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# Design and Analysis of Leaf Spring Made of Carbon Glass Fibre Composite

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**Abstract***: Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance.*

*This work deals with finding a suitable composite material that can be a replacement for conventional steel leaf spring. The stress and displacements have been calculated using theoretically as well as using ANSYS for steel leaf spring and composite leaf spring.*

*The model is designed in CREO software for the vehicle Mahindra "Model - commander 650 Analysis is done in ANSYS software for different materials (Steel, Kevlar and E- Glass Epoxy).*

*The static analysis is done to determine the deformation, stress and strain for different materials. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Transient analysis is done to determine the deformation, stress with respect to time for different materials. Fatigue analysis is done to determine the fatigue life for steel, E glass epoxy and Kevlar leaf spring.*

**Keywords:** CATIA, ANSYS

## I. INTRODUCTION

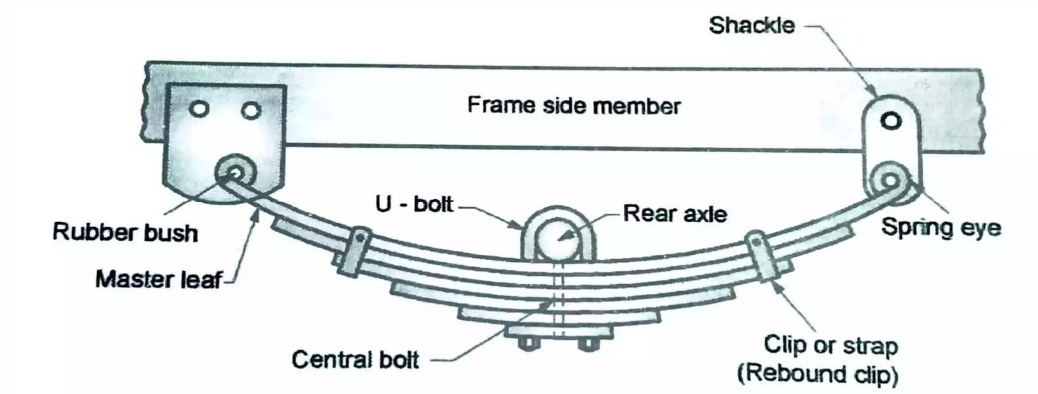
A leaf spring is a component of suspension systems. Specifically, a leaf spring is composed of several (or occasionally just one) thin strips of metal, called leaves, arranged on top of each other to form a single curved piece. The bending of the leaves and the friction between them as they slide slightly over each other while bending, absorbs the vehicle's weight as well as any bumps. Most leaf springs are curved (these are often called elliptical springs); the curvature helps the spring absorb impact.

The three major functions of any vehicle's suspension are to Support the vehicle, absorb impacts from bumps, potholes, and other road irregularities. Allow the vehicle to turn in response to the driver's inputs. (The steering system can be considered part of the suspension, or its own system, but either way the suspension has to allow for movement of the wheels as the vehicle turns).

In now a day the fuel efficiency and emission gas regulation of automobiles are two important issues. To fulfill this problem the automobile industries are trying to make new vehicle which can provide high efficiency with low cost. The best way to increase the fuel efficiency is to reduce the weight of the automobile. The weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel.

## II. WORKING OF LEAF SPRING

Leaf springs are widely used for automobile and rail road suspensions. It consists of a series of flat plates, usually of semi- elliptical shape. The leaves are held together by means of two U-bolts and a center clip. Rebound clips are provided to keep the leaves in alignment and prevent lateral shifting of the plates during the operation. The longest leaf, called the master leaf, is bent at both ends to form the spring eye. At the center, the spring is fixed to the axle of the car A leaf spring works on the principle of bending. When a load is applied at the ends bending occurs. Naturally, the structure opposes bending. This result in a reaction force which opposes the load applies




| Parameter | Specification |
|---|---|
| Material | Steel(55Si2Mn90) |
| Tensile Strength | 1962N/Sq.mm |
| Yield Strength | 1470N/Sq.mm |
| Young's Modulus | 2.1e5N/Sq.mm |
| Spring Weight | 16.4Kg |
| Thickness at the Center | 12mm |
| Thickness at extreme ends | 9mm |

**Table:**1 Design Specifications

## III. LITERATURE REVIEW

Some journal papers were selectively studied which have direct relevance with my work. A brief discussion is presented below.

Pankaj Saini, Ashish Goel, Dushyant Kumar [1], are discussed about the design and analysis of composite leaf spring. The objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy are used against conventional steel.

Naveen S, Natarajan R [2], are discussed about replacing the conventional materials by composites which has higher specific stiffness, good corrosion resistance and high strength. Finding a suitable composite material that can be a replacement for conventional steel leaf spring. The composites chosen are E-Glass/ Epoxy and Carbon/ Epoxy and are analyzed for minimizing weight of the composite leaf spring compared to that of conventional steel leaf spring.

Baviskar A. C, Bhambri V. G, Sarode S. S [3], are discussed about general study on the design, analysis of leaf spring. Now the automobile industry has shown interest in the replacement of steel spring with composite leaf spring. In general, it is found that fiberglass material has better strength characteristic and lighter in weight as compare to steel for

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leaf spring. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing.

Dev Dutt Dwivedi, V. K. Jain [4], are discussed about design and analysis of composite leaf spring. ANSYS 14.5 has been used to conduct the analysis. Static structural tool has been used of ANSYS. E-Glass/epoxy composite material has been used. Conventional steel leaf spring results have been compared with the present results obtained for composite leaf spring. E-glass/epoxy material is better in strength and lighter in weight as contrast with conventional steel leaf spring.

Y. N. V. Santhosh Kumar, M. Vimal Teja [5], are discussed about composite structures for conventional metallic structures. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modeled in Pro/E and the analysis was done using ANSYS Metaphysics software.

## IV. METHODOLOGY

The functions of springs are absorbing energy and release this energy according to the desired functions to be performed. So, leaf springs design depends on load carrying capacity and deflection.

Weight and initial measurements of Mahindra “Model - commander 650 di” light vehicle is taken.

Gross vehicle weight = 2150 kg
Un sprung weight = 240 kg
Total sprung weight = 1910kg
Taking factor of safety (FS) = 1.4
Acceleration due to gravity (g) = 10 m/s²
There for; Total Weight (W) = 1910*10*1.4 = 26740 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight.

2W = 26740/4 = 6685 N
W = 3342.5 N
Length of leaf = effective length + in effective length / (No.of leafs−1) ……… (eq. 3.1)
Effective length =1120 mm,
ineffective length =90 mm,
no of full length leafs =2,
gradual length leafs =8,
Total leafs =10.
Length of fourth leaf = 1120 ×5 +90 /(10−1) = 712 mm
Length of fifth leaf = 1120 ×6 +90 /(10−1) = 837 mm
Length of sixth leaf = 1120 ×7 +90 /(10−1) = 961 mm
Length of seventh leaf = 1120 ×8 +90 /(10−1) = 1085 mm
Length of eighth leaf = 1120 ×9 +90 /(10−1) = 1120 mm
Calculations of the stress generated in the leaf spring are as under:
Material of the leaf spring is 55 Si 2 Mn 90
Property of the material are as under:
Ultimate tensile strength = 1962 N/mm2
Tensile yield strength = 1470 N/mm2
Modulus of elasticity (E) = 200000 N/mm2

By considering the factor of safety for the safety purpose of the leaf spring is 1.4 for automobile leaf spring. So, the allowable stress for the leaf spring is as under:

Effective length =1120 mm,
ineffective length =90 mm,
no of full length leafs =2,
gradual length leafs =8, Total leafs =10


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Safe working stress = yield stress/ $factor\ of\ safety$ = 1470/1.4 =1050 MPa eq. 3.2

Design stress (σb) = 6wl / $nbt2$ …………………..(eq.3.3)
= 6×3342×530/ 10×50×62
=590.42 MPa

Deflection(y) = 6wl3/ $nEbt3$ ……………………..(eq.3.4)
= 6×3342×$(530)^3$ / 10×2×105×50×63
=138.20 mm

Weight calculations of leaf spring:
For Steel:
Weight of smallest leaf 1
=density× volume× acceleration due to gravity
=214×6×50×0.00000784×10
=5.046 N

Weight of leaf 2
=338×6×50×0.0000078×10
=7.97 N

Weight of leaf 3
=463×6×50×0.0000078×10
=10.91 N

Weight of leaf 4
Weight of leaf 5
Weight of leaf 6
Weight of leaf 7
Weight of leaf 8
Weight of leaf 9&10
=13.86 N
=588×6×50×0.0000078×10
=16.78 N
=837×6×50×0.0000078×10
=19.73 N
=961×6×50×0.0000078×10
=22.66 N
=1085×6×50×0.0000078×10
=25.66 N
=1120×6×50×0.0000078×10
=26.40 N
Total weight of steel leaf spring =175.336 N
=17.5 Kg
Total weight of E glass epoxy = 4.57 Kg Total weight of Kevlar leaf spring=3.65Kg
shows the Design Parameters of Leaf Spring

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| Leaf no. | Full leaf length (2L) | Half leaf length (L) | Radius of curvature R(mm) |
|---|---|---|---|
| 1 | 1120 | 560 | 961.11 |
| 2 | 1120 | 560 | 967.11 |
| 3 | 1085 | 542.5 | 973.11 |
| 4 | 961 | 480.5 | 979.11 |
| 5 | 837 | 418.5 | 985.11 |
| 6 | 712 | 356 | 991.11 |
| 7 | 588 | 294 | 997.11 |
| 8 | 463 | 231.5 | 1003.11 |
| 9 | 338 | 169 | 1009.11 |
| 10 | 214 | 107 | 1015.11 |

shows the Specifications of Leaf Spring

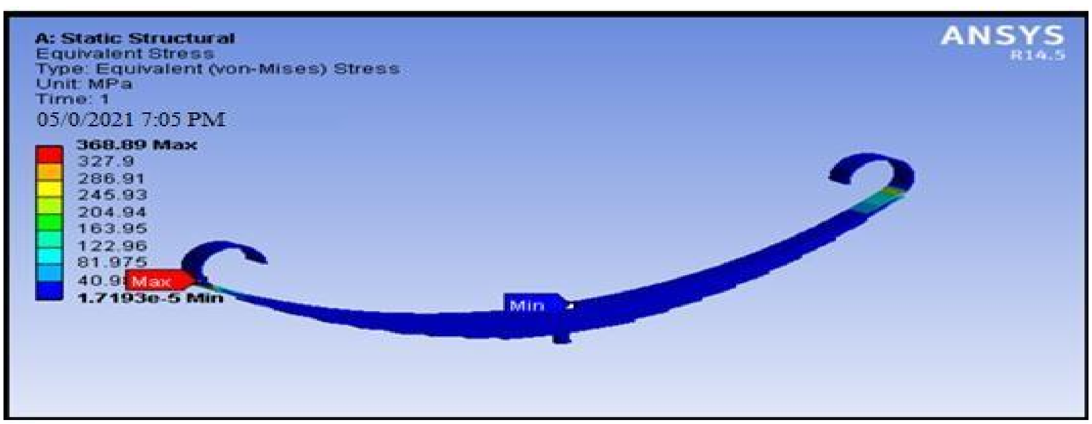
## V. STATIC ANALYSIS OF LEAF SPRING

MATERIAL PROPERTIES OF STEEL 55Si2 Mn90

| Parameter | Values |
|---|---|
| Material selected | 55Si2 Mn90 |
| Young's modulus | $2*10^5$MPa |
| Passion's ratio | 0.3 |
| BHN | 534-601 |
| Tensile strength ultimate | 1962MPa |
| Tensile strength yield | 1470MPa |
| Density | 7850Kg/m$^3$ |

**Table:** Material properties of steel

Static structural analysis for bending stress and deflection for steel leaf spring are shown in Figure 4.2 and 4.3 respectively. Figure 4.2 shows that maximum deformation contours at the centre portion of leaf spring and minimum is at the eye ends. Figure 4.3 shows that maximum stress contours at the eye ends of the leaf spring and minimum at centre portion of leaf spring




Von mises stress contours for steel leaf spring

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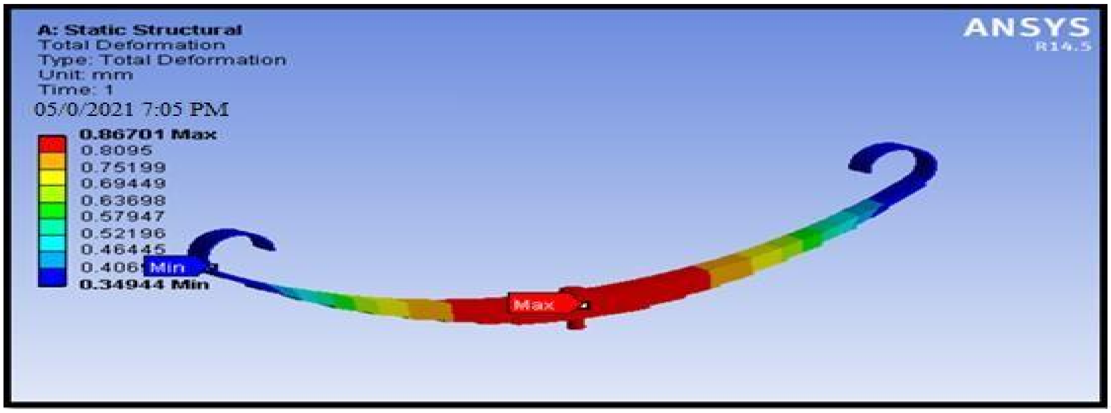


Total deformation contours for steel leaf spring

RESULT ANALYSIS OF STEEL LEAF SPRING

| Parameters | Analytical Results | Static analysis results | Percentage variation |
|---|---|---|---|
| Von-mises stress(M Pa)<br>((MPa) | 590.42<br>712.91 | 630.02<br>739.08 | 6.28%<br>3.54% |
| Deflection(mm) | 138.2<br>176.26 | 143.75<br>175.22 | 3.86%<br>0.6% |

**Table:** 4.2Comparisonoftheoreticalandanalysis results for steel leaf spring.

STATIC ANALYSIS OF COMPOSITE LEAF SPRING

| S.NO. | Properties | E-glass/epoxy | Kevlar |
|---|---|---|---|
| 1 | EX(MPa) | 43000 | 45960 |
| 2 | EY(MPa) | 6500 | 9300 |
| 3 | EZ(MPa) | 6500 | 9300 |
| 4 | PRXY | 0.27 | 0.37 |
| 5 | PRYZ | 0.06 | 0.33 |
| 6 | PRZX | 0.06 | 0.33 |
| 7 | GXY(MPa) | 4500 | 3800 |
| 8 | GYZ(MPa) | 2500 | 3500 |
| 9 | GZX(MPa) | 2500 | 3500 |
| 10 | ρ(kg/mm³) | 0.000002 | 0.0000014 |

**Table:** shows the orthotropic properties of Eglassepoxy, Kevlar materials.

Below Figures (5.1 to 5.4) shows the maximum deflection and stress values evaluated at the given load for the materials Kevlar and E glass epoxy. Figure 5.1, 5.3 shows that maximum deformation contours at the centre portion of leaf spring and minimum is at the eye ends. Figure 5.2, 5.4 shows that maximum stress contours at the eye ends of the leaf spring and minimum at centre portion of leaf spring

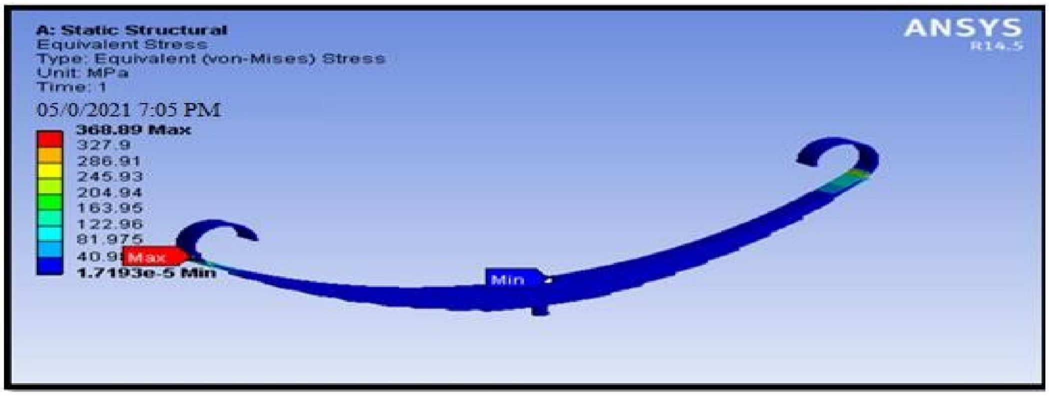


**Figure:** Vonmises stress contour of Kevlar leaf spring

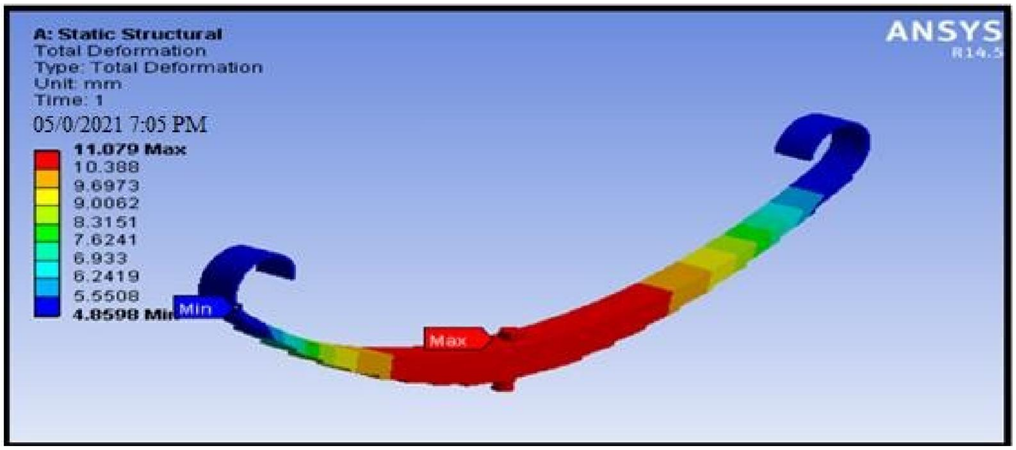


**Figure:** Maximum deflection contours of Kevlar leaf spring

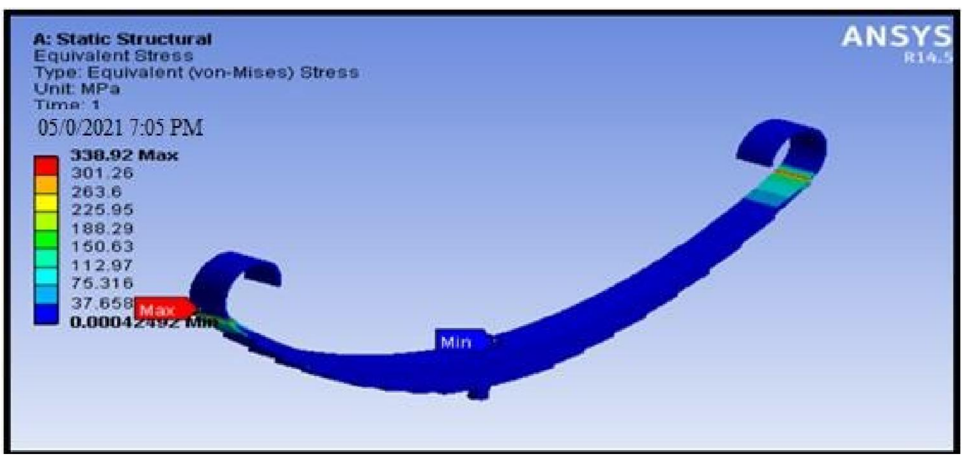


**Figure:** Maximum deflection contours of Eglass/epoxy leaf spring

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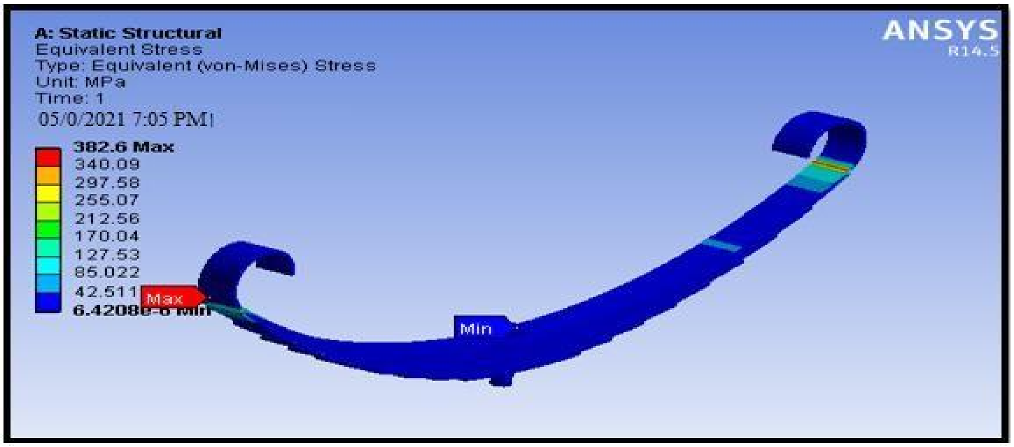


**Figure:**4.7Vonmises stress contour of Eglass/epoxy leaf spring

COMPARISION OF STEEL AND COMPOSITE LEAF SPRING ANLAYSIS DATA

| Materials | Displacements(mm) | Stress(MPa) | Weight(Kg) |
|---|---|---|---|
| Steel | 143.75 | 630.02 | 17.53 |
| E-glass/epoxy | 102.5 | 527.46 | 4.57 |
| Kevlar | 100.08 | 490.27 | 3.65 |

**Table:** Comparison of analysis results for steel and composite leaf spring.

Here, from comparison of steel leaf spring with composite leaf spring as shown in Table 4.4, it can be seen that the maximum deflection 143.75 mm on steel leaf spring and corresponding deflection in E-glass/epoxy and Kevlar are 102.5 mm, 100.08 mm. Also the von-misses stress in the steel leaf spring 630.02 MPa while in E- glass/epoxy and Kevlar the von-misses stresses are 527.46 MPa, 490.27 MPa respectively.

**FATIGUE ANALYSIS OF LEAF SPRING**

Machinery often fails under the action of repeating or fluctuating stresses, even when the calculated stress is well below the ultimate strength of the material, and in many causes even below the yield strength. The distinguishing characteristics of such failures is that the stresses have been repeated a very large number of times. This is fatigue failure

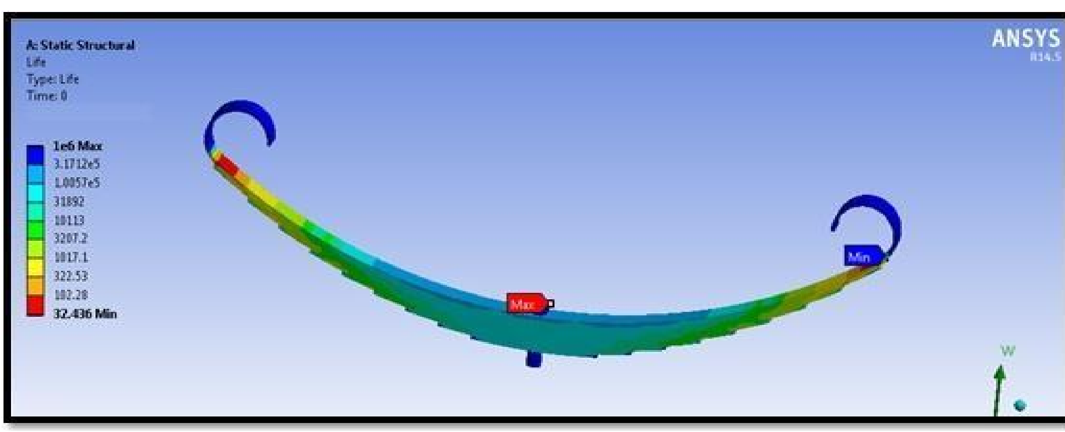


**Figure:** shows the life cycles for Kevlar leaf spring

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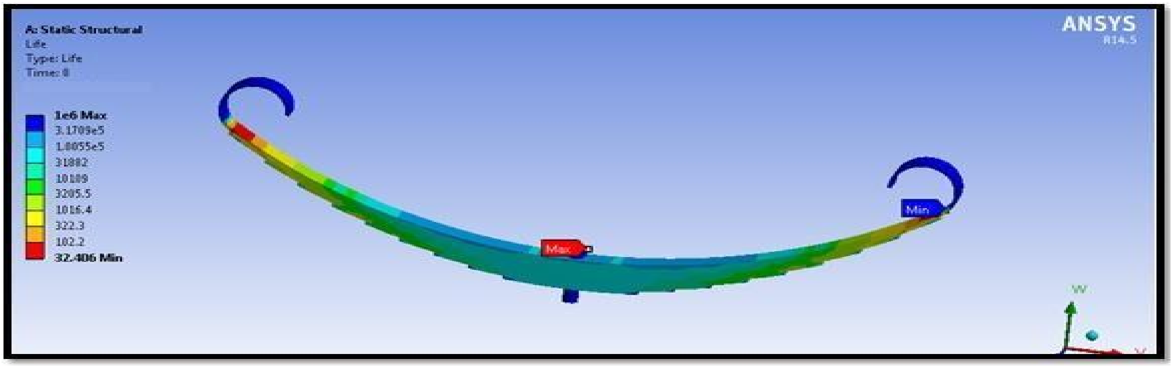


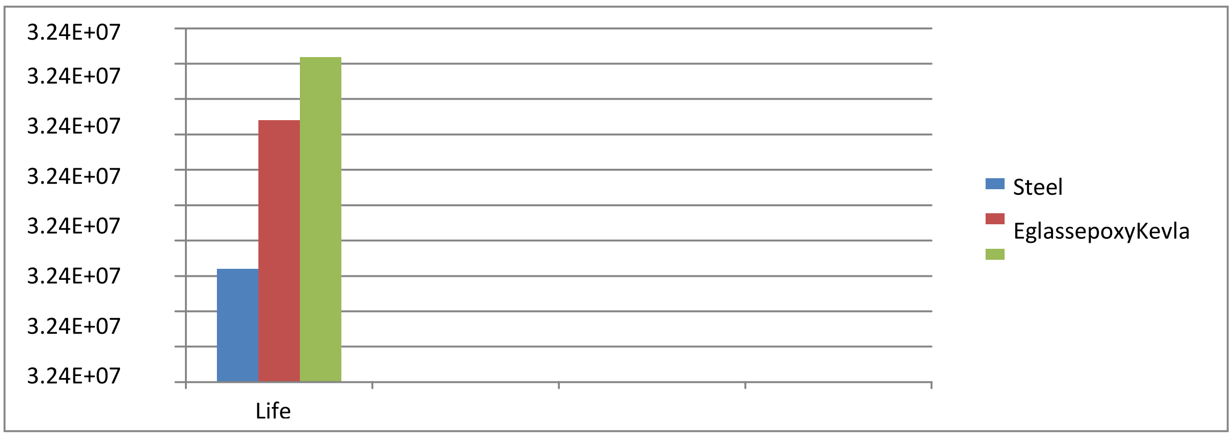

**Figure:**5.3showsthe life cycles for Eglass epoxy leaf spring

FATIGUE ANALYSIS RESULT TABLE:

| . | Steel | Eglass epoxy | Kevlar |
|---|---|---|---|
| Life | $32.406e^6$ | $32.427e^6$ | $32.436e^6$ |

Table: the analysis results of fatigue life for steel is more, compared to E glasse poxy and Kevlar leaf spring.

**RESULT GRAPHS**




**GRAPH:THREE VARIABLE MATERIAL LIFE**

## VI. CONCLUSION

The design and static structural analysis of steel leaf spring and composite leaf spring has been carried out. Comparison has been made between composite leaf spring with steel leaf spring having same design and same load carrying capacity. The stress and displacements have been calculated using theoretically as well as using ANSYS for steel leaf spring and composite leaf spring.

From the static analysis results it is found that there is a maximum displacement of 143.75 mm in the steel leaf spring and the corresponding displacements in E- glass/epoxy and Kevlar are 102.5 mm and 100.08 mm. From the static analysis results, it also seen that the von-mises stress in the steel leaf spring is 630.02 MPa corresponding in E-glass/epoxy and Kevlar are 527.46 MPa and 490.27 MPa respectively. The two composite leaf springs have lower displacements and stresses than that of existing steel leaf spring. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 74.54% for E-glass/epoxy and 79.77% for Kevlar over the steel leaf spring.

From the fatigue analysis results, it is seen that the fatigue life estimated is more for Kevlar leaf spring compared to E glass epoxy and steel leaf spring.

It can be concluded that Kevlar composite material can be a replacement for the conventional steel leaf spring

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