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DESIGN AND TRANSMISSIBILITY TESTING OF COMPOSITE MONO LEAF SPRING

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ABSTRACT

A leaf spring is commonly used for the suspension in vehicles. Leaf spring absorbs vibrations induced during the motion of vehicle. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above the trailer's axle. There are single leaf springs and multi leaf spring used based on the application required. It also acts as a structure to support vertical loading due to the weight of the vehicle and payload. The Glass fiber reinforced plastics (FRP) composite mono leaf spring reduces weight of the machine element without any reduction of the load carrying capacity. It has high strength-to-weight ratio compared with those of steel. Also multi-leaf steel springs are being replaced by mono leaf FRP spring. The objective of the present work is to design and transmissibility testing of composite mono leaf spring. The load on the leaf spring acts on the center.Thespring thus vibrates and prevents the vibrations to pass over to the other parts. In this work the frequency of the vibrations generated by the cam jump set up which is placed right below the leaf spring. Vibrations given to the spring are on the basis of the different road conditions. The experimentation is conducted for transmissibility and results are compared with steel leaf spring.

INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. 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 automobile as it accounts for ten to twenty percent of the unsprung weight. This helps in achieving the vehicle with improved riding qualities. It is well known that springs, are designed to absorb and store energy and then release it.
Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as,

$$U = \frac{\sigma 2}{\rho E}$$

Where, σ is the strength
ρ is the density
E is the Young's modulus of the spring material.

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 was made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. In every automobile i.e. four wheelers and railways, the leaf spring is one of the main components and it provides a good suspension and it plays a vital role in automobile application. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. 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.

E. Mahdi and A.M.S. Hamouda [1] shown that new composite semi-elliptical suspension spring by utilizing fiber reinforced composite. They tested three types of composites, namely, carbon/epoxy, glass/epoxy and glass/carbon/epoxy. Typical behaviors of their compression, tension, torsion and cyclic tests are presented and the results showed that the fiber type and elasticity ratio significantly influenced the spring stiffness. Y.S. Kong et.al[2] simulated the fatigue life of a parabolic leaf spring design under variable amplitude loading (VAL). VALs signal were gathered through measurements from various road conditions such as highway, curve mountain road and rough rural area road. Subsequently, fatigue life of particular leaf spring design was predicted using finite element (FE) stress–strain model together with VALs signal as load input. The results indicated that fatigue life of leaf spring is lowest during rough road mission, followed by curve mountain road and smooth highway road respectively. Yogesh G. Nadir et.al[3] studied on comparison between steel leaf spring and composite leaf spring. In case of composite leaf spring the 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. B.Vijaya Lakshmiet.al [4] compared the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. R D V Prasad et.al [5] shown that the introduction of fiber reinforced plastics (FRP) made it possible to reduce weight of the product without any reduction in load carrying capacity and stiffness. This paper deals with development of analytical formulation for Composite leaf spring and comparing the obtained results with the Conventional Steel leaf spring with 4 leaves.

Composite leaf springing this research has been developed as a mono block construction with maximum thickness at the center which is preferably glass fiber reinforced polymer. The thickness reduces towards the end in order to achieve uniform strength construction. The cross-section is constant at any section along the spring length. This condition is imposed to accommodate the unidirectional fibers and to maintain the fiber continuity from one end to the other. At first they designed a conventional Leaf spring with 4 leaves using ANSYS 11 and considered different loading conditions to obtain Stresses and Deflections. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken. Then we created a Solid Model of Composite leaf spring using CATIA V5 and imposed different loading conditions.

DESIGN OF LEAF SPRING WITH COMPOSITE MATERIAL

CROSS-SECTION SELECTION OF MONO COMPOSITE LEAF SPRING

The following cross-sections of mono composite leaf spring for manufacturing easiness are considered.

1. Constant thickness, constant width design.
2. Constant thickness, varying width design.
3. Varying width, varying thickness design.

The constant cross section design is selected due to itscapability for mass production, and to accommodate continuous reinforcement of fibers and also it is quite suitablefor hand lay-up technique.

SPECIFIC DESIGN DATA

Here Weight and initial measurements of TATA ACE light vehicle are taken.

Gross vehicle weight = 1770 kg

Taking factor of safety (FS) = 1.5

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

There for; Total Weight (W) = 1770*9.81*1.5 = 26045 N

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

F = 26045/4 = 6511 N

LEAF SPRING SPECIFICATIONS OF TATA ACE
Total Length (L) 1060 mm
Length of leaf spring from Eye to Eye 990 mm
Thickness (t) 8 mm
Width (b) 60 mm

MATERIAL PROPERTIES OF 55SI2MN90 STEEL
1. Ultimate tensile strength - 1962 Mpa
2. Yield tensile strength - 1470 Mpa
3. Modulus of elasticity (E)– 210 Gpa
4. Poisson ratio 0.3

The leaf springs are widely used in suspension system of railway carriages and automobiles. But the form in which it is normally seen is laminated leaf spring. In the cantilever beam type leaf spring, for thesame leaf thickness, h, leaf of uniform width, b considered. From the basic equations of bending stress and deflection, the maximum stress, σ max and deflection max can be derived.

For uniform width

$$\sigma_{max} = \frac{6FL}{bh^2}$$

$$\delta_{max} = \frac{4FL^3}{Ebh^3}$$

Where, E is the Elastic modulus of the spring material.
From the stress and deflection equations the thickness of the spring plate, h, can be obtained as

$$\text{h} = \frac{\sigma_{max} L^2}{E\delta_{max}}$$

Substitution of h in the stress equation above will yield the value of plate width b.

$$b = \frac{3\text{FL}}{\sigma_{max} h^2}$$

In the similar manner h and b can be calculated for leaf springs.

MANUFACTURING OF LEAF SPRING

Many techniques can be suggested for the fabrication of composite leaf spring from unidirectional GFRP. Composite leaf spring was fabricated using wet filament winding technique. In the present work, the hand lay-up process was employed. The templates (mould die) were made from wood and plywood according to the desired profile obtained from the computer algorithm. The glass fibers were cut to the desired lengths, so that they can be deposited on the template layer by layer during fabrication. In the conventional handle-up technique, a releasing agent (gel/wax) was applied uniformly to the mould which had good surface finish. This is followed by the uniform application of epoxy resin over glass fiber. Another layer is layered and epoxy resin is applied and a roller was used to remove all the trapped air. This process continued till the required dimensions were obtained. Care must be taken during the individual lay-up of the layers to eliminate the fiber distortion, which could result in lowering the strength and rigidity of the spring as a whole. The duration of the process may take up to30 min. The mould is allowed to cure about 4 – 5 days at room temperature. Mono composite leaf springs with and without eye ends was fabricated by using above said technique.

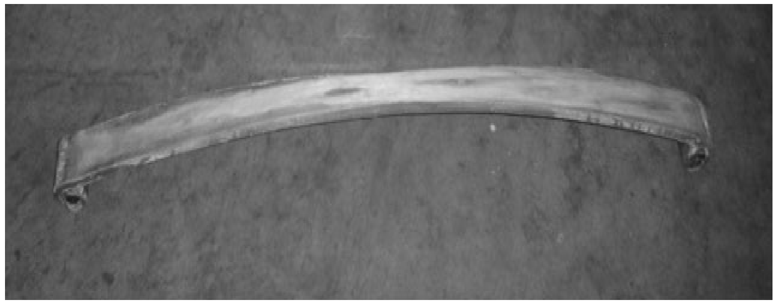

Figure 1:Complete composite mono leaf spring

EXPERIMENTAL SETUP

After design and manufacturing of the GFRP composite leaf spring we need to compare the transmissibility of composite and steel leaf spring. For all the above purpose we need to design the setup on which composite and steel leaf spring should be mounted which gives us the expected results. One end of the composite leaf spring is fixed to the rigid frame and other end is movable. Load on the leaf spring acts on the center and is then distributed all over the spring through its body. The spring thus vibrates and prevents the vibration to pass over to the other parts. In our analysis load is given by using cam follower mechanism and it gives the vibrations that will takes place on the leaf spring. A vibration receives by proximity sensor and amplitude is measured. Experimental setup diagram is as follows:

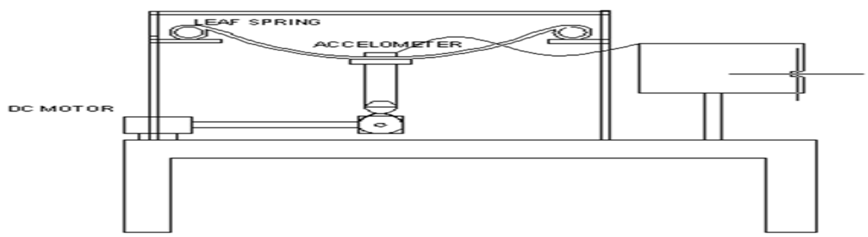

Figure 2: Experimental setup

Experimental Setup Consist of

- Leaf spring
- DC motor
- Cam and follower mechanism

The experimental test rig is used for testing of leaf spring. Amplitude checked by using proximity sensor. Test is conducted for different frequencies and transmissibility is evaluated for steel and composite leaf spring.

RESULT AND DISCUSSION

Transmissibility is defined as the force or motion transmitted to the supporting structure or foundation, to the force impressed upon the system. Transmissibility measures the effectiveness of the vibration isolating material**.**

Table 1.Transmissibility of steel leaf spring

Sr. No.	ω_n	**Amplitude(mm)**	ω	$\frac{\omega}{\omega_n}$	**Transmissibility**
1	66.67	1.25	89.85	1.347	0.235
2	66.67	1	99.27	1.488	0.1893
3	66.67	0.75	108.91	1.633	0.143
4	66.67	0.5	119.17	1.78	0.0961

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Table 2. Transmissibility of composite mono leaf spring

Sr. No.	ω_n	Amplitude(mm)	ω	$\frac{\omega}{\omega_n}$	Transmissibility
1	70.71	2	89.85	1.2706	0.2128
2	70.71	1.75	99.27	1.403	0.1870
3	70.71	1.5	108.91	1.540	0.1630
4	70.71	1.25	119.17	1.685	0.1350

From the above results we see that the ratio of (ω/ ωn) is always greater than $\sqrt{2}$ which indicates the transmitted vibration is very less and also the frequency ratio goes on increasing proportionally with increase in speed which shows that the greater vibration isolation is possible at greater speeds.
Now comparing the values for the steel and composite leaf spring we see that for same speed the value of frequency ratio for composite leaf spring is always greater than that of the steel leaf spring. This indicates that the composite leaf spring would give less transmissibility as compared with the steel leaf spring. Thus composite leaf spring would be more efficient than that of the steel leaf spring at the same speeds.

CONCLUSION

1. The natural frequency of composite material is higher than the steel leaf spring.
2. Comparison of composite leaf spring and steel spring is again done based on their working on actual road condition. The frequency ratio is determined for both the springs and it is seen that the composite leaf spring is more efficient than the steel leaf spring for every speed of vehicle and also the vibration isolation is greater in the composite leaf spring than that of the steel leaf spring.

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