Review Paper on design, analysis and weight optimization of leaf spring by using metal matrix composite

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***Abstract*- The aim of this paper is to compare three materials for leaf spring and proposed the one which is having best strength to weight ratio. Three materials used for comparison are the conventional steel and the composite E-Glass Epoxy, Carbon Epoxy and Aluminum. The composite materials are used to reduce the weight of the leaf spring without any reduction in load carrying capacity. This present work is to estimate and compare the deflection and bending stress induced in the leaf spring by these materials. The leaf spring, which is used for analyzing, is a mono leaf spring of light commercial EV Tata ACE. A model of such leaf spring has been designed from actual steel leaf spring and analyzed using ANSYS in this project. Theoretical calculations, Analysis predictions and Testing are done for validation of results.**

Key wards: **Metal matrix, Composite material, Leaf spring.**

INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of Automobile manufacturer in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the un sprung weight. This helps in achieving the vehicle with improved riding qualities. 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

$$U = \frac{\sigma^2}{\rho E},$$

The introduction of composite materials made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness, as the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio compared to those of steel. Several papers were devoted to the application of composite materials for automobiles and showed the introduction of fiber reinforced plastics (FRP) made it possible to reduce the weight of a machine element without any reduction of the load carrying capacity. Because of FRP materials high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf FRP springs. In every automobile, i.e., four wheelers and railways, the leaf spring is one of the main components and it provides a good suspension and it plays a vital role in automobile application. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The geometry of the Steel leaf spring is shown in Fig. 1.1

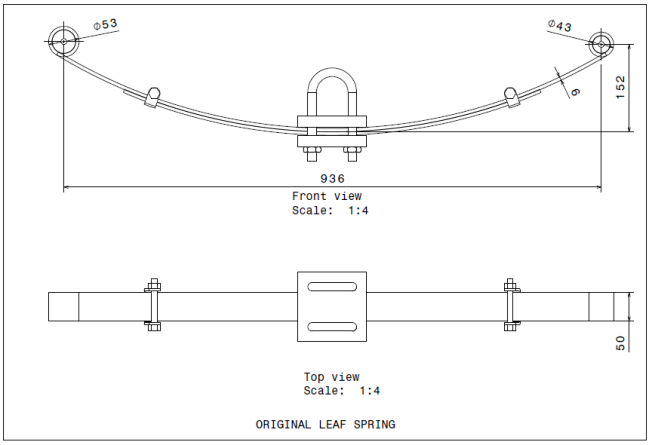

Fig. 1.1 Leaf Spring

LITERATURE REVIEW

Mahendra Sharma, Pawan Sharma and Sumit Sharma, they worked on analyzing the stresses in the multi-leaf spring using ANSYS® software. This paper analyses the mechanical characteristic of a multi-leaf spring made up of steel using the ANSYS® software. Stress analysis considers interleaf contact behavior for correctly simulating operational loading and deriving realistic stress distribution and deformations. This paper also touches on to benefits of switching to composite material for leaf spring, however they have not studied such a composite design and its performance impact. [1]

Trivedi Achyut and Prof. R. M. Bhoraniya worked on both steel and composite multi-leaf spring, they assessed the stresses using ANSYS® software. They performed physics based numerical study and compared it with analysis results on to deflection and bending stresses. However, it is not clear in their paper about which composite material they have assessed whether it is Glass-Epoxy or Graphite-Epoxy, and they did not validate FEA correlation with experimental data. [2]

M. Venkatesan, V. C. Sathish Gandhi and E. Janarthan studied 3 composite material combinations of epoxy and E-Fibreglass. Hand lay technique was used to manufacture the fibre glass reinforced specimen. They studied mechanical properties of composite materials using an experimental coupon testing and finite element analysis to finalize appropriate composition of epoxy and E-fibreglass for leaf spring. The epoxy and E-fibreglass composite is chosen in the following compositions such us 40% epoxy and 60% E-fibreglass (Specimen-I), 60% epoxy and 40% E-fibreglass (Specimen-II), 70% epoxy and 30% E-fibreglass (Specimen-III). The results show that the 40% epoxy and 60% E-fibreglass is having high value of tensile stress, bending stress, deformation, and natural frequency compare with rest of composition of materials in both experimental and Simulation. It is concluded that 40% epoxy and 60% E-fibreglass (Specimen-I) is the best composition of material for leaf spring. This paper primarily focuses on composite material validation using coupon testing, but actual composite leaf spring was not validated for the subject application. [3]

Pinaknath Dewanji worked on design and analysis of a three-layer composite leaf spring with full length leave made up of E-Glass/epoxy composite material. The results of conventional steel leaf spring have been also compared with the results obtained for composite leaf spring. E-glass/epoxy material is better in strength and lighter in weight as compared to the conventional steel leaf spring. In this work, a steel multi-leaf spring was replaced by a composite multi-leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring. All the FEA results are compared with the theoretical results, and it is found that they are within the allowable limits and nearly equal to the theoretical results. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 67.88% for E-Glass/Epoxy. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view. [4]

Amitkumar Magdum did a dynamic analysis on multi-leaf spring of Ford 5650 pick-up van using ANSYS®. In this research work leaf springs are analyzed using finite element methods considering the dynamic effect on stability of vehicle during cornering, off road drives etc. Parameters considered in the analysis are stiffness of the leaf spring, load acting on leaf spring. This paper includes the study of deflection and stress distribution of leaf spring for heavy duty vehicles. This research paper compares the result of structural steel with titanium alloy (Ti-6Al-4V) and composite materials having higher stiffness. The paper concludes that, the composite materials used are Kevlar and S-glass fibre composite. The capacity to absorb energy is more in Kevlar fabric than in s-glass composite and less in steels. Leaf spring made of composite have higher natural frequencies. To improve the stability (handling) of automobile during cornering, off road drives it is suggested to have the leaf spring of composite materials. Moreover, leaf spring of Kevlar fabric as well as s-glass fibre composite is light in weight, have higher natural frequency and thus can achieve optimum automobile stability and comfort. [5]

M.Sai kumar and Dr. C. Bhaskara Reddy also performed modeling and structural analysis of multi-leaf spring using finite element method. The leaf springs are modeled with ANSYS® Design Modeler, and the analysis is carried out using ANSYS® FEA software to predict the behavior. Then comparison of static analysis results is performed for three materials (high carbon steel, low carbon steel, Inconel 600) and multi-leaf spring combining these 3 materials. [6]

Basavaraj Kabanur and Prof. P. S. Patil present their work on finite element method of simulating steel multi-leaf spring especially consideration of friction-induced stresses during operation. This work can be utilized to set up appropriate boundary conditions when performing FEA. [7]

Kabariya Kaushal Kanubhaii and Shyam Gupta worked upon design and analysis of leaf spring of a light commercial vehicle. This work deals with modifying the cross-section area and material of the spring. They evaluated 3 shapes viz Rectangular (baseline), Trapezoidal per leaf and Trapezoidal whole shape. On to material side, they evaluated 2 materials steel (baseline) and E-glass/Epoxy. It is concluded that Trapezoidal whole shape contributes negatively on to the design. Major weight reduction is achieved by changing to E-glass/Epoxy material. [8]

Ekhlas Edan Kader, Rania Adwan and Lutfi Yousuf Zedan focused on fabrication and testing of composite leaf spring made up of 95% Epoxy, 5% carbon, 5%glass fibre, and 5% of hybrid composite of carbon and glass fibre. The effectiveness of the proposed composite leaf spring was evaluated by implementing the mechanical tests. Tensile, Impact, Hardness and Flexural tests were done. The experimental results showed an increase in Hardness, Impact, Tensile, and Flexural strength when the reinforcing fibres are

applied. The best results of the mechanical test obtained when hybrid reinforcement was applied. [9]

M. F. Mohamed et. al. provided material properties and comparison for various composites namely, E-glass, S-glass, Carbon, Kevlar 29, Kevlar 49 and Alumina. Density, Tensile strength, Young's modulus can be used to set up FEA model. [10]

RESEARCH GAP & PROBLEM STATEMENT

Leaf springs are used in suspension systems. The automobile industry has shown greater interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. From the review of past literatures, it is seen that; Glass fibre, Carbon fibre and Kevlar fibre are top material substitutes to conventional steel. Kevlar and Carbon fibre stands out when it comes to weight reduction, bending strength, deflection, stiffness, and natural frequency over conventional steel in the given order, however Kevlar is much costly than Carbon fibre.

Also, the past literature survey shows that switching to either Carbon fibre or Glass fibre may not serve as efficient substitute for conventions steel, given their negative impact on mechanical strength and durability.

OBJECTIVES

1. To developed a leaf spring with composite material and metal.
2. To perform static analysis of standard Steel leaf spring using FEA. Finding out the deflection and bending stress for the same
3. To perform static analysis of composite leaf spring made up of E-glass Epoxy, Carbon epoxy and metal (Aluminum) using FEA. Finding out the bending stress and deflection for the same.
4. To manufacture the composite leaf spring which has minimum stress under given application of loads and boundary conditions.
5. To validate the ANSYS and testing results.

CONCLUSION

From the review of above papers, it is seen that many people have work in design and analysis of composite leaf spring. Some people did static analysis, dynamic analysis and Fatigue test. They also compared analytical results with FEA results using ANSYS software. They have designed and fabricated composite leaf spring and did static and dynamic and fatigue test. They have compared the results for stress and deflection for steel and composite leaf spring.

The past literature survey shows that efforts have been made to design a leaf spring using polymeric matrix composites such as Glass fibre, Carbon fibre or Kevlar fibre; however, looking at the leaf spring application and required load carrying capacity, these materials have lesser material strength to be a better substitute for conventional leaf spring made up of steel. Metal matrix composites (MMC) take precedence over polymeric matrix composites due to higher toughness and ductility, impact resistance when it comes to suspension leaf spring application, which becomes a dedicated scope or problem statement forms a part of this project work.

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