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Comparison Of Performance Of Glass Fibre Reinforced Plastic Leaf Spring With Steel Leaf Spring

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Abstract: Increasing competition and innovation in automobile sector tends to modify the existing products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly.Leaf springs are one of the oldest suspension components that are being still used widely inautomobiles. Weight reduction is also given due importance by automobile manufacturers. The automobile industry has shown increased interest in the use of composite leaf springin the place of conventional steel leaf spring due to its high strength to weight ratio. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. Therefore the objective of this paper is to present a general study on the performance comparison of composite (Glass Fibre Reinforced plastic - GFRP) leaf spring and conventional leaf spring. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The conventional steel leaf spring and the composite leaf spring were analysed under similar conditions using ANSYS software and the results are presented.
Keywords: *Leaf spring,Composite ,Glass Fibre Reinforced plastic(GFRP).*

1. Introduction

Increasing competition and innovation in automobile sector tends to modify the existing products or replace old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of vibrations in the spring and the energy absorbed is stored in spring as strain energy and then released slowly. Thus strain energy of material used for spring is the important property to be considered. The specific strain energy is inversely proportional to the density and Young’s modulus. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Hence, composite material becomes a very strong candidate for such applications. The introduction of composite materials has made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity. Hence, steel leaf springs are being replaced by composite leaf springs.

2. Tool

ANSYS is engineering simulation software used for general purpose finite element analysis and for numerically solving mechanical problems. Here ANSYS 11.0 is used for analysing the performance of conventional and composite leaf spring. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The conventional steel leaf spring and the composite leaf spring were analysed under similar conditions using ANSYS software and the results are presented.

3. Literature survey

Al-Qureshi(2001)[2] has presented in his paper , a general study on the analysis, design and fabrication of composite leaf spring .He utilised hand lay-up vacuum bag process for fabricating composite leaf spring with variable thickness using fibre glass epoxy resin.

MahmoodM.Shokrieh (2003)[16] analysed and optimised the design of a fibre glass epoxy resin composite leaf spring using ANSYS V 5.4 software and concluded that the optimum spring width decreases hyperbolically and thickness increases linearly from spring eye towards axle seat.

Hou, *et al* (2007)[11] evolved the eye end design of a composite leaf spring for heavy axle loads by analysing there different designs of eye end attachments and found that in first and second design delamination failure occurred at interface of fibres that have passed around eye and spring body. The third design (open eye end design) was selected which overcame the delamination failure by ending the fibres at the end of the eye section.

Fuentes (2009)[9] analysed the reasons for premature fracture in leaf spring and found that it was the result of fatigue caused by combination of design, metallurgical and manufacturing deficiencies.

Mukhopadyey ,*et al* (1997)[17] investigated the premature failure of a leaf spring due to improper material processing and declared that the failure was due to improper quenching and also due to sulphur inclusions.

Composite leaf springs made from fibre glass and epoxy resin using filament winding technology was investigated by Richard Dave (2003)[4] and he declared that it eliminated the need for secondary mechanical fastening systems apart from achieving 50% of weight saving over steel leaf spring.

Ivo Cerny(2012)[13] reported that the total fatigue life and initial stiffness is related in GRP composite components and that temperature changes are of important concern in stud joints.

Sung Joon Kim (2006)[26] found that there is a strong relation between the extent of delamination or local stiffness reduction and reduction in impact force.

Subramanian(2010)[25] observed that increase in fibre length increased the bearing strength of leaf spring joint and long fibre leaf spring joint exhibits superior fatigue performance and hole elongation of long fibre reinforced leaf spring joint is low.

Subramaninan(2010)[24] declared that in glass fibre reinforced polypropylene leaf springs, the joint strength can be increased by decreasing the clearance between fastener and composite plate hole and that endurance strength of the joint is higher than that of the leaf spring design load and this can be used to improve the strength of joints.

ErolSanckatar (1999)[8] designed and manufactured composite leaf spring using E Glass and epoxy resin for a solar powered light vehicle and confirmed that stiffness requirements are met and failure does not occur.

Rajendran (2001)[19] used genetic algorithms for optimizing the thickness and the width of a composite leaf spring and achieved 75.6% of weight saving without altering the stiffness and strength of the leaf spring.

Based on the literature survey it is decided to select E glass / Epoxyresin as composite material for leaf spring and compare its performance with conventional steel leaf spring.

Table 1.Dimensions of the master leaf spring.

Parameters	Value
Length of master leaf spring	1200mm
Free camber	200mm
Thickness	6mm
Width	50mm

4.1. Dimensions of the Leaf Spring

Number of graduated leaves	=	6
Ineffective length	=	200 mm
Length of second leaf	=	1150 mm
Length of third leaf	=	1000mm
Length of fourth leaf	=	700 mm
Length of fifth leaf	=	580 mm
Length of sixth leaf	=	430 mm
Length of seventh leaf	=	300mm

This leaf spring is used in Ambassador car. Material used for steel leaf spring is 55 Si 2 Mn 90 steel.

5..Theoretical Calculations

Deflection $\delta = 6WL^3/nEbt^3$ (1)

$= 6 * 4000*500^3/7*2*10^5*50*6^3$

$= 198$ mm

Bending stress $\sigma = 6WL/nbt^2$ (2)

$= 6*4000*500/7*50*6$

$= 952.38 N/mm^2$

6. Selection of composite material

The ability to absorb and store more amount of energy ensures the comfortable operation of a suspension system. However, the problem of heavy weight of spring is still persistent when using steel leaf spring. This can be remedied by introducing composite material instead of steel which is normally used in the conventional leaf spring. It is well known that springs are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as

$U = \sigma^2/\rho E$ (3)

Where σ is the strength, ρ the density and E the Young's modulus of the spring material. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Research has indicated that E-Glass/Epoxy has good characteristics for storing specific strain energy. Hence E Glass/Epoxy is selected as the composite material.

7. Analysis of leaf springs using ANSYS

All the analysis for the springs is done by using ANSYS 11.0.For composite leaf spring the same parameters are used as that of conventional leaf spring. For designing of leaf spring the camber is taken as 200 mm. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The constraint is given at the two eye-rolled ends. One of the end is provided with translational movement so as to adjust with the deflection. This eye end is free to travel in longitudinal direction .This particular motion will help leaf spring to get flattened when the load is applied .The stress and deflection analysis is done for conventional and composite leaf spring using ANSYS software. The results for both composite and conventional leaf spring is compared and given below.

8. ANSYS Results for conventional leaf spring.

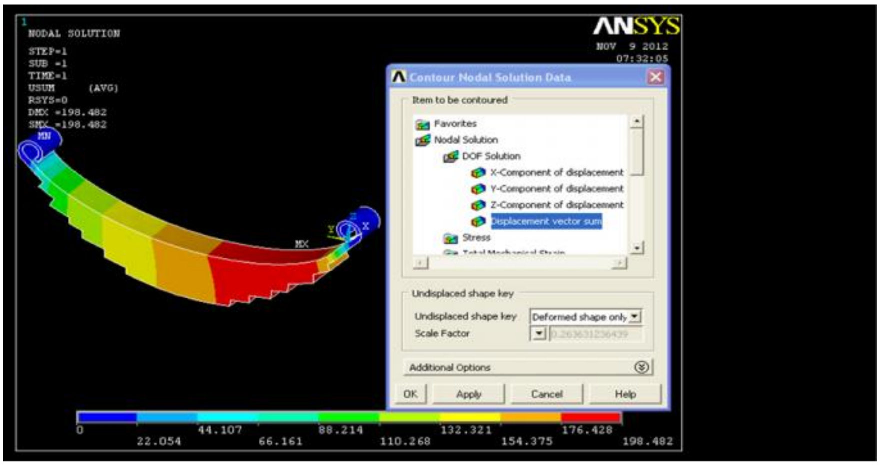

Fig. 1 Deflection analysis

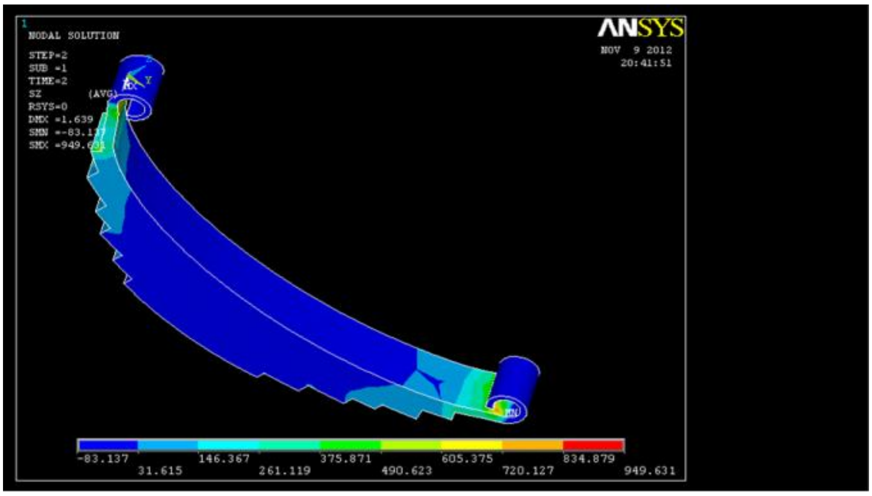

Fig 2. Stress analysis

9. Result comparison

Table 2.Comparison of Theoretical and Analytical Result.

Parameters	Theoretical Results	FEA Results	Error
Static load (N)	4000	4000	Nil
Deflection (mm)	198	198.48	0.24%
Bending Stress (N/mm^2)	952.38	949.63	0.29%

10. Ansys results for composite leaf spring

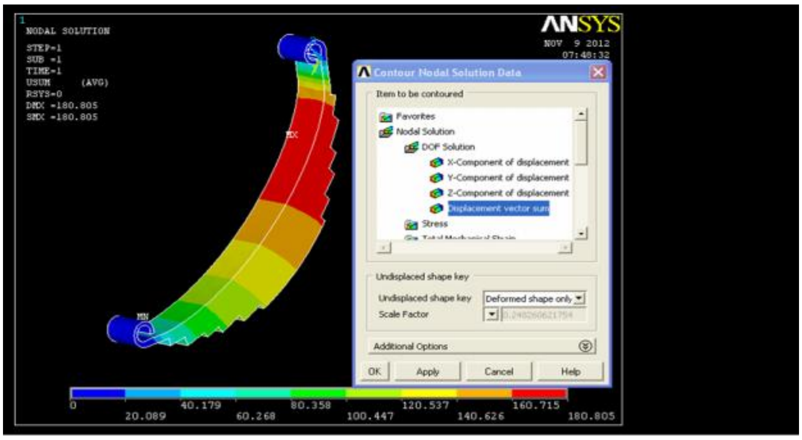

Fig.3 Deflection Analysis

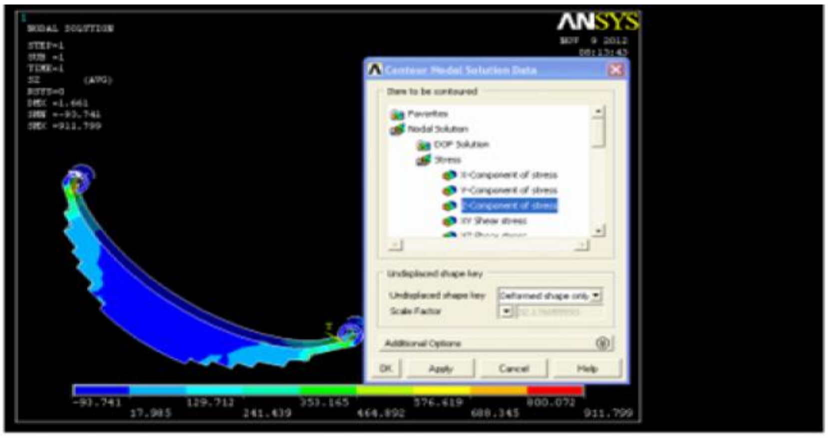

Fig 4. Stress Analysis

11. Result Comparison

Table .3 Comparison of Deflection and Stress

Material	Static Load (N)	Defection(mm)	Bending Stress (N/mm^2)
Steel	4000	198.48	949.63
E – Glass/ Epoxy	4000	180.81	911.79

For static load of 4000N the deflection is 198.48mm and bending stress induced is 949.63 N/mm^2 in steel leaf spring and for the same load the deflection is 180.81mm and bending stress is 911.79 for E – Glass/ Epoxy.

12. Conclusions

- Under the same static load conditions deflection and stresses of steel leaf spring and composite leaf spring are found with the great difference.
- Deflection of composite leaf spring is less as compared to steel leaf spring with the same loading condition.
- Bending stress is also less in composite leaf spring as compared to steel leaf spring with the same loading condition.
- Conventional steel leaf spring is also found to be heavier then E-Glass/Epoxy mono leaf spring.
- Composite leaf spring can be used on smooth roads with very high performance expectations.

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