

Finite Element Analysis of Mono Composite Leaf Spring: A Review

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Abstract

Leaf springs are one of the oldest suspension components those are still frequently used, especially in commercial vehicles. In recent time it is very necessary to reduce weight while increasing or maintaining strength of leaf springs. We are using Mono composite leaf spring of glass fiber reinforced plastic (GFRP) and steel spring with similar mechanical and geometrical properties. The primary objective of this paper is to compare the load carrying capacity, stiffness, deflection and weight saving of composite (GFRP) leaf spring with that of steel leaf spring. In Automobile sector Leaf spring of steel material which is used in suspension system can be replaceable by composite material due to its high strength to weight ratio and the composite materials have more elastic strain energy storage capacity.

Keywords: leaf spring, E-Glass/Epoxy, carbon/epoxy composites, weight reduction and strength, finite element simulation.

Introduction

The Leaf spring is used in the automobile sector since long time. Still Leaf spring is used for the suspension purpose due to its advantages over the helical spring. The advantage of Leaf spring over helical spring is that the ends of the springs are guided along a definite path so as to act as a structural member in addition to shock absorbing device. It is well known that spring, in general, 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. Weight reduction has been the main focus of automobile manufactures. Suspension leaf spring, a potential item for weight reduction in automobiles, accounts for 10-20 percent of unsprung weight, which is considered to be the mass not supported by leaf spring without any reduction on the load carrying capacity and stiffness in automobile suspension system [[9]]. Leaf springs made from fiberglass/epoxy (glass fiber reinforced plastic, GFRP). It presents advantages over graphite/epoxy such as lower sensitivity to cracks, impact and wears damage. In other words, fiberglass/epoxy leaf springs are almost similar to metallic springs with regard to life requirements, since they have sufficient impact strength, and their mechanical properties are not

greatly influenced by the typical vehicle working conditions [[6]].

In the present work, a leaf steel spring used in passenger cars is replaced with a composite leaf spring made of glass/epoxy composites. Dimension and geometry of steel leaf spring and composite leaf spring are considered to be same. Primary objective is to compare their load carrying capacity, stiffness and weight saving of composite leaf spring.

Literature Review

There are some papers which have been studied and referred on my work:

E. Mahdi, A.M.S. Hamouda (2013):-

In this paper introduces a new composite semi-elliptical suspension spring by utilizing fiber reinforced composite strength in principal direction instead of shear direction. Three types of composites were tested, namely, carbon/epoxy, glass/epoxy and glass/carbon/epoxy. A comprehensive experimental investigation of composite semi-elliptical suspension springs has been carried out. the work carried out in this investigation 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 nonhybrid one. Adding four layers of carbon fiber control the load carrying capacity of hybrid composite elliptical spring [[4]].

J.P. Hou, J.Y. Cherruault (2006):-

This paper presents the design evolution process of a composite leaf spring for freight rail applications. Three designs of eye-end attachment for composite leaf springs are described. The material used is glass fiber reinforced polyester. Static testing and finite element analysis have been carried out to obtain the characteristics of the spring. Load-deflection curves and strain measurement as a 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. Three eye-end designs of a double GRP leaf suspension have been evaluated by finite element analysis and static and fatigue testing. The first two designs consisted of integral eye ends where the skin tape layers went around the eye and along the leaf body. These layers were then maintained in place via a transverse wrap using woven GRP tape. The third design consisted of open eye ends. FEA and static test results show that the stress concentration at the tip of the fibers coming back along the leaf body for the first two designs led to a local delamination. However, this did not have any effect on the static proof loading of the suspension nor on its fatigue life [[7]].

E. Mahdi et al. (2006):-

In this paper, the influence of ellipticity ratio on performance of woven roving wrapped composite elliptical springs has been investigated both experimentally and numerically. A series of experiments was conducted for composite elliptical springs with ellipticity ratios (a/b) ranging from one to two. Typical failure histories of their failure

mechanism are presented and discussed. In general, this study demonstrated that composites elliptical spring can be used for light and heavy trucks and meet the requirements, together with substantial weight saving. The results showed that the ellipticity ratio significantly influenced the spring rate and failure loads. Composite elliptical spring with ellipticity ratios of a/b 2.0 displayed the highest spring rate. This present investigation verified that composites can be utilized for vehicle suspension and meet the requirements, together with substantial weight saving. It is also believed that hybrid composite elliptical springs have better fatigue behavior than the conventional and composite leaf and coil spring. It is interesting to note that the hybridization technique can be used effectively to improve weight saving and performance in the automotive industry. Elliptical configuration was employed to eliminate any hypothesis of delamination. The ellipticity ratio significantly influenced the spring rate and failure loads. Composite elliptical spring with ellipticity ratios of a/b 2.0 displayed the highest spring rate [[5]].

C. Subramanian, S. Senthilvelan (2010):-

In this work, to design and evaluate the performance of double bolted end joint for thermoplastic composite leaf spring. Injection molded 20% glass 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.

Joint strength of injection molded fiber reinforced polypropylene leaf spring with steel plate is investigated experimentally under static and dynamic condition. The bearing load of the investigated joint under static loading condition is found to be superior to that of the leaf spring design. Net-tension failure mode along with bearing damage is observed as failure morphology. Influence of clearance between the fastener and composite plate hole on bearing strength of the joint under static loading condition is found to be significant. Increase in joint strength is exhibited with the decrease in clearance. However for the investigated range of clearance, failure morphology is found to be same. The endurance strength of the chosen joint is found to be significantly higher than that of the leaf spring design [[1]].

Dipendra Kumar Roy and Kashi Nath Saha (2013):-

In this paper, the numerical analysis of large deflection of prismatic cantilever beams for various types of material properties with a transverse load at free end, to study the displacement response of leaf springs. Besides the free end displacement, the variation of stress, strain and the bending moment of the beam having variable material properties with the beam length are obtained by the technique of minimization of total potential energy. The mathematical formulation is based on a variational principle using Galerkin's assumed mode method. The displacement functions are approximated by linear combination of sets of orthogonal coordinate functions, developed through Gram-Schmidt scheme and substituted in the governing equilibrium equation.

The system is formulated as cantilever beam problem in which the effect of material property variations are considered. The fundamental formulation is based on a variational method using total potential energy functional and solution is sought through Galerkin's assumed mode method. The final solution of the large displacement geometric nonlinear problem is obtained iteratively with the help of MATLAB computational simulation. The present computational method has been successfully validated with existing results and some new results have been furnished. Due to adequate improvement of mechanical properties it is seen that FGM leaf springs are more economical than conventional leaf springs [[3]].

Mr. Anandkumar A. Satpute, prof. S. S. Chawan (2013):-

In this paper, Current issue in Automobile, Aerospace, Marine etc. is to reduce the weight of product by maintaining its strength. In Automobile sector Leaf spring of steel material which is used in suspension system can be replaceable by composite material due to its high strength to weight ratio and the composite materials have more elastic strain energy storage capacity. The objective of this paper is to present a composite material as an alternative to the conventional steel leaf spring by experimental tests. The results of the analytical and experimental analysis are almost same; hence we may predict the dimensions of leaf spring by analytical method. To use the composite material instead of steel, we have to change dimensions. Here we have changed the thickness from 5 mm to 12 mm. For safe side the thickness should be 14 mm. The weight reduction is 88%. The composite material is having chipping

resistance problem, but it may avoid by using Carbon fibers [[8]].

C. Subramanian, S. Senthilvelan (2011):-

In this work, to design and evaluate the performance of double bolted end joint for thermoplastic composite leaf spring. Injection molded 20% glass 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. he found that The bearing load of the investigated joint under static loading condition is found to be superior to that of the leaf spring design load. Net-tension failure mode along with bearing damage is observed as failure morphology. Influence of clearance between the fastener and composite plate hole on bearing strength of the joint under static loading condition is found to be significant. Increase in joint strength is exhibited with the decrease in clearance. However for the investigated range of clearance, failure morphology is found to be same. Load-deflection hysteresis plot of the investigated joint under fatigue loading is used as the bearing damage index The endurance strength of the chosen joint is found to be significantly higher than that of the leaf spring design load [[2]].

Shishay Amare Gebremeskel (2012):-

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 needs to be strong enough, a single E- glass/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. And it is shown that the resulting design and simulation 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.

As reducing weight and increasing strength of products are high research demands in the world, composite materials are getting to be up to the mark of satisfying these demands. In this project reducing weight of vehicles and increasing the strength of their spare parts is considered. As leaf spring contributes considerable amount of weight to the vehicle and

needs to be strong enough, a single E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials. And it is shown that the resulting design and simulation stresses are much below the strength properties of the material satisfying the maximum stress failure criterion. It has achieved an acceptable fatigue life of 221.16×10^3 cycles. This particular design is made specifically for light weight three wheeler vehicle. It is recommended that ANSYS. Its prototype is also produced using hand lay-up method. Interested researcher has to go through this project and do the dynamic analysis of the design, since only the static loading case is considered here [[12]].

M. M. Patunkar1, D. R. Dolas (2011):-

The objective of this paper is to present modeling and analysis of composite mono leaf spring (GFRP) and compare its results. Modeling is done using Pro-E (Wild Fire) 5.0 and Analysis is carried out by using ANSYS 10.0 software for better Understanding. - Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment positions. Another part has to be focused, is the automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. Therefore, analysis of the composite material becomes equally important to study the behavior of Composite Leaf Spring. Under the same static load conditions deflection and stresses of steel leaf spring and composite leaf spring are found with the great difference. Deflection of Composite leaf spring is less as compared to steel leaf spring with the same loading condition. Conventional steel leaf spring was found to weigh 3.59 Kg. Indicating reductions in weight by 84.40% same Level of performance. Conventional Leaf spring shows failure at eye end only. At Maximum load condition also Composite Leaf Spring shows the minimum deflection as compared to Steel Leaf Spring. Composite leaf spring can be used on smooth roads with very high performance expectations. However on rough road conditions due to lower chipping resistance failure from chipping of composite leaf spring is highly probable. [[10]].

M. Raghavedra et al. (2012):-

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 a laminated composite mono leaf spring with three different composite materials namely, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The design constraints were stresses and deflections.

A comparative study has been made between laminated composite leaf spring and steel leaf spring with respect to weight, stiffness and strength. By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 73%~80%, natural frequency of composite leaf springs are 27%~67% higher than steel leaf spring and 23~65% stiffer than the steel spring. Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel and other composite materials considered in this investigation. From the results, it is observed that the laminated composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications [[11]].

Method and Software Used

FEA

The finite element analysis (FEA) is a computing technique that is used to obtain approximate solutions to the boundary value problems in engineering. It uses a numerical technique called the finite element method (FEM) to solve boundary value problems. FEA involves a computer model of a design that is loaded and analyzed for specific results [[12]].

ANSYS

ANSYS is being used by designers across a broad spectrum of industries such as aerospace, automotive, manufacturing, nuclear, electronics, biomedical, and many more. ANSYS provides simulation solutions that enable designers to simulate design performance directly on desktop. In this way, it provides fast, efficient and cost-effective product development from design concept stage to performance validation stage of the product development cycle. ANSYS package help to accelerate and streamline the product development process by helping designers to resolve issues related

to structural deformation, heat transfer, fluid flow, electromagnetic effects, a combination of these phenomena acting together, and so on[[12]].

Conclusion

As reducing weight and increasing strength of products are high research demands in the world, composite materials are getting to be up to the mark of satisfying these demands. Design and analysis of composite leaf spring using glass fiber reinforce polymer has been carried out. Composite leaf spring is found to have lesser stress higher stiffness and higher deflection than that of existing steel leaf spring. Conventional leaf spring weights about 8kg whereas the E-glass/epoxy leaf spring weight only 0.9kg [[8]], thereby weight reduction is achieved. Besides reduction of weight fatigue life of composite leaf spring is predicted to be higher than that of steel leaf spring. Composite leaf spring is observed as an effective replacement for the existing steel leaf spring.

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