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Virtual Process used for Design Optimization of a Heavy Duty Leaf Spring and Effect of Vibrations on it by using CAD Tool.

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Abstract - *Heavy duty leaf spring set always undergoes large number of loadings and vibrations. Hence the chances of failure of leaf spring set are always maximum. Leafs attached in a set are often breaks while working. Sometimes entire spring set needs to be repaired as more than two leafs is braked. The major cause of failure is road conditions and driving. In India road conditions are not much better; hence the failure of leaf spring set always accurse.*

Hence there is a need of design optimization of a leaf spring set also its performance testing. But the cost of entire leaf set is relatively high. Hence we adopted the virtual method of design optimization and its performance testing. Also the vibrations during running of vehicle may affect the durability and effectiveness of leaf sets. Hence the vibrations generated are also needs to be studied well.

In this paper the existing front left leaf spring set of TATA 1512 Bus is considered to analyze. The CAD model of leaf spring set is generated with the help of CATIA V5R19 Software. Further it is imported into ANSYS Software and structural and vibration analysis are performed. Further conclusion is drawn as per the results generated.

Key Words: Leaf Spring Set, Virtual Design, CAD Model, Structural Analysis, Vibration Analysis

1. INTRODUCTION

Leaf springs were the first modern suspension system and, along with advances in the construction of roads, heralded the single greatest improvement in road transport until the advent of the automobile. The British steel springs were not well-suited for use on America's rough roads of the time, so the Abbot-Downing Company of Concord, New Hampshire re-introduced leather strap suspension, which gave a swinging motion instead of the jolting up and down of a spring suspension.

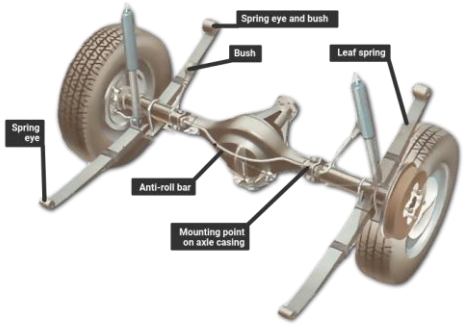

Figure 1: Suspension system for heavy duty vehicles.

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring, elliptical spring, or cart spring, it is one of the oldest forms of springing, appearing on carriages in England after 1750 and from there migrating to France and Germany.

A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the center of the arc provides location for the axle, while loops formed at either end provide for attaching to the vehicle chassis. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in striation in the motion of the suspension. For this reason, some manufacturers have used mono-leaf springs.

A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swiveling member.

Figure 2: Leaf Spring Set for heavy duty vehicle

2. LITERATURE SURVEY

The available literature is studied well and their explanations are given briefly. Also from this study the all possible troubleshoots and failure reasons are summarized. On the basis of this study outcomes were drawn.

Pankaj Saini[1], Ashish Goel[2], Dushyant Kumar[3], " Design and Analysis of Composite Leaf Spring For Light Vehicles". In their paper they described design and analysis of composite leaf spring. The leaf spring was modeled in Auto-CAD 2012 and the analysis was done using ANSYS 9.0 software. [1]

T.N.V. Ashok Kumar, E. Venkateswara Rao, S. V. Gopal Krishna, "Design and Material Optimization of Heavy Vehicle Leaf Spring". Their paper describes static and dynamic analysis of steel leaf spring and laminated composite Multi leaf spring. The objective is to compare displacement, frequencies, deflections and weight savings of composite leaf spring with that of steel leaf spring. [2]

A.K.Tarange1, Prof. M. B. Bankar2, Dr. A. M. Badadhe 3, " Design, Optimization And FE Analysis of Composite Mono Leaf Spring". The paper illustrate that, the dimensions of an existing mono steel leaf spring of a Maruti Alto 800 passenger vehicle is taken for modeling and analysis of modeling and analysis of a laminated composite mono leaf spring with glass fiber composite material. [3]

Suraj B. Pawar,Rohit R. Ghadge, "Design & Analysis of Multi Steel Leaf Spring". The main scope is illustrated in their paper is to design, analyze & manufacture a hybrid composite multi leaf spring for a multi utility vehicle. The objective is to compare the load carrying capacity, stiffness & weight of a Hybrid composite leaf spring with the present conventional steel multi leaf set-up. [4]

Prof. N. P. Dhoshi, Prof . N. K. Ingole, Prof. U. D. Gulhane, "Analysis and Modification of Leaf Spring of Tractor Trailer Using Analytical and Finite Element Method". In their work analytical and Finite element method has been implemented to modify the existing leaf spring with

consider the dynamic load effect. Leaf spring manufactured by Awachat industries Pvt. Limited has been selected for stress analysis. [5]

Zhuo Xu, Liang Hong, Xiao Lian Wang, Chun Shu Ding, "Study on the Influence of the Shape of Leaf Spring on the Stress and the Kinematic Characteristics". Their paper is based on a novel shape of asymmetric few-leaf spring, which is used in the traditional parabolic leaf spring. [6]

Arun Sam Varghese1, Et al, "Structural Design and Analysis of Leaf Spring made of Composite Material". In their paper we propose a new structurally modified trapezoidal composite leaf spring from conventional rectangular shaped steel leaf spring. [7]

Sushanta Ghuku and Kashi Nath Saha, "Design Development and Performance Analysis of Leaf Spring Testing Set Up in Elastic Domain". Their paper presents design development and performance analysis of two different leaf spring testing rigs. [8]

Mayur D. Teli, Umesh S. Chavan, Haribhau G. Phakatkar, "Design, Analysis and Experimental Testing of Composite Leaf Spring for Application in Electric Vehicle". In their study glass fiber is used to analyze the application of leaf spring for excess weight in electric vehicle. The main objective of their study is to investigate feasibility of composite material for leaf spring to withstand the excess load in Electric vehicle. [9]

Tarun kumar, G.V.R.S. Rao, Anand Kumar pathak, "Design and Structural Analysis of Leaf Spring". Their work consists of a leaf spring involving two supporting leafs with the main Leaf. Main leaf and the centre leaf are having a identical cross section throughout the length of the blade. [10]

3. CAD MODELLING OF LEAF SPRING SET

We are using CATIA V5R19 software for the preparation of leaf spring set CAD model. It is the assembly of several strips which will form leaf spring set assembly. Sketcher module, Part Module and Assembly modules are used to create this model. Below figure 3 shows the modeling of leaf spring set.

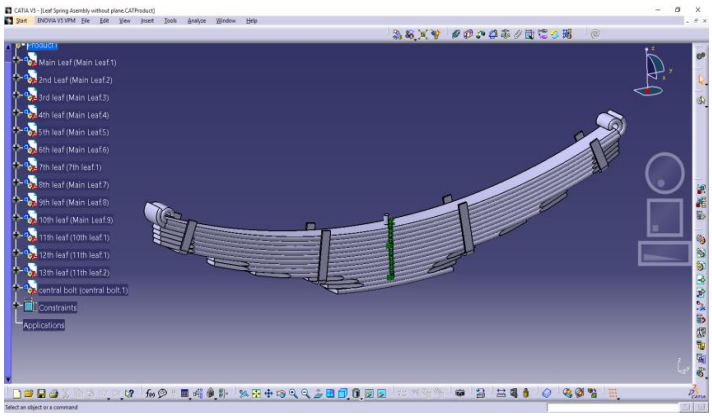

Figure 3: CAD model of Leaf Spring Set done in CATIA V5R19

As shown in figure 4, total 13 strips are bounded together by means of central bolt and clamping strips.

4. MESHING PROCESS

Figure 5 shows the meshed view of entire leaf spring set. Meshing or discretization is the important process in FEA (Finite Element Analysis). Here three dimensional tetragonal element is used to form entire leaf spring set. Where total number of nodes and elements are 119166 and 70204 respectively.

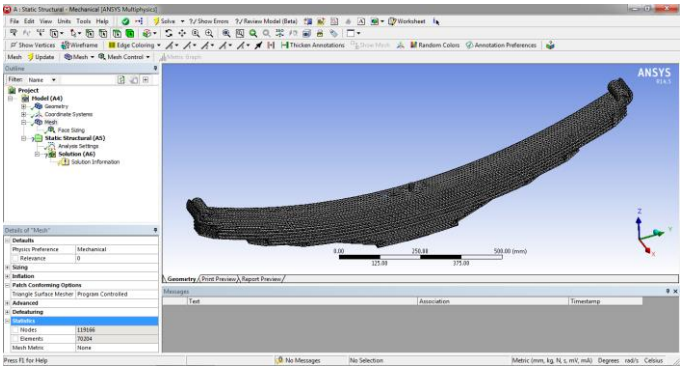

Figure 4: Meshed view of Leaf Spring Set

MATERIAL PROPERTIES REQUIRED

Table 1: Properties of Medium Carbon Steel.

Property	Value
Youngs Modulus (E)	2e5 MPA
Poisson's Ratio	0.29
Density	7870 kg/m^3

Medium Carbon Steel is the material used for the manufacturing of the leaf spring set. Table 1 shows the required properties of the material for the analysis purpose. Here we are performing structural and vibration analysis on the leaf spring set. Also we need to simulate actual physical loading conditions.

1. 6. Loading Conditions

To simulate the proper physical condition, loads and fixed displacement are to be attached properly. In case of Leaf spring set, it is fixed at the bottom plate with axle and top metal strip is attached with vehicle frame on both ends. For this paper bus leaf spring set from front axle is considered. Hence the load which is to be applied on leaf set is considered including weight of the bus and maximum loading capacity. TATA 1512 model bus is the vehicle of consideration whose total loading capacity will not exceed more than 40 tons (Including Weight of bus and maximum load capacity). This load will be distributed on all four wheels equally. Hence the maximum 10-ton load is considered on one of the front wheel and it is converted into a force in Newton and applied on both ends of leaf spring set. Figure 5 shows the actual boundary conditions applied on leaf spring set.

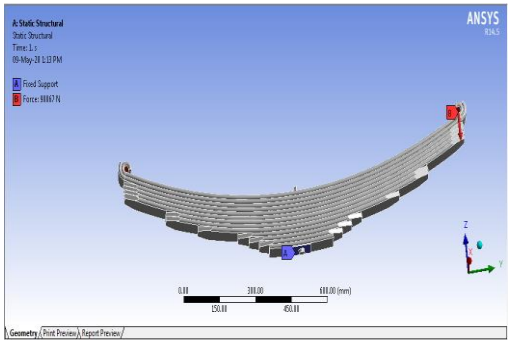

Figure 5: Load and fixed displacement applied on leaf spring set.

2. 7. Structural Analysis Results

Figure 6 shows the deformation due to the loading condition. The load is applied at the end i.e. 98067 N which the converted value of 10 Ton. By observing above figure, maximum deformation i.e. 2.97 mm accurse at the both ends. The deformation is very less. But when the vehicle is in running condition, the jerks due to pots on road will apply sudden loads on leaf springs. In such condition the deformation will be more than observed. At the center of set deformation is negligible. This is due to the fixed condition at the center. Different color pattern will show the respective deformation value as per given in the scale situated at the left side of image.

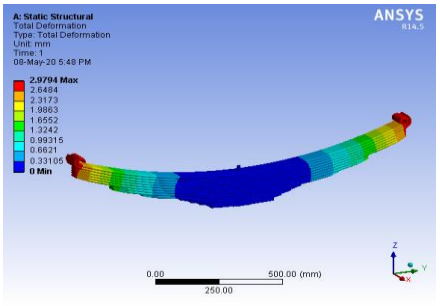

Figure 6: Total Deformation due to loading.

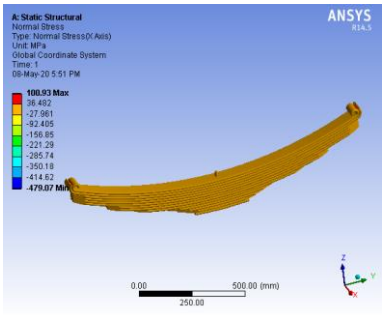

Figure 7: Normal Stresses induced due to loading.

The value of normal stress obtained in figure 7 is 100.93 PMA maximum. And it is located at the both end where the shackle pin is attached. All other portion of leaf spring set is appeared in the dark yellow color whose value range is till 36.482 MPA. Hence normal stress is also in acceptable range. Leaf spring will work properly on with this stress value without any failure.

Figure 8 shows the shear stress contours on leaf spring set. Value of maximum shear stress is 76.478 MPA which is also in permitted range. Maximum of portion (90% Approximate) of leaf spring set is appeared in green color.

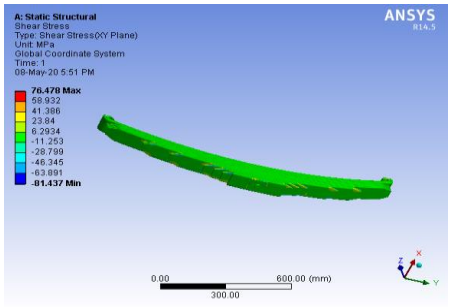

Figure 8: Shear Stresses induced due to loading.

Figure 9 shows the equivalent stresses induced in the leaf spring set due to the loading condition. The value of these stresses is quite higher than the other type of stresses induced. Figure shows the maximum equivalent stresses is 1149.8 MPA. These stresses are maximum at the both ends at very narrow region. By observing all other remaining portion of leaf spring set, it is appeared in dark

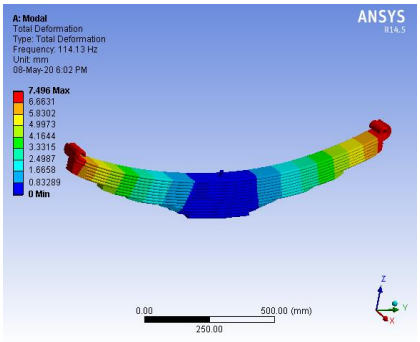

Figure 10: Frequency and Total Deformation for Mode 1

Hence the possibility of development of maximum shear stresses is very less. It means that the failure will not accurse at the load of 98067 N. Sudden jerks while running may increase the possibility of development of shear stresses more than the acceptable range. But due to the elastic property of metal strip, maximum jerks will be absorbed successfully.

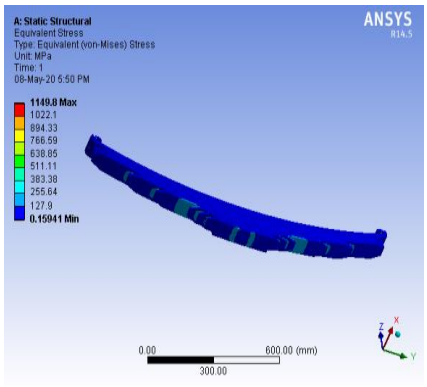

Figure 9: Equivalent Stresses induced due to loading.

blue and sky-blue color which has a range of 127 to 383 MPA. Inducement of such higher equivalent stresses may affect the performance of leaf set. Also, it will be greater on sudden jerks. Hence equivalent stresses may be the cause of worry.

3. 8. Vibration Analysis Results

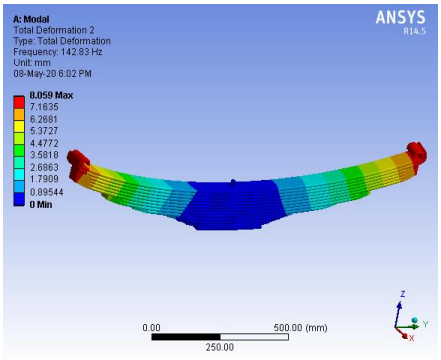

Figure 11: Frequency and Total Deformation for Mode 2

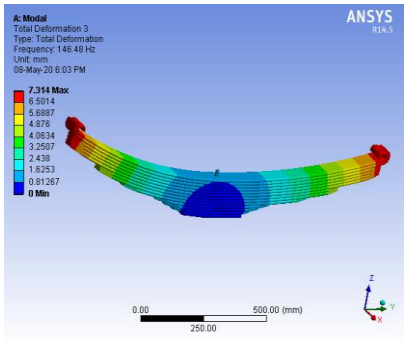

Figure12: Frequency and Total Deformation for Mode 3

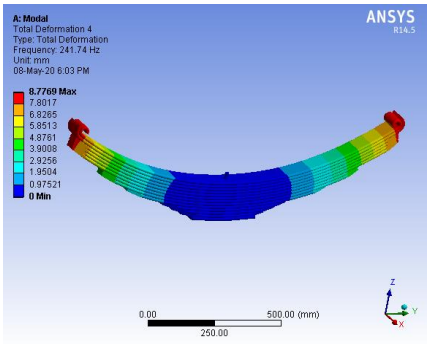

Figure13: Frequency and Total Deformation for Mode 4

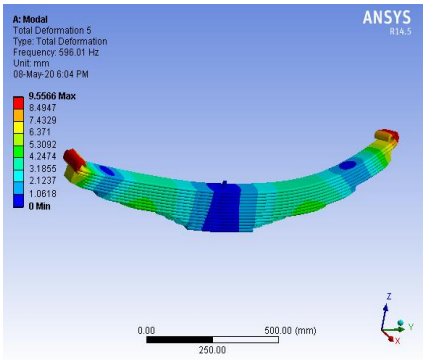

Figure14: Frequency and Total Deformation for Mode 5

9. CONCLUSIONS

By comparing both structural and vibration analysis we can conclude that the vibrations makes effective impact on leaf spring set. Normal running of vehicle will not affect the performance of leaf set. But sudden jerks will apply heavy loading on leaf spring. Hence it is recommended to use metal with better elastic properties and strength.

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