# Design of Composite Leaf spring

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**Abstract** — In this paper a research work is presented for a Automobile leaf spring made by composite having glass as fiber & reinforced by polymer. The main objective of this research is to find out or compare the stiffness, safe design, load capacity and savings of weight in a leaf spring which made of composite compare with leaf Spring manufactured of steel material and significance is describe on Economic advantages of a Polymer composites & possibilities to replace existing leaf spring manufactured of steel with the composite one. A dimension for a leaf spring manufactured by composite is considered EN45 a steel made leaf spring used for rear suspension of TATA Sumo vehicle. The experimentation is conducted by using UTM and results obtained are discussed.

**Index Terms** — Composite, leaf spring, design, automobile

## I. Introduction

Reducing weight in automobile components, at the time of increases or maintaining a strength parameter of components is very focused and important research area in the current automobile industries. The composite material made components are one which has high strength compare to weight. In this this research work by reducing vehicle weight and maintaining or increasing the proper strength of a vehicle leaf spring is considered for design. The vehicle Leaf spring transfer weight of the vehicle to wheels and it should be very strong enough to carry load for this, a single E-glass & Epoxy composite material made leaf spring is designed and structural analysis i.e. finite element analysis & experimental work is perform for considering static loading only. The cross section areas of vehicle leaf spring are considered constant for simplification of design analysis and for simple manufacturing process of composites. From this it's observed that, the final obtained design stresses and a simulation stresses are very much less than the strength parameters of the general material and it satisfies with a maximum stress criteria for failure. The new design of a leaf spring made by composite has also reached its permissible fatigue life. This new design is specifically focused on light weight four wheeler vehicles. The prototype is manufactured using the hand lay-up manufacturing method for leaf spring made by composite material.

## II. Problem Statement

Nowadays, Weight reduction with good strength is the research focus for automobile industries or manufacturers in the current market condition. The suspension of a leaf spring carries about 10 to 20% of vehicle un-sprung weight. So it's important to decrease the weight parameter of spring. The fall in weight will be achieved using better material and optimized design. By replacing of steel material with leaf spring which is optimally designed & made by composite can provide considerable weight reduction. If we reduce a vehicle weight then fuel efficiency will increase. Leaf springs made by composites especially in light weight trucks which deal with the cargo type load, safety aspect, and comfort.

For cars which are driven by electricity we require less vehicle weight so composite spring will be definitely part of these cars. Now a day's composite used in various automobile parts like hoods, trunk lids. In the advance electrical cars, the major load carrying body parts are made up using by a Carbon Fiber Reinforced Polymers (CFRP). Epoxy carbon and glass composites have very good mechanical, thermo-mechanical and fatigue resistance properties.

## III. Design

For Sumo Grande made by TATA the thickness of a suspension leaf spring from top end to bottom end are 11, 13 & 14mm respectively. Span is 1260mm and central u-band length is 100mm.

Length of smallest leaf = (effective length - 1) + ineffective length.

So, effective length for a suspension leaf spring is 1404.5, 1260 & 680mm respectively. Radius(R) to which leaf are initially bend are calculated by following equation

$$C(2R-C)=(L/2)^2 \quad (1)$$

Where C is camber and L is effective length.
The mass parameter of spring is 21.5 kg. Considering each leaf spring as a cantilever beam, the weight or load carrying/safe capacity of a spring is find out using following equation

$$\sigma = 6WL / NbT^2 \quad (2)$$

Where σ is allowable stress which is calculated using factor of safety is 3.

B is width of spring i.e. 70mm. T is thickness.

Total load or weight carrying capacity of a vehicle leaf spring is obtained 12000N.

Design of the composites leaf spring:

Material properties for e-glass/epoxy composite is as follows

Table 1. Material Properties

| $E_1$ | $E_2$ | $\tau_{12}$ | $\mu_{12}$ | $X_t$ | $Y_t$ | $Y_c$ | S |
|---|---|---|---|---|---|---|---|
| 54GPa | 18GPa | 9GPa | 0.25 | 1035MPa | 28MPa | 138MPa | 41 |

Where $X_t$ and $X_c$ are longitudinal Tensile & compressive strength.

$Y_t$, $Y_c$= transverse compressive & tensile strength.

S is the shear strength

Radius of curvature r = 1825.58mm

Straight length of a spring = 1306.35mm

Now, effective length of a spring = 1260-100 =1160mm

Length under consideration=1160/2=580mm

L = 580mm

Now, $\sigma_{max} = 6WL / bt^2$ (3)

$\delta_{max} = 4WL / Ebt^3$ (4)

$(6WL / bt^2)(4WL / Ebt^3) = \sum \max / \delta_{max}$

t≈25mm

$B = 4WL / \delta_{max} t^2$

B ≈ 75mm

$\sigma_b$ =445.45 MPa

Hence the final design is a safe.

No. of the cycle for failure:

$N=B\ (1 - r)^{1/C}$ (5)

Where, N=No. of cycles to failure,

B=10.33 C=0.14012

$r = \sigma_{max} / \sigma_u$

Where, $\sigma_{max}$=max stress , $\sigma_u$ =ultimate tensile stress

r is a applied stress value or level

Now, r=0.457

$N=(10.33(1-0.457))^{1/0.14012}$

$=222.16*10^3$ cycle

Now, the factor of safety and stress and stress level is limited to 2 or 1.5 for the conventional vehicle leaf spring made by steel material for which,

$\sigma_{yt}$=1800

$\frac{1800}{FOS}=\frac{1800}{2}=900$

$r= \frac{\sigma_{max}}{\sigma_u}= 900/1800=0.500$

$N=(10.33(1-0.500))^{1/0.14012}$

N=122.74*10³ cycle

Ncomposite > Nconventional

*IV. Finite Element Analysis*

The analysis of stress-deflection is performed using structural finite element analysis. The complete FEA analysis is done by using ANSYS-11. In the finite element structural analysis of Ansys, procedure of FEA is separated into three major steps, which are pre-processor, solution, and postprocessor. The multiples leaf spring computer aided design model is import in ANSYS-14, showing in figures. After importing, the single leaf spring manufactured by composite material is analyzed in ANSYS with dimension as calculated showing bending deflections and stresses under load condition are shown in Figs.

*A. FEA result for conventional leaf springPrepare*

Fig. 1 shows the total deformation in leaf spring manufactured by composite. Fig.2 shows the stresses in leaf spring manufactured by composite.

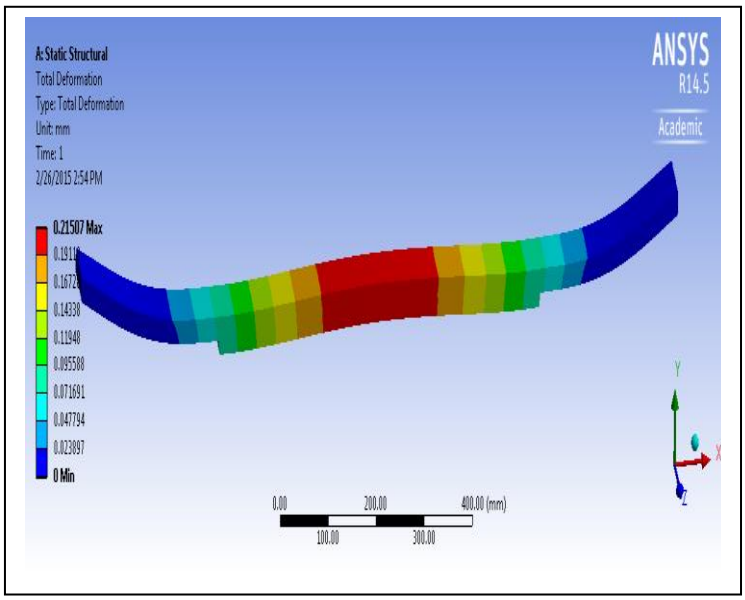


Figure 1 Total deformation

*B. FEA result for composite made leaf spring*

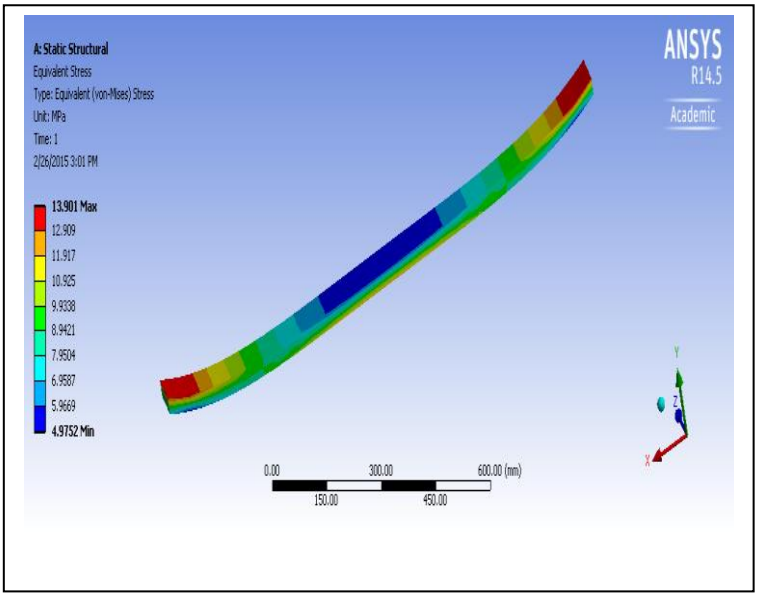


Figure 2 Stresses in composite made leaf spring

## V. Fabrication

The cross section is considered constant due to some of its advantages in mass production, and to

accommodate continuous reinforcement of a fiber and also it's easy for hand lay-up manufacturing technique. Various techniques are available for fabrication of a composite made leaf spring. In the research work presented here, the hand lay-up manufacturing process is used. The templates or mold die are made from aluminum plate. For layer by layer deposition of a glass fiber in the mold, it cuts in the desired length. In the process of the conventional manufacturing hand lay-up method, firstly a release coating like gel or wax was applied uniformly and smoothly to the mold. The mold should have good quality of a surface finish. After this process the application or implication of an epoxy resin to a glass fiber sheet is applied uniformly. Then another lay up of a glass fiber is applied, followed by resin is application and for pressing a roller application is done to removal of all the trapped air in the mold. The above process should continue till the required dimension of a vehicle leaf spring is obtained. Care must be require to take during the fabrication of individual lay-up of the layers to avoid the fiber distortion, which will lead to decreasing the strength, perfectness and a rigidity of the vehicle leaf spring as a whole part. The total time require for the process will take up to 3 hrs. The mold kept for curing about 4 to 5 days at a room temperature or atmospheric temperature. The Mono/single composite made leaf springs without having eye ends were manufactured by applying above hand layup technique. The considered glass fiber sheet is having quality of woven type roving 360 GSM and an epoxy resin is of 520F with a hardener having value 758. The glass fibers are trimmed and ground to obtained the required length of the vehicle leaf spring and which are layered in such way that to get the final shape similar like a leaf spring. For all 100 parts, by the weights of epoxy type resin, 10 to 12 parts by weight of a hardener type 758 is mixed properly at a temperature range of 20 to 40 °C. The manufactured composite material leaf spring is given in Fig.3

Figure 3 Fabrication of a vehicle leaf spring

## VI. TESTING

In this process the leaf is tested or proved under ultimate testing machine for varying loads. The deflection is measured for each load. The table for varying loads with respective deflections is shown in below.

Figure 4 Testing on UTM

RESULT

Table 2 Deflection

| Load(kg ) | Deflection(mm) |
|---|---|
| 50 | 2 |
| 100 | 15 |
| 150 | 25 |
| 200 | 31 |
| 250 | 44 |
| 300 | 52 |
| 350 | 57 |
| 400 | 64 |
| 443 | 78 |

*A. Weight comparison.*

Table 3 Weight

| Type of spring | Weight in kg. |
|---|---|
| Steel made leaf spring | 22.51 |
| Composite made leaf spring | 6.36 |

Weight $_{composite}$ < Weight $_{conventional}$

*B. Comparison of no. of cycles for failures*

Table 4 No of cycles

| Type of spring | No. of cycles for failure |
|---|---|
| Steel leaf spring | 122.74*10^3 |
| Composite made leaf spring | 222.16*10^3 |

N composite > N conventional

*C. Cost comparison*

Table 5 Cost

| Type of spring | Cost in rupees |
|---|---|
| Steel made leaf spring | 3390 |
| Composite made leaf spring | 3690 |

Cost composite > Cost conventional

## Conclusion

In the focus of reducing weight and increasing strength of components is high research demand in industries like automobile, components made by composites are good to satisfy this demand. In this research work reducing the weight or mass of vehicles through a composite made leaf spring & increasing the strength of their leaf spring is focused. As vehicle leaf spring have contribution towards the amount of a weight to the automobile or vehicle and to reduce it to a single composite E-glass & Epoxy resin leaf spring is developed and an analysis using finite element method & experimental work is carried out. And it is prove that the final composite made leaf spring design stresses and FEA stresses are far less than the strength parameters or properties of a material satisfying the high stress failure criterion. It is achieved a permissible fatigue life of 221.16*10^3 cycles. This design for leaf spring made by composite is carried out for specifically for TATA sumo Grande version. Its model is fabricated using the hand lay-up manufacturing method and its experimentation is done. These designs carry for only the static loading condition and found safe for application.

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