DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING UNDER FATIGUE LOAD CONDITION

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ABSTRACT
The leaf spring is the main part used in automobile suspension system. It needs to have excellent fatigue life. The purpose of this paper is to predict the fatigue life of steel leaf spring along with numerical stress and deflection calculations. The objective is to compare the load carrying capacity, stiffness and weight savings of leaf spring with that of steel leaf spring. The design constraints are stresses and deflections. In the present work improvement areas where one can improve the product quality while keeping the minimum cost. In the present work, Finite element method has been implemented to modify the existing leaf spring with GFRP material consider the dynamic load effect. Thickness value at different lengths plays a vital role on stiffness achieved. Hence effect of thickness variation under tolerance zone has been studied in arriving at best possible tolerance value for leaf thickness.

Keywords:
Leaf Spring, Fatigue Analysis, Suspension, GFRP

INTRODUCTION

A leaf spring is commonly used for the suspension in wheeled vehicles. Literally called a laminated or carriage spring, and often referred as a semi elliptical spring or cart spring.A leaf spring takes the form of arc-shaped length of spring steel of rectangular cross-section. The centre of the arc helps in locating the axle, while tie holes are provided at either end for clamping to the vehicle body. For very heavy load vehicles, several leaves stacked on top of each other in several layers to manufacture spring, often with progressively shorter leaves. Leaf spring servesin locating as well as damping and springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction. For this reason manufacturers have done many trials on mono-leaf springs. In this research paper the design and analysis of leaf spring made of GFRP under fatigue load conditions.Many papers have been done on the application of composite materials for automobiles. Rajendran*et al* [1, 2] have studied the application of composite materials for automobiles and design optimization of a FRP leaf spring. Numerous works has been done in the automotive industries in the application of leaf springs made from composite materials such as GFRP etc., [3, 4]. S. Vijayarangan [5] has done research work on reducing the weight of automobile parts by manufacturing the parts usingfiber reinforced plastics (FRP) for obtaining reduction of the load carrying capacity. High elastic strain energy storage capacity of GFRP materials and its high strength-to-weight ratio compared with steel, multi-leaf steel springs can be altered by mono-leaf FRP springs [6, 7].To meet the needs of natural resource and energy conservation along with cost reduction, automobile manufacturers havebeen planning to reduce the weight of wheeled vehicles recently [8]. The suspension spring is one of most important system in automobile which reduce shaking, vibration and absorb shock loadson motion. FRP have been developed for many applications, mainly because of the weight reduction factor. Other uses of using FRP instead of steel are the possibility of reducing noise, vibrations and ride harshness due to their high damping factors as well as the absence of corrosion problems that leads to lower maintenance costs and reduction in tooling costs.[9]. The principles of the suspension springs for an automobile are to maintain a stability and to improve comfort while driving [10] due to composite design and manufacturing, complications arise; for example, the change from relatively isotropic-homogeneous steel alloys to anisotropic in homogeneous FRP has not yet been achieved [11].

EXPERIMENTAL PROCEDURE

Material properties

The material of the spring steel was, according to the spring's manufacturer, SUP 9 (JIS). Standard comparison indicated that the SUP 9 spring steel is equal to the 55Cr3 spring steel in European standards. Society of Automotive Engineers (SAE) number for the 55Cr3 is 5160. Fatigue properties of the steel were determined according to SAE from the GlyphWorks material properties database. Material values from the finish standards association's standard SFS-EN 10089 and from the Glypworks material database are presented below. The material properties of the SAE5160/SUP 9/55Cr3 has been given in table 1. Table 2 & 3 represents the parameters of the leaf spring.

Table 1. Material properties

Material Properties		
SAE5160/SUP 9/55Cr3		
Elastic Modulus, E	207	GPa
Yield Strength, R_{eL}	1250	MPa
Ultimate tensile strength, R_m	1600	MPa
Work Hardening Coefficient, K	1940	MPa
Fatigue Strength Coefficient, S_f	2063	MPa
Cyclic Strength Coefficient K'	2432	MPa
Work Hardening Exponent, n	0.05	
Fatigue Strenght Exponent, b	-0.08	
Fatigue Ductility Exponent, c	-1.05	
Fatigue Ductility Coefficient E_f	9.56	
Cyclic Strain-hardening Exponent, n'	0.13	
Cut-off, N_c	2.00E+08	Reversals

Table 2. Dimensions of leaf spring

Parameters	Values
Total length (eye-to-eye), mm	1150
Arc height at axle seat(Camber), mm	175
Spring rate, N/mm	20
Number of full length leaves	2
Number of graduated leaves	5
Width of the leaves, mm	34
Thickness of the leaves, mm	5.5
Full bump loading, N	3250
Spring weight, kg	13.5

Table 3. Parameters of leaf spring

Parameters	Values
Modulus of elasticity, GPa	E11, 38.6
Modulus of elasticity, GPa	E22, 8.27
Modulus of shear, GPa	G12, 4.14
Poisson ratio, (νxy)	0.26
Tensile strength, MPa	σt11, 1062
Tensile strength, MPa	σt22, 31
Compressive strength, MPa	σc11, 610
Compressive strength, MPa	σc22, 118
Shear strength, MPa	σc12, 71

RESULTS & DISCUSSION

The suspension obtained using the deformation of GFRP leaf spring is comparably much higher than the leaf spring made of steel which is evident in figure 1&2. The deformation value of the GFRP leaf spring is 1.6836 mm whereas for the steel leaf spring is 0.011481 mm. This is because the ductile property for the GFRP material is higher than the steels.Figure 1and figure 2 show the deformation of steel leaf spring and GFRP leaf spring.Figure 3 & figure 4 shows the stress plot for steel and GFRP leaf spring, respectively. The stress value of GFRP is much lower than steel leaf spring which has been evident in figure 3 & 4. The stress value of GFRP leaf spring is 22.761 N/mm^2 whereas for the steel leaf spring is 47.617 N/mm^2. This is because toughness factor of GFRP leaf spring is comparably better than steel leaf spring.

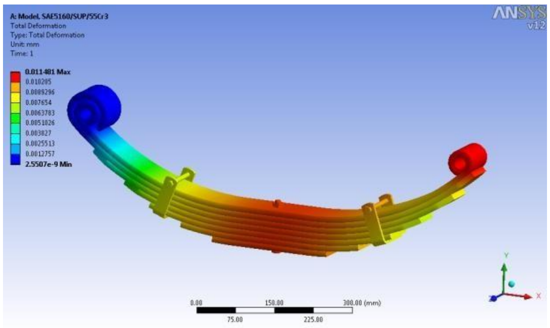

Figure 1. Deformation of steel leaf spring

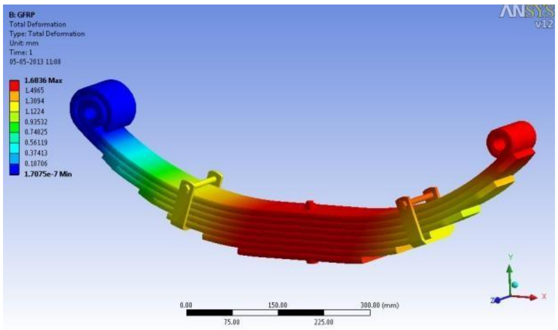

Figure 2. Deformation of GFRP leaf spring

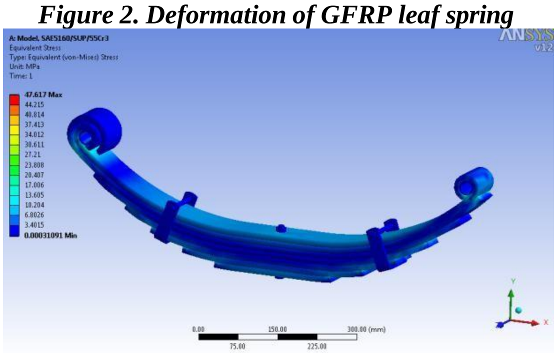

Figure 3. Stress plot for steel leaf spring

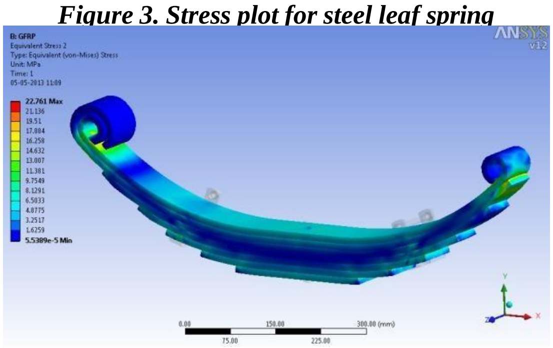

Figure 4. Stress plot for GFRP leaf spring

CONCLUSION

This research paper deals with the validation in the design and strength of the leaf spring along with structural and fatigue analysis.By observing the results, the analyzed stress values have been lesser than their respective yield stress values in the GFRP leaf spring. So the proposed design is safe. By comparing the results for both materials, the stress value for the steel leaf spring is higher than GFRP leaf spring. So it has been concluded that as per the standard analysis using material GFRP for leaf spring is considered.

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