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Experimental Investigation of Hybrid Fiber Mono Composite Leaf Spring for Automobile Applications

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Abstract:

The Automobile industry has shown keen interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance. Present study was to replace material for leaf spring. In present study the material selected was glass fiber reinforced plastic (GFRP) and Kevlar fibers reinforced plastic can be used which was more economical this will reduce total cost of composite leaf spring. A spring with constant width and thickness was fabricated by hand lay-up technique which was very simple and economical. Stresses and deflection results were verified for analytical and experimental results. The experimental analysis of a mono fiber has been carried out. Hybrid fiber composites leaf springs (i.e.) Kevlar fiber reinforcement plastic and Glass fiber reinforcement plastic (GFRP) is to be carried out. Primary objective is to compare the load carrying capacity, stiffness and weight saving of a composite leaf spring with that of a steel leaf spring.

Keywords: *Kevlar, Glass fiber, Steel leaf spring, Composite leaf spring, Experimental Analysis*

INTRODUCTION

Weight reduction has been the main/primary focus of automobile manufactures. Suspension leaf spring, a potential item for weight reduction in automobiles, accounts for 10-25 percent of unsprung weight, (which is considered to be the mass not supported by leaf spring). Application of composite materials reduces the weight of leaf spring without any reduction on the load carrying capacity and stiffness in automobile suspension system(Daugherty,1981;Breadmore,1986;Morris,1986). A double tapered beam for automotive suspension leaf spring has been designed and optimized (Yu & Kim,1988). Composite mono leaf spring(Rajendran & Vijayarangan,2001) has also been analyzed and optimized. Leaf spring should absorb vertical vibrations due to road irregularities by means of variations in the spring deflection so that potential energy is stored in the spring as strain energy and then released slowly. So, increasing energy storage capability of a leaf spring ensures a more compliant suspension system. A material with maximum strength and\ minimum modulus of elasticity in longitudinal direction is the most suitable material (Corvi, 1990) for a leaf spring. Important characteristics of composites(Springer &\ Kollar,2003) that make them excellent for leaf spring instead of steel are higher strength-to weight ratio, superior fatigue strength, excellent corrosion resistance, smoother ride, higher natural frequency, etc. Fatigue failure is the predominant mode of in-service failure of many automobile components, especially the springs used in automobile suspension systems. Fatigue behaviour of Glass Fiber Reinforced Plastic epoxy (GFRP) composite materials has been studied (Hawang & Han,1986). A composite mono-leaf spring has been designed and their end joints are analyzed and tested for a light weight vehicle (Shivasankar & Vijayarangan, 2006). Experimental and numerical analysis are carried out on a single leaf constant cross section composite leaf spring (Jadhao & Dalu, 2011). Theoretical equation for predicting fatigue life, formulated using fatigue modulus and its degrading rate, is simplified by strain failure criterion for practical application. A prediction method for fatigue strength of composite structures at an arbitrary combination of frequency, stress ratio and temperature has been presented (Yasushi,1997). In the present work, a 7-leaf steel spring used in a passenger car is replaced with a composite multi leaf spring made of glass/epoxy composites. Dimensions and number of leaves of steel leaf spring (SLS) and composite leaf spring (CLS) are considered to be same. Primary objective is to compare their load carrying capacity, stiffness and weight savings of CLS. Ride comfort of both SLS and CLS is found and compared. Also, fatigue life of SLS and CLS is also predicted. This chapter of the book explores the work done on design optimization, finite element analysis, analytical & experimental studies and life data analysis of steel and composite leaf springs (Senthilkumar & Vijayarangan,2007).

LITERATURE REVIEW

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.

PROBLEM IDENTIFICATION

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Suspension leaf spring, a potential item for weight reduction in automobiles, accounts for 10-25 percent of unsprung weight, (which is considered to be the mass not supported by leaf spring). Application of composite materials reduces the weight of leaf spring without any reduction on the load carrying capacity and stiffness in automobile suspension system (Daugherty,1981;Breadmore,1986;Morris,1986). A double tapered beam for automotive suspension leaf spring has been designed and optimized (Yu & Kim,1988). Composite mono leaf spring (Rajendran & Vijayarangan,2001) has also been analyzed and optimized. Leaf spring should absorb vertical vibrations due to road irregularities by means of variations in the spring deflection so that potential energy is stored in the spring as strain energy and then released slowly. So, increasing energy storage capability of a leaf spring ensures a more compliant suspension system. A material with maximum strength and minimum modulus of elasticity in longitudinal direction is the most suitable material (Corvi,1990) for a leaf spring. Important characteristics of composites (Springer & Kollar,2003) that make them excellent for leaf spring instead of steel are higher strength-to weight ratio, superior fatigue strength, excellent corrosion resistance, smoother ride, higher natural frequency, etc. Fatigue failure is the predominant mode of in-service failure of many automobile components, especially the springs used in automobile suspension systems. Fatigue behavior of Glass Fiber Reinforced Plastic epoxy (GFRP) composite materials has been studied (Hawang & Han,1986). A composite mono-leaf spring has been designed and their end joints are analysed and tested for a light weight vehicle (Shivasankar & 29 Vijayarangan, 2006). Experimental and numerical analysis are carried out on a single leaf constant cross section composite leaf spring (Jadhao & Dalu, 2011). Theoretical equation for predicting fatigue life, formulated using fatigue modulus and its degrading rate, is simplified by strain failure criterion for practical application. A prediction method for Materials 60 Science and Technology fatigue strength of composite structures at an arbitrary combination of frequency, stress ratio and temperature has been presented (Yasushi,1997). In the present work, a 7-leaf steel spring used in a passenger car is replaced with a composite mono leaf spring made of Kevlar/E-glass composites. Dimensions and number of leaves of steel leaf spring (SLS) and composite leaf spring (CLS) are considered to be same. Primary objective is to compare their load carrying capacity, stiffness and weight savings of CLS. Ride comfort of both SLS and CLS is found and compared. Also, fatigue life of SLS and CLS is also predicted. This chapter of the book explores the work done on design optimization, finite element analysis, analytical & experimental studies and life data analysis of steel and composite leaf springs (Senthilkumar & Vijayarangan,2007)

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 Kevlar fiber. 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.

DESIGN OF COMPOSITE MONO LEAF SPRING

From the analysis made on steel leaf spring and the available properties of carbon and E-glass fiber obtained from literature survey the design parameters of composite leaf spring has to be designed. After calculating stress and deformation by analytical method, the calculated values to be compared with design values to check whether the design is safe or not.

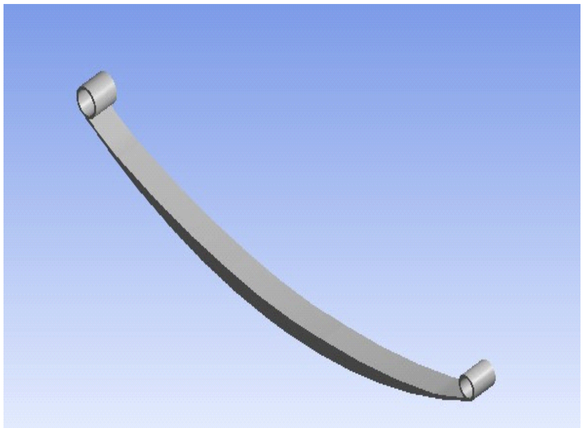

Fig 5.1 3D view of composite mono leaf spring

Table 5.1Dimension of the composite mono leaf spring

Parameter	Specification	
Length of the spring (mm)	990	
Thickness of the spring (mm)	Center	30
	End	7
Width of the spring (mm)	60	

ANALYSIS OF COMPOSITE MONO LEAF SPRING

Analytical Method

Bending Stress = $1.5WL/nbt^2$

$= (1.5*3500*990)/(1*60*30^2)$

$= 96.25\ N/mm^2$

Deflection = $4WL^3/nEbt^3$

$= (4*3500*990^3)/(1*92*10^3*60*30^3)$

= 91.44 N mm

Table 5.2 Deflection of the composite leaf spring at maximum load

S.NO	LOAD(N)	DEFLECTION(mm)
1	3500	91.44

EXPERIMENTAL METHOD

As the work of interest is regarding with maximum loading condition therefore here the maximum value of deflection

Figure 5.2 shows the comparison of load verses deformation of both steel and composite leaf springs. It is found that the deformation in composite leaf spring is higher than steel leaf spring for the given loading conditions. Figure 5.3 shows the comparison of load verses strain energy of both steel and composite leaf springs From the graph it is we can see the variations in the respective strain energies of both materials. It is found that the strain energy for composite leaf spring is higher than steel leaf spring. Figure 5.4 shows the comparison of load verses stress of both steel and composite leaf springs Observation of the graph indicates the difference level of stress of two different materials. It is found that the there is not much variation in stress for composite leaf spring is higher than steel leaf spring.

Fig 5.1 Testing of the composite leaf spring

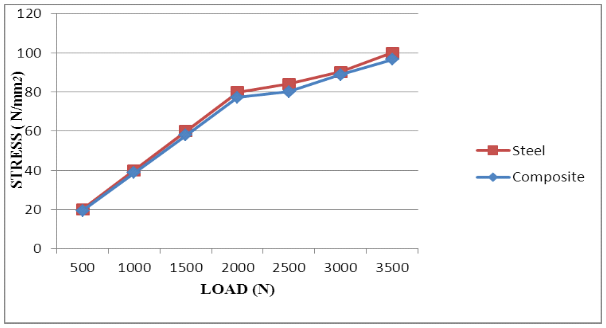

Fig.5.4 Stress Vs Load

- **CONCLUSION**

The Hybrid composite leaf spring was fabricated and tested. The Experimental results are compared with the existing steel leaf spring. The report proves that the composite material chosen (glass- and kevlar-fiber-reinforced plastic) can withstand the maximum load, the maximum deformation, and the maximum stress and can be used to create compact suspension systems.

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