Fabrication and characterization of Glass Fiber/SiC Reinforced Polymer composite

Devesh Sharma¹, Shailesh Yadav ², Suraj Chaudhary ³, Umesh Kumar ⁴, Bhaskar Chandra Kandpal ⁵, Ashok Kumar ⁶, D. K. Gupta ⁷

¹, ², ³, ⁴ Students, Mechanical engineering department, Inderprastha Engineering College, Ghaziabad, U.P., India.
⁵, ⁶, ⁷ Faculties, Mechanical engineering department, Inderprastha Engineering College, Ghaziabad, U.P., India

Abstract
In recent years, the need for manufacturing reliable and innovative components has increased rapidly. Fiber reinforced polymer (FRP) composite materials have strong candidature for fulfilling these aspects with wide applications in almost all areas of engineering and technology. Glass, Carbon, and aramid fibers are being widely used for production of fiber reinforced polymer composites. The present work deals with the processing and characterization of glass fiber reinforced epoxy composites with silicon carbide (SiC) filler. The composite material samples were fabricated by Hand layup method. In this study, the E-glass Epoxy laminates was manufactured and fabricated as per ASTM standard 300x300x4mm. The tensile and flexural strength of an E-glass epoxy laminated composite plate is to be analyzed by using UTM (Universal testing machine). Experiments like tensile test, three point bending and compression test were conducted to find the significant influence of filler material on mechanical characteristics of GFRP composites. The tests result has shown that higher the filler material volume percentage increases the strength of glass epoxy composites. An experimental study has been carried out to investigate the mechanical properties of glass-fiber reinforced epoxy composite filled with different proportions of SiC particles. It was found that bending, hardness and compressive strength was increased with the increase in percentage of glass fibres and SiC. But the fracture Strength of GFRP was decreased. SiC filler material makes FRP composite material harder and brittle which is the reason for reduction in tensile strength. It is possible to enhance the tensile strength of the composite by proper distribution of the glass fiber in the composite.

Keywords: Fiber orientation, Epoxy resin compositions, Glass fiber, laminated polymer composites

INTRODUCTION
Composite materials are combinations of two or more materials which differ in chemical composition and physical properties and are insoluble in each other. Each of the various components retains its identity in the composite and maintains its characteristic structure and properties. The properties of composite material are function of the properties of the constituent phases, their relative amount, and the geometry of the dispersed phase. Each component imparts its own properties so that the resultant properties are superior to either component alone. Epoxy resins are widely used as matrix in many fiber reinforced composites; they are a class of thermoset materials of particular interest to structural engineers owing to the fact that they provide a unique balance of chemical and mechanical properties combined with wide processing versatility. Within reinforcing materials, glass fibers are the most frequently used in structural constructions because of their specific strength properties.

Methods of manufacturing composites – The FRP composites are fabricated by various methods which are discussed here.

• Filament winding- In this process, resin-impregnated continuous fibers are wrapped around a rotating mandrel that has the internal shape of the desired FRP product; the resin is then cured and the mandrel removed. The fibers are pulled through a resin bath immediately before being wound in a helical pattern onto the mandrel. The entire process is repeated to get the desired thickness of FRP.

• Hand lay-up – It is the oldest and simplest way of making fibreglass-resin composites. Resins are impregnated by hand into fibres which are in the form of woven, knitted, stitched or bonded fabrics. For this process rollers are used for forcing resin into the fabrics by means of rotating rollers and a bath of resin.

• Resin transfer method- RTM is a process using a rigid two-sided mould set that forms both surfaces of the panel. The mould is typically constructed from aluminum or steel, but composite moulds are sometimes used. The two sides fit together to produce a mould cavity. The distinguishing feature of resin transfer moulding is that the reinforcement materials are placed into this cavity and the mould set is closed prior to the introduction of matrix material.

• Injection moulding-Injection moulding is noted for low cost production of composite parts in large quantities. Although most closely associated with thermoplastics, the process can also be adapted to thermosets. It is used for both TP and TS type FRPs.

LITERATURE REVIEW
This section stresses on the research work that has already been carried out for testing the mechanical properties of the Glass Fiber Reinforced Polymer composites. Literature review of such work needs to be done in order to understand the background information available, the work already done and also to show the significance of the current project. They discussed [1] about green composites obtained from biodegradable renewable resources. They used different cellulose fibers from used office paper and newspaper as reinforcement for glass epoxy laminates was determined by mechanical tensile tests, differential scanning calorimetry, thermo-gravimetric analysis, water absorption measurement and scanning electron microscopy. The result showed that the tensile strength and elastic modulus was improved but decrease in water absorption to 175%, 292% and 63%. The results indicated that these green composites could be utilized more as these are strong, inexpensive, plentiful and recyclable. They discussed biocomposites [2] are now replacing petroleum-based composite materials in several applications. The main motivation for developing biocomposites has been and still is to create a new generation of fiber reinforced plastics material competitive with glass fiber reinforced ones which are environmentally compatible in terms of products, use and renewal. Bio nanocomposites have very strong future prospects, though the present low level of production, some deficiency in technology and high cost restrict them from a wide range of applications. These materials are now used for various applications such as casings of electronic products, interior parts of automobiles. But the bio-composites developed so far, has tensile & flexural strengths lower than 100 MPa which restricts their usage in high strength applications.
They found [3] the use of renewable resources such as plant and animal based fibre-reinforce polymeric composites, has been becoming an important design criterion for designing and manufacturing components for all industrial products. Research on biodegradable polymeric composites, can contribute for green and safe environment to some extent. In the biomedical and bioengineered field, the use of natural fibre mixed with biodegradable and bioresorbable polymers can produce joints and bone fixtures to alleviate pain for patients. In this paper, a comprehensive review on different kinds of natural fibre composites will be given. Their potential in further development was shown in different kinds of engineering and domestic products will also be discussed in detail. They [4] discussed about recent developments in the, properties and applications of green Composites. One very important aspect of green composites is that they can be designed and tailored to meet different requirements. Recent advances in natural fiber development offer significant opportunities for improved materials from renewable resources. Biocomposites offer a significant non-food market for crop-derived fibres and resins. Considerable growth has been seen in the use of biocomposites in the automotive and decking markets over the past decade or so, but application in other sectors has been limited. Recent developments of different biodegradable polymers and biocomposites were discussed in this review article. They [5] discussed about the advances, challenges and opportunities in biocomposites. It was very important to develop biocomposites to reduce greenhouse effect. Initially biodegradable plastic, polyactic acid (PLA) and polylactic acid (PHA), were among the leading biomass-derived materials, which were finally decomposed by microorganisms into water and carbon dioxide. CFRP, in particular, have been recently used for primary structural components in airplanes and automobiles as well as sport goods and construction materials, because of their excellent mechanical properties. Biodegradable resin may also be reinforced with such fibers, similarly to the conventional petroleum-derived plastics. They [6] discussed about the tensile properties of natural fiber reinforced polymer composites. Natural fibers have recently become attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites. Due to their low cost, fairly good mechanical properties, high specific strength, non-abrasive, eco-friendly and bio-degradability characteristics, they are exploited as a replacement for the conventional fiber, such as glass, aramid and carbon. In general, the tensile strengths of the natural fiber reinforced polymer composites increased with fiber content, up to a maximum or optimum value, the value will then drop. However, the Young's modulus of the natural fiber reinforced polymer composites increased with increasing fiber loading. They discussed [7] the effect of aluminium particle reinforcement GFRP composites. Different types of laminates were fabricated at different angles of orientations of laminates (0, 10, 30 and 45 degree). It was found that there was decrement in tensile strength and modulus but increment in laminate thickness. They found that the [8] efficiency of GFRP composite made bumper was more as compared to steel made bumper. It was found that factor of safety was 64 % higher for GFRP composite made bumpers. There was degradation of 5.8 % weight in case of composite as compared to steel made bumper. There was improvement in impact strength of composite. So it was discussed that GFRP composite can be used for manufacturing bumper for saving fuel cost and also for strength purpose.

They used hand layup[9] method for fabricated GFRP composite. They used glass fibers and TiO2 as filler materials for composite. The mechanical properties such as tensile strength, impact strength, hardness, compressive strength and flexural strength were measured. It was found that GFRP composite having 20% filler material has better mechanical properties as compared to other composites. The microscope was used to investigate the surface properties of composites. There was formation of voids in composites due to non-uniform mixing. It resulted in weak bonding between resin, filler and reinforcement phases of GFRP composite. They discussed [10] the effect of drilling parameters such as feed rate, cutting speed and thrust force on delamination and surface roughness of HFRP and CFRP composites. They also discussed the effect of drill diameters and chip formation in the machining process of composites. There was increment in delamination and surface roughness when feed rate and thrust force was increased. Similar effects were observed in case of drill diameters and chips formation. It was discussed the optimum feed rate was 0.05-0.10 mm/rev and cutting speed was 200-400 m/min for better surface finish and minimum delamination factor. It was found that due to increase in drill diameter, MRR was increased but surface integrity of samples was affected. They investigated [11] the mechanical properties of Kevlar based FRP composite material. The hand layup method was used for fabricating FRP composite material using Kevlar fibers, epoxy resin-520 and hardener-509. The mild steel mould was fabricated for manufacturing FRP as per requirement. It was observed that there was improvement in tensile strength and impact strength of composite samples. So it was found that Kevlar based FRP composites can be used for automotive and sports applications. They fabricated [12] FRP helical spring for automotive applications. It was found that there was reduction in weight without any change in strength of composite based helical spring. The spring winding technique was used to fabricate GFRP based composite spring. The fabricated spring was tested for spring stiffness, compression, failure load as per ASTM standards. The spring stiffness was 9.95 N/mm for fabricated GFRP based composite spring. The mild steel mandrel was fabricated for manufacturing composite helical spring. There was 40 % reduction in weight of FRP helical spring as compared to steel spring. The cost of fiber reinforced of FRP composite spring was more but it was compensated by saving fuel in case of FRP based helical spring. The stiffness was improved in case of GFRP composite spring as compared to steel based spring. There was improvement in fatigue life of springs by using FRP for helical springs. They discussed [13] the effect of drilling parameters such as tool geometry, tool materials and tool types on cutting force generation and delamination in machining of FRP composites. They also studied the nanopolymers composites. They presented a review on drilling on conventional FRP composites. It was very important to monitor the drilling process of FRP composites. The selection of drilling factors was very important to maintain the hole quality in the drilling process. It was found that spindle speed and feed rate highly influenced the cutting forces and delamination in drilling of FRP and nanocomposites. There was increment in feed force as point angle of drill were increased. They discussed [14] the newly developed method for rapid characterization of the fiber orientation of CFRP using random transform analysis of complex eddy current data. It was important to evaluate the stacking sequence of CFRP samples. They discussed [15] the processing and characterization of banana fiber based FRP composite. The hand layup method was used to fabricate FRP containing nano silica filler. They used different percentages of banana fibers-3, 4 and 5 % with 0.1 % wt, of nano silica fillers. It was found that with the addition of nano silica fillers enhanced the wear strength of composite. But there was decrement in hardness of FRP samples. They discussed [16] the fabrication of sisal and glass fiber based FRP using hand layup method. The mechanical properties such as tensile strength, flexural strength and impact strength were measured. There was improvement in mechanical properties with the use of sisal fibers in GFRP based composites.

Materials and manufacturing process
Materials used-E class glass fibre is a material that contains extremely fine fibres of glass. It is light in weight, extremely strong, and robust. It is formed when thin strands of silica glass are extruded.
into many fibres with small diameters. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. It is used as a reinforcing agent for composites to form a very strong and light fibre reinforced polymer (FRP) composite material. Two samples were prepared as per composition as given in Table 1.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>SiC</th>
<th>Glass fiber</th>
<th>Epoxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>2 %</td>
<td>52 %</td>
<td>46 %</td>
</tr>
<tr>
<td>Sample 2</td>
<td>4 %</td>
<td>50 %</td>
<td>46 %</td>
</tr>
</tbody>
</table>

Epoxy resin Epoxy resin is used to give great binding properties between the fibre layers. The Epoxy resin used at room temperature is LY 556. Hardener (HY 951) is employed to improve the interfacial adhesion and impart strength to the composite. A resin and hardener mixture of 10:1 is used to obtain optimum matrix composition. Silicon carbide (SiC) is produced by combining silica sand and carbon in an Acheson graphite electric resistance furnace at a high temperature. It can also be prepared by the thermal decomposition of a polymer under an inert atmosphere at low temperatures. It has low density, high strength, high hardness, high thermal conductivity and also excellent thermal shock resistance. Silicon carbide is one of the best filler material that is being used in composite. The synthetic resin for such processes is a monomer for making a plastic thermosetting polymer. During the setting process, the liquid monomer polymerizes into the polymer, thereby hardening into a solid.

Preparation of composite specimen
The composite materials used for the present investigation is fabricated by hand layup process as shown in figure 2. Chopped glass fibers were used to prepare the specimen. The layers of fibers are fabricated by adding the required amount of epoxy resin. The silicon carbide powder was mixed with the epoxy resin. The prepared samples were shown in figure 3.

Mechanical testing of samples
Tensile test- The hybrid composite material fabricated is cut into required dimension using a saw cutter and the edges finished by using emery paper as shown in figure 4 for mechanical testing. The tensile test specimen is prepared according to the ASTM D638 standard. The dimensions, gauge length and cross-head speeds are chosen according to the ASTM D638 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. Length = 260mm, width = 24mm, thick = 5mm

Flexural test- The flexural specimens are prepared as per the ASTM D790 standard as shown in figure 5. 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 and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimen used for conducting the flexural test. The tests are carried out at a condition of an average relative humidity of 50%.

Compression test- The compression specimen is prepared as per the ASTM D638 standard as shown in figure 5. A compression test involves mounting the specimen in a machine and subjecting it to the compression. The compression process involves placing the test specimen in the testing machine and applying compress to it until it fractures. The compress force is recorded as a function of displacement. During the application of compression, the elongation of the gauge section is recorded against the applied force.
RESULTS AND DISCUSSION

The use of composite materials in the different fields is increasing day by day due to their improved properties. Engineers and Scientists are working together for number of years for finding the alternative solution for the high solution materials. In the present study natural fibers are added to the glass fiber reinforced composite materials and their effect on mechanical properties is evaluated and tabulated in tables 2-5.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Percentage of SiC</th>
<th>Tensile strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE – 1</td>
<td>2%</td>
<td>107.95</td>
</tr>
<tr>
<td>SAMPLE – 2</td>
<td>4%</td>
<td>88.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Percentage of SiC</th>
<th>Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE – 1</td>
<td>2%</td>
<td>172</td>
</tr>
<tr>
<td>SAMPLE – 2</td>
<td>4%</td>
<td>180</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Percentage of SiC</th>
<th>Fracture strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE – 1</td>
<td>2%</td>
<td>101.55</td>
</tr>
<tr>
<td>SAMPLE – 2</td>
<td>4%</td>
<td>83.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Percentage of SiC</th>
<th>Hardness (Shore D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE – 1</td>
<td>2%</td>
<td>85</td>
</tr>
<tr>
<td>SAMPLE – 2</td>
<td>4%</td>
<td>87</td>
</tr>
</tbody>
</table>

CONCLUSION

In this work, specimens are prepared by using hand lay-up technique with woven, glass as a fiber and epoxy resin as an adhesive. The specimens are prepared for testing as per ASTM standards to estimate the mechanical properties. The behavior of E-glass epoxy laminates were subjected to tensile and bending loading at continuous varying energy levels had investigated using UTM. These tests have shown that the static response of the systems depends on the elastic properties of fiber material. This work shows that successful fabrication of glass fiber with random oriented reinforced polyester composites with different fiber contents is possible and very cost effective by simple hand lay-up technique. Bending and compressive strength increases with when SiC is taken as a filler material. SiC filler material makes material harder and brittle which is the reason for reduction in tensile strength value. It is possible to enhance the tensile strength of the composite by proper distribution of the glass fiber in the composite.

REFERENCES