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# Validation of E-Glass Epoxy Composite Leaf Spring as an alternate to Conventional Leaf Springs

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***Abstract: The Suspension system is one of the vital parts in any automobile. The main objective of the suspension system is to absorb the shock and spring caused due to bump and road shocks like potholes on road and break etc. Leaf spring is a kind of suspension system used majorly in trucks and other heavy duty vehicles. The leaf springs are commonly made from conventional steel and in the current work, the conventional steel used for producing the leaf spring is replaced with the composite material (E-glass Epoxy composite). The objective this change is to reduce the suspension weight, cost whilst serving the same purpose as the conventional steel even in better way.***
***Keywords: GFRP, LEAF SPRING, E-GLASS, EPOXY***

## I. INTRODUCTION

The Cost & weight reduction with better alternate option is what most of the companies think of, and automobile industry is not an exceptional to it. Every automobile engineer/ manufacturer works on reducing the cost & weight of material and improving their product with better alternatives. Composite materials one such example that are cheap, more durable, possess better strength compared to metals. In our present work we have considered replacing the conventional steel material used for leaf spring production with E-glass Epoxy composite material. Based on previous studies or researches on leaf spring material selection, the material with maximum strength and minimum modulus of elasticity is best suitable [1]. E-glass Epoxy composite material posses minimum modulus of elasticity and maximum strength compared to steel. Leaf spring is nothing but a suspension system that every automobile has. They absorb the shock experienced by tires. The present work includes the design of leaf spring using CATIA V5 and analyzing for bending stresses on it during run with the help of ANSYS workbench.

### *A. Leaf Spring*

Leaf spring is suspension system that is being used in heavy commercial vehicles and light passenger vehicles [2]. Laminated spring or carriage spring is what the leaf springs were called originally [3]. The leaf spring forms slender arc shape and hence it is also often referred as cart spring or semi-elliptical spring. The axle is located at the arc centre and tie holes provided at both the ends used to connect spring to vehicle chassis. Leaf springs are usually made of several leaves stacked one over the other in layer form with progressively decreasing their length. The simple leaf spring is as shown in figure below.

The friction is generated between the interleaf produces the damping action within, which is not controlled and further results in seize up of the suspension motion thus failing suspension [3]. To overcome this failure, many manufacturers started their research on single leaf or mono leaf spring suspension system.

Fig.1 Leaf Spring

*B. Objective Of Leaf Spring*

1) Absorb sudden road shocks and prevent shock energy being transmitted to other vehicle parts.
2) To ensure occupants safety from road shocks due to road irregularity or bumps.
3) To retain vehicle stability in pitting while the vehicle is on run

1.5 Basic consideration for vertical loading

Billion number of people travel by road everyday throughout globe. And while we drive our car there's no one such person that hit car in pit. So, when a rear wheel of a vehicle comes across pit, the vehicle experiences some forces within such as vertical, compressive, tensile. The nature of these forces depends on the type of irregularity present on road [9]. These forces/shocks are absorbed by the elastic compression, shear, bending or twisting of the spring. The resistance of spring relies on the sort and material of the spring being utilized. Further when the front wheel strikes a bump/pothole it begins vibrating. These vibrations fade away exponentially due to damping present in the framework. The back wheel in any case, arrives at a similar pit or pot hole after certain time contingent upon the wheel base and the speed of the vehicle. Obviously, when the rear wheel arrives at the bump/pothole, it encounters comparable vibrations as experienced by the front wheel sometime prior.

It is seen that to diminish pitching propensity of the vehicle, the recurrence of the front springing framework be not as much as that of the back springing framework. From human solace point likewise it is seen that it is attractive to have low vibration frequencies. The aftereffects of the investigations of individuals have indicated that the most extreme adequacy which might be took into consideration a specific degree of distress diminishes with the expansion of vibration recurrence [9].

## II. LITERATURE SURVEY

SushilB.Chopade et.al. [1] Conducted experiment on E glass/Epoxy composite mono leaf spring for light vehicles. The project prominence was to reduce the suspension's overall weight while keeping same/ improving the load carrying capacity of leaf spring. They replaced traditional leaf spring material with Eglass/Epoxy composite material.

In their research, they observed 30 to 40% of weight reduction in Eglass/Epoxy composite leaf spring when compared to EN 47 steel. In addition stresses produced the calculation is found to be less compared to EN47 steel.

Ajay B.K.et.al [2] carried out project on multi layered leaf spring arrangement used in heavy commercial vehicles. They used 8 leaf springs overlapped one over the other. They considered glass fiber reinforced plastic composite to replace conventional steel material. They prepared 4 different models to study deflection and stress produced in the material.

1) *Model 1:* All layers are made of conventional steel material
2) *Model 2:* First and last layers are steel and in between epoxy resin composite leaf spring layers are placed
3) *Model 3:* First, 4th and last layers are of steel and remaining layers are of epoxy resin composite.
4) *Model 4:* All the 8 layers of leaf spring are of epoxy resin composite.

Out of the 4 different models, they observed that the model 4, which is made up of complete epoxy resin possess less deflection when subjected to load and stress produced are very less compared to other 3 models. The weight noted was also comparably low with other models of leaf spring.

Syambabu Nutalapati et.al [3] carried out study to replace the rear leaf spring of "Mahindra Commander 650DI" from steel to glass fiber reinforced polymer (Eglass/Epoxy). The leaf spring was designed using Pro-e and the same was analyzed for stress and deflection with the help of ANSYS 12.0 software.

In their study, they found out that the weight of composite mono leaf spring was reduced up to 84% of total weight of leaf spring. Von-mises stress found in steel was 352.917 MPa, where as it was 178.356 MPa for composite material.

M. Venkata Balaram et.al [5] carried out study on weight reduction of leaf spring by replacing the material for leaf spring from conventional steel to composites without lowering the load carrying capacity of the leaf spring.

Leaf springs are used to absorb the sudden road shocks, store this energy and release it gradually. The material used for leaf spring production should posses high stiffness, high strength to weight ratio and high stain energy storage capacity. In addition to it composite material also possesses low modulus and density resulting light weight of component. Light weight of the component and low cost of material is an added benefit for the producers.

V.K.Srivastava et.al [6]. Reinforced polymers/ composites are gaining more popularity in automobile industry. They are being used in vehicle radiators as these materials posses good thermal and corrosion resistant. On the other hand Eglass fiber is extensively strong material. It possess low thermal coefficient of expansion, high stiffness, rigidity, toughness and high strength to weight ratio.

K. Devendra et.al [7] carried out investigation on Eglass fiber reinforced epoxy composite material mechanical properties when they added with filler material. They investigated results for fly ash, aluminum oxide ($Al_2O_3$), magnesium hydroxide ($MgOH_2$) and

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hematite powder. The composite concentration was variable. They concluded work by stating that, the epoxy filled with 10% of MgOH2 possess maximum ultimate tensile stress where as the composite mixed with fly ash possess better impact strength
E.Janarthan et. al [8] conducted experiment on Eglass\epoxy composite to determine the deflection, stress and mode frequency induced in component. They prepared 3 models for the examination.

a) *Model 1* – 40% epoxy and 60% Eglass fiber
b) *Model 2* – 60% epoxy and 40% Eglass fiber
c) *Model 3* - 70% epoxy and 30% Eglass fiber

Through their series of experiments they found out that, the composite with 60% of Eglass and 40% of epoxy composition yielded in better results in terms of tensile stress, bending stress, deformation and natural frequency.

## III.MATERIALS FOR LEAF SPRING

Generally plain carbon steel material with 0.9 to 1% of carbon is being used for the production of leaf springs. Once the leaves are formed in forming machine, they are treated for heat resistance to ensure spring strength. It is noticed that after heat treatment, the strength of the spring is actually increased. Further the load carrying capacity is also improved in the suspension system [3].
The common materials used are listed below [9]

### *A. Carbon/ Graphite Fibers*

Carbon/graphite fibers are made from carbon atoms. These varies from 5 -10 millimeter in diameter. High strength, low coefficient of thermal expansion, light weight, high chemical resistance is some of the favorable factors of carbon/graphite fiber material being used for production of leaf spring. Whereas high material cost and high electrical conductivity are some factors which do not favor [3][9].

### *B. Glass Fiber*

The major advantage of glass fiber is that, it's very economical when compared with other materials it posses high chemical resistance, insulating property and it is also high in strength. But low elastic modulus, poor adhesion property to polymers, high density of material are some issues where it lags as these eventually increases weight of the material [3][9]..

### *C. Composite Materials*

Composite are nothing but combination of two or more material but they do not blend or mix together. Though the material used to form one composite material different properties and characteristics, when they are formed to composite they produce single unique property of a composite. One can easily part the different materials used to form a single composite [3][9].

### *D. Natural Composites*

Normal composites exist both plants and animals. The bone in your body is additionally a composite. It is produced using a hard yet fragile material called hydroxyapatite (which is for the most part calcium phosphate) and a delicate and adaptable material called collagen (which is a protein). Collagen is likewise found in hair and finger nails. All alone it would not be a lot of utilization in the skeleton yet it can join with hydroxyapatite to give bone the properties that are expected to help the body Wood is a composite – it is produced using long cellulose filaments (a polymer) held together by an a lot flimsier substance called lignin. Cellulose is likewise found in cotton, however without the lignin to tie it together it is a lot more fragile. The two feeble substances – lignin and cellulose – together structure and a lot more grounded one [3][9]..

## IV.DESIGN SPECIFICATIONS OBTAINED FOR MAHENDRA-OMMANDAR 650

1) Total leaf springs=10
2) Total length of the spring= 2L1 = 1150mm
3) Width of spring leaf = 50mm
4) factor of safety= 1.33
5) no. full length leaves (Nf ) =2
6) no. of graduated leaves (Ng )=8
7) no.of springs (Ng+Nf) =10
8) Center load = 2W=1910KG

9) 2W =1910KG*10*1.33=25403/4=6350.7N
10) No.of.springs=4
11) W=3200N
12) Material used for leaf spring is Structural steel
a) Bending stress= (6*wl)/n*b*t2
b) Bending stress =(6*1600*560)/(10*50*62)
c) $\delta^F$ = 67.5mm
13) Effective length =1120mm
14) Ineffective length =90mm
15) Number of full length leafs = 2
16) Gradual length leafs = 8
17) Total leafs =10
18) Length of smallest leaf (leaf 1) =214mm
19) Length of 2nd leaf=338mm
20) Length of 3rd leaf =463mm
21) Length of 4th leaf =588mm
22) Length of 5th leaf = 712mm
23) Length of 6th leaf =837mm
24) Length of 7th leaf =961mm
25) Length of 8th leaf =1085mm
26) 9th leaf and 10th leaf=1120mm

*A. Weight Calculation*

*A. For steel,*

a) Weight of smallest leaf (leaf 1) = density * volume * acceleration due to gravity=5.046N
b) Weight of 2nd leaf =7.97N
c) Weight of 3rd leaf =10.91N
d) Weight of 4th leaf =13.86N
e) Weight of 5th leaf = 16.73N
f) Weight of 6th leaf = 19.73N
g) Weight of 7th leaf = 22.66N
h) Weight of 8th leaf =25.58N
i) Weight of 9th leaf =26.40N
j) Weight of 10th leaf =26.40N
k) Total weight of leaf spring = 175.53

*B. For Eglass/epoxy Composite Leaf*

a) Weight of mono leaf spring = 1120*24*50*.000002*10=26.88N
b) Weight saved = total weight of steel leaf spring – total weight of composite mono leaf spring
c) =175.336-26.88=148.456N
d) Percentage weight saved = =84.66%

Table 1. Properties of steel

| Mechanical | Symbol | Unit | Value |
|---|---|---|---|
| Young's modulus | E | GPa | 207 |
| Shear modulus | G | GPa | 80 |
| Poission's ratio | µ | - | 0.3 |
| Density | P | KJ/m3 | 7600 |
| Yield strength | Sy | MPa | 370 |

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Table 2. Properties of Eglass/epoxy composite

| Properties | Eglass/Epoxy |
|---|---|
| EX(MPa) | 43000 |
| EY(MPa) | 6500 |
| EZ(MPa) | 6500 |
| PRXY | 0.27 |
| PRYZ | 0.06 |
| PRZX | 0.06 |
| GX(MPa) | 4500 |
| GY(MPa) | 2500 |
| GZ(MPa) | 2500 |
| P | 0.000002 |

## V. 3D MODELS OF THE LEAF SPRING

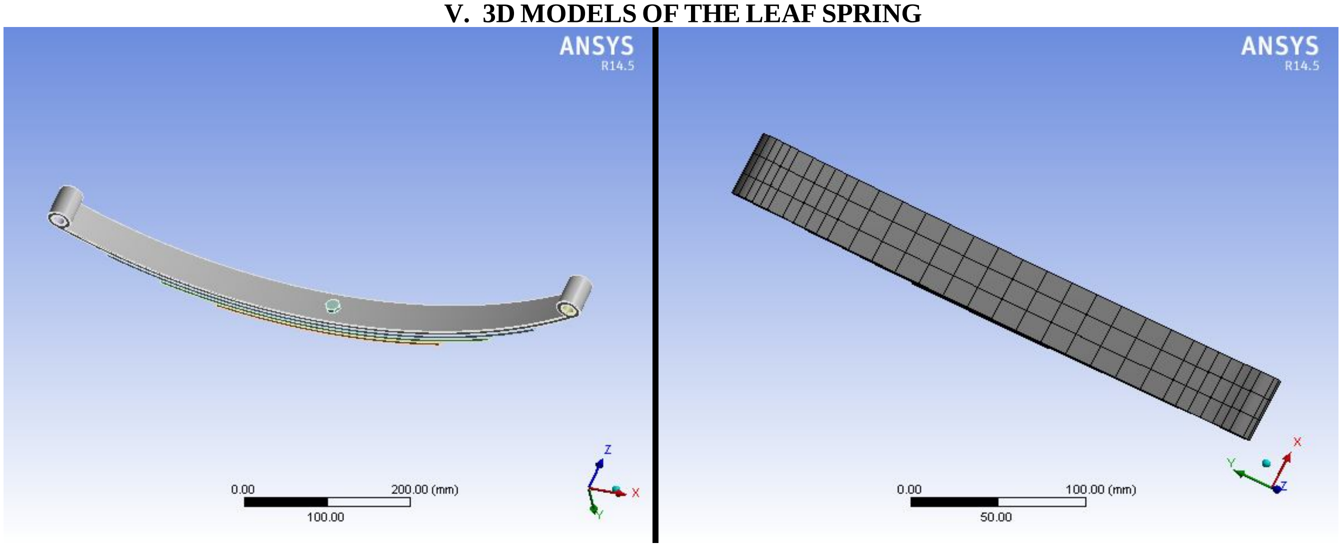


Fig2.A.Conventional Leaf Spring 3d Model B. Composite Leaf Spring 3d Model

## VI.RESULTS

### A. *Structural Analysis For Conventional Steel Used*

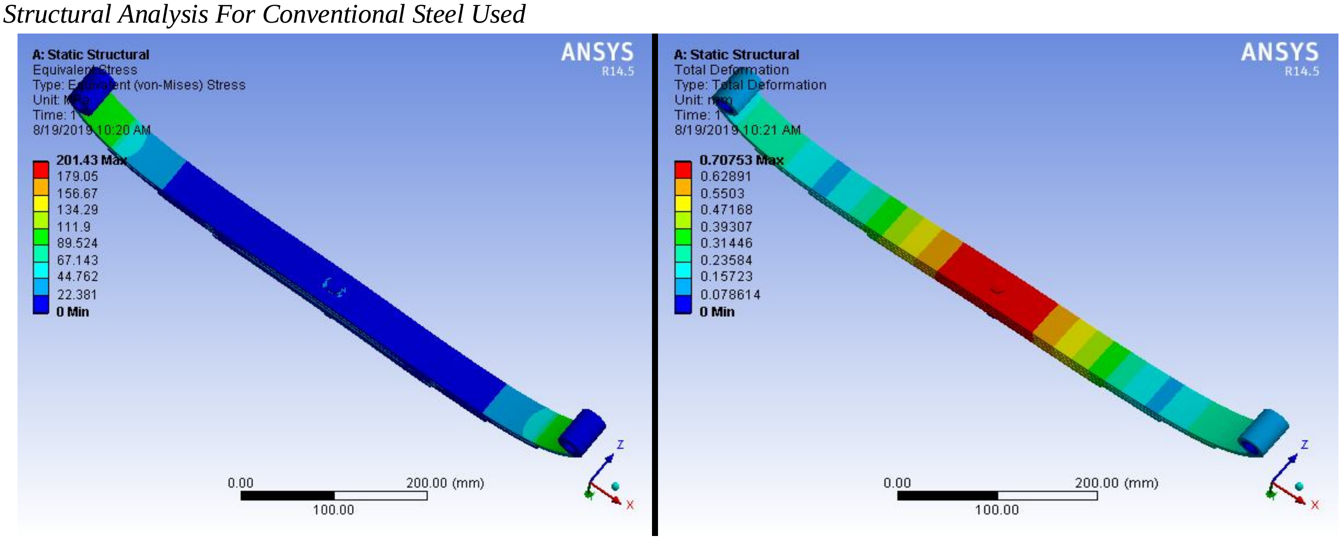


FIG.3. A VON-MISES Stress B. Deformation

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*B. Structural Analysis For Composite Material*

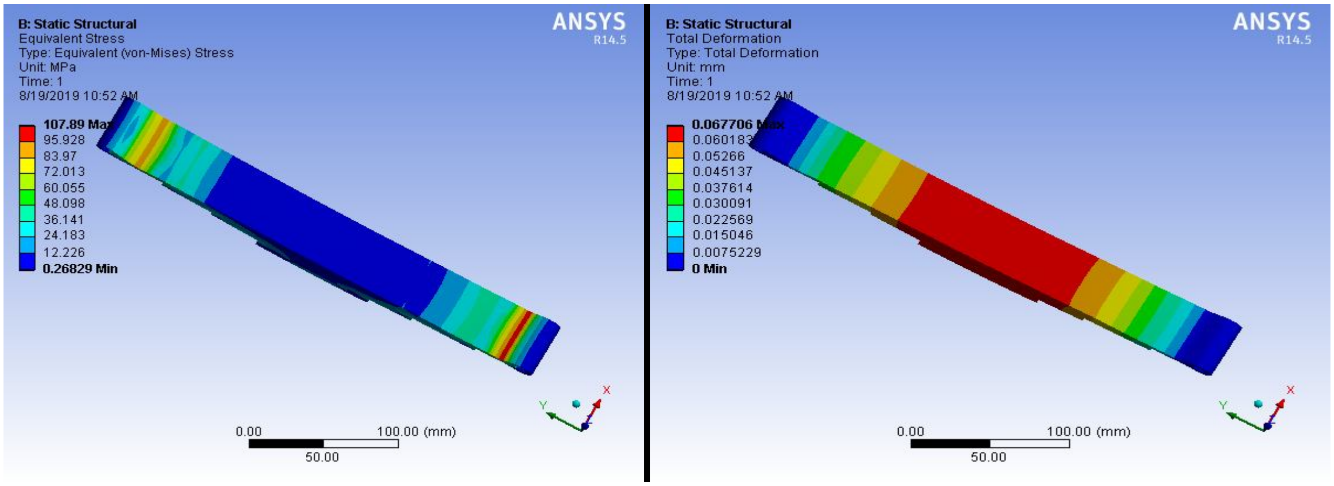
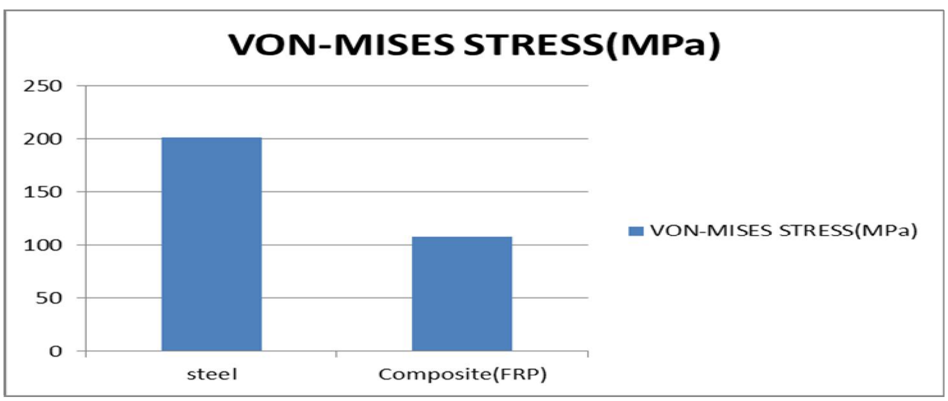


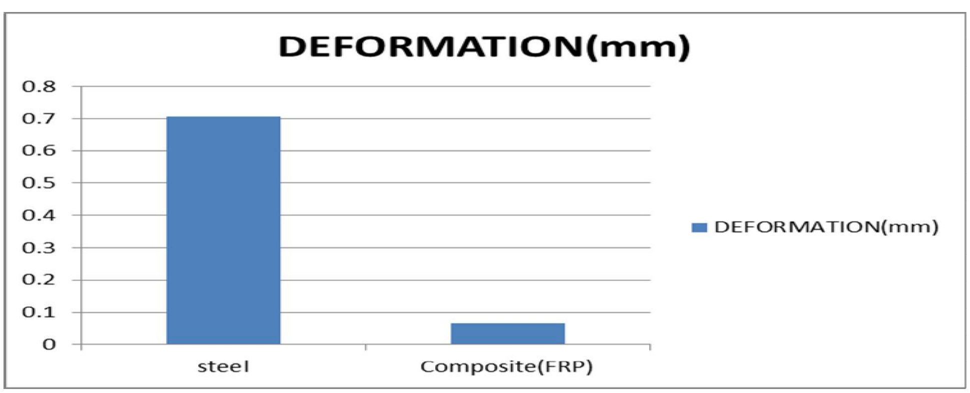

Fig.4.A Von-Mises Stress B.Deformation

Table No1 .Comparision Between Steel And Composites

| MATERIAL | VON-MISES STRESS(MPa) | DEFORMATION(mm) |
|---|---|---|
| steel | 201.43 | 0.7075 |
| Composite(FRP) | 107.89 | 0.0677 |




Graph 1.Von-Mises Stress Comparison Between Steel And Composites




Graph 2.Deformation Comparison Between Steel And Composites

1) *Summary:* The von-misses stress and deformation generated for the composite leaf spring is less compared to the conventional steel used.Hence composite leaf spring tends to have structural strength required to perform the operation.

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### C. *Fatigue Of Steel At Fixed*

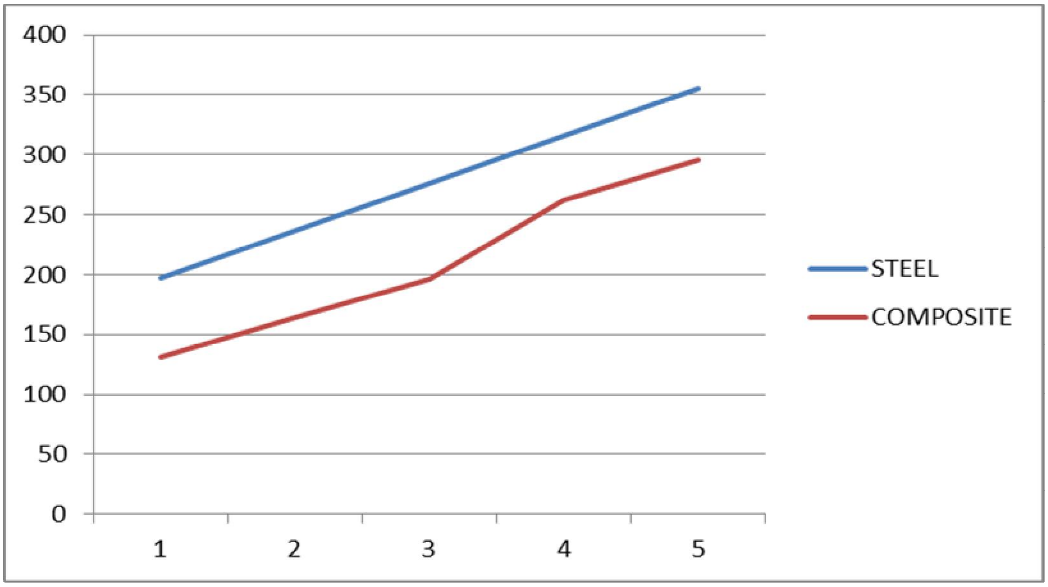
Table 3: Fatigue Test For Steel

| Event | loads | Applied cycles | Stress intensity(MPa) | No.of.cycles |
|---|---|---|---|---|
| 1 | 1000 | 50000 | 197.22 | 5e10 |
| 2 | 2000 | 50000 | 236.66 | 2.7e10 |
| 3 | 3000 | 50000 | 276.11 | 1.45e10 |
| 4 | 4000 | 50000 | 315.55 | 7.8e9 |
| 5 | 5000 | 50000 | 355 | 4.25e9 |

### D. *Fatigue Of Composite At Fixed*

Table 4: Fatigue Test For Composites

| Event | loads | Applied cycles | Stress intensity(MPa) | No.of.cycles |
|---|---|---|---|---|
| 1 | 1000 | 50000 | 131.17 | 6e10 |
| 2 | 2000 | 50000 | 163.96 | 5.1e10 |
| 3 | 3000 | 50000 | 196.75 | 4.50e10 |
| 4 | 4000 | 50000 | 262.32 | 3.9e10 |
| 5 | 5000 | 50000 | 295.32 | 2.9e10 |




Graph 3: Comparison Of Stress Intensity For Steel And Composites

## VII. CONCLUSIONS

A. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single composite leaf spring is designed and it is shown that the resulting design and simulation stresses are much below the strength properties of the material satisfying the maximum stress failure criterion.
B. From the static analysis results, we see that the von- mises stress in the steel is 201.43 MPa. And the von- mises stress in composite is 107.89 MPa. The deformation in composite leaf is less compared to steel.
C. Composite mono leaf spring reduces the weight by nearly 72% for E-Glass/Epoxy.
D. From the fatigue analysis results the stress intensity for steel is more compared to composites . Hence it is advantageous to replace steel leaf spring with composite leaf spring.

## VIII. ACKNOWLEDGEMENT

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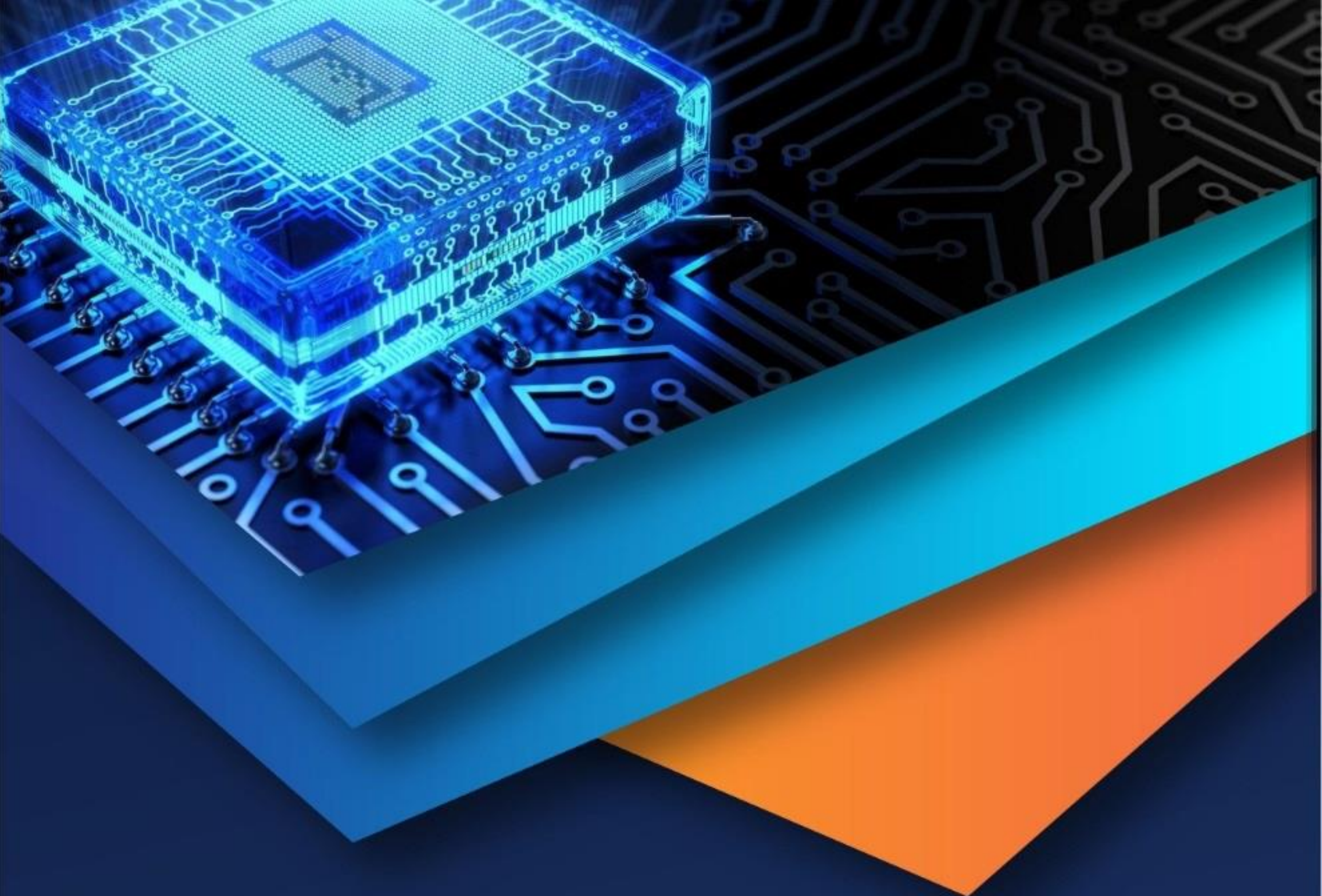

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