

Design and Optimization of Automotive Leaf Spring Using Various Composites- An Overview

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ABSTRACT: The Automobile sector are showing profound attention for substituting leaf spring using composite leaf to attain diminution in weight, which would lead in upkeep of energy as it condenses overall fuel consumption of vehicle. In regards to this, this review intended to be an ample cradle for designing a leaf spring using several composites.

KEYWORDS: Stiffness, Composite Leaf Spring, E-Glass/Epoxy, S-Glass/Epoxy, Finite element method.

I. INTRODUCTION

Automobile sectors main emphasis is on safeguarding of natural resources, economizing energy and increasing competition to condense weight of a vehicle. Suspension system of a vehicle is a zone where revolutions are carried out habitually. Introduction of enhanced material, design optimization and enhanced engineering processes would lessen the weight, since the suspension leaf is a prospective element for weight reduction in automobile as its amount for 10-20% of the unsprung weight. The composite materials compromises prospects for the sizeable weight saving without conceding on load carrying ability and stiffness. Amalgamation of maximum strength and least possible elasticity modulus can be attained by numerous combination of composite materials.

II. LITERATURE REVIEW

Individually each paper is categorized, that is leaf spring by Glass Fibre Reinforced Epoxy with different combination been analysed is being explained in brief below.

H A Qureshi in his research paper on “Automobile leaf springs from composite materials” [1] developed a GFRP single leaf spring having constant width, where the stress level at any station in the leaf spring is considered constant due to the parabolic tape of the thickness of the spring, has proved to be very effective. Such a spring normally has lower flexure stress but higher nominal shear stress. In general, this study demonstrated that composites can be used for leaf springs for light trucks (jeeps) and meet the requirements, together with substantial weight saving. However, in the case of automobiles, the significant weight reduction may not cause the technological impact that it would for aircraft. Other work has shown that composite leaf springs have better fatigue behavior than steel springs. Needless to say, the hybridization technique can be used effectively to improve weight saving and performance in the automotive industry. It is worth mentioning that additional field testing is needed to define correctly the secondary design loads such as torsion, thrust, creep, fatigue and other operational restrictions. These tests should provide correlation with the existing laboratory data.

Abdul Rahim Abu Talib, Aidy Ali b, G. Goudah, Nur Azida Che Lah, A.F. Golestaneh in their reseach paper on “Developing a composite based elliptic spring for automotive applications” [2] developed finite element models to optimize the material and geometry of composite elliptical springs based on the spring rate, log life and shear stress and presents an investigation verifying that composites can be utilized for vehicle suspension with substantial weight savings. It also showed that the ellipticity ratio significantly influenced the spring rate and the life expectancy of the structure according to the level of loading and the number of cycles specified. The results showed that composite elliptical springs have better fatigue behavior than the conventional composite leaf and coil springs. The elliptical configuration successfully eliminates any possibility of delamination. The fabricated composite elliptic spring was constructed based on the optimization developed from the finite element analysis, which has an ellipticity ratio of ($a/b = 2$) and results in a substantial weight reduction.



Shahrukh Shamim and Jamil Anwer on “Design and optimization of automotive multi-leaf spring by finite element method [3] concluded that the leaf spring based on S-Glass Fiber Composite and Ti-6Al-4V alloy has a lower mass compared to AISI 6150 Steel. Total mass of S-Glass Fiber Composite, Ti-6Al-4V alloy and AISI 6150 steel based multi-leaf spring is 10.278 Kg, 18.318 Kg and 32.532 Kg respectively. Reducing the leaf spring mass in automobiles, we can achieve better riding comfort against hard braking and acceleration. Under the same static load conditions, the stresses in leaf springs are found with great difference. Stress in S-Glass Fiber Composite is found to be more as compared to conventional AISI 6150 steel. Titanium alloy based leaf spring, under same static loading conditions, shows lesser stress than S-Glass Fiber composite and AISI 6150 steel based leaf spring.

Jenarathanan M.P, Ramesh Kumar.S, Venkatesh.G, and Nishanthan.S in their research paper on “Analysis of leaf spring using Carbon / Glass Epoxy and EN45 using ANSYS: A comparison” [4] concluded the result of their work as below:

weight reduction of Leaf Spring and thereby improving performance of the vehicle. Weight of both Steel and Carbon/Glass Epoxy Leaf Springs obtained using ANSYS WorkBench 16.2 are shown in Table.1

Table 1. % Weight Reduction

Parameter	Value
Weight of steel EN45 A leaf spring	17.262 Kg
Weight of Carbon/Glass Composite Leaf Spring	3.672 Kg
% Weight Reduction	78.73%

Advantages:

- Approximately 79% weight reduction is achieved.
- Improved Vehicle performance and Efficiency.
- Corrosion problem is eliminated.

Disadvantages:

- Since Displacement is very high for Carbon/Glass Epoxy Leaf Spring, it may cause slight discomfort.
- High wear rate.

Stephan Krall and Richard Zemann in their research article on “Investigation of the Dynamic Behaviour of CFRP Leaf Springs” [5] explain that in figure 1 an arrangement of both measurements – excitation by shaker and impact excitation – is given by the modal damping ratio correlating to the resonance frequency of the test bodies. There are noticeable differences between the results of the shaker excitation and the impact testing. All dashed lines are results of the impact excitation. This occurs mainly due to the fact that there is no physical connection between the excitation and the structure when performing the impact test. Thus, the impact test avoids the problem of interaction between the structure and the excitation unit. This determines the different results between the measurement methods. The point of coupling of the shaker excited leaf spring makes exactly the same movement as the shaker itself. Thus, the best solution to determine the material properties and the dynamic characteristics – particularly for light weight structures like the leaf spring bodies – is an excitement by an impulse.

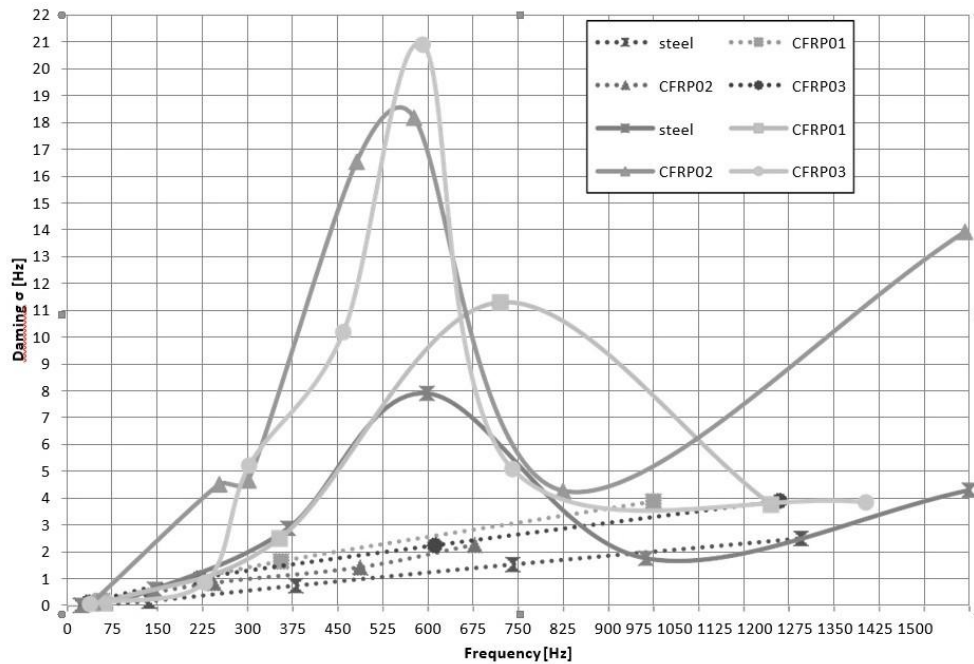


Fig. 1

Another result is the confirmation of the dependence between dynamic behavior and temperature. At lower temperatures the modal damping increases.

The analytical calculation shows that the CFRP springs can be calculated like a homogeneous body with constant Young's modulus providing a good approximation. Optimization in the construction of simple composite structures can be done by using the Euler – Bernoulli beam theory.

Thippesh L in his research paper on “Fabrication of Hybrid Composite Mono-Leaf Spring with Unidirectional Glass Fibers” [6] The deflection and maximum stress obtained for composite leaf springs experimentally have good agreement with steel leaf spring. Composite leaf spring reduces the weight by 80% for E-Glass/Epoxy compared to steel leaf spring. From the experimental results, it is observed that the stresses and deflections in integrated composite leaf spring are less compared to steel leaf spring. The composite mono composite leaf spring gives better performance and brings greater efficiency of the vehicle compared to steel leaf spring. Here the composite mono leaf spring could be replaced for the conventional steel leaf spring.

M Senthil Kumar and S Vijayarangan in their research paper on “Static analysis and fatigue life prediction of steel and composite leaf spring for light passenger vehicles” [7] carried out Design and experimental analysis of composite multi leaf spring using glass fibre reinforced polymer has been carried out. CLS is found to have lesser stress (67.35%), higher stiffness (64.95%) and higher natural frequency (126.98%) than that of existing SLS. Conventional multi leaf spring weighs about 13.5 kg whereas the E-glass/Epoxy multi leaf spring weighs only 4.3 kg, thereby weight reduction (68.15%) is achieved. Besides reduction of weight, fatigue life of CLS is predicted to be higher than that of SLS. CLS is observed as an effective replacement for the existing SLS. Simulated models (analytical and FEM) were found relatively stiffer than actual experimental design models of SLS and CLS.

E. Mahdi and A.M.S. Hamouda in their research paper “An experimental investigation into mechanical behavior of hybrid and non-hybrid composite semi-elliptical springs” [8] obtained a conclusion from their investigation as follows:

- Ellipticity ratio significantly affected the resilience energy absorption capability of composite elliptical tubes.
- For omni load direction the fiber and laminate stacking sequences were designed to withstand any resulting shear stress by employing the cross ply ($\pm 45^\circ$) laminates.
- The relaxation of the composite elliptic spring found to be very sensitive to the rate of compression. After 1.15 million fatigue cycles, composite elliptical spring's useful stroke is reduced by only 2% of its original height and no failure was observed.

- No hysteresis is observed under compression 50% of composite elliptical spring's useful stroke.
- The carbon-glass/epoxy elliptical springs exhibited higher spring rate but poor ride quality compared with the non-hybrid one.
- Adding four layers of carbon fiber control the load carrying capacity of hybrid composite elliptical spring.

III. CONCLUSION

This review provides a brief summary on the works carried out in designing and optimizing the leaf springs. To enhance the strength and diminution of overall weight of leaf spring many authors have proposed various methods of designing and optimizing of composite leaf springs.

Using experimental and analytical methods, static, fatigue and modal analysis were performed on various composite materials. Concluded that in comparison to conformist mono and multi steel leaf spring composite leaf springs have less weight, stresses, vibration and enhance in strength and fatigue life.

REFERENCES

- [1] "Automobile leaf spring from composite materials", H.A.Al-Qureshi, (Elsevier)Journal of Material ProcessingTechnology, Vol. 118, pp.58-61, 2001. Brazil.
- [2] "Developing a composite based elliptic spring for automotive applications" Abdul Rahim Abu Talib, Aidy Ali, G. Goudah , Nur Azida Che Lah, A.F. Golestaneh , (Elsevier) Materials and Design 31 (2010) 475–484. Malaysia.
- [3]"Design and optimization of automotive multi-leaf spring by finite element method" Shahrukh Shamim1, Jamil Anwer 2, IJRAME ISSN (ONLINE): 2321-3051. India
- [4] "Analysis of leaf spring using Carbon / Glass Epoxy and EN45 using ANSYS: A comparison" Jenarathanan M.P, Ramesh Kumar.S, Venkatesh.G, Nishanthan.S(Elsevier)Materials Today: Proceedings 5 (2018) 14512–14519. India.
- [5]"Investigation of the Dynamic Behaviour of CFRP Leaf Springs" Stephan Krall, Richard Zemann, (Elsevier) Procedia Engineering 100 (2015) 646 –655. Austria.
- [6] "Fabrication of Hybrid Composite Mono-Leaf Spring with Unidirectional Glass Fibers" Thippesh L, (Elsevier) Materials Today: Proceedings 5 (2018) 2980–2984. India.
- [7] "Static analysis and fatigue life prediction of steel and composite leaf spring for light passenger vehicles" M Senthil Kumar, and S Vijayarangan, Journal of Scientific & Industrial Research Vol 66, February 2007, pp 128-134. India.
- [8] "An experimental investigation into mechanical behavior of hybrid and nonhybrid composite semi-elliptical springs" E. Mahdi & A.M.S. Hamouda. (Elsevier) Materials and Design 52 (2013) 504–513. Qatar.