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Analysis of Steel Made Leaf Spring using FEA Tool ANSYS

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***Abstract*— Mathematical and computer modelling have been playing an increasingly important role in the Computer Aided Engineering (CAE) process of many products in the last 60 years. Simulation offers great advantages in the development and analysis phase of products and offers a faster, better and more cost effective way than using physical prototypes alone. This paper analyses the mechanics characteristic of a composite leaf spring made from glass fibre reinforced plastics using the ANSYS software. Considering interleaf contact, the stress distribution and deformation are obtained. Taking the single spring as an example, comparison between the performance of the GFRP and the steel spring is presented. The comparison results show that the composite spring has lower stresses and much lower weight. Then the automotive dead weight is reduced observably.**

***Index Terms*— Spring, Leaf, Laminated Stress, Strain, Equivalent stress, Shear Stress, Finite element method..**

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 [1]. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system. 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. Springs are an important and frequently used component in mechanical engineering. Whilst most people are able to recognize a few standard spring configurations, the range of springs is actually much broader: they have many different forms and perform a number of quite separate and distinct functions, with one spring often combining several functions. Some of the functions of springs, broadly defined, are shown in the table below.

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Table.1 functions of spring

Purpose	Uses/Examples
Carry load	Suspension springs of a car
Apply force	Throttles return spring for car engine. Spring-set brake. Counterbalance springs for desk lamp. Spring-loaded safety valve.
Measure force	Spring balance
Control movement	Valve spring of a car engine. Belleville washers to provide axial pre-load for bearings. Throttle returns spring for car engine.
Isolate vibration	Motor car seats. Motor car suspension. Motor car engine mountings.
Take up slack	Belleville washers located behind a bearing (also provides pre-load).
Store energy	Bungee jump. Spear-gun rubber. Hydraulic accumulator. Air compressor tank. English long bow

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 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, where as rear eye is not constrained in X-direction. This rare eye is connected to the shackle. During loading the spring deflects and moves in the direction perpendicular to the load applied. When the leaf spring deflects, the upper side of each leaf tips slides or rubs against the lower side of the leaf above it. This produces some damping which reduces spring vibrations, but since this available damping may change with time, it is preferred not to avail of the same. Moreover, it produces squeaking sound. Further if moisture is also present, such inter - leaf friction will cause fretting corrosion which decreases the fatigue Strength of the spring.

II. CASE STUDY

A literature study was conducted to obtain an idea of the leaf spring models that have been developed and whether they are able to give accurate predictions of the force-displacement behavior of the leaf spring as well as reaction forces on the vehicle attachment points. Sugiyama et al. (2006) suggests that existing leaf spring models can roughly be classified into three categories; (1) a lumped spring model, (2) a discretized model, where a number of rigid links, connected by springs and dampers, are used to account for the structural flexibility of the spring blades and (3) finite element models. Omar et al. (2004) reviews several techniques for modeling leaf springs. These include the use of empirical formulae and experimental testing, equivalent lumped systems, simple beam theory and finite-element methods. Application in vehicle simulations in a study by Cole & Cebon (1994), they describe both a 2D and 3D model of a four-axle articulated vehicle. They summarize that a 2D model may be satisfactory for predicting the tyre forces of a heavy vehicle if: (1) the vehicle speed is high enough to prevent excitation of sprung mass roll modes, and (2) the contribution of the sprung mass roll modes to the tire forces are small. Attention is also given to modeling the tandem-axle, leaf-sprung trailer suspension. The hysteresis of the leaf spring element is modeled using the method of Francher et al. (1980) and Cebon (1986). Application in vehicle simulations Hoyle (2004) extended his leaf spring model to include the relaxation and recovery regimes generated by the rubber bushes used in the suspension system. The dynamic interaction between an articulated vehicle and surface undulations is investigated by ElMadany (1987) using the equivalent technique to model the leaf spring. In the study by Huhtala et al. (1994) the aim was basically the same as that of Cole & Cebon (1994), being the prediction of the tire-road interaction forces. However, in the study by Huhtala et al. (1994) they model the multi-leaf spring as four links with two torsional springs, two bushings and a revolute joint.

III. GEOMETRY & FORMULAE'S

The top leaf is known as the master leaf. The eye is provided for attaching the spring with another machine member. The amount of bend that is given to the spring from the central line, passing through the eyes, is known as camber. The camber is provided so that even at the maximum load the deflected spring should not touch the machine member to which it is attached. The camber shown in the figure is known as positive camber. The central clamp is required to hold the leaves of the spring. However, the bolt holes required to engage the bolts to clamp the leaves weaken the spring to some extent. Rebound clips help to share the load from the master leaf to the graduated leaf. In order to carry heavy load few more additional full length leaves are placed below the master leaf for heavy loads. Such alteration from the standard laminated leaf spring, what we have learnt above, does not change the stress value, but deflection equation requires some correction.

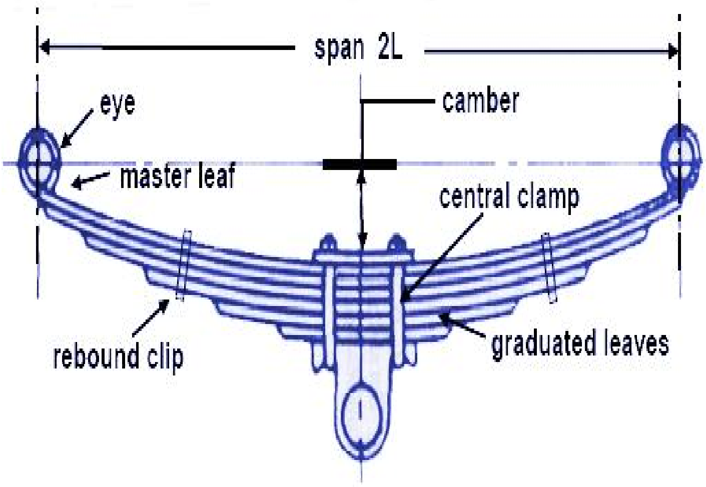

Figure 1 Leaf Spring

$$\delta_{max} = \frac{\delta_c\, qFL^3}{ENb_N h^3}$$

Where, correction in deflection, δ is given as,

$$\delta_c = \frac{1.0 - 4m + 2m^2\{1.5 - \ln(m)\}}{(1.0 - m)^3}$$

Where,

$m = N_f / N$

N_f = Number of full length leaves

N = Total number of leaves in the spring

IV. ANALYSIS AND RESULT

ANSYS is the name commonly used for ANSYS mechanical, general-purpose finite element analysis (FEA) computer aided engineering software tools developed by ANSYS Inc. ANSYS mechanical is a self contained analysis tool incorporating pre-processing such as creation of geometry and meshing, solver and post processing modules in a unified graphical user interface. ANSYS is a general-purpose finite element-modeling package for numerically solving a wide variety of mechanical and other engineering problems. These problems include linear structural and contact analysis that is non-linear. Among the various FEM packages, in this work ANSYS is used to perform the analysis. The following steps are used in the solution procedure using ANSYS

1. The geometry of the gear to be analyzed is imported from solid modeller Pro/Engineer in IGES format this is compatible with the ANSYS.
2. The element type and materials properties such as Young's modulus and Poisson's ratio are specified

3. Meshing the three-dimensional gear model. Figure1 shows the meshed 3D solid model of gear
4. The boundary conditions and external loads are applied
5. The solution is generated based on the previous input parameters.
6. Finally, the solution is viewed in a variety of displays.

Table 2 Key geometrical parameters of Leaf spring used

S. No.	Geometry Name	Gear 1
1	No. of leaf	6
2	Weight	10kg
3	Material type	Steel

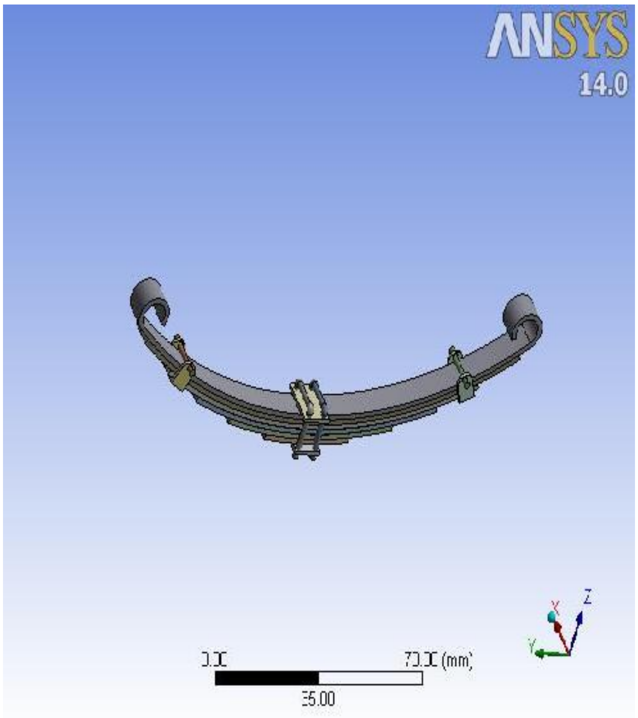

Figure 2 solid model of leaf spring generated by Pro/Engineer (imported on ANSYS)

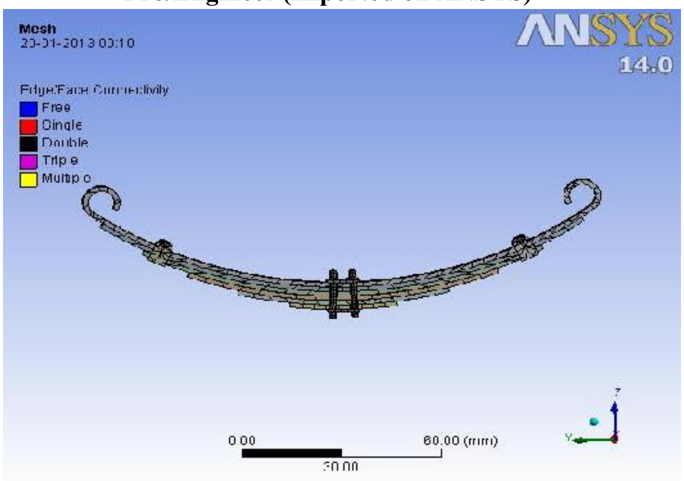

Figure 3 Mesh of leaf spring

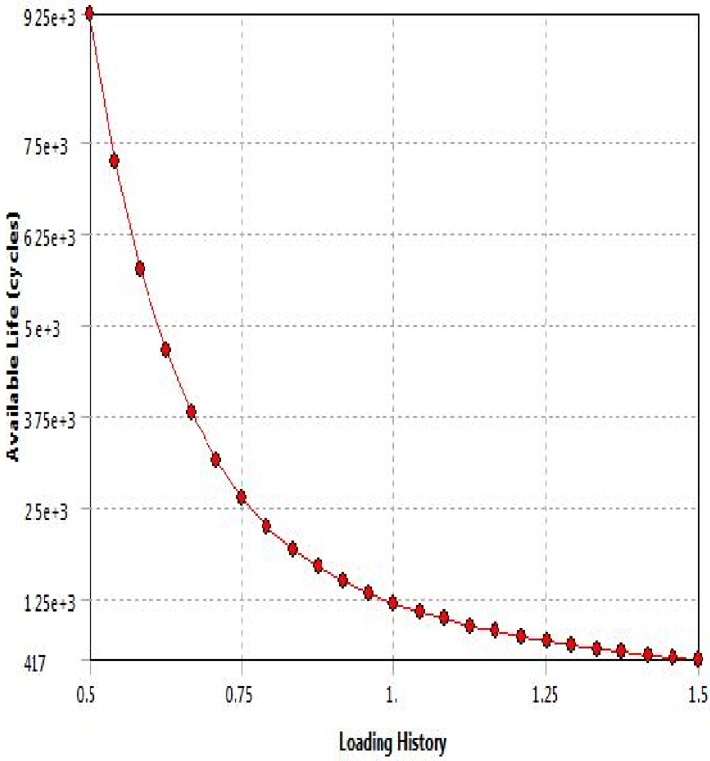

Figure 4 Fatigue sensitivity plot of leaf spring

Table 3 analysis result of leaf spring

	Leaf Spring	
Name of analysis	Maximum	Minimum
Total Deformation	0.10522mm	0mm
Equivalent Stress	537.2 Mpa	0Mpa
Shear Stress	51.5 Mpa	-52.395 Mpa
Life	$1x10^6$	1195.8
Safety Life	15	0.16039
Damage factor	8.32×10^5	1000

V. CONCLUSION

This paper helps us in analyzing the stress and load produce in the leaf spring with the help of ANYSIS software. By using this software then we get the compared result of GFRP and steel spring as shown in this work. The use of ANYSIS software had made it easier to find out the stresses and load working on leaf spring.

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