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DESIGN, ANALYSIS AND EXPERIMENTAL INVESTIGATION OF GFRP AND SIC COMPOSITE MATERIAL LEAF SPRING

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ABSTRACT

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 spring with composite leaf spring with GFRP due to high strength to weight ratio, higher stiffness, high impact energy absorption and lesser stresses. This research is aimed to investigate the suitability of glass fiber reinforced polymer combined with filler material like Silicon Carbide (SiC) in automobile leaf spring application. By using natural fibers efforts have been made to reduce the cost and weight of leaf spring. A composite leaf spring with 90% GFRP + 10% SiC composite materials is modeled and subjected to the same load as that of a steel spring. The composite leaf spring has been modeled by their consideration. Static structural analysis of a leaf spring has been performed using ANSYS.

Keywords: silicon carbide, suspension spring, GFRP.

1. INTRODUCTION

Glass fibers are better known for their impact toughness, medium modulus, high tensile strength and

Thermal stability [1] Replacing conventional metallic structures with composite structures has many advantages due to its higher specific strength and stiffness of composite materials [2].

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness so composite materials are now used in automobile industries to take place of metal parts. Since, the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. Composite materials offer opportunity for substantial weight saving [3].

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, dating back to medieval times. A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body [4].

Design of Composite leaf spring is done using the CATIA tool. Static structural tool has been used of ANSYS. A composite spring with full length leave with E-Glass/epoxy composite material has been used. Typical steel spring results are compared with the gift results obtained for composite leaf spring [5].

2. SCOPE

The aim of this project work is to design, analyze and conduct experimental investigation, so as propose composite material leaf spring (GFRP + SiC) which can be used in automobile industry. The fiber considered is glass fiber GFRP and filler material is Silicon Carbide (SiC). The epoxy resin with hardener is collected from nearby market. The glass fibers are in the form of long roving's, which is trimmed as per requirement and SiC is in the form of fine powder.

Table-1. Mechanical properties of composite materials.

Properties	Symbols	Units	GFRP	SiC	90% GFRP + 10% Sic
Density	ρ	Kg/m^3	1800	3100	1930
Young's modulus	E	GPa	26	410	64.4
Poisson's ratio	V	-	0.28	0.14	0.266

3. MATERIAL SELECTION FOR LEAF SPRING

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

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A. Glass fibers

Fiber glass is a common type of fiber-reinforced plastic using glass fiber. The fibers may be randomly arranged, flattened into a sheet (called a chopped strand mat), or woven into a fabric. The plastic matrix may be a thermo set polymer matrix - most often based on thermosetting polymers such as epoxy, polyester resin, or vinylester - or a thermoplastic. GFRP (E glass) composite materials have better mechanical properties than conventional steel as the energy storage capacity of composite material is much higher than steel [6].

B. Silicon carbide (SiC)

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide (SiC) nano-materials are widely investigated due to their unique and fascinating properties such as high strength, good creep, oxidation resistance at elevated temperatures, chemical inertness, thermal stability and resistance to corrosion. Numerous applications of SiC nano-materials such as their use as semi-conducting devices, for reinforcement in ceramic composites, in metal matrix composites and catalytic supports have been investigated worldwide [7].

4. FABRICATION/LAMINATE PREPARATION

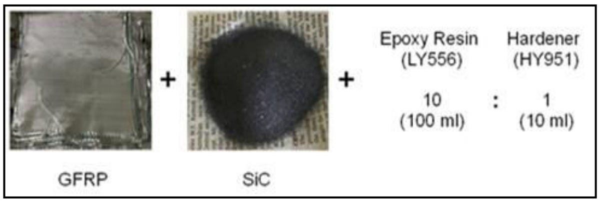

Figure-1. Materials.

A. Materials used

- GFRP - 6 layers of size 300 mm x 300 mm
- Silicon Carbide (SiC) powder
- Epoxy Resin (LY556): 100mL
- Hardener (HY951): 10mL
- Wax

B. Method

Hand layup method is employed for the preparation of laminates. Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel/wax coat has cured sufficiently, roll stock fibreglass reinforcement sheets are manually placed on the mold/table. The resin mixture is applied by pouring, brushing, spraying, or using a paint roller

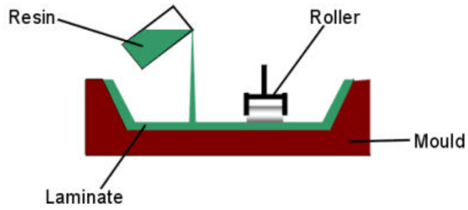

Figure-2. Hand layup process.

Step 1: Place a thin foil of plastic sheet over a table; apply wax all over the plastic sheet. Then place the first layer of GFRP layer over the plastic sheet applied with wax. Wax is used to ensure that the laminate can easily separated after curing process

Figure-3. Wax.

- Application of wax all over the plastic sheet

Figure-4. Application of wax.

Step 2: Take 25 grams of silicon carbide (SiC) powder

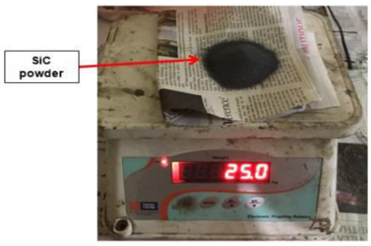

Figure-5. 25 grams of silicon powder (SiC).

Step 3: Take 100mL of Epoxy resin (LY556) in a beaker, and pour exactly 10mL of hardener (HY951) into the beaker. Now mix the 25g SiC powder to the mixture, and then start stirring the solutions for a period of about 15 minutes.

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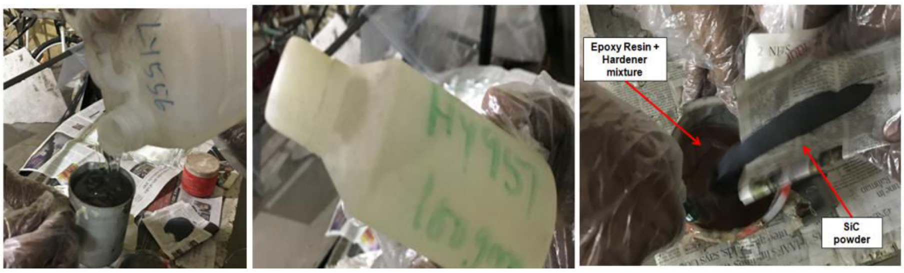

(i) (ii) (iii)

Figure-6. (i) Epoxy resin (LY556), (ii) Hardener (HY951), and (iii) Mixing of epoxy resin + hardener + SiC powder

Step 4: When the mixture is ready for application, now place one GFRP layer (300mm x 300mm) over the plastic sheet.

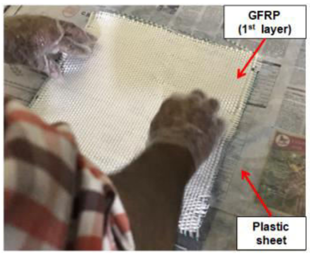

Figure-7. (i) GFRP 1st layer.

With the help of a brush, start applying the mixture (epoxy resin + hardener + SiC) over the layer.

Figure-8. (i) Applying mixture, and (ii) after applying the mixture on 1st layer.

Step 5: Now place the second (new) layer over the first layer, and then start applying the mixture over it by using a brush.

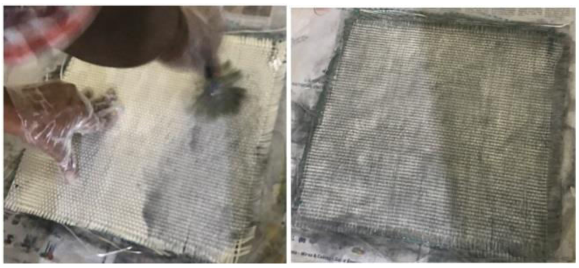

Figure-9. (i) Applying mixture on 2nd layer and (ii) After applying the mixture on 2nd layer.

Step 6: Use a roller, to roll over the laminate layers, so that excess mixture can be squeezed out through the sides.

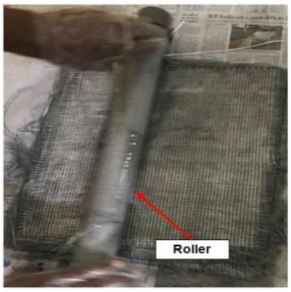

Figure-10. Usage of roller.

Step 7: Similarly, repeat the above steps for another four layers, hence a total of six layers.

Figure-11. After application of mixture on 6 layers.

Step 8: Place a dead weight over laminate layers, and leave it for about 48 hours.

Figure-12. Placing of dead weight over the layers.

Step 9: Remove the dead weight a span of 48 hours.

5. MECHANICAL TESTING

A. Tensile testing

Tensile test is one of the fundamental mechanical tests, commonly used to select material under quality control and reaction of material under different types of force. A specimen is prepared in a square section in reference to ASTM D638-14. Both end of the specimen was hold by the cross heads and they are firmly gripped during testing. Force will be applied on the specimen by driven cross head until it fractures, during this process applied force and elongated length is measured to find the tensile strength.

B. Flexure testing

Flexure testing is used to find the bending strength of the material and modulus of the rupture. Flexure test is done on the same tensile testing machine, here the specimen is placed on the bench wise and force will be applied on the center of the specimen until it gets fractured. The Figure-1 shows specimen testing.

C. Impact testing

The impact test is used find the toughness of the material it is also known as the V-notch test, determines the amount of energy absorbed by a material during fracture. The impact testing machine has a pendulum of known length and mass, then the pendulum of mass is made to impact a notched specimen. This absorbed energy is a measure of a toughness of the given materials and acts as a tool to study temperature dependent ductile brittle conversion.

D. Hardness test

Hardness is measured using a Durometer instrument. Durometer is typically used to measure of hardness in polymers, elastomers, and rubbers.

(i) (ii) (iii) (iv)

Figure-13. (i) Tensile testing machine, (ii) Flexure testing machine, (iii) Charpy impact testing machine, and(iv) DUROMETER instrument.

6. RESULTS AND DISCUSSIONS

A. Experimental test results

i. Tensile test

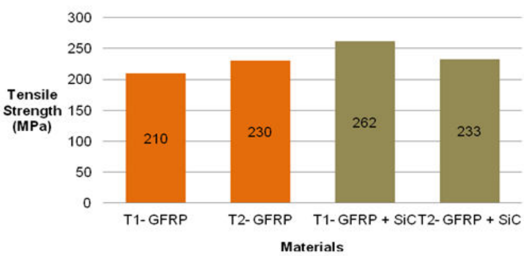

Figure-14. Tensile test experimental results graph.

Tensile strength test result values of GFRP + SiC composite materials, is greater than the GFRP composite material.

ii. Flexural strength test

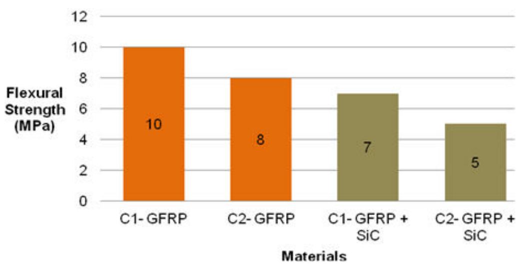

Figure-15. Tensile test experimental results graph.

Flexural strength test result values of GFRP + SiC composite materials, is lesser than the GFRP composite material.

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iii. Impact test

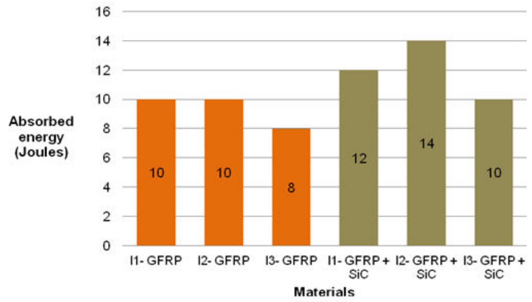

Figure-16. Impact test experimental results graph.

Impact strength test result values of GFRP + SiC composite materials, is higher than the GFRP composite material.

iv. Hardness value (GFRP + SiC material)

Average shore "D" hardness value observed for GFRP + SiC composite material is 60.44

v. Macrometer

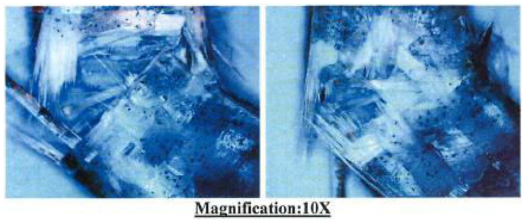

Figure-17. Macrometer results for GFRP + SiC composite material specimens.

Above image shows how the GFRP + SiC composite material had failed during the tensile test and the dots show the distribution of silicon carbide (SiC) powder over the composite material.

B. Analysis results

i. Equivalent elastic strain

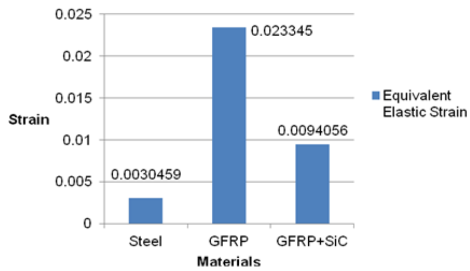

Figure-18. Equivalent elastic strain graph.

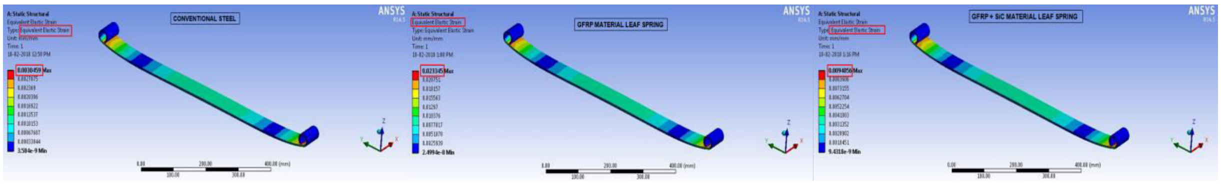

Figure-19. (i) Equivalent elastic strain - conventional steel spring, (ii) Equivalent elastic strain - gfrp material leaf spring, and (iii) Equivalent elastic strain - gfrp + SiC material leaf spring

Thus the equivalent elastic strain of GFRP + SiC material value is much lesser than the GFRP material.

ii. Equivalent (von-mises) stress

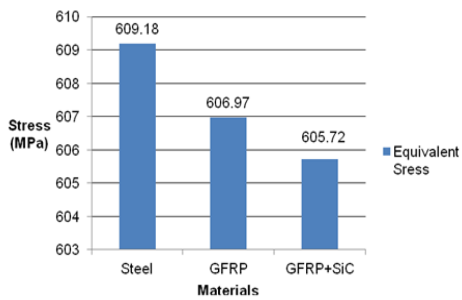

Figure-20. Equivalent elastic strain graph.

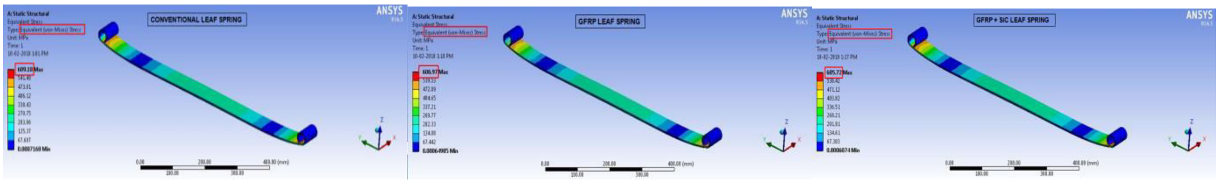

Figure-21. (i) Equivalent stress- conventional steel spring, (ii) Equivalent stress- gfrp material leaf spring, and (iii) Equivalent stress- gfrp + SiC material leaf spring

Equivalent Stress values of GFRP + SiC and GFRP materials are lesser than that of the steel material.

iii. Total deformation

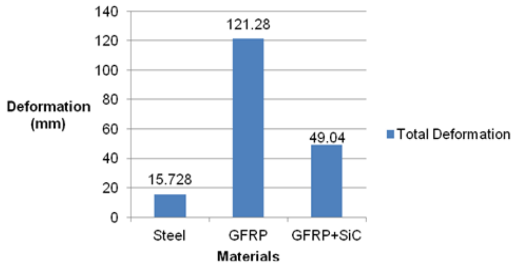

Figure-22. Equivalent elastic strain graph.

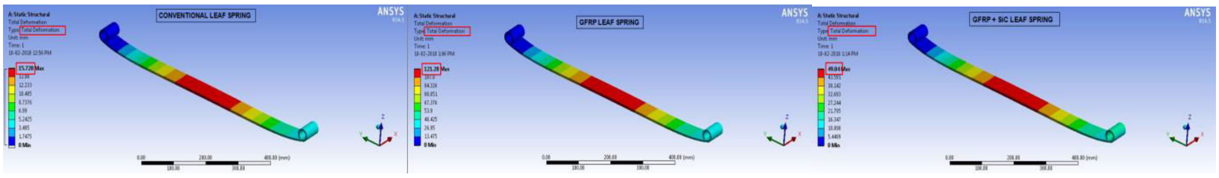

Figure-23. (i) Total deformation- conventional steel spring, (ii) Total deformation - gfrp material leaf spring, and (iii) Total deformation - gfrp + SiC material leaf spring.

Maximum total deformation value for gfrp + SiC material leaf spring is 49.04mm

7. CONCLUSIONS

The usage of composite materials (GFRP + SiC or GFRP only) will result in considerable amount of weight saving when compared to conventional steel leaf spring. Taking into account the deformation, shear stress induced and resultant frequency it is evident that GFRP + SiC composite has the most encouraging properties to act as replacement to GFRP material. The present work was aimed at identifying an alternate material composition over the GFRP material, such that it can be employed in automotive leaf springs. Apart from being lightweight, the use of composites also ensures less noise and vibration.

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