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Static Analysis of Carbon Glass Composite Leaf Spring

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Abstract- The leaf spring is an important part in a four-wheeler vehicle and it carries the load acting on the vehicle. So it must be strong enough to resist the shock, twist, vibration and other stresses. In vehicle different types of failure occur due to static and dynamic loading conditions. In this analysis we simulate real condition by notice to all of effective forces on leaf spring, two different materials namely Steel EN45 , And Carbon-Glass composite material. From the analysis we observe the stress in Steel EN45 and Carbon-Glass composite material for leaf spring respectively to be 116.56 MPa, and 124.31 MPa. From the analysis we observe the deformation in Steel EN45, And Carbon-Glass composite material of leaf spring are respectively to be 0.25mm, and 6.01mm. The dynamic characteristics of the four wheeler leaf spring such as the stresses and deformation will determine by using finite element (FEM) method in ANSYS17.2 static analysis. We will be taking ideal procedure for improve strength of leaf spring with respect to different materials. The weight of leaf spring in Steel material to be 21.2 kg and, Carbon-Glass composite material of leaf spring is 4.035kg.

Keywords:- Steel EN45, Carbon-glass composite, leaf spring, ANSYS, Structure, CATIA.

I. INTRODUCTION

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Weight reduction can be achieved by designing new materials and sophisticated manufacturing processes.

Due to increasing competition and innovation in recent decades, automobile industries show interest in replacing conventional steel leaf spring with fiber-reinforced composite leaf spring which has advantages such as higher strength to weight ratio, higher stiffness, high impact energy absorption, and lesser stresses. 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. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unsprung weight. This achieves the vehicle more fuel efficiency and improved riding qualities.

The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system.

According to the studies a material made with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. The leaf springs are more affected due to fatigue loads, as they are a part of the unsprang mass of the automobile.

During service, any vehicle is subjected to loads that cause stresses, vibrations and noise in the different components of its structure. This requires appropriate strength, stiffness and fatigue properties of the components to be able to stand these loads. Above all, quality of a vehicle, as a system, which include efficient energy consumption, safety and comfort to the user are highly desired. All the above largely demand refined and complex design and manufacturing procedures involved during the production stage. This requires good understanding of the internal systems of the vehicle and the characteristics of the different body structures in reaction to static and dynamic loads.

Different researches have been carried out regarding the performance, the response of components to static and dynamic loads, crashworthiness, safety and others by different institutions and automotive companies. Particularly, with the growing simulation capability using computers, researches are facilitated which are aimed to achieving better quality products.

The application of computer aided engineering (CAE) analysis to problems of this sort, in combination with prototype development and testing, enables to achieve structures having longer fatigue life, reduced cost, light weight and improved comfort. In light of this purpose, as stated earlier, advancements in the area are growing further. The components of the suspension system are parabolic leaf spring. Here they perform isolation task in transferring vibration due to road irregularities to driver's body.

Increasing competition and innovations in automobile sector, tends to modify the existing products and replacing old products by new and advanced material products, more efforts are taken in order to increase the comfort of user, to improve the suspension system and hence many modifications have taken place over the time.

Inventions of parabolic leaf spring and use of composite materials, for these springs are some of the latest modifications in suspension system. We can reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness due to the introduction of composite materials. Therefore composite materials are now used in automobile industries to replace metal parts. Elastic strain energy capacity is also high in composite materials. As compared to steel, they also have high strength-to-weight ratio. Composite materials offers opportunity for substantial weight saving.

II. NUMERICAL MODELLING OF LEAF SPRING

In this study, leaf spring is designed for the rear axle of a tractor trolley. The load on the rear axle of a tractor trolley is 4000 N. The span is 1000 mm and the width of the clamp is 100 mm. In all 10 leaves are used out of which two are main leaves and the remaining graduated leaves.

Assume 4KN is equally shared by two leaves, the load on each spring is

$$W = \frac{4}{2} = \text{KN or}$$

$$W = 2 \text{ KN}$$

Effective length, 2L = span – width of the clamp = 1000 -100 = 900 mm

$$L = \frac{900}{2} = 450 \text{ mm}$$

The spring material is chrome-vanadium steel having ultimate strength, $\sigma_{ut} = 1500\ N/mm^2$ and endurance limit = $0.4\sigma_{ut}$/FS

Let FS = 2 for the spring subjected to fatigue loading:

$$\sigma = \frac{6WL}{nbt^2}$$

$$300 = \frac{6x\ 2000\ x\ 450}{10\ x\ bt^2}$$

$$bt^2 = 1800 \text{ mm}^3$$

Assume width of leaf spring = 50 mm

$$\text{Thickness, t} = \sqrt{\frac{1800}{5}} = 6 \text{ mm}$$

Take minimum t = 8mm

Ratio of total depth to width of spring = $\frac{nt}{b} = \frac{10\ x\ 8}{50}$ = 1.6 which is reasonable

Max. deflection,

$$\delta = \frac{12WL^3}{Ebt^3(2n_G + 3n_F)}$$

$$= \frac{12x\ 2000\ x\ 450^3}{2x10^5\ x\ 50\ x8^3(\ 2\ x\ 8+3\ x\ 2)}$$

= 20 mm

Camber = 0.5 x max. deflection = 10 mm

Radius of curvature,

$$R = \sqrt{AC^2 + CB^2}$$

$$R = \sqrt{(R-10)^2 + 450^2}$$

R = 10130 mm

Number of leaves,

$$L1 = \frac{effective\ length}{n-1} x\ i + ineffective\ length$$

$$L1 = \frac{900}{9} x\ 1 + 100 = 200 \text{ mm}$$

$$L2 = \frac{900}{9} x\ 2 + 100 = 300 \text{ mm}$$

Similarity, other length are:
L3 = 400 mm, L4 = 500 mm, L5 = 600 mm, L6 = 700 mm, L7 = 800 mm, L8 = 900 mm, L9 = 1000 mm
Length of master leaf = 1000 + 2 x 3.14(15 + 8) = 1144.53 mm

III. LEAF SPRING MODELING IN ANSYS DESIGN MODELER

Graphics design can be done in many ways. It is always creativity how quick we can create graphics which represents leaf spring. The general procedure in ANSYS design modeller is explained in step by step

- **Step 1:** Choose plane –YZ and draw sketch which represents the top layer of the spring
- **Step 2:** Extrude in normal direction with depth = 40mm.you will get 3-Dimensional layer of leaf spring
- **Step 3:** Draw sketches from the bottom of first layer simultaneously repeat the same procedure for all other 9- layers and extrude with the same width.
- **Step 4:** Draw all other parts sketches and use 3D operation methods like extrude, revolve, pattern etc. to get complete assembly.

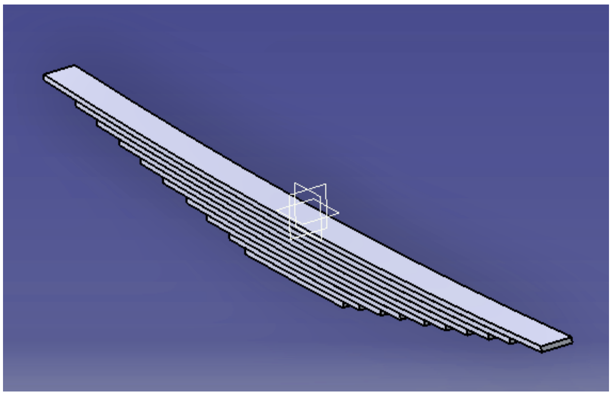

Fig 1. ANSYS design modeler.

The final drawing should looks like the fig-1 shown below, Finite element based software ANSYS 17.2 was used step by step for static analysis of steel leaf spring and composite leaf spring. The objective of this analysis is to find out the deflection of steel spring and composite leaf spring under given load and compare the result of steel spring and composite leaf spring. The comparison of result of composite leaf spring with steel leaf spring gave validation for use of composite leaf spring in place of traditional steel leaf spring.

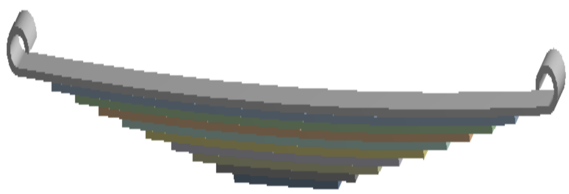

Fig 2. FEM Model of leaf spring.

Meshing of the parabolic leaf spring model was done after defining the material properties and assigning each material to each of the component. Mesh convergence test is first performed for deciding the element size for meshing of the model.

IV. RESULTS AND DISCUSSION

Assume Leaf Spring is in static loading condition shown in previous chapter and analyze Total Deformation and Von-Mises Stress values of both Steel and Composite Leaf Spring.

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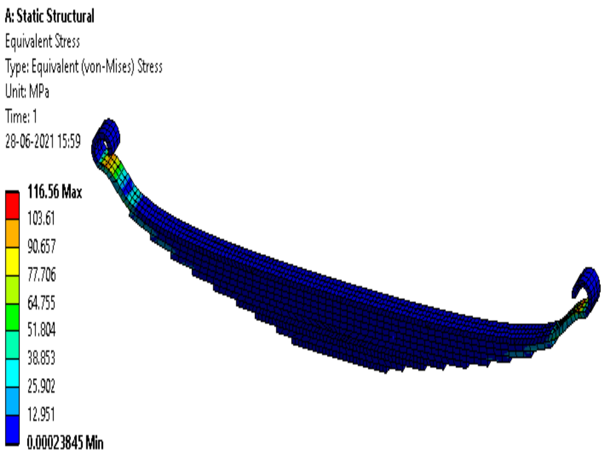

Fig 3. Equivalent stress of Steel EN45.

Von-mises stress is widely used in industries to check whether their design will withstand a given load condition, using this information we can predict the design failure, if the maximum value of von-mises stress induced in the material is more than strength of the material.

In analysis process we can see that von-mises stress is at maximum towards the fixed end of the parabolic leaf spring, and the value is less than yield point value of steel EN45 and composites. So the design of parabolic leaf spring is safe.

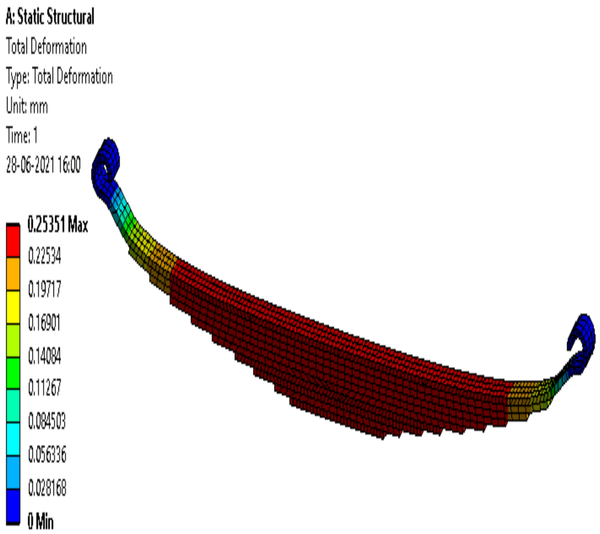

Fig 4. Total deformation of Steel EN45.

The maximum Von-Mises stress generated in conventional steel leaf spring is shown in fig. 4.1. From the results of static analysis of steel leaf spring, it is seen the max. Equivalent stress of Steel EN45 of leaf spring is 116.56Mpa and min. equivalent stress of Steel EN45 of leaf spring is 0.000238Mpa.

From the results of static analysis of steel leaf spring, it is seen the max. Total deformation of Steel EN45 of leaf spring is 0.25mm.

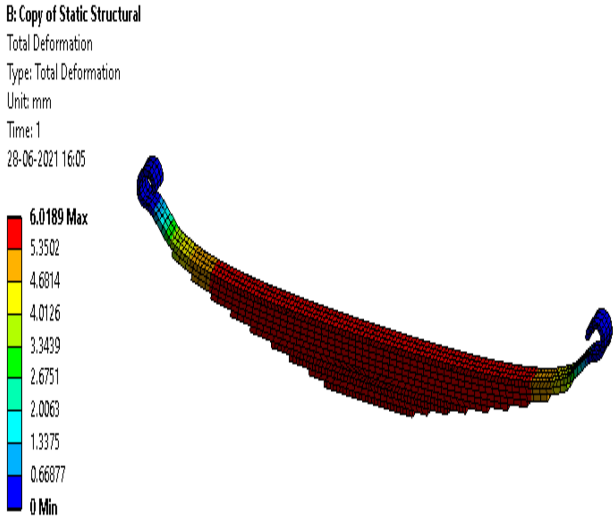

Fig 5. Total Deformation of Carbon- glass composite.

From the results of static analysis of steel leaf spring, it is seen the max. Total deformation of Carbon- glass composite of leaf spring is 6.01mmand min. Total deformation of Carbon- glass composite of leaf spring is 0 m shown in fig.3.

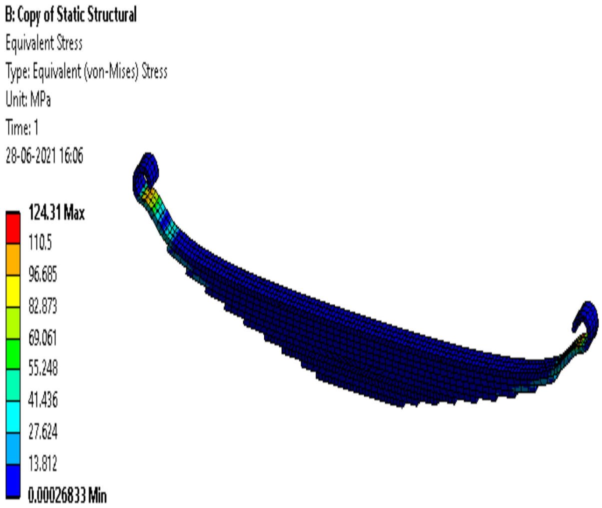

Fig 6. Equivalent stress of Carbon- glass composite.

From the results of static analysis of steel leaf spring, it is seen the max. Equivalent stress of Carbon- glass composite of leaf spring is 124.31Mpa and min.

Equivalent stress of Carbon- glass composite of leaf spring is 0.000268Mpa shown in fig.4.

Table 1. Static Structural Analysis Results.

Parameter	Steel EN45	Carbon- glass composite
Max. stress (Mpa)	116.56	124.31
Max. deformation (mm)	0.25	6.01

Table 2. Percentage Weight Reduction.

Parameter	Steel EN45	Carbon- glass composite
Weight (Kg)	21.2 Kg	4.035 Kg
% weight reduction	80.9%	

V. CONCLUSION

According to the results obtained from ANSYS software, It can be concluded that the weight of Carbon- Glass composite is lighter and maximum stress also predicted when compare with Steel EN45 material.

The results clearly indicate that the leaf spring with Carbon- glass composite materials much lighter and has more strength than initial design of leaf spring (Steel EN45 materials). Hence Carbon-Glass composite material is the best replacement material in place of steel EN45 for present generation leaf spring.

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