International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 09 | Sept - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Analysis Of Semi Elliptical Multi Leaf Spring Using Ansys

Swastika Patel[1], Rahul Sahu[1*], Vinod Bareth[1], Ishwar Dhruw[1]
[1]*Assistant Professor, Dept. of Mechanical Engineering, Government Engineering College, Raipur, Chhattisgarh, India PIN-492015*

**Corresponding author: rahuliitb14@gmail.com (Rahul Sahu)*

---***---
-

Abstract
A multi-leaf spring is one of the most important components of automobile suspension system. Leaves are basically a series of flat plates, usually of semi-elliptical shape. Generally, a multi leaf spring used in automobile suspension, consists of two types of leaves i.e. graduated-length leaves and full-length leaves. The present work is an attempt to estimate the magnitude of bending stresses in the above-mentioned leaves for a semi-elliptic multi-leaf spring made of structure steel and titanium alloy. A lot of research work has been carried out in the context of leaf spring considering its material and a significant progress has been observed in the field of weight reduction, improvement of load carrying capacity. This project includes the study of deflection and stress distribution of leaf spring for heavy duty vehicles, considering two materials. The results highlight the best suitable material for better dynamic behavior of leaf spring and its design optimization. Finally referring to the results obtained in these research studies, the present work proposes a new idea regarding the construction of multi-leaf spring based on practical applications and cost analysis.

Keywords: Leaf spring, Torsion, Static analysis. Semi elliptical, Fatigue failure

1. Introduction
A spring is an elastic machine element which undergoes deflection for the application of any load and intends to regain its original shape depending upon the magnitude of the applied load. The major applications of spring may include its use as a shock and vibration absorber and storing potential energy by its deflection during the application of load. A multi-leaf spring or laminated spring is a very important component in automobile suspension system. It is one of the oldest suspension components too and still today it is extensively used in all the heavy and light duty commercial vehicles, railway wagons and usually in the rear suspension of passenger vehicles. It differs from the conventional helical spring in a way that it can be guided along a definite path and it deflects under the application of load while acting as a structural member. This concept is employed during the analysis of bending stresses in different leaves by consideration of cantilever beam.

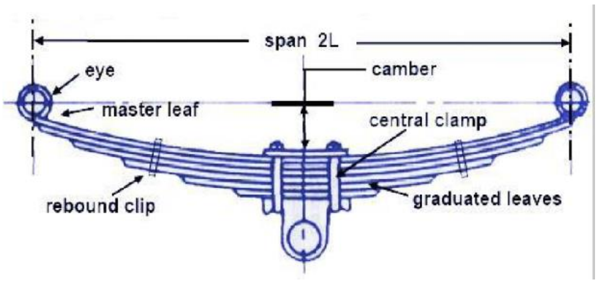
There were a variety of leaf springs, usually employing the word "elliptical". "Elliptical" or "full elliptical" leaf springs referred to two circular arcs linked at their tips. This was joined to the frame at the top center of the upper arc, the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailing arms, would usually be needed for this design, but not for "semi-elliptical" leaf springs as used in the Hotchkiss drive. That employed the lower arc, hence its name. "Quarter-elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over its differential that were curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non-metallic sheets in between the metal leaves, such as wood.
.

1.1. Construction of Leaf Spring
The construction of leaf spring consists of a series of flat plates or leaves, usually of semi- elliptic shape, which are held together with the help of U-bolts and center clip. Generally, two types of leaves may be observed in a multi-leaf spring i.e. some graduated -length leaves and a few extra full-length leaves. The length of the leaves gradually decreases from top to bottom. The longest leaf in the top is known as master leaf which is bent at both the ends to form spring eyes. The extra full-length leaves are inserted between the master leaf and the graduated-length leaves to support the transverse shear force. In order to maintain proper alignment and to restrict the lateral shifting of leaves, rebound clips are used. In practice, these springs rest on the axle of an automobile. Its front end is connected with the frame by means of a simple pin joint and the rear end is

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 09 | Sept - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

connected with the frame through a flexible link (known as shackle).

Fig. 1 Construction of leaf spring [1]



1.2. Objectives

The objective of the present work is to find the equivalent stress and total deformation for two different leaf spring materials and compare the results for choose the best material for leaf spring.

By performing static and dynamic analysis using ANSYS software and mathematical calculations, the maximum bending stress and corresponding payload have to be determined by considering the factor of safety.

2. Literature Review

Zliahu Zahavi et. al [1] the leaf spring works is very complicated from the point of view of mechanics and numerical computations. The magnitude of loading is high as well as spring deformations. Multi-surfaces 3D contact between subsequent leaves also takes place. The main advantage of leaf springs is that the ends of the spring are guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Practically, a leaf spring is subjected to millions of load cycles leading to fatigue failure. Free vibration analysis determines the frequencies and mode shapes of leaf spring.

Strzat and T. Paszek et. al 1992 [2] performed a three-dimensional contact analysis of the car leaf spring. They considered static three-dimensional contact problem of the leaf car spring. Different types of mathematical models were considered. The static characteristics of the car spring was obtained for different models and later on, it is compared with one obtained from experimental investigations.

Fu-Cheng Wang et. al [3] performed a detailed study on leaf spring.. His work mainly discusses the active suspension control of vehicle models. The employing active suspension through the analysis of the mechanical networks is discussed. He derived a parameterization of the set of all stabilizing controllers for a given plant. He considered practical parameters and applications of a leaf spring model through his work, thus supporting both the situations, that is active and passive suspension cases, individually. This literature review has considered a total of thirty-four reports. spring of a passenger car. Finite element analysis has been carried out to determine natural frequencies and mode shapes of the leaf spring. A simple road surface model was considered.

Shiva Shankar et. al [4] performed test on the leaf springs under static loading condition & the stresses and deflection are listed. These results are also compared with FEA. Testing has been done for unidirectional E-Glass/Epoxy mono composite leaf spring only. Since the composite leaf spring is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. Since, the composite spring is designed for same stiffness as that of steel leaf spring, both the springs are considered to be almost equal in vehicle stability. The major disadvantages of composite leaf spring are chipping resistance. The matrix material is likely to chip off when it is subjected to a poor road environment (that is, if some stone hit the composite leaf spring then it may produce chipping) which may break some fibers in the lower portion of the spring. This may result in a loss of capability to share flexural stiffness.

Venkatesan M. et. al [5] perform design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer & compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. Compared to steel spring, the composite leaf spring is found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf spring. A weight reduction of 76.4% is achieved by using optimized composite leaf spring.

3. Problem Description

The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for 10-20 % of the un-sprung weight. The steel leaf spring has some problems which are listed as follow:

1.It is observed that the leaf spring tend to break and weaken at the eye end portion which is very close to the shackle and at the center.

2.Due to continuous running of the mini loader vehicle, there is a decrease in the level of comfort provided by the spring.

4. Methodology

4.1. Design Specification –

In The objective of the present course of study includes, determination of maximum bending stress for two different materials and to establish the relationship for the magnitude of bending stresses existing in the graduated-length leaves and extra full-length leaves -

I. Here weight and initial measurements of four wheeler "TATA 407- Pickup vehicle is taken. Gross Vehicle Weight = 4450 kg

II. Kerb Weight = 2250 kg Payload = 2200 kg

III. Total load = 4450×9.81= 43654.5 N

IV. Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up 1/4th of the total weight. 43654.5 /4 = 10913.625 N

Parameters	Value	Notation
Total length of the semi-elliptic spring (distance between two eyes)	1220mm	2L
width of each leaf	60mm	b
thickness of each leaf	7mm	t
number of extra full-length leaves	2	n_f
number of graduated-length leaves including the master leaf	6	n_g
Total number of leaves present in the multi-leaf spring	8	n
Load acting at the center of the spring	10000N	2P

Table 1 Specification of multi-leaf spring

In this project three software are used, namely ANSYS: - This software provides means for both, creation of CAD file i.e. modelling and analysis of the model under various circumstances and field of engineering. We used this software for analysis of our model.
CATIA V5: - This is all in one software i.e. it contains CAD, CAM and Analysis tools. We created our model using this software.
MATLAB: - It is the renowned mathematical software which contains all the tools we come across in engineering mathematics. We plotted the conclusion graph with the help of this software.

4.2. Geometry Creation –

STEP 1: Open the SOLIDWORKS software and select geometric option of plane.
STEP 2: Now draw the line (eye to eye center distance) of length 1220 mm.
STEP 3: Next step is to draw the circle of diameter 20 mm and 13 mm at the ends of line.
STEP 4: Elliptical arc is generated to connect these two eyes with the camber of 80 mm.

Fig. 2 Elliptical arc

STEP 5: Now this geometry is extruded with the help of extrude option to generate the solid geometry. This is the extra full-length leaf of leaf spring.

STEP 6: Similarly, we create other leaves with the help of main leaf by reducing the length of main leaf spring by 40 mm at the both ends.

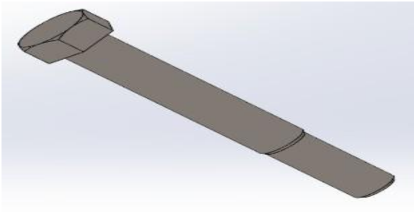
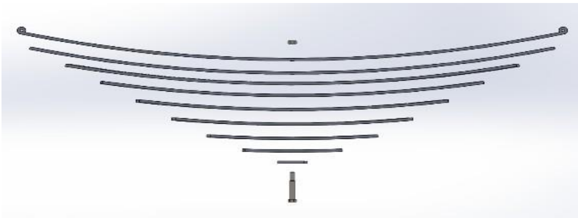


Fig. 3 Nut

STEP 7: Now the bolt and nut are taken from design library of SOLIDWORKS. The nut size is M10.



Step 4 Each leaf and nut separated

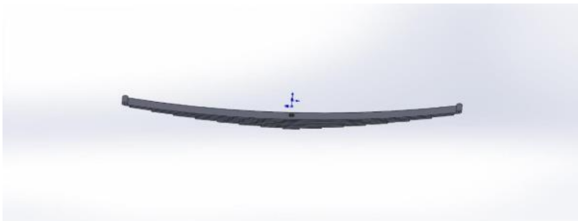


Fig.5 Final geometry of the spring

4.3. Static Analysis –

After geometric modeling in SOLIDWORKS software the spring is subjected to static analysis, performed in ANSYS (Workbench 17.2) software. The computer compatible mathematical description of the geometry of the object is called geometric modeling.

Meshing is basically the division of the entire model into small elements. In order to maintain the shape, it is convenient to select the free mesh, as the geometry of leaf spring contains sharp curves. Element size of 15 mm with medium smoothing was considered for mesh generation. Minimum edge length of the elements was 10 mm.

Fig.6 Meshing of the geometry

The load is uniformly distributed by all the nodes associated with the bottom surface of the bottom most leaf. The Load is applied in the direction as shown in Figure. To apply the load, under the static structural domain of ANSYS Software, Force was introduced and the magnitude of load was given for the direction shown.

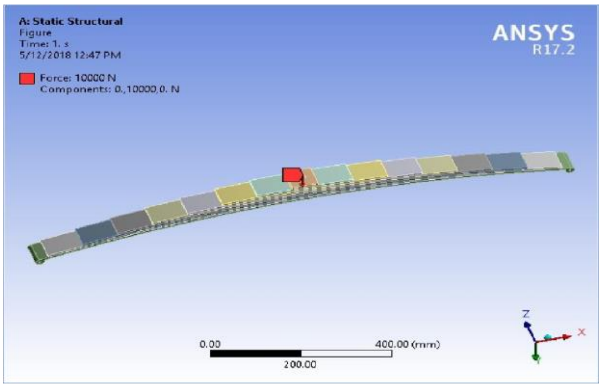


Fig.7 Boundary conditions

Fig. shows the boundary conditions employed in front and rear ends of leaf spring. The front end is fixed to the frame and allowed to displace only in Z-direction (rotation). The rear end is connected to the frame with shackle and allowed to displace in X-direction (translation) and in Z-direction (rotation).

The load applied is 10000 N which acts in the direction shown in fig. below

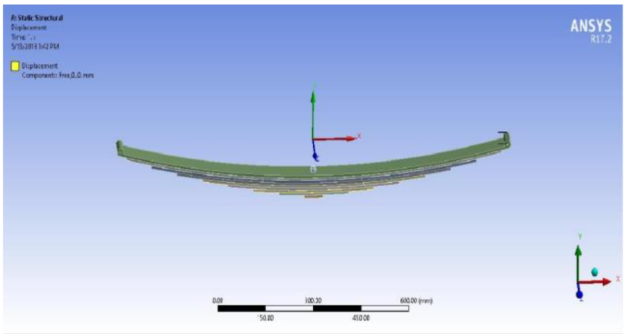


Fig. Boundary conditions at the center

Fig. 8 Point load at the center

The back eye of the spring is linked to the shackle which is a flexible link the next end of the shackle is linked to the frame of the vehicle.

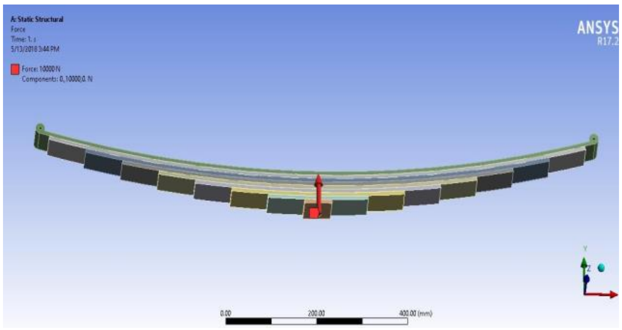


Fig.9 Point load at the center

5. Results

After associating the real-world physics to the generated model in ANSYS software, the solutions obtained for Equivalent (Von-Mises) Stress and Deformation using static structural as the Analysis System. The results obtained after the solution, are presented in the following figures.

1. Equivalent Stress (structural steel)

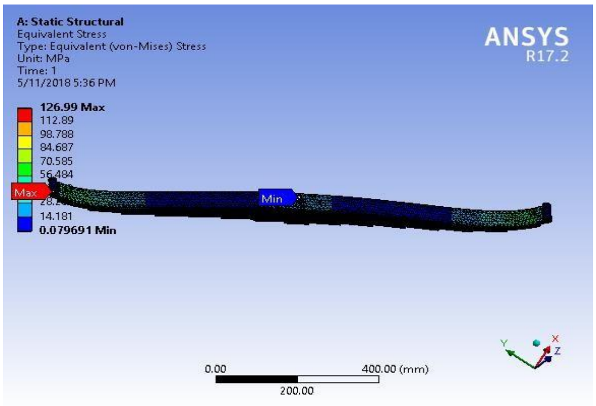


Fig.10 Equivalent stress

2. Total Deformation(Structural Steel)

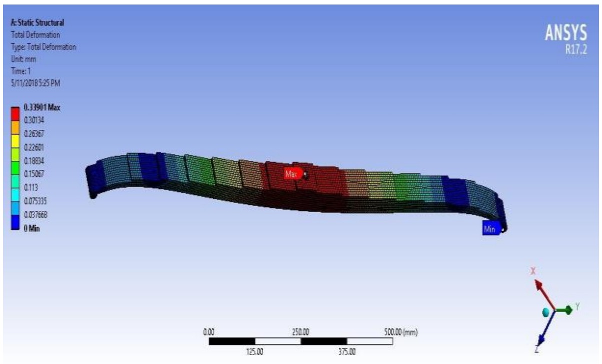


Fig.11 Total deformation of S Steel

3. Equivalent Stress (Titanium Alloy)

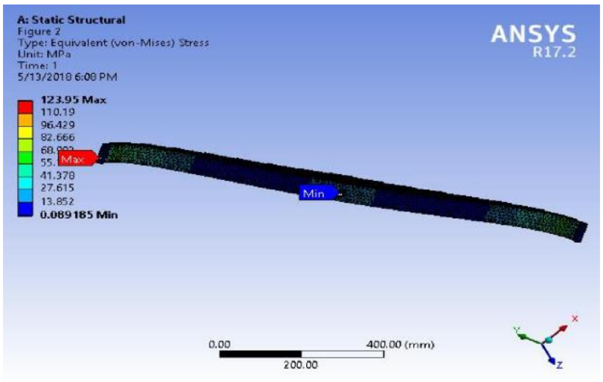


Fig.12 Equivalent Stress of Titanium Alloy

4. Total Deformation (Titanium Alloy)

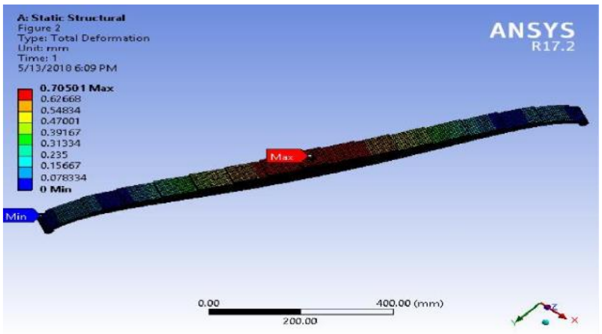


Fig.11 Total deformation of Titanium Alloy

Material	Max. Equivalent Stress (MPa)	Total Deformation (mm)
Structure Steel	126.99	0.33901
Titanium Alloy	123.95	0.70501

Table 2 Comparison of S. Steel and Titanium Alloy

6. Conclusion

In the present work, the multi-leaf spring is modeled in SOLIDWORKS and same were analyzed in the Static Structural domain of ANSYS software. The results were discussed in the preceding section and it is concluded that, for the given design specifications the bending stress under static analysis in Structure Steel leaf spring is greater than the stress in the Titanium Alloy leaf spring. In dynamic analysis the stress in Titanium Alloy is greater than the stress in Structure Steel. So, the recommended material of leaf spring for dynamic loading in Structure Steel. We further concluded that, stresses in the extra full-length leaves were almost 50% more (1.5 times) than that of the graduated length leaves.

References

[1] Eliahu Zahavi The Finite Element Method in Machine Design. Prentice Hall, Englewood Cliffs, N.J, 07632.

[2] A Skrtz, T.Paszek,(1992) “Three dimensional contact analysis of the car leaf spring”, Numerical methods in continuum mechanics, 2003, Zilina, Skrtz republic

[3] Cheng Wang, (1999) “Design and Synthesis of Active and Passive vehicle suspensions.

[4] Shiva Shankar “Mono Composite Leaf Spring for Light Weight Vehicle – Design, End Joint Analysis and Testing, ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 12, No. 3. 2006

[5] M. Venkatesan, D. Helmendevaraj (2012), Design And Analysis Of Composite Leaf Spring In Light Vehicle int. jr. of modern engineering research Vol.2: pp-213-218

BIOGRAPHIES

Mrs. Swastika Patel is an Assistant Professor at GEC Raipur. She did his MTech from NERIST Itanagar and pursuing PhD from IIT Bhilai.

Mr. Rahul Sahu is an Assistant Professor at GEC Raipur. He did his MTech from IIT Bombay and pursuing PhD from IIT Bhilai.

Vinod Bareth and Ishwar Dhruw, student of Mechanical Engineering department during 2016-20.