Design and analysis of composite leaf spring for TATA 407 truck

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Abstract - *Leaf spring is one of the fundamental components and it gives a brilliant suspension. Shocks and struts are critical for riding safety. Their function is to maintain the tyres on the street via way of means of controlling spring and suspension moves and through keeping a vertical load at the tyres. The primary purpose of the suspension machinery is to damp the vibrations because of street irregularities. It additionally helps to permit fast cornering without intense rolling. It performs a important function in automobile handling mainly in rolling, braking. The better the suspension is mounted, the better the CG of the vehicle shifts from the floor which in turn results into growth in tendency of rolling. The suspension system accounts to 15-20 % of unsprung weight of the automobile. Unsprung weight is the load that is not supported through the suspension which incorporates wheel axles, wheel bearings, wheel hubs, tires, and a part of the load of driveshafts, springs, shock absorbers, and suspension links. There are one-of-a-kind varieties of suspension system, however in this research, leaf springs are being studied.*

Key Words: **Suspension, Leaf Spring, Automobile, Vibration, Riding Safety.**

1. INTRODUCTION

The springs, shock absorbers, and connectors that connect the vehicle to the wheel are referred to as the "suspension system.". The suspension system's primary function is to dampen vibrations caused by road irregularities. It also serves as a support weight, allowing for quick cornering without excessive rolling. It's important for car control, especially when it comes to rolling and braking. The higher the suspension, the further the car's centre of gravity is shifted away from the ground, increasing the chances of rolling. The suspension system accounts for 15-20% of the vehicle's unsprung weight. Wheel axles, wheel bearings, wheel hubs, tyres, and a percentage of the weight of driveshafts, springs, shock absorbers, and suspension links are all examples of unsprung weight that is not supported by the suspension. Suspension systems come in a variety of shapes and sizes, but leaf springs are the focus of this study.

1.1 Methodology

- Reverse Engineering.
- Design of leaf spring using calculation.
- Design of 3D model of leaf spring by using solidworks.
- Static analysis of leaf spring for various composite materials by using ANSYS software.
- Comparison of results.

1.2 Theory of leaf spring

Engineering materials constructed from two or more constituent materials that remain separate and distinct on a macroscopic level while creating a single component are known as composite materials. The two categories of component materials are matrix and reinforcement. The matrix materials' principal tasks are to transfer stresses between reinforcing elements and to protect them from mechanical and/or environmental degradation, whereas the presence of fibers/particles in a composite increases mechanical qualities such as strength, stiffness, and so on. By preserving their relative locations, the matrix material surrounds and supports the reinforcement or fibre elements. The mechanical and physical features of the reinforcing material improve the matrix quality.

1.3 Principle of leaf spring

A leaf spring is commonly used for the suspension in vehicles. The suspension of leaf spring is that the area which needs to focus to enhance the suspensions of the vehicle for comfort ride. The suspension spring is one among the potential items for weight reduction in automobiles because it accounts for 10% to 20% of unsprung weight. it's well known that springs are designed to absorb shocks. therefore, the strain energy of the material becomes a significant consider designing the springs. The introduction of composite material will make it possible to reduce the load of the leaf spring without reduction in load carrying capacity and stiffness. Since the composite material encompasses a high strength to weight ratio and has more elastic strain energy storage capacity as compared with steel. The relationship of specific strain energy is often expressed as: $U = \sigma 2 / 2Pe$

It can be observed that material having lower density and modulus have a greater specific strain energy capacity. Thus, composite material offers high strength and light-weight. The leaf spring of a Tata "Model-407" motor vehicle is used in this study for further analysis. By reducing vertical vibrations, hits, and bumps caused by road irregularities, the suspension quality can be enhanced, resulting in a more comfortable ride. The vehicle industry is introducing a variety of cars that are newly developed and updated with sophisticated and composite materials to provide a more comfortable ride, lower weight, and superior mechanical qualities.

1.4 Comparison with metals

- Composites are long-lasting.
- Composites are lighter in weight and can resist higher temperatures than metals.
- Composites have a high elasticity modulus.

2. Experimental setup

The data of TATA 407 truck is taken. Total weight of the vehicle is 4450 Kg.

Length of the leaf spring = 1428.8 mm.

Factor of safety = 2.5.

Elasticity = 207000 MPa.

The force is the product of weight of the vehicle and the acceleration due to gravity

$$F = 4450 \times 9.81 = 43665.5 \text{ N}$$

Since the vehicle is 4-wheeler the one fourth of the force can be sustained by single leaf spring.

$$43665.5 \div 4 = 10913.62 \text{ N}$$

The leaf spring acts as a simply supported beam so, the force on one end of leaf spring can be calculated as

$$2F = 10913.62$$

Therefore, the force is 5456.81 N.

$$2L = 1428.8$$

$$L = 714.4 \text{ mm}$$

There are two equations to calculate the thickness (t) and width (b) of leaf spring.

i. σ (stress) = $3FL/bh^3$

ii. δ (deflection) = $3FL/Ebh^3$

By re-arranging and putting the values of force and length, the values of b and t are 80mm and 16mm respectively.

The values of maximum stress and maximum deflection can be calculated by putting the values of b, t, F, L and E in the above two equations.

Thus, the values of the maximum stress and maximum deflection are 571.04 N/mm^2 and 87.99mm.

To calculate the camber of leaf spring,

$$C/L = 0.089$$

Therefore, the camber value is 127.16mm.

3. Results and discussion

3.1 Load Vs Deformation

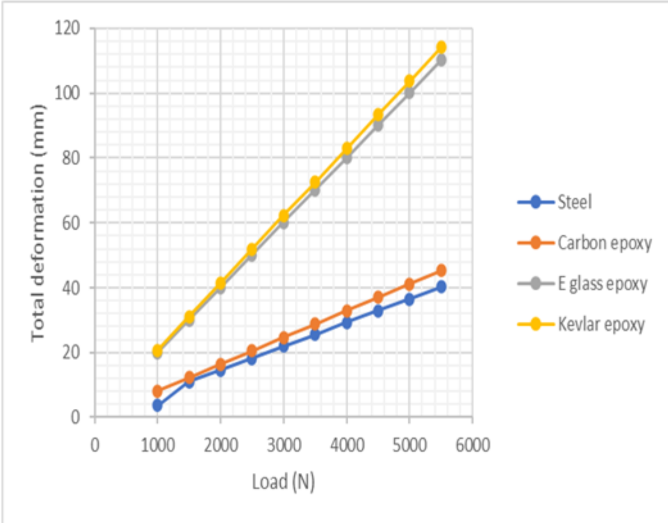

Chart -1: Load Vs deformation

The chart represents the load vs deformation of various materials. The Carbon epoxy and Structural Steel readings are almost identical to each other. The Kevlar epoxy and E glass epoxy are almost showing the same properties.

The maximum deflection of Carbon epoxy and Structural Steel are less than 50 mm, the deflection of Kevlar epoxy and E-glass epoxy are greater than 100 mm which is not feasible according to design configuration. So, the Kevlar and E-glass epoxy fail in design configuration and hence cannot be used as a material for leaf spring.

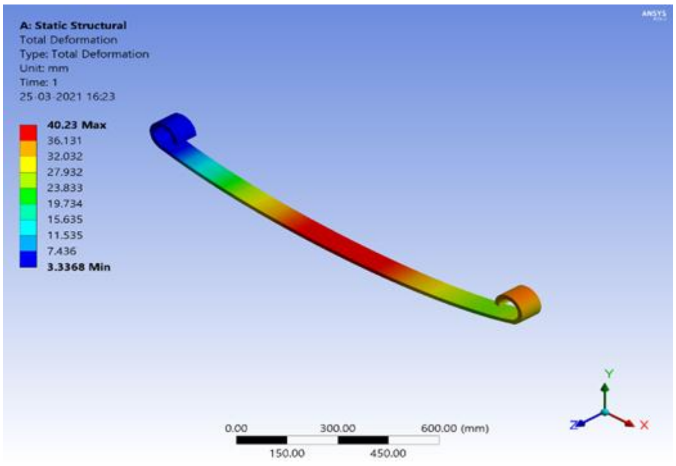

Fig -1: Schematic diagram of deformation (Steel)

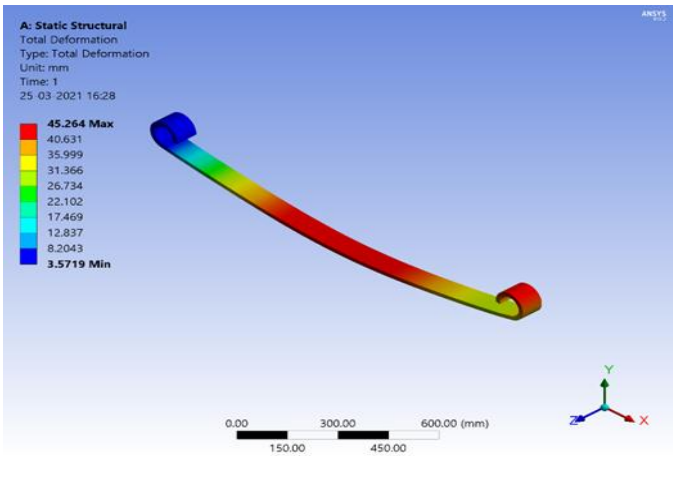

Fig -2: Schematic diagram of deformation (Carbon epoxy)

The schematic diagrams represent the static analysis of maximum deformation against the maximum load for various materials such as Structural Steel, Carbon epoxy, E-glass epoxy and Kevlar epoxy respectively. The highlighted red part in the above schematic diagrams show the maximum deflection and the blue part shows the minimum deflection of the leaf spring.

The maximum deflection is at the centre of the leaf spring because the leaf spring acts a simply supported beam and the force is on mid span of the length of leaf spring and causes it to deform.

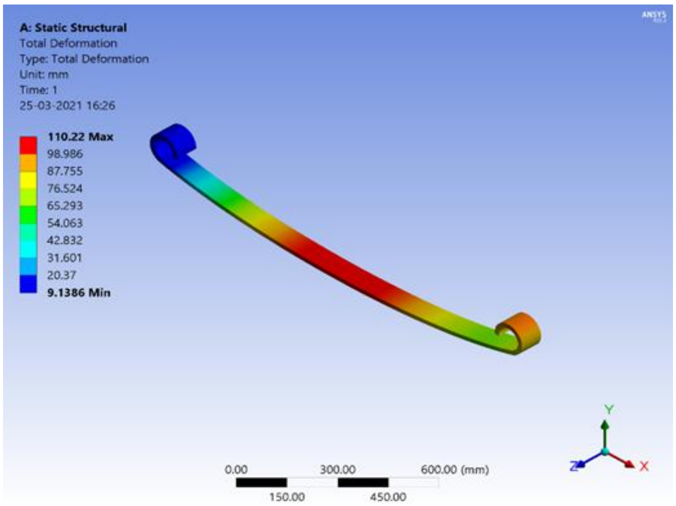

Fig -3: Schematic diagram of deformation (E-glass epoxy)

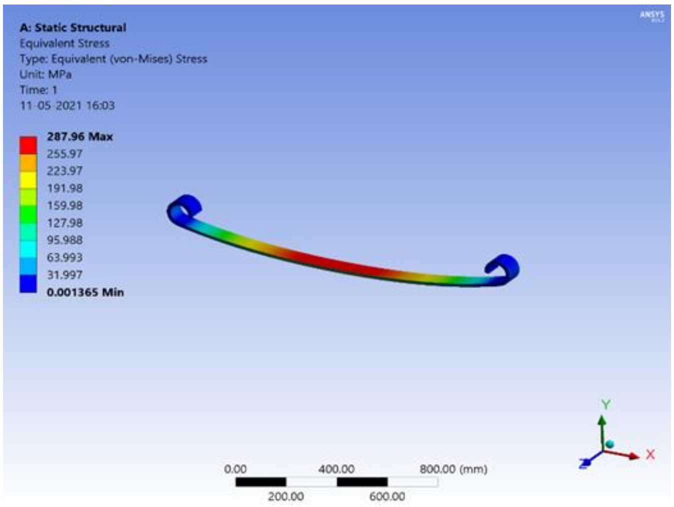

Fig -4: Schematic diagram of deformation (Kevlar epoxy)

3.2 Load Vs Equivalent (von-mises) stress

The chart represents the load vs equivalent stress for various materials such as Steel, Carbon epoxy, E-glass epoxy and Kevlar epoxy respectively. The carbon epoxy is sustaining the large amount of stress at maximum load as compare to the other given materials. The other materials such as Steel, E-glass epoxy and Kevlar epoxy are sustaining nearly same amount of stress at the given load.

The values of stress which are sustained by the Steel, Carbon epoxy, E-glass epoxy and Kevlar epoxy are 287.96MPa, 313.77MPa, 287.57MPa and 287.48MPa respectively

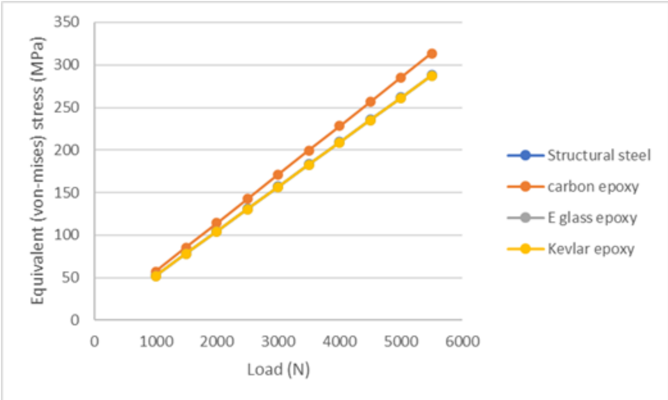

Chart -2: Load Vs Equivalent (von-mises) stress

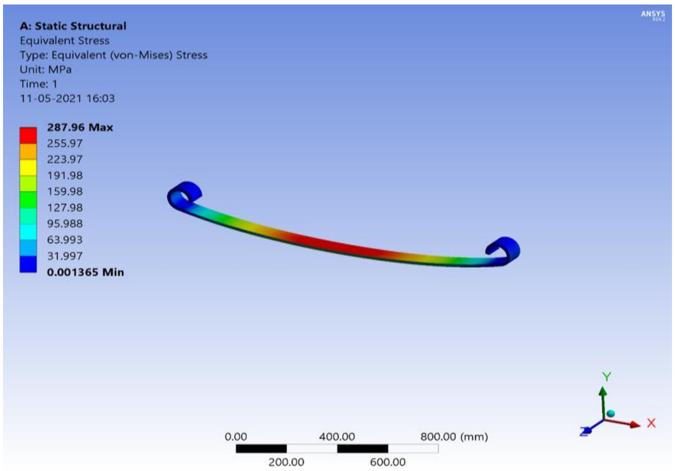

Fig -5: Schematic diagram of equivalent stress (Steel)

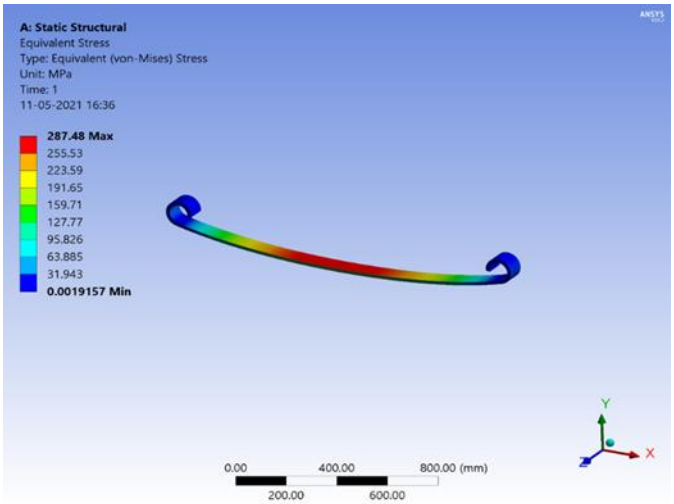

Fig -6: Schematic diagram of equivalent stress (Carbon epoxy)

The above schematic diagrams represent the static analysis of equivalent (von-mises) stress against the maximum load for various materials such as Structural Steel, Carbon epoxy, E-glass epoxy and Kevlar epoxy respectively. The highlighted red part in the above schematic diagrams shows the maximum stress and the blue part shows the minimum stress induced in the leaf spring.

The maximum stress areas are showing that the force induced in that area is maximum. Thus, induces the stress in that particular area.

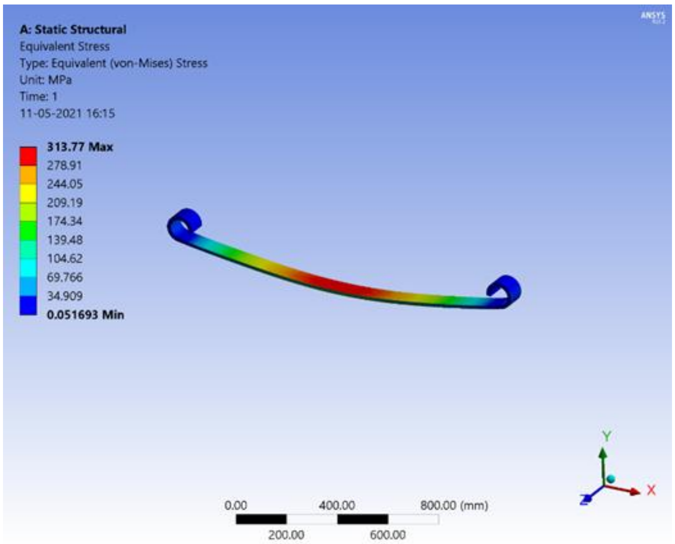

Fig -7: Schematic diagram of equivalent stress (E glass epoxy)

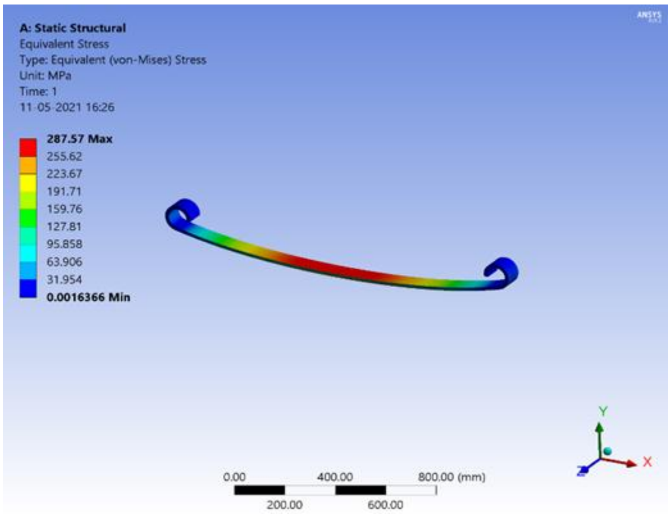

Fig -8: Schematic diagram of equivalent stress (Kevlar epoxy)

3.3. Load Vs maximum principal elastic strain

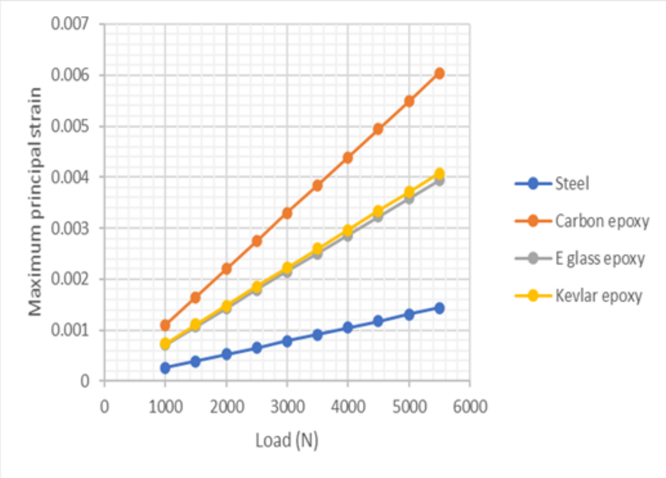

Chart -2: Load Vs maximum principal elastic strain

The above chart represents the maximum load vs maximum principal elastic strain of various materials. Here the Carbon epoxy has the maximum value of maximum principal elastic strain which is 0.006.

The Kevlar and E-glass epoxy have the value of 0.004 and the structural steel has the value 0.002 which is less than the other materials.

3.4. Load Vs strain energy

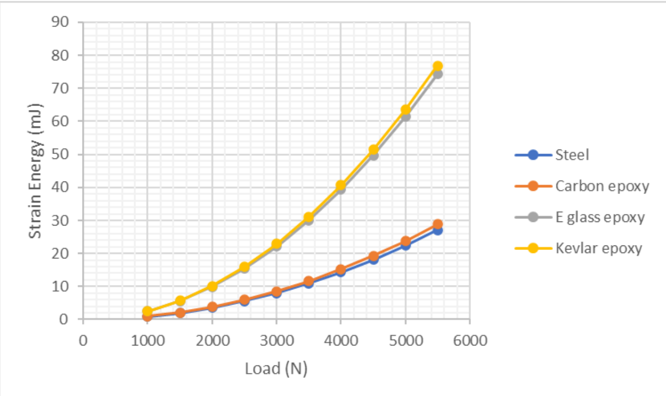

Chart -3: Load Vs strain energy

The above graph represents the load vs strain energy of various materials. By observing the graph, In this case study the values of Structural Steel and Carbon epoxy and Kevlar and E-glass epoxy are almost identical to each other.

The strain energy storing capacity of Steel and Carbon epoxy are almost 30 mJ. The strain energy storing capacity of Kevlar epoxy and E glass epoxy are almost 80 mJ.

3.5 Weight reduction of composite materials with respect to the structural steel

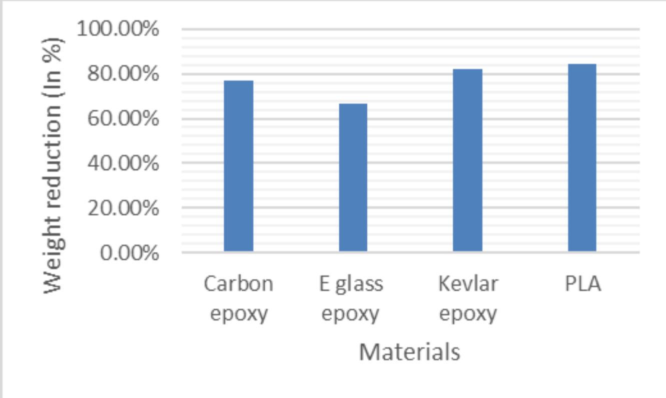

Chart -3: Weight reduction of composite materials with respect to the structural steel

The objective of this project is to achieve weight reduction above 50% in comparison with the conventional steel leaf spring. After the analysis the results for weight reduction are greater than 50%.

By observing the above chart of the weight reduction of Carbon, Kevlar, E glass epoxy and PLA is 77.07%, 82.16%, 66.87% and 84.07% respectively in comparison with the weight of conventional Steel leaf spring. The weight of the conventional leaf spring is 18.84 Kg.

The readings of composite material PLA is taken only to inspect whether it is suitable to use as a material for leaf spring. It has given the reduction of 84.07% but cannot be used as a material for leaf spring.

4. Conclusion

As lowering weight and increasing strength of components of vehicles are the most demanded research topics around the globe, composite materials are getting to be up to the mark of satisfying these needs. In this paper lowering weight of automobiles and increasing the strength of the components is considered.

As leaf spring contributes sizable quantity of weight to the vehicle and needs to be strong enough, a single composite leaf spring is designed and it is shown that the resulting design and simulation stresses are much below the strength properties of the material satisfying the utmost stress failure criterion.

From the static analysis results, we see that the deflection in the steel is 40.23 mm. And the deformation in E-glass epoxy, Kevlar epoxy and Carbon epoxy is 110.22mm, 114.12mm and 45.264mm respectively. Among the three composite leaf springs, only carbon epoxy has the less deflection which is under design configuration. Carbon epoxy composite leaf spring can be suggested for replacing the steel leaf spring from the analysis. In terms of strength and weight, a comparison was made between steel and composite leaf springs. Composite PLA leaf spring reduces the weight by 84.07 % for E-Glass Epoxy 66.87% for Kevlar Epoxy 82.16% and 77.07% for Carbon Epoxy over conventional leaf spring.

The Composite material has a moderate deflection w.r.t load as compared to steel hence composite material is better than steel on base of deflection. As we consider the stiffness the composite material has a higher stiffness than the steel leaf spring hence it is better than steel. Gerber and Goodman approach is found to give better results for the analysis of life data for parabolic leaf springs. According to total life approach, the fatigue life of Carbon Epoxy composite parabolic leaf spring is higher than that of steel EN45 parabolic leaf spring. From the aforementioned points it can be concluded that replacing conventional Steel leaf spring with Carbon epoxy leaf spring results in tremendous weight reduction, increases overall engine efficiency.

4.1. Future scope

The design and analysis of the leaf spring is carried out by the analytical method and static analysis, one can validate the results by manufacturing the prototype and by performing the dynamic tests on it.

Use of UTM (Universal Testing Machine) to find out the actual results and to compare the results carried out by dynamic analysis with static analysis for validation of this project.

Vibration analysis of leaf spring is to be carried out for material fatigue analysis.

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