**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

# LIGHTWEIGHT COMPOSITE LEAF SPRINGS FOR IMPROVED VEHICLE PERFORMANCE

**[1]S. K. Vignesh and [2]E. Sangeeth Kumar**
[1]M.Tech (Automobile) Final Year, Hindustan Institute of Technology and Science, Padur
[2]Assistance Professor (Department Of Automobile), Hindustan Institute of Technology and Science, Padur

**ABSTRACT:** The use of fibre reinforced polymer (FRP) composites in the manufacturing of leaf springs for automotive suspension systems has gained significant interest due to their high strength-to-weight ratio, excellent fatigue resistance, and durability. This paper presents a study on the dynamic behavior and mechanical properties of composite leaf springs that can improve the performance of heavy loaded vehicles. The manufacturing process of FRP leaf springs and the comparison of their properties with conventional EN45 steel are discussed. The analysis of FRP leaf springs using CAD software, SOLIDWORKS and ANSYS workbench, indicates that the composite material reduces interleaf friction, resulting in improved riding qualities and fuel efficiency. Various types of matrices and fibers suitable for making composite leaf springs, such as S-glass and LY556 epoxy resin, are also evaluated. The results indicate that composite leaf springs can reduce the unsprung weight of automobiles and improve their performance through their high elastic strain energy storage capacity. The study concludes that the use of FRP composites in the manufacturing of leaf springs is a promising approach for weight reduction without compromising the load carrying capacity and stiffness of the suspension system.

**Keywords:** Composite leaf springs, FRP, interleaf friction, stiffness, elastic strain energy, fatigue resistance, SOLIDWORKS, ANSYS workbench, S-glass, LY556 epoxy resin.

## INTRODUCTION

Leaf springs are used in suspension system to absorb shock and load in vehicle. It carries lateral loads, brake torque, driving torque along the shock absorbing. Due to shear amount of the metal layered together, leaf springs gives a large support between the wheels, axles and the vehicle chassis.

Leaf spring will take vertical loads being applied to them due to their tight-knit structure. Vertical loading is also distributed throughout the length of the leaf spring through a small spring and damper, which can create a concentrated force too large for the suspension to handle. Leaf springs is used to vehicle damping due to the friction between each plate of steel which made the response time after a vertical flex in the suspension much quicker. Weight reduction can be done by the replacement of material, and different manufacturing processes. This will give the vehicle with more fuel efficiency and improved riding qualities. For reduction of weight in automobiles we need to the reduction of un-sprung weight of automobile. The component whose weight is not transmitted to the suspension spring are called the un-sprung component of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% of the un-sprung weight.

Advanced International Journal of Materials Science and Engineering (AIJMSE)
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

The composite materials made it possible to reduce the weight of un-sprung mass without any reduction of the load carrying capacity. Composites has high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel. FRP springs also have excellent fatigue resistance and durability. Moreover the composite leaf spring has lower stresses compared to steel spring. All these will result in fuel saving and better performance of the vehicle.

**Fig 1.1 Multi leaf spring**

**MATERIALS AND METHOD 3.1 COMPOSITE MATERIALS**

A composite material or composition material is a material made up of more than two constituents with significantly different physical and chemical properties that when combined, produce a material with characteristics different from the individual components. The individual components remains separate and distinct within the finished structure.

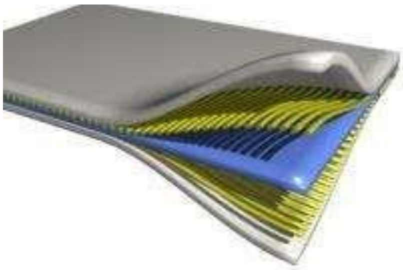


**Fig 3.1 Composite Material**

The composite materials has three kind of matrices there are,

1. Metal matrix composites
2. Ceramic matrix composites

In which are composite matrices contains oxides, carbides, nitrides of metals. Examples are granite stones, lime stones, cements, clay based materials, oxides, carbides.

3. Polymer matric composites

Polymer matrix involves the union of small molecules to form molecules having higher molecular weight. Examples, plastics, Adhesives, natural fibres, artificial fibres, coating resins.

***FIBRES***

Fibre is a string used as a component of composite materials, or matted into sheets to make products such as paper or felt. Fibres are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibres, for example carbon fibre and glass fibre.

Synthetic fibres can often be produced very cheaply and in large amounts compared to natural fibres, but in natural fibres the jute has much tensile strength and flexural than other fibres. And for clothing natural fibres can give some benefits, such as comfort, over their synthetic counter parts.

## ARTIFICIAL FIBRES

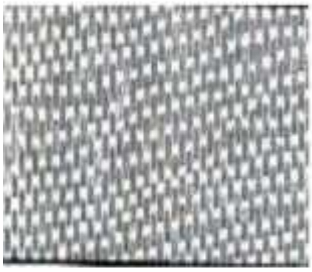
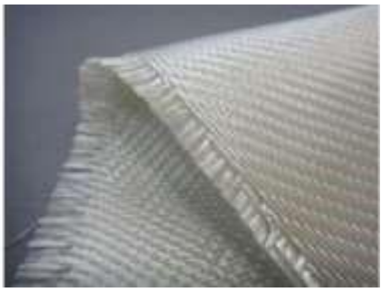
Artificial fibres classified into two classes,

(i) Short fibres

Short fibres are known as discontinuous fibres, with a general aspect ratio (defined as the ratio of fibre length to diameter) between 20to60.

(ii) Long fibres

Long fibres are also known as continuous fibres, the general aspect ratio is between 200to500.

In metal matrix composites has prepared by melting the different kind of metals and mixed as a one composition. The metal composites are called as alloys, examples are brass (copper and zinc alloy), high carbon steel, low carbon steel alloy, and bronzes (copper and tin alloys).

The synthetic fibres have the high tensile strength, flexural and brittle materials compared to the natural fibres. from its strength, flexural strength, load with sand able capacity and usage of the fibres.

**Glass-fibre reinforced polymer (woven Roving glass fibre)**

Glass-fibre reinforced plastic, or GFRP is a fibre reinforced polymer made of a plastic matrix reinforced by fine fibres of glass. Fibreglass is a lightweight, extremely strong, and robust material.Although strength properties are somewhat lower than carbon fibre and it is less stiff, the material is typically far less brittle.Glass Fibre Reinforced Polymers (GFRPs) is a fibre reinforced polymer made of a plastic matrix reinforced by fine fibres of glass. Fibre glass is a lightweight, strong, and robust material used in different industries due to their excellent properties. Although strength properties are somewhat lower than carbon fibre and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive.

**Table 3.1 Mechanical property of S GLASS**

| PROPERTY | VALUES | UNIT |
|---|---|---|
| Young's modulus | 93000 | Mpa |
| Tensile strength | 4800 | Mpa |
| Poisson ratio | 0.23 | - |
| Elastic limit | 4085 | Mpa |

Advanced International Journal of Materials Science and Engineering (AIJMSE)
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

***RESIN***

A resin is a basic binding material consisting of long chain organic polymer, whichundergoes polymerization reaction during moulding. The resins has two types there are thermosetting resins, thermoplastic resins. The resin we chose as Araldite LY556 is an epoxy resin. The layers of fibres are fabricated by adding the required amount of epoxy resin. In making of the fibre composite materials the resin is playing a major role in this process, the various kinds of the resins are available in the shops. The key data for the epoxy LY556 resin taken and listed below from reference [5].

**Table 3.2 PROPERTIES OF EPOXY LY556**

| Sl.no | Araldite LY 556 | Properties |
|---|---|---|
| 1. | Aspect (visual) | clear, pale yellow liquid |
| 2. | Colour (Gardner, ISO 4630) | <2 |
| 3. | Epoxy content (ISO 3000) | 5.30 - 5.45 [eq/kg] |
| 4. | Viscosity at 25 °C (ISO 9371B) | 10000 –12000 [mPas] |
| 5. | Density at 25 °C (ISO 1675) | 1.15 - 1.20 [g/cm3] |
| 6. | Flash point (ISO 2719) | > 200 [°C] |
| 7. | Storage temperature | 2 - 40 [°C] |

Anhydride-cured, low-viscosity standard matrix system with extremely long pot life. The reactivity of the system is adjustable by variation of the accelerator content. The system is easy to process, has good fibre impregnation properties and exhibits excellent mechanical, dynamic and thermal properties. It has an excellent chemical resistance especially to acids at temperatures up to 80 °C. The epoxy resins are applicable for high performance
composite parts.

For the glass fibre the epoxy LY556 resin is suitable resin compared to other resins it has the better performance than the other resins and less cost. The thermosetting resin epoxy LY556 is used for the composite specimen coating, the resin cannot remould and it cannot be reheat. The resin contains the cross links c=c covalent bond links and formed in the condensation polymerisation process. Araldite LY 556 which has crystallized and looks cloudy can be restored to its original state by heating to 60 - 80 °C.

**EN45 STEEL**

Steel is an alloy of iron and carbon and other elements. EN45 Steel is used commonly to make leaf spring. Iron is the base metal of steel. Composition of EN45 Steel is 0.5-0.6% Carbon,0.7-1.1% of Manganese,1.5-2% of Silicon. It is the interaction of the allotropes of iron with the alloying elements, primarily carbon, that gives steel and cast iron their range of unique properties.

**Table 3.3 Mechanical properties of EN45 Steel**

| PROPERTIES | VALUES | UNIT |
|---|---|---|
| Young's modulus | 200000 | MPa |
| Tensile strength | 650-880 | MPa |
| Elongation | 8-25 | % |
| Fatigue | 275 | MPa |
| Yield strength | 350-550 | MPa |
| Density | 7700 | $Kg/m^3$ |

**REINFORCEMENT**

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different fibres used in composites have different properties and so affect the properties of the composite in different ways.

The properties and characteristics of common fibres are explained below. However, individual fibres or fibre bundles can only be used on their own in a few processes such as filament winding (described later). For most other applications, the fibres need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different ways for assembling fibres into sheets and the variety of fibre orientations possible lead to there being many different types of fabrics, each of which has its own characteristics. These different fabric types and constructions are explained later.

**MATERIAL USED FIBRES**

S – GLASS(CSM,WRM)

**RESIN**

Epoxy resin – LY556

**HARDNER** – HY951 **AND RELESING AGENT (PVA)**

Resin and hardener ratio =10:1

**3.6 MANUFACTURING PROCESS**

**HAND LAYUP** Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate. This is known as sandwich construction

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

**VACCUM BAG MOULDING** This is basically an extension of the wet lay-up process described above where pressure is applied to the laminate once laid-up in order to improve its consolidation. This is achieved by sealing a plastic film over the wet laid-up laminate and onto the tool. The air under the bag is extracted by a vacuum pump and thus up to one atmosphere of pressure can be applied to the laminate to consolidate it

**LEAF SPRING**

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles.

**WORKING PRINCIPLE**

The suspension system having main element termed as leaf spring is one of the potential and very critical term for weight reduction in automobile industries as its having a ten to twenty percent of the unsprung weight. By introducing composites, it can helpful for design a better suspension system having a better ride quality but the condition is it must be achieved without much increase cost and also decrease quality and reliability. In the design of springs, strain energy becomes the major factor. The relationship of the specific strain energy can be expressed as

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

Where $\sigma$ = strength, $\rho$ =density

E =Young's Modulus of the spring material

It can be noted that material which is having a lower modulus and also having a lower density will have a greater specific strain energy capacity. So the introduction of composite materials can made it possible to reduce the weight of the leaf spring without any reduction into the load carrying capacity and stiffness.

A Composite mainly is any materials that have been physically assembled to form one single bulk without physical blending to foam a homogeneous material. The resulting material would still have components identifiable as the constituent of the different materials. One of the advantages of composite is that two or more materials could be combined to take advantage of the good characteristics of each. A spring eye section is used to attach the front end of semi-elliptic shape leaf spring to the chassis frame, and a free end having a bracket constraining vertical motion to attach the back end of semi-elliptic leaf spring to the chassis frame

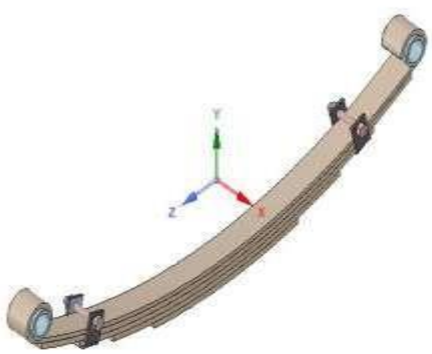


**Fig 4.3 CAD Model of leaf spring**

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

**DESIGN CALCULATION 5.1 SPECIFICATIONS**

- Weight of vehicle = 500 Kg
- Maximum load carrying capacity = 325 Kg
- Total weight = 500+325
- So , total weight = 825 Kg
- Static load apply on vehicle = 825*9.81 N (ie)8000 N (approx.)
- At every wheel load = 2000 N and same as reaction force = 4000 N at downward point.

But 2F = 4000 N, F = 2000 N

Span length, 2L = 1072 mm, L= 536mm.

**5.2 CALCULATIONS**

Now the Maximum Bending stress of a leaf spring is given by the formula σ = (6 × × )/ × × $^2$ σ = (6 × 2000 × 536)/(3 × 60 × $8^2$) σ = 558.33N/mm2

Measured data of the above stated light weight four wheeler vehicle.

Straight length of the parabolic leaf spring (L)=1072mm

The ratio of camber length of parabolic leaf spring is given by manaspatnaik et al(2012)

/ = 0.089

= 0.089 × 1072

= 95.4

Since the leaf spring is fixed with the axle at its centre, only half of it is considered for analysis purpose (Khurmi and Gupta, 2000)

Hence, a is /2= 536

Calculation for "t" and "b" dimensions which are capable of withstanding the loading behavior of the conventional and composite parabolic leaf spring is the result of this design. From equation of strength of material we have, now the Maximum Bending stress of a leaf spring is given by the formula, Solving these two equations the thickness and width of the parabolic leaf spring can be, formulated, respectively, as follows;

σ =(6 × 2000 × 536)/(3 × × $8^2$) 558.33 =(6 × 2000 × 536)/ (3 × × $8^2$) b=60mm

The Total Deflection of the leaf spring is given by 128.79 = (6 × 2000 × 5363) / (2.1 × 105 × 3 × 60 ×$^3$)

t=8mm

**Table 5.1Specification of TATA ACE Leaf Spring Ref[9]**

| Design parameter | Value |
|---|---|
| Total length of spring(L) | 1072mm |
| Length of spring from eye to eye | 754mm |
| Thickness(t) | 8mm |
| Width of leaf spring(b) | 60mm |

**TESTING METHODS**

There are several kinds of mechanical testing are available to check the tensile strength, flexural strength, impact strength, hardness of the materials. Among these tests tensile test, flexural test,
hardness test are conducted. The various mechanical testing and testing results are shown below.

**Destructive tests**

In destructive type of testing, the component or specimen to be tested is destroyed and cannot be reused. Examples are tensile test, impact test, bend test, fatigue test, torsion test, and creep test etc..,

**TENSILE TEST**

The hybrid composite material fabricated is cut into required dimension using a saw cutter and the edges finished by using emery paper for mechanical testing. The tensile test specimen is prepared according to the ASTM D790 and ASTM A370 (American Society of Testing and Manufacturing) standard. The dimensions, gauge length and cross-head speeds are chosen according to the ASTM standard. A tensile test involves mounting the specimen in a machine and subjecting it to the tension.

The testing process involves placing the test specimen in the testing machine and applying tension to it until it fractures. The tensile force is recorded as a function of the increase in gauge length. During the application of tension, the elongation of the gauge section is recorded against the applied force.

**FLEXURAL TEST**

Flexural test is one of the mechanical test for to know the flexural strength and flexural deflections of the material. The flexural specimens are prepared as per the ASTM standards. The four test piece samples are fitted in the flexural test machine. The flexural load is applied slowly on the composite specimens. The test is conducted until the test piece is broke. The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is measured by the
crosshead position. Test results include flexural strength of the materials.

The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks.

**HARDNESS TEST**

Hardness implies the ability of a material to resist deformation. There is a wide variety of hardness assessment procedures available, including static indentation, scratch, rebound, damping, cutting, abrasion and erosion tests. Recently, nano indentation techniques have also been used for the investigation of hardness of composites. Hardness is a routinely measured mechanical characteristic that is sensitive to structural parameters as well as to mechanical behaviour. A classical method used to measure hardness is the static indentation test, which involves forcing a hard tool of known geometry into the sample body.

The hardness of the sample is then defined as the ratio of the applied force to the size of the resulting indentation.

**TESTING PROCEDURE:**

The material to be tested is held on the anvil of the machine. The test piece is raised by turning the hand wheel, till it just touches the indenter. A minor load of 10 kg is applied to seat the specimen. Then the dial indicator is set at zero. Now the major load (60 kg for Rscale is applied to the indenter to produce a deeper indentation. After the indicating pointer has come to rest, the major load is removed. With the major load is removed, on the appropriate scale of the dial.

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

**Fig 7.1 Sample specimen of EN45 Steel**

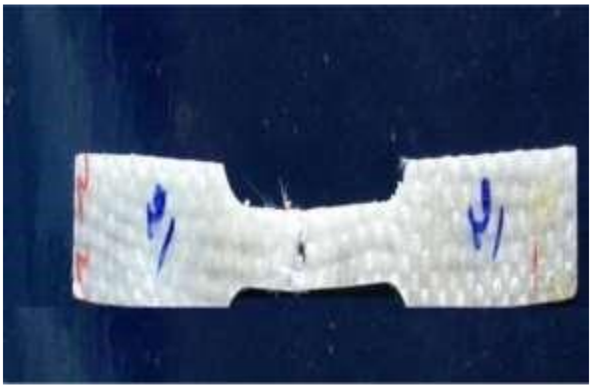


**Fig 7.2Sample specimen of S glass-Epoxy**

**RESULT AND DISCUSSION**

| | **TENSILE STRENGTH (YIELD) MPa** | **FLEXURAL STRENGTH MPa** | **HARDNESS HRR** |
|---|---|---|---|
| **EXISTING MATERIAL** | 968 | 450 | 44 |
| **COMPOSITE** | 480 | 397 | 53 |

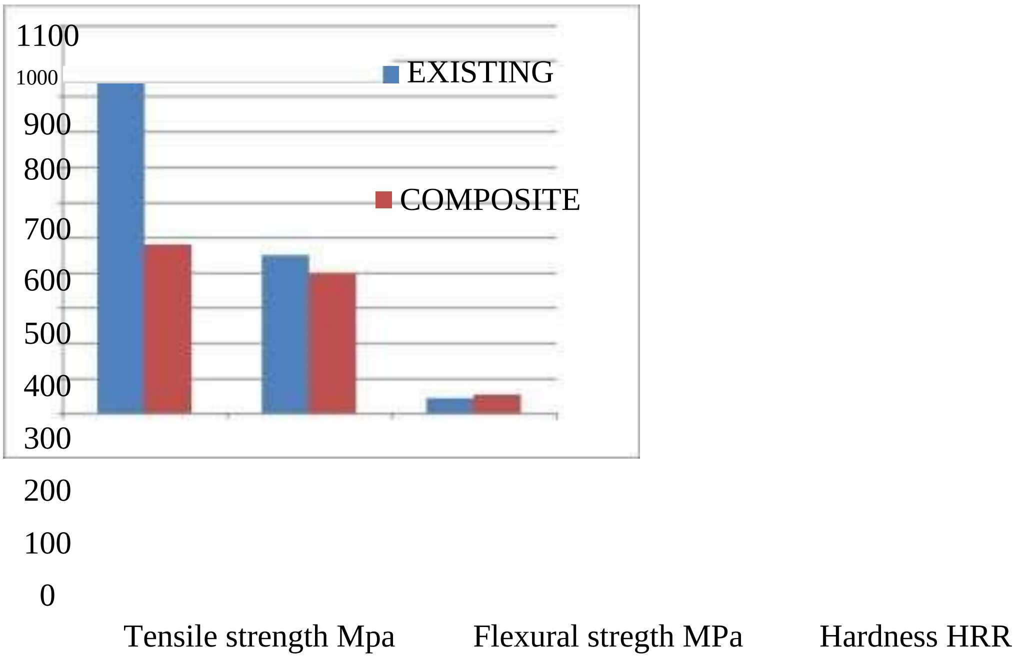



**Table 7.1 Mechanical test of materials**

**DISPLACEMENT TEST**

The composite leaf spring is placed in the UTM machine and gradually given the load in terms of 100,250,500,1000,1500 N and the displacement for the corresponding load is noted and compared with existing material.

**FEA ANALYSIS 8.1 EQUIVALENT STRESS**

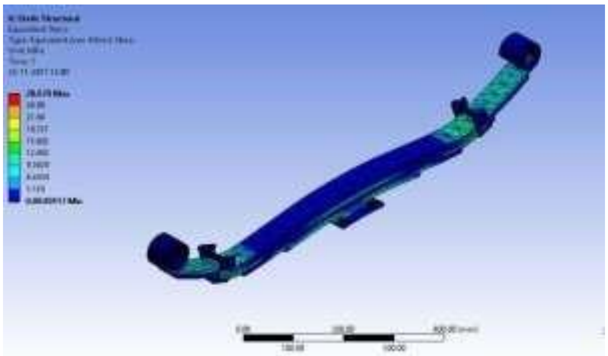


**Fig 8.1 Equivalent stress of conventional leaf spring**

**Fig 8.2 Equivalent stress of composite leaf spring**

By comparing both the analysis the conventional has 28.07MPa and composite has13.65 MPa of stress induced on the leaf spring. So the bending Stress induced in material is low so the life of the material would be increased with less wearing.

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

### TOTAL DEFORMATION

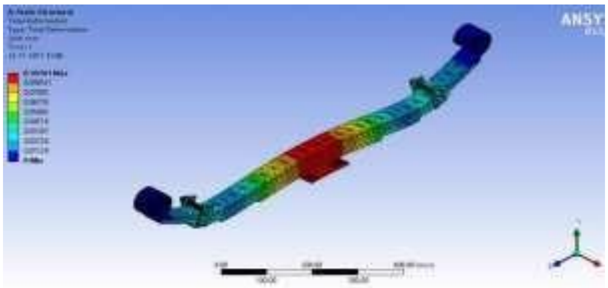


**Fig 8.5 Total deformation of conventional leaf spring**

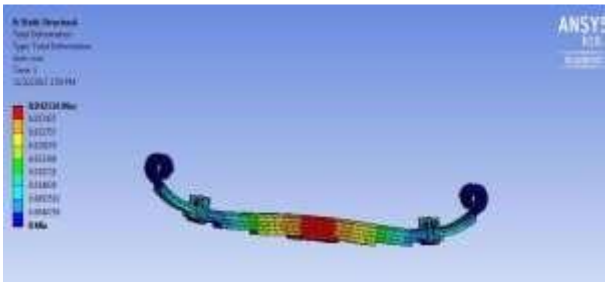


**Fig 8.6 Total deformation of composite leaf spring**

By comparing both the analysis the conventional has 0.101 mm deflection and composite material has 0.042mm of deflection with the same loading condition. So it is clear that the strength will be increased in composite for the better fatigue life

### 8.3 ELASTIC STRAIN

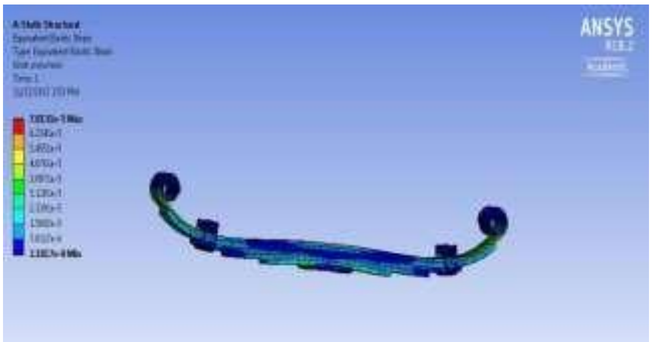


**Fig 8.3 Elastic strain of conventional leaf spring**

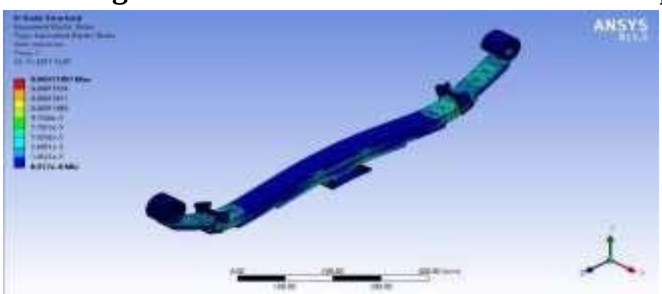


**Fig 8.4 Elastic strain of composite leaf spring**

By comparing both the analysis the conventional has 7.01e-5 mm/mm and composite has 1.7e-4 mm/mm of elastic strain. So the elastic strain is more in the composite so that the damping will be improved so that the comfort and performance will be increased.

Advanced International Journal of Materials Science and Engineering (AIJMSE)
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

### 8.4 STRAIN ENERGY

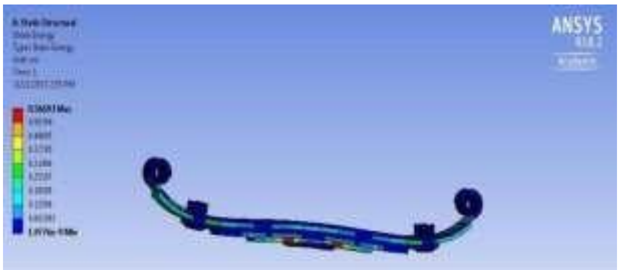


**Fig 8.7 Strain energy of conventional leaf spring**

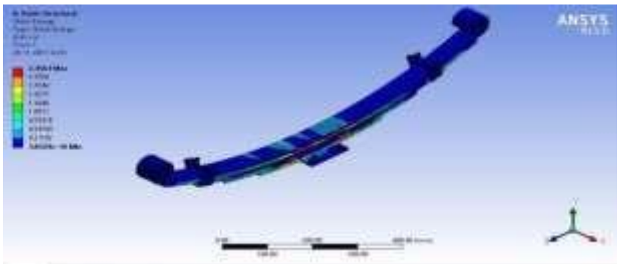
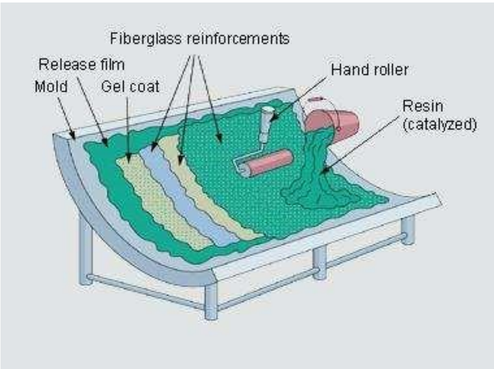


**Fig 8.8 Strain energy of composite leaf spring**

By comparing both the analysis the conventional has 0.566 mJ and composite material has 2.45 mJ of strain energy. Hence I shows that composite is much tougher than conventional steel. So it able to withstand heavy loading without change in performance of the vehicle.

## FABRICATION




**Hand Layup Process CSM - CHOPPED STRAND MAT WRM - WOVEN ROVING MAT**

- Material cut in the 1072 mm length and 80 mm width
- Total number of csm 6
- Total number of wrm 14
- Total number of layers 20
- Layer arrangement

**2csm,7wrm,2csm,7wrm,2csm**

- Total weight of fiber **810grms**
- RESIN : HARDNER **810:81**

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

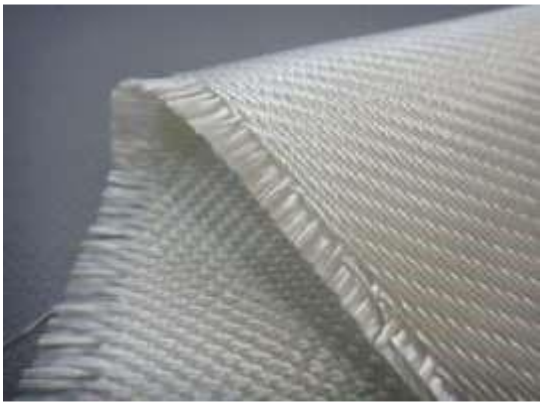
- Total thickness of component **25mm**

**CSM- chopped strand mat**

**CSM** is used here for the better finish and bonding between the wrm fibers.

**WRM BIDIRECTIONAL**

**WRM** is the woven roving matrix glass fibre with bidirectional woving. This type of fibe is used for high strength but for our application the flexural strength is achieved by the unidirectional type.



**WRM UNIDIRECTIONAL**

This type of wrm is selected for the replacement of existing material. This satisfies the flexural strength and other property of existing material.

**RESULT AND DISCUSSION**

| VERTICAL LOAD IN | DEFLECTION OF CONVENTIONAL | DEFLECTION OF | DIFFERENCE IN |
|---|---|---|---|

**Advanced International Journal of Materials Science and Engineering (AIJMSE)**
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

| UTM(KG) | (mm) | COMPOSITE (mm) | DEFLECTION (mm) |
|---|---|---|---|
| 50 | 2.8 | 9.65 | 6.85 |
| 100 | 35.2 | 39.3 | 4.1 |
| 150 | 41.6 | 53.7 | 12.1 |

| WEIGHT OF STEEL LEAF SPRING(KG) | WEIGHT OF COMPOSITE LEAF SPRING(KG) |
|---|---|
| **15.86** | **4.8** |

In this research we can conclude that with respect to conventional steel leaf spring composites having high strength to weight ration. composites having nearly 350% less weight than conventional steel leaf spring. And also from FEA analysis we can conclude that composite leaf spring is better in stress, elastic strain and deformation properties. So this material can satisfy our requirement of identified problem without any drawbacks.

## FUTURE SCOPE

This work can be further developed by changing the manufacturing process and changing the material composition and this work can also be simulated in the MBS software with different road condition for testing the component

## REFERENCE

Stephan Krall and Richard Zemann (2014), A review on "Investigation of the Dynamic Behaviour of CFRP Leaf Springs",Vienna University of Technology, Institute for Production Engineering and Laser Technology, Landstraber Hauptstrabe 152,1030 Vienna, Austria

Basaran Ozmena, Berkuk Altiokb, Alper Guzelb, Ibrahim Kocyigitb and Serter Atamera (2015). A review on "A novel methodology with testing and simulation for the durability of leaf springs based on measured load collectives"

Rajagopal , Varun S, Manikanth M, Bysani Somasai and Sriram Kumar (2014) A review on "Automobile Leaf Spring from Composite Materials", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-4 Issue-1.

Pankaj Saint, Ashish Goel and Dushyant

Kumar(2013) A review on "Design and analysis of composite leaf spring for light vehicles", International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 5, May 2013.

R M Patila, S M Hatrotea, A K Pharalea, V S Patila, G V Chiniwalara and A S Redd (2014) "Fabrication and Testing of Composite Leaf Spring for Light Passenger Vehicle", International Journal of Current Engineering and Technology ISSN 2277- 4106

Advanced International Journal of Materials Science and Engineering (AIJMSE)
Volume.1, Number 1; March-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/aijmse
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.com

S.W.Burande1,G.R.Chavhanand Dr.L.P.Dhole(2012), A review on "Analysis of leaf spring in light automotive vehicles by experimental and finite element approach", International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974 AL-Qureshi,H.A(2001), A review over "Automobile leaf springs from composite materials, Journal of Processi ng Technology", International Journal of Advanced Engineering Research. B.Vijaya Lakshmi and I.Satyanarayan (2012), A review on "Static and dynamic analysis on composite leaf spring in heavy vehicle", International Journal of Advanced Engineering Research and Studies ,Vol. 2, Issue , 80-84

M. Raghavedra and Syed Altaf Hussain (2012), "Modeling and Analysis of Laminated Composite Leaf Spring under the Static Load Condition by using FEA", International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol.2, Issue.4, 1875-1879 ISSN: 2249-6645

Ghodake A. P, Patil K.N.(2013) A review on "Analysis of Steel and Composite Leaf Spring for Vehicle" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684 Volume 5, Issue 4(Jan-Feb. 2013), PP 68-76. Mahmood M. Shokrieh , Davood Rezaei "Analysis and optimization of a composite leaf spring", Composites Research Laboratory, Department of Mechanical Engineering, Composite Structures 60 (2003) 317–325

U. S. Ramakant& K. Sowjanya, "Design and analysis of automotive multi leaf springs using composite material", IJMPERD 2249-6890 Vol. 3, Issue 1,pp.155-162, March 2013

M.Venkatesan (2015) A review on "Performance analysis of composite leaf spring in a defence sumo vehicle" Journal of Engineering Science and Technology Vol. 10, No. 5 (2015) 680 - 691© School of Engineering, Taylor's University

Ajay D. Dighe(2016) A review on "TESTING OF STEEL LEAF SPRING" International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 05| May-2016

Sivasankar(2015) A review on "Design and Numerical Investigation of Static and

Dynamic Loading Characters of Heterogeneous Model Leaf Spring" International Journal of Mechanical Engineering and Research, ISSN 0973-4562 Vol. 5 No.1 (2015)

Subhash Chandrabose(2014) A review on"Design Optimization and Analysis of a Parabolic Leaf Spring" Middle-East Journal of Scientific Research : 1590-1596, 2014 ISSN 1990-9233

Akshay Kumar(2014) A review on **"**Design, Analysis, Manufacturing and Testing of Mono Composite Leaf Spring Using UD E-Glass Fiber/Epoxy" International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 12, December 2014