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MODELING AND ANALYSIS OF CORBAN STEEL AND CORBAN FIBER LEAF SPRING

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Abstract
This paper describes design and analysis of composite mono leaf spring. 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 materials is modeled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. 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 a 3-D model has been performed using ANSYS 12.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found lesser stresses and weight reduction of 22.5% is achieved.

Keywords: Composite leaf spring (LCLS), Static analysis, Carbon/Epoxy, ANSYS 12.

1.INTRODUCTION

1.1 Leaf Spring

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi elliptical spring or cart spring. It consists of a number of flat plates of varying lengths held together by means of clamps and bolts. These are mostly used in automobiles.Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. 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. Thus the leaf springs may carry lateral loads, brake torque, driving torque etc., in addition to shocks.

1.2 History of Leaf Springs

There were a variety of leaf springs, usually employing the word elliptical. Elliptical or full elliptical leaf springs referred to two circular arcs linked at their tips. This was joined to the frame

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at the top centre of the upper arc; the bottom centre was joined to the live suspension components, such as a solid front axle. The other type of leaf spring is 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 their differentials that were curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non-metallic sheets in between the metal leaves, such as wood.A more modern implementation is the parabolic leaf spring. This design is characterised by fewer leaves whose thickness varies from centre to ends following a parabolic curve. In this design, inter-leaf friction is unwanted, and therefore there is only contact between the springs at the ends and at the centre where the axle is connected. Spacers prevent contact at other points. Aside from a weight saving, the main advantage of parabolic springs is their greater flexibility, which translates into vehicle ride quality that approaches that of coil springs. The characteristic of parabolic springs is better riding comfort and not as stiff as conventional multi-leaf springs. It is widely used on buses for better comfort. A further development by the British GKN company and by Chevrolet with the Corvette amongst others is the move to composite plastic leaf springs.

1.3 Overview of Leaf Springs

A leaf spring commonly used in automobiles is of semi-elliptical form, it built of a number of plates or leaves called blades. The leaves vary in length. The longest leave has eyes on its ends. This leave is called main leaf or master leaf and the other leaves of the spring are known as graduated leaves. The leaves are held together by means of a band shrunk around them at the centre or by a bolt passing through the centre. The leaves are usually given an initial curvature or cambered so that they will tend to straighten under load. The spring is supported on the axle, front or rear by means of a U-blot. One end of the spring is mounted on the frame with a simple pin, while on the other end connection is made with a shackle or hanger as shown in figure. When the vehicle comes across a projection on the road surface, the wheel moves up, deflecting the spring.

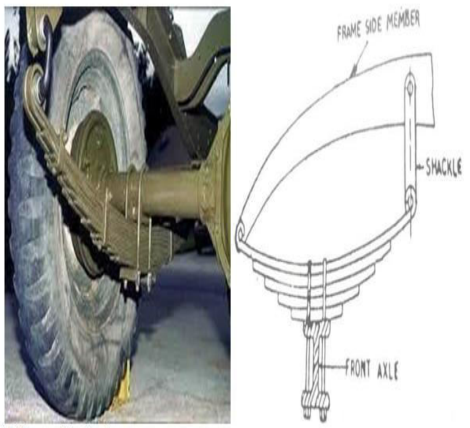

Figure 1.1: Rear end leaf spring

The material used for leaf springs is usually 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 produces greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.Spring eyes for heavy vehicles are usually bushed with phosphor bronze bushes. However, for cars and light transport vehicles like vans, the use of rubber has also become a common practice. This obviates the necessity of lubrication as in the case of bronze bushes, where it was a necessity. The life of spring can be increased by shot-peening the top surface of each leaf, which introduces a compressive residual stress, Rounding the edges of the leaves also avoid stress concentration, thereby improving the fatigue strength.

1.4 Applications of Leaf Springs

Leaf springs are one of the oldest forms of spring-type suspension systems, having been in use since medieval times. Leaf springs were commonly used in rear suspension of most automobiles. Leaf springs are generally used in heavier commercial-type vehicles such as trucks, vans, trailers, and railroad cars.

2.LITREATURE SURVEY

This chapter outlines some of the recent reports published in literature on replacement of steel leaf spring with the composite leaf spring.

Ashish V. Amrute et al. [1] discussed replacement of conventional steel leaf spring of a light commercial vehicle with composite leaf spring using E-glass/Epoxy. The finite element modeling and analysis of a multi leaf spring has been carried out. They reported that composite multi leaf spring is an effective replacement for the existing steel leaf springs in vehicles.

A.Venkata Vishnu et al. [2] discuss design and analysis of leaf spring made of mild steel and composite materials S2 glass and Kevlar. FEA Structural analysis and Modal Analysis are conducted. They reported that leaf spring made of composite S2 Glass Epoxy is advantageous than mild steel.

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M.Venkatesan et al. [3] discussed development of a composite leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings.

T.N.V.Ashok Kumar et al. [4] discussed static and dynamic analysis of steel leaf spring and laminated composite Multi leaf spring. 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 Glass/Epoxy and Kevlar/Epoxy 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 is compared with that of steel leaf spring. They reported that the strength of the composites is more compared to that of Mild Steel.

Manjunath H.N et al. [5] discussed the vibration behaviour of leaf spring under dynamic forces and to check the suitability of composite materials like E-Glass/Epoxy, Graphite/Epoxy, Boron/Aluminium, Carbon/Epoxy and Kevlar/Epoxy for light commercial vehicle leaf spring. First the modal analysis is performed to determine the Eigen values (natural frequencies) and mode shapes (eigenvectors), Harmonic analysis is carried out to determine the amplitude of response and random vibration analysis is carried out for smooth and rough road excitations using FE solver ANSYS V10. They reported that Boron/Aluminium is best suitable composite material for leaf spring.

3.COMPOSITE MATERIALS

3.1 Introduction

A composite material is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder maintains the

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position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibres and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

3.1Advantages of Composites

Light Weight - Composites are light in weight, compared to most woods and metals. Their lightness is important in automobiles and aircraft, for example, where less weight means better fuel efficiency (more miles to the gallon). People who design airplanes are greatly concerned with weight, since reducing a craft's weight reduces the amount of fuel it needs and increases the speeds it can reach. Some modern airplanes are built with more composites than metal including the new Boeing 787, Dreamliner.

High Strength - Composites can be designed to be far stronger than aluminium or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction.

Corrosion Resistance - Composites resist damage from the weather and from harsh chemicals that can eat away at other materials. Composites are good choices where chemicals are handled or stored. Outdoors, they stand up to severe weather and wide changes in temperature.

High-Impact Strength - Composites can be made to absorb the sudden force of a bullet, for instance, or the blast from an explosion. Because of this property, composites are used in bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions

3.2 Types of Fibre Reinforcements:

The following are the kinds of fibre reinforcements: Glass Fibres,Carbon Fibres, Natural Fibres ,Boron Fibres,Fibres based on Silica Fibres based on Alumina

Carbon fibre

Carbon fibre–reinforced polymer, carbon fibre–reinforced plastic or carbon fibre– reinforced thermoplastic (CFRP, CRP or often simply carbon fibre, or even carbon), is an extremely strong and light fibre-reinforced polymer which contains carbon fibres.In CFRP the reinforcement is carbon fibre, which provides the strength and the matrix is usually a polymer

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resin, such as epoxy, to bind the reinforcements together. The reinforcement will give the CFRP its strength and rigidity.To produce carbon fibre, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fibre as the crystal alignment gives the fibre high strength to volume ratio.

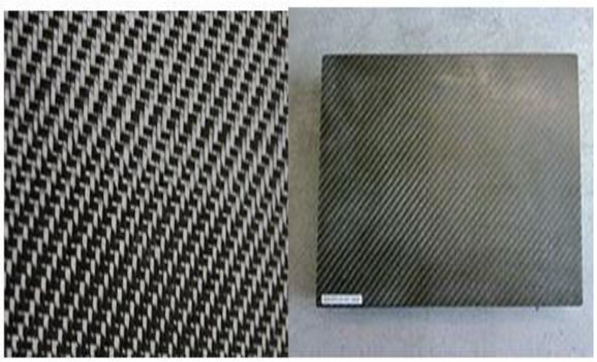

Figure 3.1: Carbon fibre

3.3 Material Properties

The below mentioned properties of materials are standard values taken from material library.

Table 3.1 Properties of Materials

Properties	Carbon Fibre	High carbon Steel
Young's Modulus (GPa)	388	190
Poisson's Ratio	0.358	0.3
Density (kg/m^3)	1600	7850
Tensile Strength (GPa)	4.1	1.1

4. CAD/CAM

Computer Aided Design:

Computer aided design is the use of wide range of computer based tools that assist engineers, architects and other design professionals in their design activities. Computer aided design encompasses a wide variety of computer based methodologies and tools for a spectrum of engineering activities planning, analysis, detailing, drafting, construction, manufacturing, monitoring, management, process control and maintenance. CAD is more concerned with the use of computer-based tools to support the entire life cycle of engineering system.

Fields of Use:

- Architecture
- Industrial design
- Engineering
- Mechanical (MCAD)
- Automotive
- Aerospace
- Machinery
- Building Engineering

4.1specific Design Data

Here measurements and weight of heavy truck is taken Span length 2L=1625 mm, L=812.5 mm

Width b=76 mm Thickness t=15 mm Weight of vehicle 5000 kg

Maximum load carrying capacity = 35 tons Acceleration due to gravity

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= 9.81 m/s2 Therefore, total weight =40000*9.81=392400 N

Since the vehicle is 10 wheeler, a single leaf spring corresponding to one of the wheels takes up 10th of the total weight. Therefore 392400/10=39240

N But 2F = 39240 N: F = 19620 N

4.2Modeling of Leaf Spring

Main Leaf:

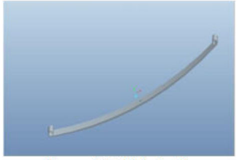

Figure 4.1: Main leaf

Graduated leaf:

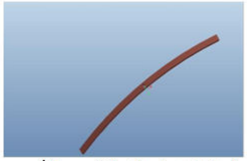

Figure 4.2: Graduated leaf U bolt:

Strap or Clip:

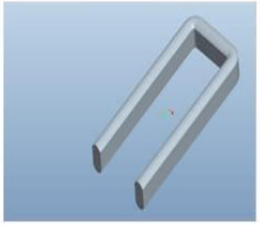

Figure 4.3: U-Bolt

Figure 4.4: Strap Plate: Bolt:

Figure 4.5: Plate

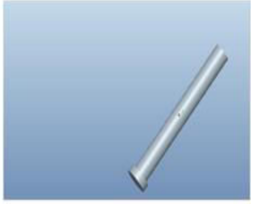

Figure 4.6: Bolt

5.FINITE ELEMENT METHOD ANALYSIS (FEM A)

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. The finite element method has become a powerful tool for the numerical solutions of a wide range of engineering problems. It has been developed simultaneously with the increasing use of the high- speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum problem, started in terms of different equations.

5.1 Design Considerations

Engineering Design is the process of devising a system component or process to meet desired needs. It is the decision-making process (often iterative) in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, syntheses,

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analysis, construction, testing and evaluation. The typical design criteria that should be satisfied for a particular structure are listed Below.

- Cost
- Reliability
- Weight
- Ease of operation and maintenance
- Appearance
- Compatibility
- Safety features
- Noise level
- Effectiveness
- Durability

6.RESULTS AND DISCUSSION

6.1 Stress Distribution

Figures 6.1 and 6.2 shows the equivalent von-misses stress induced in steel and carbon fibre leaf springs under the action of 19620 N load. The maximum stress is induced at the fixed eye end of the leaf spring its maximum value is 231.69 MPa for steel leaf and 216.82 MPa for carbon fibre leaf spring. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

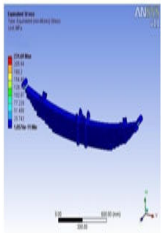

Figure 6.1: Stress distribution in Carbon steel

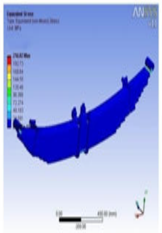

Figure 6.2: Stress distribution in Carbon Fiber

Table 6.1 Stress variation in different materials

MATERIAL	LOAD(N)	MAXIMUM STRESS (MPa)
CARBON STEEL	19620	231.69
CARBON FIBER	19620	216.82

6.2 Theoretical Calculations: Stiffness

A low spring stiffness implies that the spring will gently bounce up and down, in its free state which has low natural frequency of vibration and therefore provides soft ride. Conversely high spring stiffness refers to spring which has high natural frequency of vibration which produces a hard uncomfortable ride.

Spring stiffness (k) = applied load/deflection for carbon steel,

k =19620/107.45

k = 182.59 N/m

For carbon fibre,

k = 19620/ 222.01

K = 88.37 N/m

From the above calculations we can conclude that carbon fibre has less stiffness when compared to carbon steel.

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7.CONCLUSION

In the present work, a steel leaf spring was replaced by a composite CARBON FIBER leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimensions as that of steel leaf spring. We have found that

• The maximum stress distribution in the Carbon Fiber is less as compared with Carbon steel.

• The total deformation in the Carbon Fiber is more as compared with Carbon steel.

• The spring stiffness of Carbon Fiber is less as compared with Carbon steel.

• The strain energy stored in Carbon Fiber is more as compared with carbon steel.

• The weight reduction in Carbon Fiber is approximately 79.5% as compared to Carbon steel

• The frequency of the Carbon Fiber is also less as compared with Carbon steel.

Finally it is found that the composite leaf spring is the better than that of conventional steel leaf spring. Therefore, it is concluded that CARBON FIBER composite leaf spring is an effective replacement for the existing steel leaf spring in heavy trucks.

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