E is the modulus of elasticity and
ρ is the density.

Table 1: Properties of (65Si7) EN47 Steel leaf spring

Sr. No.	*Parameter*	*Value*
1	Young's Modulus E	2.1×105 MPa
2	Poisson's Ratio	0.266
3	Tensile Strength Ultimate	1272 MPa
4	Tensile Yield Strength	1158 MPa
5	Density	7.86×10-6 Kg/mm3

Table 2: Properties of E-Glass/ Epoxy composite leaf spring

Sr. No.	*Parameter*	*Value*
1	Tensile Strength (MPa)	900
2	Compressive Strength(MPa)	450
3	Possions Ratio	0.217
4	Density (kg/m^3)	2.16x10^5
5	Flexural modulus (E) (MPa)	40000

Table 3: Strain Energy Stored By Material (KJ/Kg)

Sr. No.	*Material*	*Strain Energy store by Material (KJ/Kg)*
1	Steel (65Si7)	0.3285
2	E-Glass/ Epoxy	4.5114

Throughout we find the composite material have better mechanical properties than conventional steel as the energy storage capacity of composite material is much higher than steel therefore it is the best material for application selected. Also from eq.1 the material with maximum strength and minimum modulus of elasticity is the most suitable material for leaf spring application.

4. Analysis

Analytical Design for Steel Leaf Spring:
Let,
Total Weight (W) = 2100 N
Thickness (t) = 8 mm
Leaf span, 2L= 860 mm
Width (b) = 60 mm
Total No of Leaves = 3
Now the Maximum Bending stress of a leaf spring is given by the formula [14]
Bending Stress, σb = 6FL / nbt2

= (6*2084*430) / (3*60*82)
= 466.84 MPa

The Total Deflection of the leaf spring is given by [14]

δmax = 6FL3/ Enbt3

= (6*2084*4303) / (2.1*105*3*60*83)
= 51.38 mm
For composite E-Glass/eproxy

FEA Analysis:

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. The stresses generated in composite leaf spring at full load are shown in fig.1.

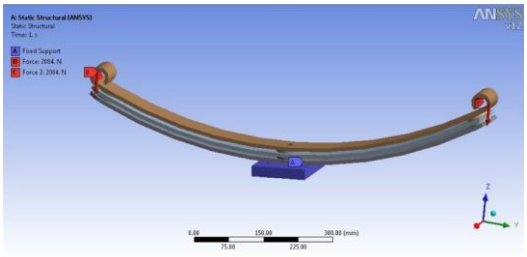

Figure 1: Meshed model of Steel Leaf Spring.

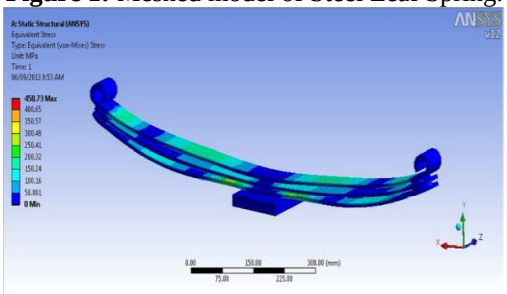

Figure 2: Bending Stresses of Steel Leaf Spring

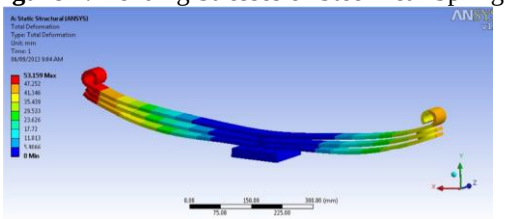

Figure 3: Total Deformation of Steel Leaf Spring.

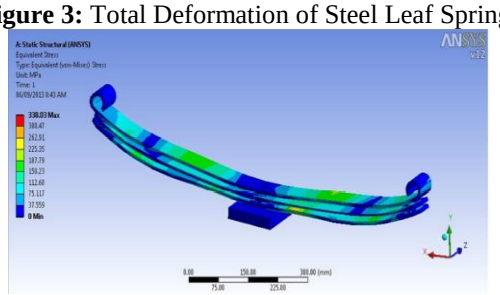

Figure 4: Bending Stresses of Composite Leaf Spring

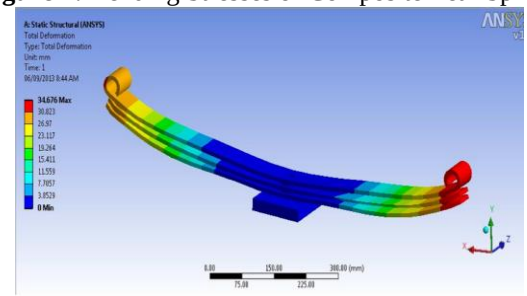

Figure 5: Total Deformation of Composite Leaf Spring

5. Result Table

From the results of static analysis of steel leaf spring, it is seen the displacement of leaf spring is 53.159 mm which is well below the camber length of leaf spring shown in fig.4. It is seen that the maximum bending stress is about 450.73MPa, which less than the yield strength of the material is shown in

fig.3. The FEA results are compared with the theoretical results and found that the theoretical result and FEA result are nearer to each other.

Table 4: Result comparison between steel and composite leaf spring

Parameter	*Theoretical Results for steel leaf spring*	*FEA Results for steel leaf spring*	*Variation*
Load, N	4169	4169	NIL
Bending Stress, MPa	466.84	450.73	3.04 %
Total Deflection, mm	51.24	53.159	3.06 %

After that the multi leaf spring with E-Glass/Epoxy material is analyzed in ANSYS-12 with same dimension and same boundary condition as that of conventional leaf spring, showing bending stress and deflection under load in figures.4 & 5. The comparison between steel leaf spring and composite leaf spring for deflection and bending stress results from the ANSYS is shown in the Table 5

Table 5: FEA results comparison between steel and composite leaf spring

Parameter	*FEA Results for steel leaf spring*	*FEA Results for Composite Leaf Spring*	*Variation*
Load, N	4169	4169	NIL
Bending Stress, MPa	450.73	338.03	-25.08 %
Total Deflection, mm	53.159	34.66	-34.77 %

By the comparison of results between steel leaf spring and the composite leaf spring from ANSYS-12 the deflection is decreased by 34.76 % in composite leaf spring that is within the camber range. The bending stresses are decreased by 25.05% in composite leaf spring means less stress induced with same load carrying conditions. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring. Totally it is found that the composite leaf spring is the better that of steel leaf spring.

Table 6: Percent saving of weight by using composites

Materials	*Weights*	*% weight saving*
Conventional Steel	10.27 kg	-----
E-glass/epoxy	3.26 kg	67.88%

6. Conclusion

In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring.

- A semi-elliptical multi leaf spring is designed for a four wheel automobile and replaced with a composite multi leaf spring made of E-glass/epoxy composites.
- Under the same static load conditions the stresses and the deflection in leaf springs are found with great difference. Stresses and deflection in composite leaf springs is found out to be less as compared to the conventional steel leaf springs.
- All the FEA results are compared with the theoretical results and it is found that they are within the allowable limits and nearly equal to the theoretical results.
- A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 67.88% for E-Glass/Epoxy.
- E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view.

Totally it is found that the composite leaf spring is the better that of steel leaf spring. Therefore, it is concluded that composite multi leaf spring is an effective replacement for the existing steel leaf spring in vehicles

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