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Modelling and Reinforcement of a Heavy Vehicle Leaf sprig for the Material Glasses Carbon Composite

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ABSTRACT

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, breaker torque in addition to shock absorbing. The advantage of leaf spring over helical spring is that the ends of spring may be guided along a definite path as is deflects to act as structural member in addition to energy absorbing device. Reducing weight while increasing or maintaining strength of products is getting to be a highly impotent research issue in this modern world. Composite materials are one of the material families which are attracting reaches and being solution of such issue .in this page we describe design of leaf spring. The design constraint is stiffness. The auto mobile industry has great interest for replacement of steel leaf spring with that of composite leaf spring. Since the composite material has high strength to weight ratio, good corrosion resistance. The design parameters were selected and analysed with the objective of minimizing weight of the composite leaf spring as compared to steel. The design parameters spring SolidWorks is used as a CAD TOOL for designing leaf spring suspension. SolidWorks is an advanced CAD SOFTWARE which is used for a good sketcher design. Leaf spring is designed using part design workbench and later it is assembled in assembly workbench.

Keywords: Leaf springs, Suspension system, Shock absorption, Composite materials, Design, spring, CAD (Computer-Aided Design), SolidWorks, Part design workbench, Assembly workbench.

1. INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. 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. Spring consists of several leaves called blades. The blades vary in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. 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 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 relates to 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, leading to deflection of the spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is provided as one end, which gives a flexible connection. The front eye of the leaf spring is constrained in all the directions, whereas rear eye is not constrained in X-direction. This rare eye is connected to the shackle. During loading the spring deflects and moves in the direction perpendicular to the load applied.

The springs are initially cambered. More cambered leaf springs are having high stiffness, so that provides hard suspension. Use of longer springs gives a soft suspension, because when length increases the softness increases. Generally rear springs are kept longer than the front springs. Spring eyes for heavy vehicles are usually bushed with phosphor bronze bushes. However, for cars and light transport vehicles like vans, the use of rubber has also become a common practice. This obviates the necessity of lubrication as in the case of bronze bushes. The rubber bushes are quiet in operation and the wear on pin, or the bush is negligible. Moreover, they allow for slight assembly misalignment, "Silentbloc' is an example of this type of bushes. Fatigue strength and hence the life of spring can be increased by shot – peening the top surface of each leaf, which introduces a compressive residual stress, rounding the edges of the leaves also avoids stress concentration, thereby improving the fatigue strength.

1.1 OBJECTIVE OF THE PROJECT

The automobile industry is showing increased interest in the replacement of steel spring with fiberglass composite leaf spring due to high strength to weight ratio. Therefore, this project aims at comparative study of design parameters of a traditional steel leaf spring assembly and mono composite leaf spring with bonded end joints. By performing static analysis using ANSYS software and mathematical calculations, the maximum bending stress and corresponding payload must be determined by considering the factor of safety. Determining and assessing the behavior of the different parametric combinations of the leaf spring, their natural frequencies are compared with the excitation frequencies at different speeds of the vehicle with the various widths of the road irregularity. These excitation frequencies are calculated mathematically.

2. LITERATURE REVIEW

Zliahu Zahavi [1] the leaf spring works are very complicated from the point of view of mechanics and numerical computations. The magnitude of loading is high as well as spring deformations. Multi-surface 3D contact between subsequent leafs also takes place. The main advantage of leaf springs is that the ends of the spring are guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Practically, a leaf spring is subjected to millions of load cycles leading to fatigue failure. Free vibration analysis determines the frequencies and mode shapes of leaf spring.

A.strzat and T.Paszek [2] performed a three-dimensional contact analysis of the car leaf spring. They considered the static three-dimensional contact problem of the leaf car spring. Different types of mathematical models were considered. The static characteristics of the car spring were obtained for different models and later, it is compared with one obtained from experimental investigations.

Fu-cheng Wang [3] performed a detailed study on leaf spring. His work mainly discusses the active suspension control of vehicle models. The employing active suspension through the analysis of the mechanical networks is discussed. He derived a parameterization of the set of all stabilizing controllers for a given plant. He considered practical parameters and applications of a leaf spring model through his work, thus supporting both the situations, that is active and passive suspension cases, individually.

I.Rajendran and S. Vijayarangan [4] performed a finite element analysis on a typical leaf spring of a passenger car. Finite element analysis has been carried out to determine natural frequencies and mode shapes of the leaf spring. A simple road surface model was considered.

Further literature is available on concepts and design of leaf springs [5], [6]. Some of the springs manufacturing companies publish catalog on leaf spring giving dimension details [7]. Some of the passenger manufacturers also publish manuals, which give important dimensions of leaf spring [8].

3. OVERVIEW OF LEAF SPRING

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. Spring consists of several leaves called blades. The blades vary in length. The blades are usually given an initial curvature or cambered so that they will tend to straighten under the load. 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 relates to 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.

3.1 Suspension System

The automobile chassis is mounted on the axles, not directly but 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 cause additional stress in the automobile frame anybody. All the parts, which perform the function of isolating the automobile from the road shocks, is collectively called a suspension system. It includes the springing device used and various mountings for the same. Broadly speaking, the suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber.

3.1.1Objective of Suspension

1. To prevent the road shocks from being transmitted to the vehicle components.
2. To safeguard the occupants from road shocks
3. To preserve the stability of the vehicle in pitting or rolling, while in motion.

3.2 Bending Stress of Leaf Spring

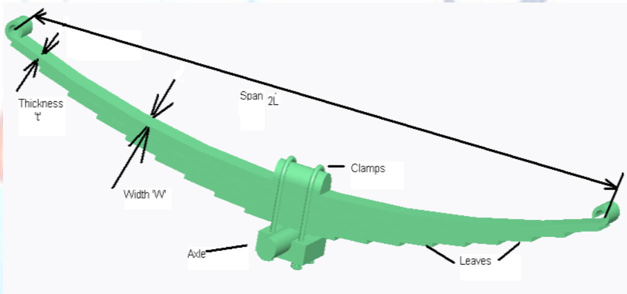
Leaf springs (also known as flat springs) are made from flat plates. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Thus, the leaf springs may carry lateral loads, brake torque, driving torque etc., in addition to shocks.

Consider a single plate fixed at one end and loaded at the other end. This plate may be used as a flat spring.

Let t = thickness of plate

b= width of plate, and

L= length of plate or distance of the load W from the cantilever end, as shown in Fig. 3.1.



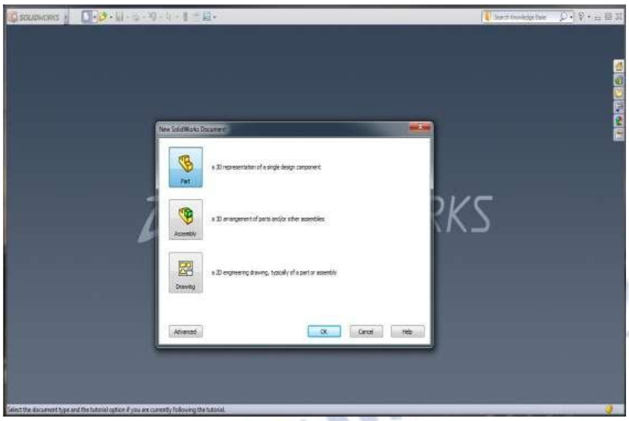
3.1 Elements of Leaf spring

4. SOLIDWORKS

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aidedengineering(CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes.More than 3,246,750 product designers and engineers worldwide, representing 240,010 organizations, use SOLIDWORKSto b r i n g their designs to life–from the coolest gadgets to innovations that deliver a bettertomorrow.

Dassault SystèmesSOLIDWORKS Corp. offers complete 3D software tools that let you create, simulate, publish, and manage your data. SOLIDWORKS products are easy to learn and use and work together to help you design products better, faster, and more cost-effectively. The SOLIDWORKSfocus on ease-of-use allows moreengineers, designers and other technology professionalsthan ever before to take advantage of 3D in bringing their designs tolife.

4.1 The SolidWorksModel

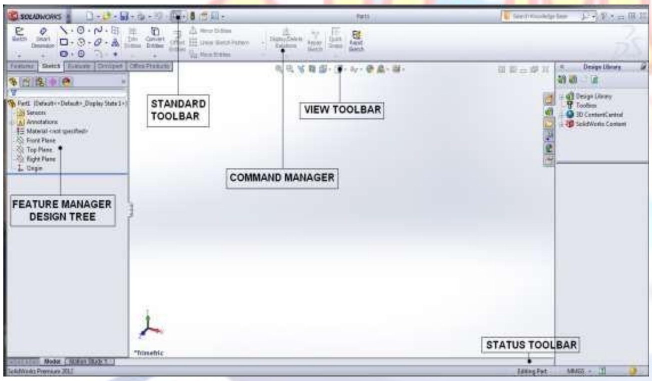


The SolidWorks model is made up of:

- **Parts** -2D design (Sketch), 3D design (Features), Partdesign consider in the part designsection.
- **Assemblies** - Assembling of two or more than two parts consider in thissection.
- **Drawings**- Designing with standards is consideredin the drawingsection.

4.2 SOLIDWORKS USERINTERFACE

The interface isnative Windowsinterface, and such behaves in the same manner as other Windowsapplications.



4.3 Menus:

1. It provides access to all commands that the SolidWorksoffers.
2. When a menu item has a right pointing arrow, it means thereisasub-menu associated with thechoice,
3. When a menu item is followed by a series of dots, it means that option opens adialog box with additional choices orinformation

4.4 Design of Leaf Spring

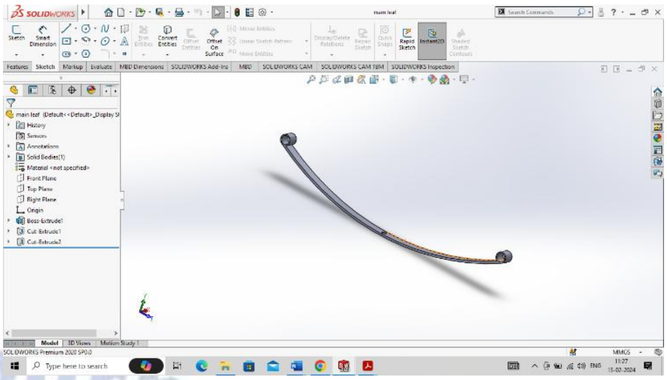


Fig.4.1 Main leaf

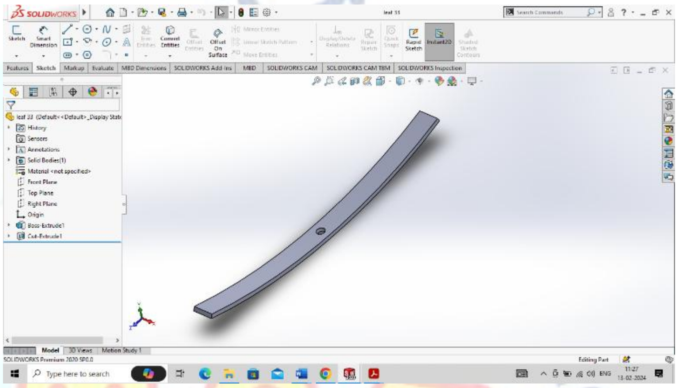


Fig.4.2 leaf 3

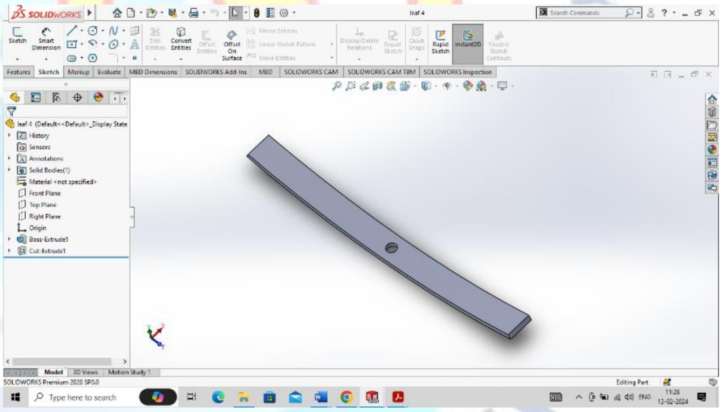


Fig.4.3 Leaf 4

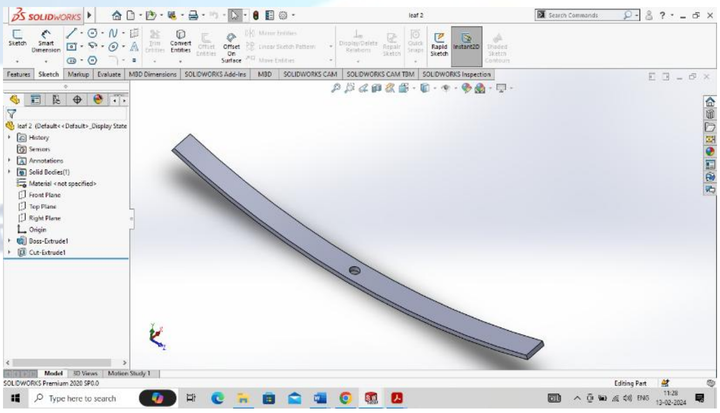


Fig.4.4 Leaf 2

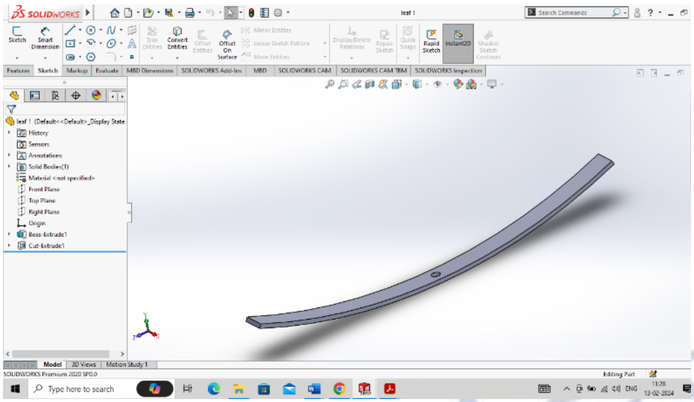


Fig.4.5 Leaf 1

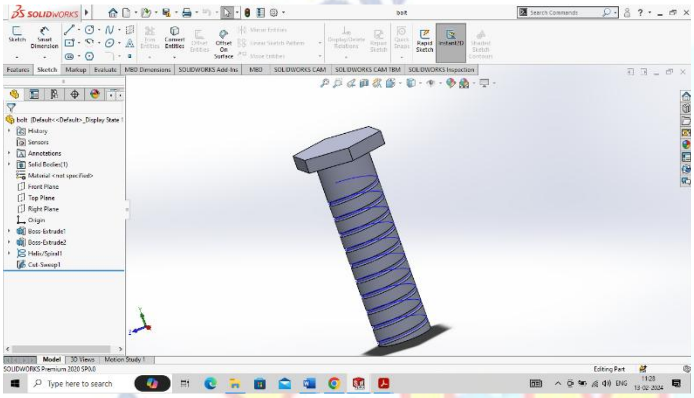


Fig.4.6 Screw

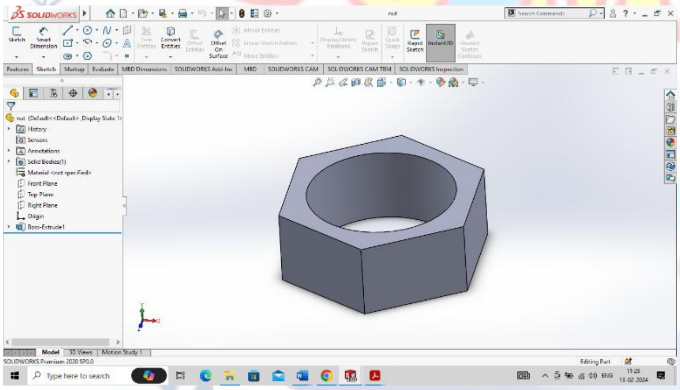


Fig.4.7 Nut

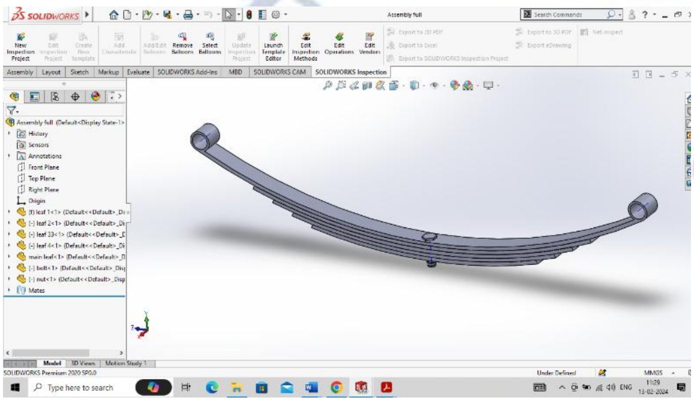


Fig.4.8 Leaf spring assembly

5. ANALYSIS

The essential idea in fem is that the body or structure may be separated into littler components of limited measurements called "Finite Elements". The first body or the structure is then considered as a gathering of these components associated at a limited number of joints called "nodes" or "nodal points". Basic capacities are approximated the relocations over each limited component. Such accepted capacities are called "shape capacities". This will speak to the uprooting within the component as far as the remit Element technique is a scientific apparatus for illuminating common and fractional at the hubs of the components. The Final differential comparison because it is a numerical instrument, it can take care of the unpredictable issue that can be spoken to in differential mathematical statement from. The use of FEM is boundless as respects the arrangement of commonsense configuration issues. FEM has good efficiency to solve problems and cost critical problems as the cost for computing power is high.

The finite element method can be utilized to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulation.
- Mould flow simulations

Now a days, even the simplest of products rely on the finite element method for design evaluation. This is on account of contemporary configuration issues normally can't be understood as precisely and inexpensively utilizing some other system that is at present accessible. Physical testing was the standard in the years passed by, however now it is just excessively costly and tedious too.

Who?

The reference credited is to Courant (Mathematician), Turner (aircraft industry), Clough (California University), Martin (air craft industry), Argyris (German university), etc. However, it was probably established by several pioneers independently.

When?

- Initial idea in mathematical terms was put in 1940s.
- Application to simple engineering problems in 1950s.
- Implementation in large computers in 1960s.
- Development of pre and post processors in 1980s.
- Analysis of large structural problems in 1990s.

Where?

Implementation and application were mainly in aircraft industry and automobile sectors (large and fast computers were available only in these industries).

What?

Field problems in the form matrix of organizing large numbers of algebraic equations are used and matrix equations are solved. Differential equations are changed into an algebraic form. Blocks with different geometry are hooked together for creating complex geometry of the engineering problem.

Why?

The advantage of doing FEM analysis is that it is simple to change the geometry, material and loads recomputed stresses for modified product rather than build and test. The method can be used to solve almost any problem that can be formulated as a field problem. The entire complex problem can be cast as a larger algebraic equation by assembling the element matrices within the computer and solved.

5.1.1 More About FEA:

Finite Element Analysis was first initially produced for use in the nuclear and aerospace industries where the safety of the structures is critical. Today, the growth in usage of the method is directly attributable to the rapid advances in computer technology in recent years. As a result, not just structural analysis most sophisticated problems can also be solved. Be that as it may, utilized for a wide variety of uses for example, consistent state and transient temperature appropriations, liquid stream reenactments furthermore recreation of assembling procedures, for example, infusion mounding and metal framing. FEA comprises a computer model of a material or design that is analysed by applying the loads for specified results. It is utilized as a part of new item plan, and existing item refinement. An outline specialist should have the capacity to confirm the proposed plan, which is planned to meet the client prerequisites preceding the assembling. For example, adjusting the outline of a current item or structure to qualify the item or structure for another administration condition.

5.1.2 The Basic Steps Involved In FEA:

Numerically, the structure to be examined is subdivided into a cross section of limited estimated components of straightforward shape. Inside of every component, the variety of dislodging is thought to be dictated by basic polynomial shape capacities and nodal relocations. Comparisons for the strains and hassles are created as far as the obscure nodal relocations. From this, the mathematical statements of the balance are amassed in a grid from which can be effortlessly customized and illuminated on a PC. In the wake of applying the proper limit conditions, the nodal relocations are found by understanding the framework firmness mathematical statement. Once the nodal relocations are known, component hassles and strains can be figured out. Those steps are.

- Discretization of the domain.
- Applying the boundary conditions.
- Assembling the system equations.
- Solution for system equations.
- Post processing the results.

5.2 MESHING:

MESHING: Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined as long as the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components. If we need this kind of lattice, we must form geometry as an arrangement of genuinely normal volumes and/or regions that can acknowledge a mapped network.

5.3 Structural Static Analysis:

The load effects can be calculated on a structure by ignoring the damping and inertia effects, such as those caused by time varying loads can be calculated by structural static analysis. Steady equivalent loads like steady inertia loads and time varying loads are included in Static analysis. Static analysis is utilized to decide the removals, burdens, strains and powers in structures or segments brought about by burdens that don't instigate noteworthy dormancy and damping impacts. Enduring stacking and reaction conditions are accepted, i.e. the stress and the structure's reactions are expected to differ gradually as for time. The kinds of load can be applied in static analysis include:

- Force and pressure application on body.
- Steady state inertial forces.
- Displacement.
- Thermal behavior.

5.4 Analysis Steps:

The steps needed to perform an analysis depend on the study type. You complete a study by performing the following steps:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties.
- Specify restraints and loads.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.
- Run the study.
- View results.

6. ANALYSIS OF LEAF SPRING

6.1 3D Model of a Leaf Spring

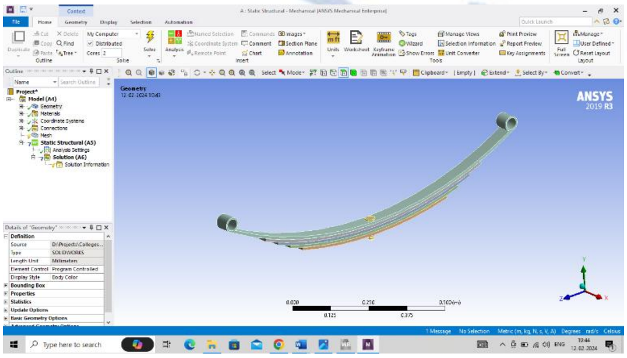


Fig.6.1 3d view of leaf spring

6.2 Analysis of Leaf Springs using ANSYS

All the analysis for the springs is done by using v5. For composite leaf spring the same parameters are used as that of conventional leaf spring. For designing of leaf spring, the camber is taken as 2000 mm. Leaf spring is modelled in Catia software and it is imported in v5. The constraint is given at the two eyes of the ends is provided with translational movement to adjust with the deflection. This eye end is free to travel in longitudinal direction. This motion will help leaf spring to get flattened when the load is applied. The stress and deflection analysis are done for conventional and composite leaf spring using ANSYS software. The results for both composite and conventional leaf spring are compared and given below.

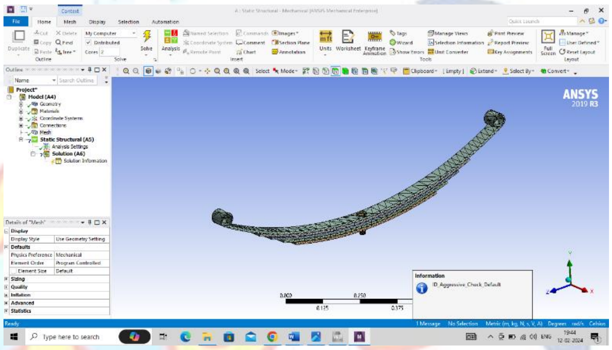


FIG:6.2 Mesh of leaf spring

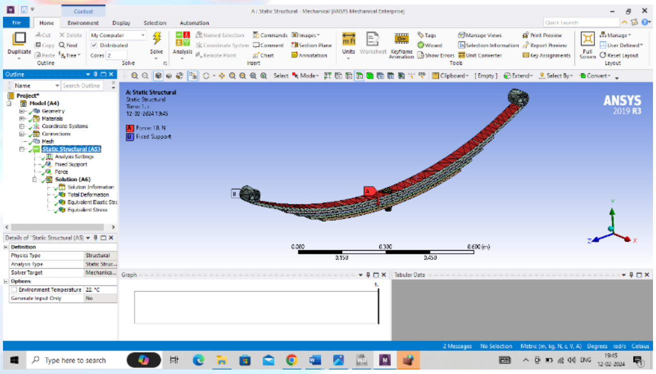


Fig.6.3 Boundary Conditions

6.1. Epoxy E-Glass UD

Epoxy E-Glass UD

Density	2e-06 kg/mm³
Structural	
Orthotropic Elasticity	
Young's Modulus X direction	45000 MPa
Young's Modulus Y direction	10000 MPa
Young's Modulus Z direction	10000 MPa
Poisson's Ratio XY	0.3
Poisson's Ratio YZ	0.4
Poisson's Ratio XZ	0.3
Shear Modulus XY	5000 MPa
Shear Modulus YZ	3846.2 MPa
Shear Modulus XZ	5000 MPa
Orthotropic Stress Limits	
Tensile X direction	1100 MPa
Tensile Y direction	35 MPa
Tensile Z direction	35 MPa
Compressive X direction	-675 MPa
Compressive Y direction	-120 MPa
Compressive Z direction	-120 MPa
Shear XY	80 MPa
Shear YZ	46.154 MPa

Table 6.1 Material Properties of Epoxy E-Glass UD

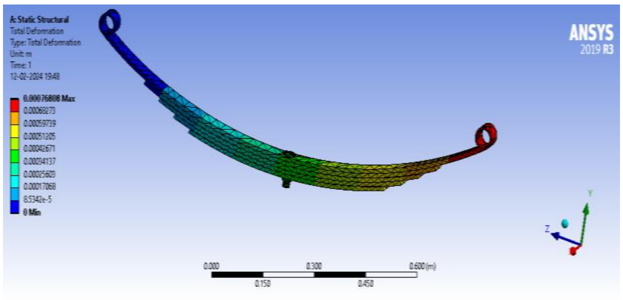


Fig.6.4 Total Deformation

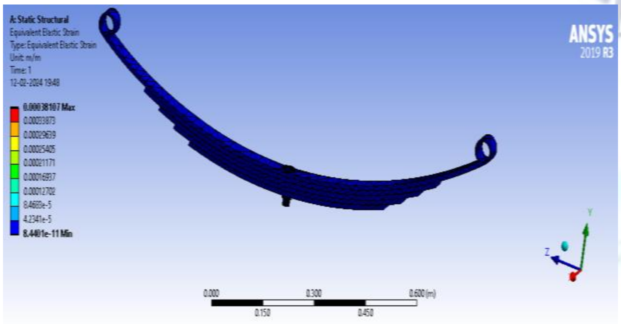


Fig. 6.5 Equivalent elastic strain

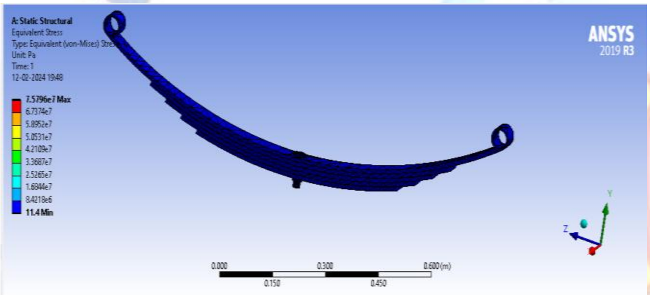


Fig. 6.6 Equivalent Stress

6.2 S-Glass

S-Glass

Fibers only

Density	2.5e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	90000 MPa
Poisson's Ratio	0.22
Bulk Modulus	53571 MPa
Shear Modulus	36885 MPa

Table 6.2 Material Properties of S-Glass

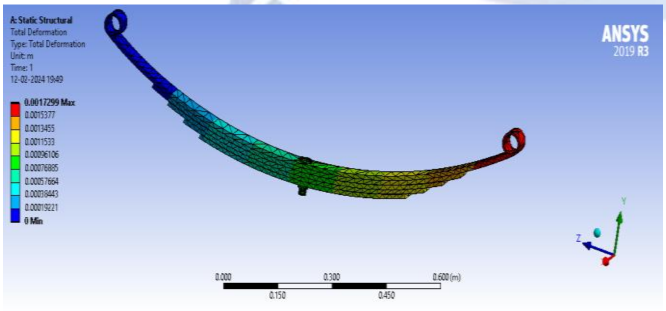


Fig.6.7 Total deformation

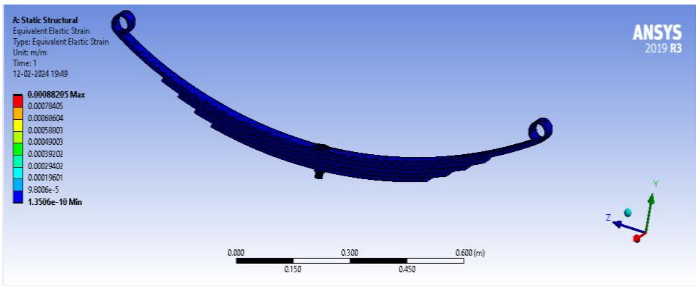


Fig.6.8 Equivalent elastic strain

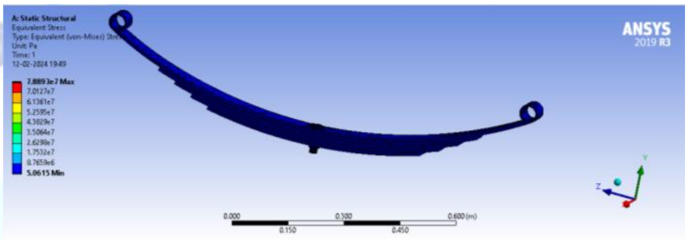


Fig.6.9 Equivalent stress

6.3. E-GLASS

E-Glass

Fibers only

Density	2.6e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	73000 MPa
Poisson's Ratio	0.22
Bulk Modulus	43452 MPa
Shear Modulus	29918 MPa

Table 6.3 Material properties of E-Glass

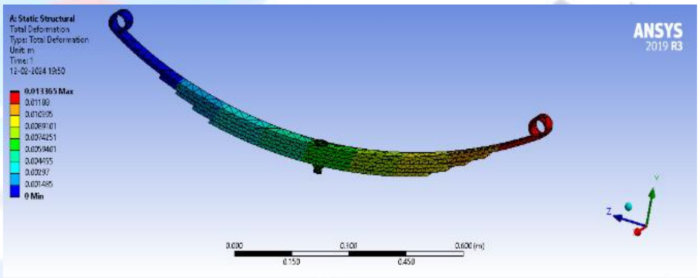


Fig.6.10 Total deformation

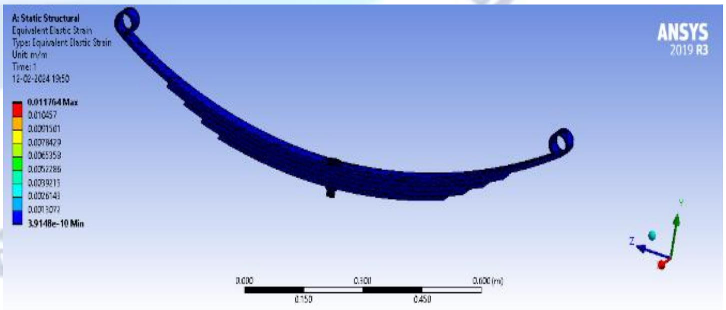


Fig.6.11 Equivalent elastic strain

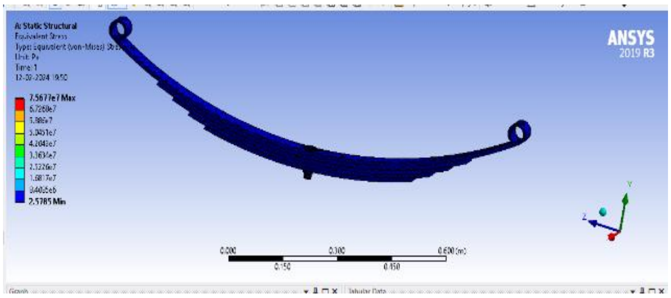


Fig.6.12 Equivalent stress

Materials	Total Deformation (m)		Equivalent Elastic Stain		Equivalent Stress (MPa)	
	Min.	Maximum	Minimum	Maximum	Minimum	Maximum
S-Glass	0	1.17299e-003	1.3506e-010	8.8205e-004	5.0615	7.8893e+007
E-glass	0	1.3365e-002	3.9148e-010	1.174e-002	2.5785	7.5677e+007
Carbon epoxy	0	76808e-004	8.4401e-011	3.8107e-004	11.4	7.5796e+007

Table 6.4 Results of all materials

7. CONCLUSION

As compared to the materials epoxy, e glass, s glass for leaf spring, epoxy is the best material. It has less weight and is good efficiency. The design of ling spring parts is designed in SolidWorks. We used SolidWorks 2020 for design and for analysis we used ANSYS workbench 2019. In workbench we analysed the leaf spring with static structural and we got best results in epoxy.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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