Finite Element Analysis of a Leaf Spring using Radioss Linear: An alternate approach

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Abstract: The paper presents critical review on the finite element analysis (FEA) of a conventional leaf spring finds widespread application in automobile industry; it has been carried out using CAE tools. In the first phase importance and significance of the leaf spring will be discussed. Which is an inevitable part of an automobile suspension system, the spring industry has grown along with the growth of the Railways, defense, automobile and other engineering industries. In this research study the CAD model has been prepared in CATIA & the meshing tool used is Hyper mesh & the solver used is Redioss linear. In the next phase results have been validated by comparing with the experimental results. Moreover, the paper will also focus on Meshing techniques, Geometry shape and size, Element Length, Quality checks, Aspect ratio, Rigid elements, Collectors and Constraints.

Keywords: Leaf Spring, FEA analysis, Meshing, CAD modeling, Rigid elements, Mesh Size, Hyperview.

1 Introduction: A Leaf spring is an elastic body which perform the desire function as distortion while loading and to recover its original shape when the load is removed. Springs are usually made from oil-tempered carbon steel wires that contain 0.6 to 0.7 percent carbon and 0.6 to 1.0 percent manganese [1]. Some non-ferrous metals are also used parts requiring fatigue confrontation, including phosphor bronze and titanium. however, its deformation is small if it is made of metal as shown in Figure-1.1.

Figure-1.1 Tension & Leaf Spring

Combinational of many springs result in the formation of Beams. The load F deflection at the end of a cantilever can be appreciable, it depends on the geometry and elastic modulus of the cantilever, as predicted by the theory of elementary beams. Unlike the constant cross-section beam, the leaf spring load shown in Figure-1.2.

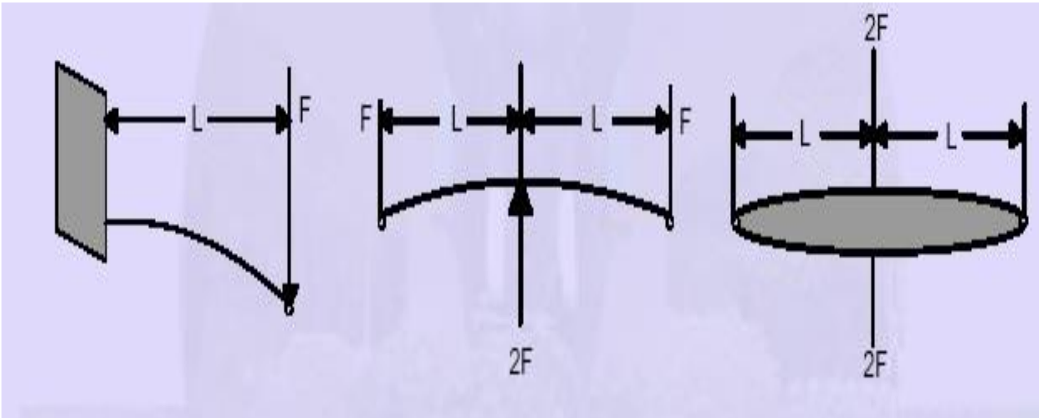

Figure-1.2 Type of loading

It Stacked between the leaves of the master leaf and the graduated length [2]. To support the transverse shear force, the extra full length is provided. Leaves are divided into two groups for study, for forming one group namely the master leaf along with graduated length leaves and extra full-length leaves creating the other group [3-4]. Now the next step is to understand the method of the finite element procedure and its utility.

2. FEM Procedure

The following steps summarize the finite element procedure:

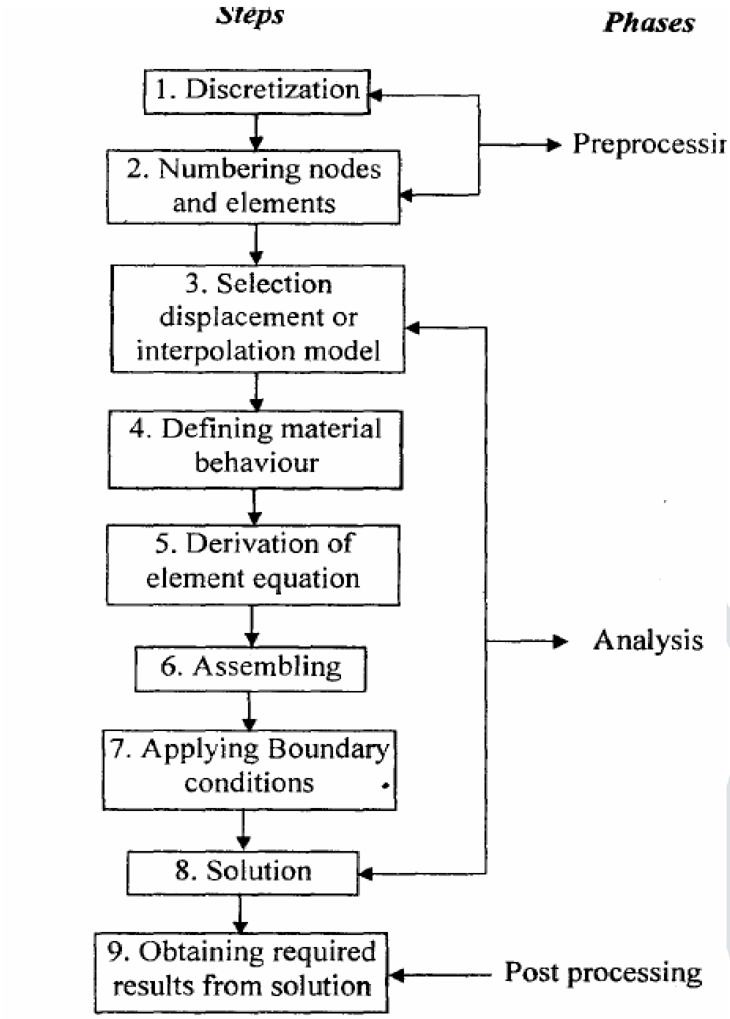

Figure – 1.3 Procedure of FEM

2.1 FE Modeling Methodology-Pre-processing- The first step in pre-processing is to design a leaf spring CAD template. Using CATIA [16] code, CAD leaf spring modeling is developed. In generative surface layout, CATIA has reforming methods for building typical and surfaces that are later converted to solid. Both Solid models' sub-parts of complete assembly of the structure are combined to create henceforth.

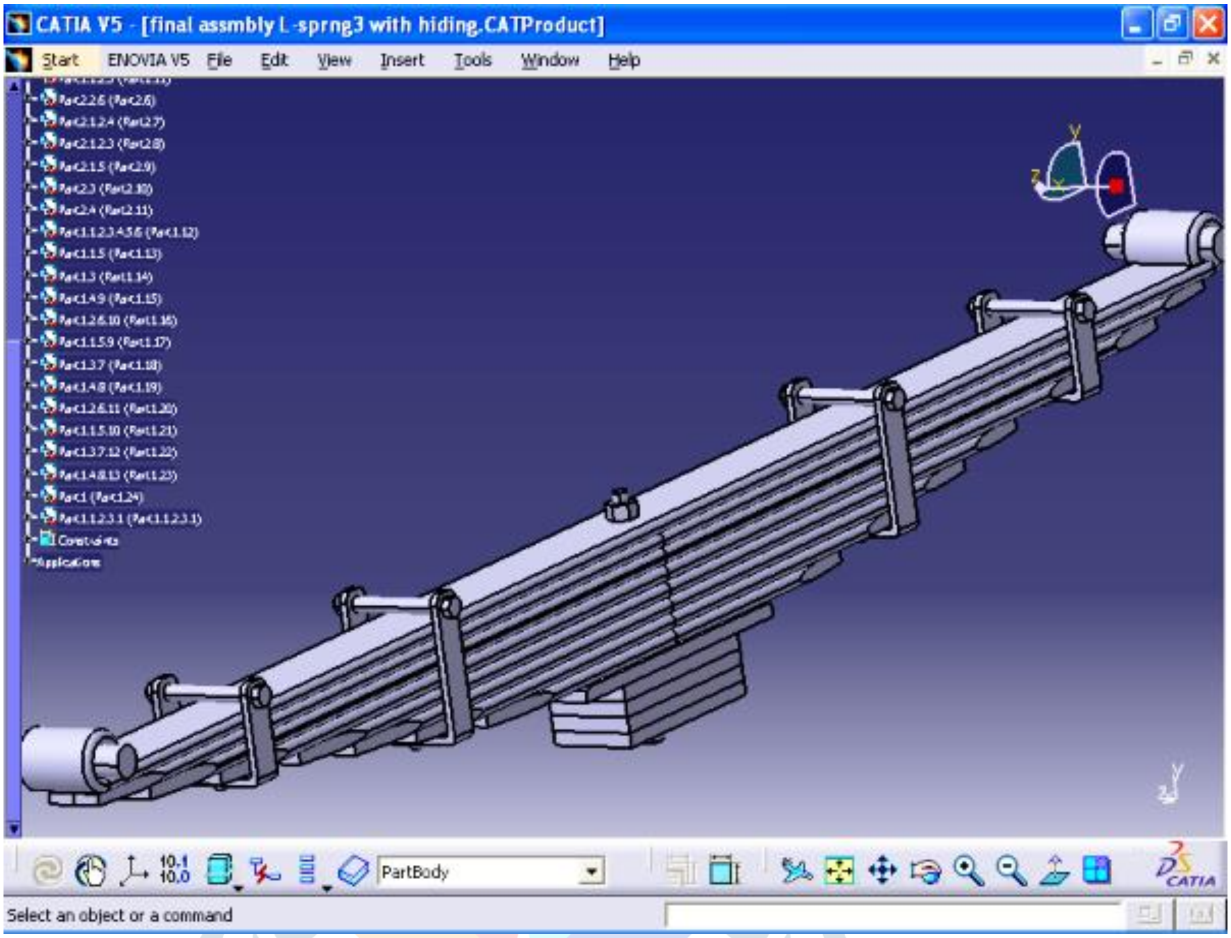

Figure-1.4 CAD Model of Leaf spring in CATIA

The assembly process is very similar to the general manufacturing process of structure in real production. CAD model of our issue consists of four parts that are combined to make a complete Leaf spring model in assembly layout. The CAD model of leaf spring used for analysis is shown in Figure 1.4. The CAD model has been prepared from various 2D drawing. After preparing the Leaf spring FE Model is generated in Hyper mesh, Importing the CAD Model.

The model used in this is prepared in IGES (Initial Graphics Exchange Specification) format which is companionable with all CAD software. After importing the CAD file into Hypermesh, it is then saved in form of .hm format (say Leaf spring.hm as shown in Figure. 1.5) until the FE model is not completed.

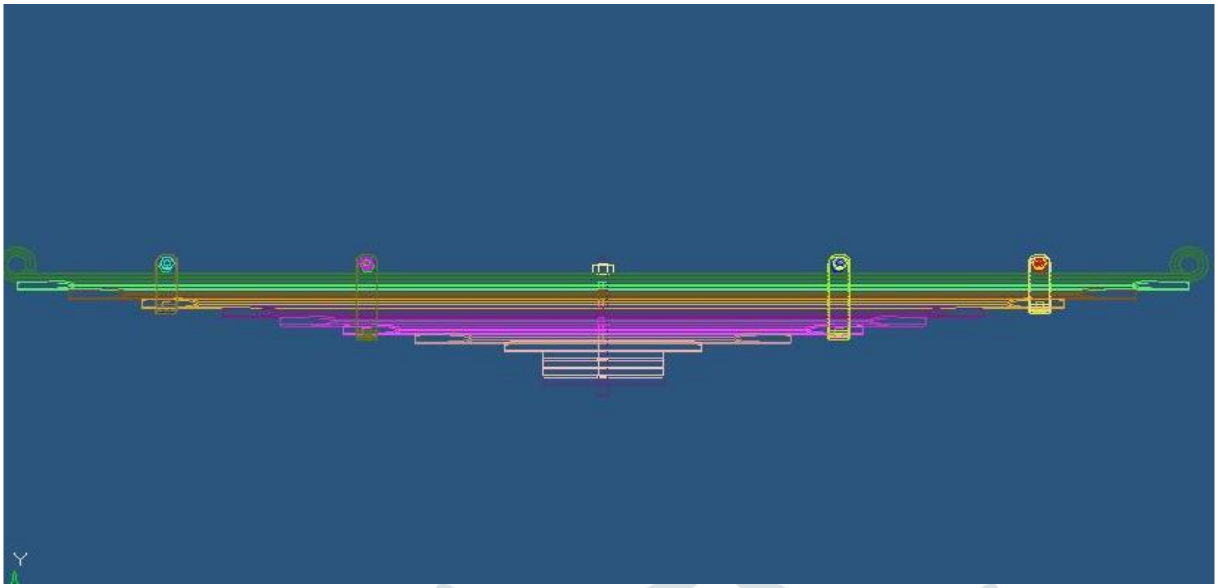

Figure 1.5-.Hm Model of Leaf spring in Hypermesh

Geometry can be imported into Hyper Mesh from many sources. A number of Hyper Mesh functions rely on having surfaces properly connected, especially the auto mesh panel. Figure 1.6 shows the Leaf spring model after geometry simplification. If we compare this model with the previous one as shown in Figure 1.4, we can observe that all the complex features like thread, projected ribs, fillets etc. have been removed that were considered too small to be captured by the desired element size of 2. The model is now represented in a much simpler form that suits the analysis that will be performed.

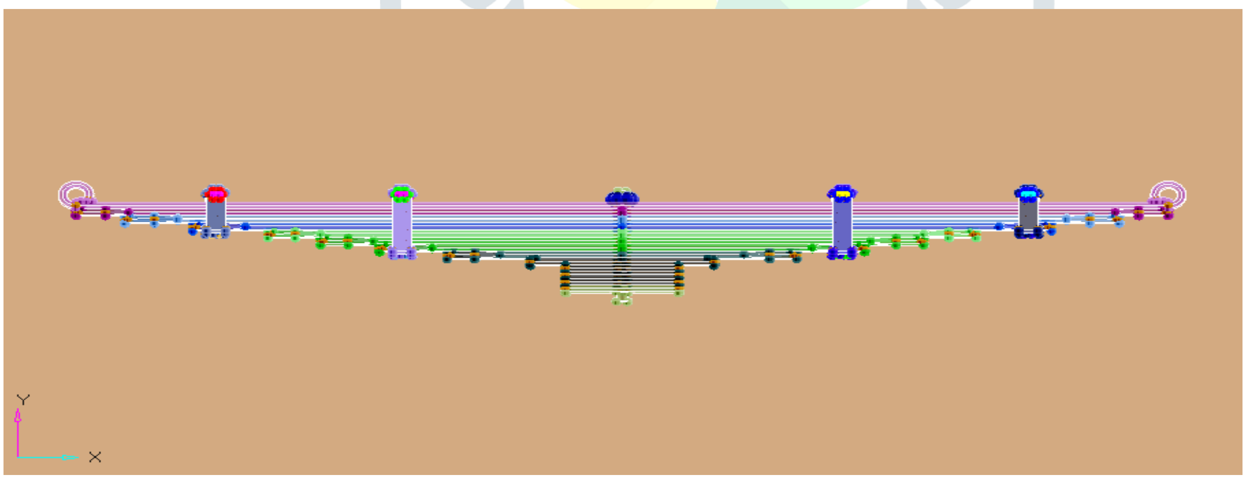

Figure 1.6 Leaf spring after Geometry Simplification

The basic method of the FEA is to provide a small number of points and then apply the findings for the entire field. Any continuous object has an infinite degree of freedom and it is impossible to solve the problem in this format. FEM by means of choice reduces the degree of freedom from infinite to finite.

a) Geometry shape and size

b) Type of analysis

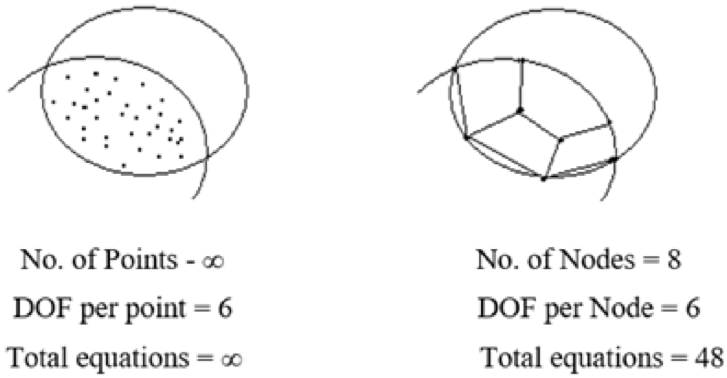

Figure. 1.7 Meshing

Geometry shape and size

Geometry shape and size are categorized as 1-Dimension, 2-Dimension and 3-Dimension

3-Dimension mesh & Tetra element is preferred for meshing all the four components**.** Afterwards it is primarily knowing the concept of rigid bodies, Rigid element (node to node connection) has infinite stiffness and transfers all the forces and moments or in other words dofs from one node to other as it is. Rigid link are examples of rigid elements. the leaf model is constrained at two positions. First position is the left side revolute joint of the leaf spring. In this portion a rigid node is created from the selected nodes & this node is constrained as shown in Figure. 1.8. here the model is constrained in translational motion along x, y and z axis & along with rotational motion along x and y axis. Only rotational z motion is not constraint. Second position is the right-side revolute joint of the leaf spring. In this position translational motion along y & z position is fixed only translational motion along x direction is there & this is shown in Figure 1.9

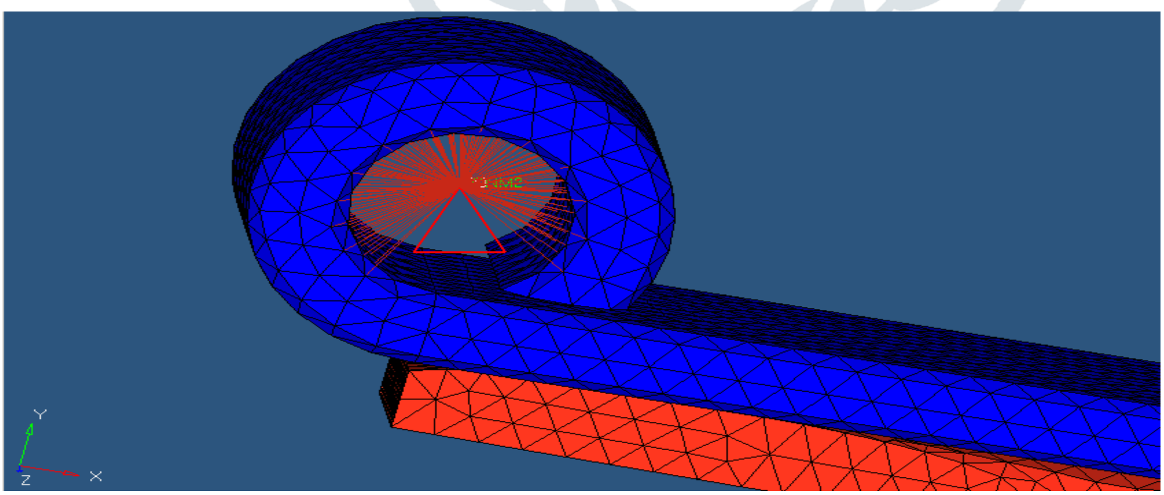

Figure 1.8 Left side revolute joint is constrained in all direction except rotational Z

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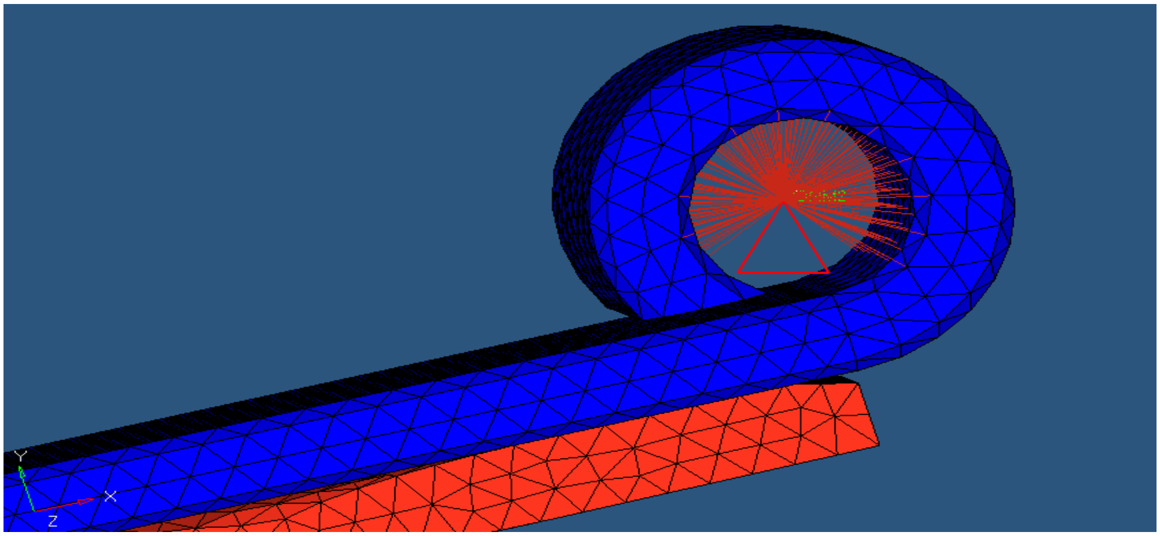

Figure 1.9 Right side revolute joint is constrained in translational y & z direction

The FEA of Leaf spring the case chosen is linear static. This analysis is used when the response of the body is linear, and there is no variation with time. In stress analysis, model is appropriate when operating within elastic region (stress strain curve is linear) and when the deformations are small and load do not vary with time. It is the simplest and most commonly used type of analysis.

3 Result and discussion

The results of linear static analysis of Leaf spring as obtained by using redioss linear are shown in Figure 1.10 & Figure 1.11. The Figure 1.10 depicts displacement contours while Figure 1.11 shows stress contours for the given load of 35KN. The post processing has been done in Radioss Linear which can read the .hm files written as output from Hypermesh. The elapsed time is the time taken by software to convert the model from .hm file to .fem file. Maximum memory used gives the information about the memory used during pre-processing. Maximum disk space used gives the information about the amount of space used by temporary files for preprocessing. Shading and wire frame options, animation options and contour colors are used to study, and compare the results. The output file .out gives the detail about total number of nodes, element type, total number of degree of freedom, load and boundary information, and material and property information.

It is observed from the Figures 1.10 that the max value of the displacement and stress are 130.5mm and 156 kgf/mm^2 respectively. The max bending stress is well under the safe range as the yield stress for a given material i.e. 220.6 kgf/mm^2.

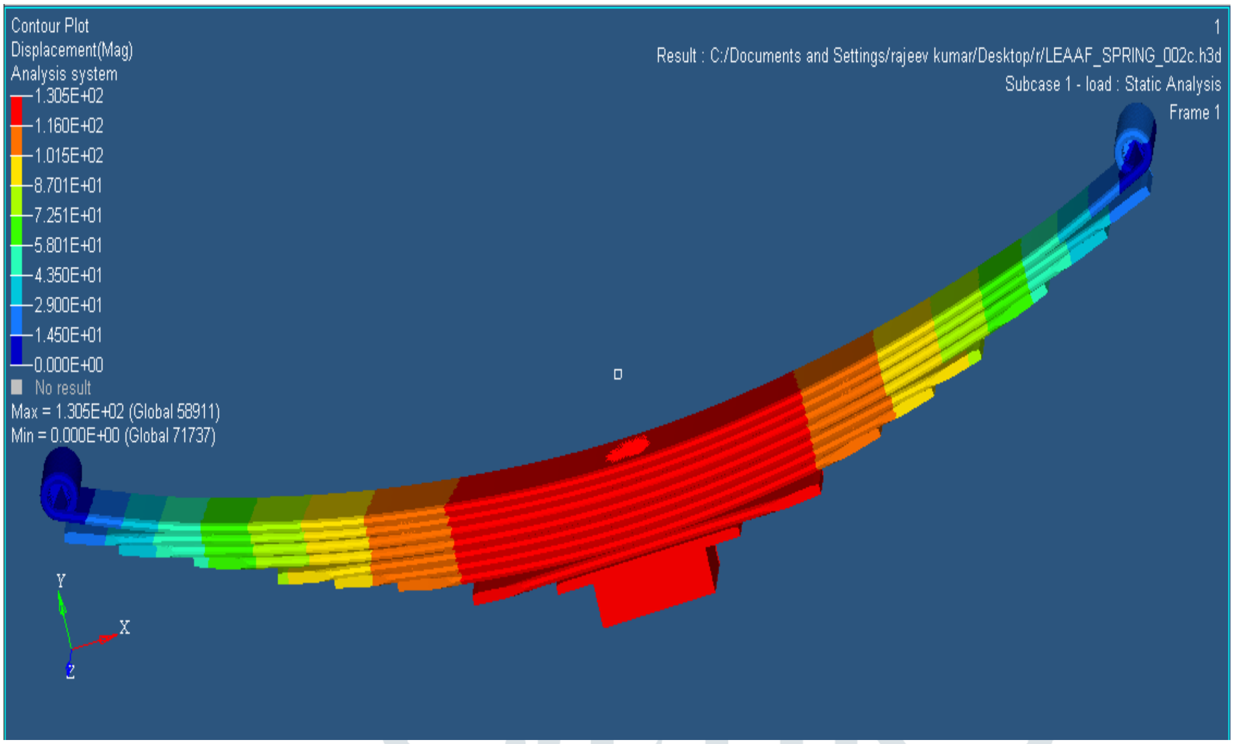

Figure -1.10 Displacement contours in leaf spring

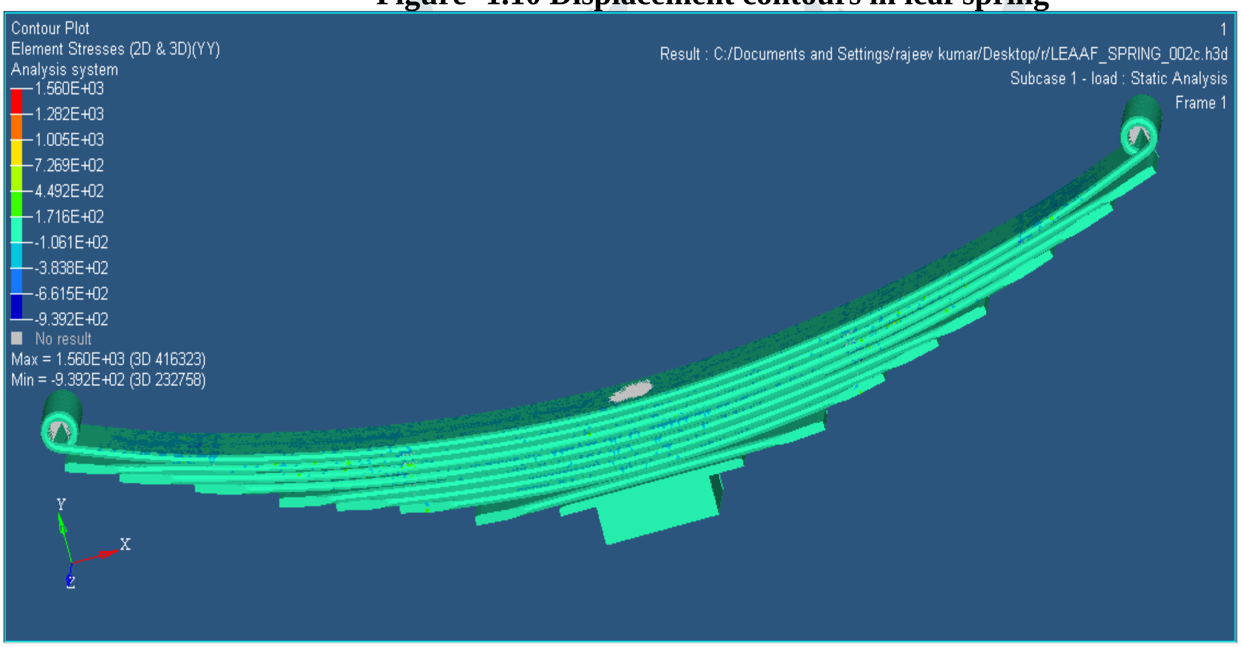

Figure -1.11 Stress contour in leaf spring

To validate the analysis, the results have been compared with experimental result under similar loading condition. As the experimental results were available for the leaf spring at 35KN, the same FE analysis has been carried out for the load of 35KN. The experimental and FEA results are shown in table 1.1. The same results have also been shown on bar chart in Figure 1.12.

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Parameters	**Exp. Results**	**FEA Results**	**Variation**
Normal static Load	35000 N	35000 N	Nil

Deformation	158 mm	130.5mm	17.40 %
Bending Stress	126 Kgf/mm^2	156kgf/mm^2	23.80 %
Spring rate	221.5 N/mm	268.19N/mm	21.07 %

Table 1.1 Comparison of Experimental & FEA results

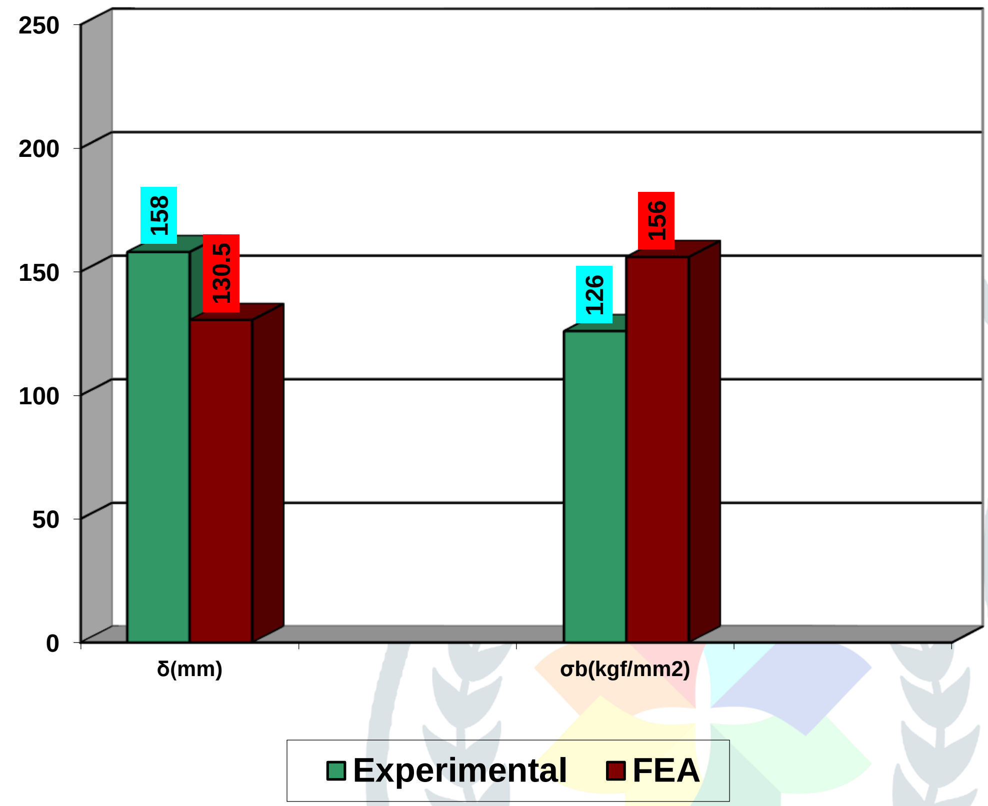

Figure- 1.12 Bar chart for experimental and FEA results

It was concluded that deflection in experimental results is 158 mm for the same static charging conditions (35KN) and deflection for FEA results is 130.5 mm. Bending stress is 126kgf / mm2 and 156 kgf / mm2 for experimental results and FEA results. The deflection and bending Stress differences were 17.40% and 23.80% respectively.

4 Conclusion and Future Work Scope It has been obtained from HYPERMESH, many discussions have been made and it will be concluded that for the load of 35KN on leaf spring the maximum displacement is 130.5mm. The maximum bending stress under same loading condition is 156 kgf/mm^2 which is found below the yield stress of the given material (spring steel) i.e. 220.6 kgf/mm^2.The variation in FEA and experimental results are 17.40 % & 23.80 % for the displacement and stress respectively. The results are well acceptable with the similar available experimental results. And for future work composite material can be considered for the analysis of leaf spring as a low weight analysis. The various analysis of design can also be analyzed.

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