DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING BY USING ANSYS V15

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Abstract: — In recent year automobile industries are mostly concentrating on weight reduction and in improving the riding quality. To reduce vehicle weight, three techniques have been studied rationalizing the body structure, utilizing lightweight materials for parts and decreasing the size of the vehicles. In this approach by introducing composite materials into automobile industries, which is having low cost, high strength to weight ratio and excellent corrosive resistance can fulfill the requirement. The suspension leaf spring is one of the potential entities for weight reduction in automobiles as it results in large unstrung mass. The introduction of fiber reinforced plastics (FRP) is used to reduce the weight of the product without any reduction on load carrying capacity and spring rate. As the materials high strain energy storage capacity and high strength-to weight ratio compared to steel, multi-leaf springs are being replaced by mono-leaf FRP spring .FRP springs also have excellent fatigue resistance and durability.

Keywords— leaf spring, composites, CATIA, ANSYS, suspension system

1. INTRODUCTION

A suspension system is one having springs and other devices that insulate the chassis of a vehicle from shocks transmitted through the wheels. The main components of the suspension system are:

- Struts
- Shock absorbers
- Springs
- Tires

The automobile chassis is mounted by the axles, not directly but through some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the part performs the function of isolating the automobile from the road shocks are collectively called a suspension system. It also includes the spring device and various mountings. A suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate.

2. LITERATURE SURVEY

Pankaj Sain et.al [2013] studied on design and analysis of composite leaf spring for light vehicles. Main objective of this work is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. Here the three materials selected which are glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is used against conventional steel. The design parameters were selected and analyzed with the steel leaf spring from results, they observed the replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction and also the composite leaf spring has lower stresses compared to steel spring. From the static analysis results it is found that there is a maximum displacement of in the steel leaf spring. From the result, among the three composite leaf springs, only graphite/epoxy composite leaf spring has higher stresses than the steel leaf spring. From results it's proved that composite mono leaf spring reduces the weight by 81.22% for E-Glass/Epoxy, 91.95% for

Graphite/Epoxy, and 90.51 % for Carbon/Epoxy over steel leaf spring. Hence it is concluded that E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view. The Leaf spring was modelled in Auto-CAD 2012 and the analysis was done by using ANSYS 9.0 software

D.V Ramana Reddy et.al [2018] studied on Composite leaf spring has been carried out in this present work. Comparison has been made between composite and steel leaf springs under the same load conditions. The Stress, displacement and weight have been calculated analytically and compared with FEA results. The results obtained from the Ansys and theoretical values, it has been concluded that all the composite leaf springs have better displacement, stresses and weight compared to the conventional steel leaf springs. The materials selected are Epoxy glass, Epoxy carbon, Aluminum Alloy, Titanium Alloy is used against conventional steel leaf spring. The leaf spring was modeled in CATIA and the analysis was done in ANSYS software.

P.sai Krishna et.al [2012] studied on Design and analysis of leaf spring. The Modeling of leaf spring is done in solidworks2016 design software. Structural analysis is carried out in ANSYS by applying three different materials such as carbon epoxy, carbon steel and e-glass epoxy at load 6685n force is applied on leaf spring for three different thickness leaf springs. The material properties of the above materials are studied. From the results we can conclude that 6mm thickness had reduced it to 5mm and 4mm by varying the thickness reduction in weight occurred from the analysis carbon steel material for 5mmthicknesss is showing less stress compared to 4mm thickness leaf spring. Leaf spring containing 4mm thickness undergone maximum stress though the weight reduction is maximum but stability to oppose the load is low but 5mm thickness leaf spring got the values nearer to 6mm and it has low weight compared to 6mm leaf spring Hence we can conclude that the leaf spring containing 5mm thickness applied with carbon steel material is showing best results

Tarun Kumar et.al [2013] Studied on design and structural analysis of leaf spring using CATIA V5R12 software for modeling and simulation result. It is concluded that the CAE tools provide a cost effective and less time consuming solution than the complex time consuming numerical solutions. According to the analysis it is concluded that leaf spring may be made by polycarbonate, jute/epoxy composite. Because it is more effective as compare to existing leaf spring material or other material (Iron, steel, steel EN C45). By which leaf springs are normally made. When load is increase then leaf spring displacement is also increase. Then after a certain limit iron, steel, steel EN C45 got fail. But, at that limit leaf spring which made by other materials is not fail. That means its elastic property is better than previous material and its loading capacity is more as compare to other material. Component can be optimized if it is over designed and material can be saved or some of the parts can be strengthened by adding material at proper place.

M Sai Kumar et.al [2007] Studied on modeling and structural analysis of leaf spring. The leaf spring has been modelled analyzed using ANSYS FEA Software. By performing static analysis it is concluded that the maximum safe load is 50000 N for the given specification of the leaf spring and itis concluded that for the given specifications of the leaf spring FEM gives quite accurate prediction of critical area stresses from the viewpoint of static loading. These static analysis results of 10 layered laminated leaf springs are compared to high and low carbon steel, Nickel based alloy (Inconel 600) to multi material leaf spring. By analyzing the design, it is found that all the stresses in the leaf spring are well within the allowable limits and with good factor of safety for the materials high carbon, Inconel and multi-layer metals. This study will help to understand more the behavior of the spring and give information for the manufacturer to improve the strength of the spring using CAE tools. It can help to reduce cost and time required for research and development of new products.

Anjis M George et.al [2003] Studied on design and analysis of leaf spring by using hybrid composite material. In This research work provides comparative analysis between conventional steel, and E-Glass/Flax/Epoxy based hybrid composite leaf spring. The hybrid composite leaf spring is found to have lesser stresses and negligible higher deflection as compared to conventional steel leaf spring. Weight can be reduced by 88.49% if steel leaf spring is replaced by E- glass/Flax/Epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle. The leaf spring was modelled in CATIA and analysis is done by using ANSYS 15.O software.

Dev Dutt Dwivedi et.al [2010] Studied on automobile leaf spring by using ANSYS 14.5 Results states that composite leaf spring deflection for a particular load is less compared to conventional leaf spring. Stress generated in the E-Glass/Epoxy leaf spring is lower than steel leaf spring. Composite (E-Glass/Epoxy) leaf spring directional deformation is low compared to steel leaf spring. Composite leaf spring is lighter in weight compared to conventional steel leaf spring.

Ajay B.K et.al [2014] Studied on different arrangements of composite leaves with steel leaves of a leaf spring. For the analysis ANSYS is used. Deflection and Stresses results were verified for analytical results. Result shows that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was reduced. By capturing the fundamentals of combining dissimilar materials and thus its equivalent modulus affects the overall stiffness characteristics of multi-leaf design. The material selected was glass fiber reinforced plastic.

Kabariya Kaushal Kanubul et.al [2018] Studied on leaf spring by changing cross sectional area and compared it with composite material. 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. From static analysis it is observed that by using trapezoidal cross- section the material is reduced rather than by using rectangular cross section. It's found that by using trapezoidal cross section per leaf of steel, weight is reduced by 7.67% but by using composite material it's reduced by 11.244%. The leaf spring is designed in the shape of trapezoidal cross section in the PRO-E software and FEA analysis is carried out by ANSYS 14.5. The material used for the cross section is 65si7.

Priyanka Kothari. et.al [2012] Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The literature has indicated a growing interest in the replacement of steel spring with composite leaf spring. The suspension system in a vehicle significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort, stability etc. Leaf springs are commonly used in the vehicle suspension system and are subjected to millions of varying stress cycles leading to fatigue failure. A lot of research has been done for improving the performance of leaf spring.

Venkatesan M. et.al [2012] in their work design and experimental analysis of composite leaf spring were described. This work attempted to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. In this work the dimensions of leaf spring taken from existing conventional steel leaf spring of a light commercial vehicle and the material was used for fabricating the composite one as E-glass/epoxy unidirectional laminates. Here in this work using design data the conventional steel leaf spring was modeled and analyzed using ANSYS 15.0 and compared with the experimental results. Modeled leaf spring again analyzed by changing the material as composite one and compared with experimental results. After comparing analytical and experimental results, conventional steel leaf spring and composite leaf spring were compared with each other. From comparison it was concluded that composite material can be use in place of steel for leaf spring and also the weight of the leaf spring was reduced by using composite material without affecting its load carrying capacity.

Erol Sancaktar et.al [2016] in his work described the design and manufacture of a functional composite leaf spring for solar powered light vehicle. The main objective of this work was to provide and understanding of the manufacture, use and capabilities of composite leaf spring. The material selected for the fabrication of the initial design leaves consisted of a full thickness of unidirectional E-glass fibers with two layers of bi-directional fabric on the outer layers embedded in a vinyl ester resin matrix. The bi-directional fabric used to prevent leaf deformation and subsequent failure in bending about its longitudinal axis it was selected due to overall weight reduction of the vehicle primarily considered. This work attempted due to some failure aspect which occurs in the previous leaf spring.

Patunkar et.al [2011] studied on the research paper discussed the analysis of composite mono leaf spring made of glass fiber reinforced plastic. Initially conventional leaf spring has been tested for static conditions. Then simulation was done for the composite spring of glass fiber under the same static load condition. The comparison of the deflection and the stress distribution has been carried out. It has been observed that there is large deflection in the conventional spring than composite spring. Conventional leaf spring also possesses more weight than composite leaf spring.

Krishan et.al [2012] studied on the work presented the analysis of multi leaf spring using finite element methods. This work has been carried out on a multi leaf spring having nine leaves used by a commercial vehicle. It was having two full length leaves in which one is with eyed ends and seven graduated length leaves. The material of the leaf spring is SUP9. Bending stress and deflection were the target results. A comparison of both i.e. experimental and FEA results have been conducted. When the leaf spring was fully loaded, the variation in the defection was 0.632 % in experimental and FEM results.

3. DESIGN OF LEAF SPRING:

The design of the leaf spring is done in CATIA V5 R20. All the leaves, clamps and bolt are designed separately in the part drawing and are assembled in the assembly drawing section in CATIA. The leaves are assembled by giving surface contact between the bottom surfaces of one leaf to the top surface of the other leaf. In this way all the 10 leaves are assembled in the CATIA, after that the clamps and bolts are assembled in the leaf spring

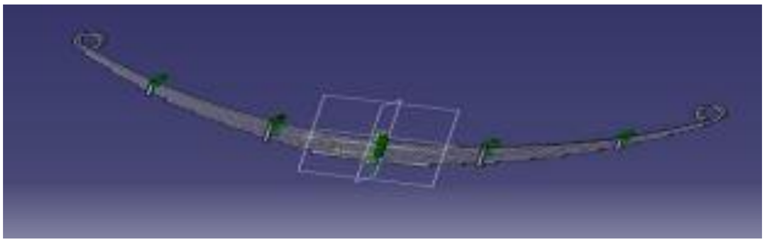
A. Design specifications of leaf spring:

1	TOTAL LENGTH OF THE SPRING(EYE TO EYE)	3000 mm
2	FREE CAMBER	272.7 mm
3	NO OF FULL LENGTH LEAVES	1
4	NO OF GRADUATED LEAVES	6
5	THICKNESS OF THE LEAF	59.3 mm
6	WIDTH OF THE LEAF	200 mm
7	YOUNG'S MODULUS OF THE STEEL	210 KPa
8	POISSON RATIO	0.3

Table 1 Dimensions

B. CATIA drawing of leaf spring:

Figure 1 shows the final assembled diagram of the leaf spring designed in CATIA



4. MATERIALS USED FOR ANALYSIS:

In Analysis of Leaf spring, the authors are considered different materials to compare the conventional steel leaf spring. The selected materials are Epoxy glass, Epoxy carbon, Aluminum Alloy, and Titanium Alloy. The following are the material properties of selected materials are compared with the steel properties.

4.1 Steel the material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel products has greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

4.2 E-Glass/Epoxy The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties.

4.3 Epoxy Carbon the advantages of Epoxy carbon include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength

5. ANALYSIS PROCEDURE OF LEAF SPRING

5.1. Geometry

First generate the geometric model of the leaf spring from CATIA into Ansys software. That is possible to create the geometry of the leaf spring using Design Modeler in ANSYS workbench, beyond this From a CAD system supported by Workbench or one that can export a file that is supported by ANSYS Workbench

Before attaching the geometry, specifies several options to determine the characteristics of the geometry to import. These options are; solid bodies, surface bodies, line bodies, parameters, attributes, named selections, material properties analysis type 2D or 3D

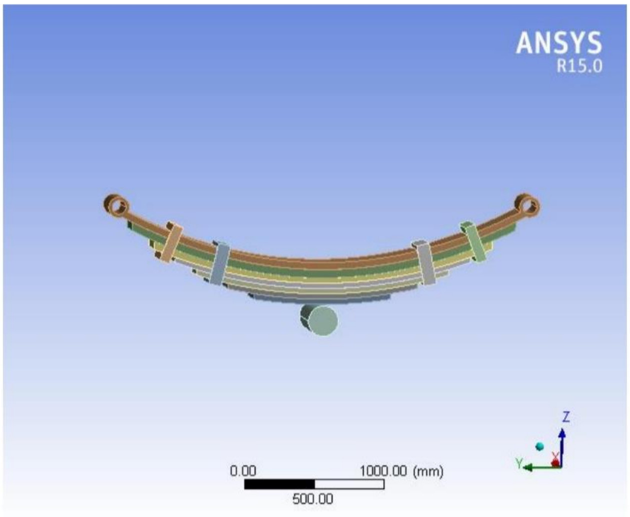


Figure 2 Model of leaf spring

5.2Apply Mesh Controls/Preview Mesh:

Applying mesh, Provide an adequate mesh density on contact surfaces to allow contact stresses to be distributed in a smooth fashion. Likewise, provide a mesh density adequate for resolving stresses; areas where stresses or strains are of interest require a relatively fine mesh compared to that needed for displacement or nonlinearity resolution. Then the meshed model of the carbon /epoxy leaf spring looks like in the figure below with 20697 node and 2903 number of Elements.

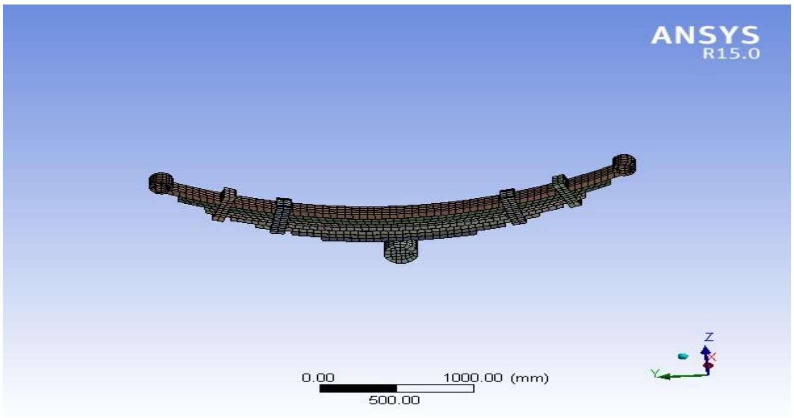


Figure 3 Meshing of the leaf spring

5.3Apply Loads and Supports

For a static structural analysis applicable loads are all inertial, structural, imported, and interaction loads, and applicable supports are all structural supports. Loads and supports vary as a function of time even in a static analysis as explained in the role of time in tracking.

5.4 Generating solution

The solution is generated from the above input parameters of the project. The total deformation and equivalent (Von Misses) stress are the basic variables to be solved by this software analysis. Beyond this, directional deformation and normal stress in X, Y, and Z directions are also solved and the results are displayed in the appendix part of this study. Solution Output continuously updates any listing output from the solver and provides valuable information on the behavior of the structure during the analysis.

Now obtain the solution for the stress, deformation and elastic strain and generate the results.

6. RESULTS OF LEAF SPRING

Now, let us check the results obtained in Ansys for stress, deformation, elastic strain and weight for the specified materials. In this chapter the results of both laminated carbon/epoxy composite and steel leaf spring materials obtained from the static structural analysis clearly stated.

Then the results presented here are the leaf spring materials namely laminated carbon/epoxy composite and steel materials of; total deformation, directional deformation in X, Y, and Z directions, normal stress and equivalent elastic strains.

The most important step of finite element analysis procedure is the physically realistic interpretation of the results by the analysis. Since finite element analysis procedures are invariably accompanied by an extensive output of data, interpret the results correctly.

1. TOTAL DEFLECTIONS:

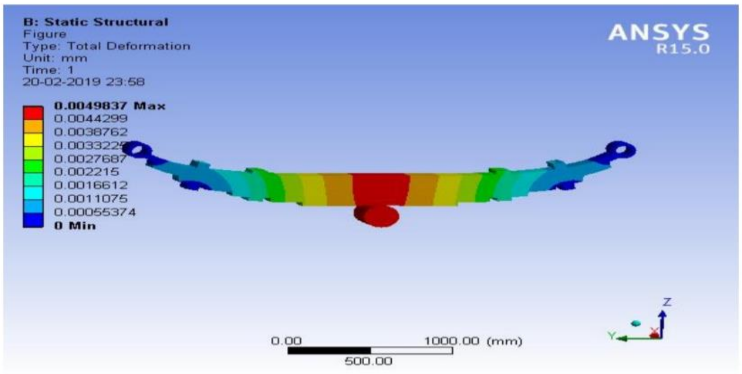


Figure 4 Deflection of Steel

Fig. 4 Shows the deflection of model in which all steel leaves are used. Steel leaf spring is loaded under the application of 4903 N load. The maximum deflection is at the center of the leaf spring its maximum value is 0.004983 mm. Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection.

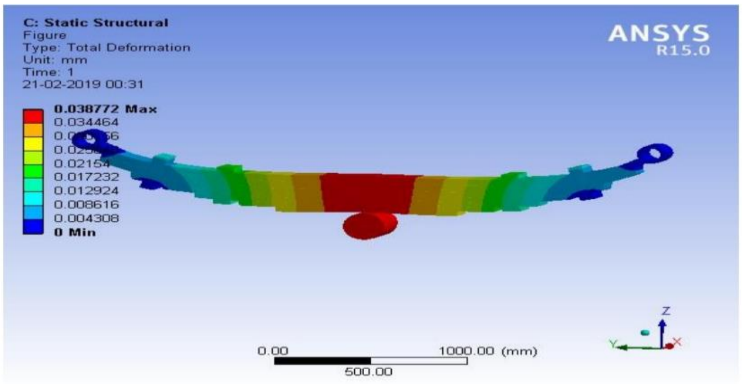


Figure 5 Deflection of E-glass

Fig. 5 shows the deflection of model 2 in which all E-glass fibers leaves are used. Steel leaf spring is loaded under the application of 4903 N load. The maximum deflection is at the center of the leaf spring its maximum value is 0.003877 mm. Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection

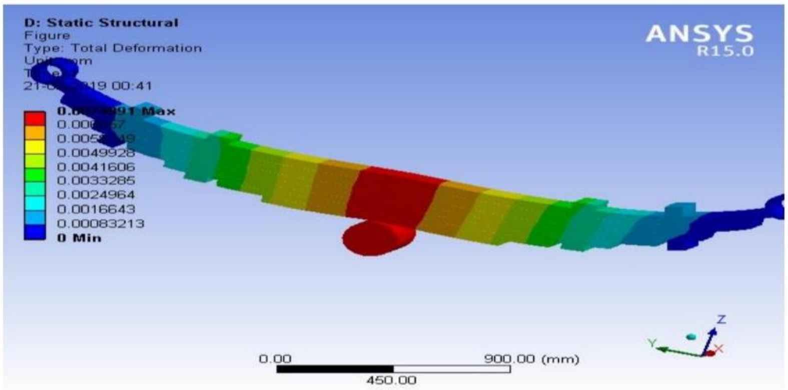


Figure 6 Deflection of Composite leaf spring

Fig. 6 shows the deflection of model 3 in which all Composite leaves are used. Steel leaf spring is loaded under the application of 4903 N load. The maximum deflection is at the center of the leaf spring its maximum value is 0.004891 mm. Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection

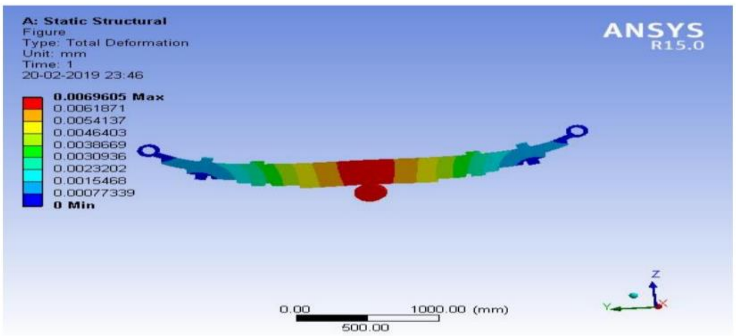


Figure 7 Deflection of Carbon Epoxy

Fig. 7 shows the deflection of model 4 in which all carbon epoxy leaves are used. Steel leaf spring is loaded under the application of 4903 N load. The maximum deflection is at the center of the leaf spring its maximum value is 0.0069605 mm. Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection

2. STRESS:

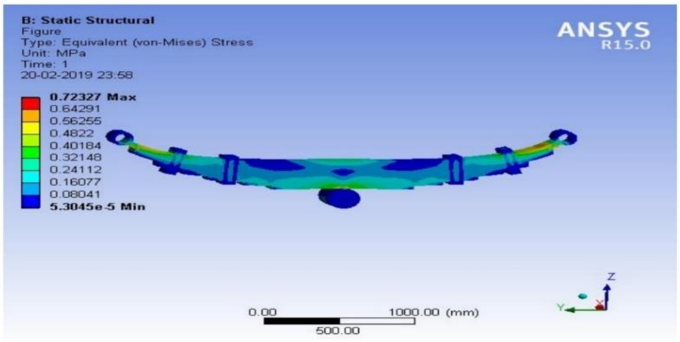


Figure 8 Stress in leaf spring

Fig 8 shows the equivalent von-Mises stress induced in steel leaf spring under the load of 4903N load. The maximum stress is induced near the fixed eye end of the leaf spring its maximum value is 101.19 MPa.maximum ultimate stress is 460MPa, shows stress acted on model under safe zone, gives FOS= 4.5. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

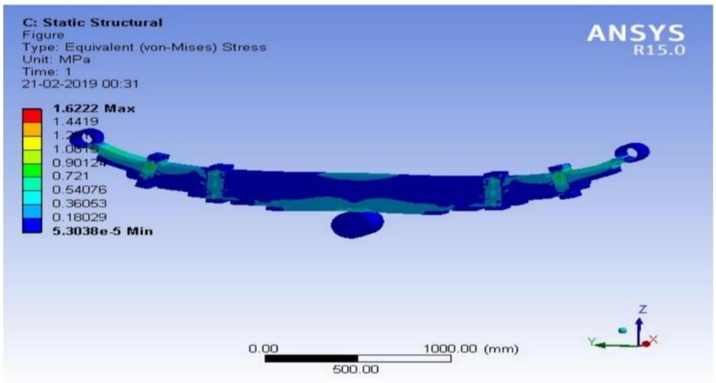


Figure 9 Stress in E-glass

Fig 9 shows the equivalent von-Mises stress induced in E-glass leaf spring under the load of 4903N load. The maximum stress is induced near the fixed eye end of the leaf spring its maximum value is 112.19 MPa.maximum ultimate stress is 220.6 MPa, shows stress acted on model under safe zone, gives FOS= 4.5. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

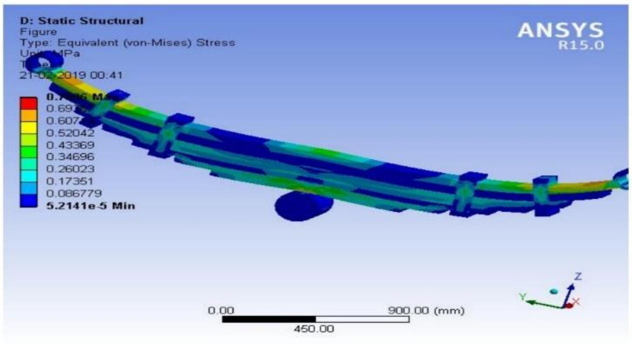


Figure 10 Stress in Composite leaf spring

Fig 10 shows the equivalent von-Mises stress induced in composite leaf spring under the load of 4903N load. The maximum stress is induced near the fixed eye end of the leaf spring its maximum value is 125.19 MPa. Maximum ultimate stress is 460 MPa, shows stress acted on model under safe zone, gives FOS= 4.5. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

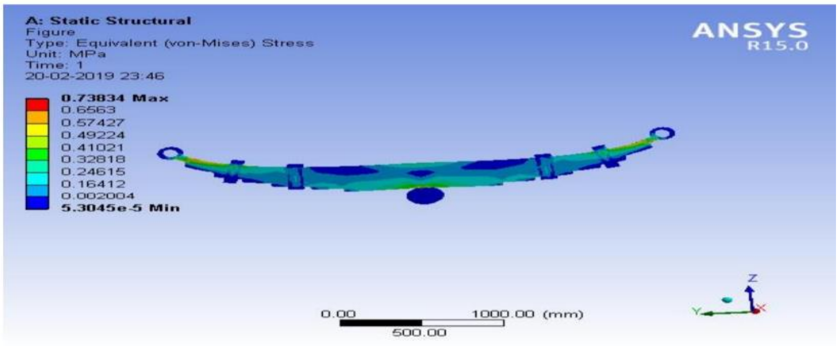


Figure 11 Stress in Carbon Epoxy

Fig 11 shows the equivalent von-Mises stress induced in carbon epoxy leaf spring under the load of 4903N load. The maximum stress is induced near the fixed eye end of the leaf spring its maximum value is 105.19 MPa. Maximum ultimate stress is 76 MPa, shows stress acted on model under safe zone, gives FOS= 4.5. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

3 STRAIN:

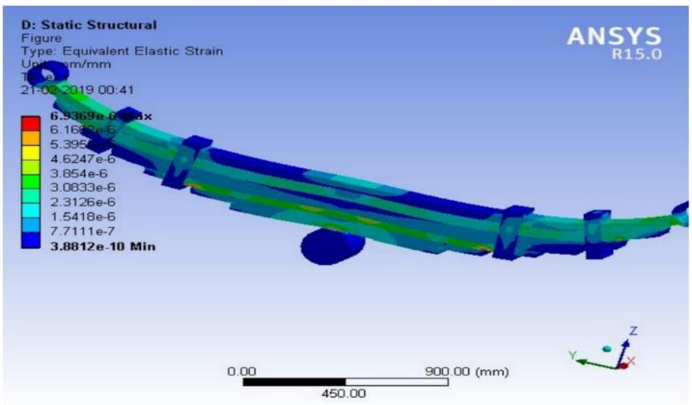
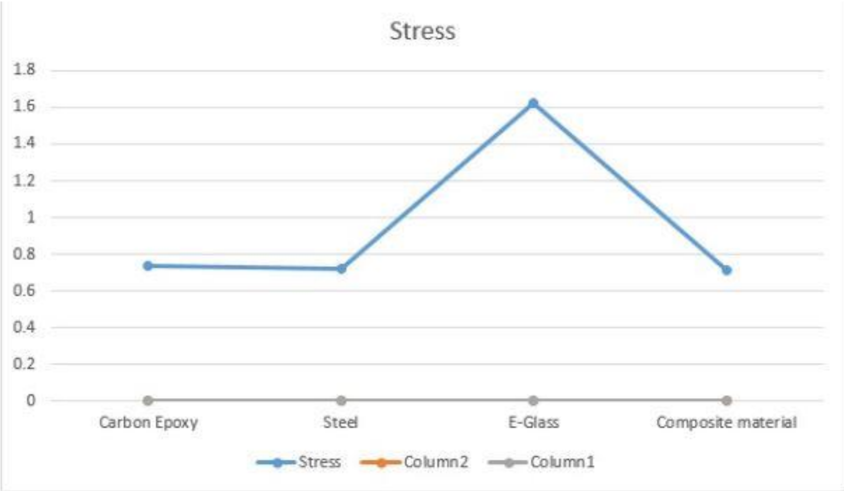


Figure 12 Strain in composite material

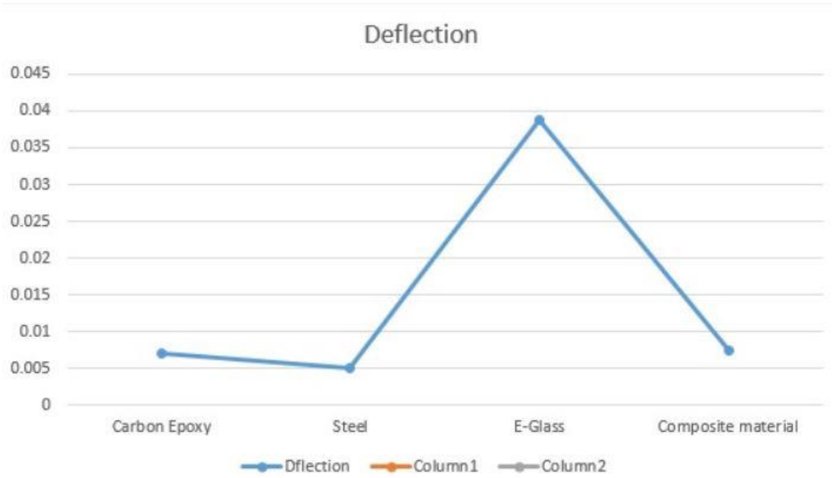
Fig. 12 shows the strain of model in which all composite leaves are used. Composite leaf spring is loaded under the application of 4903 N load. The maximum deflection is at the center of the leaf spring its maximum value is 0.0069605



Graph 1 Stress in various material

this graph the blue line indicates various stress values of various materials. The carbon epoxy is 0.73834,steel value is 0.72327,E-glass value is 1.6222 and composite material value is 0.7086

In



Graph 2 Deflection in various material

this graph the blue line indicates various Deflection values of various materials. The carbon epoxy is 0.00690,steel value is 0.0049837,E-glass value is 0.038772 and composite material value is 0.078491

Properties of Materials

Sr no	property	E -Glass	Carbon epoxy	Composite material	Steel
1	Youngs modulus(N\mm^2)	2*10^05	1.41*10^005	2*10^05	2*10^005
2	Poisson ratio	0.3	0.3	0.23	0.23
3	Tensile strength Ultimate	220.6	76	460	460
4	Tensile Yield Strength	1950	1925	1985	1985
5	Density(kg|mm^3)	152	7.85*10^-009	7.85*10^-009	7.85*10^-009

CONCLUSION:

Conclusion this thesis work involves, the comparison of Damas II multi steel leaf spring with laminated carbon/epoxy mono composite leaf spring under a static loading condition. Then to make the comparison using theoretical calculation and ANSYS software results.

The finite element analysis (FEA) is a powerful computational tool for analyzing complicated structural bodies. It can reduce prototype parts' producing and the number of physical tests to shorten the development cycle and reduce the development investment; i.e., it saves much time, effort and costs.

To conclude, this work as explained above, stress, weight and deformation in carbon/Epoxy composite leaf spring compared with conventional steel leaf spring for Damas II automobile suspension system. This is done to achieve the following.

As it was seen from the comparisons of the two leaf spring ANSYS results, the equivalent stress induced and deformation in the Carbon/Epoxy composite leaf spring is 74.58 % and 68.287% less than the conventional steel leaf spring for the same load carrying capacity respectively and achieve about 76.85% weight reduction in the suspension system. Then standing from design and static analysis of the study, steel leaf spring replaced with a laminated carbon/epoxy composite mono leaf spring is best one. The aim of replacing leaf spring with carbon/epoxy composite is to obtain a leaf spring which is light weight and capable of carrying given static load by constraints limiting stresses and displacements

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