Design And Analysis of Composite Leaf Spring: A Review

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Abstract- *Leaf spring is used for the suspension in vehicles. Now a day's automobile industry improving very fast and trying to replace old components with new and better components. Leaf Spring is one of them as the weight of conventional leaf spring is up to 10-20 % of the total unsprung weight of Vehicle. Hence the automobile industry trying to replace conventional steel leaf spring with composite leaf spring. As the composite material having high strength and low weight, It becomes a favorite material for researchers. This review paper focused on compatibility composite material and design and analysis of composite material.*

Keywords- E Glass/Epoxy, S Glass/ Epoxy, carbon fiber material, composite material, F.E.A, Static analysis.

I. INTRODUCTION

Leaf Spring is a very important suspension system element in the vehicle because it used to minimize the vertical vibration, Impact, and bumps due to road irregularities and creates a comfortable ride. Composite materials are now used to a large extent in the automotive industry to replace the metal components. For conventional cars and vans, composite leaf spring offers the advantage of improved packaging in addition to reduced sprig with a reduced spring rate and uniform stress, which utilizes glass fibers and other carbon fibers. So it is essential to provide composite leaf spring with a reduced spring rate, which evenly distributes glass fibers and other carbon fibers throughout the resin matrix.

The composite materials have advantages like maximum strength, minimum modulus of elasticity in the longitudinal direction, weight & vibration reduction, improved packaging, strain energy capacity, improved durability & fatigue life.

In present work, Conventional steel spring is replaced with Glass/Epoxy composite material. Dimensions of both, Composite material and Conventional Steel leaf spring are considered the same. The main objective is to compare the weight savings of composite leaf spring, load carrying capacity, and stiffness.

II. LITERATURE REVIEW

W. J. Yu and H. C. Kim [1] have introduced Double Tapered FRP Beam for Automotive Suspension Leaf Spring. Fundamental dimensioning properties of the double tapered FRP leaf spring were explored. The optimal taper ratio was 0.5. Prototype longitudinal type double tapered leaf springs replace four-leaf steel springs from glass fiber and epoxy. A prototype of GRP leaf spring has good endurance and fail-safe characteristics, and the GRP leaf spring has sufficient strength. They proposed two composite materials as E Glass/Epoxy and S2 Glass/Epoxy.

Erol Sancaktar and Mathieu Gratton [02] The objective is to provide an understanding of the manufacture, use, and capabilities of composite leaf springs produced by using unidirectional E glass roving impregnated with an epoxy resin for light vehicle applications where the vehicle weight is of primary concern.

I. Rajendra and S. Vijayarangam [03] have investigated the optimal design of a composite leaf spring using genetic algorithms. The suspension system in automobiles significantly affects the behavior of the vehicle i.e. vibration characteristics including ride comfort, directional stability, etc. Leaf springs are commonly used in suspensions systems of the automobile and subjected to millions of varying stress cycles leading to fatigue failure. If the unsprung weight is reduced, then the fatigue stress induced in the leaf spring is also reduced. A composite material offers minimum weigh. A reduction of 75.8% weight is achieved when several steel leaf springs are replaced with a mono-leaf composite spring.

H. A. Al-Qureshi [04] has introduced Automobile leaf spring from composite materials. A single leaf variable thickness spring of glass fiber reinforced plastic with similar mechanical and geometric properties to the multi-leaf steel spring.

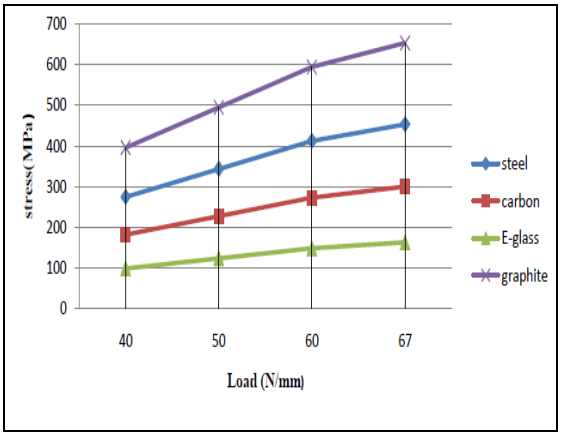
Mahmood M. Shokrieh and Davood Rezaei [05] have investigated the Analysis and optimization of a composite leaf spring. A four-leaf steel spring is used in the rear suspension system of light vehicles is analyzed using ANSYS software.

Results of stresses and deflections are verified by the existing analytical and experimental solutions. Using these results of the steel leaf spring, a composite made from fiberglass with epoxy resin is designed and optimized using ANSYS. Mainly focused on the optimization of the spring geometry. The aim was to reduce spring weight and it is capable of taking given static external forces without failure. The design constraints were taken as stresses and displacements. The results it is known that spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. On comparing composite leaf spring with Conventional steel leaf spring, it is concluded that composite spring has fewer stresses, High natural frequency, and the spring weight without an eye is 80% lower.

B. Vijaya Lakshmi and I. Satyanarayana [06] have investigated Static and Dynamic Analysis on Composite Leaf Spring in Heavy Vehicle. A leaf spring is commonly used for the suspension in vehicles. The mono leaf springs are of one plate of spring steel. They are thick in the middle and taper out toward the end, and they don't have too much strength and suspension for towed vehicles. For heavier loads typically multi-leaf springs are used, which consist of several leaf springs of different lengths place on above one another. This paper focused on comparing the weight savings, load carrying capacity, and stiffness of composite leaf spring concerning steel leaf spring. The stresses and deflections are taken as design constraints. The dimensions of an existing conventional steel leaf spring of a Heavy commercial vehicle are used to fabricate a composite multi-leaf spring using E-Glass/Epoxy, C- Glass/Epoxy, S- Glass/Epoxy unidirectional laminates. Pro/Engineer software is used for modeling and COSMOS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using COSMOS.

Ghodake A. P., Patil K.N. [07] have conducted Analysis of Steel and Composite Leaf Spring for Vehicle. In the present study, he selected was glass fiber reinforced plastic (GFRP) and the polyester resin (NETPOL 1011) and is used against conventional steel. By hand lay-up technique, he fabricated spring with constant width and thickness. This technique was simple and economical. The analysis is carried finite element analysis using ANSYS software for Stresses, deflection, and strain energy for both steel and composite leaf spring material. The result indicates that the composite spring has maximum strain energy than that of steel material and weight is reduced up to 85 % compared with steel material.

Pankaj Saini, Ashish Goel, Dushyant Kumar [08] have investigated the design and analysis of composite leaf spring for light vehicles. Reducing weight with increasing or maintaining the strength of products is a highly important research issue in this modern world. Composite materials are attracting researchers as solutions to this issue. In this paper, he describes the design and analysis of composite leaf spring. The aim is to compare the stresses and weight of composite leaf spring with steel leaf spring. The design constraint is stiffness. The material selected for this study is E-glass/epoxy, carbon epoxy, and graphite-epoxy against conventional steel.
The plot below, we can see that stresses in E glass Epoxy are minimum.



Plot of Stress Vs Load

Manjunath H.N, Manjunath.K, T.Rangaswamy [09] has investigated Static Analysis and Fatigue Life Prediction of Composite Leaf Spring for a Light Commercial Vehicle (TATA ACE). In this research, he attempted to check the suitability of composite materials like E Glass/Epoxy, Graphite/Epoxy, Boron/Aluminum, Carbon/Epoxy, and Kevlar/Epoxy for light commercial vehicle leaf spring. Static analysis is carried out for different composite leaf spring and Steel leaf spring using ANSYS. And then results are compared with theoretical values and found that they have good agreement with each other. The fatigue life of composite leaf springs is calculated using Hwang and Han relations. From the results, they found that Boron/Aluminum and Graphite/Epoxy are suitable composite material for leaf spring**.**

Gulur Siddaramanna, Shiva Shankar, Sambagam Vijayarangan [10] In this paper a single leaf with variable thickness and width for the constant cross-sectional area of unidirectional glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to that of multi-leaf steel spring, was designed, fabricated and tested. Three-dimensional finite element analysis is used for verification of the result obtained from the experiment. E-glass /epoxy material and hand layup technique is used for the fabrication of mono composite leaf spring. It is observed that composite leaf spring is more superior to steel leaf spring and a large amount of weight reduction achieved.

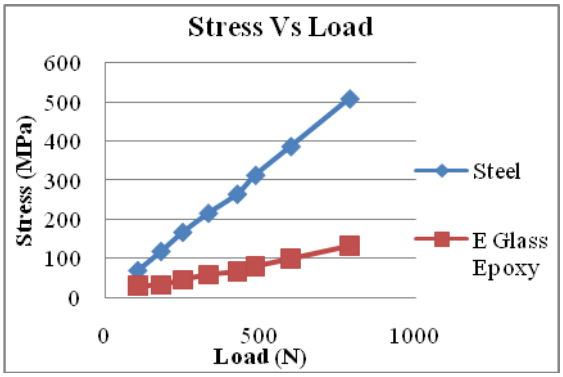
B. Vijaya Lakshmi and I. Satyanarayana [11] have investigated Static and Dynamic Analysis on Composite Leaf Spring in Heavy Vehicle. A leaf spring is commonly used for the suspension in vehicles. The mono leaf springs are of one plate of spring steel. They are thick in the middle and taper out toward the end, and they don't have too much strength and suspension for towed vehicles. For heavier loads typically multi-leaf springs are used, which consist of several leaf springs of different lengths place on above one another. This paper focused on to compare the weight savings, load carrying capacity and stiffness of composite leaf spring with respect to steel leaf spring. The stresses and deflections are taken as design constraints. The dimensions of an existing conventional steel leaf spring of a Heavy commercial vehicle are used to fabricate a composite multi leaf spring using E-Glass/Epoxy, C- Glass/Epoxy, S- Glass/Epoxy unidirectional laminates. Pro/Engineer software is used for modeling and COSMOS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using COSMOS.

N. Anu Radha, C. Sailaja, S. Prasad Kumar, U. Chandra Shekar Reddy & Dr. A. Siva Kumar [12] have investigated Stress analysis and material optimization of master leaf spring. Leaf springs are frequently used in automobile vehicles. These are used to absorb the fluctuating loads from the vehicle. The main function of leaf spring is to isolate road induced vibrations that leading to fatigue failure. Due to this they attempted study of the material optimization. Hence, they evaluated and optimized existing steel, carbon fiber and boron fibers. The boron fiber composite material is found to be best for replace existing master leaf steel spring. The master leaf spring is modeled in Pro/E 5.0 and analysis is done by using ANSYS 13.0. The aim of this project is to modeling, stress analysis and material optimization of master leaf spring and comparison of deformation and stress results between steel leaf spring and composite leaf springs under same conditions.

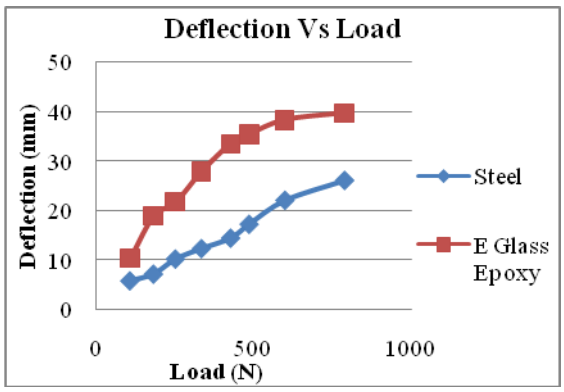
Senthilkumar Mouleeswaran [13] has study Design, Manufacturing and Testing of Polymer Composite Multi-Leaf Spring for Light Passenger Automobiles. Design and experimental analysis of composite multi leaf spring using glass fiber reinforced polymer are carried out. After Studying he found that, composite leaf spring has 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of Present conventional steel leaf spring. The conventional multi leaf spring has about 13.5 kg weighs whereas the E-glass/Epoxy multi leaf spring has only 4.3 kg weighs. Thus the weight reduction of 68.15% is achieved. Besides the reduction of weight, the performance of the leaf spring is also increased. Compared to the steel leaf spring (13.5 kg), the optimized composite leaf spring weighs nearly 76.4% less than the steel spring. Ride comfort and life of Composite leaf spring are also more than that of Conventional Steel Leaf Spring. Therefore, it is concluded that present conventional steel multi leaf spring can be effectively replace with composite multi leaf spring in light passenger vehicles.

Kumar Krishan and Aggarwal M.L. [14] have investigated A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools. They carried out their work on a nine leaves multi leaf spring including two full length leaves in which one is with eyed ends and seven graduated length leaves used in a commercial vehicle. They carried out finite element modeling and analysis of a multi leaf spring. SUP9 is material of the leaf spring .The FE model of the leaf spring was generated in CATIA and imported in ANSYS for finite element analysis, which are most popular CAE tools. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining them under defined boundary condition. They did analysis for Bending stress and deflection. They compare this FEA results with experimental to conclude.

G Gopal and L Suresh Kumar [15] have investigated Design and Analysis of a Laminated Composite Leaf Spring. The paper deals with the basic design of a laminated leaf spring and analyzing the composite material values for different orientations of the fiber. For this purpose the laminated leaf springs are made of steel and composite material of unidirectional E-glass/ Epoxy, with the same dimensions. The deformations are compared for both the above materials. A 3-D model of leaf spring is modeled using Solid Works. The static analysis is done using ANSYS. It is observed that the deflections in the Composite leaf spring are greater than the steel leaf spring for the same load. The stresses in the Composite leaf spring are less than the steel. The weight of the Composite leaf spring is about 70% lower than the steel.



Plot of Stress Vs Load



Plot of Deflection Vs Load

M. Venkatesan, D. Helmen Devraj [16] describes design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer. Their interest is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. They take design constraints are as stresses and deflections. They take dimensions of an existing conventional steel leaf spring and same dimensions of conventional leaf spring are used to fabricate a composite leaf spring using E Glass/Epoxy unidirectional laminates. Static and dynamic analysis of steel leaf spring and composite leaf spring are done then compared with experimental results. Compared to steel spring, the composite leaf spring has 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than steel leaf spring. A 76.4% weight reduction is achieved by using optimized composite leaf spring. Also give the details about the how they composite leaf spring modeled with different methods like 1. Constant Thickness, Varying Width Design, 2. Constant Width, Varying Thickness Design, 3. Constant Cross-Selection Design.

III. CONCLUSION

This review paper gives detailed information about the work done by previous researchers for replacing the conventional steel leaf spring with composite leaf spring. Firstly in material selection, various materials like E glass/Epoxy, S Glass/Epoxy, Carbon Fibers, C Glass/ Epoxy etc. are referred by the researchers but mainly E glass/Epoxy composite material was referred by researchers for light Motor Vehicles. Because it's cost as it is cheaper then S Glass/Epoxy and Carbon Fiber. Some of the materials recommended by some researchers are bellow.

Sr. No.	Composite Material Recommended	Researcher
1	E Glass/Epoxy and S2 Glass/Epoxy	W. J. Yu and H. C. Kim (1988) [1]
2	E Glass/Epoxy	Erol Sancaktar and Mathieu Gratton (1999) [2]
3	E Glass/Epoxy	Mahmood M. Shokrieh and Davood Rezaei (2003) [3]
4	E-Glass/Epoxy, C-Glass/Epoxy, SGlass /Epoxy	B.Vijaya Lakshmi I. Satyanarayana(2012) [4]
5	E Glass/Epoxy	G Gopal and L Suresh Kumar (2014) [6]

Many Researchers take Stress and Deflection as main constraints for designing the composite leaf spring. Designed composite spring modeled with Constant Cross-Selection Design because of its capability for mass production and accommodation of continuous reinforcement of fibers. As the cross-section area is constant through out the leaf spring, same quantity of reinforcement fiber and resin can be fed continuously during manufacture.

The different types of analysis Like static analysis, fatigue analysis, modal and shock analysis were conducted using analytical, numerical and experimental approaches on conventional steel leaf spring and composite leaf spring by many researchers. Also they use software's like CATIA, ANSYS for analysis with Experimental Methods. At the End from various research papers, it is known that composite leaf spring have less stresses, weight, noise, vibration, and increased in fatigue life, strength and gives comfortable ride. Also it is seen that lot of work was did on E glass/Epoxy Material and only some work has been take place on S2 Glass/Epoxy Composite Material that is only limited to Tensile Testing.

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