# DESIGN AND MATERIAL OPTIMIZATION OF MULTI LEAF SPRING BY FEA

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***ABSTRACT*: The automobile industry has shown increased interest in the use of composite leaf spring in the place of conventional steel leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance. Therefore the objective is to compare deflections and weight savings of composite leaf spring with that of steel leaf spring. 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 weigh reduction, improvement of load carrying capacity when we replace the material of the spring by any advanced material like composites as E-glass/epoxy, carbon/epoxy and Graphite Epoxy. The multi-leaf spring is modelled in CATIA V5R18 and the same were analysed under similar conditions using ANSYS (Workbench 16.0) software. Result shows that, the weight of composite leaf spring was nearly reduced up to 85% compared with steel material.**

**The leaf spring used here is a simpler one.**

***Keywords*: Leaf spring, composite, steel**

## INTRODUCTION

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. Springs are crucial suspension elements on cars, necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. In this paper we have assumed simple leaf spring as the vehicle moves on a smooth road. A leaf spring should support various kinds of external forces but the most important task is to resist the variable vertical forces. The advantage of leaf spring over Helical spring is that the end of the springs may be guided along a definite path. In its construction the 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 centre clip. Generally two types of leaves may be observed in a 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.

**Fig 1. A Traditional Leaf Spring Arrangement**

## 1. SOLID MODELLING OF LEAF SPRING

The solid modelling of the leaf spring was made with the help of CAD tool CATIA v5 as shown in Figure 2. Different models of leaf spring have been drawn based on number of springs and thickness, in this project 4 different designs have been taken:

- Based on no. of springs-10 and 7 (no. of springs).
- Based on thickness-8 and 12mm thickness.

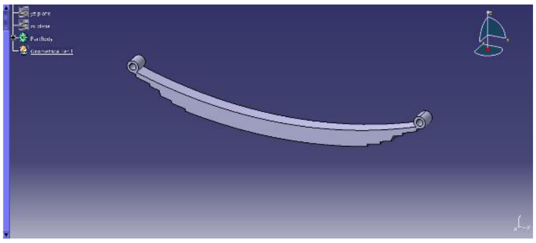

**Fig. 2 plate leaf spring**

## 2. STRUCTURAL ANALYSIS IN ANSYS

- First, prepare assembly in CATIA V5 for different leaf springs and save as this part in .igs file format. Import .igs file model in ANSYS Workbench Simulation Module.
- Apply different materials for leaf spring:

**Materials details:**

Apart from steel which is commonly used, different composite materials such as Eglass epoxy, carbon epoxy, graphite epoxy.

**Table 1: Properties of Eglass/epoxy**

| Parameter | Value |
|---|---|
| Tensile Strength (MPa) | 900 |
| Compressive Strength (MPa) | 450 |
| Passion's Ratio | 0.217 |
| Density (kg/m3) | 2.16*10^5 |
| Flexural modulus (MPa) | 40000 |

**Table 2: Properties of Graphite epoxy**

| Parameter | Value |
|---|---|
| Density(kg/m^3) | 1600 |
| Young's modulus(pa) | 7e10 |
| Poisson's ratio | 0.33 |
| Bulk modulus(pa) | 6.8627e10 |
| Shear modulus(pa) | 2.6316e+10 |

**Table 3: Properties of Structural steel**

| Parameter | Value |
|---|---|
| Density(kg/m^3) | 7850 |
| Young's modulus(pa) | 2e+11 |
| Poisson's ratio | 0.3 |
| Bulk modulus(pa) | 1.667e+11 |
| Shear modulus(pa) | 7.6923e+10 |

**Table 4: Properties of Epoxy carbon**

| Parameters | Value |
|---|---|
| Density(kg/m^3) | 1600 |
| Young's Modulus(GPa) | 70 |
| Shear Modulus(GPa) | 5 |
| Compressive Strength(MPa) | 570 |

- Mesh the leaf spring(4mm)
- Define boundary condition for Analysis.
- Boundary conditions play an important role in finite element calculation.

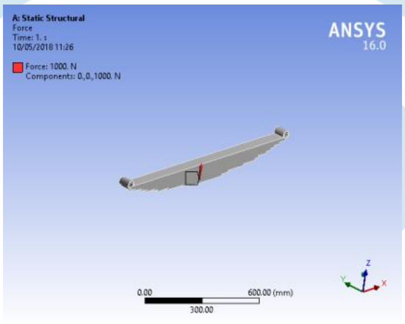


**Fig. 3: 10000N force is applied**

As above shown, different forces have been taken for different thickness i.e. 15000N, 20000N applied at the same place as shown above.

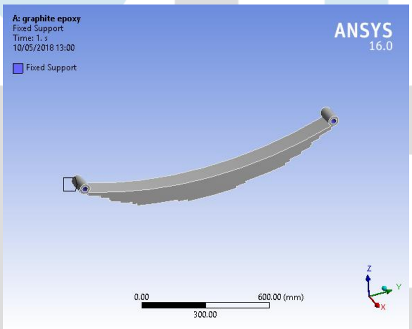


**Fig. 4: Fixed Support**

This fixed support shown in Fig 4 is used in all other conditions for different designs of leaf springs.

**Structural analysis of leaf spring**

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. Static analysis determines the displacements, stresses, strains and forces in structures and components caused by loads that do not induce significant inertia and damping effect.

Following are the deformation and stress analysis (equivalent stresses) diagrams shown (fig. 5-10). In this section we have shown stresses and deformation of only the optimized material i.e. carbon epoxy.

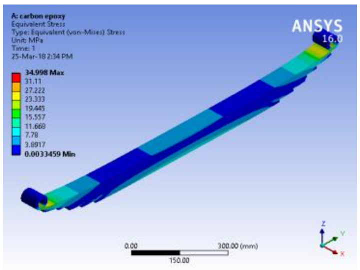


**Fig 5. Stress for 10000N**

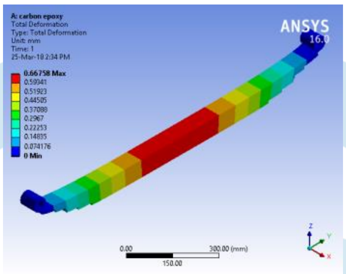


**Fig 6. Deformation for 10000N**

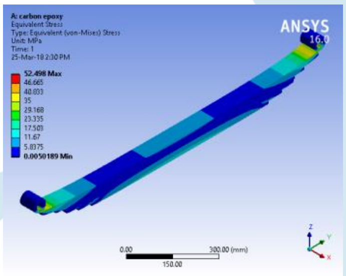


**Fig 7. Stress for 15000N**

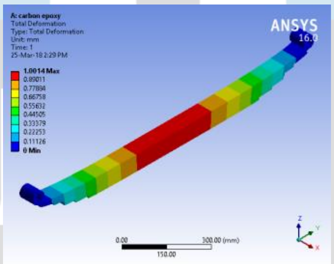


**Fig 8. Deformation for 15000N**

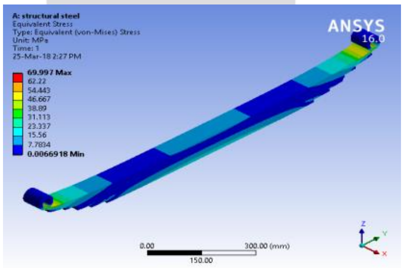


**Fig 9. Stress for 20000N**

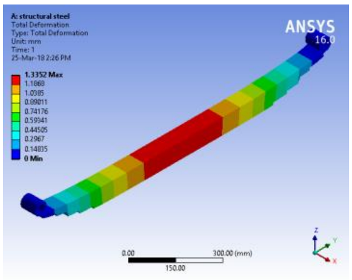


**Fig 10. Deformation for 20000N**

## 3. RESULT TABLE

**CASE-1 THICKNESS-10 mm**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.052757 | 25.093 | 70.382 |
| Eglass-Epoxy | 1.045 | 23.11 | 17.932 |
| Carbon epoxy | 0.44196 | 23.599 | 13.359 |
| Graphite Epoxy | 0.1503 | 23.393 | 14.345 |

**Table 5: Comparison of Materials for different parameters for 10000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.079136 | 34.962 | 70.382 |
| Eglass-Epoxy | 1.5678 | 34.667 | 17.932 |
| Carbon epoxy | 0.66294 | 35.399 | 13.359 |
| Graphite Epoxy | 0.2258 | 35.009 | 14.345 |

**Table 6: Comparison of Materials for different parameters for 15000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.10543 | 46.616 | 70.382 |
| Eglass-Epoxy | 2.0903 | 46.223 | 17.932 |
| Carbon epoxy | 0.88. | 47.198 | 13.359 |
| Graphite Epoxy | 0.30106 | 46.678 | 14.345 |

**Table 7: Comparison of Materials for different parameters for 20000N Force**

**CASE-2 THICKNESS-12 mm**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.55352 | 23.078 | 55.804 |
| Eglass-Epoxy | 1.0943 | 21.957 | 14.218 |
| Carbon Epoxy | 0.5107 | 31.79 | 10315 |
| Graphite Epoxy | 0.15812 | 23.455 | 11.374 |

**Table 8: Comparison of Materials for different parameters for 10000N Force**

| Material | Maximum deformation (mm) (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.083028 | 34.617 | 55.804 |
| Eglass-Epoxy | 1.6415 | 32.936 | 14.218 |
| Carbon epoxy | 0.76604 | 47.685 | 10.315 |
| Graphite Epoxy | 0.23718 | 35.183 | 11.374 |

**Table 9: Comparison of Materials for different parameters for 15000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.1107 | 46.157 | 55.804 |
| Eglass-Epoxy | 2.1887 | 43.914 | 14.218 |
| Carbon epoxy | 1.0214 | 63.58 | 10.315 |
| Graphite Epoxy | 0.31625 | 46.91 | 11.374 |

**Table 10: Comparison of Materials for different parameters for 20000N Force**

**CASE-3 THICKNESS-8 mm**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.12569 | 54.066 | 37.65 |
| Eglass-Epoxy | 2.494 | 54.261 | 9.5925 |
| Carbon epoxy | 0.9705 | 42.301 | 6.9593 |
| Graphite Epoxy | 0.35884 | 54.125 | 7.674 |

**Table 11: Comparison of Materials for different parameters for 10000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.18846 | 81.099 | 37.65 |
| Eglass-Epoxy | 3.7409 | 81.392 | 9.5925 |
| Carbon epoxy | 1.4588 | 63.452 | 6.9593 |
| Graphite Epoxy | 0.53826 | 81.188 | 7.674 |

**Table 12: Comparison of Materials for different parameters for 15000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.25127 | 108.13 | 37.65 |
| Eglass-Epoxy | 4.9879 | 108.52 | 9.5925 |
| Carbon epoxy | 1.941 | 84.603 | 6.5953 |
| Graphite Epoxy | 0.71767 | 108.25 | 7.674 |

**Table 13: Comparison of Materials for different parameters for 20000N Force**

**CASE-4 No of plates- 7**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.09031 | 32.347 | 39.957 |
| Eglass-Epoxy | 0.66758 | 34.998 | 10.18 |
| Carbon epoxy | 1.7922 | 32.195 | 7.228 |
| Graphite Epoxy | 0.25798 | 32.406 | 8.1442 |

**Table 14: Comparison of Materials for different parameters for 10000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.13546 | 48.521 | 39.957 |
| Eglass-Epoxy | 1.0014 | 52.498 | 10.18 |
| Carbon epoxy | 2.6883 | 48.293 | 7.228 |
| Graphite Epoxy | 0.38697 | 48.609 | 8.1442 |

**Table 15: Comparison of Materials for different parameters for 15000N Force**

| Material | Maximum deformation (mm) | Maximum equivalent stress (MPa) | Weight (Kg) |
|---|---|---|---|
| Steel | 0.18062 | 64.694 | 39.957 |
| Eglass-Epoxy | 1.3352 | 69.997 | 10.18 |
| Carbon epoxy | 3.5844 | 64.39 | 7.228 |
| Graphite Epoxy | 0.51596 | 64.812 | 8.1442 |

**Table 16: Comparison of Materials for different parameters for 20000N Force**

## 4. MATERIAL OPTIMIZATION

From above Result table it is concluded that the weight of Carbon epoxy is lesser as compared to the weight of other materials therefore the optimum material is Carbon Epoxy.

## 5. CONCLUSION

The stress analysis of Multi leaf spring has been presented and discussed in this project report. It is found that the weight is reduced by 81.01 % of the Multi leaf spring. Displacement is also increased by 88.06% respectively for Static Load case. Also maximum equivalent stress reduced by 6.33% for Multi-leaf spring. This work will help to understand more the behaviour of Multi leaf spring and it can help to reduce weight and cost in research and development of new product.

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