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Impact Analysis of Steel and Composite Leaf Spring for Light Commercial Vehicle

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***Abstract*- This paper investigated the dynamic behavior of steel and composite leaf springs using theoretical and FEA approach. The multi steel leaf spring of Tata Ace light commercial was taken for study. The steel and composite leaf springs was modeled and analyzed for strain energy at minimum and maximum and loading condition. The results demonstrate that compared to steel leaf spring composite leaf spring has more strain energy. It has been observed that , percentage error of strain energy for steel and composite leaf spring was less than 10%.Hence, this indicate better agreement between theoretical and FEA results.**

Key Words: Steel leaf spring, E-glass fiber/epoxy, dynamic analysis, Finite element analysis, toughness

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1. INTRODUCTION

In recent year, the automobile manufacturer is receiving an attention to reduce weight of the vehicle and it is found that the leaf spring is the major source for reducing the weight of the vehicle because it accounts for10 to 20 % unsprung mass. Generally, metal leaf spring buffers shocks, jerks and vibration. The failure of metal leaf spring was identified as catastrophic. Great effort has made by automotive industries in the application of leaf springs made from composite material [1][2]. Because of high strain energy, high strength to weight ratio compared with those of steel are being replace by composite leaf spring [3].Unidirectional glass fiber was used for fabricating composite leaf springs and stressed the importance of enhanced ultimate and fatigue strength [4].However, unidirectional fiber makes weak joint at the eye end of leaf spring so decreases the performance of composite leaf spring. However, when vehicle come across certain bumps then because of sudden impact load there is a possibility of composite leaf spring getting damaged. These damages may be in the form of de-lamination, matrix cracking and fiber failures. Hence, strength and stability of composite leaf spring decrease. Therefore, it is necessary to estimate the effect of sudden impact load on the strain energy absorbed by the leaf spring material. However, toughness is a measure of the amount of strain energy a material can absorb before fracturing. Generally strain energy can be calculated on the basis of deflection, different loading and using different type of structure. In present work (i) theoretical and (ii) Analytical (FEA) method has been proposed and used for estimating the strain energy of leaf springs.

2. MATERIAL AND METHOD

2.1 Specification of steel leaf spring

For this purpose Tata Ace (two tone) commercial vehicle multi steel leaf spring has been selected and with design parameters of existing multi steel leaf spring used in this work are : Material of leaf spring 65Si7; Total length (eye to eye) 860 mm; Arc height of axle seat (camber) 90 mm; spring rate 23.1 N/mm ; number of full-length leaves 01; number of graduated leaves 02;width of leaves 60mm; thickness of each leaves 08 mm ; full bump loading 4169N ; spring weight 10.5 kg ; Young's modulus $2.1x10^5$(N/mm^2); Available space for spring width 40-45 mm.

2.1.1 Properties of steel leaf spring

The material properties of existing leaf spring are : Material of leaf spring -65Si7, Young's Modulus-2.1 x 105 MPa, Poisson ratio-0.266, Tensile strength Ultimate-1272 MPa, Tensile Yield strength-1158 MPa, Density-7.86x10-6 kg/mm3, Allowable stress -540MPa.

2.2 Selection of fiber

However, Different kinds of fibers such as carbon fiber, C-glass, S-glass were used by many researchers in numerous applications. Even if, carbon/epoxy material was more suitable for leaf spring than other fibers, but carbon fiber is found to be too expensive. Because of its high cost, it has limited applications. Therefore, promising relations between cost and properties of a material can be attained with E-glass fiber/epoxy. E-glass fiber with $(0/45/0/45)_S$ is selected as the leaf spring material having following mechanical properties: modulus of elasticity ,E11, 34GPa and E22,6.53GPa; modulus of shear,G12, 2.4GPa; Poisson ratio,0.21;tensile strength ,σ_t ,900MPa; compressive strength , σ_c,610MPa; density, ρ, $2.6x10^{-6}$ kg/mm^3.

2.3Theoretical Method to Estimate Strain Energy

Strain energy is the energy stored in a body due to deformation. The strain energy of steel and mono composite leaf spring was calculated using mathematical equations of specific elastic strain energy for strain energy.

$$S = \frac{1}{2}\left(\frac{\sigma 2}{\rho E}\right) \ldots\ldots\ldots(I)$$

Where, S- strain energy, ρ - density of material, ,σ – Stress and E - Young's modulus of spring material. Therefore, strain energy is the energy stored in steel and composite leaf spring using theoretical approach are shown in table.1

2.4 Analytical Method to Estimate Strain Energy

The strain energy response of leaf springs was computed using the finite element method (FEM). Composite leaf spring (CLS) having 24 mm thickness was designed and modeled in CATIAV5R18 then this was finally imported into ANSYS. An element selected was solid 46 and the layer selection was done in ANSYS composite prepost (ACP) using the stacking sequence arrangement of $[0/45/0/45]_s$

2.4.1 Procedure

The leaf springs designed for (FEM) in ANSYS was taken and three basic steps were used for modeling and analyses of leaf spring as shown below:

- ***Preprocessing*** :Building FEM model ,Geometry Construction, Mesh Generation, Application of Boundary Input other load and supporting condition.
- ***Solving***: Submitting the model to ANSYS solver ,Take the result required. Insert-Strain –Energy,Solve the solution after all inputs are given.
- ***Post Processing***: Checking and evaluating results,Presentation of results- Strain contour plot, The geometric model of leaf springs was imported into ANSYS. A 3D structure element with nodes was being used to mesh the geometry of leaf spring.
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Type of Element	Solid 46
Number of Elements	3468
Modes Generated	3689
Type of meshing	Tetrahedral Mesh
Refinement factor	1

Table 1 : Comparative analysis of Steel and Composite leaf spring

Steel leaf spring				Composite leaf spring		
	Strain Energy (J)			Strain Energy (J)		
Load (N)	**Theoretical**	**FEA**	**% Error**	**Theoretical**	**FEA**	**% Error**
4169	6.59	6.2329	-5.42	57.69	60.217	4.38
5169	10.13	9.5817	-5.41	78.7	83.539	6.15
6768	14.43	15.01	-3.8	112.09	119.01	5.8
7000	18.59	17.572	-5.48	144.9	153.2	5.73
8000	24.29	22.951	-5.51	188.59	200.1	6.1
9000	30.32	29.048	-4.2	238.66	253.26	6.12

Assuming a simply supported condition of leaf spring, a vertical force from 4169 N was applied at the eye end of steel leaf spring shown in fig. Later on load on steel leaf spring were increased in step of 1000N and corresponding strain energy was determined represented in Table1. Similar procedure was used for modeling, meshing, boundary and loading condition for composite leaf spring. Fig1. shows corresponding strain contour plot of steel leaf spring for the load ranging from 4169 to 9000 N.

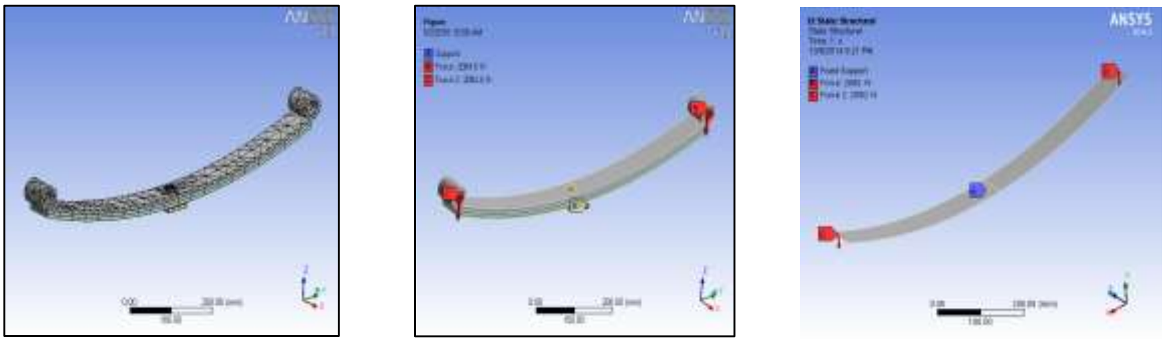
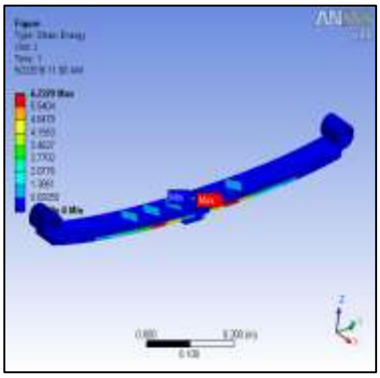


FIGURE 3: Meshing and Boundary and Loading condition of steel and composite leaf spring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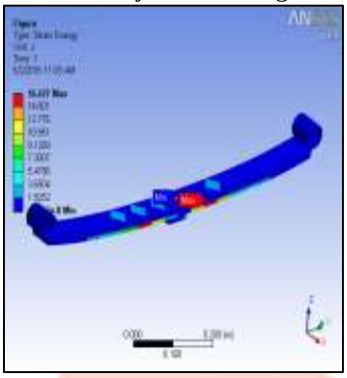
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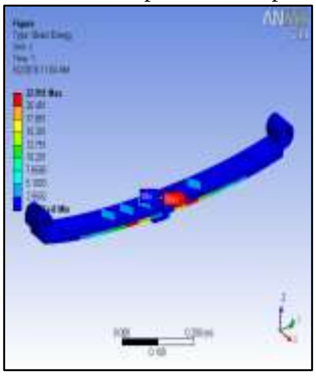
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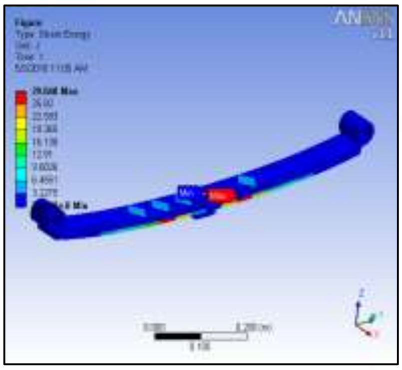
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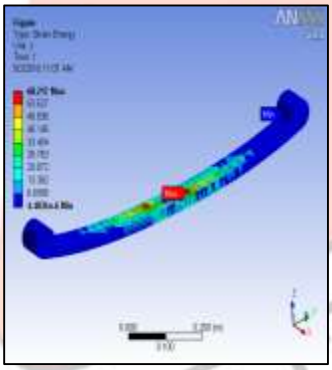
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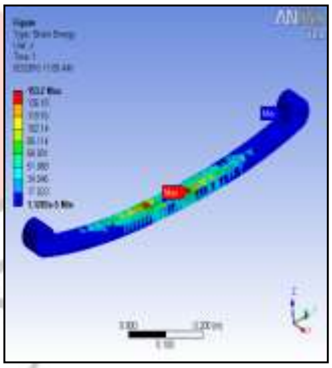
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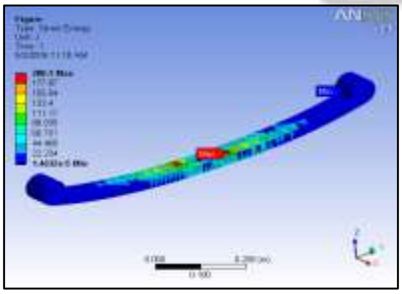
(g)

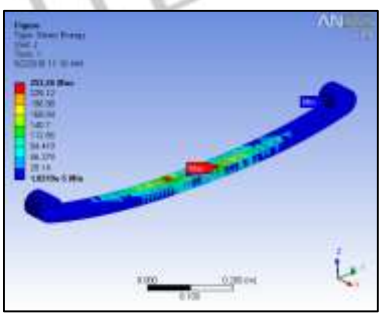
(h)

Fig.: Strain contour plots for composite and steel leaf spring

3. RESULT AND DISCUSSION

The strain energy at which last failure occurs in steel leaf spring was seen to vary from 30.32J and for composite leaf spring it was 200.38 J. A different result was also observed by earlier researchers such as Assarudeen [11] when they computed strain energy by FEA on composite mono leaf spring with unidirectional E-glass fiber**.** The strain energy of composite leaf spring is increased by approximately 88.39 % when the leaf spring was subjected to 4169 N load. As E-glass fiber has lower modules of elasticity therefore, all of strain energies calculated for composite leaf spring in this study, were significantly higher than the strain energy of steel leaf spring. Hence this shows, composite leaf spring is tougher than steel leaf spring, thus, this be able to sustain the sudden impact force of a large magnitude up to 9000N. Accordingly, it enhances the life of the composite leaf spring for the sudden impact by the road conditions. Besides, the maximum load sustained by the composite leaf spring can also be considered to be as measure toughness. Table demonstrated the strain energy of both steel and composite leaf spring with respect to various load. It can be seen that, percentage error for strain energy of both leaf springs was found to be less than 10 %. Thus, better agreement between theoretical and FEA results were observed.

4. CONCLUSION

Thus from above analysis, it can be concluded that The strain energies of steel and composite mono leaf spring were estimated using the theoretical approach and its results were compared with commercial FEA software. Composite leaf spring has higher strain energy than steel leaf spring. Therefore composite leaf spring was found to be tougher than steel leaf spring and can sustain maximum sudden impact load by the road during running of vehicle. Besides, better agreement for strain energy was observed in theoretical and FEA method.

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