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CONTENTS

ABSTRACT

A leaf spring is a simple form of suspension spring used to absorb vibrations induced during the motion of a vehicle. The automobile industry has shown increased interest in the replacement of steel leaf springs (55Si7) with composite leaf springs (E-glass/Epoxy) due to high strength to weight ratio, higher stiffness, high impact energy absorption, and lesser stresses.

This project is aimed to investigate the suitability of natural and synthetic fiber reinforced hybrid composite material in automobile leaf spring applications. By using natural fibers efforts have been made to reduce the cost and weight of leaf springs. In this work, an attempt is made to develop a natural and synthetic fiber-enforced hybrid composite material with optimum properties that can replace the existing synthetic fiber-reinforced composite material in automobile leaf springs.

Jute and E-glass woven roving mats are used as reinforcements and epoxy resin LY556 is used as the matrix material. The CAD models of Leaf springs are prepared in CATIAV5 and imported into the static structural analysis workbench of Ansys 14.5 where ignite element analysis (FEA) is performed.

The design constraints are stresses and deflections. This study gives a comparative analysis between steel leaf spring and Jute/E glass-reinforced Epoxy leaf spring. The hybrid composite leaf spring is found to have lesser weight, lesser cost, lesser stresses, and higher stiffness.

Keywords: Automobile Industry; design; composite leaf spring; CARBON; E-glass; EPOXY28 CATIA V5:

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CHAPTER – I

INTRODUCTION

1.1 OVERVIEW OF LEAFSPRING

A leaf spring is along, flat, thin, and flexible piece of spring steel or composite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple, and leaves have been used in various capacities since medieval times. Most heavy-duty vehicles today use two sets of leaf springs per solid axle, mounted perpendicularly to the axle and supporting the vehicle's weight. This system requires that each leaf set act as both a spring and a horizontally stable link. Because leaf sets lack rigidity, such a dual-role is only suited for applications where load-bearing capability is more important than precision in suspension response. Older transverse leaf spring arrangements mounted the single leaf set running parallel to a live axle but used it both as a suspension link and a spring element in a similar manner to the traditional arrangement. In vehicles with independent suspension and a transverse leaf spring arrangement, the leaf is not used to control the wheel's location and acts only as a spring element. In this arrangement double wishbones act to locate the wheel, while a single leaf or leaf set connected to the front or rear sub-frame in the middle of the vehicle and the lower wish bone on each side provides the spring element. In some applications, two transverse leaf springs are used on a single axle with each providing separate springing action to each wheel. In the past, most transverse leaf springs arrangement suspend multiple steel elements in asset similar to their traditional longitudinal counterparts, but most modern applications use a composite (generally fiberglass) mono leaf element.

Fig.1.1 A traditional leaf spring arrangement.

Originally called laminated or carriage spring a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is one of the oldest forms of springing, dating back to medieval times.

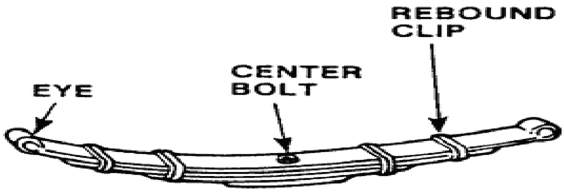


Fig.1.2 Leaf Spring of Automobiles

Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The centre of the arc provides a location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with systematically shorter leaves. Leaf springs can serve to locate and to some extent damping as well as springing functions.

1.2 HISTORY OF A LEAF SPRING

Many early vehicles such as the Ford Model T used transverse leaf springs on both the front and rear suspension in conjunction with a live axle. In the early 1930s, Dante Giacosa developed the Fiat Topolino which used transverse steel leaf springs and double wishbones in an independent front suspension. The Triumph Motorcar Company also developed an independent rear suspension with a transverse leaf spring arrangement for their line of small cars in the 1950s. The Triumph arrangement, first seen on the 1959 Herald was developed to introduce an inexpensive independent rear suspension. Results were mixed with considerable safety issues surrounding the vehicle’s tendency to snap into oversteer.

There were a variety of leaf springs, usually employing the word" elliptical". "Elliptical" or" full elliptical "leaf springs referred to two circular arcs linked at their tips. This was joined to the frame at the top Centre of the upper arc; the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailing arms, would be needed for this design, but not for "semi- elliptical" leaf springs as elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over their differentials that were curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non- metallic sheets in between the metal leaves, such as wood.

Leaf springs were very common in automobiles, right up to the 1970s, when the move to front-wheel and more sophisticated suspension designs saw automobile manufacturers use superior coil springs instead. U.S. passenger carsused leaf springs until 1989 when the Chrysler M platform was the final production vehicle marketed. However, leaf springs are still used in heavy commercial vehicles such as vans and trucks, and railway carriages. Heavy vehicles have the advantage of spreading the load more widely over the vehicle's chassis, whereas coil springs transfer it to a single point. Unlike coil springs, leaf springs also locate the rear axle, eliminating the need for trailing arms and a Pan hard rod, there by saving cost and weight in a simple live axle rear suspension.

A more modern implementation is the parabolic leaf spring. This design is characterized by fewer leaves whose thickness varies from center to end following a parabolic curve. In this design, inter-leaf friction is unwanted, and therefore there is only contact between the springs at the ends and at the center where the axle is connected. Spacers prevent contact at other points.

CHAPTER 2

LITERATURESURVEY

2.1 LITERATURE REVIEW

There are various researches for the comparison between composite leaf springs and laminated leaf springs for various types of vehicles.

Kumar Krishna and Aggarwal M.L carried out a multiculti-leaf spring having nine leaves used by a commercial vehicle. The finite element modeling and analysis of a multi-leaf spring have been carried out. It includes two full-length leaves in which one with eyed ends and seven graduated length leaves. The material of the leaf spring is SUP9. The FE model of the leaf spring has been generated in CATIAV5R17 and imported in ANSYS-11 for finite element analysis, which is the most popular CAE tool. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining the under-defined boundary condition. Bending stress and deflection are the target results. A comparison of both i.e. Experimental and FEA results has been done to conclude.

Pankaj Saini, Ashish Goel, and Dushyant Kumar reducing weight while increasing or maintaining the strength of procuresses getting to be 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 touch issues. In the papermaker redescribe the design and analysis of a composite leaf spring. The objective is to compare the stressed weight saving of composite leaf spring with that of steel spring. The design constraint is stiffness. The Automobile Industry as the of the replacement of steel leaf spring with that of composite leaf spring, since the composite materials have the strength to weight ratio, and good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite-epoxy is used against conventional steel. The design parameters were selected and analyzed to minimize the weight of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modelled inAuto-CAD2012andtheanalysis was done using ANSYS 9.0 software.

Shisha Amare Gebremeske Reducing weight while increasing or maintaining the strength of products is getting to be 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. In this project, reducing the light of vehicle sand increasing or maintaining the strength of their asparaguses are considered. A leaf spring contributes considerable of weight to the vehicle and needs to be strong enough, a single E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials considering static loading only.

The constant cross-section design of leaf springs is employed to take advantage of the ease of design analysis and its manufacturing process. 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. The designed composite leaf spring has also achieved its acceptable fatigue life. This particular design is made specifically for lightweight three-wheeler vehicles Its prototype is also produced using the hand lay-up method.

Jadhav Mahesh, Zoman Digambar B, YR Kharde and R R Kharde efforts have been made to reduce the cost of composite leaf springs that of steel leaf sspspringshe achievement of weight reduction w h adequate improvement of mechanical properties has made composite a very replacement material conventional teel. Material and manufacturing processes are selected upon on the cost and strengfactorstor. His design met is selected on the basis as production. From the comparative study, it is seen that the composite leaf spring are higher and more economical than conventional leaf springs. After prolonged use of conventional metal Coil Spring, its strength reduces and the vehicle starts running backside down and also hits on the bump stoppers (i.e. Chassis). This problem is entirely removed by our special purpose Composite leaf Springs.

Santhosh Kumar and Vimal Teja composite structures for conventional metallic structures have many advantages because of the higher specific stiffness and strength of composite materials are discussed. The automobile industry has shown increased interest in the replacement of steel springs with fiber glass composite leaf springs due to the high strength to weight ratio. This deals with the replacement of conventional steel leaf spring with a Mono Composite leaf spring using E-Glass/Epoxy. The design parameters were selected and minimizing whether right post the spring as compared to the steel leaf steel was modelled in modelled and the analysis was done using ANSYS Metaphysics software

Manas Patnaik, L.P. Koushik and Manoj Mathew have been carried out on a parabolic leaf spring of mini truck. The spring has been analyzed by applying a load of 3800N and the corresponding values of stress and displacement are computed. In this work, Design of experiments has been applied under various configurations of the spring (i.e by varying camber &eye distance). Camber and Leaf span of a Parabolic Leaf Spring was found for Optimized Stress and Displacement value using Artificial Neural Networks. Various networks with different architecture were trained and the network giving the best performance was used for optimization.

Baviskar A. C.1, Bhamre V. G.2, Sarode S. S.3 (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 6, June 2013. The aim of this review paper is to of present general study on the design, analysis of leaf springs. The suspension system in a vehicle significantly affects he 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. Now the automobile industry has shown interest in the replacement of steel spring with composite leaf spring. In general, it is found that fiberglass material has better strength characteristic and lighter in weight as compare to steel for leaf spring. In this paper there is reviewed some papers on the design and analysis leaf spring performance and fatigue life prediction of leaf spring. There is also the analysis of failure in leaf spring. Al so the analysis of leaf spring with ANSYS is done. The automakers can reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing.

Bhushan, Deshmukh, Dr. Santosh and B. Jaju Int J Engg Tech sci. Weight reduction is now the main issue in automobile industries. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The introduction of FRP material has made it possible to reduce the weight of spring without any reduction on load carrying capacity. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel. Selection of material is based on cost and strength of material. The composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, somulti-leaf steel springs are being replaced by mono-leaf composite springs. The paper gives the brief look at the suitability of composite leaf springs on vehicles and their advantages. The objective of the present work is the design, analysis and fabrication of a mono composite leaf spring. The design constraints are stress and deflections. The finite element analysis is done using ANSYS software. An attempt has been made to fabricate the FRP leaf more spring economically than that conventional leaf spring.

Venkatesan and Helmen Devaraj describes the design and experimental analysis of a composite leaf spring made of glass fiber reinforced polymer. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken. Same dimensions of conventional leaf spring are used to fabricate a composite multi-leaf spring E Glass/Epoxy unidirectional laminate. Static analysis of the 2a-3Dmodel of conventional leaf spring is also performed using ANSYS10 and compared with experimental results. Finite element analysis with faull load then3-D model of composite multi-leaf spring is done using ANSYS10 and the analytical results are compared with experimental results. Compared to the steel spring, the composite leaf spring is found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that existing steel leaf spring. A weight reduction of 76.4% is achieved by Using optimized composite leaf spring.

Gulur Siddaramanna and shivashankar, Sambagam interest in the replacement of steel spring with fiber glass composite leaf spring due to high strength to weight ratio. Therefore; the aim of this paper is to present a low-cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints Also, general study on the analysis and design. A single leaf with variable thickness and width for constant cross-sectional area of unidirectional glass fibre reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi-leaf spring, was designed, and fabricated (hand-lay-up technique) and tested. A computer algorithm using C-language has been used for the design of a constant cross-section leaf spring.

The results showed that a spring width decreases hyperbolically and thickness increases linearly from the spring eyes towards the axle seat. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses (Tsai-Wu failure criterion) and displacement. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit.

Patunkar1and Dolas Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment positions. Another part that has to be focused; is the automobile industry has shown increased interest in the replacement of steel springs with composite leaf spring due to high strength to weight ratio. Therefore, analysis of the composite material becomes equally important to study the behavior of Composite Leaf Spring. The objective of this paper is to present modeling and analysis of composite mono leaf spring (GFRP) and compare its results. Modelling is done using Pro-E(Wild Fire) and Analysis is carried out by using ANSYS 10.0 software for better understanding

CHAPTER3

METHODOLOGY

3.1 SELECTION OF MATERIALS FOR STEEL AND COMPOSITE LEAF SPRING

3.1.1 Construction of Leaf Spring

A leaf spring commonly used in automobiles is of semi-elliptical form. It is built up of a number of plates (known asl eaves). The leaves are usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaves are held together by means of a band shrunk around them at the centre or by a bolt passing through the centre. Since the band exerts stiffening and strengthening effect, therefore the effective length of the spring for bending will be overall length of the spring minus width of band. In case of a centre bolt, two-third distance between centers of U-bolt should be subtracted from the overall length of the spring in order to find effective length. The spring is clamped to the axle housing by means of U-bolts.

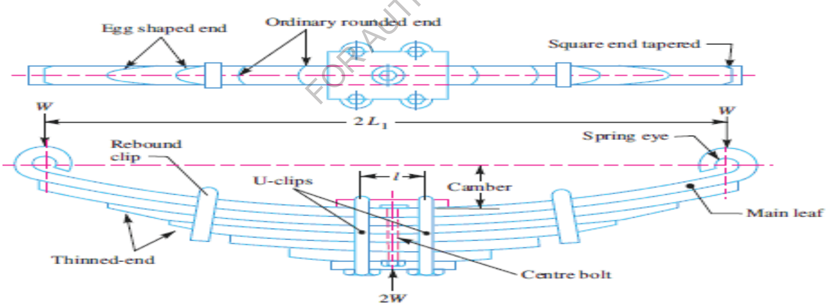


Fig.3.1Semi-EllipticalLeafSpring

3.2 SEMI-ELLIPTICALLEAFSPRING

The longest leaf known as main leaf or master leaf has its ends formed in the shape of an eye through which the bolts are passed to secure the spring to its supports. Usually the eyes, through which the spring is attached to the hanger or shackle, are provided with bushings of some antifriction material such as bronze or rubber.

The other Leaves of the spring are known as graduated leaves. In order to prevent digging in the adjacent leaves, the ends of the graduated leaves are trimmed in various forms. Since the master leaf has to with stand vertical bending loads as well as loads due to sideways of the vehicle and twisting, therefore due to the presence of stresses caused by these loads, it is usual to provide two full-length leaves and the rest graduated leaves. Rebound clips are located at intermediate positions in the length of the spring so that the graduated leaves also share the stresses induced in the full-length leaves when the spring rebounds.

3.3 MATERIALUSEDINLEAFSPRING

The basic requirement for spring steel is that it should have sufficient hardening ability relative to leaf thickness to ensure a fully martensitic structure throughout the entire cross section of the leaf spring.

The Japanese standard, JISG4801 for hot formed spring steel, can be widely applied to coil spring, and leaf spring of automobiles. SUP9, Mn–Cr steel, shows good hot deformability and good hardenability to be applied for the relatively large sized stabilizers, torsion bars, and coil springs. SUP9A, which is equivalent to SAE5160 steel, has basically the same chemical composition as the SUP9 with a little bit higher carbon and higher range of Mn and Cr to improve its hardenability. Silicon is the key component to most spring steel alloys. Composition of sup 9 steel is as under.

3.3.1 Basic Characteristics of Spring Materials

Basic characteristics of spring materials are:

1. Static mechanical properties, especially tensile strength, elastic limit, spring deflection limit, hardness and elastic modulus.
2. Dynamic properties, especially, fatigue strength (fatigue life at a constant stress amplitude, or fatigue endurance limit),
3. creep (progressive deformation of material at constant stress) or stress relaxation (time-dependent decrease in stress under constant constraint), that causes permanent set, and
4. Corrosion resistance.

Besides these characteristics, the elastic modulus which can greatly affect to spring characteristics is discussed here

An elastic modulus of metallic material under constant temperature has been regarded as a microstructure insensitive constant decided only by chemical compositions. However, the demands for more precise Mechanical Evaluation of parts have been increasing to apply more precise elastic modulus. (Materials for springs)

3.4 MECHANICAL PROPERTIES OF LEAFSPRING

Steels of the same hardness in the tempered martensitic condition have approximately the same yield and tensile strengths. Ductility, as measured by elongation and reduction in area, is inversely proportional to hardness. Based on experience, the optimum mechanical properties for leaf spring applications are obtained with in the hardness range 388 to 461 HBN. A specification for leaf springs usually consists of arrange covered by four of these hardness numbers, such as 415 to 461 HBN (for thin section sizes)

The mechanical performance of vehicle leaf Spring is influenced, in a complex way, by the number of material and processing details, for example, spring steel is typically subjected to hot farming and heat-treating operations followed by mechanical processing such as shot penning and presetting. Each of these steps can significantly affect the structure and properties of the material as well as the residua1stress patterns built up in surface layers. Service loading may also alter original residual stress levels as a result of cyclic stress relaxation.

3.5 MANUFACTURINGOFLEAFSPRING

In Landhi engineering works multi-leaf springs are manufactured for the vehicle's suspension from low alloy medium carbon steel (manganese-chrome steel) JIS G4801sup9 in the shape of a flat bar have a different cross-section for different vehicles. Sup 9 material is locally manufactured in people steel mill Karachi. The manufacturing steps of the leaf spring employed in Landhi engineering works are shown diagrammatically in the flow chart.

Fig.3.2 manufacturing of a leaf spring

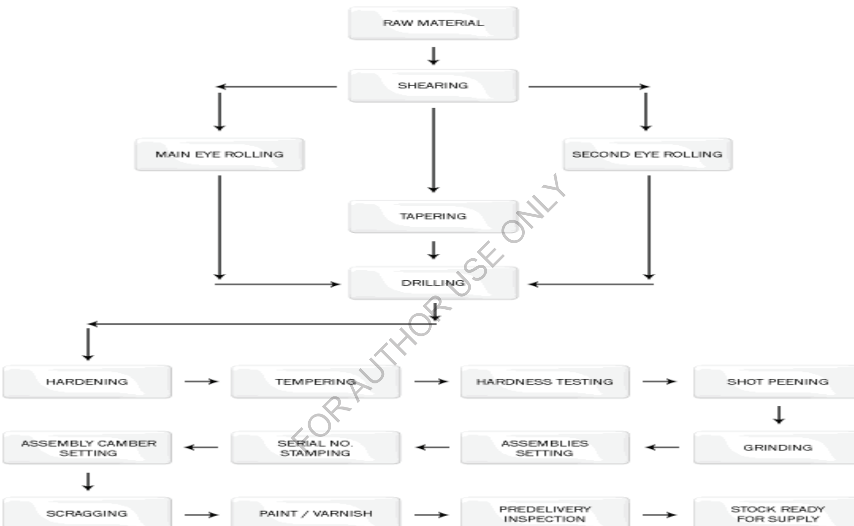


Fig.3.3 Flow chart Manufacturing Process of Leaf Spring

The manufacturing steps shown in flow chart Fig 3.3 are briefly described below.

3.5.1 Shearing

Cutting of steel bars in required specification using shearing machine is known as shearing.

3.5.2 Main Eye Rolling

After shearing bars are taken to rolling machine for bending the corners/ends. This step is known as eye rolling.

3.5.3 Tapering

Tapering is a process of making curve like structure by bending the flat bars.

3.5.4 Drilling

In drilling holes in the center of all leaf are produced for fastening leaf spring by nut and bolt.

3.5.5 Hardening

Hardening a ferrous alloy by automatizing and then cooling rapidly enough so that some or all of the austenite transforms to martensite. A very rapid rate of cooling forces carbon to remain in solution and austenite transforms to martensite. Martensite is an interstitial supersaturated solid solution of carbon in α-iron and has body centered tetragonal lattice. Martensite is very hard and brittle. The austenitizing temperature for low alloy (Mn-Cr) steel is (850-900 ^{0}c).

3.5.6 Tempering

The martensite formed in quench hardened steel is exceedingly brittle, hard and highly stressed; the cracking and distortion of the hardened article is liable to occur after quenching. For this reason, the use of steel in this condition is inadvisable except in cases where extreme hardness is required.

It is therefore necessary to return towards equilibrium, after quench hardening, by heating the (hardened) steel to a temperature below the lower critical temperature (A1); this is tempering. In Landhi works leaf springs after hardened are tempered at 430-500^{o}C temperature.

3.5.7 Hardness Test

Hardness is the property of material to resist plastic deformation usually by indentation. Tests such as Brinell, Rockwell, Vickers etc, are generally employed to measure hardness. In Landhi engineering works Brinell tester is used.

3.5.8 Shot Peening

This process results in increasing the fatigue life of the steel bar sand is normally applied on the products which are manufactured. This process is carried out in specifically designed machine; the small steel balls are strike the surface of the Leaf spring and induce stresses on the surface which causes an increase in fatigue life.

Then necessary grinding of leaves surfaces is applied. Finally, different sizes of bars are assembled by central bolt and their serial and identification numbers are punched on them Before Paint and Varnish they are tested for Curvature Arc Height.
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

The spring consists of a number of leaves called blades. The blades are varying 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 up on the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called the 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 is connected with a shackle. The shackle is the flexible link which connects between the 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.

3.6 SUSPENSION SYSTEM

The automobile chassis is mounted on the axles, not direct but in 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, anybody. All the part, which performs 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, 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.

3.6.1 ObjectiveofSuspension

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.

3.7 EQUALIZED STRESS IN SPRING LEAVES(NIPPING)

We have already discussed that the stress in the full-length leaves is 50% greater than the stress in the graduated leaves. In order to utilize the material to the best advantage, all the leaves should be equally stressed. This condition may be obtained in the following two ways.

1. By making the full-length leaves of smaller thickness than the graduated leaves. In this way, the full- length leaves will induce smaller bending stress due to the small distance from the neutral axis to the edge of the leaf.

2. By giving a greater radius of curvature to the full-length leaves than graduated leaves, before the leaves are assembled to form a spring by doing so, a gap or clearance will be left between the leaves. This initial gap is called nip. When the central bolt, holding the various leaves together, is tightened, the full-length leaf will bend back and have an initial stress in direction opposite to that of the normal load. The graduated leaves will have an initial stress in the same direction as that of the normal load. The graduated leaves will have an initial stress in the same direction as that of the normal load.

3. When the load is gradually applied to the spring, the full-length leaf is first relieved of this initial stress and then stressed in opposite direction. Consequently, the full-length leaf will be stressed less than the graduated leaf. The initial gap between the leaves may be adjusted so that under maximum load conditions the stress in all the leaves is equal, or if desired, the full-length Waves may have the lower stress. This is

desirable in automobile springs in which full-length leaves are designed for lower stress because the full-length leaves carry additional loads caused by the swaying of the car, twisting and in some cases driving the car through the rear springs.

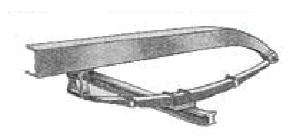
A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm.

The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. There are different varieties of leaf springs which are used according to the requirement.

3.8 TYPES OF LEAF SPRING

Elliptic :

Semi-elliptic :



Three quarter-elliptic:

Quarter-elliptic :

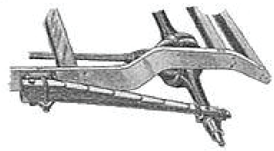


Fig.3.4 Equalized stress in spring leaves (Nipping)

3.9 SELECTION OF COMPOSITE MATERIAL

3.9.1 Experimental Materials

There are three types of materials employed in this study:1.] Steel2.] E-Glass/Epoxy3.] Jute/E-Glass/Epoxy65Si7 is the most popular grade of spring steel being used in automobile leaf spring.

Table3.1: Mechanical Properties of 55Si7.

Parameter	Young's Modulus	Poisson's Ratio	Tensile Strength	Density
Value	190-210MPa	0.27-0.30	572.3MPa	1000 kg/m^3

Springs are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as:

$$U = \sigma^2/\rho E$$

Where, σ is the strength, ρ is the density and E is the young's modulus of the spring material. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Research has indicated that E-Glass/Epoxy has good characteristics for storing specific strain energy as E-glass has
Lower young's modulus and lower density than steel. Hence, E-Glass/ Epoxy is selected as the composite material. In this research work, a natural fiber i.e. Jute is IntroducedinE-Glass/Epoxytodevelopahybridcompositematerialwhichcanreduce the weight as well as cost of leaf spring.

For experimental work, ARALDITE LY-556 Epoxy resin having density 1.1gm/cm3 and curing agent ARADUR HY-951 from HUNTSMAN Ciba-Geigy India Ltd. Is used. E-Glass fiber as woven roving mat having surface density 400 GSM and Jute fiber as woven roving mat having surface density 350 GSM is used.

3.10 Preparation of Composite Laminates

Hybrid laminates of woven jute and glass mat are prepared by hand layup technique. A mild steel mold of dimension 165x165x5 mm is used for the fabrication of composite sheet. The mold is coated with a mold releasing agent for the easy removal of the sample. At first the glass fiber and jute fiber mats of required size are cut so that they can be deposited on the template layer by layer during fabrication. Next the epoxy resin is preheated for about 3minutes at 400C temperature in order to increase the flowability of resin. The resin is then cooled and mixed with hardener in a weight ratio of 10:1 and stirred slowly for a bout10 to15minutes.Two OHP sheets are used at the top and bottom of the mold to give smooth surface finish. Now some amount of resin is poured into the mold, care is taken to avoid formation of air bubbles during pouring. Ten layers of fiber mats are placed one over Another with resin layer in between. Brush and roller are used to impregnate fiber mats and also to avoid air entrapped. The fiber weight fraction is maintained at 40 to 45%, since optimum mechanical properties are achieved at this much fiber fraction. Now the mold is placed in the compression molding machine. Approximately 80 kgf pressure is applied on the mold and it is allowed to cure at room temperature for 24 hours. After 24 hours the mold is removed from the compression molding machine and the sample is taken out of the mold. Samples are prepared having 100% glass, 10% jute-90% glass, 20% jute-80% glass, 30% jute-70% glass and 40% jute-60% glass fiber.

3.11 Tensile Property Test

Mechanical properties such as tensile strength, Young’s modulus, elongation at break and Poisson’s ratio are measured by using a universal testing machine of the INSTRON model 3382, USA with the maximum load capacity 100 KN. Tensile test is Conducted according to ASTMD-638 at 2mm/min test speed for each composition, five measurement are taken and average values of strength, modulus, elongation at break and Poisson’s ratio are reported. 100% glass and 20% jute-80% glass compositions both having epoxy as the base matrix are selected for automobile leaf spring application.

Table3.2: Mechanical Properties of E-glass/Epoxy.

Parameter	**Young’s Modulus**	**Poisson’s Ratio**	**Tensile Strength**	**Density**
Value	24000 MPa	0.3	205 MPa	1520 Kg/mm^3

Table3.3: Mechanical Properties of Jute/E-glass/Epoxy.

Parameter	Young's Modulus	Poisson's Ratio	Tensile Strength	Density
Value	21000 MPa	0.22	185 MPa	1460 Kg/mm^3

The following methodology is adopted for the present work.

- Present work is related to the comparative study of "55 Si 7 steel and composite leaf spring" Component details.
- The component details is studied andprepared3-D model in CATIAV5 software.
- The component is studied for the operation required to convey the different types of loads on it. Design the component in the required shape and dimensions and analyzed.
- Design calculations are carried for the component leaf spring with the help of material properties which are specified by the previous research.
- Analysis work is carried by importing 3-D model into Ansys software. A FEM model of leaf spring, only one leaf is created by using Ansys processor. The material properties loads and boundary conditions are also specified in the Ansys Processor.
- Analysis work is done by applying loads on the leaf spring then the results such as stress, strain, total deformation are obtained.
- The results are compared with material properties of the material used for the component. Then we find that results obtained by using FEM are within the material properties. There we find that the component can withstand for given loads during operation.

3.12 Standard Size Of Automobile Suspension Spring

Following are the standard sizes for the automobile suspension springs:

1. Standardnominalwidthsare:32,40*,45,50*,55,60*,65,70*,75,80,90,100and125 mm. (Dimensions marked*are the preferred widths)
2. Standard nominal thicknesses are: 3.2,4.5, 5,6, 6.5, 7,7.5, 8,9, 10,11, 12,14 and 16mm.
3. At the eye, the following bore diameters are recommended:19,20,22,23,25,27,28,30, 32,35, 38, 50 and 55 mm.
4. Dimensions for the center bolts, if employed, shall be as given in the following table.

Leaf springs are also made of various fine grade alloy steel. The most commonly used grades of spring steel are 55 Si 7,60 SiCr7, 50CrV4. In India at UAW manufacture springs using EN 45A, 55 Si 7, 60 Si 7, 65 Si 7, 55 Si Cr 7, 60 Si Cr 7 & 65 Si Cr 7 grades of steel. The flats should be free of defects like Piping, Seams, Edge Cracks, End links, Rust pitting and other Rolling Defects. Flats shall usually be with round edges. The edges shall be rolled convex with the radius of curvature of the edge approximately equal to the thickness of the flat or as agreed between the purchaser and supplier. Different cross sections of steel are used for the manufacture of leaf springs depending on the design. The chemical composition of spring steel mentioned above is as under in table 3.4.

Table3.4: Chemical Composition of Different Grades.

	GRADE	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**V**
1	**EN 45A**	0.55-0.65	1.70-2.10	0.70-1.00	0.040 Max	0.040 Max	-	-
2	**55 Si7**	0.55-0.6	1.50-1.80	0.70.1.00	0.045 Max	0.045 Max	-	-
3	**60 Si7**	0.55-0.65	1.50-2.00	0.80-1.00	0.040 Max	0.040 Max	-	-
4	**65 Si7**	0.60-0.68	1.50-1.80	0.70-1.00	0.050 Max	0.050 Max	-	-

CHAPTER-4

MODELINGOFALEAFSPRING

4.1 Standard Semi Elliptical Leaf Spring

This chapter involves the determination of bending stress by using mathematical formula. Determination of length of leaf spring leaves, consequently the rotation angle and the radius of curvatures of each leaf, these are used in geometric modeling. There is a difference in measurement between the terms "spring arch" and "spring camber". Both are a height measurement, and both are referenced from the center mounting surface. Arch is measured to the center of the end mounting eyes. Camber is measured to the top of the main leaf immediately below the center of the end eyes. As such, if you load the spring until the main leaf is flat, camber will be zero, but arch will be 1/2 the diameter of the end eye.

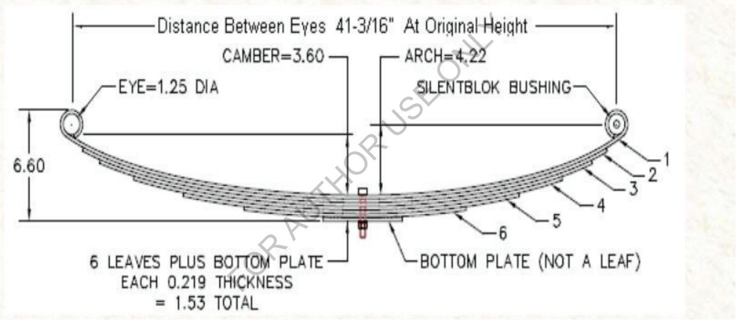


Fig.4.1. Standard Semi elliptical leaf spring

Distance between eyes = 1100

Camber=96.8

Height= 167.64

For the leaf spring in original form,

Free Camber = 3.60" (factory specification)
spring eye=1-1/4"diameter (0.625"-radius). Leaf
thickness = 7/32"
Number of functional leaves=6

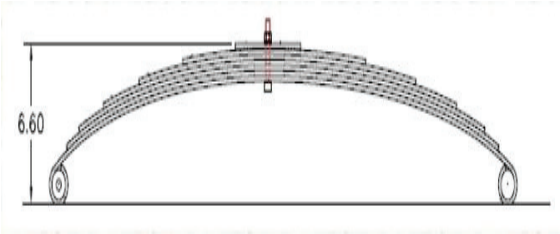


Fig.4.2. Standard Semi standard height of elliptical leaf spring

If you place the original leaf spring up side down on the floor, then start measuring from the floor up, you get:

0.22= Thickness of top loop

1.25 =Eye inside diameter

3.60=Free camber

1.31=Spring thickness (7/32 x 6 leaves)

0.22=Bottom plate (short, flat, non-functional)

6.60=Total Spring height, not including center bolt

4.2 LENGTH OF LEAF SPRING LEAVES

The length of the leave spring leaves obtained as discussed below

Let

$2L_I$=Length of span or overall length of the spring

I= Distance between centers of U- Bolts

It is the ineffective length (I.L) of the leaf spring n_F= Number of full-length leaves

n_G = Number of graduated leaves and

n=Total number of leaves =n_F+n_G

E.L =Effective length of the spring = $2L_I$– (2/3)I

Length of smallest leaf= $\frac{\text{Effective length } X1+\text{Ineffectivelength}}{n-1}$

Length of next leaf= $\frac{\text{Effective length } X2+\text{Ineffectivelength}}{n-1}$

Similarly,

Length of $(n-1)^{th}$= $\frac{\text{Effective length } X1+X(n-1)+\text{In effective length}}{n-1}$

Length of master leaf $=2L_I+2\pi\,(d+t)$

Where
d= Inside diameter of eye

t=Thickness of master leaf

Relation between radius of curvature(R) and the camber(C)of the spring $C\,(2R-C) = L_1{}^2$

Table 4.1: Design Parameters of Steel Leaf Spring.

Total Length of Leaf Spring (Eye to Eye)	1100mm
Arc Height at Axle Seat	170mm
Thickness of Leaf Spring	6 mm
Width of Leaf Spring	56 mm
Outer Diameter of Eye	50 mm
Inner Diameter of Eye	44 mm

The following table shows the specifications of a leaf spring in CATIA V5.

INTRODUCTIONTOCATIA

Introduction To CAD/CAM/CAE

The Modern world of design, development, manufacturing so on, in which we have stepped can't be imagined without interference of computer. The usage of computer is such that, they have become an integral part of these fields. In the world market the competition is not only cost factor but also quality, consistency, availability, packing, stocking, delivery etc. So the requirements are forcing industries to adopt modern technique rather than local forcing the industries to adapt better techniques like CAD / CAM / CAE, etc.

The Possible basic way to industries is to have high quality products at low costs is by using the computer Aided Engineering (CAE), Computer Aided Design (CAD) And Computer Aided Manufacturing (CAM) set up. Further many tools been introduced to simplify & serve the requirement CATIA, PRO-E, UG are some among many.
This penetration of technique concern has helped the manufacturers to

a) Increase productivity
b) Shortening the lead-time
c) Minimizing the prototyping expenses
d) Improving Quality
e) Designing better products

CAD: Computer Aided Designing (Technology to create, Modify, Analyze or Optimize the design using computer.

CAE: Computer Aided Engineering (Technology to analyze, Simulate or Study behaviour of the cad model generated using computer.

CAM: Computer Aided Manufacturing (Technology to Plan, manage or control the operation in manufacturing using computer.

Need for CAD,CAE & CAM:

The usage of CAD CAE &CAM have changed the overlook of the industries and developed healthy & standard competition, as could achieve target in lean time and ultimately the product reaches market in estimated time with better quality and consistency. In general view, it has lead to fast approach and creative thinking.

ADVANTAGES:

- Cut off of the designing time
- Cut off of the editing time
- Cut off of the manufacturing time
- High& controlled quality
- Reduction of process cost.
- Consistency
- Maintenance of Universal accessing data

DRAWBACKS:

- Requires skilled operators
- Initial setting & assumption consumes time
- Setting cost is more
- Over heads are high and
- Applicable if production is high

Introduction to CATIA

CATIAisarobustapplicationthatenablesyoutocreaterichandcomplexdesigns. The goals of the CATIA course are to teach you how to build parts and assemblies in CATIA, and how to make simple drawings of those parts and assemblies. This course focuses on the fundamentalskillsandconceptsthatenableyoutocreateasolidfoundationforyourdesigns.

Parametric

The dimensions and relations used to create a feature are stored in the model. This enables you to capture design intent, and to easily make changes to the model through these parameters. Driving dimensions are the dimensions used when creating a feature. They include the dimensions associated with the sketch geometry, as well as those associated with the feature itself. Consider, for example, a cylindrical pad. The diameter of the pad is controlled by the diameter of the sketched circle, and the height of the pad is controlled by the depth to which the circle is extruded. This type of information is typically communicated on drawings using feature control symbols. By capturing this information in the sketch, CATIA enables you to fully capture your design intent up front.

Solid Modelling:-

AsolidmodelisthemostcompletetypeofgeometricmodelusedinCADsystems.Itcontainsallthewir eframe and surface geometry necessary to fully describe the edges and faces of the model. In addition to geometric information, solid models also convey their ―topology, which relates the geometry together. For example, topology might include identifying which faces (surfaces) meet at which edges (curves). This intelligence makes adding features easier. For example, if a model requires a fillet, you simply select an edge and specify a radius to create it.

Fully Associative: -

ACATIAmodelisfullyassociativewiththedrawingsandpartsorassembliesthatreferenceit.Change stothe model are automatically reflected in the associated drawings, parts, and assemblies. Likewise, changes in the context of the drawing or assembly are reflected back in the model.

Constrains: -

Geometric constraints (such as parallel, perpendicular, horizontal, vertical, concentric, and coincident) establish relationships between features in your model by fixing their positions with respect to one another. In addition, equations can be used to establish mathematical relationships between parameters. By using constraints and equations, you can guarantee that design concepts such as through holes and equal radii are captured and maintained.

<u>What is CATIA.</u>

CATIA is mechanical design software. It is a feature-based, parametric solid modeling design

tool that takes advantage of the easy-to-learn windows graphical user interface. You can create fully associative3- D solid models with or without constraints while utilizing automatic or user-defined relations to capture design intent.
To further clarify this definition, the italic terms above will be further defined:

Feature-based

Like an assembly is made up of a number of individual parts, a CATIA document is made up of individual elements. These elements are called features.

When creating a document, you can add features such as pads, pockets, holes, ribs, fillets, chamfers, and drafts. As the features are created, they are applied directly to the work piece. Features can be classified as sketched-based or dress-up:

• Sketched-based features are based on a 2D sketch. Generally, the sketch is transformed in to a 3D solid by extruding, rotating, sweeping, or lofting.

• Dress-up features are features that are created directly on the solid model. Fillet sand chamfers are examples of this type of feature.

CATIA User Interface:

Below is the layout of the elements of the standard CATIA application.

- Menu Commands
- Specification Tree
- Window of Active document
- File name and extension of current document
- Icons to maximize/ minimize and close window
- Icon of the active work bench
- Tool bars specific to the active work bench
- Standard toolbar
- Compass

Different types of engineering drawings, construction of solid models, assemblies of solid parts can be done using inventor.
Different types of files used are:

1. Part files: CAT Part
2. Assembly files.CAT Product

Workbenches

Work benches contain various tools that you may need to access during your part creation. You can switch between any primary workbenches using the following two ways:

A. Use the Start Menu.

B. Click File >New to create a new document with a particular file type. The associated work bench automatically launches. The parts of the major assembly is treated as individual geometric model, which is modeled individually in separate fil. All the parts are previously planned & generated feature by feature to construct full model

Generally all CAD models are generated in the same passion given below :

Enter CAD environment by clicking, later into part designing mode to construct model

Select plane as basic reference

Enter sketcher mode.

In sketcher mode:

Tool used to create2-D basic structure of part using line, circle etc.

Tool used for editing of created geometry termed as operation

Tool used for Dimensioning, referencing. This helps creating parametric relation.

Its external feature to view geometry in &out

: Tool used to exit sketcher mode after creating geometry.

Sketch-Based Feature:

Pad: On exit of sketcher mode, the feature is to be padded. (adding material)

Pocket: On creation of basic structure further pocket has to be created (removing material)

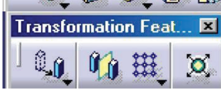
Revolve: Around axis the material is revolved, the structure should be same profile around axis.

Rib: sweeping uniform profile along trajectory (adding material)

Slot: sweeping uniform profile along trajectory (removing material)

Loft: Sweepingnon-uniform/uniformprofileondifferentplanealonglinear/non- linear trajectory

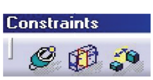
: Its 3D creation of features creates chamfer, radius, draft, shell.



: Its tool used to move geometry, mirror, pattern, scaling in 3D Environment on creation of individual parts in separate files.

Assembly environment: In assembly environment the parts are recalled &constrained.

Product structure tool :To recall existing components already modeled.



: Assembling respective parts by mean of constraints

 **Update**: updating the made constrains.

- Additional features are: Exploded View, snap shots, clash analyzing numbering, bill of material etc.
- Finally creating draft for individual parts & assembly with possible details

The parts of the major assembly is treated as individual geometric model, which is modeled individually

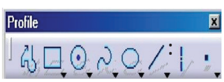
Generally, all CAD models are generated n the same passion given below:

: Enter CAD environment by clicking, later into part designing mode to construct model.

 : Select plane as basic reference.

 : Enter sketcher mode.

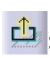
In sketcher mode:



Tool used to create2-Dbasicstructureof part using line, circle etc.

Tool used for editing of created geometry termed as operation.

Tool used for Dimensioning, referencing. This helps creating parametric relation

: Tool used to exit sketcher mode after creating geometry.

Sketch-Based Feature:

 **Pad**: On exit of sketcher mode the feature is to be padded (Adding material).

 **Pocket**: On creation of basic structure further pocket has to be created removing material)

 **Revolve**: Around the axis, the material is revolved, and the structure should have the same profile around axis.

 **Rib**: sweeping uniform profile along the trajectory (adding material)

 **Slot**: sweeping uniform profile along the trajectory (removing material)

 **Loft**: Sweeping non-uniform/uniform profile on the different plane along linear/non-linear Trajectory

: Its3D creation of features creates chamfer, radius, draft, shell,thread

Its tool is used to move geometry, mirror, pattern, and scaling in 3D Environment

4.3.1 FINAL DESIGNED MODEL OF LEAF SPRING IN CATIAV5 FOR 55SI7.

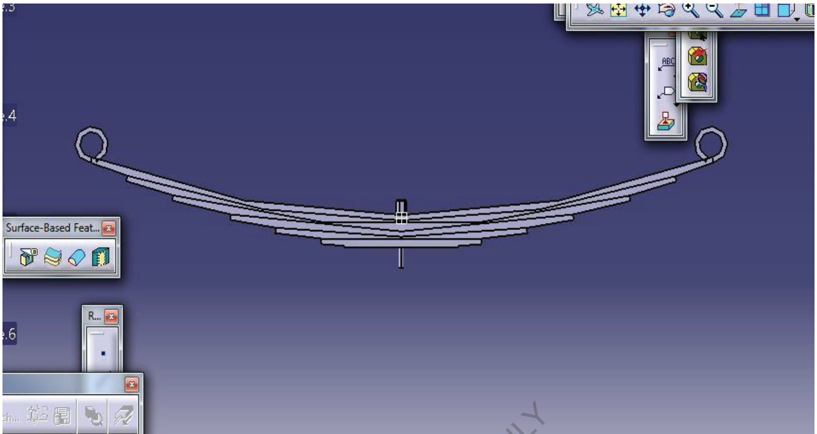


Fig.4.3 55 SI7 Leaf Spring Designed in Catiav5

4.4 PROCEDURE USED TO FIND THE RESULTS IN ANSYS.

Select type of analysis Static structural [Double click] >Engineering data [Double click] >Isentropic materials> Update project(select) >Return to project > Geometric(Right click)>Import Geometry>Browse> from desktop>Model[RC] > Edit > Select geometry > part select structural >Mesh(Right click) > Generate mesh > Select the surface where we want to fix > static structural >> Insert > Fixed support > ctrl Select the surface b> static structural > insert > Displacement > x_o > 250>Z_o enter > Right click on solution > solve >Right click solution> Deformation> Total Deformation> Right click on solution>insert>strain>Equivalent –von mesh > solution > Insert > stress > maximum shear stress > solution Right click > Insert > stress > Equivalent –von mesh > Right click on solution > insert >stress> maximum shear stress > Right click on solution > Evaluate all results > Total Deformation > play > next report preview Engineering materials + General materials Al + Add Update project return to project.

4.5 ANALYSIS OF THE LEAF SPRING

About ANSYS:

Historically, finite element modelling tools were only capable of solving the simplest engineering problems which tended to reduce the problem to a manageable size and scope. These early FEA tools could generally solve steady-state, linear problems in two dimensions. The factors that forced these simplifications were the lack of efficient computational techniques and the computing power to model more complex real-life problems.

As numerical computation techniques have advanced and computing power has increased, analysis tools have also advanced to solve more complex problems. A real-life engineering problem may involve different physics such as fluid flow, heat transfer, electromagnetism and other factors. The finite element method has been used to solve engineering problems in all of these areas successfully and the goal of most software developers is to include as much of the real world in the simulation they perform as possible.

However, in many situations, the use of simplifying assumptions such as symmetry, axis symmetry, plane stress, plane strain, etc., is still preferable to using a complete three-dimensional model because of the efficiency they provide. These assumptions should be used if the problem being solved requires it. In other words, there is no need or justification to perform a full three-dimensional analysis of symmetry is present in the problem being solved.

The ANSYS philosophy can be summarized as one that aims to simulate a complete real-life engineering problem. The simulation usually begins by using a three-dimensional CAD model to construct a finite element mesh followed by imposing loads and boundary conditions and then computing the solution to the finite element problem.

PRODUCTS OF ANSYS

Simulation Technology: Structural Mechanics, Multiphysics, Fluid Dynamics, Explicit Dynamics, Electromagnetics, Hydrodynamics (AQWA).

Work flow Technology: ANSYS Work bench Plat form, High-Performance Computing, Geometry Interfaces, Simulation Process & Data Management.

HISTORY OF ANSYS

The company was founded in 1970 by Dr John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold to TA Associates. The new owners took SASI's leading software, called ANSYS®, as their flagship product and designated ANSYS, Inc. as the new company name.

ANSYSoffersengineeringsimulationsolutionsetsinengineeringsimulationthatadesig nprocess requires. Companies in a wide variety of industries use ANSYS software. The tools put a virtual product through a rigorous testing procedure (such as crashing a car into a brick wall, or running for several years on a tarmac road) before it becomes a physical object.

Advantages using ANSYS:

Unequalled Depth

The ANSYS commitment is to provide unequalled technical depth in any simulation domain. Whether it's structural analysis, fluids, thermal, electromagnetics, meshing, or process &data management we have the level of functionality appropriate for your requirements. Through both significant R&D investment and key acquisitions, the richness of our technical offering has flourished. We offer consistent technology solutions, scalable from the casual user to the experienced analyst, and seamless in their connectivity. In addition, we have world class expertise for all of these domains, available to help you implement your ANSYS technology successfully.

Unparalleled Breadth

Unlike other engineering simulation companies, who may possess competence in one, or maybe two, fields, ANSYS can provide this richness of functionality across a broad range of disciplines, whether it be explicit, structural, fluids, thermal, or electromagnetics. All of these domains are supported by a complete set of analysis type sand wrapped by a unified set of meshing tools. Together, these domains form the cornerstones of the ANSYS portfolio for Simulation Driven Product Development, and constitute a complete portfolio of unparalleled breadth in the industry.

Comprehensive Multi physics

A strong foundation for multi physics sets ANSYS apart from other engineering simulation companies. Our technical depth and breadth, in conjunction with the scalability of our product portfolio, allows us to truly couple multiple physics in a single simulation. Technical depth in all fields is essential to understand the complex interactions of different physics. The portfolio breadth eliminates the need for clunky interfaces between disparate applications. The ANSYS capability in multi physics is unique in the industry; flexible, robust and architected in ANSYS Workbench to enable you to solve the most complex coupled physics analyses in a unified environment.

Engineered Scalability

Scalability is a critical consideration when considering software for both current and long-term objectives. At ANSYS engineered scalability means flexibility you need has been designed for your particular needs. ANSYS provides you with the ability to apply the technology at a level that is appropriate for the size of the problem, execute it on a full range of computing resources, based on what's appropriate and available, and finally the ability to deploy the technology with in your company's user community. The result is efficient usage and optimum return on your investment, whether you have a single user or an enterprise-wide commitment to Simulation Driven Product Development. As your requirements grow and the level of sophistication and maturity evolves, the technology from ANSYS also will scale up accordingly.

Adaptive Architecture

Adaptive software architectures are mandatory for today's world of engineering design and development where a multiplicity of different CAD, PLM, in-house codes and other point solutions typically comprise the overall design and development process. A software environment is needed which anticipates these needs and gives you the tools and system services for customization as well as interoperability with other players. Such adaptability is a mandatory requirement and characteristic of the ANSYS simulation architecture, enabling your organization to apply the software in a manner which fits with your philosophy, environment and processes. ANSYS Workbench can be the backbone of your simulation strategy, or peer-to-peer with other software environments, or ANSYS technology can be a plug-in to your CAE supplier of choice. The ANSYS commitment to Simulation Driven Product Development is the same in any case.

Now moving forward to the analysis part, we have to save the part that has been modeled by using the tool that helps us in modeling a part into the format that is understandable by the tool that we use for doing various analyses on the created part model.

All the analysis for the springs is done by using ANSYS 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 91.44. Leaf spring is modeled in CATIA software and it is imported in ANSYS. The constraint is given at the two eye-rolled ends. One of the ends is provided with translational movement so as to adjust with the deflection. This eye end is free to travel in longitudinal direction. This particular motion will help leaf spring to get flattened when the load is applied. The stress and deflection analysis is done for conventional and composite leaf spring using ANSYS software.

4.5.1 STATIC STRUCTURAL ANALYSIS FOR (55Si7) STEEL LEAF SPRING

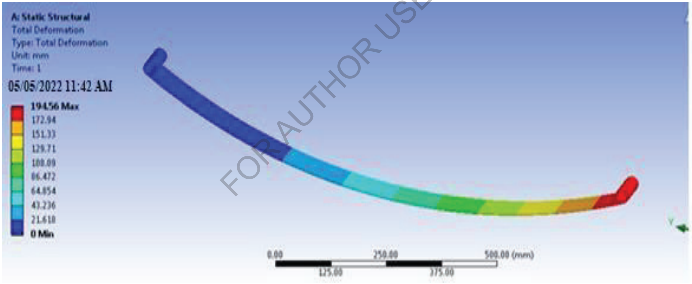


Fig.4.4 Total deformation 500(N).

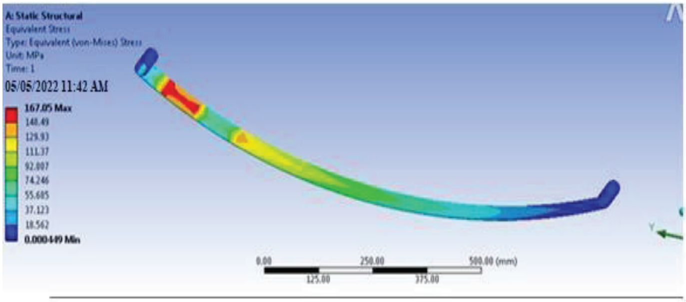


Fig 4.5 Equivalent Stress 500(N)

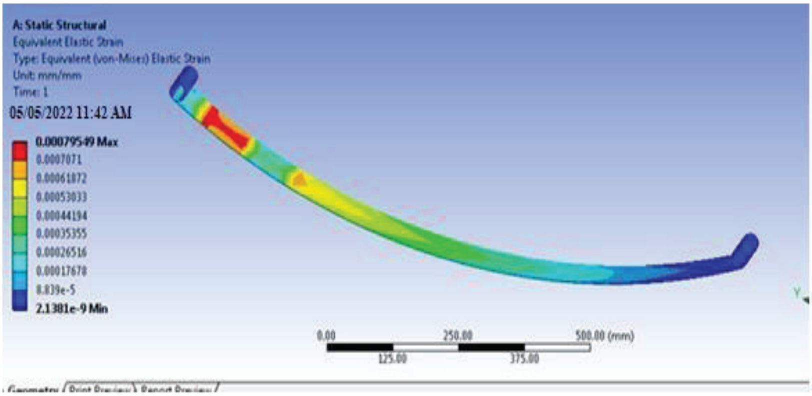


Fig.4.6 Equivalent Elastic Strain 500(N).

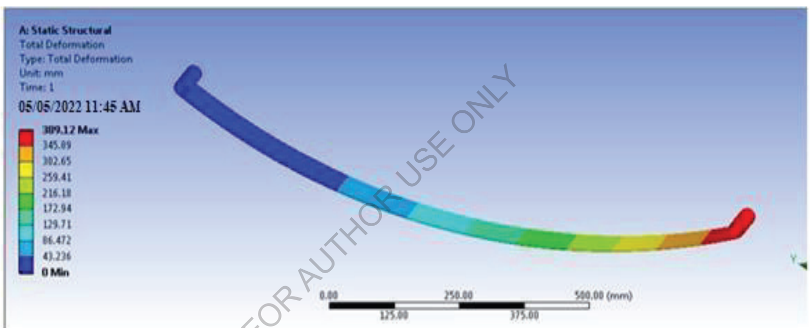


Fig.4.7 Total deformation1000(N).

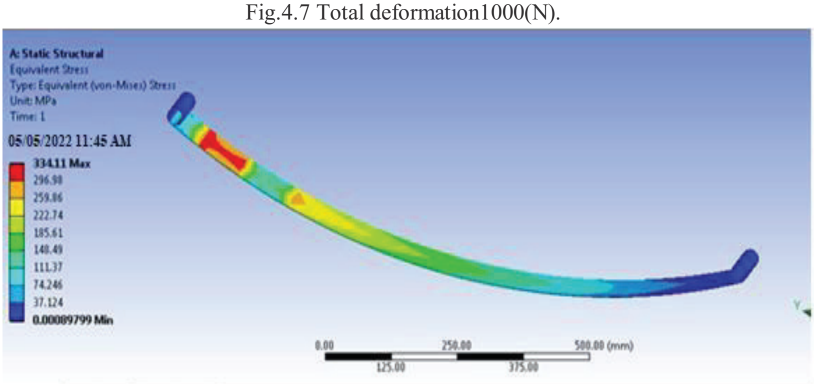


Fig.4.8 Equivalent Stress1000(N).

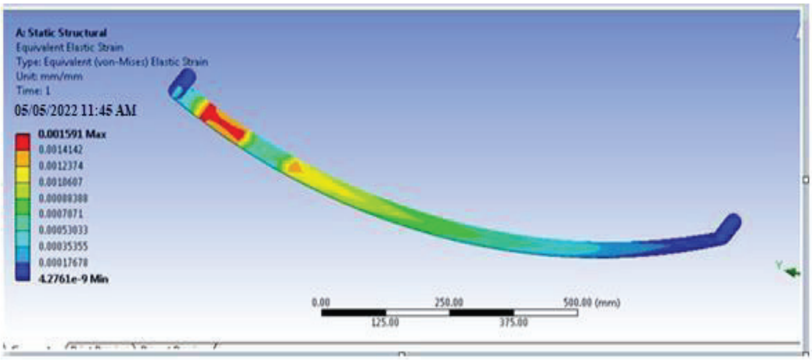


Fig.4.9 Equivalent Elastic Strain 1000(N).

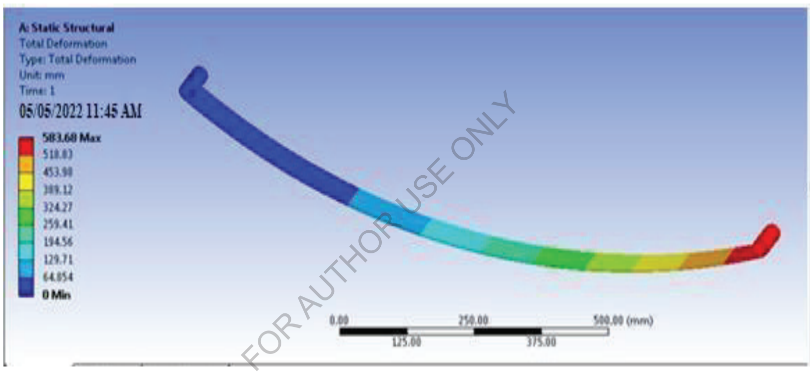


Fig.4.10 Total deformation1500(N).

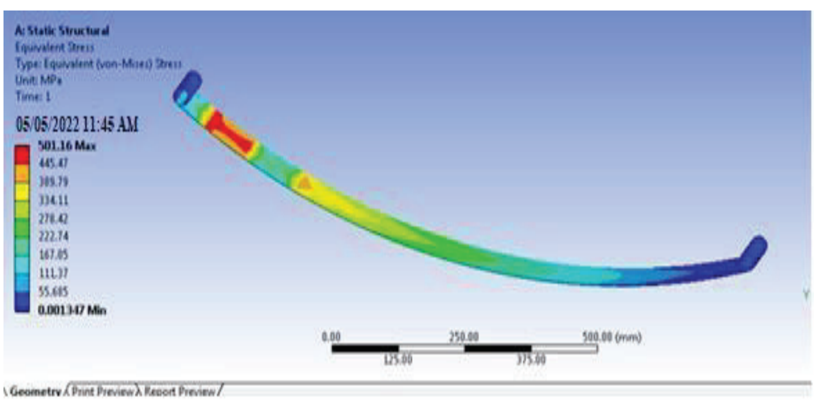


Fig.4.11Equivalent Stress1500(N).

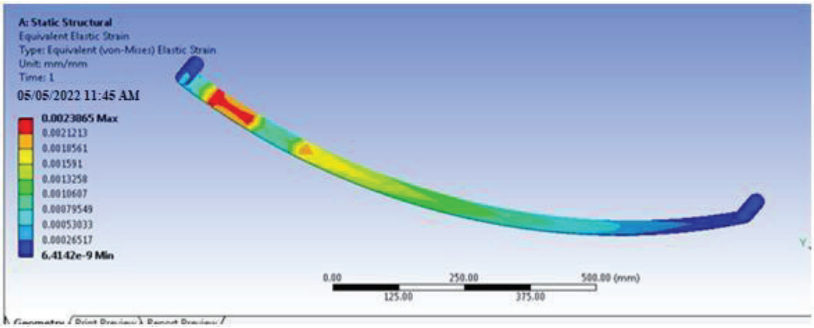


Fig.4.12 Equivalent Elastic Strain1500(N).

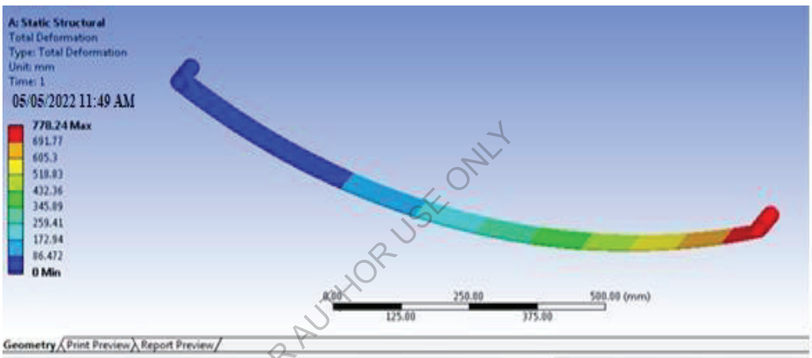


Fig.4.13 Total deformation 2000(N).

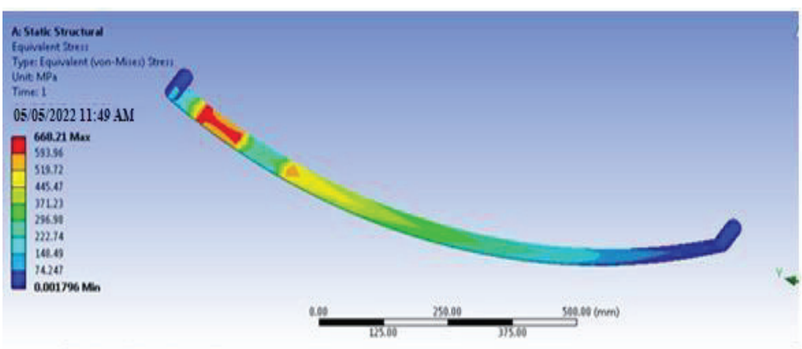


Fig.4.14 Equivalent Stress2000(N).

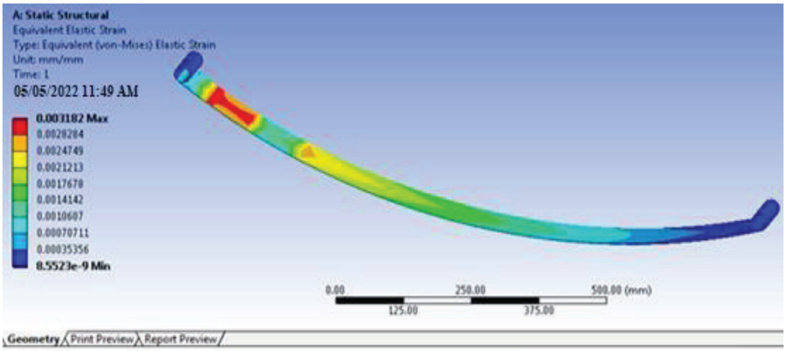


Fig.4.15 Equivalent Elastic Strain 2000(N).

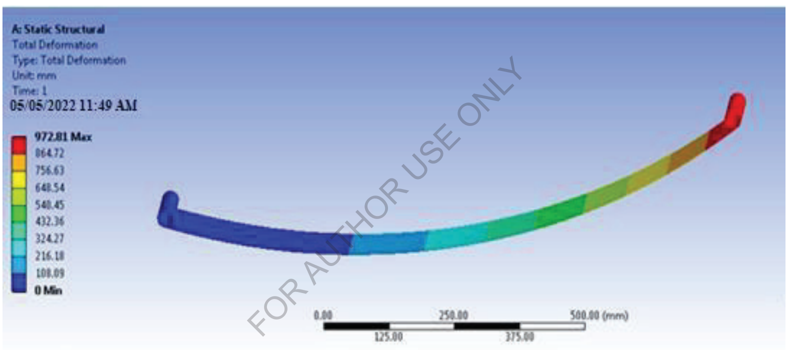


Fig.4.16Totaldeformation2500(N).

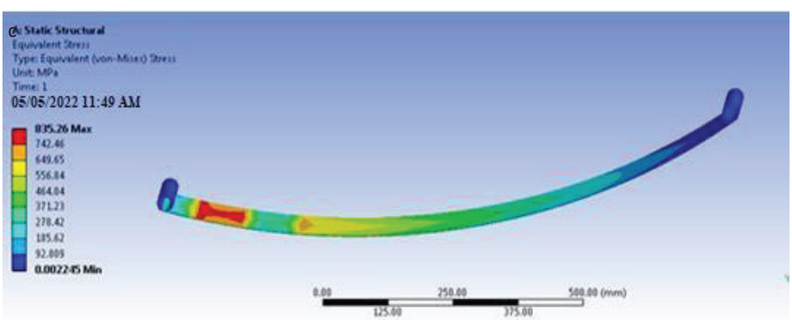


Fig.4.17EquivalentStress2500(N).

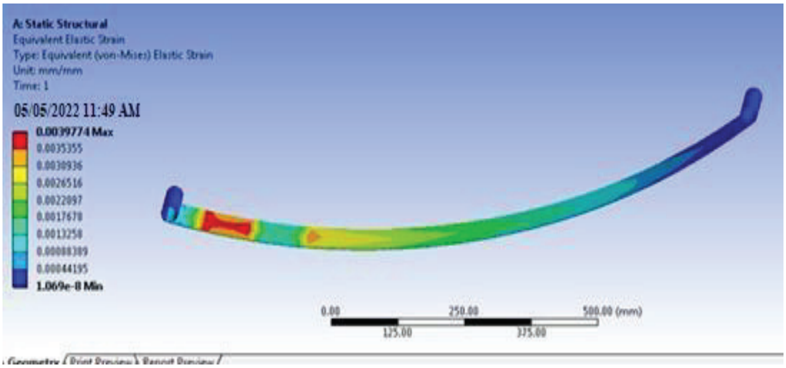


Fig.4.18 Equivalent ElasticStrain2500(N)

4.6 DESIGNPARAMETERSOFCOMPOSITELEAFSPRING.

Table 4.2: Design Parameters of Composite Leaf Spring.

Total Length of Leaf Spring (Eye to Eye)		965mm
Arc Height at Axle Seat		125mm
Thickness	At Centre	60 mm
	At Ends	10 mm
Width	At Centre	30 mm
	At Ends	45 mm

4.7 FINAL DESIGNED MODEL OF LEAF SPRING IN CATIA V5 E-GLASS/EPOXY LEAF SPRING AND JUTE/EGLASS/EPOXY.

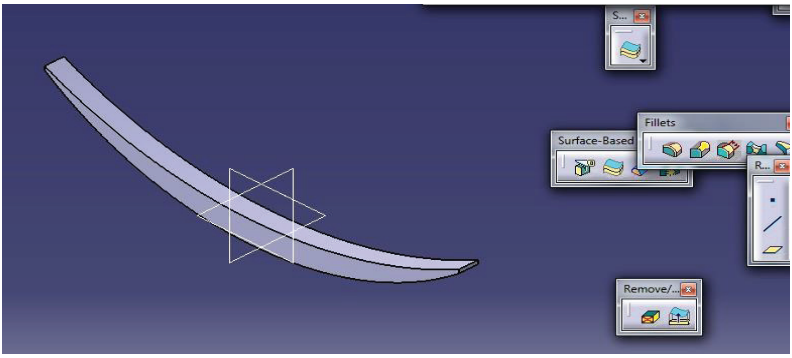


Fig.4.19 Composite leaf Spring Designed in Catia

1. By varying the dimensions and considering the composite material large variation of stress, strain and deformation is obtained when compared with 55si7 steel.
2. By considering the modified design values the weight of E-glass/Epoxy leaf spring weight 2.8Kg and Jute/E-glass/Epoxy leaf spring weighs 2 Kg.

4.8 STATICSTRUCTURAL ANALYSIS FOR E-GLASS/EPOXY LEAF SPRING.

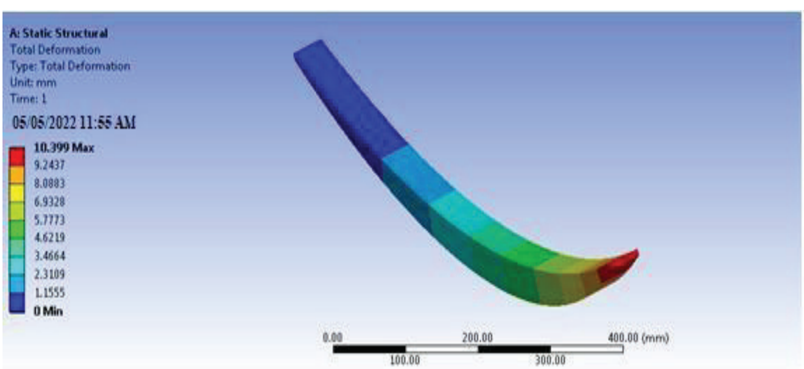


Fig.4.20 Total deformation1000(N).

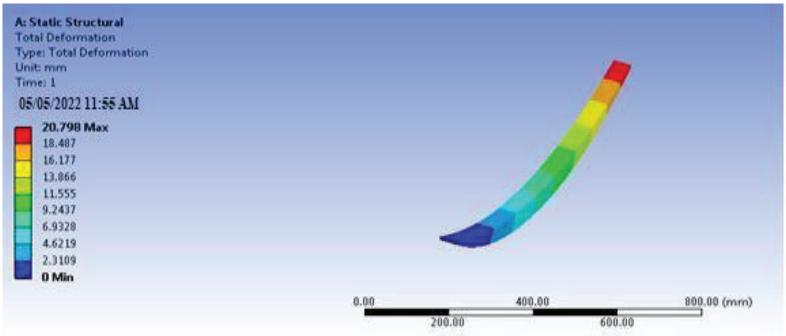


Fig.4.21Totaldeformation2000(N).

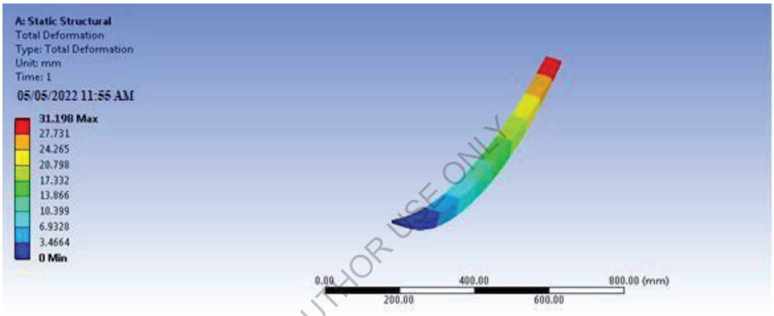


Fig.4.22Totaldeformation3000(N).

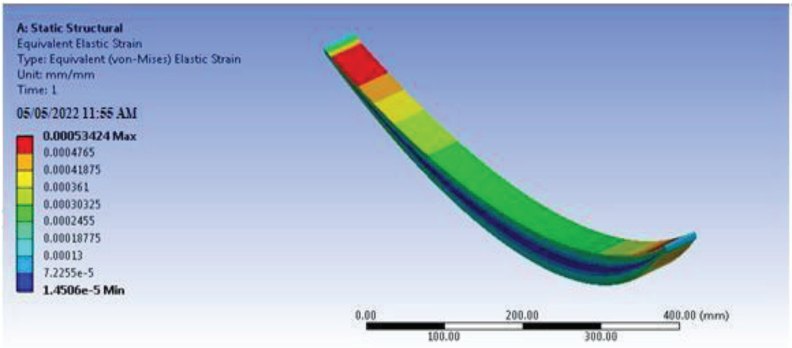


Fig.4.23Equivalent ElasticStrain1000(N)

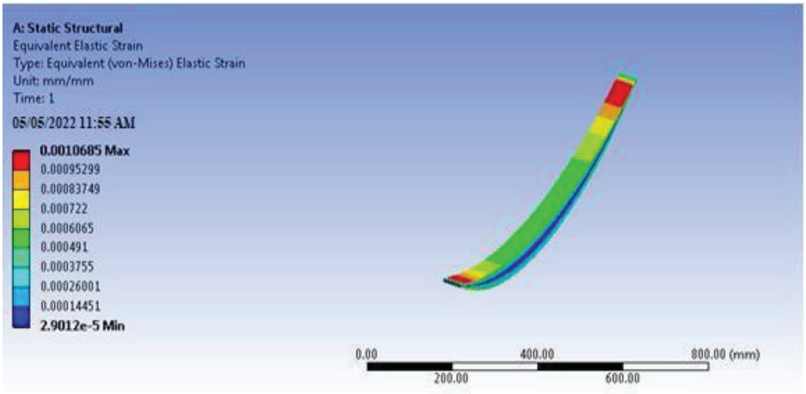


Fig.4.24 Equivalent Elastic Strain 2000(N)

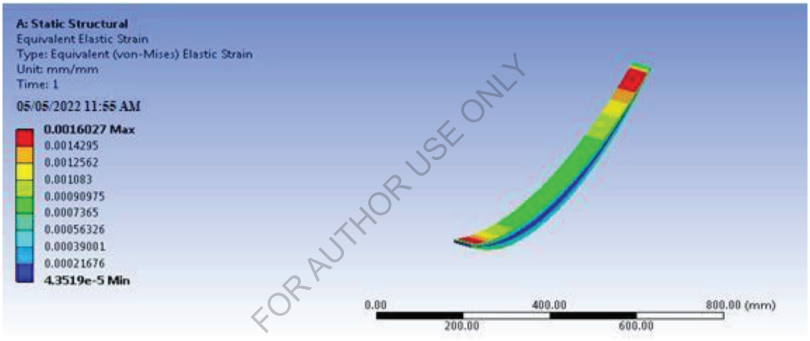


Fig.4.25 Equivalent Elastic Strain 3000(N)

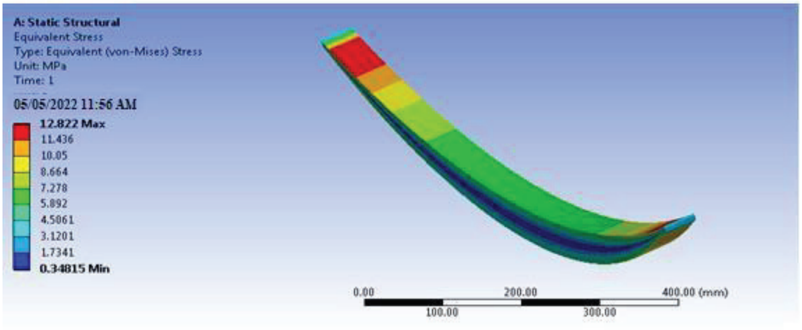


Fig.4.26 Equivalent Stress 1000(N).

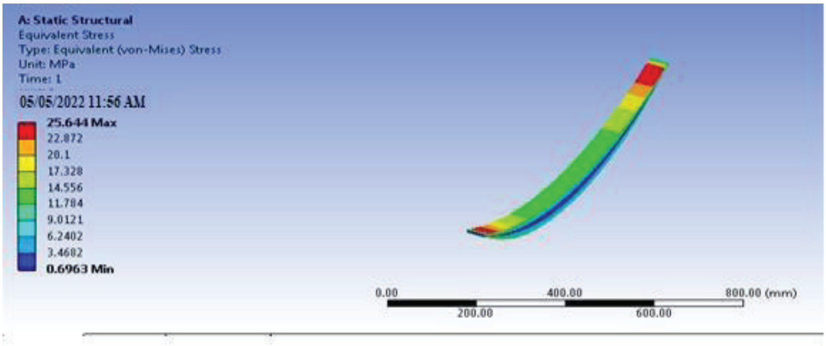


Fig.4.27 Equivalent Stress 2000(N).

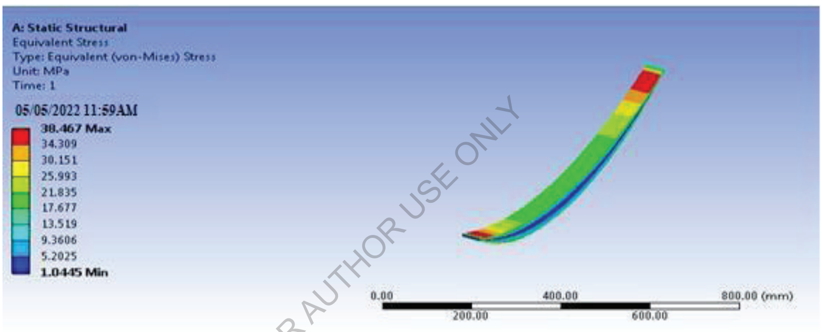


Fig.4.28 Equivalent Stress 3000(N).

4.9 STATIC STRUCTURAL ANALYSIS FOR JUTE/E- GLASS/ EPOXY

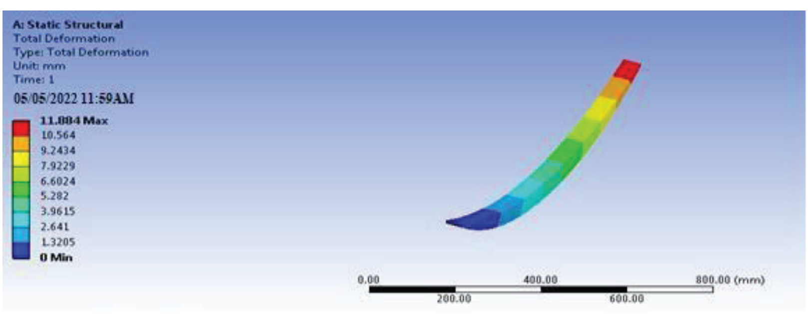


Fig.4.29 Total deformation1000(N).

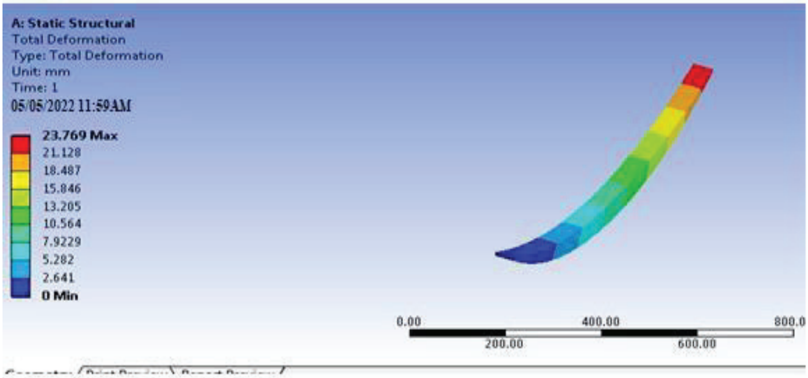


Fig.4.30 Total deformation 2000(N).

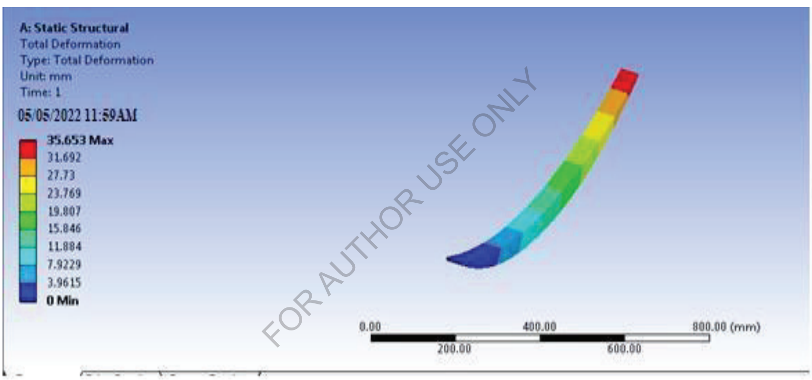


Fig.4.31Total deformation 3000(N).

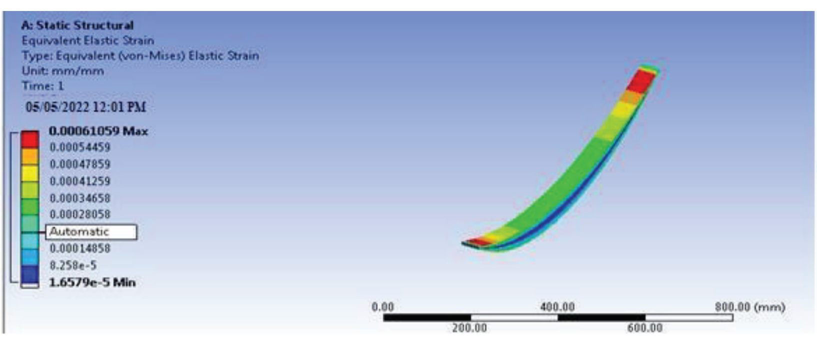


Fig.4.32 Equivalent Elastic Strain 1000(N).

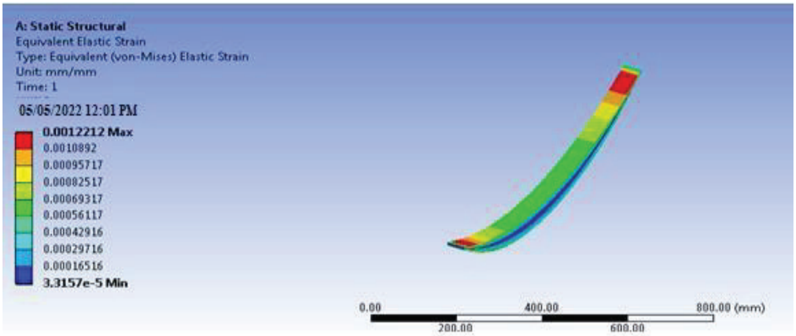


Fig.4.33 Equivalent Elastic Strain 2000(N).

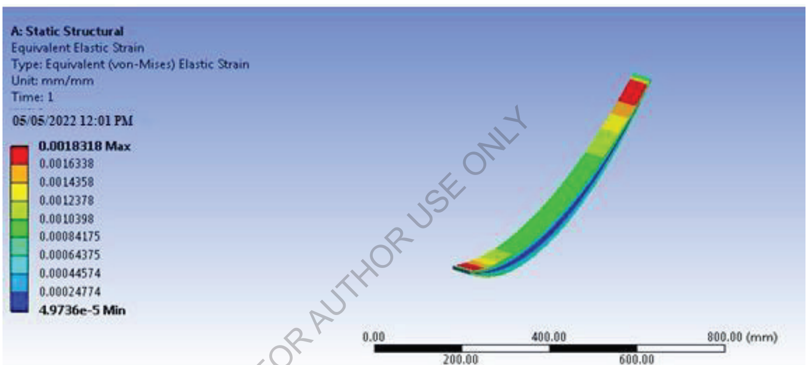


Fig.4.34 Equivalent Elastic Strain 3000(N).

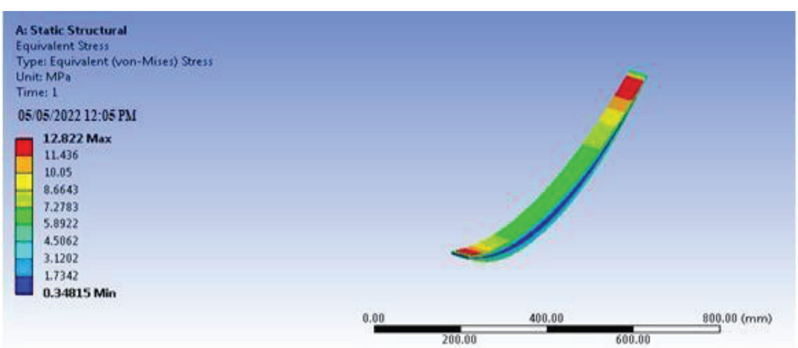


Fig.4.35EquivalentStress 1000(N).

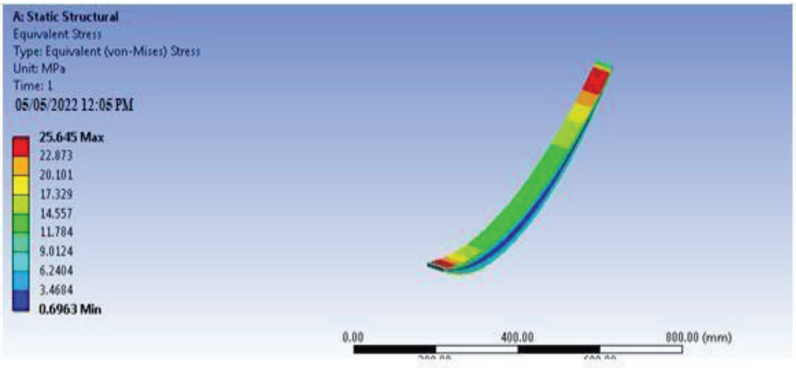


Fig.4.36 Equivalent Stress 2000(N).

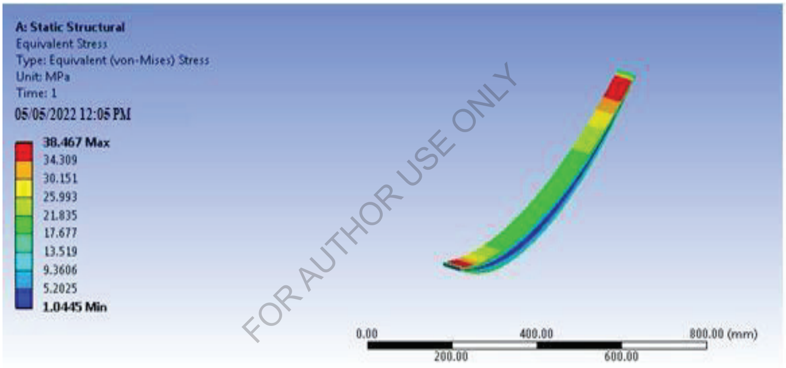


Fig.4.37 Equivalent Stress 3000(N).

CHAPTER-5

RESULTS AND DISCUSSION

5.1 THEORICATICAL CALCULATION

A semi-elliptical leaf spring may be considered as two cantilever leaf springs,

and a full-elliptical leaf spring. Let

F=force applied at the end of the leaf spring b = width of each leaf spring

t=thickness of each leaf

n=number of graduated leave

l = length of the spring

σ_b = bending stress

Maximum bending movement, M_{max}=Fl

M_{max}

Bending stress, $\sigma_b = \frac{Mmax}{Z}$

$$\sigma_b = \frac{6X\ 500\ X\ 1049.26}{6\ X\ 56\ X\ 6^2} = 260.23\ N/mm^2$$

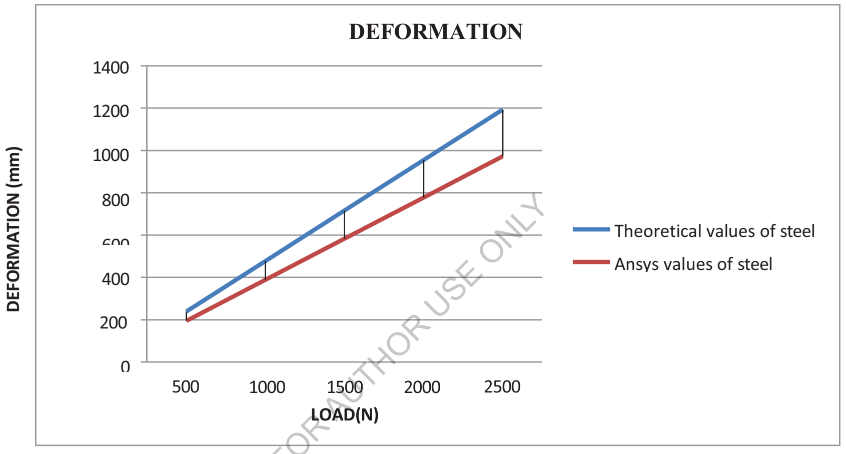
Maximum deflection, δ max = $6fl^3/\ Enbt^2$

Stain Energy U = P^2/AXE

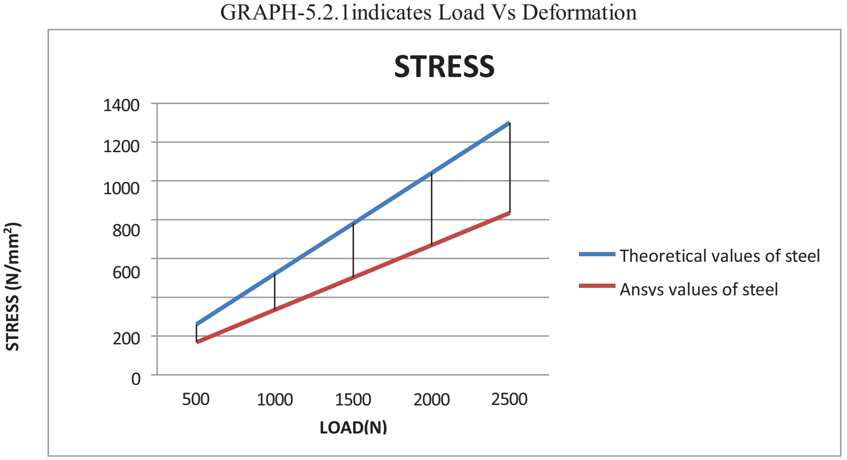
5.2 COMPARISON OF 55 SI 7 STEELS WITH THEORETICAL AND SIMULATIONRESULTS

Table 5.1: Comparison between Theoretical and Simulation results of 55Si7.

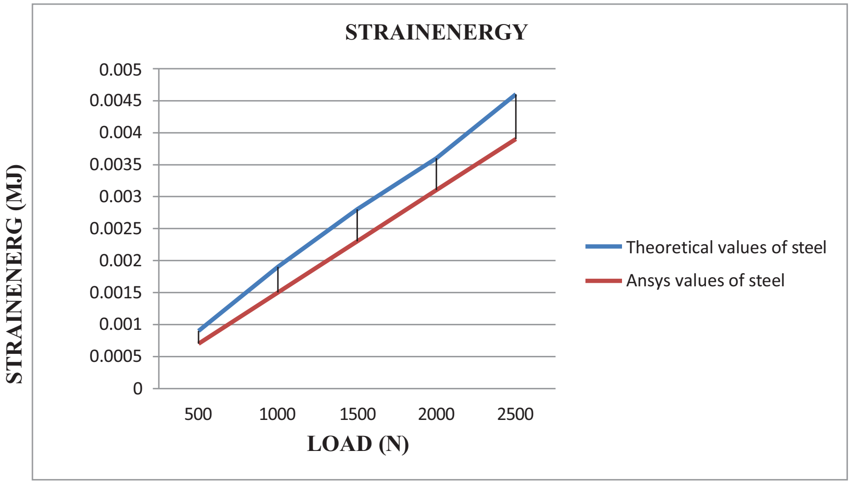
	Total deformation(mm)		Stress(N/mm^2)		Strain energy (MJ)	
LOAD(N)	Theoretical Values of steel	Ansys Values of steel	Theoretical Values of steel	Ansys Values of steel	Theoretical Values of steel	Ansys Values of steel
500	238.75	194.56	260.23	167.05	0.0009	0.0007
1000	477.50	389.12	520.46	334.11	0.0019	0.0015
1500	716.25	583.68	780.699	501.16	0.0028	0.0023
2000	955.00	778.25	1040.93	668.21	0.0036	0.0031
2500	1193.76	972.81	1301.165	835.26	0.0046	0.0039



GRAPH-5.2.1indicates Load Vs Deformation



GRAPH- 5.2.2 indicates Load Vs Stress

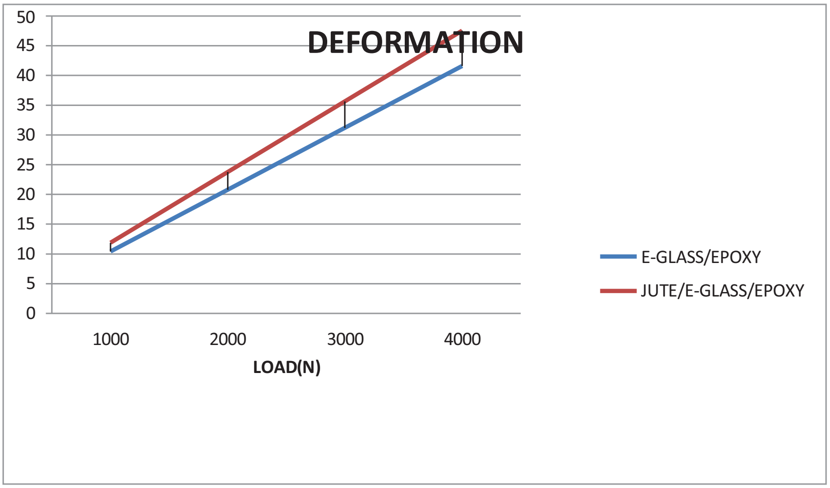


GRAPH-5.2.3 indicates Load Vs Strainenergy

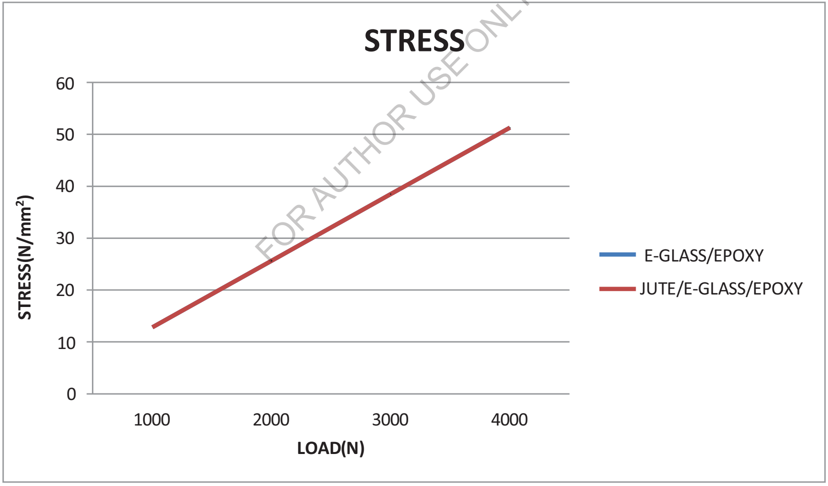
5.3 COMPARISON BETWEEN [A](E-GLASS/EPOXY) LEAF SPRING AND [B](JUTE/E-GLASS/EPOXY).

Table5.2: Comparison between E-Glass/Epoxy and Jute/E-Glass/Epoxy results.

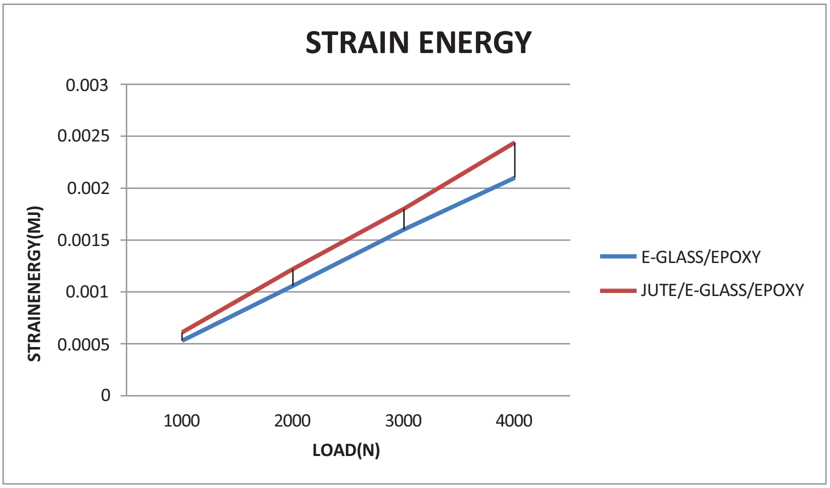
	Total Deformation(mm)		**Stress(N/mm^2)**		**Strain energy (MJ)**	
LOAD (N)	**[A]**	**[B]**	**[A]**	**[B]**	**[A]**	**[B]**
1000	10.39	11.88	12.822	12.822	0.00053	0.00061
2000	20.78	23.76	25.644	25.645	0.00106	0.00122
3000	31.19	35.65	38.466	38.467	0.00160	0.0018
4000	41.59	47.53	51.287	51.289	0.0021	0.00244



GRAPH-5.3.1indicatesLoad Vs Deformation.



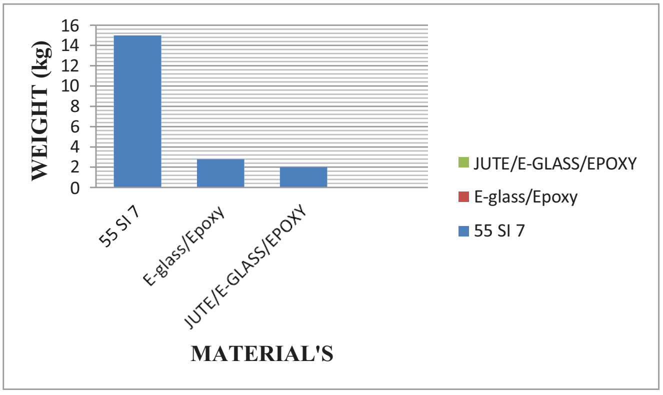
GRAPH-5.3.2 indicates Load Vs Stress



GRAPH–5.3.3indicates strain energy VS load

5.4 COMPARISON OF WEIGHTS

Bar- Chart drawn for the comparison of weight of both steel and composite leaf springs. The bar chart drawn below shows the comparisons in leaf spring weight (Kg) in case of steel and composite material. From this comparison of bar chart it is easily observed that the weight reduction in leaf spring. For steel leaf spring weight is 15kg and for composite leaf springs it is 2 & 2.8 kg.



GRAPH-5.4.1indicates Weight Vs Material

CHAPTER-6

CONCLUSIONS

6.1 CONCLUSIONS

The 3-D modeling of both steel and composite leaf spring is done and analyzed.
A comparative study has been made between composite and steel leaf spring with respect to deflection, strain energy and stresses. From the results.

1. The project work provides optimum values for design variables (leaf spring thickness and width) of hybrid composite leaf spring by using finite element analysis.
2. Weight can be reduced by 55% if steel leaf spring is replaced by Jute/E-Glass/Epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle.
3. At various loading conditions, hybrid composite leaf spring is found to have lesser stresses and deflections as compared to conventional steel leaf spring.
4. Jute/E-glass/Epoxy hybrid composite has higher elastic strain energy storage capacity than both steel and E-glass/Epoxy composite because it has lower young's modulus and lower density as compared to both. Hence hybrid composite leaf spring can absorb more energy which leads to good comfortable riding.
5. Jute/E-glass/ Epoxy hybrid composite leaf spring is found to be more economical than E-glass/Epoxy composite leaf spring as the cost of jute fiber is very much less as compared to E-glass fiber and it is abundantly available in nature.

CHAPTER 7

FUTURESCOPE

1. Spring can be modeled with different dimensions and static analysis could be done on different loading.
2. Dynamic analysis of leaf spring may be done and obtained results could be compared with software and experimental results.
3. Experimental analysis may be conducted and obtained results could be compared with software results.
4. Composite materials may be used for leaf spring for light weight and more efficiency

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