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FINITE ELEMENT ANALYSIS (FEA) OF MULTI-LEAF AND MONO-LEAF SPRINGS WITH MATERIAL OPTIMIZATION OF E- RICKSHAW

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Abstract—**a leaf spring is commonly used for the suspension in wheeled vehicles. Multi Leaf Springs consist of long and narrow plates attached to the frame that rest above or below the axle. There are mono leaf springs, or single-leaf springs, that consist of simply one plate. Today, the main focus of every automobile industry is weight reduction in order to safeguard natural resources and economize energy. This aim of weight reduction in the E Rickshaw can be achieved by the introduction of better material, design optimization and better manufacturing processes. The leaf spring is one of the potential items for weight reduction in E Rickshaw as it accounts for ten to twenty percent of the un-sprung weight. The objective function is to minimize the deflection in the leaf spring and reduce the weight by changing the parameters i.e. design and material. Firstly the model of both leaf springs i.e. multi and mono type are designed in CATIA V5 software and saved in iges format. This iges file of leaf springs is then imported in ANSYS workbench. The material for multi leaf spring is EN45 steel and GFRP for mono leaf spring. The deformation, strain and stress values are noted. The results obtained for the leaf springs are compared for final conclusion.**

Keywords—Leaf Spring, mono leaf spring, EN45 Steel, GFRP, FEA, CATIA V5, ANSYS

I. INTRODUCTION

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. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device [3]. The suspension system of vehicle with Leaf spring shown in Fig. 1 [1]

Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load [4].The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps. The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes [5].

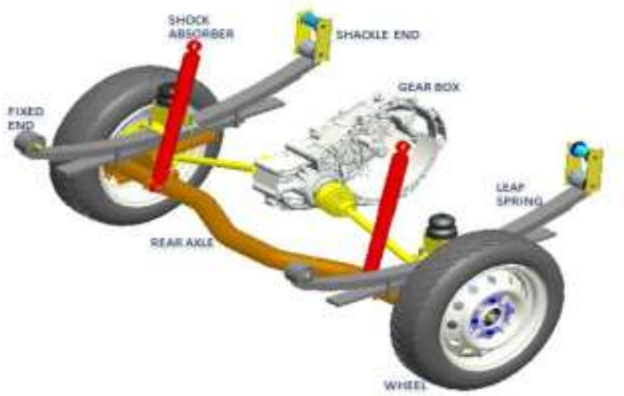

Fig. 1 Suspension System

II. LITERATURE REVIEW

Dhia A. Alazawi et al. [12] designed and tested a composite leaf spring made from woven glass fiber-reinforced polymer (GFRP). His objective was to evaluate its load-bearing capacity, stiffness, and potential for weight savings as a lightweight alternative. Leaf spring is designed for a 1000 kg vehicle; finite element analysis was used to predict optimal spring thickness under load. Both experimental and numerical results confirmed the composite's strength, durability, and fatigue resistance. Notably, the prototype achieved an 80% weight reduction compared to traditional steel springs, proving its effectiveness for high-efficiency vehicle applications.

Mahesh Dhaytonde et al. [13] performed various optimization methods to find suitable alternatives to traditional materials for reduce costs while preserving strength and load-bearing capacity of leaf spring. His studies focused on replacing conventional steel leaf springs with composite materials as many researchers had emphasized the advantages of fiber-reinforced composites, particularly carbon fiber, due to their superior performance. This paper offers a brief overview of carbon fiber-reinforced composites for leaf spring applications.

Ashvini P.lad et al. [8] carried out the analysis to reduce the weight of leaf spring by maintaining its strength and results from the study were taken for changed the material for proposed models. And based on FEA results change the material of this model was done to optimize weight of leaf spring and for ease for manufacturing. It was concluded that this model structure is safe except some localized stresses are high. FEA of this model indicates that stresses and displacements are near to existing design.

B.Vijaya Lakshmi et al. [9] analyzed composite leaf spring in heavy vehicles. To compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring and concluded that E-glass epoxy was better than using Mild-steel as though stresses are little bit higher than mild steel.

Baviskar A. C. et al. [10] designed and analysed the leaf spring for automobile suspension system and observed that the weight of the leaf spring was reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring and the composite leaf spring is lighter than conventional steel leaf spring with similar design specifications but not always is cost- effective over their steel counterparts. Composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel. Therefore, it is concluded that composite leaf spring is an effective replacement for the existing steel leaf spring in automobile.

C.K. Clarke et al. [11] evaluated the failure of leaf spring and calculated that the presence of sulphur segregation at the mid plane weakened the spring. The spring was cracked for some time in advance of the accident. The rock strike possibility was ruled out because forces adequate to rupture the spring were present well in advance of the rock strike, and wheel well marks were not consistent with short-duration forces expected from a rock strike.

III. OBJECTIVE

There are several benefits of using composites materials in today's era. But the main Objective of the thesis as follows:-

- To design the model of Leaf Spring and perform Finite Element Analysis to find the deformation and stress strain distribution with the help of ANSYS workbench.
- To compare the values of stress, strain and deformation obtained with the values of actual model of Leaf Spring.
- Optimization of Leaf Spring with a view to reduce weight and cost from analysis.

IV. METHODOLOGY

Pre-Processing- The first step in Pre-Processing is to prepare a CAD model of Multi leaf spring and mono leaf spring. The dimensions of multi leaf spring determined by measuring the original part using the measuring instruments. The model of both leaf springs are designed in CATIA V5 software and saved in iges format. The geometrical specification of leaf spring is given in Table 1.

Table 1 Specification of Leaf Spring (Pre loading design)

Parameter	Multi Leaf Spring	Mono Leaf Spring
Total length (eye to eye)	500 mm	500 mm
Leaf width	50 mm	50 mm
Each leaf thickness	6 mm	7 mm
Number of leaves	6	1
Initial camber height	90 mm	85 mm
Eye diameter	20 mm	20 mm
Material	EN45 spring steel	Glass fiber reinforced polymer (GFRP)

This iges file of leaf springs are then imported in ANSYS workbench and analysis performed by applying boundary condition. The deformation, strain and stress contours have find out using ANSYS workbench and results obtained are compared. The Fig. 2 and Fig. 3 shows the drawing of multi and mono leaf spring respectively.

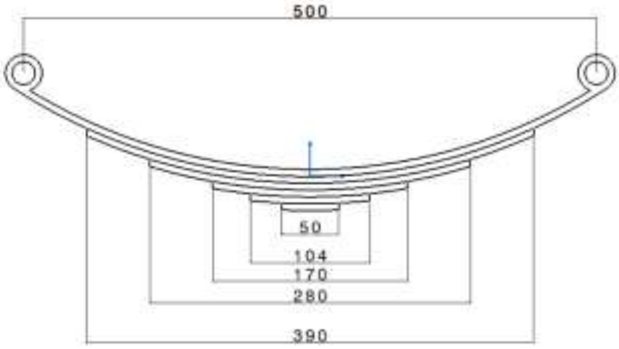

Fig. 2 Multi Leaf Spring Drawing

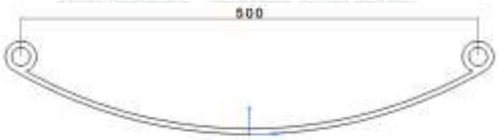

Fig. 3 Mono Leaf Spring Drawing

4.1 Material Properties

The materials used in this work are EN45 Steel and GFRP (Glass Fiber reinforced polymer). Selected mechanical property of EN45 Steel and GFRP composite are discussed in Table 2.

Table 2 Material Properties

Property	**Steel (EN45)**	**Composite (GFRP)**
Young's Modulus (E)	204 GPa	89 GPa (Longitudinal)
Poisson's Ratio (ν)	0.3	0.1
Yield Strength	1034 MPa	550 MPa
Density	7850 Kg/m³	1850 Kg/m³

The Fig. 4 and Fig. 5 shows the CAD model of Multi and mono leaf spring respectively in CATIA V5 Software.

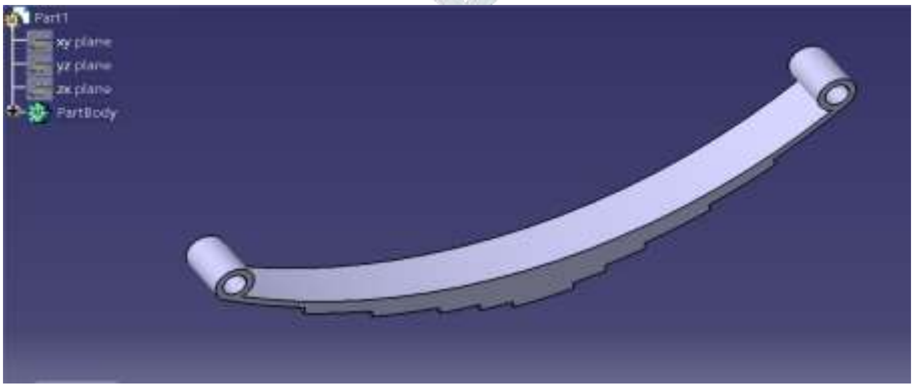

Fig.4 CAD model of Multi leaf spring

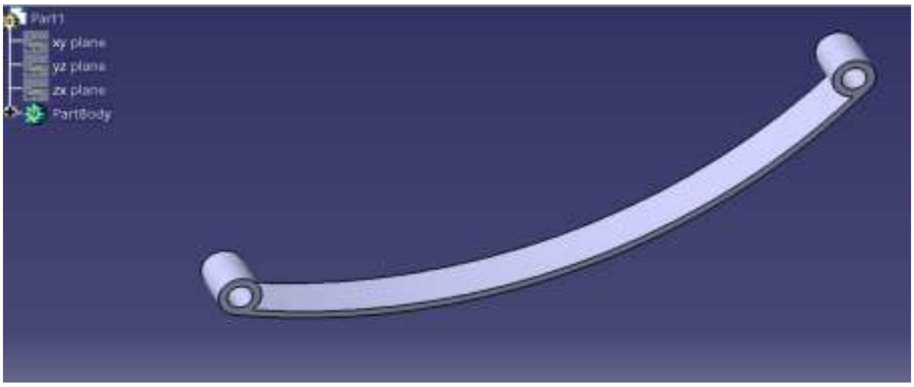

Fig.5 CAD model of Mono leaf spring

4.2 Mesh generation

Finite Element mesh is generated using parabolic tetrahedral elements. The Von-Mises stress is checked for convergence. An automatic method is used to generate the mesh in the present work. Fig. 6 shows the meshed model of leaf springs in AYSYS workbench.

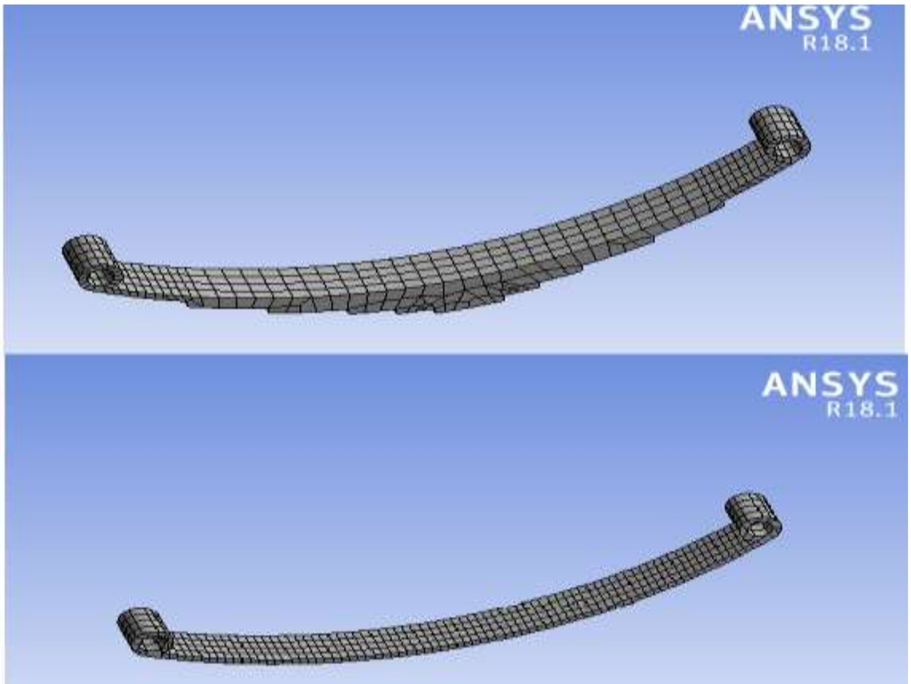

Fig.6 Meshed model of Leaf Springs in ANSYS workbench

4.3 Boundary Conditions

After completion of the Finite Element Model, boundary condition and loads are applied. User can define constraints and loads in various ways. This helps the user to keep track of load cases. The boundary condition is the collection of different forces, supports, constraints and any other condition required for complete analysis. Applying boundary condition is one of the most typical processes of analysis. A special care is required while assigning loads and constraints to the elements. Loading conditions involves force of 5886 N calculated as below:

Total load = Electric auto rickshaw self-weight + five passenger's average weight

= 300 kg + 300 kg = 600 kg

= 600*9.81 = 5886 N

Boundary conditions for both the leaf spring involving load and fixed support at the eye end are shown in Fig. 7.

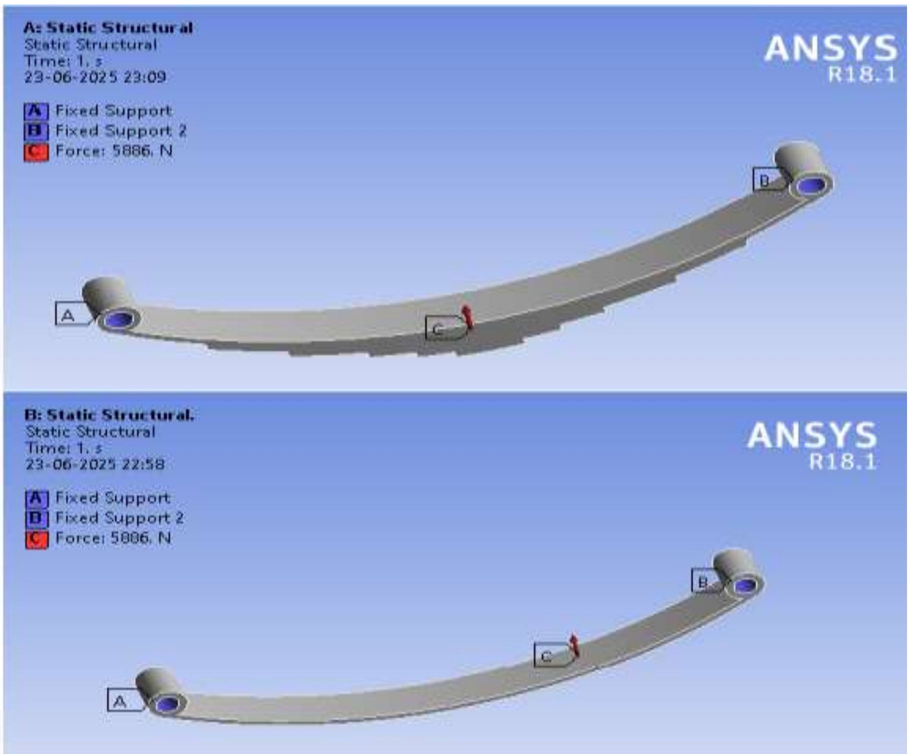

Fig.7 Applied constraints on the Leaf Springs

4.4 Model Display

While applying the boundary conditions, it is necessary to view the model from different angles Pre-Processor offers capabilities of rotating, smoothness, scaling, regions, active set, etc. for efficient model viewing and editing.

4.5 Solution

The Solution phase deals with the solution of the problem according to the problem definitions. All the tedious type of work of formulating assembling of matrices is done by the computer and finally displacements and stress values are given as output.

4.6 Post- Processor

It is a powerful user friendly Post-Processing program using interactive color graphics. It has extensive plotting features for displaying the results obtained from the Finite Element Analysis. One picture of the analysis results (i.e. the results in a visual form) can often reveal in seconds what would take an engineer hour to assess from a numerical output, say in tabular form. The engineer may also see the important aspects of the results that could be easily missed in a stack of numerical data. The entire range of Post-Processing options of different types of analysis can be accessed through the command/menu mode there by giving the user added flexibility convenience

Employing state of art image enhancement techniques facilitates the viewing of:

- Contours of stresses, displacements, temperatures etc,
- Deform geometric plots, light source shaded plot,
- Animated deformed shapes,
- Time-history plots,
- Solid sectioning hidden line plot and boundary line plot etc.

V. STATIC STRUCTURAL ANALYSIS

Static structural analysis is done in ANSYS workbench to find out the equivalent von-mises stress, strain and total deformation. The maximum von-mises stress and maximum deformation in multi leaf and mono leaf spring are shown in Fig. 8 to Fig.10.

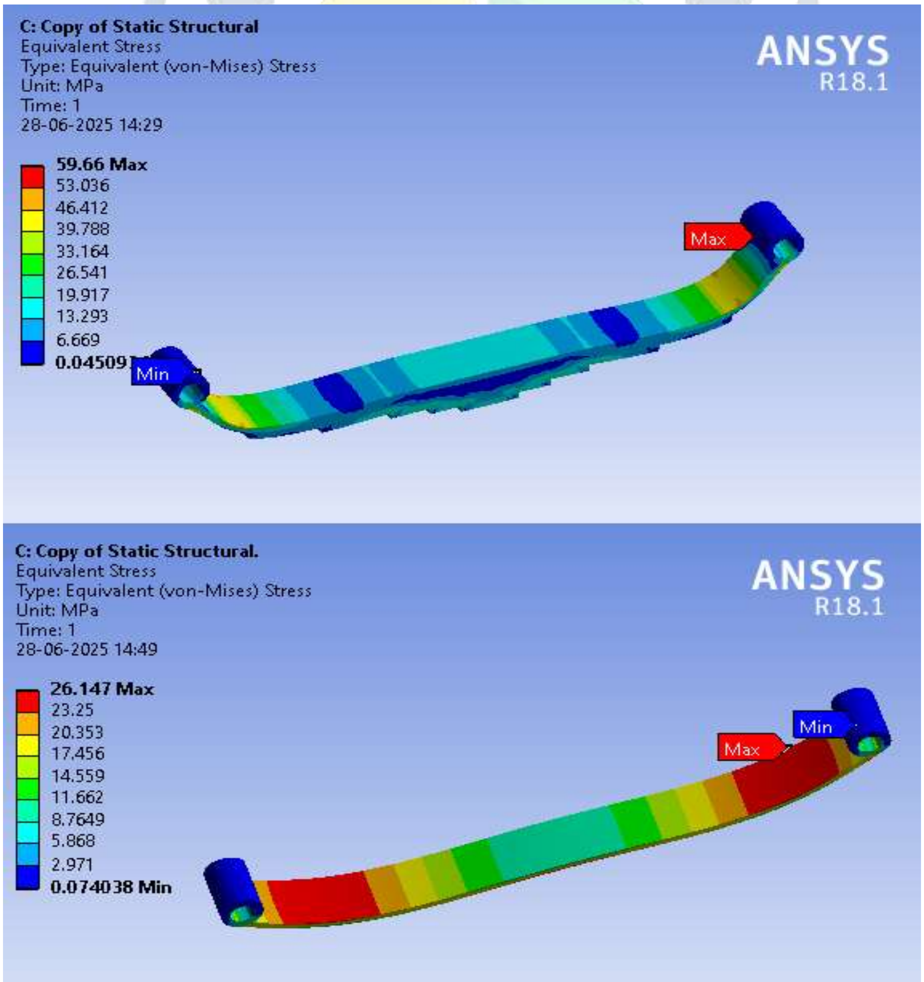

Fig. 8 Von-mises stress

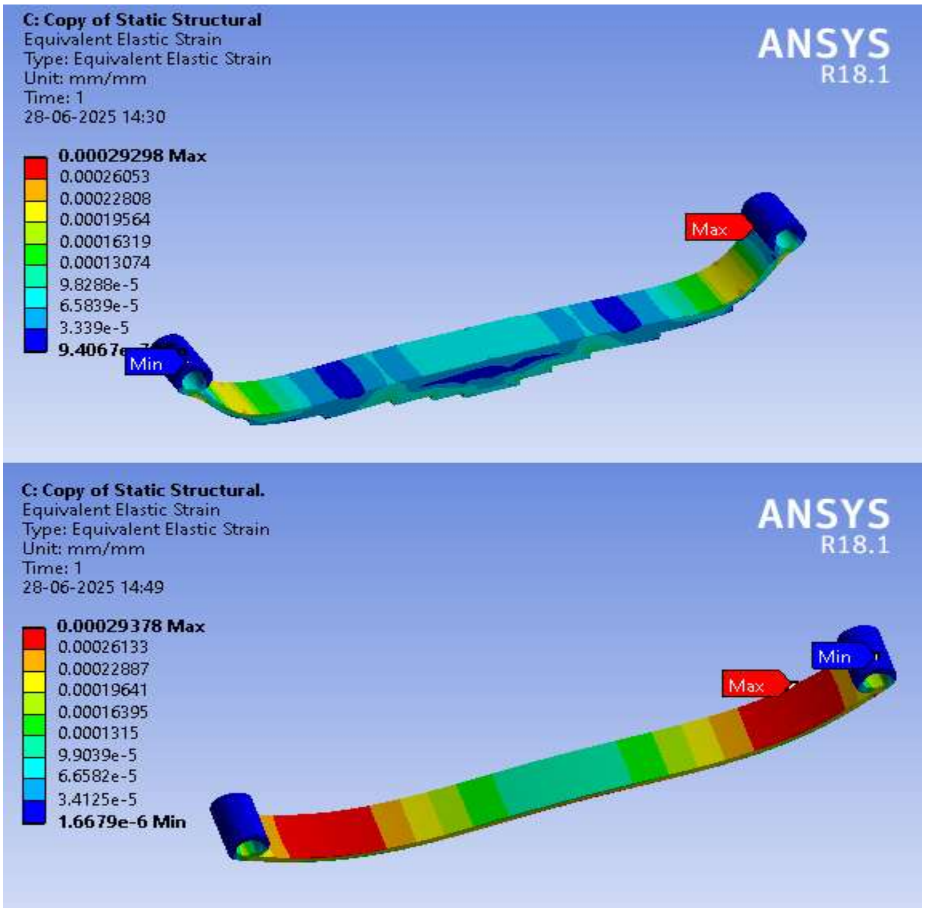

Fig.9 Equivalent Elastic Strain

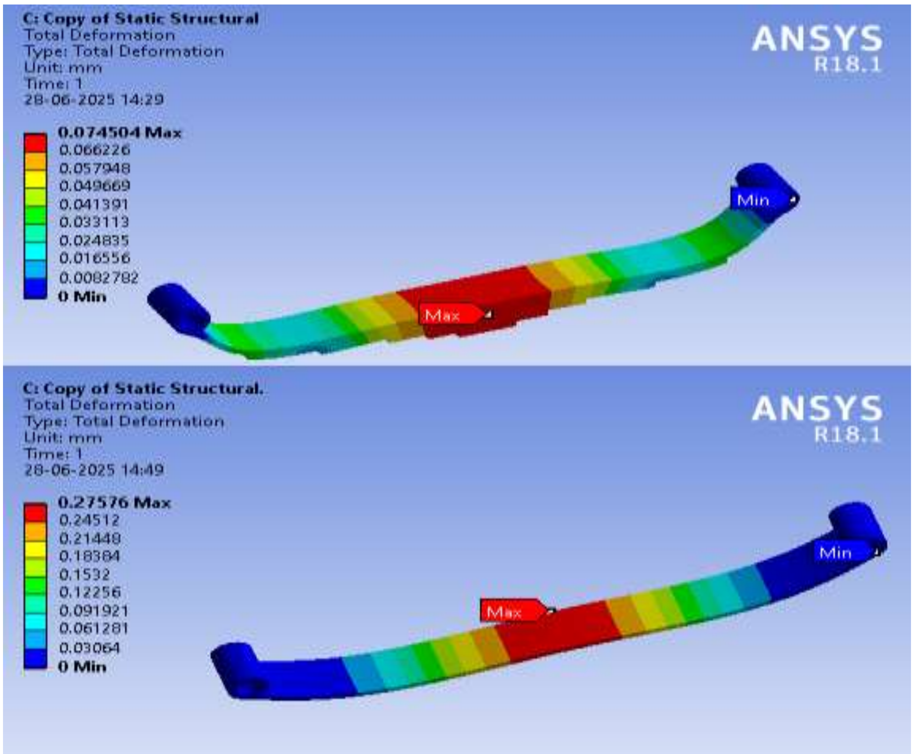

Fig.10 Total Deformation

Table 3 shows the result comparison for the maximum von-mises stress, maximum equivalent elastic strain and maximum deformation in EN45 steel[14] multi leaf spring and GFRP composite [15] mono leaf spring.

Table 3 Results Comparison

Properties	EN45 Steel	GFRP Composite
Von mises stress (MPa)	59.6	26.1
Equivalent Elastic Strain (mm/mm)	0.00029	0.00029
Total Deformation (mm)	0.074	0.275
Mass (Kg)	4.0	0.4

The mono leaf spring of GFRP composite has lower mass as compared to Multi leaf spring of AN45 Steel. Reducing the leaf spring mass in automobiles, we can achieve better riding comfort against hard braking and acceleration. Under the same static load conditions, the deformation, stress and strain in leaf springs shows that mono composite leaf spring is better than multi AN45 steel leaf spring.

V1. CONCLUSION

Finite Element Analysis of the leaf spring has been done using ANSYS Workbench. From the results obtained from FE Analysis, many discussions have been made. The model presented here, is well safe and under permissible limit of stresses. The following conclusions are drawn from the present work of static structural analysis of leaf spring:

i. It can be seen from the Fig. 8 that the maximum von mises stress in mono leaf spring is 26.1 MPa which is lower than the value of multi leaf spring having value of 59.6 MPa. This characteristic is beneficial in extending fatigue life and improving long-term performance under cyclic loading typical of urban E-Rickshaw operations.
ii. The maximum total deformation for multi leaf spring is .074 mm and for mono leaf sprig is 0.275 mm respectively. The modified composite spring exhibited little higher deflection under identical loading conditions, but in between the safe range. This indicates not much effect on stiffness and load-handling capacity
iii. The Equivalent Elastic Strain for multi leaf spring is 0.00029 mm/mm and for mono leaf sprig is 0.00029 mm/mm i.e. no change in the value.
iv. The mass of the Composite mono leaf spring is reduced by approx 89% without compromising its strength and functionality.

On the basis of the current work, it is concluded that the design parameters of proposed leaf spring with GFRP material give sufficient improvement in the existing results.

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