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# MODAL ANALYSIS OF COMPOSITE LEAF SPRING USED FOR MEDIUM UTILITY VEHICLE.

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## ABSTRACT

*Leaf spring is a simple form of suspension spring used to absorb vibrations induced during the motion of a vehicle. The automobile industry has shown increased interest in the replacement of steel leaf spring (65Si7) with composite leaf spring (E-glass/Epoxy) due to high strength to weight ratio, higher stiffness, high impact energy absorption and lesser stresses. The design and comparative simulation analysis was done in ANSYS Software. Similar mechanical properties for E-Glass epoxy composite material were considered for all simulation procedure. The design constraints and meshing were also being similar for all conventional and composite models of leaf spring. Design and simulation results were predicted by considering linear static analysis and presented. This paper covers modal analysis of mono E - Glass/Epoxy composite leaf spring.*

***Keywords*: E - Glass/Epoxy, FEA, Layup, Leaf spring.**

## I. INTRODUCTION

Leaf spring is a simple form of a spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. Just for the common form of its conception in Italian language a leaf spring suspension is called “balestra” (cross bow). An advantage of a leaf spring over a helical spring is that the end of the leaf spring may be guided along a definite path. Sometimes referred to as a semi elliptical spring or cart spring it takes the form of as lender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action .it is not well controlled and results in stiction in the motion of the suspension. For this reason manufactures have experimented with mono leaf spring [1-4].

The automobile industry is exploiting composite material technology for structural components in order to obtain the reduction of weight without decrease in vehicle quality and reliability. Energy conservation is one of the most important objectives in any vehicle design and reduction of weight is one of the most effective measures for energy conservation as it reduces overall fuel consumption of the vehicle [1]. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unsprung weight. The leaf spring should absorb vertical vibrations, shocks and bump loads by means of

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spring deflection so that the potential energy is stored in the leaf spring as strain energy and then released slowly. Thus elastic strain energy storage capacity is an important criterion while selecting the material for leaf spring [2]. The specific elastic strain energy is inversely proportional to the density and young's modulus. The automobile industry has shown increased interest in the replacement of steel leaf spring with fiber glass composite leaf spring because FRP composites possess lower young's modulus, lower density and
lesser weight as compared to steel [3-5].

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. As reducing weight and increasing strength of products are high research demands in the area of automotive, composite materials are getting to be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a mono E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials. Due to catastrophic failure nature of materials already used in automotive leaf spring, it is considerably replaced by high strength, high stiffness composite material [4].

In this analysis the material of mono leaf spring is E- glass epoxy used. There are four layers of material is lay up by following way:

The E glass Epoxy is also type of fiber.

SiO254wt% , Al2O314wt% ,CaO+MgO 22wt% ,B2O310wt% Na2O+K2O less then 2wt%. The properties of E-glass epoxy material used for the analysis which are following:

## II. MATERIAL PROPERTIES OF E-GLASS EPOXY

| Sr. No. | Properties | Value |
|---|---|---|
| 1 | Tensile modulus along X-direction | 73000 MPa |
| 2 | Tensile modulus along Y-direction | 6530 MPa |
| 3 | Tensile modulus along Z-direction | 6530 MPa |
| 4 | Tensile strength of material | 900 MPa |
| 5 | Compressive strength of the material | 450 MPa |
| 6 | Shear modulus along XY-direction | 2433 MPa |
| 7 | Shear modulus along YZ-direction | 1698 MPa |
| 8 | Shear modulus along ZX-direction | 2433 MPa |
| 9 | Poisson ratio along XY-direction | 0.217 MPa |
| 10 | Poisson ratio along YZ-direction | 0.0366 MPa |
| 11 | Poisson ratio along ZX-direction | 0.217 MPa |
| 12 | Mass density of the material | 2.6*103 $Kg/mm^3$ |
| 13 | Flexural modulus of the material | 40000 MPa |
| 14 | Flexural strength of the material | 1200 MPa |

## III. THEORETICAL ANALYSIS

The natural frequency of both the steel leaf spring and composite leaf spring is calculated analytically by Euler's Beam Theory for Continuous System.

The Euler's Equation for natural frequency is given as

$F = (1/2\pi)(Bnl)^2(EI/\rho Al^4)^{1/2}$

Where,

$(Bnl)^2$= constant depending on end conditions

I = Moment of inertia of system

ρ = Density of Material

A = Area of cross section

l = Length of spring

The end conditions for system are same as that of suspension connected to vehicle body. Both ends are fixed.

The values of different parameters for conventional spring are

$(Bnl)^2$ = 22.4., 61.7, 121.

E = $200*10^3$ N/mm$^2$

I = $624*10^6$ mm$^4$

ρ = $7.41*10^{-7}$

A = $156*10^3$ mm$^2$

l = 1170 mm

By Substituting these values in above equation we get natural frequencies for steel leaf spring as

The fundamental natural frequency equals 85.56 Hz

The second natural frequency equals 235.67 Hz

The third natural frequency equals 462.18 Hz

The values of different parameters for conventional spring are

$(Bnl)^2$ = 22.4, 61.7, 212.

E = $73*10^9$ N/mm$^2$

I = $918*10^3$ mm$^4$

P = $3.193*10^{-4}$

A = $156*10^3$ mm$^2$

L = 1170 mm

By Substituting these values in above equation we get natural frequencies for composite leaf spring as

The fundamental natural frequency equals 95.51 Hz

The second natural frequency equals 263.08 Hz

The third natural frequency equals 515.93 Hz

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## IV. NUMERICAL ANALYSIS

The numerical analysis of the system using the ANSYS program, a comprehensive finite element package, which enables students to solve the nonlinear differential equation and to obtain the modulus of elasticity of the beam material. For this, it is required to fit the experimental results of the vertical displacement at the free end to the numerically calculated values for different values of the modulus of elasticity or Young's modulus by minimizing the sum of the mean square root. Using the modulus of elasticity previously obtained, and with the help of the ANSYS program, we can obtain the elastic curves of the cantilever beam for different external loads are obtained and these curves are compared with the experimental ones. ANSYS is a finite element modelling and analysis tool. It can be used to analyze complex problems in mechanical structures, thermal processes, computational fluid dynamics, magnetic, electrical fields, just to mention some of its applications. ANSYS provides a rich graphics capability that can be used to display results of analysis on a high-resolution graphics workstation.

The physical problem typically involves an actual structure or structural component subjected to certain loads. The idealization of the physical problem to a mathematical model requires certain assumptions that together lead to differential equations governing the mathematical model. Since the finite element solution technique is a numerical procedure, it is necessary to access the solution accuracy. If the accuracy criteria are not met, the numerical solution has to be repeated with refined solution parameters until a sufficient accuracy is reached.

### 4.1 Cad Model and FE model of steel leaf spring are as shown in Fig.1

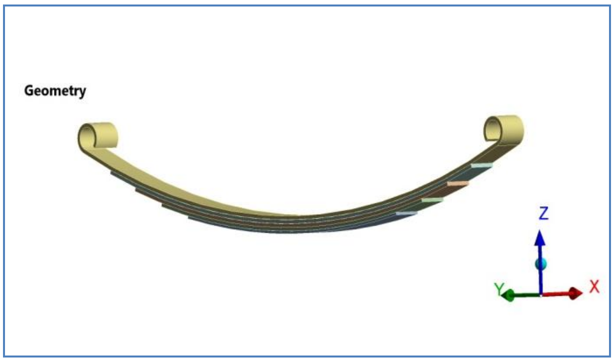
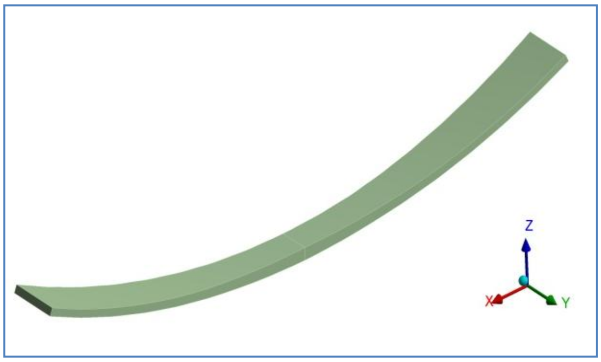




**Fig.1 Cad Model and FE model of steel leaf spring**

### 4.2 Cad Model and FE model of composite leaf spring are as shown in Fig.2



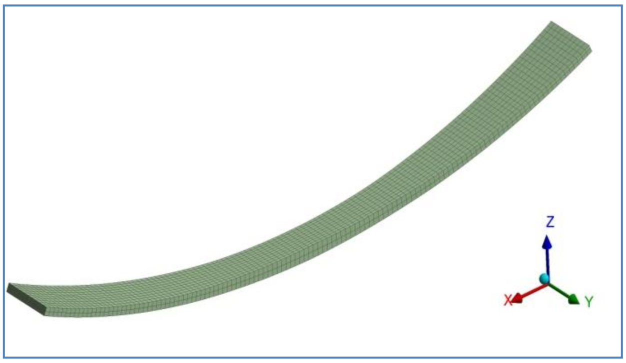



Fig.2 Cad Model and FE Model of Composite Leaf Spring

## 4.3 Numerical Results of Steel Leaf Spring

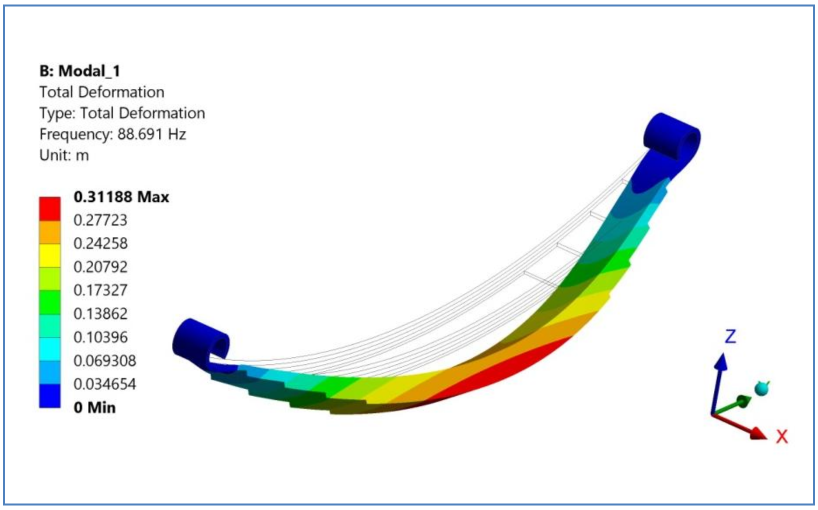



Fig.3. 1st Mode Shapes of Free Vibration of Steel Leaf Spring

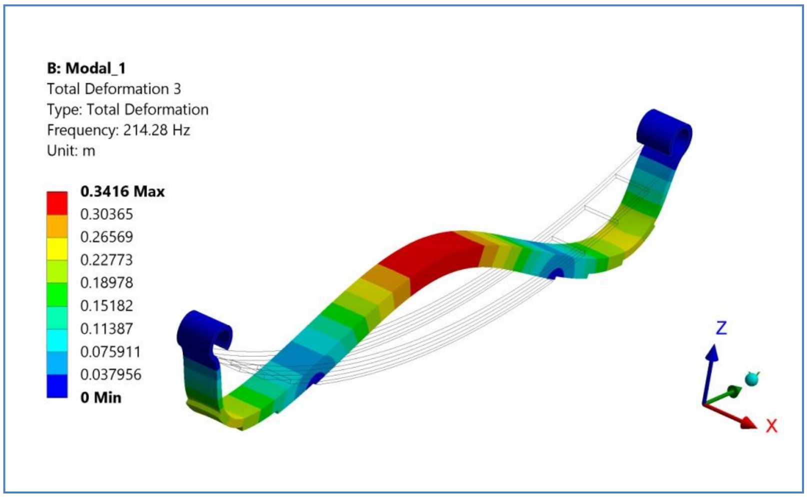



Fig.4. 2nd Mode Shapes of Free Vibration of Steel Leaf Spring

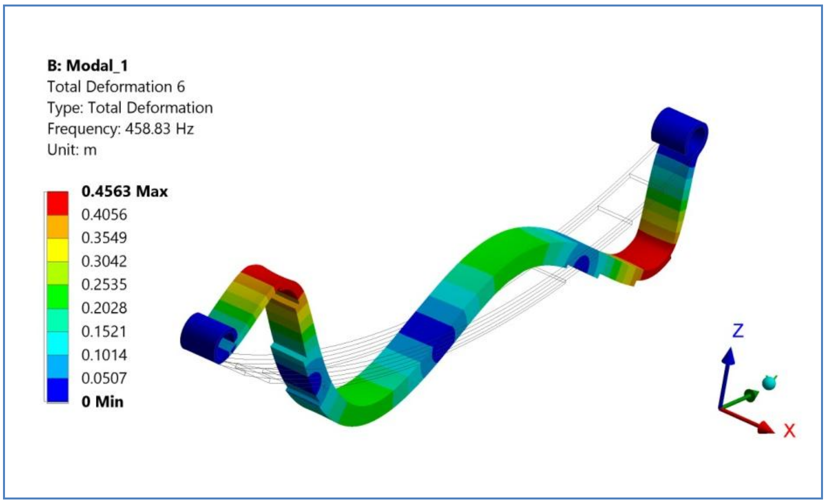



**Fig.5. 3rd Mode Shapes of Free Vibration of Steel Leaf Spring**

### 4.4 Numerical Results of Composite Leaf Spring

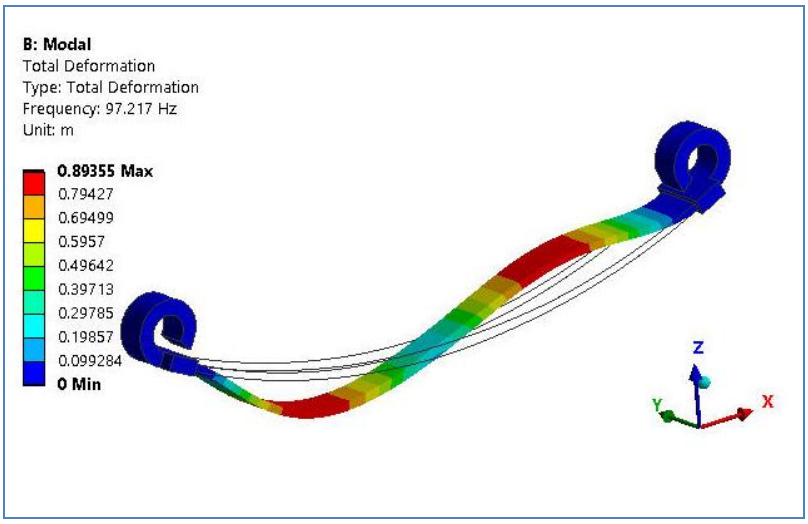



**Fig.6. 1st Mode Shapes of Free Vibration of Composite Leaf Spring**

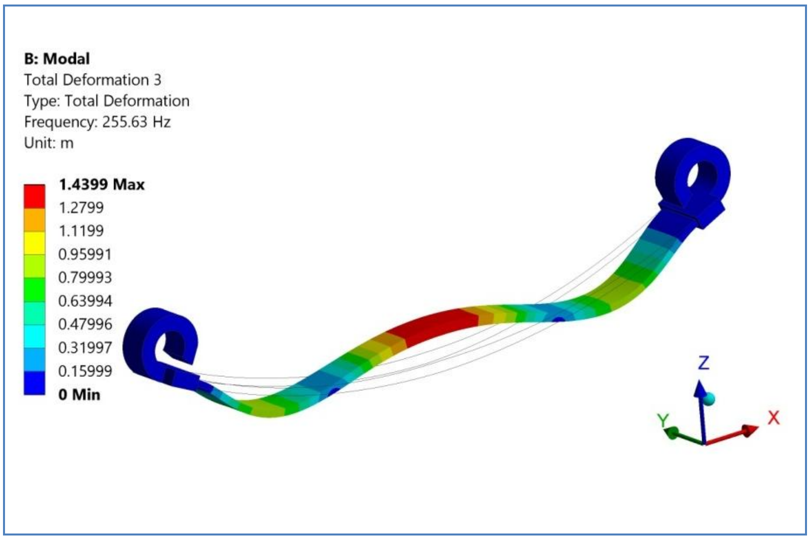


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**Fig.7. 2nd Mode Shapes of Free Vibration of Composite Leaf Spring**

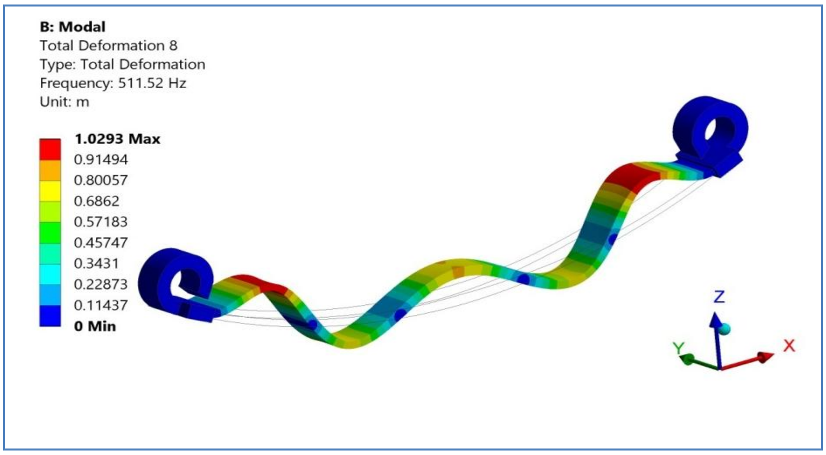


**Fig.8. 3rd mode shapes of free vibration of composite leaf spring**

## V. RESULT AND DISCUSSION

**Table No.1 Theoretical and Simulated Natural Frequencies**

| Sr. No. | Modes of vibration | Steel Leaf spring | | Composite Leaf spring | |
|---|---|---|---|---|---|
| | | Theoretical | Numerical | Theoretical | Numerical |
| 1 | Ist | 85.56 | 88.69 | 95.51 | 97.17 |
| 2 | IInd | 235.67 | 214.28 | 263.08 | 255.63 |
| 3 | IIIrd | 462.18 | 458.83 | 515.93 | 511.52 |

From Above results it is observed that there is good agreement between theoretical and simulated natural frequencies of both steel and composite leaf spring. Natural frequencies those are calculated from theoretical formula are compared with simulated values.

## VI. CONCLUSIONS

Comparative modal analysis of composite Leaf spring used in Medium utility vehicle is carried out. The mode shapes and frequencies are carried out of both steel leaf spring and composite leaf spring. The numerical results from Finite Element Analysis showed in general a good agreement with the theoretical values.

## VII. ACKNOWLEDGEMENTS

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