Modelling and Analysis of Leaf Spring by Using Composite Material – A Review

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Abstract— Increasing competition and innovation in automobile sector tends to modify the existing products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are one of the oldest suspension components that are being still used widely in automobiles. Weight reduction is also given due importance by automobile manufacturers. The automobile industry has shown increased interest in the use of composite leaf spring in the place of conventional steel leaf spring due to its high strength to weight ratio. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. The objective is to estimate the mode frequency, deflection and stress in the leaf spring of most commonly used light commercial vehicle Tata magic. First the modal analysis is performed to determine the mode shapes and natural frequencies, stress and deflection analysis is carried out to the determine the von-misses stresses and deflection when steel leaves are replaced by fibrous composite leaves. Leaf spring will modelled in ANSYS. The conventional steel leaf spring and the composite leaf spring will be analyzed under similar conditions using ANSYS software and the results are presented.

Key words: Composite leaf spring, static analysis, Finite element method, ANSYS, weight reduction, light passenger vehicle

I. INTRODUCTION

Spring is a mechanical device used to store mechanical energy. It returns to its original shape, size and shape when it is stretched and twisted. Spring is also known as resilient member. Depending on the design and required operating environment, any kind of material can be used to construct a spring, so as long as the material has the required combination of rigidity and stiffness. Material used generally for manufacturing of springs are stainless steel, copper, nickel based alloys, Oil tempered high carbon steel, hard drawn high carbon steel and phosphor bronze etc. When a coil spring is compressed or stretched slightly from position of rest, then exerts force is approximately proportional to its change in length.

A spring's Spring Rate of a spring is the change in the force it exerts, divided by the change in deflection of the spring. Spring has units of force divided by distance, for example N/m.

Spring is extensively used in suspension system of automobile for greater stiffness and rigidity. It is also used in aerospace, military, defence, medical devices, windows and shades etc. mostly two types of springs are more common coiled and non-coiled, the non-coiled is around us from a long time ago, great example of non – coiled spring is a bow and arrow.

A leaf spring commonly used for suspension in wheeled vehicles. Leaf spring sometimes called a laminated or carriage springs and sometimes semi-elliptical or cart spring. Leaf spring is one of the oldest forms of spring used since medieval era. Leaf spring is also known as flat spring which is made up of flat plates.

In a vehicle, the leaf spring is located between the axle housing and the vehicle chassis, and it can be considered as a simply supported beam with a concentrated load at the centre. The bending moment is the maximum at the centre of the spring, and it reduces towards the ends, and hence, the spring selection is varied from a maximum at the centre to a minimum at the ends. In a conventional multi-leaf steel spring construction, this is achieved by assembling a number of leaves of variable length in such a way that the thickness maximum at the centre and reduces towards the ends.

A. How FEA does work?

The finite element method is a numerical technique which is commercially used for the finding of an approximate solution of partial differential equation as well as integral equation. In some solving partial differential equations the first problem is to create an equation that approximate the equation which is to be studied. It means that during calculations the error should not accumulate, thereby causing the output as to be meaningless.

Introduction of ANSYS - ANSYS is a finite element analysis (FEA) software package. It uses a pre-processor software engine to create geometry. Then it uses a solution routine to apply loads to the meshed geometry. Finally it outputs desired results in post-processing. FEA is used throughout almost all engineering design including mechanical systems and civil engineering structures.

The goal of meshing in ANSYS Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. These tools have the benefit of being highly automated along with having a moderate to high degree of user control.

B. Advantages of FEA:

- Visualization increases
- Design cycle time reduces
- No. of prototypes reduces
- Testing reduces
- Optimum design

The process of performing ANSYS can be broken down into three main steps.

1) Pre-processing
2) Solver
3) Post-processing

C. Pre-processing:

1) CAD modeling: - CAD model is created by using sketching and modeling tools for the creation of the required part/ geometry, which is to be performed in FEA.
2) Meshing: - one of the critical operations in FEA is meshing. In this the geometry is divided into pieces of large number. These pieces are called mesh. The accuracy of analysis mainly depends on this. By decreasing the size of mesh, the FEA speed decreases but the accuracy increases to a great extent.
3) Defining boundary condition: we have to feed the boundary conditions like direction of deformation, load application etc.

D. Solve:

In this step we tell the FEA package to solve the problem for the defined material properties, boundary conditions and mesh size.

E. Post processing:

In this step the interpretation and viewing of result is performed. The results can be viewed in various formats: graph, contour profile, 3d view, value, animation etc.

II. LITERATURE REVIEW

Various related literature such as transactions, proceeding of various national and international conferences and other journals which available on Google scholar were reviewed.

2.1.1 M Rama Laxmi, et. al. [2015]: The main objective of this is to use composite material for comparison of the load carrying capacity, stiffness and weight reduction of composite leaf spring with that of steel leaf spring, by considering design constraints like stresses and deflections. In this research paper leaf spring is designed in CATIA and analyzed in ANSYS. Researchers used r-glass, carbon epoxy and s-glass composite material for design and analysis of leaf spring and finally conclude that s-glass is the best material for manufacturing leaf spring because it has good structure stability.

2.2.2 Surekha S. Sangale, et. al. [2015]: In this paper carbon/epoxy composite material is used for design and analysis of leaf spring. Leaf spring is one of suspension system using from a long time and innovation in automobile field carried out regularly. The commonly used composite materials are Kevlar, glass, carbon etc. Among these, the carbon fiber has been chooses based on the stiffness and strength. Results obtained by analysis shows in carbon/epoxy stress and deflection are minimized. It is also analyzed that deflection and bending stress induced in carbon fiber is less than conventional steel leaf spring.

2.2.3 Sagar B Mahajan, et. al. [2015]: In this paper experimental and FEA analysis of composite leaf spring by varying thickness. The material used for leaf spring in E-glass manufactured by hand lay-up method which were evaluated and analyzed. Modeling and analysis of leaf spring is done by using ANSYS for stress and deflection under defined loading condition. Under static loading condition stresses and deflection of composite material are found with great difference with varying thickness.

2.2.4 Syambabu Nutalapati, et. al. [2015]: In this research paper design and analysis of leaf spring of MAHINDRA "MODEL-COMMANDER 650 DI is considered. Main objective is to compare the weight reduction, stresses and deformation of composite leaf spring over conventional leaf spring. The material selected for this process is glass fiber reinforced polymer (E-glass/epoxy) is used in place of conventional steel leaf spring. Modeling of leaf spring was done by Pro/Engineer and analysis was done by ANSYS software. Results shows that, the weight of leaf spring using composite material is reduced up to 85% that of conventional spring.

2.2.5 Akhil Mehndiratta, et. al. [2015]: in this research paper analysis of glass fibre reinforced plastic leaf spring has been done. In this work hand layup method is used for manufacturing of leaf spring by vacuum passing. Plywood is used as a molten metal and prototype is used as desired dimension. The solution of epoxy resin and K6 Hardener was prepared and fabric was impregnated with epoxy resin. Results shows GFRP leaf spring is 86.424% lighter than conventional leaf spring and GFRP blades are 56.66 % cheaper than conventional leaf spring blades.

2.2.6 Manjunath H.N, et. al. [2014]: In this paper vibration analysis of composite leaf for a light commercial vehicle with respect to random vibration. Vibration plays important role in design of leaf spring, since the failure due to vibration is more dominating than material failure. In this research work an attempt has been made to predict the vibration behavior of leaf spring leaf spring using to check suitability of composite material using Graphite/epoxy, Carbon/epoxy, E-glass/epoxy and Kevlar epoxy. E-Glass/Epoxy and Kevlar/Epoxy are having high amplitude of response than other materials and Steel and Boron/Aluminum have minimum amplitude of response.

2.2.7 N.V. Hargude, et. al. [2014]: The study described that composites can be used for leaf springs for light weight vehicles for meet the requirements, together with substantial weight savings. Main objective of this paper is to compare the stiffness, weight saving and load carrying capacity of composite leaf spring that of steel leaf spring. The three dimensional modeling of composite leaf spring is done and analyzed using ANSYS. E-glass/epoxy used for leaf spring and it shows greater weight reduction as compared to steel leaf spring.

2.2.8 Ganesh K., et. al. [2014]: In this paper multi leaf spring is used for design and analysis. The composite materials used for leaf springs are SAE 9260 and Glass fiber reinforced epoxy for comparative study. ANSYS software used for A Finite element approach of a multi leaf springs. Modeling of the leaf spring is done by using Pro/Engineer and analysis in ANSYS. Harmonic analysis are done due to road irregularities and static analysis for gross vehicle mass load analysis are carried out for both materials, and also comparative behaviors' are observed such as deflection and stress of the multi leaf spring. fiber glass reinforced epoxy composite leaf spring has a greater mass reduction compared with the leaf spring based on SAE 9260. Total mass reduction obtains 22.46 kg (100.45%) by using composite material.

2.2.9 Parkhe Ravindra, et. al. [2014]: this paper describes the modeling and analysis of carbon fiber epoxy used leaf spring by using finite element analysis. Mono leaf spring is used in this research work. Modeling of composite mono leaf springs has done by considering Varying cross-section, with unidirectional fiber orientation angle for each

lamina of a laminate. Static analysis of composite mono leaf spring has been performed by ANSYS software. Results show that carbon fiber epoxy has superior strength and stiffness and also less weight as compared to conventional leaf spring.

2.2.10 Shahrukh Shamim, et. al. [2014]: in this harmonic analysis of leaf spring has been done by using ANSYS software. Ti-6Al-4V alloy and S-Glass fiber Composite material are used for leaf design and analysis. The leaf spring based on Ti-6Al-4V alloy and S-Glass fiber Composite has a lower mass as compared to the conventional steel leaf spring. Both materials shows greater strength and stiffness and reduction in leaf spring mass in automobile we can achieve acceleration and better riding comfort against rough road. Titanium alloy based leaf spring shows less stress than other two materials s-glass and AISI 6150 steel based leaf spring.

2.2.11 R M Patil, et. al. [2014]: in this paper fabrication and testing of composite leaf spring for light passenger vehicle has been done. In this work for manufacturing of composite leaf spring Hand Lay-Up Vacuum Bagging technique is used. Testing of composite leaf is done on universal testing machine for stiffness and strength. Result shows that cost of fabrication of composite leaf spring mesh less than the conventional leaf spring.

2.2.12 Mhaske Raman, et. al. [2014]: in this paper C-glass material is used for replacement of steel leaf spring for weight reduction. In this work comparative analysis of c-glass using composite leaf spring and steel leaf spring is done by ANSYS software. In this work we also compared the strain energy with the other composite material like e-glass, and s-glass. Results shows that the stress induced in c-glass material is 69% less than of steel leaf spring. Weight reduction achieved in c-glass material is about 48%.

2.2.13 T.N.V.Ashok Kumar, et. al. [2013]: automobile industry has keen interest in replacing steel spring by composite leaf spring. The objective is to compare weight saving, deflections, frequency and displacement of composite leaf spring to conventional leaf spring. Kevlar epoxy and s-material are used here for design and analysis of leaf spring. Here static, modal, harmonic, transient dynamic, spectrum, buckling, and explicit buckling analysis of leaf spring have been done. Analysis is done by layer stacking method for composites by changing reinforcement angles for 3 layers, 5 layers and 11 layers. By comparing all the three materials based on the results Kevlar/epoxy is better material because it has less weight also less stress and frequencies analyzed than s-glass material.

2.2.14 Ravi Kumar V, et. al. [2013]: in these paper natural fibers composite leaf is analyzed by finite element analysis. In that work mono leaf spring is constant thickness, constant width design anysed. In this work jute glass and e glass are mixed by using hand lay-Up technique. The objective was to fabricate and analyze the leaf springs with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacement. Results shows that jute glass epoxies are almost equal to e-glass and natural fibers. Only a major disadvantage of natural fiber and jute glass epoxy are chipping resistance.

2.2.15 Patil Deogonda1, et. al. [2013]: this paper describes the mechanical properties of glass fiber reinforcement epoxy composites. Fiber reinforces plastics now a day's widely in the mechanical system and they had also good strength and stiffness. In this work bending test and tensile of the composite material has been done. Results show that bending, tensile and impact strength increases with addition of filler material. Zns based composite shows better results than Tio2 filled composites. ZnS and TiO2 filler material makes brittle and harder.

2.2.16 Ghodake A. P., et. al. [2013] : the study described that composite material has high strength to weight ratio, tailor able properties and corrosion resistance. The composite material selected was polyester resin and glass fiber reinforced plastic (GFRP) is used in the place of steel spring. Leaf spring is fabricated by hand layup method which is very simple and economical. Finite element analysis is carried out by ANSYS software. Results shows that leaf spring using composite material has maximum strain energy as compared to steel leaf spring and weight of composite leaf spring was reduced up to 85% of compared with conventional leaf spring.

2.2.17 Y. N. V. Santhosh Kumar, et. al. [2012] : in this paper conventional leaf spring is replaced by composite leaf spring for higher specific stiffness and strength. Researcher replace steel leaf spring with composite mono leaf spring using glass fiber reinforced plastic E-glass/epoxy. Cross-section of leaf spring for manufacturing is selected as constant thickness, constant width design, and constant thickness, varying width design and varying width, varying width design. Model of the leaf spring is prepared in pro/engineer and analyzed in ANSYS software. TATA SUMO vehicle is used for the study of the analysis of leaf spring. Results show that composite leaf spring weighted only 39.40% of the steel leaf spring.

2.2.18 Shishay Amare Gebremeskel, et. al. [2012]: in this paper design, simulation, and prototyping of single composite leaf spring for light weight vehicle has been carried out. Manufacturing is done by hand - lay - up method and plywood is used as a mould material. The glass fibers were cut to desired length, so that they can be deposited on mould layer- by-layer during fabrication of composite leaf spring. Results show that an acceptable fatigue life achieved is 221.16*103 cycles.

III. CONCLUSION

From the literature review it is seen that the objective is to obtain a spring that is capable of carrying given static load by constraints limiting stress and deflections. In all above discussed literature review it can be concluded that weight reduction is very common issue to increase the fuel efficiency and reduce the air pollution in automobile industries in now a day. The reduction of the weight is achieved by replacing composite material in place of steel leaf spring. Most of the researchers generally used composite material for leaf spring is E-glass/epoxy, Carbon/epoxy, Kevlar/epoxy, Graphite/epoxy, S-glass/epoxy, and Natural fibers. Out of these E-glass and s-glass/epoxy material shows greater stiffness and strength. Here in this work basalt fiber a new composite material is used for modeling and analysis of leaf spring, also R-glass/epoxy, S-glass/epoxy, Boron/aluminum and E-glass/epoxy material used for comparative study. First the modal analysis is performed to determine the mode shapes and natural frequencies, stress and deflection analysis is

carried out to the determine the von-misses stresses and deflection when steel leaves are replaced by fibrous composite leaves.

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