STATIC AND DYNAMIC FINITE ELEMENT ANALYSIS (FEA) OF LEAF SPRING

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Abstract::- The current study is focused on analysis of Suzuki Mehran leaf spring for static and dynamic loading conditions. The CAD model of spring was prepared in solid works with the description as reported in [1]. Meshing and FEM modelling was done in Ansys Mechanical environment. The current work is presented in two section, the static analysis and dynamic case. The loading considered for static analysis is associated to a scenario when the vehicle is turning in a circular path with turning radius of 10m at a speed of 50m/s. While for dynamic loading, a transient boundary condition is applied for a bump profile as given in [2]. Before the calculations, a mesh sensitivity analysis is performed to optimize the grid size which is followed by actual calculations. In static case, stress analysis is performed for principal stresses and von misses stresses. Factor of safety based on ultimate strength is found to be 1.5 under static loading. In transient analysis, the stress histories are recorded and presented here for reference.

Keywords: CAD, Suzuki Mehran leaf spring, principal stresses, static & dynamic loading conditions, von misses stresses, ANSYS Suspension

Introduction

The leaf spring is an important component in automobiles because it provides a nice ride and ensures the vehicle's stability. In the transportation and automotive industries, the need to replace leaf springs with more robust and durable leaf springs is a serious challenge. It was thought that the car would be more dependable, comfortable, and faster with this input. Several studies on metallic and composite materials have been conducted in recent years to investigate the use of leaf springs and have showed that the use of composites in vehicle suspension can have significant implications. This chapter delineate comparison of composite and traditional leaf springs. This chapter also contains the research goals and objectives. Automobile suspension systems are also evolving on a regular basis to give protection from impact loading, as well as to prevent chassis distortion and damage [3].

Leaf springs and helical springs are both important components of vehicle suspension systems, however leaf springs are employed more commonly than helical springs due to their superior ability to absorb shock loads in the vehicle [4]. The important elements in lowering weight in automobiles are the leaf spring suspension systems, as a result of which fuel efficiency and ride quality improve. The simplicity and inexpensive cost of the leaf spring design are among its advantages. However, the type of leaf springs utilized in automobiles varies depending on the vehicle's gross weight [5]. The shape of a leaf spring determines how it differs from others. The quantity of leaves packed together in the parabolic and conventional leaf springs differs. Normal leaf spring, on the other hand, necessitates a greater number of leaves than parabolic leaf spring. This is because the parabolic shape distributes stress uniformly [6]. This paper discuses numerical structural analysis of Suzuki Mehran leaf spring under static and dynamic loading conditions. The leaf spring under consideration have three leafs connected by a clip. The description of CAD model, Meshing and assigned boundary conditions are given in the subsequent sections. The discussion is concluded by static structural analysis and dynamic structural analysis.

2.1. **Principle and Structure Design of Leaf spring***Model Details.* The CAD model is prepared with Solid works according to the description given in table 4.1. The main analysis is performed on full scale model with spring span of 965mm as the load is applied unsymmetrically in real scenarios. The geometric details of the spring can be seen in *Figure.1.*

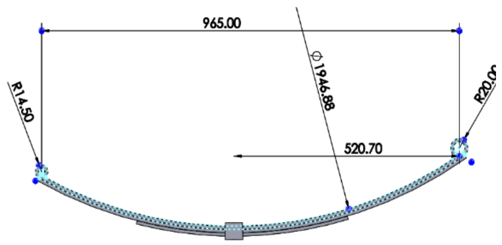


Figure.1: Full scale leaf spring

For the purpose of model validation, 520.7mm section of the mid leaf is considered here. Two different models are used for numerical calculations, a flat plate model cantilevered at root, and a curved plate with the same curvature is of the original spring. Thickness of these two models remain the same i.e. 7mm.

2.2. Meshing. The model assembly is meshed in Ansys Masher with Hex elements. From the mesh sensitivity analysis an element global size of 7mm was finalized and assigned in the global mesh settings. The curvature and proximity functions were kept off as no need was assessed for higher resolution of results.

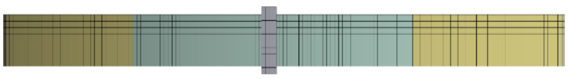


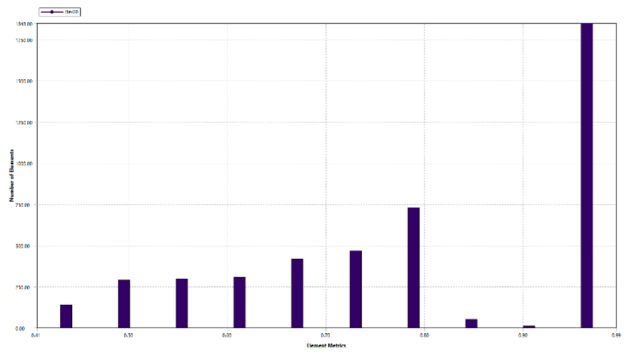
Figure.2: Mesh Layout of the full scale model

The details of component level mesh is given in Table.1 for reference. The total number of node was found to be 30444 (4536 Elements).

2.3. Structure Design of the Leaf spring. In order to meet the best result the following requirements are proposed for the shape and size of the leaf spring. The details of component level mesh are given in Table.1 for reference. The total number of node was found to be 30444 (4536 Elements).

	Mass [kg]	No. of Elements	No. of Nodes	Element type
Leaf 1	3.1372	2688	16197	Hex20
Leaf 2	2.7679	1168	8949	Hex20
Leaf 3	1.3457	568	4374	Hex20
Clip	0.2401	112	924	Hex20

Table 1: Component Level Mesh Details



Graph.1: Overview of Mesh Quality

A high-quality mesh was obtained with minimum element quality of 0.4 (refer *Table*. 2) with average value of 0.799. Considering Mesh sensitivity results, this mesh was finalized for further analysis. The Mesh matric for Element quality can be seen in *Figure*. *3*.

Mesh Metric	Element Quality
Min	0.40604
Max	0.99488
Average	0.79941
Standard Deviation	0.18273

Table 2: Mesh Quality

3. *Boundary condition*

The actual leaf spring mounting is done in such a way that axil moment in allowed subjected to some mechanism. The correct formulation for this moment is not known hence it was assumed to be free in x-direction. The front eye and rear eye of the spring were set to remote Displacement. This Boundary condition let you opt to define motion in all three translational direction (X, Y, Z) and in all three rotational Directions. For the current settings the rotation of both eyes (z-directed) was set to free while the translation of the frontal eye was set to free. Rest of the motions were restricted and set to fixed. A bi-directional Force load was defined at the upper surface of the clip. The load application occurs due to the dead load of the car Plus the centrifugal effects while turning the car in a circular path. Further loading on the leaf spring occurs due to acceleration OR deceleration of the vehicle which is directed in longitudinal direction (X-direction).

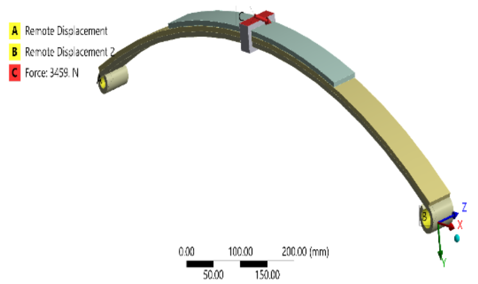


Figure 3: Boundary Conditions over the spring

For the current calculations, A scenario is considered when the vehicle is going with a speed of 50 km/hr in a road curve of radius 10 m. Under this condition, the vehicle is stressed under two loadings,

- the Dead load of the Vehicle
- The Centrifugal force acting due to turning

The Load distribution is consider to be equal on all wheels as done by [1]. These forces are calculated as given below:

$$Fc = \frac{mv^2}{r}$$

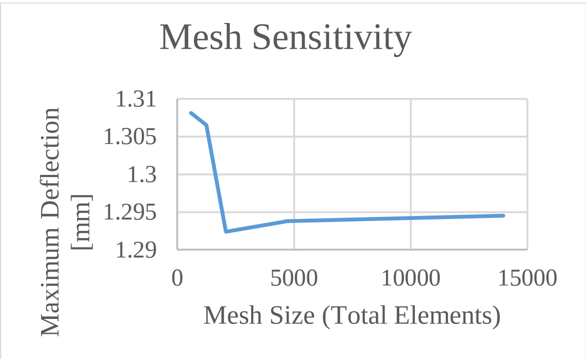
$$Fc = \frac{640 * \left(50 * \frac{1000}{3600}\right)^2}{10} = 12329.88N$$

$$Force\ per\ spring = F_{\frac{c}{4}} = \frac{F_C}{4} = 3082.47N \rightarrow F_Z$$

$$Kerb\ weight\ of\ the\ car = W = 640 * 9.81$$
$$= 6278.4N$$

$$Weight\ of\ the\ spring = \frac{W}{4} = 444.25N \rightarrow F_Y$$

3.1. *Mesh Sensitivity Analysis.* The sensitivity of analysis for mesh density was performed by creating a mesh control for global mesh size and parameterizes it into workbench. The element size was varied from 100mm to 1mm. the full scale model was subjected to a force of 6125N bi-directional force and the corresponding maximum deflection was recorded. The changes in deflection values was found to be negligible when the element size reached to 7mm, hence this setting was finalized and the corresponding mesh was used for further analysis.



Graph.2 Mesh Convergence Curve

3.2. *Validation of Model.* For validation of the numerical model, two cantilevered type plates were considered. One, a flat plate, with cross sectional dimensions same as the that of a leaf the original spring and second with curved layout , with the same curvature and cross sectional dimensions as that of original spring leaf. The Bending stress calculated with several loading conditions are compared with results obtained through analytical formulations as given in equation.

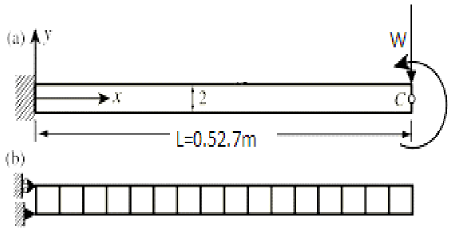


Figure.5 Contiliver Beam

Dimesion of contiliver beam

$$L = 0.52.7m$$

$$b = 0.05m$$

$$t = 0.007m$$

The bending stress in the beam at the above figure can be calcukated as

$$\sigma \frac{3\omega l}{bt^2} - (1)$$

The analytical colculation can be obtain through above equation

The models used for comparison can be seen in fig.7. The models are fixed at root, and a force loading in applied on the free end of the plate. The mesh settings for both the models are kept same as is used in original model. The comparison of results obtained for loading of 50N to 500N are given in table 2 given below.

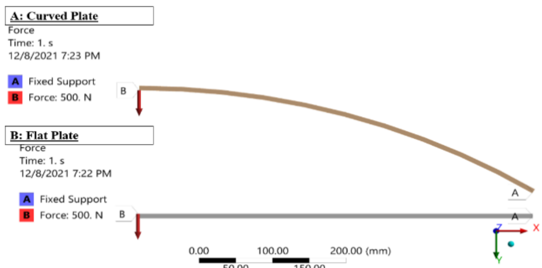
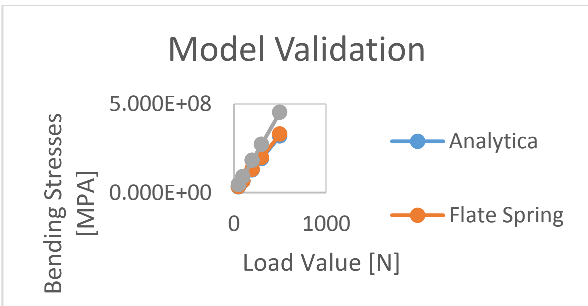


Figure 4 Models used for Validation purpose



Graph.3 Results comparison for validation of numerical model

The deviation in results obtained in low in flat plat case as compared to the curved plate. Also the relative deference increases as the loading is increased. This behaviour is expected due to the included geometric non-linearity in numerical calculations which is otherwise, ignored in analytical results,

4. Structure Response under Static Loading

The vehicle is assumed to be stationary and the leaf spring undergoes static loading in this section, a spring response to a static loading is discussed. The assumed operating conditions are taken, when the vehicle is turning at a rate of 40 km in a circular arc of radius 10m. Under these conditions, leafs are subjected to a force due to centrifugal action of the car inertia and the dead weight of the vehicle. The load acting on spring is considered to be ¼ of the total loading as the vehicle CG is ideally located at equal distance from all the four wheels. These loading are calculated be 3082N along z-axis (due to centrifugal action) and along y-axis (due to kerb weight). The spring moment is restricted in "Y" and "Z" direction but the stretch is allowed in "X" direction i.e. the spring is only allowed to bend and stretch in axial direction. Under these conditions, the von-mises and Bending Stresses distribution are taken from the mid-section of the outer surface of each leaf [fig-9] and are presented as under.

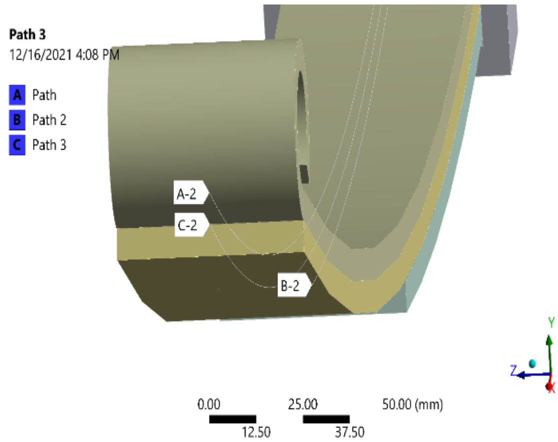


Figure 6 Location of path for stress distribution.

4.1. Von Mises Stresses. The maximum von-mises stresses are developed in the eye region the spring with the value of 550.35 MPa. These stresses are lower from the upper bond of the allowable stresses value of 1250 MPa.

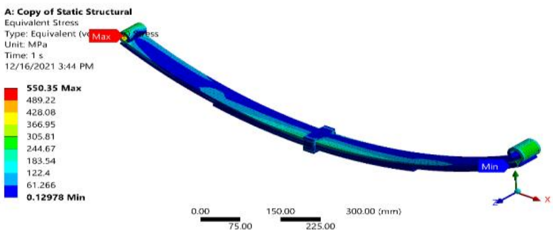
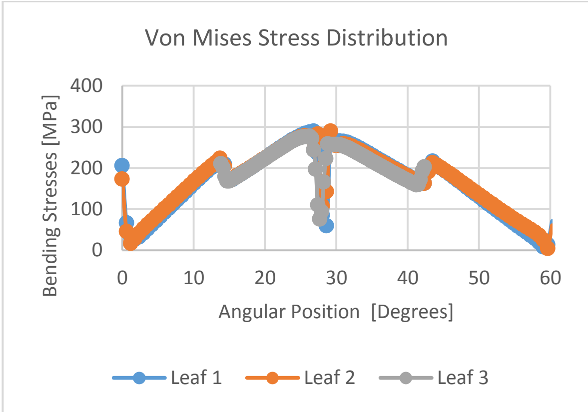


Figure.7 Von-misses stresses under static loading

The stress distributions are plotted for each leaf and mid-section outer surface of each leaf. A very small offset can be observed with irregular trend for each leaf. As the central clip was defined as bounded, the central deep in the distribution curves can be seen.



Graph.4 stress distributions

4.2. Bending Stress. The maximum bending stresses are developed in the eye region of the spring with the value of 340 MPa. These stresses are lower from the upper bond of the allowable stresses' value of 1250 MPa.

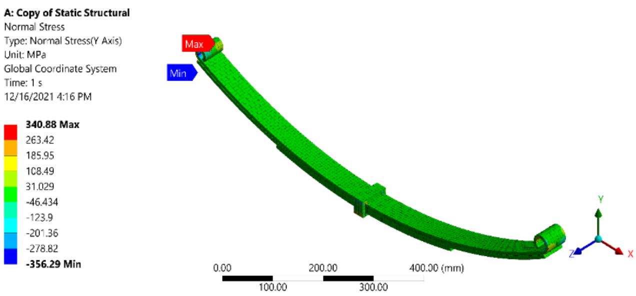
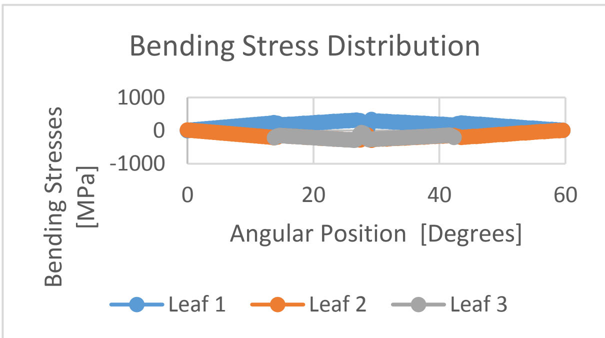


Figure.8 Contours of Bending stresses

The bending stress distributions are plotted at mid-section's outer surface of each leaf. A very small offset can be observed with irregular trend for each leaf. It can be seen, that the inner surfaces for Leaf 2 and Leaf 3 are under compression but Leaf 1 in under tension.



Graph.5 Stress distributions

4.3. Principal Stresses. Following figure shows stress distribution contours for Principal stresses. The maximum stresses are developed in the eye region with the value of 511.75 MPa, which is again lower than the upper bound of the allowable stresses value.

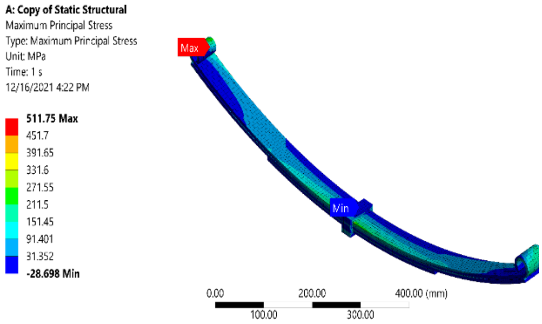


Figure.9 Contours for principal stresses

5. *Safety Factor*

Following figure show safety factor distribution against Tensile yield per material value of 1200MPa. The eye region is found to be most critical region as stresses concentration is observed in all of the above discussion. The minimum safety factor value is found to be 2.1

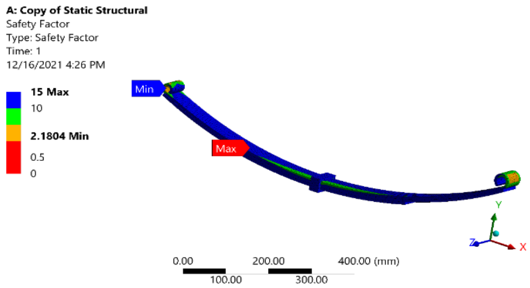
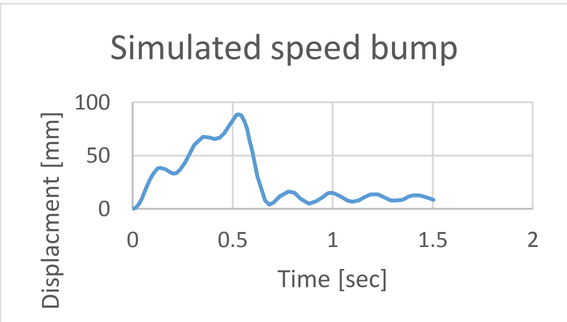


Figure.10 Contours for safety factor

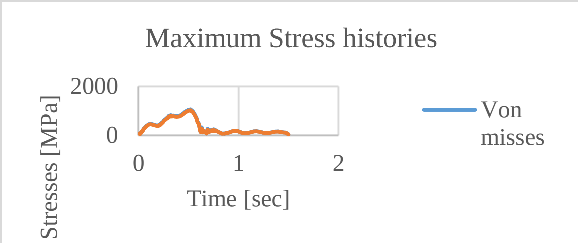
6. *Structural Response under Dynamic Loading*

For the transient analysis, the boundary conditions are implemented in-order to simulate the leaf spring behaviour going over a speed bump. The bump profile considered for this analysis is given in the fig.14. This displacement profile is applied at the central clip with the same constraints as used in static case.



Graph.6 Speed bump displacement profile

6.1. Maximum Stresses under transient loading. The maximum stresses values are plotted in fig.15 for von misses and principal stresses with time histories. It can be seen, that the trends in stresses values corresponds to the applied boundary conditions. Maximum value observed at deflection level of 88mm i.e. 1061.9 MPa.



Graph.7 Max Von misses Stress history

Similar trends are seen in Principal stresses values but with slit lower offset. The principal stresses value corresponding to the maximum deflection condition is reported to be 1025.5 Mpa.

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REFRENCES

[1] Mawiz Muaz Tariq, 2020, “Design and Analysis of Composite Leaf Spring”, Master Degree Thesis, capital university of science and Technology, Islamabad

[2] Himanshu Arun Raut, Fall 2016, Static and dynamic FEA analysis of A composite leaf spring, Master Degree Thesis, The University of Texas at Arlington.

[3] V. Amrute, E. N. Karlus, R. J. I. j. o. r. i. a. Rathore, and m. engineering, "Design and assessment of multi leaf spring," vol. 1, no. 7, pp. 115-124, 2013.

[4] Rajendran and S. J. J. o. t. I. o. E. Vijayarangan, Part MC, Mechanical Engineering Division, "Design, analysis, fabrication and testing of a composite leaf spring," vol. 82, no. 4, pp. 180-187, 2002.

[5] D. D. Dwivedi, V. J. F. T. i. E. Jain, Science, Humanities,, and T. FTESHT-16, "Design and analysis of aotomobile leaf spring using ansys," p. 102, 2016.

[6] T. A. Kumar, E. V. Rao, S. G. J. I. J. o. r. I. M. e. Krishna, and technology, "Design and material optimization of heavy vehicle leaf spring," vol. 4, no. 1, pp. 80-88, 2014.