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Design and Analysis of Leaf Spring Using Composite Material

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ABSTRACT
Reducing weight while increasing or maintaining strength of products is getting to 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 paper we describe design and analysis of composite leaf spring. For this purpose, a rear leaf spring for MAHINDRA "MODEL-COMMANDER 650 DI" is considered. The objective is to compare the stresses, deformations 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 has high strength to weight ratio, good corrosion resistance.The material selected was glass fibre reinforced polymer (E-glass/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. Result shows that, the weight of composite leaf spring was nearly reduced up to 85% compared with steel material. The leaf spring was modelled in Pro/ENGINEER and the analysis was done using ANSYS software. The fatigue life of both steel and composite leaf is compared using ANSYS software.
Key words: Stiffness, Composite Leaf Spring, E-Glass/Epoxy, ANSYS, NX UG.

1. INTRODUCTION

1.1. Leaf Springs

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times.The advantage of leaf spring over helical spring is that the end of the springs may be guided along a definite path. Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason, manufacturers have experimented with mono-leaf springs.

Figure 1 A traditional leaf spring arrangement.

A leaf spring is a long, flat, thin, and flexible piece of spring steelorcomposite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple, and leaf's have been used in various capacities since medieval times. Most heavy duty vehicles today use two sets of leaf spring per solid axle, mounted perpendicularly to support the weight of the vehicle. This Hotchkiss system requires that each leaf set act as both a spring and a horizontally stable link. Because leaf sets lack rigidity, such a dual-role is only suited for applications where loadbearing capability is more important than precision in suspension response.

1.2. How Leaf Springs Work

Before you start your towing trip, it's a good idea to go over a brief checklist -- for safety's sake. You take a good look in your mirrors, adjusting them correctly in order to see passing traffic on the road. You've chosen the correct hitch and connected the towing vehicle to the trailer properly. The brake lights and braking systems are working synchronously, assuring you of the ride's legality. With everything loaded up, you're pretty confident the truck is ready for the job, so you head out on the road toward your destination. Once you reach a steady speed, however, the trailer behind your truck starts to bounce and sway a little more than it should. Pulling over to the side of the road, you rack your brains to figure out what you missed. You start to wonder if your cargo weight is maybe too high -- but what can you do about it?

1.3. Overview of Leaf Spring

1.3.1. Introduction

Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps.

The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes.

1.3.2. Suspension System

The automobile chassis is mounted on the axles, not direct but some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame anybody. All the part, which performs the function of isolating the automobile from the road shocks, is collectively called a suspension system. It includes the springing device used and various mountings for the same. Broadly speaking, suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber.

1.3.2.1. Objective of Suspension

- To prevent the road shocks from being transmitted to the vehicle components.
- To safeguard the occupants from road shocks.
- To preserve the stability of the vehicle in pitting or rolling, while in motion.

2. CONCEPT OF FATIGUE

2.1. Fatigue

In narrow sense, the term fatigue of materials and structural components means damage and damage due to cyclic, repeatedly applied stresses. In a wide sense, it includes a large number of phenomena of delayed damage and fracture under loads and environmental conditions. It is expedient to distinguish between high-cycle (classic) and low-cycle fatigue.

Plastic deformations are small and localized in the vicinity of the crack tip while the main part of the body is deformed elastically, then one has high-cycle fatigue. If the cyclic loading is accompanied by plastic deformation in the bulk of the body, then one has a low-cycle fatigue. Usually we say low-cycle fatigue if the cycle number up to the initiation of a visible crack or until final fracture is below 104 or 5.104 cycles.

2.2. Fatigue Strength

Fatigue strength is defined as the maximum stress that can be endured for a specified number of cycles without failure. Low cycle fatigue strength approaches the static strength. When the cycle number exceeds to one limit, the fatigue strength falls to fraction of the static strength.

The fatigue strength is the value of the alternating stress that results in failure by fracture a specific number of cycles of load application. It can also be the ordinate of the σ-n (stress versus number of cycles to failure) curve.

The fatigue behaviour of a specific material, heat treated to a specific strength level is determined by a series of laboratory tests on a large number of apparently identical samples of those specific materials.

2.3. Fatigue Failure

Failure is one of most important aspects of material behaviour because it is directly influent the selection of material for certain application, the method of manufacturing and service life of component. The majority of engineering failures are caused by fatigue. Fatigue failure is defined as the tendency of a material to fracture by means of progressive brittle cracking under repeated alternating or cyclic stresses of intensity considerably below the normal strength. Although the fracture is of a brittle type, it may take some time to propagate, depending on both the intensity and frequency of the stress cycles. Nevertheless, there is very little, if any, warning below failure if the crack is not noticed. The number of cycles required to cause fatigue failure at a particular peak stress is generally quite large, but it decreases as the stress is increased. For some mild steels, cyclical stresses can be continued indefinitely provided the peak stress (sometimes called fatigue strength) is below the endurance limit value.

2.4. Materials for Leaf Spring

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel products has greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties [14].

Making composites

Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibres or fragments of the other material, which is called the reinforcement.

2.5. Literature Review

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 [1]. 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 [2]. 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 [3].To meet the need of natural resources conservation, automobile manufacturers are attempting to reduce the weight of vehicles in recent years [4].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 unsprang 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[5].

2.6. Problem Definition

The suspension leaf spring is one of thepotentialitems for weight reduction in automobile as it accounts for ten to twenty percent of the un-sprung weight. The introduction of composites helps in designing a better suspension system with better ride quality if it can be achieved without much increase in cost and decrease in quality and reliability. The relationship of the specific strain energy can be expressed as it is well known that springs, are designed to absorb and store energy and then release it slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system.

It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of composite materials made it possible to reduce the weight of the leaf spring without reduction of load carrying capacity and stiffness due to more elastic strain energy storage capacity and High strength to weight ratio.

Table 1 Mechanical Properties of Steel

Mechanical	Symbols	Units	Values
Young's modulus	E	Gpa	207
Shear modulus	G	Gpa	80
Poisson's ratio	μ	-	0.3
Density	p	Kj/m3	7600
Yield strength	Sy	Mpa	370

3. Composite material

A composite material is characterized as a material made out of two or more constituents joined on a naturally visible scale by mechanical and chemical bonds. Composites are blends of two materials in which one of the materials isknown as the "matrixphase" and is implanted in the other material called the "reinforcing stage". Numerous composite materials offer modulus that is either equivalent or superior to any metals. In light of their low specific gravities, the strength to weight-proportion and modulus to weight-proportions of these composite materials are better than those of metallic materials.

Table 2 Properties of composite materials

S. No	Properties	Eglass/Epoxy
1	EX(MPa)	43000
2	EY(MPa)	6500
3	EZ(MPa)	6500
4	PRXY	0.27
5	PRYZ	0.06
6	PRZX	0.06
7	GX(MPA)	4500
8	GY(MPA)	2500
9	GZ(MPA)	2500
10	p	0.02

UG NX-8

- Unsurpassed geometry creation capabilities allow superior product differentiation and manufacturability.
- Fully integrated applications allow you to develop everything from concept to manufacturing within one application.
- Automatic propagation of design changes to all downstream deliverables allows you to design with confidence.
- Complete virtual simulation capabilities enable you to improve product performance and exceed product quality goals.

- Automated generation of associative tooling design, assembly instructions, and machine code allow for maximum production efficiency

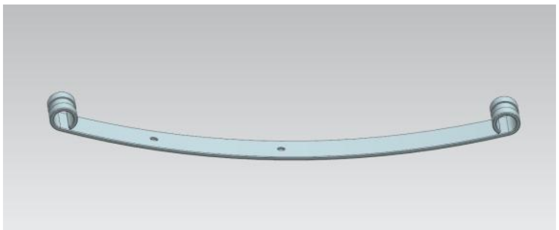

Figure 2 Master leaf modelled

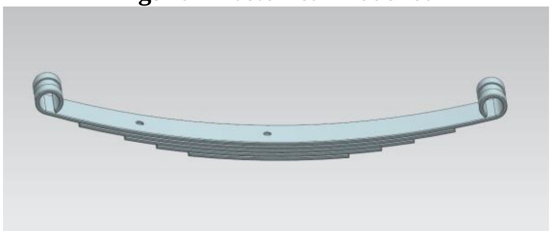

Figure 3 Assemble model developed

4. ANALYSIS IN ANSYS

4.1. Introduction

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

4.2. Boundary Conditions

The front eye of the leaf spring is coupled directly with a pin to the frame so that the eye can rotate freely about the pin, but no translation is occurred. The rear eye of the spring is connected to the shackle which is a flexible link the other end of the shackle is connected to the frame of the vehicle. The force 4169N applied at both the eye end of leaf spring. The both eyes of the leaf spring have the flexibility to slide along the X-direction when load applied on the spring and also it can rotate about the pin in Z- direction. The link oscillates during load applied and removed. So, the displacement at the both eyes is constrained along the X and Z directions

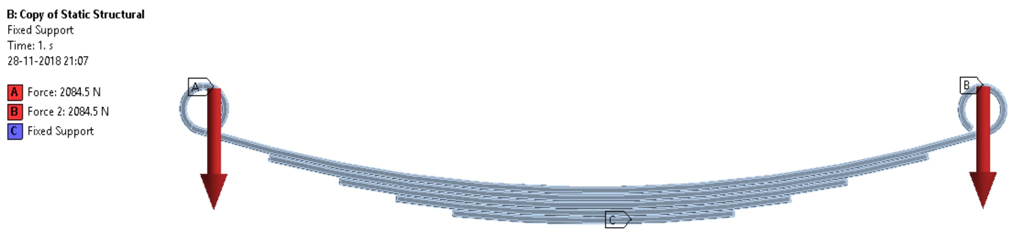

Figure 4 Structure of leaf spring

4.3. Analysis Resultsfor E-glass/epoxy

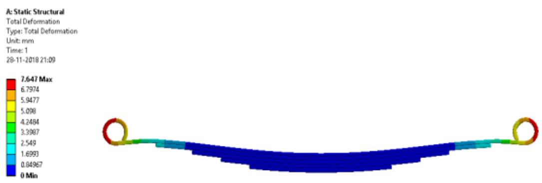

Figure 5 Deformations in E Glass/Epoxy

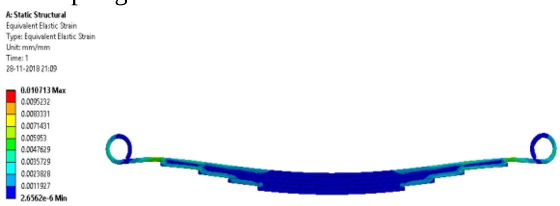

Figure 6 Strain in E Glass/Epoxy

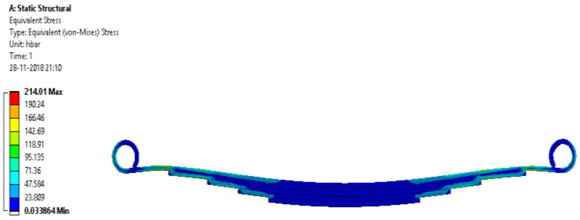

Figure 7 Stressin E Glass/Epoxy

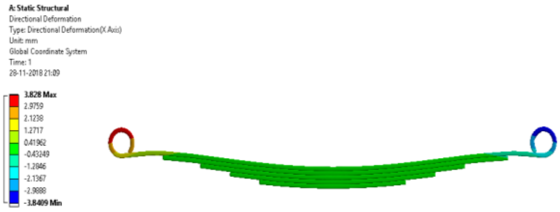

Figure 8 Directional deformationsin E Glass/Epoxy

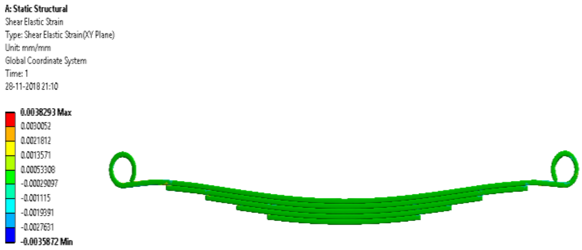

Figure 9 Shear Strainin E Glass/Epoxy

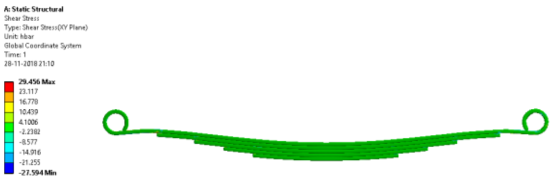

Figure 10 Shear Stress in E Glass/Epoxy

4.4. Analysis Results for STEEL

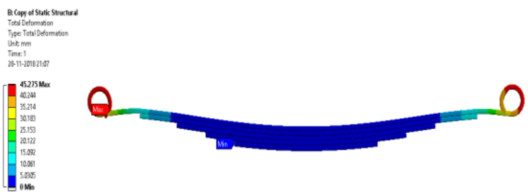

Figure 11 Deformationsin steel

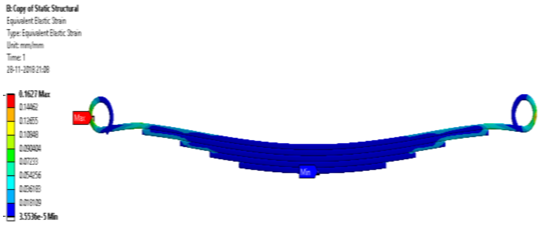

Figure 12 Strain in steel

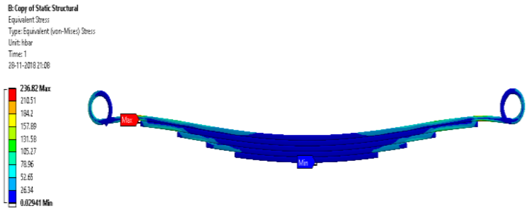

Figure 13 Stress in steel

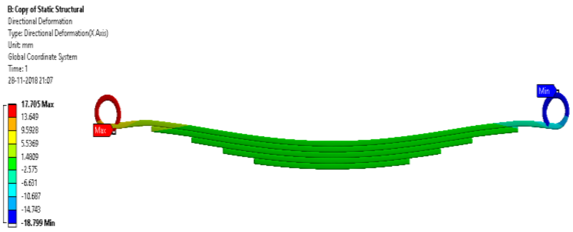

Figure 14 Directional deformationsin steel

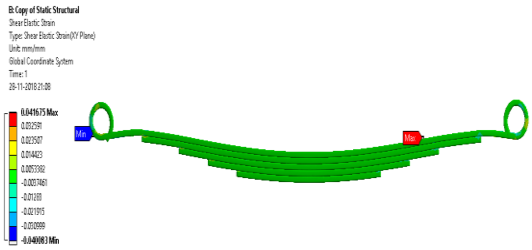

Figure 15 Shear Strainin steel

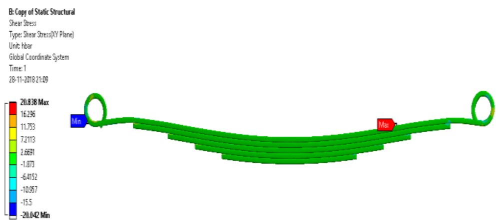

Figure 16 Shear Stressin steel

5. RESULTS

After that the multi leaf spring with E-Glass/Epoxy material is analyzed in ANSYS-12 with same dimension and same boundary condition as that of conventional leaf spring, showing bending stress and deflection under load in figures9and10. The comparison between steel leaf spring and composite leaf spring for deflection and bending stress results from the ANSYS is shown in the Table-V. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus, the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring.

Table 5 FEA results comparison between steel and composite leaf spring

Parameter	FEA Results for steel leaf string	FEA Results for composite leaf spring
Load, N	4169	4169
Bending Stress, MPa	236.82	214.01
Total Deflection, mm	45.275	7.647

Totally it is found that the composite leaf spring is the better that of steel leaf spring.

Table 6 Percent saving of weight by using composites

Materials	Weights	% weight saving
Conventional Steel	10.27 kg	-----
E-glass/epoxy	3.26 kg	67.88%

6.CONCLUSION

1. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single composite leaf spring is designed, 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.
2. From the static analysis results, we see that the von- mises stress in the steel is 236.82 MPa. And the von- mises stress in Eglass/ Epoxyis 214.01MPa.
3. Composite mono leaf spring reduces the weight by nearly 84% for E-Glass/Epoxy.
4. From the fatigue analysis results, the usage factor of Eglass/Epoxy is very much less compared to steel. Hence it is advantageous to replace steel leaf spring with Eglass/Epoxy.

REFERENCES

[1] M. Venkateshan, D. Helmen Devraj, Design and analysis of leaf spring in light vehicles, IJMER 2249-6645 Vol.2, Issue.1, pp.213-218, Jan-Feb 2012.

[2] R. S. Khurmi and J. K. Gupta Machine Design chapter 23.

[3] U. S. Ramakant& K. Sowjanya, Design and analysis of automotive multi leaf springs using composite material, IJMPERD 2249-6890 Vol. 3, Issue 1,pp.155162, March 2013,

[4] Rajendran I, Vijayarangan S, Design and Analysis of a Composite Leaf Spring, Journal of Institute of Engineers, India ,vol.-8,2-2002.

[5] DakshrajKothari,Rajendra Prasad Sahu and Rajesh Satankar Comparison of Performance of Two Leaf Spring Steels Used For Light Passenger Vehicle, VSRD-MAP 2249-8303 Volume2 (1), 9-16, 2012

[6] Mr. V. Lakshmi Narayana, Design and Analysis of Mono Composite Leaf SpringFor Suspension in Automobiles, IJERT 2278-0181, Vol. 1 Issue 6, August – 2012.

[7] Shishay Amare Gebremeskel, Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle, Global Journals Inc. (USA) 2249-4596, Volume 12 Issue 7, 21-30, 2012.

[8] Manas Patnaik, NarendraYadav, Study of a Parabolic Leaf Spring by Finite Element Method & Design of Experiments, IJMER 2249- 6645, Vol.2, 19201922, July-Aug 2012.

[9] Design and Analysis of E-Glass/Epoxy Composite Monoleaf Spring for Light Vehicle SushilB.Chopade1, Prof.K.M.Narkar2 , Pratik K Satav3.

[10] Investigation on different Compositions of E-Glass/Epoxy Composite and its application in Leaf Spring Suhas1 ,Jaimon D. Q.2 , Hanumanthraya R. 3 , Vaishak N. L4 , Mahesh B. Davanageri5.

[11] Tribological Behaviour of E-Glass /Epoxy & E-Glass /polyester Composites for Automotive Body Application Esmael Adem1 , P.Prabhu2.

[12] Rakesh Hota, Kshitij Kumar, Ganni Gowtham and Avinash Kumar Kotni. Experimental Investigation of Fiberglass Reinforced Mono-Composite Leaf Spring, *International Journal of Design and manufacturing Technology*, 4(1), 2013, pp. 30-42.

[13] Prof. N.V. Hargude, Mr. J.G. Herekar and Prof. P.P. Awate. Analysis of Composite Mono Leaf Spring, *International Journal of Advanced Research in Engineering and Technology*, 5(5), 2014, pp. 09-16.

[14] Mechanical Properties of Composite Material Reinforced by Jute and E-Glass Fibers B Durga Prasad1 , G. Kiran Reddy1 , A. Anusha Yadav1