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DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING FOR LIGHT MOTOR VEHICLE

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Abstract : Reducing weight while increasing or maintaining strength of products is becoming a highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions to such issues. As the leaf spring contributes a considerable amount of weight to the vehicle and it needs to be strong enough, the achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel spring.

The main function of leaf spring assembly as suspension element is not only to support vertical load, but also to isolate road-induced vibrations. The Automobile Industry has great interest in the replacement of steel leaf springs with composite leaf springs, Since the composite materials have high strength to weight ratio, good corrosion resistance. The leaf spring should have low mass, low displacement and high fatigue life. The aim of this project is to design and analyze the leaf spring using different composite materials. The development of the leaf spring model is done using CATIA V5 and the analysis part is done in ANSYS V10 software.

***IndexTerms*–Suspension System, Design and Analysis, CATIA.**

I. INTRODUCTION

In automobile engineering, one process which is known as comfort vehicle design (CVD) is done to make the vehicle more comfortable and safer. Apart from safety the big challenge is weight reduction while maintaining the desired factor of safety. Weight reduction is a very important design criteria for vehicles as it reduces the fuel consumption which reduces the running cost and has a very positive impact on the environment by reducing the level of pollution. The present work is the analysis of Leaf spring which is a very important part of any suspension system. The vibration, bending and stress analysis was done for Leaf spring for both the conventional as well as for advanced composite materials.

1.1 Suspension system

To reduce the effects of shocks and vibrations on the occupant of the vehicle, some sort of springs and shock absorbers are used to mount the automobile frame and body on the front and rear axle. The parts which are involved to carry out this function are basically called a suspension system. The most comfortable ride we enjoy today is attributed to modern advances in suspension system.

1.2 Importance of suspension system

- To isolate the vehicle from disturbances this leads to better vehicle control with a comfortable ride.
- To minimize the rolling and flipping over of the vehicle by maintaining the wheel.
- To maintain contact with the ground all the time, this improves the safety and overall performance of the vehicle.
- To have better road holding while taking turns, accelerating or braking.
- To maintain directional stability.

As the analysis of leaf spring is the core area of this research work, the detailed discussion of springs is quite important to be done to have a better understanding.

1.3 Functions of spring

- Springs are used to absorb unwanted energy resulting from shocks and vibrations.
- In automobile, rail-wagons etc.
- Springs are used to store energy like clocks, toys etc.
- It is used to measure force e.g., Spring balance and gauges.
- It is used to apply force in valves, clutches, and brakes etc.

- Springs are used to maintain contact between two elements, e.g., cam and follower mechanism

1.4 Leaf Spring

Leaf springs are the key element of any suspension system. They are designed not only to absorb road shocks, but also to carry lateral loads, driving torques, braking torques etc. It consists of a bundle of thin, long, curved strips joined by a bolt at the center. The spring eyes are made on the master leaf, which is the longest leaf of a leaf spring. The rear end is connected to the frame with a swinging arm called shackle. The spring is held to the axle with the help of U-bolt as shown in the Fig.1.3.

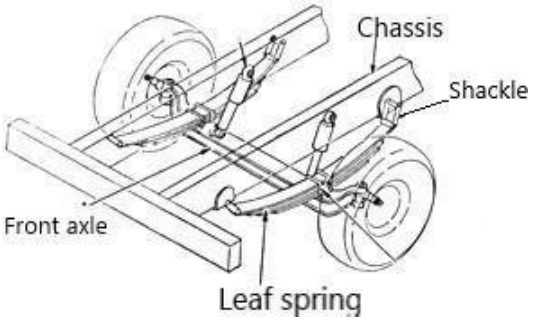

Fig. 1.1 Leaf spring view

1.5 Materials used for leaf spring

Minimization of weight is an important requirement in automobile design as the fuel efficiency of the vehicle will have a direct effect on the change in weight. As far as the weight of springs are concerned it has a very significant effect on the quality of ride as it is supposed to be in the category of us-sprung or semi-sprung mass. Thus, the weight reduction in leaf spring, drive shaft and wheel is greatly monitored as it is the main constituent of unsprung weight of a vehicle. Thus, the selection of the material for leaf spring is an important factor which can satisfy many of the design requirements. The required characteristics of the leaf spring the strength to weight ratio should be high, It should have high resilience, good vibration absorbing capacity, Good corrosion resistance and High fatigue strength.

The conventional materials springs are Plain carbon steel, Chrome vanadium steel, Manganese Silicon steel and Chrome Nickel- Molybdenum steel etc. Apart from the conventional materials mentioned above there are various other materials like composite are tried for springs to have better performance with less weight ,like carbon/epoxy, glass/epoxy, glass-carbon/epoxy etc. Are being tested and used.

II. Literature Survey

There are various researches on composite leaf spring for various types of vehicle Syambabu Nutalapati [1] have compared the stresses, deformation and weight saving of composite leaf spring with that of steel leaf spring. Gulur Siddaramanna et al [2] presented a low-cost fabrication of complete mono composite leaf spring with bonded end joints. T.N.V. Ashok Kumar et.al [3] described static and dynamic analysis of steel leaf spring and laminated composite Multi leaf spring. Their objective is to compare displacement, frequencies, deflections and weight savings of composite leaf spring with that of steel leaf spring. achieved weight reduction of 27.5 % by using composite leaf springs.

Mahmood M. shokrieh , et al[4] have made a composite one made from fiberglass with epoxy resin that is designed and optimized using ANSYS. Devendra. K Damor, et al [5] In this project they described the design and analysis of a composite leaf spring made of glass fiber reinforced polym. M. Arther clive [6] Describes the design and analysis of composite leaf springs. Their objective is to compare the deflection, equivalent elastic strain and equivalent stress of carbon epoxy Carbon fiber, E glass epoxy over conventional leaf spring. Vaibhav Edake, et al [7] Designed the leaf spring with the standard dimensions and analyzed in ANSYS for maximum and minimum stress regions.

Chatwant Singh Pandher, et la [8] Their research paper presents the general study, fabrication, static and fatigue analysis on carbon epoxy composite leaf spring. A rear leaf spring of Tata Ace (mini truck) made of EN45 spring steel was selected as practical application. Results shows that deflection of carbon epoxy composite leaf spring is 14% less as compared to the steel leaf spring which means increase in stiffness. Sorathiya Mehul, et al [9[This research describes static analysis of steel leaf spring and laminated composite Multi leaf spring. Their objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. A weight reduction of 79.617 % is achieved by using composite leaf springs. And if considered Mono leaf spring then Weight reduction achieved is 90.09%.

Hishay Amare Gebremeskel [10] designed composite leaf spring has achieved its acceptable fatigue life. He made sure that the material is satisfying the maximum stress failure criterion. the prototype is also produced using a hand lay-up method. Achamyeleh A Kassie1, et al [11] He Compared material to steel spring, the composite leaf spring has lesser stress, higher stiffness and higher natural frequency.

M.venkatesan, et al [13] described the design and experimental analysis of a composite leaf spring made of glass fiber reinforced polymer. Comparing significance and properties of composite leaf spring that of steel leaf spring. They noted down the dimensions of light commercial vehicles. The same dimensions are used to fabricate composite leaf springs.

III. METHODOLOGY

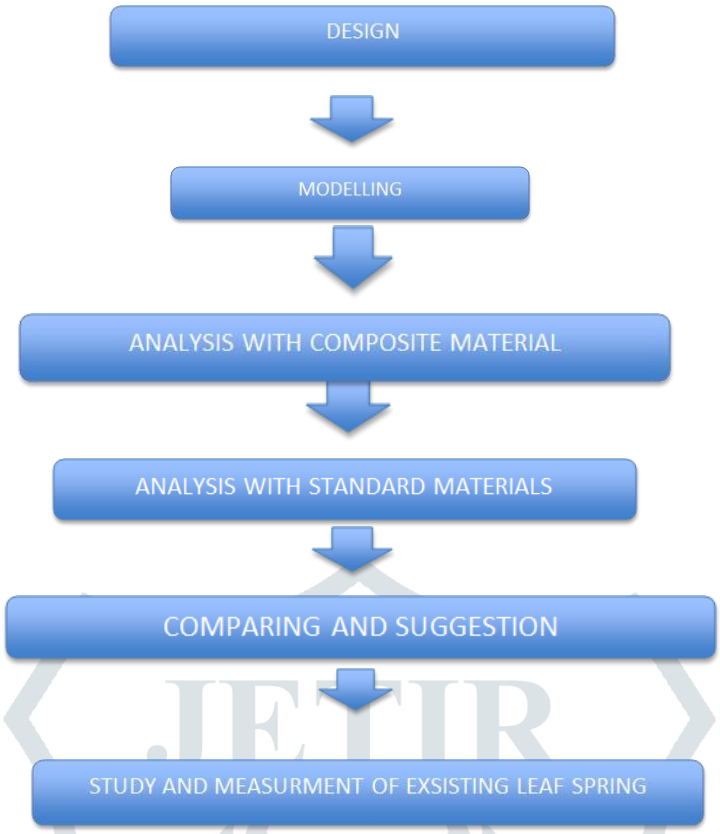

Fig. 3.1 Methodology Flow Chart

Our methodology for the project is to start with literature review, understand the different constraints considered for designing leaf springs and performing static and dynamic analysis of the designed 3D model with selected composite materials. Evaluating the designed composite material model with the conventional steel model and justifying best material for leaf spring in heavy vehicles.

IV. DESIGN OF LEAF SPRING

4.1 Selection of cross section

The different cross-sections used for mono-leaf spring for manufacturing easiness are Constant thickness, varying width design, Varying width, varying thickness design, and Constant thickness, constant width design In the present work, only a constant cross-section design method is selected due to the following reasons: due to its capability for mass production and accommodation of continuous reinforcement of fibers. Since the cross-section area is constant throughout the leaf spring, same quantity of reinforcement fiber and resin can be fed continuously during manufacturing.

Table 4.1 Specifications of TATA ACE leaf spring and Material properties of conventional material Properties s of the material

Sr.no	Design parameter	Value
1	Total length of spring(L)	1034mm
2	Length of spring from eye to eye	865mm
3	Thickness(t)	8mm
4	Width of leaf spring(b)	60mm
5	Young's Modulus E(MPa)	8.6E+9
6	Poisson's Ratio	0.27
7	Tensile Strength Ultimate (MPa)	3.5E+07
8	Compressive Strength (MPa)	-1E+08
9	Density (km/mm^3)	1490

Table 4.2 Properties of Epoxy Carbon leaf spring

Sr no.	Parameter	Value
1	Young's Modulus E(MPa)	8.6E+9
2	Poisson's Ratio	0.27
3	Tensile Strength Ultimate (MPa)	3.5E+07
4	Compressive Strength (MPa)	-1E+08
5	Density (km/mm^3)	1490
6	Tensile Strength (MPa)	3.5E+07
7	Compressive Strength (MPa)	-1.2E+08
8	Poisson's Ratio	0.3
9	Density (Kg/m^3)	2000

Table 4.3 Properties of E-glass/ Epoxy composite leaf spring

Sr no.	Parameter	Value
1	Tensile Strength (MPa)	3.5E+07
2	Poisson's Ratio	0.3
3	Density (km/m^3)	2000
4	Young's Modulus (MPa)	8E+09

V. ANALYSIS OF LEAF SPRING

Static analysis has been performed using ANSYS, by making the eye points of the Leaf Spring constraint. A load of 8191.35 N is considered as the force is observed at the middle of the Leaf Spring. Considering the center of the leaf spring, two constraint points are fixed on either side of the LeafSpring.

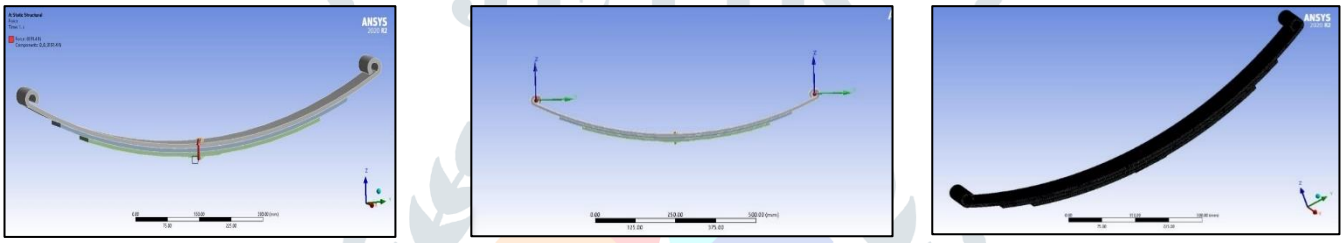

Fig. 5.1 Modeling of Leaf spring in CATIA

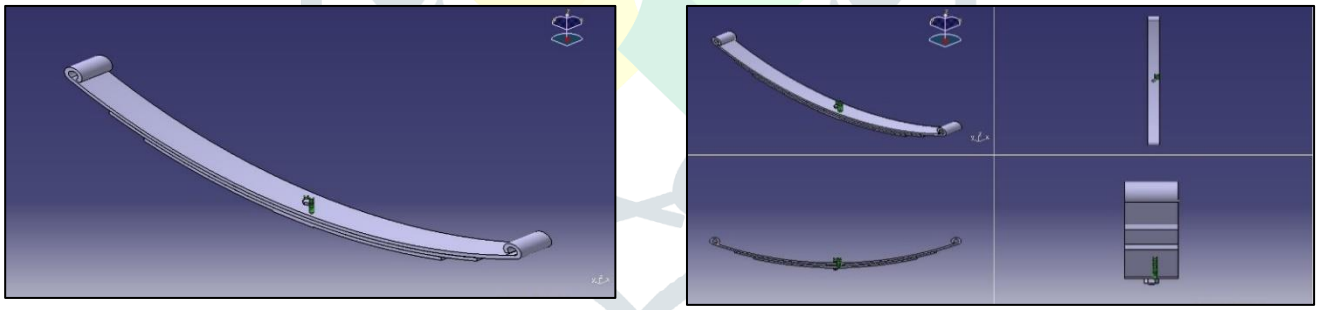

Fig. 5.1 Constraint Points of Leaf Spring and Meshed Model of Leaf Spring

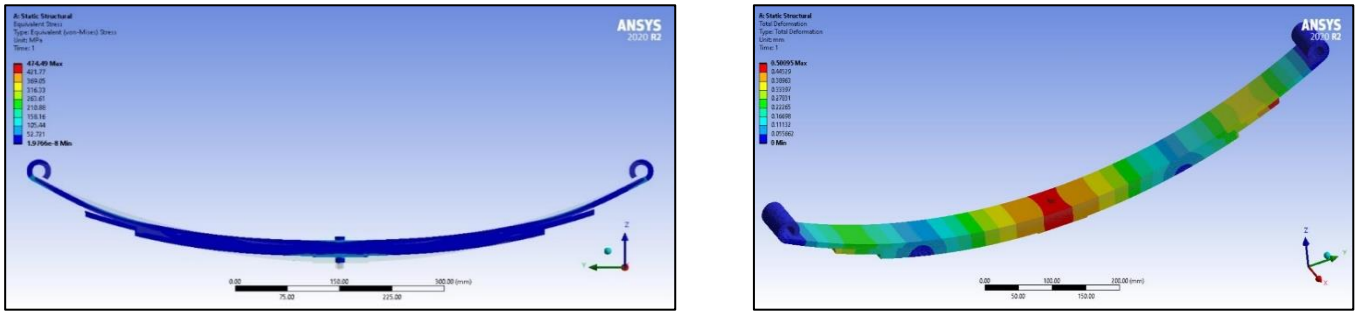

Fig. 5.2 Stress Distribution and Deformation of Structural steel

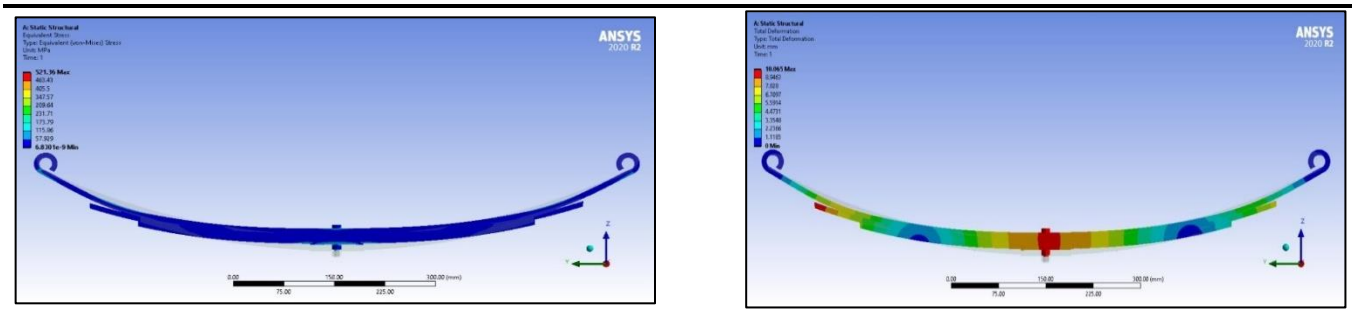

Fig. 5.3 Stress Distribution and Deformation of E-glass Epoxy

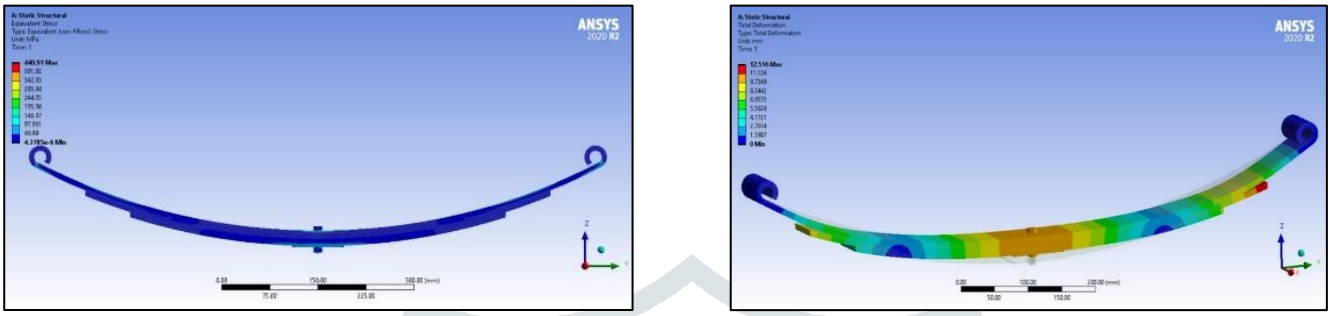

Fig. 5.4 Stress Distribution and Deformation of S-Glass Epoxy

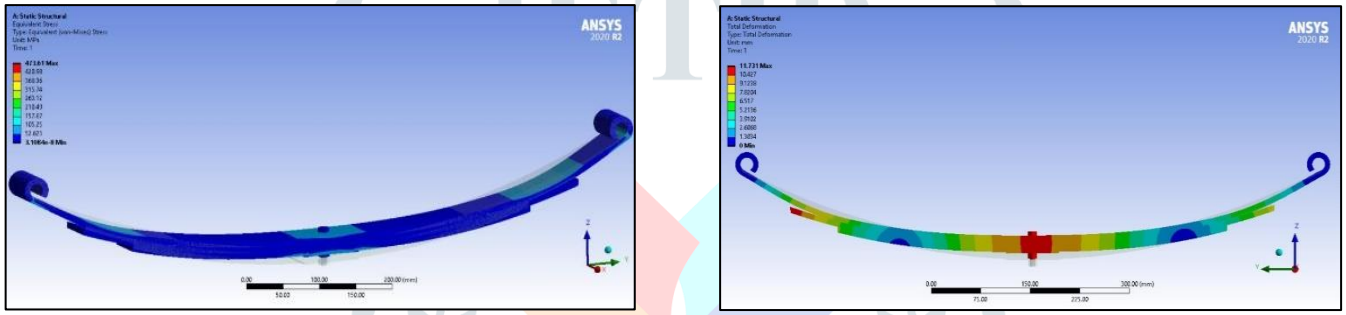

Fig. 5.5 Stress Distribution and Deformation of Epoxy Carbon Fiber

It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of composite materials made it possible to reduce the weight of the leaf spring without reduction of load carrying capacity and stiffness due to the following factors of composite materials as compared to steel. One of the advantages of composite is that two or more materials could be combined to take advantage of the good characteristics of each.

VI. Results and Discussions

Reducing weight and increasing strength of products are high research demands in the automobile industries. Composite materials are getting to be up to the mark of satisfying these demands. Leaf spring is designed by using Ansys software used by researchers as it gives good results. Hand lay- up manufacturing methods are used which are economical and most suitable. In almost all papers it is concluded that composite with the E-glass / epoxy leaf spring are lighter, high strength, more economical than conventional leaf springs. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of composite materials made it possible to reduce the weight of the leaf spring without reduction of load carrying capacity and stiffness due to the following factors of composite materials as compared to steel. One of the advantages of composite is that two or more materials could be combined to take advantage of the good characteristics of Each.

Table 6.1 Comparison between the results obtained by Static loading

Property	Structural steel	E-glass Epoxy	S-glass Epoxy	Epoxy CarbonFiber
Equivalent Stress	440.91	474.49	521.36	473.61
Deformation	0.50095	10.065	12.516	11.731

From the above comparison, the maximum Equivalent Stress is observed in E-Glass Epoxy material as that of other three materials. As well as the maximum deformation is observed in S- Glass epoxy composite material.

VII. CONCLUSIONS

As reducing weight and increasing strength of products are high research demands in the world, composite materials are getting to be up to the mark of satisfying these demands. In this paper reducing weight of vehicles and increasing the strength of their spare parts is considered. As leaf spring contributes considerable amount 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 maximum stress failure criterion.

From the static analysis results, we see that the von-mises stress in the steel is 440.91 MPa. And the von-mises stress in E-glass/epoxy, S-glass/epoxy and Carbon/epoxy is 474.49 MPa, 521.36 MPa and 473.61 MPa respectively. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view. 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 60% for E-Glass/Epoxy, over conventional leaf spring.

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