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Static and Fatigue Behavior of Steel and Glass Epoxy Composite Leaf Spring of Light Motor Vehicle

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Abstract: The automotive sector has heart enthusiastic interest for the replacement of steel leaf spring with that of glass fiber along with epoxy resin composite leaf spring. In this study the material selected is glass fibers reinforce plastic and Epoxy resin can be used which is more economical to reduce total cost of composite leaf spring. The objective is to reduce cost, weight that is capable of carrying given static external forces without failure. The constraints are stresses and displacements. In the present work the static analysis of the glass epoxy composite material is done experimentally and validates their result by using ANSYS 14.0.The stresses developed in the steel leaf spring is higher than that of composite leaf spring. According to the previous literature of SAE it is predicted that the fatigue life of steel leaf spring is up to 10^6(10, 00,000) cycles. In this work with help of ANSYS workbench 14.0 the fatigue life of the glass epoxy composite is predicted it is up to 10^9(1000000000)cycles which are higher than steel leaf spring. The weight of the composite leaf spring nearly 64.28%l lower than that of the steel leaf spring.

Keywords: composite leaf spring,static analysis, fatigue life, FEA.

I. INTRODUCTION

Highlight Leaf spring is one of the important elements of the suspension system. Steel leaf spring is relatively high weight and so that whole suspension system becomes bulky. Because of weight during cornering of vehicle that will lead to over steer and directional instability under such condition it is difficult for driver to control the vehicle during negotiating the curve and also leads to discomfort of the occupants. The suspension system is responsible for the ride comfort and handling of the vehicle. Quality of vehicle ride depends on the individuality of the leaf spring used in the suspension unit. The leaf springs serve to absorb and store energy and then release it. The number of steel leaf spring required more for desirable output in case of steel leaf spring. Weight and stresses are the predominant issues occur in the use of the steel leaf spring. So there is necessity for the replacement of the steel leaf spring with composite leaf spring. Though composite leaf spring having better strength to weight ratio and having lighter weight than that of steel leaf spring.

II. TOOLS

ANSYS Workbench 14.0 is used for analyzing the performance of the existing and composite leaf spring. The model is prepared in the Pro-E wildfire 5.0 and import in the ANSYS workbench 14.0.The analysis is carried out at the same condition for both the springs by using ANSYS workbench 14.0 and results are represented.

III. LITERATURE SURVEY

The vehicle manufacturing company attempting to reduce the weight of the vehicle and also to enhance the performance of the vehicle without changing the load carrying capacity and function of the leaf spring. The available literature on leaf spring made of steel and composite materials were reviewed in the following paragraph, Kothari et al(2012) describe the static and fatigue life analysis of two conventional leaf spring made of respectively SUP9 and EN45.This springs are compare for maximum stress, deflection and stiffness as well as fatigue life. The CAD model prepare in CATIA and analyzed by using ANSYS 12.1.Goud et al (2012) consider the typical leaf spring configuration of TATA-407 light commercial vehicle is chosen for study.Finite element analysis is carried out by using ANSYS to determine safe stresses and pay loads. Charde et al(2012) consider the master leaf and studied the effects of cyclic loading on the performance of the suspension system.

The work evaluation of stress in master leaf over the span is studied using finite element method and strain gauge technique. Gubeljak ,et al(2011) consider high strength steel grade 51 Cr V4 in thermo mechanical treated condition is used as bending parabolic spring of heavy vehicles. The investigation show that fatigue threshold for very high cycle fatigue depends on inclusion’s size and material hardness. Based on the literature survey it is decided to select E-glass fiber/Epoxy resin as composite material for leaf spring and compare the results with the results of the available results of EN45 for same working condition.

IV. Tables: Table 1.Dimension of the steel leaf spring

parameter	Specification
Length of the spring(mm)	990
Camber of the spring(mm)	127
Width of the spring(mm)	50
Thickness of the spring(mm)	10

The above dimension are same for the composite leaf spring only the difference is that here in this work the design selection is varying width varying thickness type. so the thickness is gradually decreased from axel seat to eye end and width is gradually increase from axel seat to eye end.

Table2Dimension of the Composite leaf spring,

Parameter	Specification	
Length of the spring(mm)	990	
Camber of the spring(mm)	150	
Width of the spring(mm)	Center	35
	End	65
Thickness of the spring(mm)	Center	20
	End	9

IV. SELECTION OF THE COMPOSITE MATERIAL

The capability to soak up and accumulate more amount of energy ensures the comfortable operation of a suspension system. However the high weight and more stress are the main causes for existing steel material. Which can more overcome due to characteristics of the glass fiber and epoxy resin So in this work the selection of fibers are 0.7. This was having less modulus of elasticity and mass density and high specific strain energy capacity.

V. STATIC ANALYSIS OF COMPOSITE LEAF SPRING

Fig.1 Static Analysis of Composite Leaf Spring

As the work of interest is regarding with maximum loading condition therefore here the maximum value of deflection shown in the following table 1.

Table 1. Deflection of the composite leaf spring at maximum load

Sr No.	Load(N)	Deflection(mm)
1	3250	118

As the deflection of the composite leaf spring is more it means it having high load per unit deflection characteristic, such spring offers high stiffness coefficient.

VI. STRESS ANALYSIS USING STRAIN GAUGE TECHNIQUE

Fig.2 Experimental Method to calculateStresses induced in the Leaf Spring.

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Table 2 Strain value at Maximum Deflection

Sr.No	Deflection(mm)	Load(N)	Strain (Microstrain)
1	118	3250	7299

The above reading measured according to deflection value as the deflection reaches to 5mm note the load applied. At the same time note the reading of strain gauges fixed at some distance from After doing simple conversion the value of strain is, $\varepsilon = 7299\text{x}10^{-3}$.By using Hook's law we are getting the values of stresses.knowing the young's modulus of elasticity which is calculated by using imperial relations of volume percentage of fiber and matrix 28.9 Mpa.So the maximum stresses induced in the leaf spring is,

$\sigma = E \text{ x } \varepsilon = 210.9411\text{N/mm}^2$

VII. ANALYTICAL METHOD TO CALCULATE DEFLECTION AND STRESSES IN THE COMPOSITE LEAF SPRING

1) Calculation for deflection of composite leaf spring is done by using

$$\delta = \frac{WL^3}{3EI}$$

Maximum deflection by analytical method, **δ =**112.63mm

2) Calculation for stresses induced in the spring is done by using,

$$\sigma = \frac{6WL}{bt^2}$$

Maximum stress by using analytical method, $\sigma = 232.75 \text{ N/mm}^2$

VIII. STRESS AND FATIGUE LIFE ANALYSIS BY USING ANSYS WORKBENCH 14.0

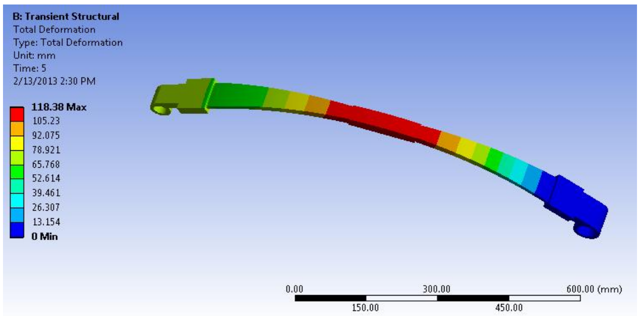

Fig. 3Defelection of Composite leaf spring

The maximum deflection of the composite leaf spring was 118.38 mm. Which is lower than that of the steel leaf spring (EN45) 127.01 mm available in literature. The lower deflection offers high stiffness. That was one of the desirable properties of the leaf spring. It means in this case the stiffness of the leaf spring is higher than steel leaf spring.

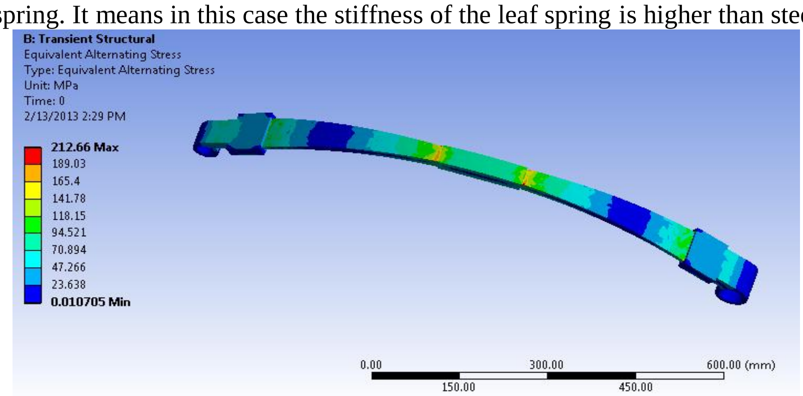

Fig.4 Stress analysis of the composite leaf spring

The stresses induced in the composite leaf spring was 62.27% lower.which was concetrated at the center of the leaf spring.Which was 212.66N/mm^2.As the fatigue life evaluation is one of the criteria for checking the performance of the leaf spring .Further analysis done for life prediction of composite leaf spring by using ANSYS workbench 14.0

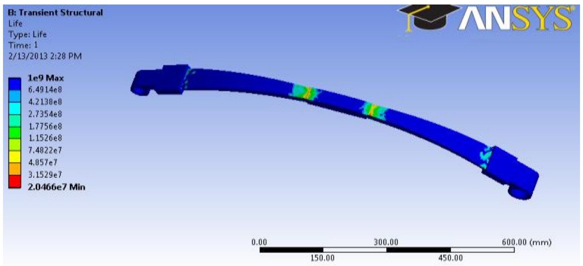

Fig.5 Prediction of Fatigue Life of the Composite Leaf Spring

As fatigue life prediction was one of the objective of the present thesis so with the help of ANSYS workbench 14.0 It was predicted that the minimum fatigue life of the composite leaf spring $2.0466 x 10^7$ and maximum predicted fatigue life of the composite leaf spring up to $1x10^9$cycles.

IX. WEIGHT REDUCTION ANALYSIS OF COMPOSITE AND STEEL LEAF SPRING.

As one of the objective of the present work is to reduce the weight of the leaf spring .Though in the present thesis the material is replace from steel to glass epoxy composite material the weight comparison is as follows,

Table 5.6 Weight Comparison of Steel and Composite Leaf Spring

Leaf spring type	Steel	Composite
Weight(Kg)	13.4 (with eye)	4.652 (with eye)

It was cleared that the weight reduction is achieved up to 65.28% than that of composite leaf spring.

X. RESULTS AND DISCUSSION

Parameter	Steel Leaf spring[7]		Composite leaf spring		
	Analytical	FEA	Expt.	Analytical	FEA
Load(N)	3250	3250	3250	3250	3250
Max. Stress(N/mm^2)	960	1004	232.7	210.94	212.66
Maximum Deflection(mm)	116.49	127.01	118	112.63	118.38
Stiffness(N/mm)	27.89	25.58	27.54	28.85	27.45
Predicted Fatigue life (cycles)	-	10^6	-	-	10^9
Weight(Kg)	13.4		4.652		

After finding the performance of the composite leaf spring by using different techniques at this stage of thesis the concert of the steel leaf spring is compare with the fabricated Composite leaf spring.

As the main interest of the study was to check the performance of the composite leaf spring over to that of existing steel leaf spring at high load 3250N.It was clear from above results that the deflection of the steel leaf spring was less than that of the steel leaf spring. Also the stresses induced in the steel leaf spring 62.27 % higher than that of the composite leaf spring. It was observed that the fatigue life of the steel leaf spring was up to 10^6 cycles and the fatigue life of the composite leaf spring predicted up to 10^9 cycles.

XI. CONCLUSION

These results are validated with analysis software. After validating the experimental result with the ANSYS 14.0, it will be concluded that By using composite leaf spring the weight is reduced by 65.28% as compare to steel leaf spring. This reduction is considerable and helps to reducing the unsprung weight, which in turn insures better control. The stiffness of the composite leaf spring is higher than steel leaf spring by 6.81% and 3.32% according to FEA and Analytical. So there will be improvement in comfortless. The amount of stresses for the same loading is less by 62.27% as compared to steel leaf spring. The life of the spring is an important criterion. In this aspect as well composite leaf spring proves to

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be much better than EN45 steel leaf spring. The predicted life of the composite leaf spring is 10^9cycles as compared to 10^6 cycles of steel leaf spring. With the above conclusions, the composite leaf spring proves much better in all aspects as compared to EN45 leaf spring.

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