Design and Development of Mono Leaf Spring by using Composite Material (Epoxy-Carbon Fiber)

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Abstract— *For weight reduction in automobiles as it leads to the reduction of un-sprung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% of the un-sprung weight. The composite materials made it possible to reduce the weight of machine element without any reduction of the load carrying capacity. Because of composite material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel. FRP spring also have excellent fatigue resistance and durability. But the weight reduction of the leaf spring is achieved not only by material replacement but also by design optimization. Weight reduction has been the focus of automobile manufacturers in the present scenario. The replacement of steel with optimally designed composite leaf spring can provide 75%-78% weight reduction. The material selected is carbon epoxy against conventional steel. The design constraint is bending stress. The optimization study consists of use of software's such as NASTRAN / ANSYS software.*
Moreover, the composite leaf spring has lower stresses compared to steel spring. All these will result in fuel saving which will make countries energy independent because fuel saved is fuel produced.

Keywords—bending stress, composite leaf spring, carbon epoxy, FRP, NASTRAN / ANSYS software

I. INTRODUCTION

Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. 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. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction, is the most suitable material for a leaf spring. To meet the need of natural resources conservation, automobile manufacturers are attempting to reduce the weight of vehicles in recent years. 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 automobiles unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities.
The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness.

II. RELEVANCE /MOTIVATION

Reducing weight while increasing or maintaining strength of products is getting be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this project reducing weight of vehicles and increasing or maintaining the strength of their spare parts is considered. As leaf spring contributes considerable amount of weight to the vehicle and need to be strong enough, a single leaf spring is designed and simulated following the design rules of the composite materials considering static loading only. The constant cross section design of leaf springs is employed to take advantages of ease of design analysis and its manufacturing process. And it is shown that the resulting design and simulation stresses are much below the strength properties of the material, satisfying the maximum stresses are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life. This project will deals with the study of effect of weight percentage of carbon fiber on the properties of composite mono leaf spring. The composite material used for the project consists of carbon fiber and epoxy resin having high strength compared to other materials which is around 72 MPa [1]. The study will be carried by three methods, the first method is experimental method to carryout tensile test after this second method consist of identification of natural frequency by FFT analyzer will be done then at last optimization study consist of use of software's such as NASTRAN / ANSYS software.

III. LITERATURE REVIEW

Shishay Amare Gebremeskel [1], reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite material is one of the material families, which are attracting researchers and being solution of such issue. In this project, reducing weight of vehicles and increasing or maintaining the strength of their spare part is considered. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single E-Carbon/Epoxy leaf spring is designed and simulated following the design rules of the composite materials considering static loading only. The constant cross section design of leaf springs is employed to take advantages of ease of design analysis and its manufacturing process. In addition, it is shown that the resulting design and simulation stresses are much below the strength properties of the material, satisfying the maximum stress are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life. This particular design is made specifically for lightweight three wheeler vehicles. Its prototype is also produced using hand lay-up method.

Mahmood M. Shokrieh et.al.[2] in this paper, A four leaf steel spring used in the rear suspension system of light vehicles is analyzed using ANSYS V5.4 software. The finite element results showing stresses and deflection verified existing analytical and experimental solution. Using the results of the steel leaf spring, a composite one made from fiberCarbon with epoxy resin is designed and optimized using ANSYS. Main consideration is given to the optimization of the spring geometry. The objective was to obtain a spring with minimum weight that is capable of carrying given static external forces without failure. The design constraints were stresses (Tsai-Wu failure criterion) and displacements. The results showed that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. Compared to steel spring, the optimized composite spring has stresses that are much lower, the natural frequency is higher and the spring weight without eye units is nearly 80% lower.

Pankaj Saini, et. al[3] In this paper we describe design and analysis of composite leaf spring. The objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. The design constraint is stiffness. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials have high strength to weight ratio and good corrosion resistance. The material selected was Carbon fiber reinforced polymer (E-Carbon/epoxy), carbon epoxy and graphite epoxy is used against conventional steel. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modeled in Auto-CAD 2012 and the analysis was done using ANSYS 9.0 software.

J. P. Hou, et.al [4] This paper presents the design of eye-end attachment for a composite leaf spring for freight rail applications. Three designs of eye-end attachment for composite leaf spring are described. The material used in Carbon fiber reinforced polyester. Static testing and finite element analysis have been carried out to obtain the characteristics of the spring. Load-deflection curves and measurement as function of load for the three designs tested have been plotted for comparison with FEA predicted values. The main concern associated with the first design is the delamination failure at the interface of the fibers that have passed around the eye and the spring body, even though the design can withstand 150 KN static proof load and one million cycles fatigue load. FEA results confirmed that there is a high interlaminar shear stress concentration in that region. The second design feature is an additional transverse bandage around the region prone to delamination. Delamination was contained but not completely prevented. The third design overcomes the problem by ending the fibers at the end of the eye section.

C. Subramanian et.al [5], Commercial utilization of the composite leaf spring in the suspension application is significantly decided by its eye end joint performance. Present work attempts to design and evaluate the performance of double bolted end joint for thermoplastic composite leaf spring. Injection molded 20% Carbon fiber reinforced polypropylene leaf springs were considered for the joint strength evaluation. Servo hydraulic test facility is utilized to evaluate the static and fatigue performance of the bolted joint. Various bolt sizes were utilized for the joint and its performances were evaluated under static loading condition to understand the effect of fit between bolt and its hole of the joints. Ultimate bearing strength of the joint is found to decrease with the increase in the clearance between bolt and part hole. Joints were subjected to various amplitudes of completely reversed fatigued loads to evaluate the endurance strength. Load-deflection hysteresis plot of the joint under fatigue conditions is continuously measured and used as the bearing damage index of the joint. Inspection of the bearing surface tested under static and fatigue loading condition revealed severe matrix deformation and fibrillation. In spite of unidirectional load being acted at the joint, curved nature of the bearing surface induces biaxial stresses, which results in severe matrix fibrillation at the bearing surface. Failure morphology under fatigue condition revealed net-tension, and shear-out failures besides the bearing damages.

Ravi Kumar V et.ai. [6] Automobile world has an increased interest in reduction of weigh by the replacement of steel by natural fiber reinforced composites. Moreover, the composite materials have more elastic strain energy storage capacity and high strength capacity and high strength to weight ratio compared to steel. Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to Carbon fibers in composites. The aim of present work is to compare the Carbon-Fiber Reinforced-Composite (GFRC) leaf spring with a Natural-Fiber-Reinforced Composite/jute-Fiber-Reinforced-Composite (NFRC/JFRC) leaf spring. Fabrication is carried by hand lay-up technique and tested. The present work carries analytical and simulated results comparison of both types of composite leaf springs. The testing was performed experimentally with the help of Universal Testing Machine (UTM) and by Finite element Analysis FEA using ANSYS. Stresses and Deflection were verified with analytical and experimental results. Compared to the GFRC leaf spring, the NFRC Composite material spring has stresses much lower to steel and the spring weight is also reduced nearly to 60-70%. The NFRC leaf spring resulted reduction in deflection and stresses without compromising stiffness as experimentally and analytically.

E. Mahdi. [7] This study introduces a new composite semi-elliptical spring by utilizing fiber reinforced composite strength in principal direction instead of shear direction. Three types of composites were tested, namely, carbon/epoxy, Carbon/epoxy and Carbon/carbon/epoxy. A comprehensive experimental investigation of composite semi-elliptical suspension springs has been carried out. Typical behaviors of their compression, tension, torsion and cyclic tests are presented and discussed. The results showed that the fiber type and ellipticity ratio significantly influenced the spring stiffness. After1.15 million fatigue cycles, composite semi-elliptical suspension spring's useful stroke is reduced by only 2%. The relaxation of composite elliptic spring found to be very sensitive to the compression rate.

R D V Prasad [8] This paper deals with development of analytical formulation for Composite leaf spring in this project has been developed as a mono block construction with maximum thickness at the center which is preferably Carbon fiber reinforced polymer. The thickness reduces towards the end in order to achieve uniform strength construction. The cross-section is constant at any section along the spring length this condition is imposed to accommodate the unidirectional fibers and to maintain the fiber continuity from one end to the other.

M. Raghavedral, et.al [9] This paper describes design and analysis of laminated composite mono leaf spring. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle is taken for modeling and analysis of modeling and analysis of a laminated composite mono leaf spring with three different composite materials namely, E-Carbon/Epoxy, S-Carbon/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The three different composite mono leaf springs have been modeled by considering uniform cross-section, with unidirectional fiber orientation angle for each laminate. Static of a 3-d model has been performed using ANSYS 10.0. Compared to mono steel spring the laminated mono leaf spring is found to have 47% lesser, 25%~65% higher stiffness,27%~67% higher frequency and weight reduction of 73%~80% is achieved.

B. Raghu Kumar et. al [10] In the present scenario, composites are widely used in most of the industries in place of steel, due to low weight to strength ratio. In automobile industry, one can think of replacing parts with composites. The aim of this paper is to suggest the best composite material for design and fabrication of complete mono composite leaf spring. A single leaf with variable thickness and variable width for constant cross sectional area of different composite materials, with similar mechanical and geometrical properties to the multi leaf spring, were modeled and analyzed. The finite element results using ANSYS software showing stresses and displacement. Compared to the steel spring, the composite spring has stresses and deflection that are much lower, and spring weight is nearly 78% lower.

Parkhe Ravindra et. al [11] This paper describes design and analysis of composite mono leaf spring. Weight reduction is now the main issue in automobile industries. Weight reduction is now the main issue in automobile industries. In the present work, existing mono steel leaf spring of a light vehicle is taken for modeling and analysis. A composite mono leaf spring with Carbon/Epoxy composite material is modeled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflection. The composite mono leaf springs have been modeled by considering varying cross-section, with unidirectional fiber orientation angle for each lamina of a laminate. Static analysis of 3- D model has been performed using ANSYS12.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found lesser stresses and weight reduction of 22.5% is achieved.

T. N. Ashok Kumar et. al [12] The Automobile Industry has shown increase interest for replacement of steel leaf spring with that composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance. The paper describes static and dynamic analysis of steel leaf spring and laminated composite Multi leaf spring. The objective is to compare displacement, frequencies, deflections and weight savings of composite

leaf spring of a light design calculation. Static and Dynamic Analysis of 3-D model of conventional leaf spring is performed using ANSYS 10.0. Same dimensions are used in composite multi leaf spring using S2 Carbon/Epoxy and Kevlar unidirectional laminates. Analysis is done by layer stacking method for composites by changing reinforcement angles for 3 layers, 5 layers and 11 layers. The weight of composite leaf spring reinforcement angles for 3 layers, 5 layers and 11 layers. The weight of composite leaf spring is compared with that of steel leaf spring. The design constraints are stresses and deflection. A weight reduction of 27.5% is achieved by using by using composite leaf spring.

IV. CONCLUDING REMARK

From the literature review it is observed that, the suspension system in a vehicle significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort, stability etc.Prof.Dipendra Kumar Roy and Prof. Kashi Nath Saha presented a technique of minimization of total potential energy from which the variation of stress, strain and the bending moment of the beam having variable material properties with the beam length are obtained. Prof.U. S. Ramakanth & Prof.K.Sowjanya worked on conventional leaf springs to determine the safe stress and pay loads. Prof.J.P. Hou, J.Y. Cherruault, I. Nairne, R.M. Mayer studied on the design evolution process of a composite leaf spring for freight rail applications. Prof.Mouleeswaran S Kumar, Sabapathy Vijayarangan concluded that the experimental fatigue analysis of composite multi leaf spring is carried out using life data analysis. In our dissertation, the calculation of strength of composite leaf spring at different loading conditions is to be calculated by using theoretical method and verification of the same with the help of numerical analysis. We are also performing the parametric study based on composite material.

V. PROPOSED WORK

It is proposed to carry out the Experimental study & analysis of composite leaf spring with the help of FEA software. For this dissertation work, the proposed work is divided in to the following phases.

Phase I: Study of parameters required for the development of composite leaf springs and also the study of composite material which are particularly suited for leaf spring application. The special emphasis is given on fiber reinforced composites (FRC).

Phase II: Study of CAD/CAE software like CATIA, HYPERWORKS and study of Finite Element Analysis software like ANSYS for analysis of leaf spring.

Phase III: Calculation of composite leaf spring strength at different load conditions by using theoretical & experimental method.

Phase IV: Experimentation of composite leaf spring with various parameters.

Phase V: Validation of leaf spring by finite element methods with experimental data.

Phase VI: The best configuration will be suggested to the company. This shall be done upon verifying the structural strength of recommended solution.

VI. SCOPE

i) Well Definition of the problem.
ii) To study the existing leaf spring in Maruti 800 for possible designing.
iii) Learning and use of ANSYS software.
iv) The inputs for Designing of would be secured from the Sponsoring Company, typically the geometry (3D model). The same is normally created using a modelling interface like CATIA, SolidWorks, etc.
v) Loads and boundary conditions shall be applied to the model in the pre-processor. The input deck for the designated solver shall be prepared.
vi) Suitable solver for structural analysis (like ANSYS) would be deployed for finding the solution.
vii) Recommendation to be made upon evaluating the results.
viii) Physical experimentation towards validation hypothesis proposed to be carried out.
ix) Conclusion to be inferred over the work done.

VII. PROBLEM STATEMENT

In this project reducing weight of vehicles and increasing or maintaining the strength of their spare parts is considered. The design for the leaf spring would be subjected to FEA to find the effect of loads on the composite leaf spring. The composite leaf spring would be assessed for its performance like strength. The problem for this work is being evaluation of the design using software in the FEA followed by experimentation.

VIII. METHODOLOGY

i. Numerical Methodology (using Finite Element Analysis)

Numerical / Computational Approach:

The proposed method utilizes software in the FEA domain for analyzing the effect of the variation in the values of the design parameters influencing the performance criterion and corresponding strength would be recorded for changing load within given range. The FEM method is used to analyze the

stress state of an elastic body with a given geometry, such as leaf spring.

In this synopsis the analysis of leaf spring in Maruti 800 is intended for study using FEM software (ANSYS or any other software).

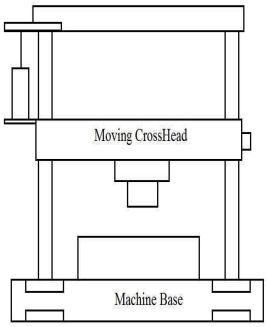
ii. Experimentation Methodology (using Physical Experimentation)

The objective of the work is to design and analyses of composite leaf spring made of different composite materials. A virtual model of composite leaf spring will generate in modeling software will import in post processing software for analysis by applying normal load conditions. After analyis a comparison is made between simulation and experimental result of composite leaf spring.

1. To increase the breaking strength of automobile mono leaf spring.
2. To carry out finite element analysis and experimental investigation of mono leaf spring.
3. To reduce the overall weight of the Automobile mono leaf spring.

IX. PROPOSED EXPERIMENTAL SET-UP:

(Universal Testing Machine)



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