Design And Analysis Of Composite Leaf Spring- Review Paper

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***Abstract*- Present time the main issue of automobile industry are weight reduction. The automobile industry has looking for any implementation or modification to reduce the weight of the vehicle. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for 10% to 20% of the unsprung weight. The introduction of composite leaf spring made of glass fiber rein forced plastic (GFRP) has made it to possible to reduce the weight of spring without any reduction on load carrying capacity and stiffness. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel spring. This work deals with the replacement of multileaf steel spring with mono composite leaf spring for the LCV. It is possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness**.

***Keyword*- Ansys, Catia, FEA, Theoretical analysis of conventional leaf spring.**

I. 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.

Fig.1 Leaf spring assembled at rear axle of automotive

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.

Problem Statement:-

The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the un-sprung weight.

The conventional steel leaf spring has some problems which are listed as follow:

- Due to continuous running of the mini loader vehicle there is a decrease in the level of comfort provided by the spring.
- It is observed that the leaf springs tend to break and weaken at the eye end portion which is very close to the shackle and at the center.
- The conventional steel leaf spring has higher weight, which also affect the fuel efficiency.

Objective of the work:-

The objective of this project is:

- To reduce the weight
- Reduce product development cost.
- Increase the comfort.

Aim and Scope of the work:-

The objective of the present work is to design, analyse and propose a method of fabrication of composite mono-leaf spring for automobile suspension system.

This is done to achieve the following-

- This design helps in the replacement of conventional steel leaf springs with composite mono-leaf spring with better ride quality.
- To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with mono composite leaf spring.

Methodology:-

1. Material selection
   i. Fiber selection
   ii. Resin selection
2. Selection of design method
3. Fabrication of composite leaf spring by hand lay-up technique
   i. Strain Gauge Installation
   ii. Testing of leaf spring
   a. Selection of operating parameter
   b. Analysis of resulting data
4. Analytical analysis
5. FEA analysis
   i. Creating 3-dimensional model using modelling software
   ii. Analysis of model using FEA software.
   iii. Plotting various result from FEA software.
6. Comparison between conventional steel leaf spring and composite leaf spring.

II. MATERIAL AND METHODS

General

In leaf springs made of solid materials, the energy is stored as elastic strain energy. Further since a portion of the spring's mass is associated with vertical motion of the wheel, it is desirable to reduce its mass as well as other contributing unsprung mass to maximize vehicle control. Therefore the spring configuration and material of construction should be selected to maximize the strain energy storage capacity per unit mass without exceeding stress levels consistent with reliable long life operation.

Materials For Steel Leaf Spring

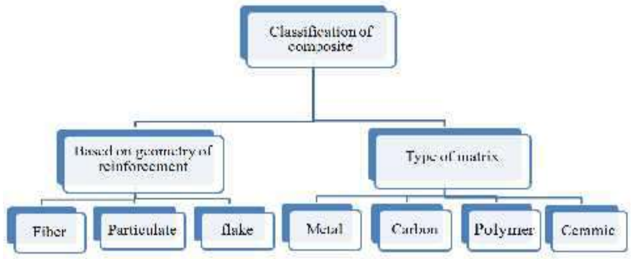
Many industries are manufactured steel leaf spring by EN45, EN45A, 60Si7, EN47, 50Cr4V2, 55SiCr7 and 50CrMoCV4 etc. These materials are widely used for production of parabolic leaf spring and conventional multi leaf spring. Leaf spring absorbed the vertical vibrations, shocks and bumps loads (induced due to road irregularities) by means of spring deflection, so that the potential energy stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy insures the comfortable suspension system.

Material for Composite Leaf spring

Many of modern technologies require material with unusual combinations of properties that can be made by metals, conventional metallic alloys, ceramics, and polymeric materials, e.g. materials needed for aerospace, underwater and transportation applications. For example engineers working in aircraft industry are looking and searching for structural material that have low densities are strong, stiff, abrasion and impact resistance and are not easily corroded. Usually strong materials are relatively dense; also increasing the strength or stiffness generally parts where two materials combine to rein force and bind together. Composites include multiphase metal alloys, ceramic and polymers. A composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constitutes phases such that a better combination of properties is realized. This is termed as the principle of combined action. According to this principle, better combinations are fashioned by the judicious combination of two or distinct materials.

Composite Materials

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds. Composites are combinations of two materials in which one of the material is called the "matrix phase" is in the form of fibers, sheets, or particles and is embedded in the other material called the "reinforcing phase". Many composite materials offer a combination of strength and modulus that are either comparable to or better than any tradigonal metalic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of metallic materials. The fatigue strength weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries. Another unique characteristic of many fiber reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighboring structures. High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort.



III. MATERIAL SELECTION

Materials constitute nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

Fiber Selection

The designer or material specialist has a wide range of fibers from which to make a selection. Often a fiber is selected because of physical properties. Fiber selection should also consider mechanical and thermal properties. The silent mechanical properties are modulus and strength. Those for thermal properties include coefficient of thermal expansion and thermal conductivity.

Vertical vibrations and impacts are buffered by variations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system. The material used directly affects the quantity of storable energy in the leaf spring. The specific strain energy can be written as Equation.

The material with maximum strength and minimum modulus of elasticity is the most suitable material for the leaf spring application.

TABLE I
STRAIN ENERGY STORED BY MATERIAL (KJ/KG)

Sr. No.	Material	Strain energy stored by material(KJ/Kg)
1	Carbon/epoxy	2.45
2	E-glass/epoxy	4.5814
3	C-glass/epoxy	18.76
4	S-glass/epoxy	32.77

The commonly used fibers are carbon, glass, Kevlar etc. Among these, the carbon fiber has been selected based on the strength and stiffness. Although carbon fibers have better mechanical properties than other fibers, and their advantageous include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength which is used as standard reinforcement fiber for all mechanical property requirements. Thus, Carbon fiber was found appropriate for this application.

Resin Selection

In a FRP leaf spring, the inter laminar shear strengths is controlled by the matrix system used. Since these are reinforcement fibers in the thickness direction, fiber do not influence inter laminar shear strength. Therefore, the matrix system should have good inter laminar shear strength characteristics compatibility to the selected reinforcement fiber. Many thermo set resins such as polyester, vinyl ester, epoxy resin are being used for fiber reinforcement plastics (FRP) fabrication. Among these resin systems, epoxies show better inter laminar shear strength and good mechanical properties. Hence, epoxies are found to be the best resins that would suit this application. Different grades of epoxy resins and hardener combinations are classifieds based on the mechanical properties which in combination with hardener 758 cures into hard resin.

It is characterized by
1. Good mechanical and electrical properties.
2. Faster curing at room temperature.
3. Good chemical resistance properties.

Matrix materials or resins in case of polymer matrix composites can be classified according to their chemical base i.e. thermoplastic or thermo sets. Thermoplastics have excellent toughness, resilience and corrosion resistance but have fundamental disadvantage compared to thermosetting resins, in that they have to be molded at elevated temperature. Thermosetting plastics or thermo sets are formed with a network molecular structure of primary covalent bonds. Some thermo sets are cross-linked by heat or a combination of heat and pressure. Others may be cross-linked by chemical reaction, which occurs at room temperature. At present, epoxy resins are widely used in various engineering and structural applications such as aircraft, aerospace engineering, sporting goods, automotive, and military aircrafts industries. In order to improve their processing and product performances and to reduce cost, various fillers are introduced into the resins during processing. Epoxy resins are the most commonly used thermo sets plastic in polymer matrix composites. Hence from the above listed advantages of epoxy resin it has been selected for the study.

IV. Design selection

The leaf spring behaves like a simply supported beam and the flexural analysis is done considering it as a simply supported beam. The simply supported beam is subjected to both bending stress and transverse shear stress. Flexural rigidity is an important parameter in the leaf spring design and test out to increase from two ends to the center.

Constant Thickness, Varying Width Design

In this design the thickness is kept constant over the entire length of the leaf spring while the width varies from a minimum at the two ends to a maximum at the center.

Constant Width, Varying Thickness Design

In this design the width is kept constant over the entire length of the leaf spring while the thickness varies from a minimum at the two ends to a maximum at the center.

Constant Cross Section- Selection Design

In this design both thickness and width are varied throughout the leaf spring such that the cross section area remains constant along the length of the leaf spring. Out of the above mentioned design concepts, the constant cross section design method is selected due to the following reasons:-

- Due to its capability for mass production and accommodation of continuous reinforcement of fibers.
- Since the cross section area is constant throughout the leaf spring, same quantity of reinforcement fiber and resin can be fed continuously during manufacture.
- Also this is quite suitable for hand layup technique.

Leaf Spring Design

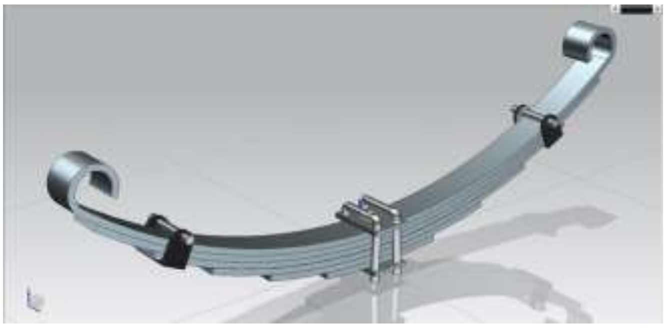


Fig. 2 Leaf spring cad model

TABLE II
Steel leaf spring specification (mm)
Maruti Suzuki Alto

Straight lenght	965
Leaf thickness	10
Leaf width	50
camber	112

- Bending Stress of the leaf spring-

$\sigma_{max} = (6wL/bt^2)$

where, W = cantilever load

t = leaf thickness

b = leaf width

- Deflection of Plate-

$\delta_{max} = (WL^3/3EI)$

where, W = central load

E = modulus of elasticity

I = moment of inertia

Finite Element Analysis Of Steel Leaf Spring:

Static analysis is performed on the steel and composite leaf spring. The steps required for static analysis are:

1. Creating 3-dimensional model using modelling
2. Software Import given model in FEA software
3. Defining Preferences
4. Defining Element Types
5. Defining Material Properties
6. Meshing of Model
7. Defining Boundary Conditions
8. Define Loads
9. Solve
10. Result

The deflection and stress plot of Steel and composite leaf spring obtain from FEA software.

V. 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. In this paper 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 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. Carbon fibre/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view.

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