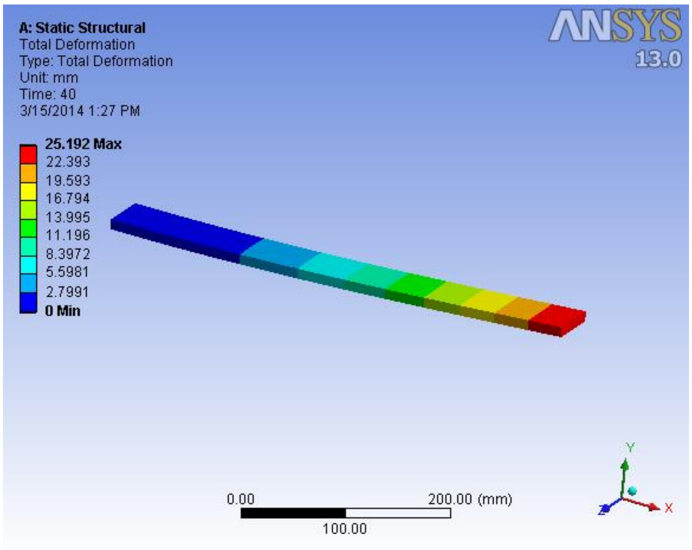

Fig1:Total deformation of Carbon/Epoxy

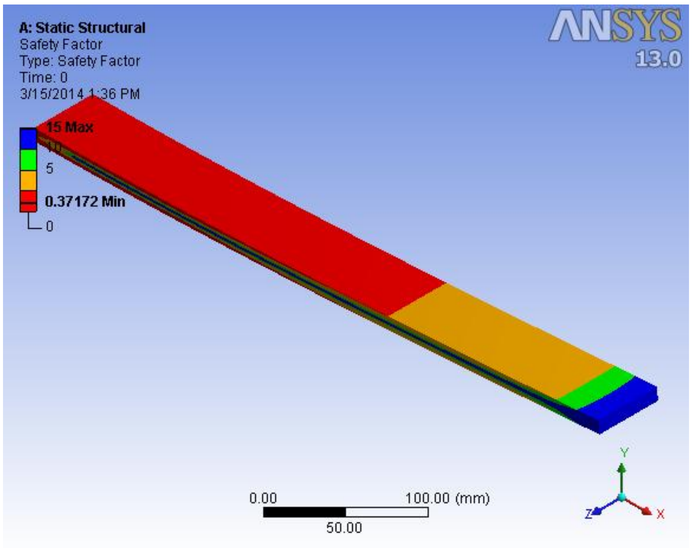

Fig4:Saftey factor of steel

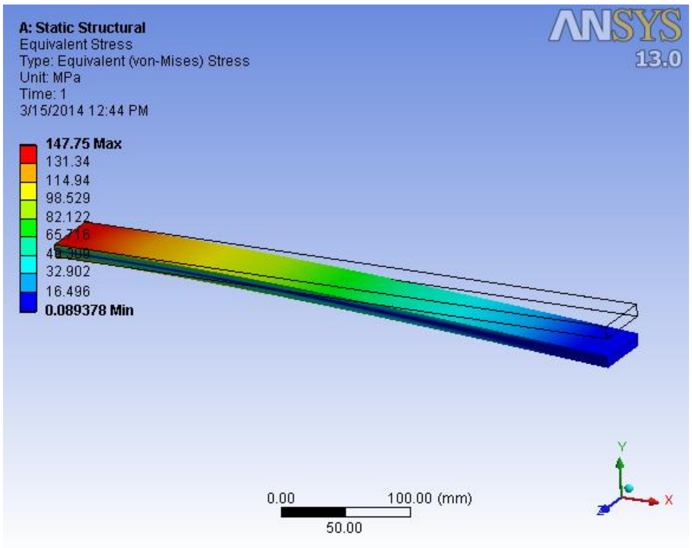

Fig2:Equalent Stress of Carbon/Epoxy

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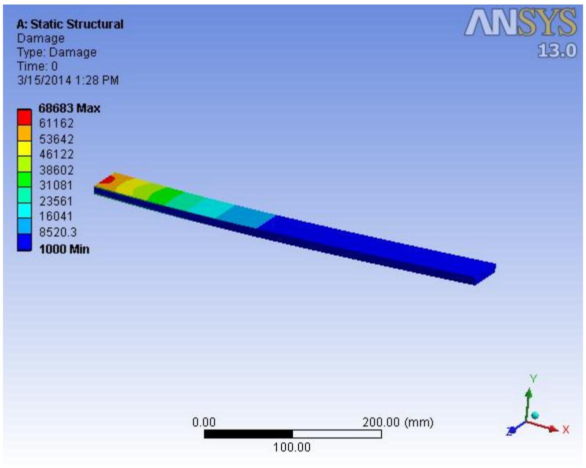

Fig3:damage of Carbon/Epoxy

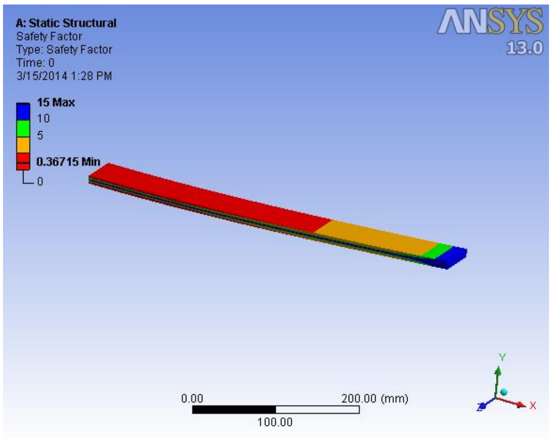

Fig4:Saftey factor of Carbon/Epoxy

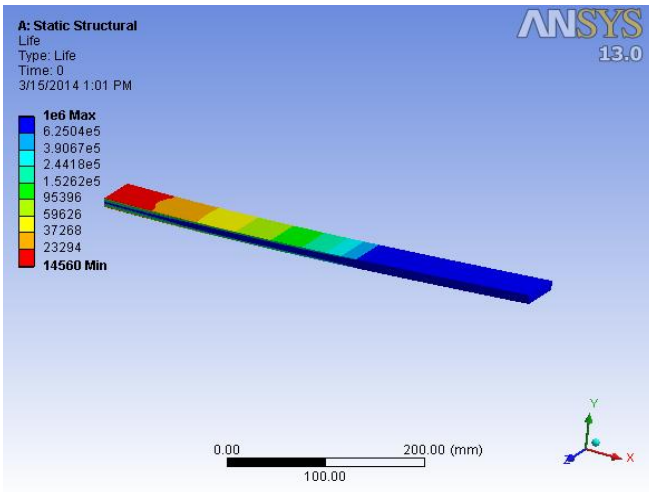

Fig5:Life factor of Carbon/Epoxy

Table 1: Deformation comparison

Time [s]	Steel [mm]	Carbon/Epoxy (mm)
10.	10.605	15.853
20.		
30.	16.852	25.192
40.		

Table 2: Stress comparison

Time [s]	Steel Min [MPa]	Steel Max [MPa]	Carbon/Epoxy Min(Mpa)	Carbon/Epoxy Max(Mpa)
10.	0.14736	145.93	8.9378e-002	147.75
20.				
30.	0.23416	231.9	0.14203	234.78
40.				

Table 3: Life, Damage and safety factor comparison

	Life	Damage	Safety Factor
Steel Min	15190 cycles		0.37172
Steel Max		65834	
Carbon/Epoxy Mini	14560 cycles		0.36715
Carbon/Epoxy Max		68683	

IV. CONCLUSIONS

A comparative study has been made between composite leaf spring and steel leaf spring with respect to stress, deformation, life, damage and safety factor. By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight higher than steel leaf spring and stiffer than the steel spring. Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel in this investigation. From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.

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