Experimental Study and Optimization of Leaf Spring

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***Abstract* - Leaf spring has been a matter of study for many researchers in various areas i.e. static and fatigue characteristics, composite leaf springs, optimization of leaf spring, design of leaf springs for heavy axle loads etc have been studied by researchers. This paper also aims at comparative study of leaf spring by finite element method. Results of both the methods are compared even though composite springs show better results. Attempt has been made to optimize the factors of two different steels. Second method has shown better performance.**
Keyword: Optimization

INTRODUCTION:

Leaf spring is a very crucial and important component used in automobile industry. In most cases during truck operation, spring leaves are subjected to five deformation modes such as tension, compression, bending torsion and shear. Therefore, special requirements are imposed on the material and structure of this critical part of the truck chassis. As shown by truck maintenance practices, the material of spring leaves, particularly the main and auxiliary spring leaves, undergoes degradation over a certain time interval, due to which its physical-mechanical characteristics change with the material embrittlement occurring most intensely. This results in the initiation and propagation of fatigue cracks, which under heavy load conditions of truck operation cause early failure of this most critical part of the suspension assembly. [1]

Over the last few years the number of applications of composite materials outside the aerospace sector has been steadily increasing in both range and volume. Glass fibre reinforced composite (GFRC) leaf springs for transportation have attracted many researchers.[2]

Composite materials are now used extensively in the automotive industry to take the place of metals parts. Several papers were devoted to the application of composite materials for automobiles.[3]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 amount of elastic energy that can be stored by a leaf spring volume unit [3] is given by Eq. (1)

$$S = \sigma^2/2E \qquad (1)$$

Where σ is the maximum allowable stress induced into the spring and E is the modulus of elasticity, both in the longitudinal as well as transverse direction. Considering that the dominant loading on leaf spring is vertical force [4], the Eq.(1) shows that a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Fortunately, composites have these characteristics [5].One of the most advantageous reasons for considering composites instead of steel is their weight. Another important characteristics of composites which make them excellent for leaf spring are: higher strength

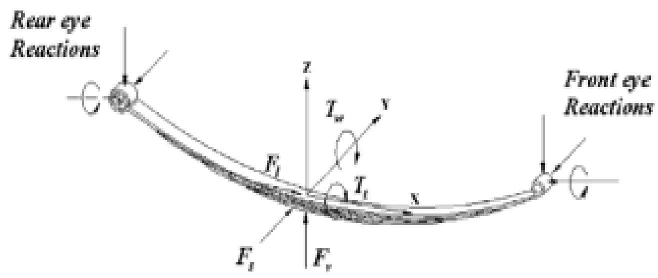

Figure: 1 Forces acting at the axle seat of a leaf spring.Fv: vertical load,Fs side load. Ft:longitudinal load ,Tt: twisting torque,Tw: wind up torque.

to weight ratio (up to five times that of steel), no interleaf friction, superior fatigue strength, "fail-safe" capabilities, excellent corrosion resistance, smoother ride and higher natural frequency.etc.

LITERATURE SURVEY

In the paper titled "Evaluation of a leaf spring failure", C. K .Clarke and G. E. Borowski evaluated the point of the failure for a typical sports car is discussed. He has described the condition of the failure of the eye end of the sports bike such as the operating condition like road ups and downs, dirt and dust and the load acting on the vehicle. The failure occurs at the eye end and starts first to unwrap the eye end figure 2 shown in the diagram. To evaluate the point of failure at number of cycles and load he used the horizontal testing machine on which the load condition is applied and the stress condition is evaluated by using the spring model and using a rubber material the analysis work is carried out in the ALGOR software.

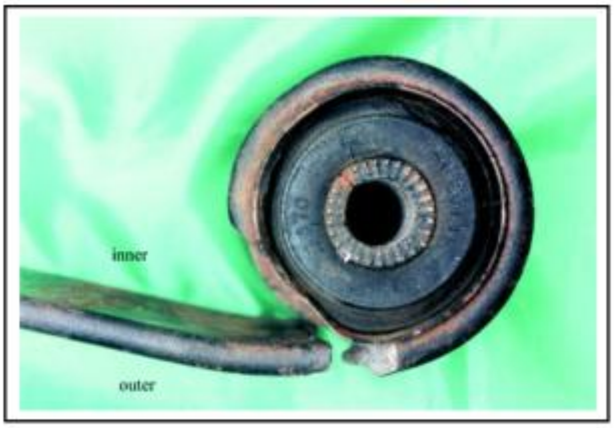

Figure: 2 Opening of the eye at rear end due to road ups and downs

In the paper "Modelling and Analysis of composite Leaf spring under the static load condition by using FEA" M.M.Patunkar and D.R.Dolas made the comparison of the actual spring tested with the virtual model of the composite leaf spring by FEA and the result is discussed and found the better quality of the leaf spring .

In the paper, "Static Analysis of Master Leaf Spring", V. R. Bawiskar, P.L.Sarode, I.N. Wankhede and N. P. Salunke described static analysis of conventional structural leaf spring (master leaf).In their work they constructed three models of leaf spring and did the analysis using FEA software. And compared the performance of three models.[6]

"Leaf Spring Analysis with Eyes using FEA", in this paper B.Mahesh Babu , D. Muralidhar Yadav and N. Ramanaiah worked with an objective to estimate the deflection, stress and mode frequency induced in the leaf spring. The component for analysis is a leaf spring which is an automotive component used to absorb vibrations induced during the motion of vehicle. It also acts as a structure to support vertical loading due to the weight of the vehicle payload. The natural frequencies are compared with the excitation frequencies at different speeds of the vehicle with the various widths of the road irregularity. It has been found that the excitation and natural frequencies are same for both the leaf springs.

METHODOLOGY:

Extensive literature survey is done. Considering various factors related with leaf spring, the literature was studied. The data generated by various researchers was collected and various factors were analyzed. Testing of leaf spring was done in order to get the practical performance result of leaf spring. Bending stress, deflection, safety factor, fatigue strength were studied. For this analysis and finding appropriate results ANSYS 12.0 V workbench was used. A comparative study was done. The best performing factors were identified. The leaf spring design was finally optimized.

In this study the design was done and the model was prepared in the PRO-E software. The three dimensional model was exported in the ANSYS workbench as shown in figure 3. The model was fixed to its boundary condition. The meshing was done on the model which is shown in the figure : 4.The model was loaded with the central load at point B as shown in the figure : 5.

Figure 6 shows the stressed parts of the leaf spring which is subjected under the full load. It shows equivalent stress which varies from 5.4375 × 10^{-5} to 817.32 MPa. The maximum equivalent stress limit in

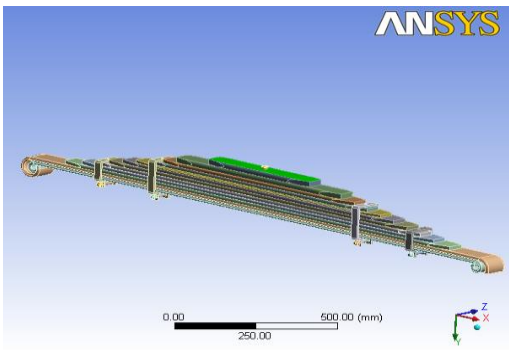

Figure :3 Leaf spring model

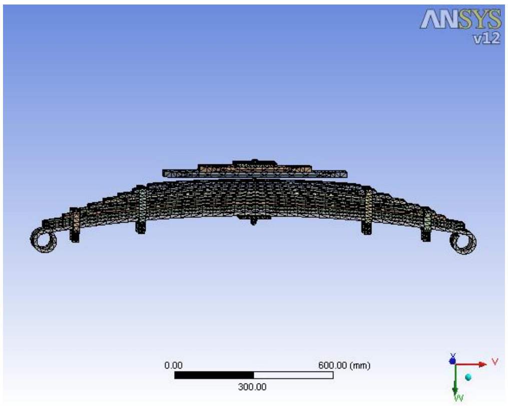

Figure:4 Leaf spring model in meshing condition

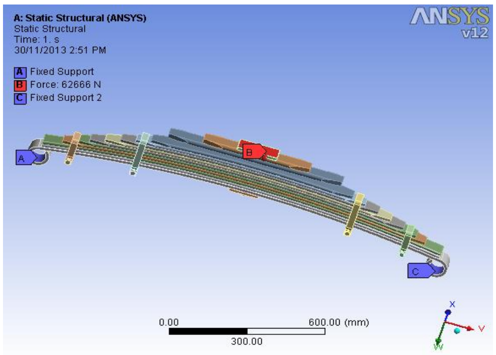

Figure 5: Leaf Spring Model with Boundary Condition

the engineering design is 700 MPa.the stress having value more than 700 MPa tends to failure. Means the design is unsafe Figure 7 shows the leaf spring model subjected under the load for safety factor.For the safer side the safety factor should be more than 1.At center the safety factor had minimum value means it is not safe at the center. Figure 8 shows the total deformation which is having value 2.0038 mm which is less than 20 mm.

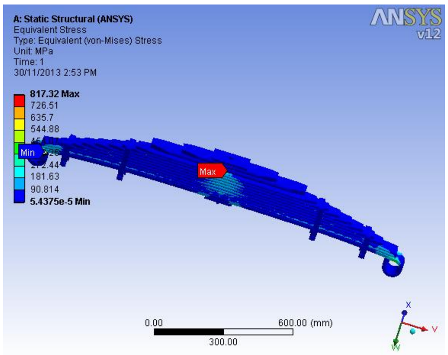

Figure 6 : Leaf spring under Full Load
(For Equivalent Stress).

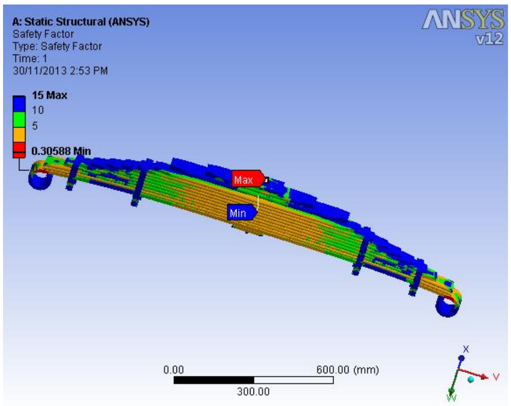

Figure 7: Leaf spring Model showing Safety Factor

In the analysis of the leaf spring it was found that the stress value is more.It means the area which shears the load had minimum value. The inertia also depends on the area. Therefore by using more number of leaves, the spring was optimised for design and drawing. Figure 9 shows the optimised leaf spring model for equivalent stress. The maximum value observed is 678 MPa which is at safer side.

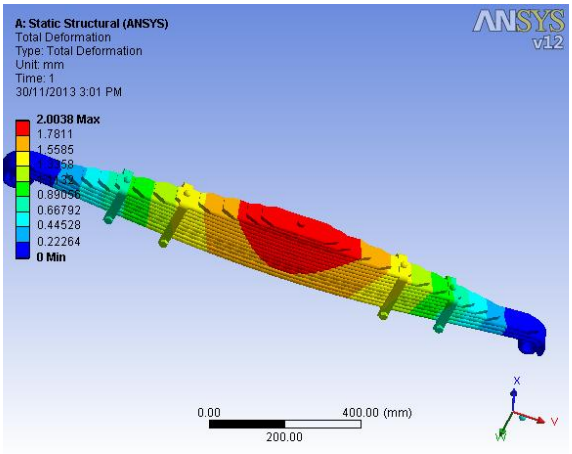

Figure 8: Leaf spring Model showing Total Deformation

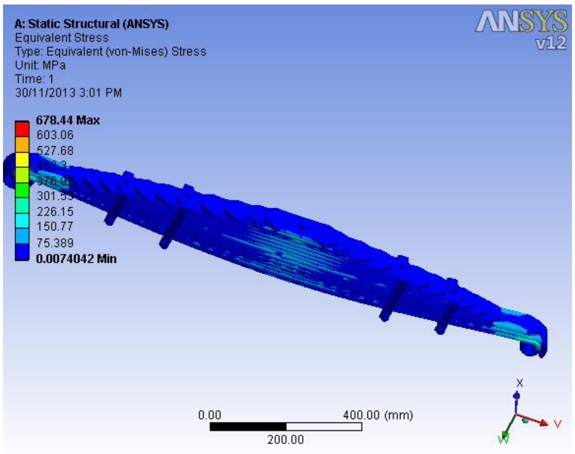

Figure 9: Optimized Model of Leaf Spring showing the Equivalent Stress.

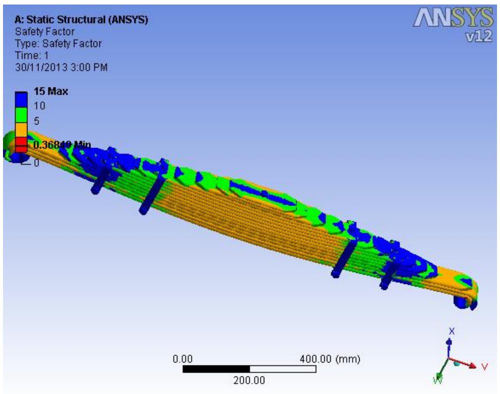

Figure 10: Optimised leaf spring model subjected for safety factor

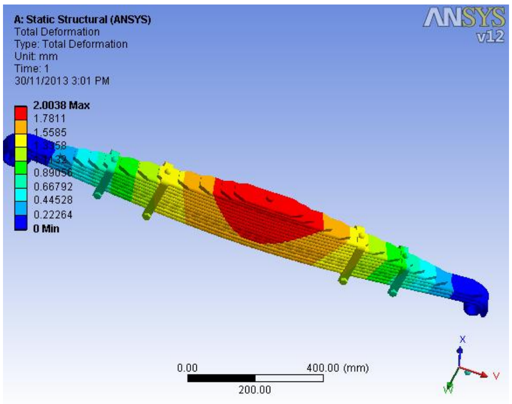

Figure 11: Total deformation of the leaf

Figure 10 Shows the optimised leaf spring when the load is applied on it. The analysis is done for the safety factor. It has been observed that safety factor varies from 1 to 15. It is more than 1. Thus it is safe figure11 shows the maximum total deformation of the spring which is 2.0038 mm .The values lie in the safer side.

Figure 12 :Fatigue Testing Machine (leaf spring at initial stage)

Figure 13: Fatigue Testing Machine (leaf spring at load applied stage)

Figure 12 shows the leaf spring which is actually tested on the fatigue testing machine. In this test the leaf spring is tested for the numbers of cycles under repeated load. The capacity of the machine is 10 tonne. When the load is applied the one end is free and the other end is fixed. For a semi elliptic leaf spring 100000 cycle are applied. Figure 13 shows the final stage of the leaves when the load is applied. Thus the leaf is tested for static loading as well as for the fatigue test Figure 13 shows the loaded leaves in fatigue testing one end of the eye is fixed and the other end is free so that the deformation of the leaf take s place parallel to the load. The load and the attached spring is shown in figure 13. Table 1 shows the properties of material

Table 1 : Material Properties of the Leaf Spring

Parameter	Value
Material selected-steel	65Si7/SUP9
Young's Modulus, E	2.1×10^5N/mm^2
Poisson's Ratio	0.266
BHN	400-425
Tensile strength Ultimate	1272MPa
Tensile strength Yield	1158MPa
Spring Stiffness	221.5N/mm
Normal Static loading	6388Kgf
Density	0.00000785Kg/ mm^2
Behaviour	Isotropic

RESULT AND DISCUSSION:

The leaf spring prepared in the R and D department is tested under the load condition in ANSYS 12.0 where it is found unsafe. Then the leaf spring is optimized for the design and a leaf spring having fourteen leafs is designed for the 6388 kg load. The values of deformation, stress and safety factor are found safe. Table 2 shows the result.

Table 2 : Comparision between the values observed and the FEA values

Parameters	Results Before optimisation	FEA Results	Results after optimisation	FEA Results
Normal Static Load	6388Kg	6388Kg	6388Kg	6388Kg
Deflection	75mm	2.0038mm	125mm	2.0038mm
Spring Rate	41.71Kg/mm	40.77Kg/mm	121 Kg/mm	120Kg/mm
Equivalent Stress	700Mpa	817.32Mpa	700Mpa	678.44Mpa

CONCLUSIONS:

1. The analysis leaf spring is carried out. The factors considered for analysis are stiffness, deformation, equivalent stress, safety factor area, moment of inertia ,width ,thickness length of leaves and no. of leaves.

2. It was found that stiffness, deformation, equivalent stress, safety factor, area, moment of inertia ,width ,thickness length of leaves and no. of leaves are significantly influencing factor on developed stress and stiffness of the spring.

3. Area is the most predominant factors amongst stiffness, deformation, equivalent stress, safety factor, area, moment of inertia ,width ,thickness length of leaves and no. of leaves

4.Testing of finally designed spring was carried out for optimization.Number of leaves are increased from 12 to 14.The performance in terms of load carrying capacity increased. Increase in stiffness ultimately caused reduction in stress and deflection contributing to the optimization of leaf spring.3

FUTURE SCOPE :

The same experimentation can be applied on the composite leaf spring and the advantageous leaf spring can be used without increasing cost and time.

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