ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# Static and Modal Analysis on Composite Leaf Spring in Heavy Vehicle

**Thella Ashok Kumar**
**M.Tech-Machine Design,**
**Nova College of Engineering and Technology,**
**A.P-India.**

**Jithendra**
**Associate Professor & HOD,**
**Dept of Mechanical Engineering,**
**Nova College of Engineering and Technology,**
**A.P-India.**

**Abstract:**

The objective of this present work is to estimate the deflection, stress and mode frequency induced in the leaf spring of an army jeep design by the ordinance factory. The emphasis in this project is on the application of computer aided analysis using finite element concept. The component chosen for analysis is a leaf spring which is an automotive component used to absorb vibrations induced during the motion of vehicle. It also acts as a structure to support vertical loading due to the weight of the vehicle and payload. Under operating conditions, the behavior of the leaf spring s complicated due to its clamping effects and interleaf contact, hence its analysis s essential to predict the displacement, mode frequency and stresses.

The leaf spring, which we are analyzing, is a specially designed leaf spring used in military jeeps. This spring is intended to bare heavy jerks and vibrations reduced during military operations. A model of such jeep has been shown in this project report. In analysis part the finite element of leaf spring is created using solid tetrahedron elements, appropriate boundary conditions are applied, material properties are given and loads are applied as per its design, the resultant deformation, mode frequencies and stresses obtained are reported and discussed and model is designed in catia or pro-e and finally analysis take place in ansys software.

## I. INTRODUCTION:

A spring is defined as an elastic body, whose function is to distort when loaded and to recovers its original shape when the load is removed. Semi- elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps.

The spring is mounted on the axle of the vehicle. The entire vehicle rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, leading to deflection of the spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is provided as one end, which gives a flexible connection.

## II. LITERATURE REVIEW

Zliahu Zahavi [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 leafs 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. A.strzat and T.Paszek [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 [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.

## III. OVERVIEW OF LEAF SPRING

### Introduction

Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps. The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame.

When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes.

### Suspension System

The automobile chassis is mounted on the axles, not direct but some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame anybody. All the part, which performs the function of isolating the automobile from the road shocks, is collectively called a suspension system. It includes the springing device used and various mountings for the same. Broadly speaking, suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber.

### Objective of Suspension

To prevent the road shocks from being transmitted to the vehicle components.

To safeguard the occupants from road shocks

To preserve the stability of the vehicle in pitting or rolling, while in motion

### Basic Considerations for vertical loading

When the rear wheel comes across a bump or pit on the road, it is subjected to vertical forces, tensile or compressive depending upon the nature of the road irregularity. These are absorbed by the elastic compression, shear, bending or twisting of the spring. The mode of spring resistance depends upon the type and material of the spring used.Further when the front wheel strikes a bump it starts vibrating. These vibrations die down exponentially due to damping present in the system. The rear wheel however, reaches the same bump after certain time depending on the wheel base and the speed of the vehicle. Of course, when the tear wheel reaches the bump, it experiences similar vibrations as experienced by the front wheel some time ago. It is seen that to reduce pitching tendency of the vehicle, the frequency of the front springing system be less than that of the rear springing system. From human comfort point also it is seen that it is desirable to have low vibration frequencies. The results of the studies of human beings have shown that the maximum amplitude which may be allowed for a certain level of discomfort decreases with the increase of vibration frequency.

### Rolling:

The centre of gravity of the vehicle is considerably above the ground. Due to this reason, while taking a turn, the centrifugal force acts outwards on the C.G of the vehicle, while the road resistance acts inward at the wheels. This gives rise to a couple turning the vehicle about a longitudinal axis. This is called rolling. The manner in which the vehicle is sprung determines the axis about which the vehicle will roll. The tendency to roll is checked by means of a stabilizer.

### Brake-dip:

On braking, the noise of the vehicle has a tendency to be lowered or to dip. This depends upon the position of centre of gravity relative to the ground, the wheelbase, and other suspension. In the characteristics the same way, torque loads during acceleration end the front of the vehicle to be lifted. These forces on account of braking and driving are carried directly by deflecting the springs, by wishbone arms or by radius rods.

### Side Thrust:

Centrifugal force during cornering, cross-winds, cambering of the road etc, cause a side-thrust to be applied to the vehicle, such forces are usually absorbed by the rigidity of the leaf springs or by fitting pan hard rods.

### Unsprung Weight:

Un-sprung weight is the weight of vehicle components between the suspension and then road surface. This includes rear axle assembly, steering knuckle, and front axle in case of rear drive rigid suspension, wheels, tires and brakes. The sprung weight i.e. the weight supported by the vehicle suspension system, includes the frame, body, engine, and the entire transmission system. When the wheels strike against a bump, they vibrate along with other unsprung parts which store the energy of the vibrations and then further transmit it to the sprung parts via the springs. Thus it is seen that greater the weight of the unsprung parts, greater will be the energy stored due to vibrations and consequently greater shocks. When a small shock results in the large movements of the wheel, the suspension is said to be soft, such a soft suspension is more comfortable to the occupants. However, excessively soft suspension will result in the loss of braking efforts are decreased. Thus a good suspension system should be an optimum compromise between softness and hardness.

## IV. BASICS OF VIBRATION AND FINITE ELEMENT METHOD

### Introduction to Vibrations

The study of vibration is concerned with the oscillatory motions of bodies and the forces associated with them. All bodies possessing mass and elasticity are capable of vibration. Thus most engineering machines and structures experience vibration to some degree, and design generally requires consideration of their oscillatory behavior. Vibration in generally, is a form of energy and undesirable in many cases. For example in machinery, it generates noise causes damage to the parts and transmits unwanted forces moments to other bodies nearby. Oscillatory systems can be broadly characterized as linear and non – linear. For linear systems the principle of superimposition holds, and the mathematical techniques available for their treatment are well developed. In contrast, techniques for the analysis of non – linear systems are less well known, and difficult to apply. There are two general cases of vibrations called free and forced vibrations. Free vibrations, takes place when a system oscillates under the action of forces inherent in the system itself, and when external impressed forces are absent. The system under free vibration will vibrate at one or more of its natural frequencies, which are properties of the dynamical system established by its mass and stiffness distribution. Vibration taking place under the excitations of external forces is called forced vibration. When the excitation is oscillatory, the system is forced to vibrate at the excitation frequency. If the frequency of the excitation coincides with one of the natural frequencies of the system, the condition of resonance is encountered, and large oscillations may result. The failure of major structures, such as bridges, buildings or airplane wings, is an awesome possibility under resonance. Thus, the calculation of natural frequencies is very important.

### Definition in Vibration

### Period of vibration

The time interval required to complete one cycle of to and fro motion is termed as "time period" of the vibration.

### Frequency of vibration

The number of cycles per unit time is called "frequency of vibration". So, it follows that frequency is reciprocal of time period.

$F = 1 / T$

Where f = frequency

T = time period

### Amplitude of vibration

The maximum displacement of the system from its equilibrium position is called "Amplitude" of the vibration.

### Free vibration

When the motion is maintained by restoring forces only, the vibration is said to be "Free vibration".

### Forced vibration

When a periodic force applied to the system, the resulting motion is described as "Forced vibration"

### Undamped vibration

When the effect of friction may be neglected, the vibration is said to be "Undamped vibration".

### Damped vibration

When the effect of friction is taken into account, the vibration is said to be "Damped Vibration".

Thus, there are four distinct cases of vibration possible:

a) Free vibrations without damping
b) Free vibrations with damping
c) Forced vibrations without damping
d) Forced vibrations with damping.

The frequency associated with any vibration is called natural frequency. While vibrating, if the frequency of vibration coincides with the natural frequency, the amplitude of vibration increases. This phenomenon is called "Resonance". The consequences of Resonance are very ominous as it leads to the failure of the machine as a whole. The decay of vibration with time due to resistance to the motion of the vibrating body is called "Damping". It provides an effective means of reducing vibrations in any machine.

### Forced vibration

Vibration that takes place under the excitation of external forces is called forced vibrations. When the excitation is oscillatory, the system is forced to vibrate at the excitation frequency. If the frequency of excitation coincides with one of the natural frequencies of the system, a condition of resonance is encountered.

### Table 1: Length of leaves when thickness is 7mm

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

| Leaf Number | Full Leaf length (mm) | Half leaf Length (mm) | Radius of Curvature (mm) | Half Rotation angle (Degrees) |
|---|---|---|---|---|
| 1 | 1240 | 620 | 2372.6 | 15.010 |
| 2 | 1240 | 620 | 2379.6 | 14.960 |
| 3 | 1108 | 554 | 2386.6 | 13.338 |
| 4 | 978 | 489 | 2393.6 | 11.738 |
| 5 | 846 | 423 | 2400.6 | 10.124 |
| 6 | 716 | 358 | 2407.6 | 8.543 |
| 7 | 584 | 292 | 2414.6 | 6.951 |
| 8 | 454 | 227 | 2421.6 | 5.385 |
| 9 | 322 | 161 | 2428.6 | 3.809 |
| 10 | 190 | 95 | 2436.6 | 2.005 |

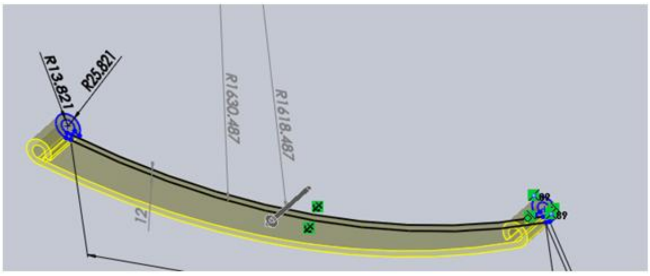
Model Calculation for leaf number 10
Span $2L_1 = 1220$mm
Number of leaver = n = 10
Ineffective length = l = 60mm
Effective length = E.L = $2L_1 - (2/3)l$
So effective length = 1220 – (2/3) 60 = 1180mm

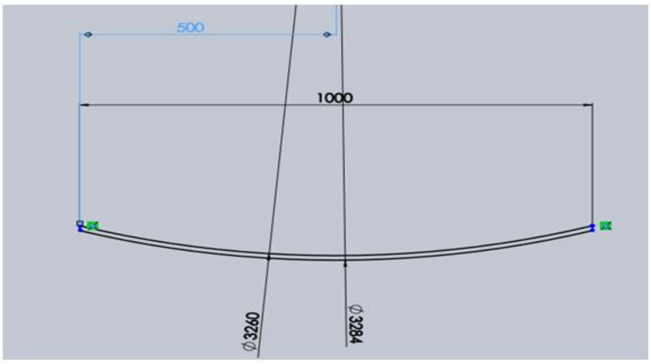
$$\text{So length of leaf number 10} = \frac{\text{Effective length}}{n-1} X (n-1) + \text{Ineffective length}$$

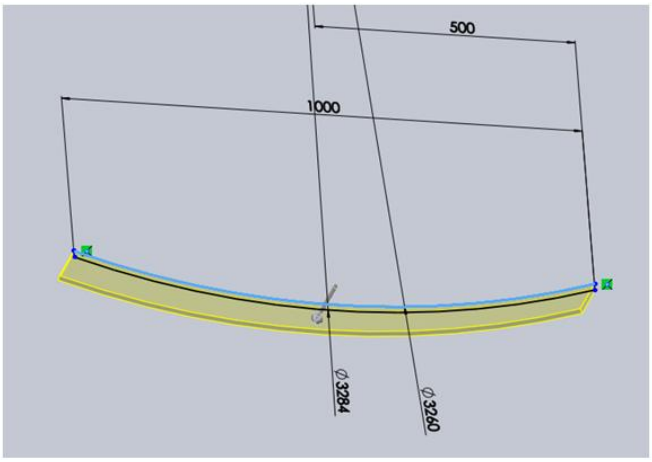
$$\frac{1180}{9} X 9 + 60 = 190$$

Case (b): Thickness of leaves = 8mm

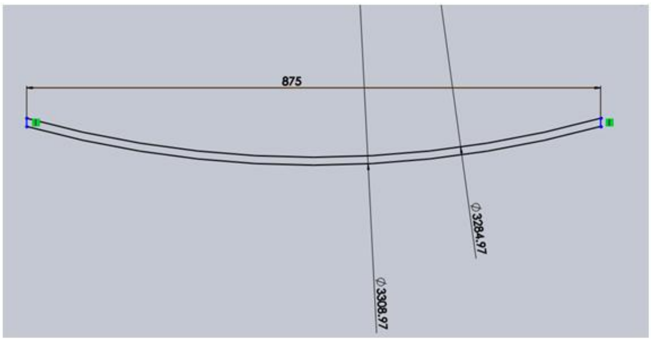
## Leaf spring drawing in solid works step by step

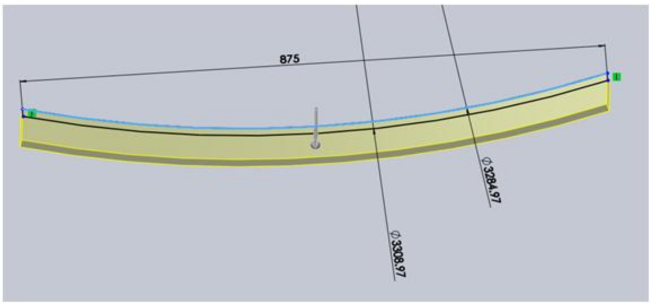


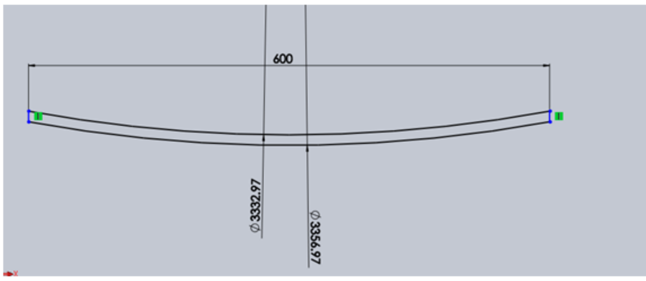




## Step three

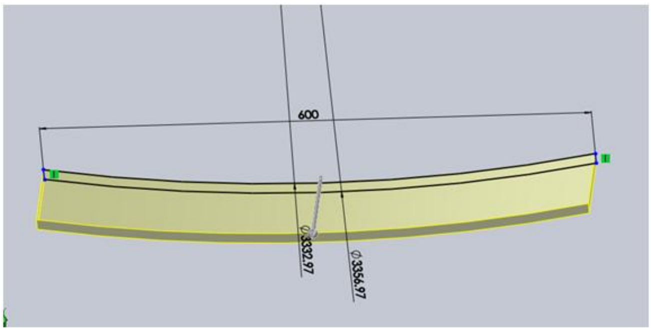


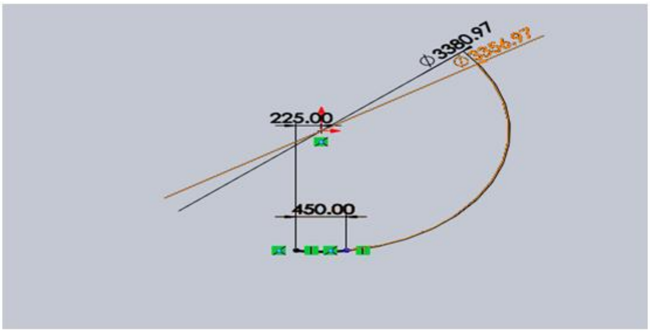

## Step four



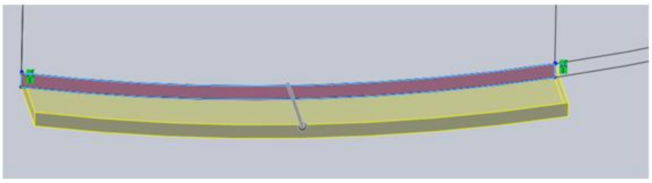
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal




**Step six**




**100 mm extrude**



## V. ANALYSIS OF LEAF SPRING

### Introduction

In computer – aided design, geometric modeling is concerned with the computer compatible mathematical description of the geometry of an object. A cad model of a typical LCV leaf spring is modeled on based on mathematical calculations on Pro/Engineer software After geometric modeling of the leaf spring with given specifications it has to be subjected to analysis. ANSYS software is used to analyze the stresses by performing static analysis for the given leaf spring specification to assess the behavior of the leaf spring with various parametric combinations. Analysis involves discrimination called meshing, boundary conditions, and loading conditions.

### Modeling of leaf spring

### Steel leaf spring assembly

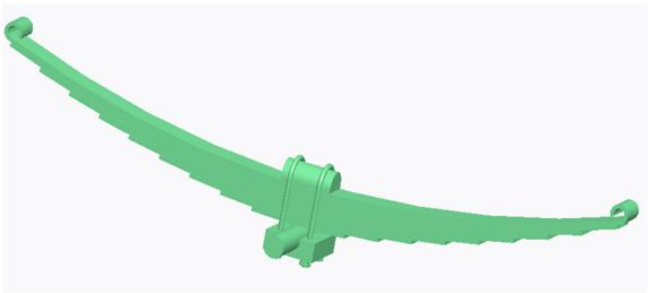
Pro Engineer software was used for this particular model and the steps are as follows:

1. Start a new part model with Metric units set.
2. Draw the sketches of the trajectories of each leaf of spring with the radius obtained from calculations with span1220mm camber 80.
3. Using sweep command draw a section 60 mm X 7 mm thick sweep along the above drawn curves of leaf.
4. According the spring design manual the eye diameter is formed on the first leaf.
5. Thickness of leaves = 7mm.
6. After all the features of all leaves as are modeled, generate family table for each leaf.
7. Generate models for u-clams, axle rod, top support plate etc.
8. Assemble each of the leaf in an assembly model and assemble all other models.
9. Provide a ½ inch dia hole in the leaf spring for bolt.
10. Export the model to iges – solid – assembly – flat level.

The following are the model dimensions.

1. Camber = 80mm
2. Span = 1220mm
3. Thickness of leaves = 7mm
4. Number of leaves = 10
5. Number of full length leaves nF = 2
6. Number of graduated length leaves nG = 8
7. Width = 60
8. Ineffective length = 60mm
9. Eye Diameter = 20mm
10. Bolt Diameter = 10mm

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



**Assembly Model of Steel Leaf Spring**

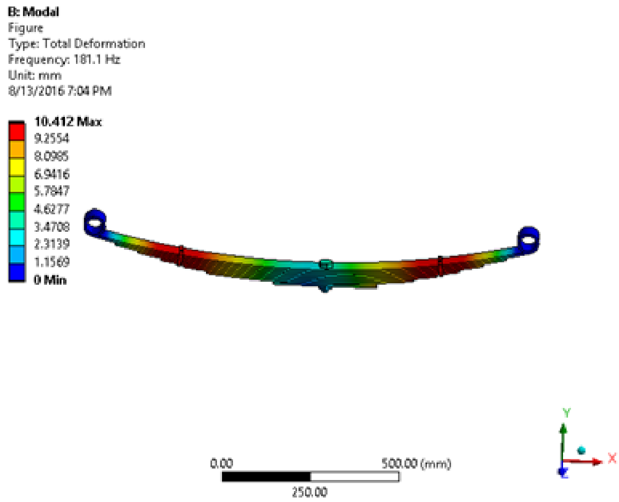
**Composite mono leaf spring**

The steps for modeling are as follows:

1. Start a new part model with Metric units set.
2. Draw the sketch of the trajectory with dimensions of first leaf of spring of steel spring assembly without eyes, span is same as 1220mm and camber 80.
3. The geometrical dimensions are carried forward from the steel leaf spring except for the number of plates and thickness in order to maintain the required cross section area. Generate sketches cross section dimensions at center and ends as mentioned in table follows:
4. Using swept blend
5. Select trajectory
6. Pivot direction
7. Select plane for pivot direction
8. Select origin trajectory
9. Select cross section sketches. The model is ready.
10. Export the model to iges – solid – part – flat level.

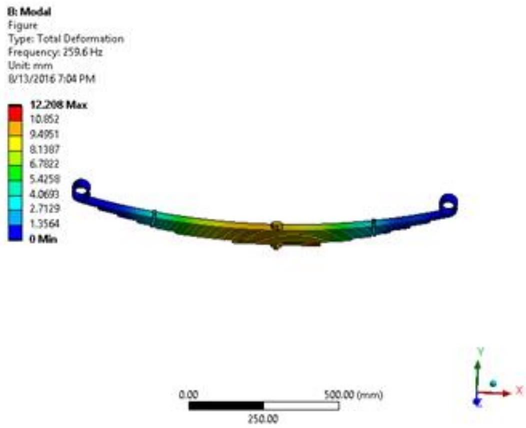
**Table 2: Dimensions of Mono composite leaf spring**

| Parameters | At center | At end |
|---|---|---|
| Breadth in mm | 70 | 70 |
| Thickness in mm | 150 | 21 |

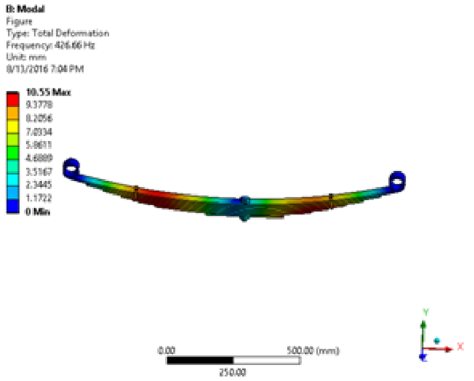


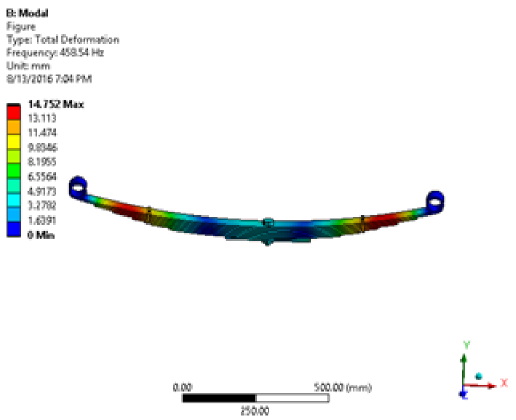

**Model (B4) > Modal (B5) > Solution (B6) > Total Deformation 4**

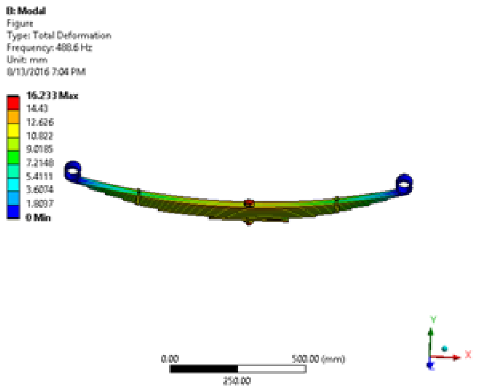
| Mode | Frequency [Hz] |
|---|---|
| 1. | 116.15 |
| 2. | 181.1 |
| 3. | 259.6 |
| 4. | 426.66 |
| 5. | 458.54 |
| 6. | 488.6 |



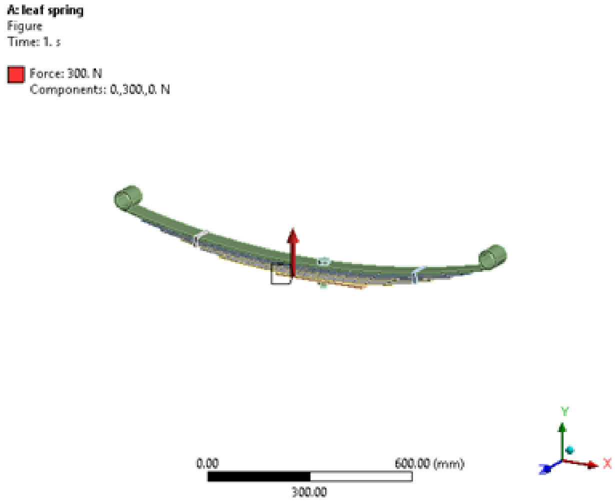
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

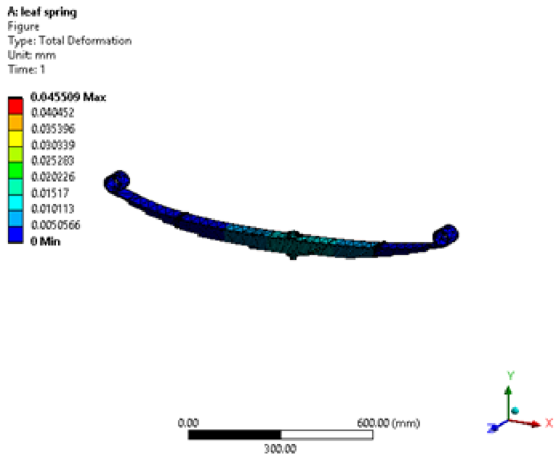


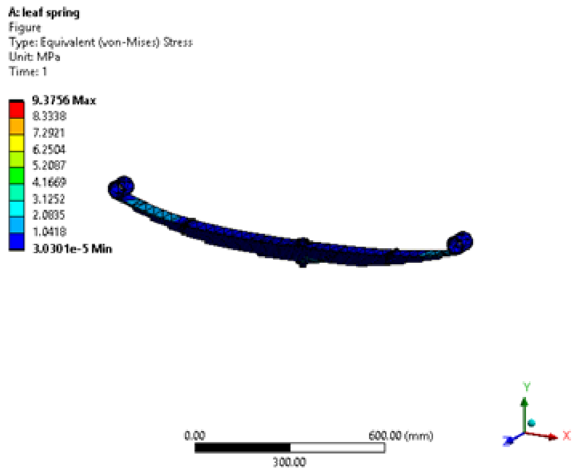




## VI. STATIC ANALYSIS



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

## VII. CONCLUSIONS AND FUTURE SCOPE OF WORK

The automobile chassis is mounted on the axles, not direct but with some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the part which performs the function of isolating the automobile from the road s hocks are collectively called a suspension system. Leaf spring is a device which is used in suspension system to safeguard the vehicle and the occupants. For safe and comfortable riding i.e, to prevent the road shocks from being transmitted to the vehicle components and to safeguard the occupants from road shocks it is necessary to determine the maximum safe load of a leaf spring. Therefore in the present work, leaf spring is modeled and static analysis is carried out by using ANSYS software and it is concluded that for the given specifications of the leaf spring, the maximum safe load. It is observed that the maximum stress is developed at the inner side of the eye sections, so care must be taken in eye design and fabrication and material selection. The selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.

## REFERENCES

[1] Senthil kumar and Vijayarangan, "Analytical and Experimental studies on Fatigue life Prediction of steel leaf soring and composite leaf multi leaf spring for Light passanger veicles using life data analysis" ISSN 1392 1320 material science Vol. 13 No.2 2007.

[2]Shiva Shankar and Vijayarangan "Mono Composite Leaf Spring for Light Weight Vehicle Design, End Joint, Analysis and Testing" ISSN 1392 Material Science Vol. 12, No.3, 2006.

[3]Niklas Philipson and Modelan AB "Leaf spring modelling" ideon Science Park SE 22370 Lund, Sweden

[4] Zhi'an Yang and et al "Cyclic Creep and Cyclic Deformation of High-Strength Spring Steels and the Evaluation of the Sag Effect: Part

I. Cyclic Plastic Deformation Behavior" Material and Material Transaction A Vol 32A, July 2001—1697

[5]Muhammad Ashiqur Rahman and et al "Inelastic deformations of stainless steel leaf

springs-experiment and nonlinear analysis" Meccanica Springer Science Business Media B.V. 2009

[6]C.K. Clarke and G.E. Borowski "Evaluation of Leaf Spring Failure" ASM International, Journal of Failure Analysis and Prevention Vol5 (6) Pg. No.(54-63)

[7] J.J. Fuentes and et al "Premature Fracture in Automobile Leaf Springs" Journal of Sc

ience Direct, Engineering Failure Analysis Vol. 16 (2009) Pg. No. 648-655.