

Design, Analysis and Weight Optimization of Composite Material Mono Leaf Spring Using FEA

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ABSTRACT

The leaf spring is widely used in automobiles as major component of suspension system. This spring is intended to bare jerks and vibrations during traveling on uneven surfaces. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unsparing weight. The reduction in weight will achieve fuel efficiency and improve riding quality. The objective of the project is to apply FEA concept to compare two materials for leaf spring and proposed the one who is having best strength to weight ratio. In this paper I used composite Carbon Fiber Epoxy material to replace Omni leaf spring with steel material.

Keywords– *Multi leaf spring, Composite material, E Glass Fiber, Static analysis, Weight optimization.*

I. INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Leaf springs absorb the vehicle vibrations, shocks and bump loads (induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. The spring consists of a number of leaves called blades. The blades are varying in length but in this case blades are same 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 [1].

As shown in figure 1 the leaves are held together with the help of two U-bolts and also centre clip. Also in that Rebound clips are provided to keep the leaves in alignment and save from lateral shifting of the plates during the working condition [2].

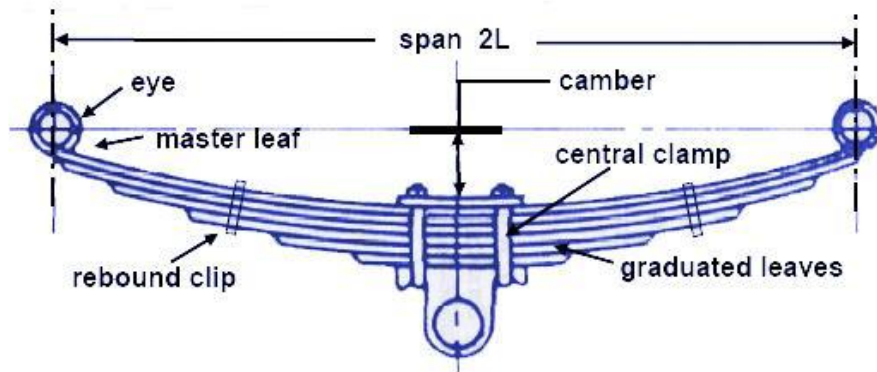


Fig.1 Geometry of Leaf Spring [1]

The spring is mounted on the axle of the vehicle. The entire vehicle load 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, leading to deflection of the spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is provided at one end, which gives a flexible connection. The front eye of the leaf spring is constrained in all the directions, whereas rear eye is not constrained in X-direction. This rear eye is connected to the shackle. During loading the spring deflects and moves in the direction perpendicular to the load applied [4].

Composite Material

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds. Typical composite materials are composed of inclusions suspended in a matrix. The constituents retain their identities in the composite. Normally the components can be physically identified and there is an interface between them. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic materials. Because of their low specific gravities, the strength weight-ratio and modulus 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 excellent. For these reasons, fiber composite have emerged as a major class of structural material.

II. LITERATURE REVIEW

Mr. V. K. Aher and Mr. P. M. Sonawanepredict the fatigue life of semi-elliptical steel leaf spring along with analytical stress and deflection calculations. The work describes static and fatigue analysis of a modified steel leaf spring of a light commercial vehicle (LCV). The dimensions of a modified leaf spring of a LCV are taken and are verified by design calculations. The non-linear static analysis of 2D model of the leaf spring is performed using NASTRAN solver and compared with analytical results. The preprocessing of the modified model is done by using HYPERMESH software. The stiffness of the modified leaf spring is studied by plotting

load versus deflection curve for working range loads. The simulation results are compared with analytical results. The fatigue life of the leaf spring is also predicted using MSC Fatigue software. Mouleeswaran SenthilKumar, SabapathyVijayaranganhas describes composite leaf spring design on the basis of fatigue failure .Theoretical equation for prediction fatigue life is formulated using fatigue modulus and its degrading rate. The dimensions and number of leaves for both steel leaf spring and composite leaf spring are considered to be same. The stress analysis is performed using finite element method .The element selected for analysis is solid 45 which behave like a spring. For the fabrication of each leave the filament winding machine is used and assembled this leaves together with the help of center bolt and four side clamps. The testing of steel multi leaf spring and composite multi leaf spring are carried out with the help of an electro hydraulic leaf spring test rig. Design and experimental fatigue analysis of composite multi leaf spring are carried out using data analysis. It is found that composite leaf spring has 67.35%lesser stress, 64.95% higher stiffness and 126.98%higher natural frequency and also 68.15% weight reduction is achieved. M.Venkatesan and D.HelmenDevarajDescribes design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer. Their objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken. Same dimensions of conventional leaf spring are used to fabricate a composite multi leaf spring using E- Glass/Epoxy unidirectional laminates. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 10 and compared with experimental results. Finite element analysis with full load on 3-D model of composite multi leaf spring is done using ANSYS 10 and the analytical results are compared with experimental results. Compared to steel spring, the composite leaf spring is found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf spring. A weight reduction of 76.4% is achieved by using optimized composite leaf spring.

V.K.Aher, R.A.Gujar, J.P.Wagh& .M.Sonawanedescribes the importance high fatigue life. As a general rule, the leaf spring is regarded as a safety component as failure could lead to severe accidents. The purpose of the work is to predict the fatigue life of steel leaf spring along with analytical stress and deflection calculations. The work describes static and fatigue analysis of a steel leaf spring of a light commercial vehicle (LCV). The dimensions of the leaf spring of a LCV are taken and are verified by design calculations. The non-linear static analysis of 2D model of the leaf spring is performed using NASTRAN solver and compared with analytical results. The preprocessing of the model is done by using HYPERMESH software. The stiffness of the leaf spring is studied by plotting load versus deflection curve for various load applications. The simulation results are compared with analytical results. The fatigue life of the leaf spring is predicted using MSC Fatigue software.

GulurSiddaramanna, Shiva Shankar&SambagamVijayarangan [4] describes a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. A single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multiyear spring, was designed, fabricated (hand-layup technique) and tested. Computer algorithm using C-language has been used for the design of constant cross-section leaf spring. The results showed that an spring width decreases hyperbolically and thickness increases

linearly from the spring eyes towards the axle seat. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses (Tsai-Wu failure criterion) and displacement. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit.

III. OBJECTIVE

- 1 To reduce the weight of the mono leaf spring in vehicle to increase the fuel efficiency.
- 2 Static analysis of standard Steel leaf spring, E-glass epoxy spring, & Carbon fiber spring using FEA. Determining effects of deflection and bending stress.
- 3 Manufacturing and Testing of Composite Leaf springs
- 4 Comparison and Validation of results by Theoretical calculations and Testing

IV. THEORETICAL CALCULATION

Design Specification

Here Weight and initial measurements of four wheeler “MARUTI OMNI” Light weight vehicle is taken.

Weight of vehicle= 1200kg

Maximum load carrying capacity= 1000 kg

Total weight= 1200+ 1000 = 2200 kg

Taking factor of safety (FS) = 2

Acceleration due to gravity (g) = 9.81m/s²

Therefore; Total Weight = 2200×9.81 = 21582N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one 4th of the total weight.

= 21582/4 = 5395.5N

But 2F = 5395.5 N, F = 2697.75 N

Span length, 2L = 1072 mm, L= 536mm.

For Steel Leaf Spring -

Now the Maximum Bending stress of a leaf spring is given by the formula-

$$\sigma = (6 \times f \times l) / (n \times b \times t^2)$$

$$\sigma = (6 \times 2697.75 \times 536) / (3 \times 60 \times 8 \times 8)$$

$$\sigma = 753.12\text{N/mm}^2$$

The Total Deflection of the leaf spring is given by

$$\delta = (6 \times f \times l^3) / (E \times n \times b \times t^3)$$

$$\delta = (6 \times 2697.75 \times 536 \times 536 \times 536) / (2.1 \times 10^5 \times 3 \times 60 \times 8 \times 8 \times 8)$$

$$\delta = 128.79\text{mm}$$

For Glass Fiber Leaf Spring-

Now the Maximum Bending stress of a leaf spring is given by the formula-

$$\sigma = (6 \times f \times l) / (n \times b \times t^2)$$

$$\sigma = (6 \times 2697.75 \times 536) / (3 \times 60 \times 24 \times 24)$$

$$\sigma = 83.68 \text{ N/mm}^2$$

The Total Deflection of the leaf spring is given by

$$\delta = (6 \times f \times l^3) / (E \times n \times b \times t^3)$$

$$\delta = (6 \times 2697.75 \times 536 \times 536 \times 536) / (43000 \times 3 \times 60 \times 24 \times 24 \times 24)$$

$$\delta = 123.29 \text{ mm}$$

Measured data of the above stated light weight four wheeler vehicles.

Straight length of the parabolic leaf spring (L) = 1072mm

V. CONCLUSION

1. All research work is done on single composite material.
2. Carbon fiber is best suitable material for leaf spring application.
3. Composite material eye joint are weaker than steel eye joint.

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