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Design and Static Analysis of Hybrid Leaf Spring using FEA: A Review

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Abstract: ***Leaf spring is one of the oldest forms of spring which is used to provide good suspension in wheeled vehicles. Reducing weight to reduce overall fuel consumption and reducing cost are getting to be highly important research issues in present scenario. With increasing competition, the Automobile Industry has shown interest in overall weight reduction of vehicle by the replacement of steel leaf spring with composite leaf spring in order to improve safety, comfort, durability and reducing weight since the composite material has a high strength to weight ratio, good corrosion resistance, more elastic strain energy storage capacity. A lot of research has been done for improving the design and performance of leaf spring. The aim of this review paper is to study of all the such previous work in which weight reduction of vehicle was achieved by replacement of steel leaf spring with that of composite leaf spring having suitable mechanical properties and capable of carrying such heavy load of vehicle. This work is focused on study of design and analysis of hybrid leaf spring which is the combination of steel and composite material in order to obtain qualitative spring at affordable mid-range of cost.***
Keywords: Leaf spring, composite material, hybrid leaf spring, static analysis etc.

I. INTRODUCTION

Leaf spring was 1st used in 1804 by Obadiah Elliot for suspending the horse drawn cart. It was than incorporated in early designs of motor vehicles. A spring is an elastic machine element which undergoes deflection for the application of any load and intends to regain its original shape depending upon the magnitude of applied load. Major application of spring may include its use as a shock and vibration absorber and storing potential energy by its deflection during the application of load. Leaf spring is used in almost all the trucks and light vehicles. It improves the suspension quality and can support heavy load. Advantages of leaf spring over the helical spring are that the ends of the spring are guided along a definite path and it is act as structural member.

Nearly 20% of un-sprung mass of the vehicle is usually leaf spring assembly which makes it attractive option for weight reduction study for the design improvements. Weight reduction is an effective measure for energy conservation. It reduces overall fuel consumption of the vehicle. The strain energy of the material becomes a major factor in designing the springs. The material having lower modulus and density will have a greater specific strain energy capacity. It helps in achieving the vehicle with improved riding qualities.

A leaf spring is a simple type of suspension commonly used in vehicles. The leaf spring can be arranged in two different ways based on the vehicles. First type is simple supported type of leaf spring in which both the ends of the leaf spring are fixed to the chassis of the vehicle and the second one is cantilever type of leaf spring in which one end is fixed to the chassis of the vehicle and other end is left free for displacement. The Leaf spring is generally made of Steel. A leaf spring takes the form of a slender arc-shaped of spring steel of rectangular cross section. In the most common configuration the Centre of arc provides location for the axle while loop formed at either end provide for attaching to vehicle chassis.

Leaf spring is an important component of automobile act as a linkage for holding axle in a position. Multi leaf spring carries lateral load, break torque, driving torque in addition to shock absorbing. In its construction the leaf spring consists of a series of flat plates or leaves, usually of semi-elliptic shape, which are held together with the help of U-bolts and Centre clip. Generally two types of leaves may be observed in a multi-leaf spring i.e. some graduated -length leaves and a few extra full-length leaves. The length of the leaves gradually decreases from top to bottom. The longest leaf in the top is known as master leaf which is bent at both the ends to form spring eyes. The extra full-length leaves are inserted between the master leaf and the graduated-length leaves to support the transverse shear force. In order to maintain proper alignment and to restrict the lateral shifting of leaves, rebound clips are used. In practice, these springs rest on the axle of an automobile. Its front end is connected with the frame by means of a simple pin joint and the rear end is connected with the frame through a flexible link (known as shackle).

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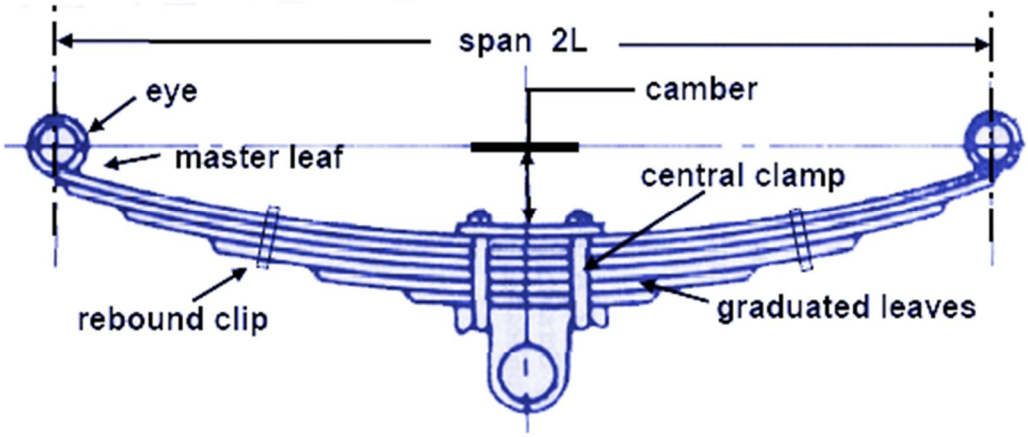

Fig. leaf spring

II. LITERATURE REVIEW

A. *Amol Bhanage & Dr. K. Padmanabhan*

In this research paper, steel leaf spring used in passenger cars is replaced with a composite leaf spring made of a glass/epoxy composite. The primary objective is to compare fatigue characteristics of SAE1045-450-QT steel and E – Glass/ Epoxy Composite material. Due to Weight reduction and stress, stiffness criteria, multi steel leaf spring is proposed to be replaced with E- Glass Epoxy composite leaf springs. Finite element method using CAE tool like ANSYS Workbench prove the reliability of the validation methods based only on simulation, thereby saving time, material and production costs for a complete product realization. The fatigue life of the leaf spring has also been improved.

B. *Manjunath H.N,*

In this paper a comparative study has been made between different composite (E-Glass/Epoxy, Graphite/Epoxy, Boron/Aluminum, Carbon/Epoxy, Kevlar/Epoxy) materials and steel in respect of stiffness, deflection and stress. It is found that all the composite leaf spring has good performance characteristics as compared to conventional steel spring with similar design specifications. Boron/Aluminum has minimum deflection and stress, and posses high stiffness as compared to other composites.

C. *Pinaknath Dewanji*

This paper deals with the Design and analysis of composite leaf spring. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus, the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring. Totally it is found that the composite leaf spring is the better that of steel leaf spring.

D. *Vamsi Krishna dommeti, Raghavendra rao*

This paper deal with FEA analysis of leaf spring by composite glass fiber epoxy reinforced with natural fibre material. Static analysis has been conducted to predict the displacement and stress at different location. A comparative study has been made between Steel, GFRP and GFRP reinforced with natural fiber's springs with respect to weight, riding quality, cost and strength. From the study it is seen that Banana fiber reinforced composite material spring is lighter 72% compared to conventional steel leaf spring and stress is reduced 4.15% from steel for similar performance.

E. *Dara Ashok, M.V. Mallikarjun, and Venkata Ramesh Mamilla*

The objective of this paper is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. Leaf spring consist two full length leaves and five graduated leaves. The material of the conventional leaf spring was 65Si7 and the material of the composite material was E-Glass/Epoxy. Dimensions of the composite leaf spring are to be taken as the same dimensions of the conventional leaf spring for modeling. It is concluded that composite multi leaf spring is an effective replacement for the existing steel leaf spring in vehicles.

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F. Mouleeswaran Senthil kumar, Sabapathy Vijayarangan

This paper describes static and fatigue analysis of steel leaf spring and composite multi leaf spring made up of glass fiber reinforced polymer using life data analysis. Compared to steel spring, the composite leaf spring is found to have 17.35 % lesser stress and weight reduction of 68.15 % is achieved. It is found that the life of composite leaf spring is much higher than that of steel leaf spring.

G. Rohit Ghosh, Sushovan Ghosh and Shirish Ghimire

Average cost of E-Glass that can be used to manufacture the springs, ranges from 40-55 USD per square foot. Whereas steel ranges from 16-20 USD per square foot, hence, if the entire spring is made of composite material then it would not be cost effective at all. He further concluded that, stresses in extra full-length leaves were almost 50% more (1.5 times) than that of the graduated-length leaves. Finally, the present work offers an exclusive idea regarding the construction of multi-leaf spring through its proposal for manufacturing the extra full-length leaves with composites, while using steels for the rest of the leaves, to minimize the cost.

H. N. Vijiya Rami Reddy, B Rajnaveen

In this paper the leaf spring has been modeled using solid tetrahedron 4-node element. By performing static analysis it is concluded that the maximum safe load is 4000 N and the stresses in the mono composite leaf spring are much lower than that of conventional steel leaf spring. Result shows that the composite spring can design to strength and stiffness much closer to steel spring by varying the layer configuration and fiber orientation angles. The strength to weight ratio is higher for composite leaf spring than conventional leaf spring with similar design.

I. Dev Dutt Dwevedi, V.K. Jain

This paper deal with the design and analysis of automobile leaf spring using Ansys. Results demonstrate that composite leaf spring for a particular load is less compared to conventional leaf spring. Stress generated in E-glass/Epoxy is lower than steel leaf spring. Composite has lower directional deformation compared to steel leaf spring.

J. D.Lydiamahanthi

In this paper design and analysis of composite of leaf spring is done for light weight vehicles. As automobile world demands research of reducing weight and increasing strength of products, composite material should be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, we introducing Kevlar material which is least in weight and bears more load with less deformation when compared to other materials. The results of static analysis of both steel and composite leaf springs like EN47, KEVLAR, S-Glass Epoxy & E-Glass shows that Kevlar material is better than conventional steel, E-Glass/Epoxy, S-Glass Epoxy and the other composite materials.

K. Rakesh hota, Kshitij kumar

This paper deals with experimental investigation of fiber glass reinforced mono-composite leaf spring. It was found that there was a weight reduction of 88.95% in composite leaf spring. The maximum stiffness produced was found to be 66.9N/mm which is almost comparable of steel (76.68N/mm). Both composite samples passed the heat deflection tests which prove their feasibility for practical use. Fatigue life was found to be 10112 cycles as compared to 6164 cycles of steel spring. Moreover the natural frequency was 1.3 times more than 12Hz produced on road which decrease resonance and hence increased rider comfort.

III. CONCLUSION

From the above literature survey we find that, a lot of work has been done in designing of leaf spring which is discussed briefly in this text. On the basis of this study, problems in overall weight reduction by using composite material are identified. But the only problem in replacing conventional steel leaf spring with composite material is that the cost of composite material is very high as compared to steel. Hence if the entire spring is made of composite material then it would not be cost effective at all. Result also shows that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was nearly reduced up to 85%. The stresses in the extra full-length leaves were found almost 50% more (1.5 times) than that of the graduated leaves. Hence I proposed to make a model of leaf spring which is the combination of both conventional material and composite, can be used in different combination in a multi leaf spring to reduce the overall cost of composite leaf spring, and the result can be compared with that of conventional steel leaf spring and composite leaf spring.

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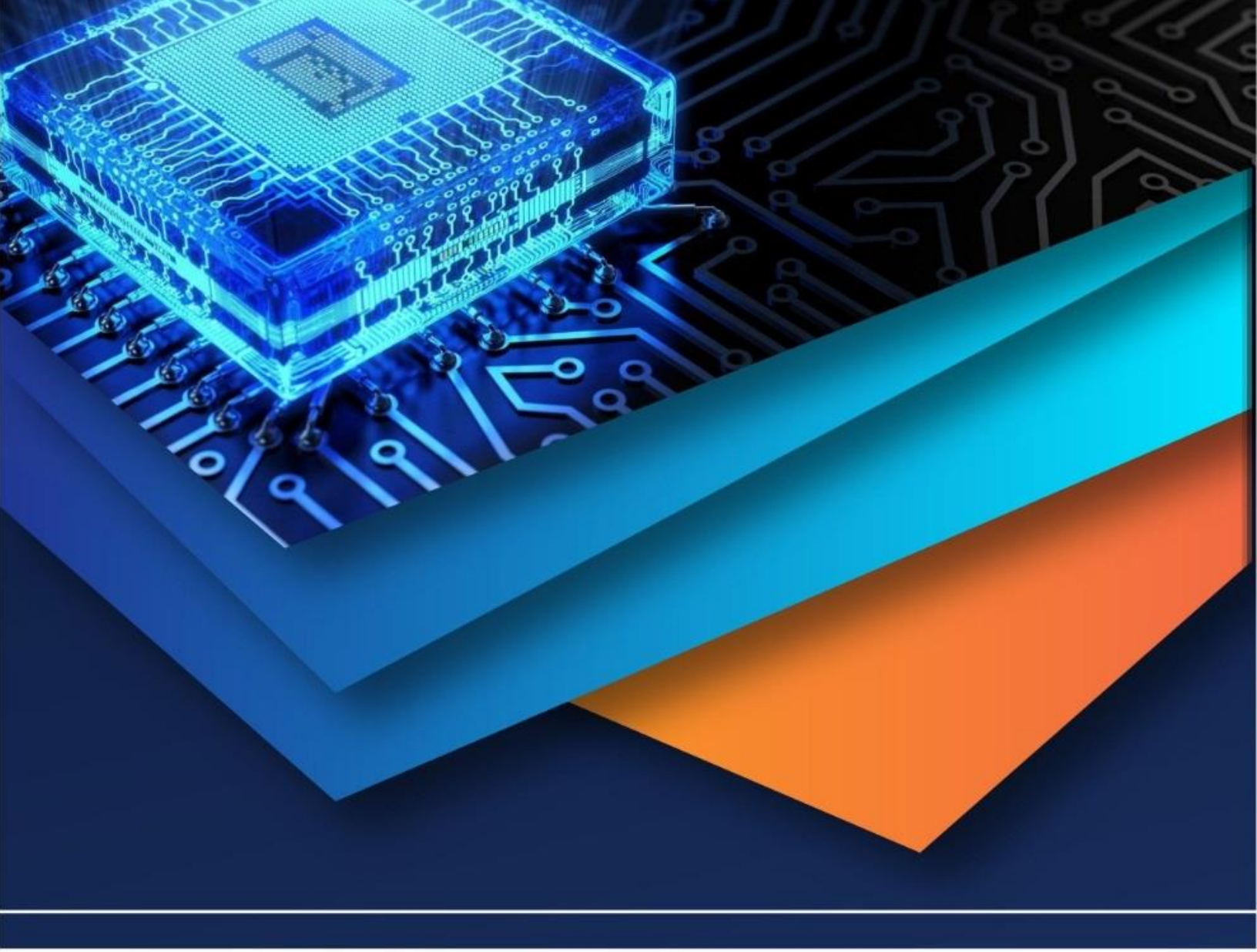

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