Static Structural Analysis of Composite Leaf Spring Under Dynamic Loads

V.T.V. Rupesh, Y. Ajay Kumar, K. Siva, K.Vikas, A. S .Vinay Kumar and Mr. Ch. Sivarama Krishna
Department of Mechanical Engineering
Vignan's Institute of Information Technology,Visakhapatnam, India
rupesh.velaga@gmail.com, ajay.yenugupalli123@gmail.com, Kannurusiva1234@gmail.com, vikasjackson99@gmail.com, vinay20083@gmail.com, srkchadharam@gmail.com

Abstract

Due to the excellent strength and stiffness to weight ratio, composite materials are widely used in many technical applications. The goal is to compare the stresses, deformations, and weight savings of steel and composite leaf springs. Stiffness is a design restriction. Because composite materials have a high strength-to-weight ratio and strong corrosion resistance, the automobile industry is very interested in replacing steel leaf springs with composite leaf springs. When compared to standard steel, the material chosen was glass fibre reinforced polymer (E-glass/epoxy). The design parameters were chosen and examined with the goal of reducing the composite leaf spring's weight in comparison to the steel leaf spring. Steel replacement is a hot topic in the automotive industry.and also Glass fibre reinforced polymer (E-glass/epoxy) was chosen as a replacement for traditional steel. The design parameters were chosen and examined with the goal of reducing the composite leaf spring's weight in comparison to the steel leaf spring. The automobile industry is very interested in steel replacement.

Keywords
Automobile, Compositematerial, E-Glass Epoxy,Stiffness, Composite Leaf Spring.

1. Introduction

A leaf spring, also known as a laminated or carriage spring, is a simple type of spring that is widely used for suspension in wheeled vehicles. It's also one of the oldest springing techniques, dating back to the Middle Ages. The advantage of a leaf spring over a helical spring is that the springs' ends can be steered along a predetermined path. It is a narrow arc-shaped length of spring steel with a rectangular cross-section that is sometimes referred to as a semi-elliptical spring or cart spring. The axle is located in the centre of the arc, and tie holes are supplied on both ends for attachment to the vehicle body. A leaf spring can be attached to the frame at both ends or at one end, generally the front, with the other end attached through a shackle, a short swinging arm. The shackle compensates for the leaf spring's inclination to stretch when squeezed, resulting in gentler springness. There were several types of leaf springs, most of which used the term "elliptical." Two circular arcs joined at their tips were referred to as "elliptical" or "complete elliptical" leaf springs. The top centre of the upper arc was attached to the frame, while the bottom centre was attached to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailing arms, would be needed for this design, but not for "semi-elliptical" leaf springs as used in the Hotchkiss drive. That employed the lower arc, hence its name. "Quarter-elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over its differential that was curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid nonmetallic sheets in between the metal leaves, such as wood.

1.1Objectives

The main objective of this research is to carry analysis of leaf spring by selecting different materials and selecting a material good load carrying properties to avoid ground contacting of leaf spring at higher loads.

2. Literature Review

Goudah et al. (2006) work has done on design and analysis of conventional mono leaf spring is done and the modelling is done by using CATIA and analysis part is done in ANSYS in some load conditionsto get an overview on deformations,von-mises stresses,normal stresses etc. (Kumar Krishan, et al., 2011) work has done on a conventional SUP9steel multi leaf spring having full length leaf springnwith eyed ends and containing seven complete graduated length leaves.the modelling is carried in CATIA V5R17 and it further moved to ANSYS for analysis on the basis of finite element analysis. Full and half load conditions on application basis are applied to get the required parameters like bending stresses and deflections of spring . (Goudah et al. 2006) etc. work has done and reported research on vehicle suspension using light composite elliptic springs. They developed a research that combined an elliptical design with woven roving composites. The effect of ellipticity ratio on the performance of woven roving wrapped composite elliptical springs was studied experimentally and numerically in this paper. (Doshi, et al., 2014) workis done in the way by utilising analytical and finite element methods, has proposed design adjustment in existing leaf spring with dynamic load effect consideration. ANSYS 11.0 was used to perform the stress and deflection analysis. They found that by lowering the number of leaf springs from 17 to 13, the weight was decreased by 6 kg and the cost was reduced by 20%. (Goudha, et al., 2006) By considering spring rate, shear stress, and log life as working design constraints, has created finite element models to optimise geometry and material of composite elliptical leaf springs. Both physically and statistically, the effect of ellipticity ratio on the performance of composite elliptical leaf springs was explored. They came to the conclusion that the composite elliptical leaf spring may be employed for both light and heavy commercial vehicles while reducing weight. The composite elliptical leaf spring with a/b=2 ellipticity ratio produced the best results.

3. Methods

CATIA V5 R20 is used to design the leaf spring. All of the leaves, clamps, and bolts are developed independently in the part drawing and combined in CATIA's assembly drawing. Surface contact between the bottom surface of one leaf and the top surface of the other leaf is used to assemble the leaves. The clamps and bolts are then assembled in the leaf spring after all 10 leaves have been assembled in the CATIA.

3.1 Design specifications of leaf spring

The design specification data are presented in the table below (Table 1).

Table 1. Design specification

1	Total length of the spring(eye to eye)	1120 mm
2	Free camber(vertical bank b/w eyes and leaves)	180 mm
3	No.of full length leaves	2
4	No.of graduated leaves	8
5	Leaf thickness	6 mm
6	Leaf width	50 mm
7	young’s modulus of material(steel)	210 GPa
8	Poisson ratio	0.3

3.2 Catia drawing of leaf spring (Figure 1)

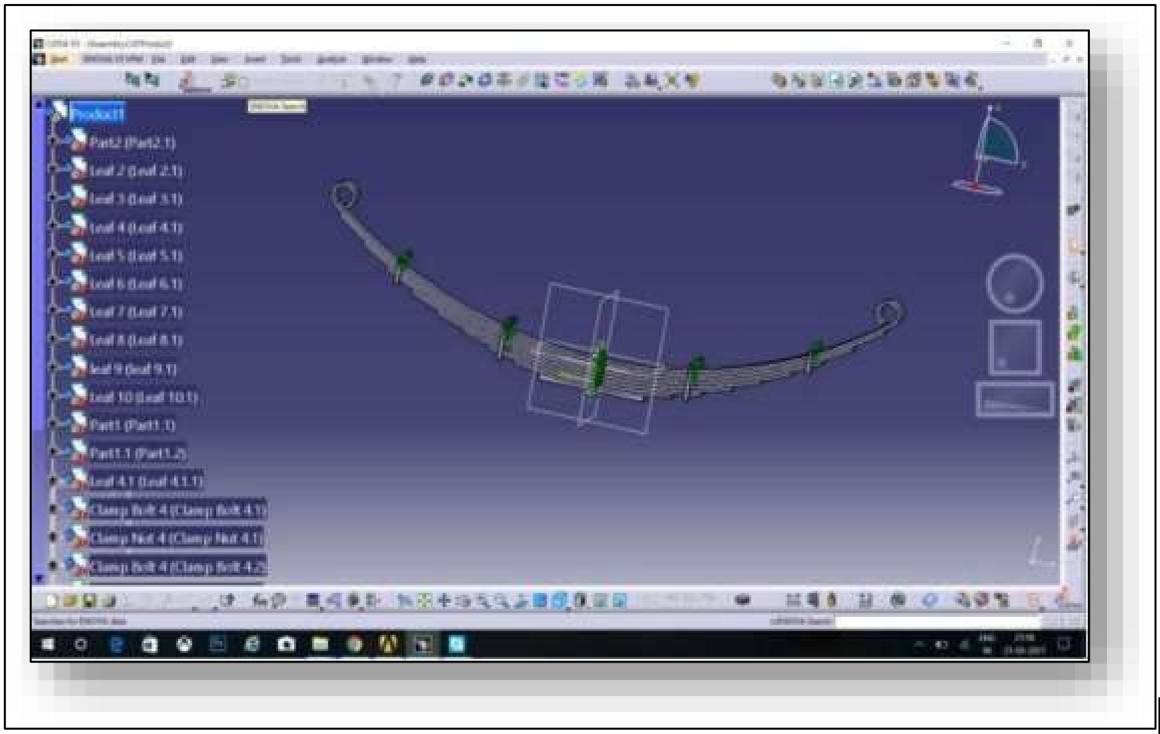

Figure 1. design of leaf spring having 7 leafs

3.3 properties of material used:
For structural Analysis of Leaf spring under dynamic loads, many researchers are considered different of materials to compare the conventional steel leaf spring. The materials they selected for their research are E- glass, Epoxy carbon, Aluminum Alloy, and Titanium Alloy. And the properties of different selected materials are given below to compare with the properties of steel. STEEL: Leaf springs are commonly made of plain carbon steel with a carbon content of 0.90 to 1.0 percent. Following the forming process, the leaves are heat treated. Heat treatment of spring steel products increases strength, allowing for improved load capacity, deflection range, and fatigue attributes. E-Glass/Epoxy: Glass fibre has a significant cost advantage over other materials. It has exceptional insulating characteristics, great strength, and chemical resistance. Epoxy Carbon: Epoxy carbon has a high specific strength and modulus, as well as a low coefficient of thermal expansion and a high fatigue strength. Titanium Alloy: Titanium's material is made up of several titanium alloys that have great strength, stiffness, toughness, low density, and good corrosion resistance. It is the most versatile and powerful metal accessible.

4. Procedure for Analysis of Leaf Spring

1. Design:
firstly we need to select a geometry for design of leaf spring and design procedure is to be carried out using catia software.

2) Selecting materials:
Create a materials library for analysis. Steel, E-Gglass, Epoxy-carbon, Alloys of Alluminium and Titanium are among the materials used in this leaf spring analysis. The engineering data accessible in Ansys software can be used to pick these materials.

3) Generating Mesh:
Create the mesh now. The drawing is then divided into a finite number of components. After meshing is complete, it will display the number of nodes and elements in the drawing.

4) Applying boundry conditions:

For the leaf spring, simple supported boundary conditions are examined. Both ends(eyes) of the leaf spring are made as fixed support in this situation, and the load applied on the leaf spring is at bottom of the leaf and load applied direction is upwards.

5) Generating results:

The values about stresses, deformations and flexibility for given loads are obtained from results

4. Materials to be selected

For structural Analysis of Leaf spring under dynamic loads, many researchers are considered different of materials to compare the conventional steel leaf spring. The materials they selected for their research are E- glass, Epoxy carbon, Aluminum Alloy, and Titanium Alloy. And the properties of different selected materials are given below to compare with the properties of steel.

STEEL: Leaf springs are commonly made of plain carbon steel with a carbon content of 0.90 to 1.0 percent. Following the forming process, the leaves are heat treated. Heat treatment of spring steel products increases strength, allowing for improved load capacity, deflection range, and fatigue attributes.

E-Glass/Epoxy: Glass fibre has a significant cost advantage over other materials. It has exceptional insulating characteristics, great strength, and chemical resistance

Epoxy Carbon: Epoxy carbon has a high specific strength and modulus, as well as a low coefficient of thermal expansion and a high fatigue strength.

Titanium Alloy: Titanium's material is made up of several titanium alloys that have great strength, stiffness, toughness, low density, and good corrosion resistance. It is the most versatile and powerful metal accessible.

5. Results and Discussion

Now, let us examine the Ansys results for stress(von-mises), elastic strain, deformations, and weight for the Selected materials (Figure 2, 3 and 4).

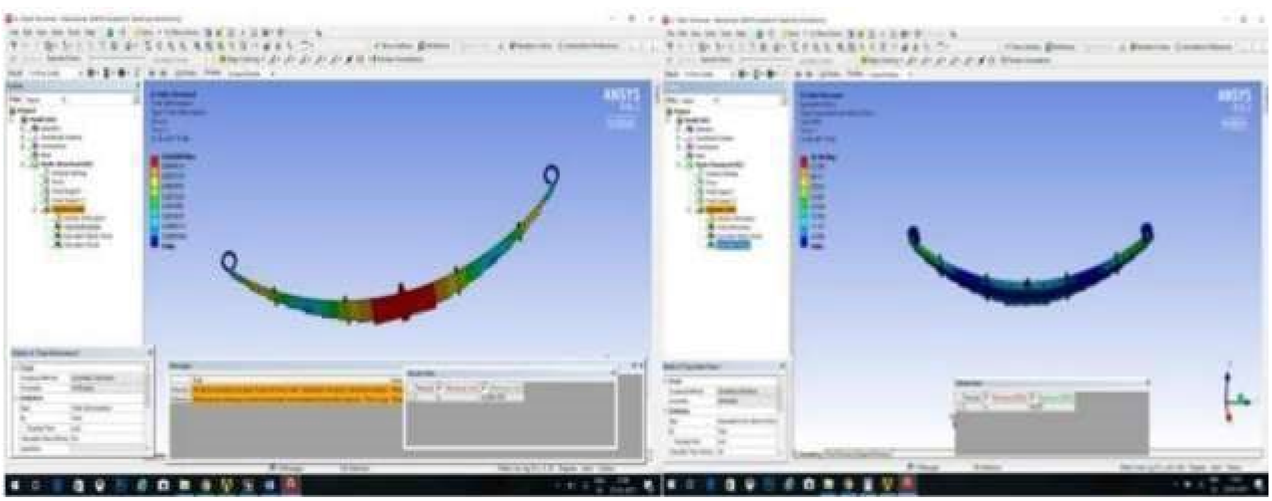

Figure 2. steel

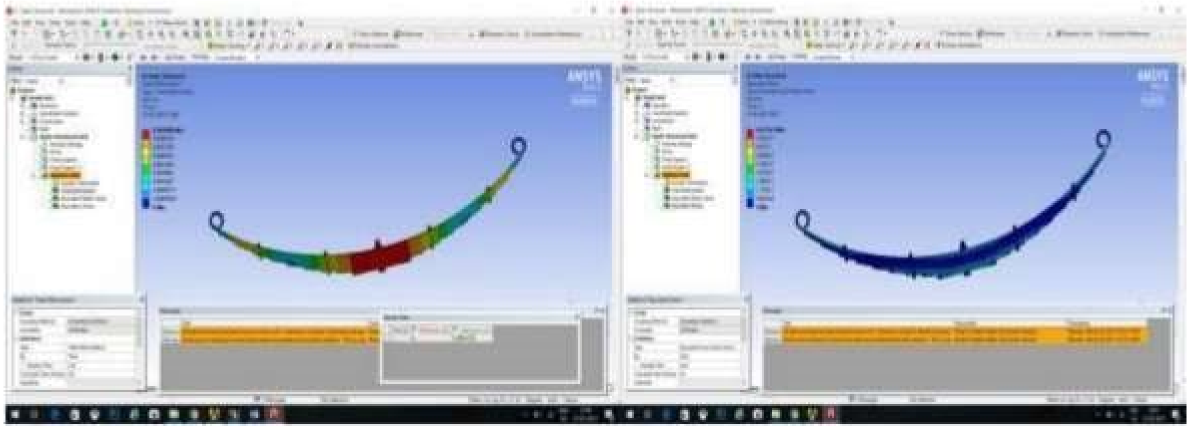

Figure 3. E-Glass/epoxy

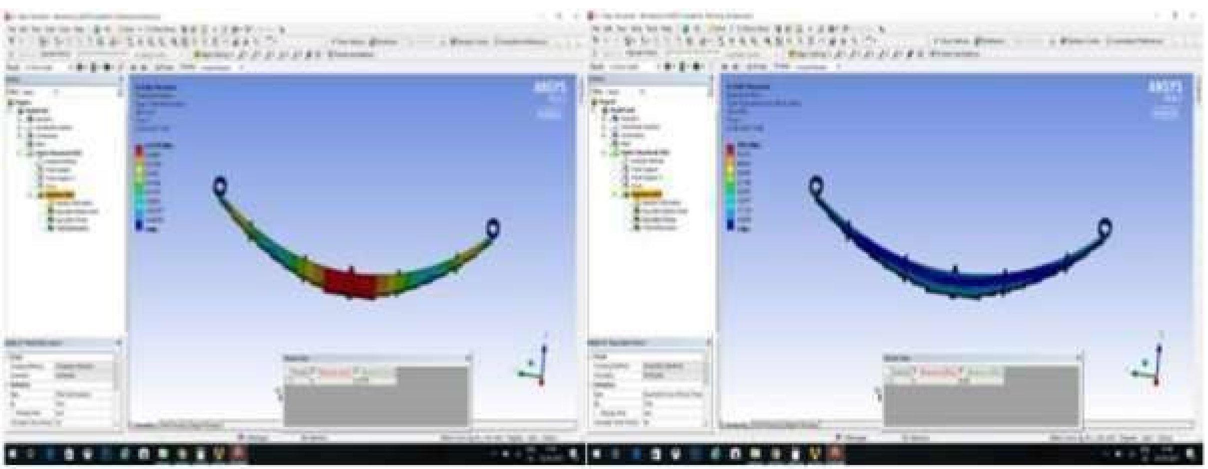

Figure 4. Titanium Alloy

4.1 Comaparing on Basis of Theoretical and Analytical Results:

Validating the stresses and deformation values from the results obtained from the analysis done in the ANSYS software and comparison is to be done to for the E-Glass/epoxy with titaniumalloy and steel to know about the betterment in use of composite material in the place of steel and titanium alloy (Table, 2, 3, 4).

Table 2. comparision of stresses

S.No	Material Used	Theoretical Value (In N/Mm^2)	Analysis Value (In N/Mm^2)
1.	steel	60	59.36
2.	E-Glass/epoxy	60	69.86
3.	Titanium alloy	60	59.96

Table 3. Comparison of deformations at 3600N

S.No	Material Used	Theoretical Value(In Mm)	Analysis Value(In Mm)
1.	Steel	0.143	0.133
2.	E-Glass/epoxy	3.356	3.36
3.	Titanium Alloy	0.297	0.275

Table 4. Comparison of individual weights

S.No	**Material Used**	**Theoretical Value (kg)**	**Analysis Value (kg)**
1.	Steel	16.65	18.4
2.	E-Glass/epoxy	4.25	3.61
3.	Titanium alloy	9.85	13.4

From the above tables of camparison of stresses,deformations and weights of different leafspring materials ,we can observe that in every coparison we are getting analysis values as nearer to the theoretical values.

6. Conclusion

1. Total deformation,equivalent elastic strain,equivalentstress,strainenergy,and mass results have been analysed for various material combinations in various leaf spring design cases.
2. For each design case, a static analysis of the leaf spring was performed using different material combinations under similar loading conditions.
3. For all leaf spring design cases, results for selected parameters are obtained.
4. The results are examined for the five parameters listed above. Design case D2 has been determined to be optimal for total deformation, equivalent elastic strain, equivalent (Von-Mises) stress, strain energy, and mass optimization.
5. For meshing and analysis of leaf springs, ANSYS 14.0 is used. This method of analysis is less expensive, more efficient, and takes less time than other methods of solution.

References

Dhoshi, Prof. N. K. Ingole, Prof. U. D. Gulhane, “Analysis and modification of leaf spring of tractor trailer using analytical and finite element method”, International Journal of Modern Engineering Research, Vol.1, Issue.2, pp 719-722, 2015.

Dara Ashok, M. V. Mallikarjun, Venkata Ramesh Mamilla. Design and Structural Analysis of Composite Multi Leaf Spring.IJETED, 5(2): pp30-37, 2012

Goudah, E. Mahdi, A.R. Abu Talib, A.S. Mokhtar, et al.Automobile Compression Composite Elliptic Spring. IJET. 3(2): pp-139-147, 2006.

Jadhao, DR. R. S. Dalu, “Experimental investigation & numerical analysis of composite leaf spring”, International Journal of Engineering Science and Technology, Vol. 3, No. 6, 2011.

Joo-teck Jeffrey, Tarlochan Faris, “Finite element analysis on the static and fatigue characteristics of composite multi-leaf spring”, Journal of Zhejiang University- Science, Vol. 13, 2012, pp 195-164, 2020.

Kumar Krishan, Aggarwal M.L. A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools. RJRS, 1(2): pp-92-96, 2012.

Patunkar, D. R. Dolas. Modelling and Analysis of Composite Leaf Spring under theStatic Load Condition by using FEA.IJMIE. 1(1): pp-1-4, 2011.