Design Analysis and Fatigue Life of a Leaf Spring Assembly

Kuahal R[1], Jayaram A S[2], Chandan R[3]

[1]*Student, Master of Technology, Dept. of Mechanical Engineering, Dr. Ambedkar Institute of Technology, Bangalore, Karnataka, India*
[2]*Associate Professor, Dept. of Mechanical Engineering, Dr. Ambedkar Institute of Technology, Bangalore, Karnataka, India*
[3] *Assistant Professor, Dept. of Mechanical Engineering, Dr. Ambedkar Institute of Technology, Bangalore, Karnataka, India*

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Abstract - *The suspension system of an automobile is required to withstand harsh working conditions while performing its function of absorbing shocks .The Leaf spring is widely used in automobiles and one of the components of suspension system. It needs to have high fatigue life. The leaf spring of suspension system is subjected to cyclic stresses due to road undulations. As a general rule, the leaf spring is regarded as a safety component as failure could lead to severe accidents. In the present paper Structural Design validation analysis is performed by static, modal and fatigue loading conditions. Model of the leaf spring is performed using SOLID EDGE, then Imported to ABAQUS/CAE and mesh the leaf spring using Hexahedron elements, wedge elements are used to mesh wedge surfaces for fine meshing. Static analysis is performed to find deflection and stress of the leaf spring assembly. To study the dynamic behavior of the leaf spring assembly modal analysis is performed to find its natural frequency. This shows the stiffer suspension of leaf spring assembly. Fatigue life of leaf spring is analyzed by using FE-SAFE fatigue analysis software for both medium steel alloy and EN47 material of two different ultimate tensile strength. Substantial increase in life cycles is observed by using EN47 material. So the design is safe when we use the EN47 is used.*

Key Words: Leaf spring, Static analysis, Modal analysis, Fatigue life

1. INTRODUCTION

Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicle, heavy duty trucks and in rail systems. It carries lateral loads, longitudinal loads, side loads, brake torque, driving torque. Initially it called as laminated or carriage leaf spring. Leaf Spring is a simple form of spring commonly used for the suspension in wheeled vehicles. It is additionally perhaps the one of the most established type of springing, going back to medieval occasions. Sometimes referred to a semi elliptical spring or cart spring. It takes the shape of a slender arc-shaped length of spring steel of rectangular cross-section. The middle of the arc provides location for the shaft, whereas tie holes are provided at either end for attaching to the vehicle body. For automobile vehicles, by combining several leaves stacked on top of each other in many layers by which leaf spring can be made, often with progressively shorter leaves. 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 to a shackle, a short swinging arm. For softer springiness the leaf spring elongates when compressed. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swiveling member. The leaf spring mainly consists of different parts like Master leaf, Center bolt, central clamp, Eye, and Rebound clip. The leaf spring assembly is one of the main concerns for weight reduction in automobile as it accounts for 10-20% of the un-sprung weight.

Leaf spring absorbs vertical vibrations and impacts because of load irregularities by means that of variation within the spring deflection show that potential energy is hold on in spring as strain energy and so unleash slowly so, increasing energy stored capability of a leaf spring insures a better suspension system. The huge vehicle needs a decent suspension framework that can convey a decent ride and taking care of to the drivers while driving. At the same time that component needs to have high fatigue life to resist more jerks while running.

2. Aim

The main aim of this project is to determine the stress distribution, modes of vibration and Fatigue life of leaf spring assembly.

3. METHODS AND METHODOLOGY

The assessment of the Leaf spring assembly is considered for the evaluations. The design is evaluated for tension load condition of 4 kN. The stress distribution is studied. Further analysis is performed for static analysis, modal analysis and fatigue life of leaf spring. Load conditions for all the tests are as per standards applicable.

STEP 1: Create Leaf spring design using SOLID EDGE.

STEP 2: Import to ABAQUS/CAE and mesh the leaf spring assembly using Hexa elements.

Step 3: Performing linear static analysis using ABAQUS/Solver

STEP 4: Perform modal analysis and determine the fatigue life of leaf spring.

4. GEOMETRIC MODELING

Fig -1: Front View of a Leaf Spring Assembly

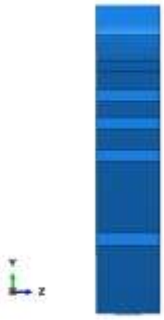

Fig -2: Side View a leaf spring assembly

Fig -3: Isometric View a leaf spring assembly view

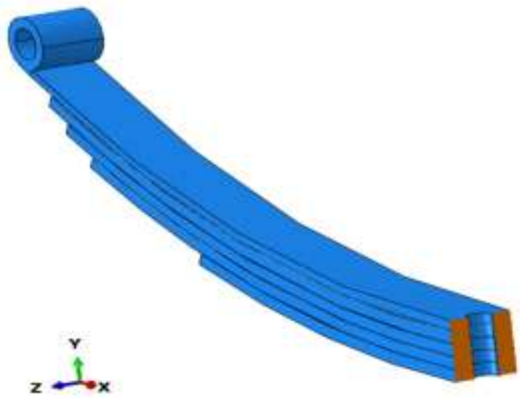

Fig -4: Cut section View a leaf spring assembly

4. MESHING

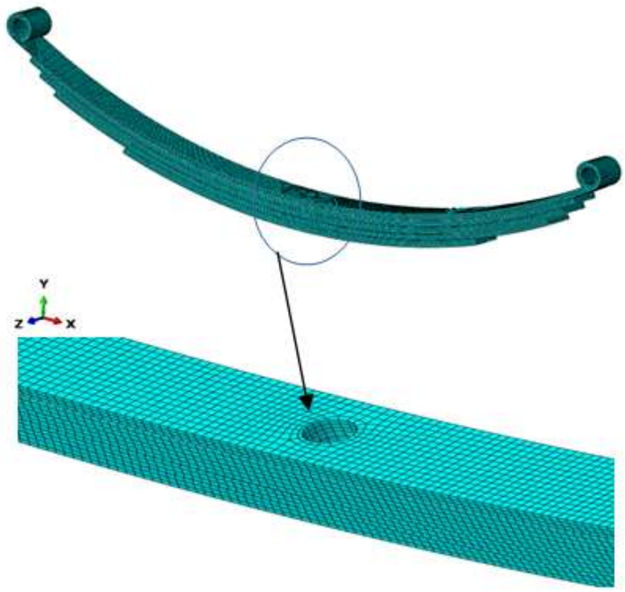

Fig -5: Meshing

Table -1: Elements and Nodes Count

Total number of nodes	77916
Total number of elements	54055
Element type	Linear Hexahedral element

The FE modeling in linear hexahedral elements of type C3D8R as shown in above Fig 5. Since hexahedral elements have higher accuracy compared to other elements it has been used for meshing and 13 elements of linear wedge elements of type C3D6 has been used for wedge surfaces. Each element of hexahedral has 8 nodes and 6 faces. A suitable finer element size is used to capture the bending and static deflection in the structure. Free meshing techniques are common meshing technique in ABAQUS and use hexahedral element to obtain the accurate and DOF.

5. MATERIAL PROPERTIES

Most common important aspect is to check whether Leaf spring assembly withstands the load by applying material properties at pre-processing step. Here the material properties were applied while meshing.

Table -2: Material property for EN47 material

Sl. No	Properties	value
1	Density	7800 kg/m^3
2	Young's Modulus	205 GPa
3	Poisson's Ratio	0.29
4	Tensile yield Strength	455 MPa
5	Ultimate Tensile Strength	880 MPa

For EN47 material good wear and abrasion resistance characteristics are often obtained by oil hardening and tempered condition. Processed EN47 material offers excellent shock resistance and toughness hence it is suitable material for the parts exposed to stress, shock and vibration. EN47 is utilized broadly in the automobile industry and many general designing applications. For the material with high tensile strength and toughness EN47 is preferred. Important applications of the EN47 include crankshafts, steering knuckles, gears, spindles and pumps.

Table -3: Material property for medium alloy steel material

Sl no	Properties	Value
1	Yield strength	338.8 Mpa
2	Ultimate strength	621 Mpa
3	Pulsating strength	500.3 Mpa
4	Alternating strength	279.5 Mpa

6. Loads and Boundary Conditions

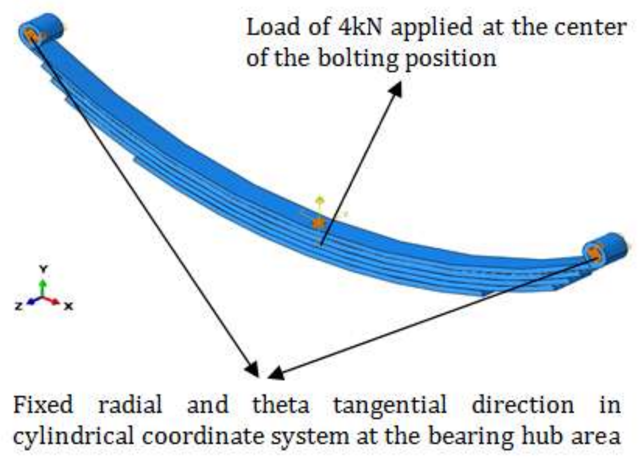

Fig -6: Loads and Boundary Conditions

The output results of FEA is govern by the application of boundary conditions and loading condition, loads or forces, acceleration or deformations applied to a structure or its components. Deformations, displacement and stress in structures are caused by the applying load conditions. Boundary condition is the necessary constraints that must be applied to the particular order of problem to obtain the required solution. Boundary value problem can be solved as set of boundary conditions are known. Boundary conditions are the major factor for the output of the solution. The boundary condition is shown in Fig 6 and leaf spring assembly is fixed at radial and theta tangential direction, hence no rotational and translational motion

7. RESULT AND DISCUSSION

The analysis of the leaf spring assembly was carried out with loads and boundary conditions. The results obtained from static stress analysis (stresses and displacement) modal analysis and fatigue analysis is shown below.

7.1 Static Analysis Results

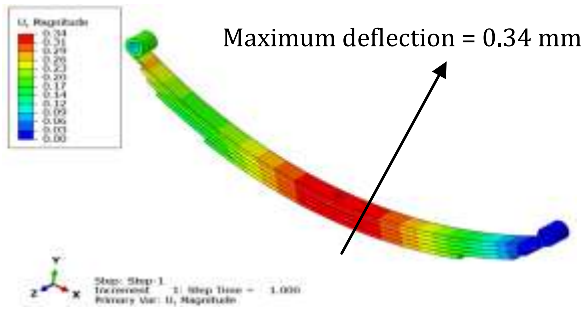

Fig -7: Static Analysis

The model subjected static analysis to determine the maximum deflection shown in the Fig .7 Maximum deflection of 0.34mm can be observed at the center of the leaf spring shown in Fig.7 by the applied load condition of 4kN. Maximum stress of 125.5 Mpa can be observed at the roots of the bearing hub. Stress at the bolt load point is 49 Mpa can be observed in Fig. 8 this shows the factor of safety around 7 which shows higher margin of safety.

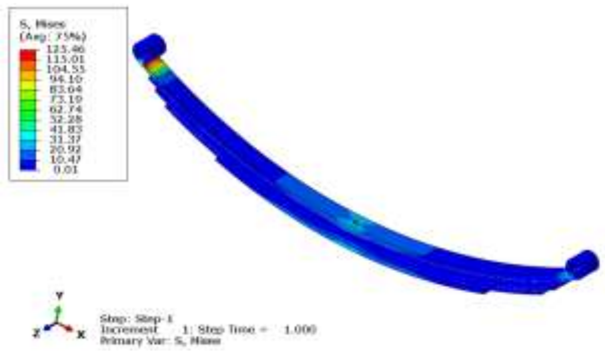

Fig -8: Maximum Stress

7.2. Modal analysis

Mode shape and natural frequency of mechanical system can be determined by using modal analysis. In the frequency domain the figures indicates four different modes of vibrations the dynamic properties are studied by analyzing the different modes. To obtain better results the model created is incorporated to the ABAQUAS solver.

7.2.1. Bending mode (1st Mode)

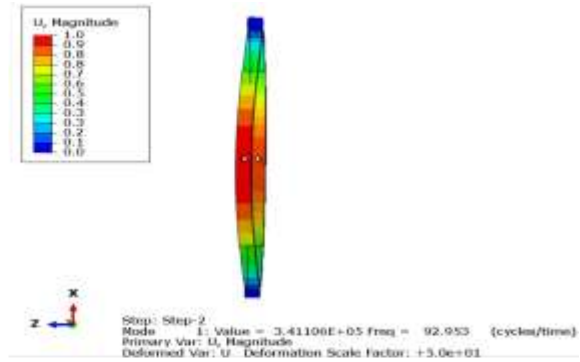

Fig -9: Bending mode

The 1st modes of vibration shown in Fig. 9 plotted to obtain independents from applied load; the nature frequency obtained is 92.953 Hz.

7.2.2 Twisting mode (2nd Mode)

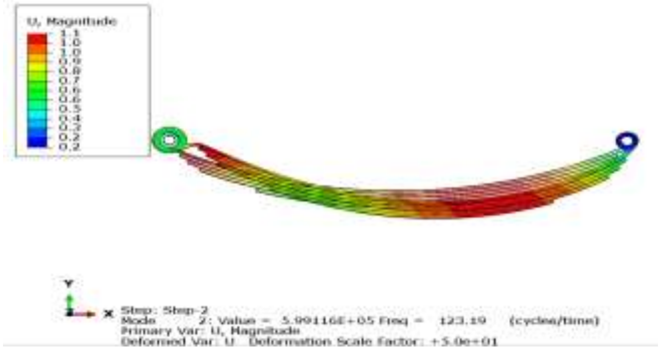

Fig -10: Twisting mode

The 2nd mode of vibration the natural frequency is 123.19Hz.which represented as twisting mode in Fig. 10

7.2.3 Lateral Twisting mode (3rd Mode)

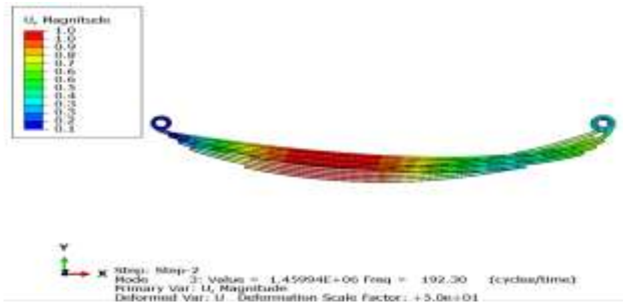

Fig -11: Lateral Twisting Mode

In the 3rd mode of vibration as natural frequency of 192.30Hz.which represented as lateral twisting mode in Fig. 11

7.2.4 Bending mode (4th Mode)

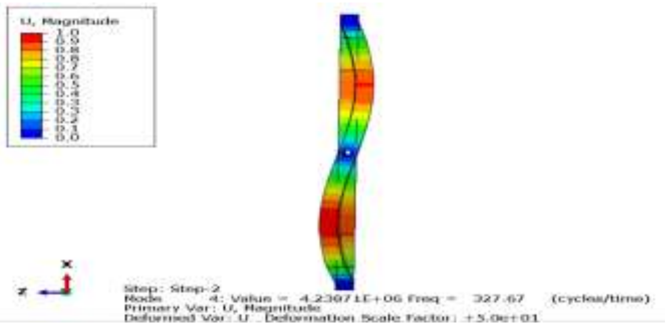

Fig -12: 2nd Bending Mode

In the final mode i.e. in the 4 th mode of vibration the natural frequency is 327.7Hz. From the above results, finally it can be concluded that 1st mode natural frequency is found to be 92.953 Hz. This is above the normal range of 30Hz which indicates a stiffer suspension of the leaf spring assembly.

7.4 Fatigue Life Analysis

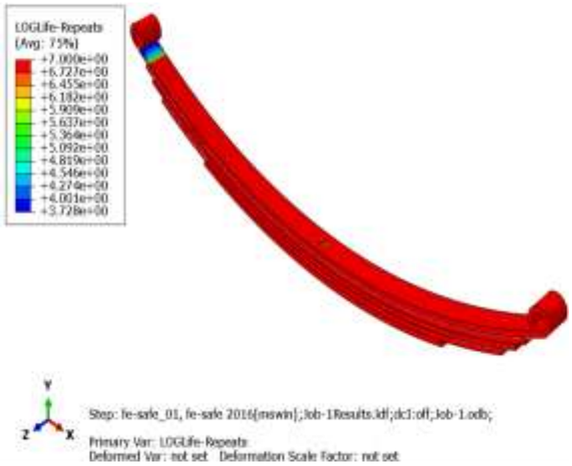

Fig -13: Fatigue life of medium alloy steel

Fatigue life of medium steel alloy is as shown in Fig. 13 the ultimate strength of medium steel alloy is 621Mpa. Maximum stress is observed at the roots of the bearing hub. It shows the minimum fatigue life cycle of 3728.

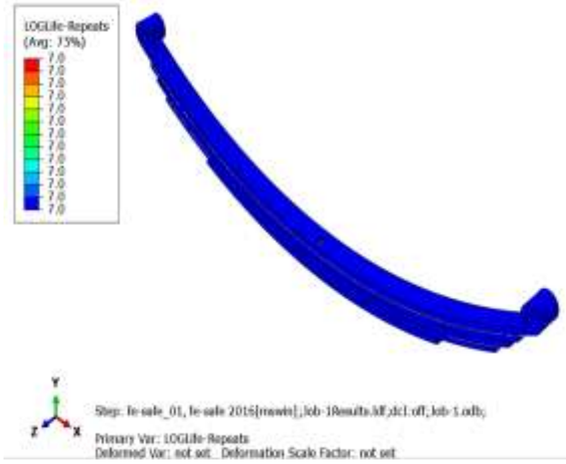

Fig -14: fatigue analysis of EN47 material

Fatigue life of medium steel alloy is as shown in fig 3.7.The ultimate strength of EN47 material is 880 Mpa. It shows the minimum fatigue life cycle of 10^7. Material change has been taken into consideration so that life of leaf spring will be improved.

8. CONCLUSIONS

The structural design validation analysis is performed by static, modal and fatigue loading conditions.

- The static result shows a maximum deflection of 0.34 mm at the Centre for 4 kN load and maximum stress of 125.5 Mpa. The deflection and stress are well within the safety limits of the material yield strength.

- To study the dynamic behavior of the leaf spring assembly, modal analysis is carried out to check the natural frequency of the system. The first mode is observed at 92.935 Hz which shows a stiffer suspension to absorb shocks in road conditions.

- To check the fatigue life of the system, the system is analyzed for spring steel with two different ultimate tensile strength limits. One with 621 Mpa and another with 880 Mpa. The EN47 material spring steel with 880 Mpa shows minimum fatigue life cycle of 10^7, whereas the earlier shows minimum cycles of 3728. So the design is safe when EN47 is used.

8.1 Scope of Future Work

- Stress analysis may generate results which could assist in modification of the leaf spring structure for better performance.
- Results are discussed as shown above and based on which conclusions are made by analysis above results we can further use these data's and experiments in future for different conditions and material.
- Fatigue analysis can be extended to other leaf spring and for different components.
- By changing the material and its properties to determine the stress and fatigue analysis in improved manner.
- The graduated leaf spring numbers can be varied.
- By optimizing the thickness of the leaf spring for the required load conditions.

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