



EVALUATION AND TESTING OF FIBER-REINFORCED POLYMERIC COMPOSITES THROUGH EXPERIMENTATION

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Abstract

The quest for metal and alloy substitutes has been ongoing for a number of decades in an effort to reduce the high cost of manufacturing, maintenance, and repairs for metal structures harmed by corrosion and repeated use. This sparks curiosity about finding new metal structure substitutes. by developing novel composite materials that maintain their strength, durability, and excellent mechanical properties without sacrificing any of these qualities. Fiber Reinforced Polymers' presence A relatively new class of composite materials called polymeric composite (FRP) is made of reinforcing fibers and a polymeric matrix. Its improved strength, reduced weight, and recyclable nature all at a low cost of production have demonstrated its effectiveness. FRPs' mechanical qualities make them perfect for a wide range of global applications in the building industry and other industries. Plant fibers have drawn a lot of interest lately as an alternative to reinforcements made of synthetic fibers. This is due to the fact that thermoplastics reinforced with natural fibers have a significant chance of replacing traditional inorganic fibers in the future. Furthermore, natural fibers are elements that are found in nature that have cellulose fibrils embedded in a lignin matrix. Researchers' attention has turned from synthetic to natural fiber-reinforced polymer composites due to the special qualities of NFRP, which include low density, low cost, high specific strength, environmental friendliness, and more. The production and testing of natural fiber reinforced polymeric composite's mechanical properties are the main objectives of this project.

Keywords: *FRP, Fibers, Resin, Composite*

1.INTRODUCTION

The most common emerging materials during the past thirty years have been composite materials, polymers, and ceramics. Composite materials have become more widely used and have a greater range of uses. They are aggressively encroaching on new markets. In the market for engineered materials, which ranges from commonplace goods to complex applications, modern composite materials make up a sizeable share. Although the value of composites as materials that reduce weight has previously been established, their cost-effectiveness remains a problem. The composites industry today uses a number



of cutting-edge manufacturing techniques that were developed in an effort to make economically attractive composite components.

Recent years have seen a rise in the use of composite applications. With the advent of more advanced polymer resin matrix materials and high-performance reinforcement fibers, high-performance fiber reinforced polymers (FRP) are becoming more widely used in a wide range of applications. These include fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, highway bridge support beams, explosive impact-resistant composites, and even paper rollers. In fact, using composites instead of metals has reduced costs and weight in several applications. Engine cascades, curved fairing and fillets, substitutes for welded metallic components, cylinders, tubes, ducts, blade containment bands, etc. are a few examples. Additionally, the necessity for composite in lighter materials has made the utilization of traditional materials like steel, new and advanced materials allow for the structural features to be taken into account while designing the composite's qualities. In many cases, using composites will be the obvious choice; in other cases, the choice of material will depend on factors like the required working lifetime, the quantity of items to be produced, the complexity of the product shape, potential cost savings during assembly, and the designer's experience and aptitude in utilizing composites to their fullest potential. In some cases, using composites in addition to conventional materials may yield the optimum results.

2. CHARACTERISTICS OF COMPOSITES

There are two stages in a composite material: a discontinuous phase and a continuous phase. The continuous phase is referred to as the "matrix," whereas the discontinuous phase, which is often harder and stronger than the continuous phase, is called the "reinforcement or reinforcing material." Generally speaking, the matrix is less rigid and more ductile. It shares a burden and contains the dispersed phase. Any of the three fundamental material types—polymers, metals, or ceramics—can make up a matrix. The product, component, or bulk form is formed by the matrix. A discontinuous phase is the secondary phase that is embedded in the matrix. Generally speaking, it is stronger and harder than the continuous phase. It enhances the matrix's overall mechanical characteristics and helps to strengthen the composites.

The characteristics of the constituent materials, their distribution, and their interactions with one another all have a significant influence on the properties of composites. The composition of the constituent materials and the geometry of the reinforcement—that is, its shape, size, and distribution—have a significant impact on the composite's characteristics. The characteristics are also influenced by the reinforcement's orientation and concentration distribution. The interfacial area is a crucial factor in determining the degree of interaction between the reinforcement and the matrix. It is determined by the shape of the discontinuous phase, which can be cross-sanctioned prisms or platelets that are spherical, cylindrical, or rectangular, as well as by the size and size distribution that govern the texture of the material. Concentration, which is typically expressed as a weight fraction or volume, indicates the amount that a single component to the composites' overall characteristics. It is not just the single most significant factor affecting the composites' characteristics, but it is also a readily adjustable production variable that can be utilized to change those characteristics.

3. FIBERS

A type of materials resembling hair, called fibers, come in either single, elongated portions or as continuous filaments, much like thread. It is possible to spin them into rope, thread, or filaments. They are suitable for usage as a constituent of composite materials.

3.1 Classification of Fibers:

There are two kinds of fibers: synthetic or man-made fiber and natural fiber. Fibers derived from plants, animals, and minerals are considered natural fibers. Natural fibers can be divided into three categories based on where they came from: plant, mineral, and animal.

3.1.1 Animal Fiber (wool or hair):

Animal fiber generally comprises proteins; it is taken from animals or hairy mammals. E.g. Sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, wool, silk etc.

3.1.2 Avian fiber:

Fibers from birds, e.g. feather fiber.

3.1.3 Mineral fiber:

Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories:

Asbestos: The only naturally occurring mineral fiber. Varieties are serpentine and amphiboles, anthophyllite.

Ceramic fibers: Glass fibers (Glass wool and Quartz), aluminum oxide, silicon carbide, and boron carbide.

Metal fibers: Aluminum fibers

3.1.4 Plant fiber:

Plant fibers, such as cotton, jute, flax, ramie, sisal, and hemp, are often primarily composed of cellulose. Paper and textiles are made from cellulose fibers. These fibers can be further divided into the following categories.

Seed fiber: Fibers collected from the seed and seed case e.g. cotton.

Leaf fiber: Fibers collected from the leaves e.g. sisal.

Skin fiber: Fibers are extracted from the bast or skin that surrounds the stem of the corresponding plant. Comparing these fibers to other fibers, their tensile strength is higher. For this reason, these fibers are utilized to make sturdy yarn and cloth; flax, jute, banana, hemp, and soybean are a few examples.

Fruit fiber: Fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.

Stalk fiber: Fibers are actually the stalks of the plant. E.g. straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood is also such a fiber.

It is possible to strengthen thermosetting and thermoplastic matrices using natural fibers. Polyamide (PA or Nylon) and polypropylene (PP) are examples of thermoplastic resins. In natural fiber composites, polycarbonate and polyethylene (PE) are frequently utilized to give adequate mechanical qualities, specifically strength and stiffness, at somewhat low cost points. All vegetable fibers are primarily made of cellulose, a type of carbohydrate that is



present in all plants. The natural fabrics that are most frequently used to produce apparel are silk, cotton, hemp, linen, ramie, and wool. Natural fiber use predates written history; by the sixth century, wool and flax were being woven into textiles, according to archeological findings. However, man-made fibers, or fibers that have undergone significant structural and chemical alteration during production, were not created until after the Industrial Revolution. Though in a significantly altered form, the same cellulose polymers present in many natural fibers formed the basis of the first of these fibers, rayon and acetate. Subsequently, synthetic fibers were produced using only artificial methods, and they became classed in a separate category of fibers known as synthetics. Choosing natural fibers instead of synthetic ones is just the beginning when it comes to the ecological elements of material choices. New materials that are fully based on renewable resources are being developed as a result of restrictions on the release of gases that contribute to the greenhouse effect, such as CO₂, into the atmosphere and growing awareness of the limited supply of fossil energy resources. Nowadays, natural fibers are used in every country to produce composite materials. The following table.1 shows the annual fiber production of different countries.

Name of the Fiber	India	Worldwide
Banana	1632	100,296
Coir	160000	282,000
Sisal	3000	600,000
Pineapple	1576	258,000
Jute	2856	456,725

Table. 1 Annual fiber production / availability of some of the cellulose fibers (ton)

4. POLYMER

The two main categories of polymers, thermoset and thermoplastic, are distinguished by the way they behave during thermal processing. Polymers that can be melted and treated in a number of ways, such as extrusion and molding, are referred to as thermoplastics. These consist of polyvinyl chloride, polyethylene, polypropylene, and polystyrene. Conversely, thermoset polymers are those whose individual chains have undergone chemical bonding either during polymerization or after additional chemical or heat processing. The crosslinked networks are resistant to solvent assault, creep, and heat softening after they are created. This study's primary focus is thermoplastic materials. Since polypropylene (PP) can be processed at temperatures below 230°C without degrading the fiber, it has been selected as the composite's matrix material. One of the most popular products made of synthetic polymers is PP. Following polyester, polyamide, and acrylic fibers in terms of volume, PP comes in fourth. Its excellent crystallinity, low density (0.905 g/cm³), rigidity, and hardness are its main selling points. These qualities are why the polymer is used in so many different countries. The volume of polypropylene produced in different nations is displayed in the following Table.2

Table. 2 Production volumes of glass and PP polymers worldwide

Grade	Area	Volume	Year	Change Wrt previous year (%)
		(k ton)		
Glass-PP	Europe	100	2007	10
Glass-all	Europe	1,200	2007	5.6
Glass-all	US	1,600	2007	-10
PP	Worldwide	45,000	2007	Few %
PVC	Worldwide	33,200	2006	Few %

4.1 Fiber-matrix adhesion

Adhesion between fibers and the matrix is crucial for composite reinforcement. In the loading process, loads are applied to the matrix rather than the fibers directly. In order for composites to possess outstanding mechanical qualities (maximum strength combined with toughness), the load needs to be efficiently transferred from the matrix to the fibers. A robust and effective fiber-matrix interface that is, good interaction as well as adhesion between the fibers and the matrix are necessary for this. The fiber's surface can be treated to control this, or coupling agents or other additives can be used.

4.2 Alkaline treatment

The strength of the fiber was found to be enhanced by a light NaOH treatment. The inter fibrillar region is anticipated to be less dense and less rigid as a result of the alkaline treatment, which removes hemicellulose and lignin. This allows the fibrils to more easily reorganize themselves in the direction of tensile loading. These configurations between the fibrils would improve load sharing and, as a result, increase the formation of stress in the fiber as it is stretched. In more severe circumstances, the NaOH treatment did not significantly improve the fiber's tensile strength.

5. METHODOLOGY

5.1 Fiber Reinforced Polymer

A matrix and fibers make up typical fiber reinforced composites. The matrix holds all the fibers together in shape and distributes stresses among the reinforcing fibers, whereas the fibers serve as reinforcement and the primary source of strength. The loads are carried by the fibers in their longitudinal directions. Filler is occasionally added to improve the production process, influence a composite's unique qualities, or lower the cost of the final product.

Fibers made of asbestos, carbon or graphite, natural fibers, beryllium, beryllium oxide, beryllium carbide, molybdenum, aluminum oxide, glass fibers, polyamide, etc. are examples of common fiber reinforcing agents. Epoxy, polyester, polyurethane, polypropylene (PP), and other similar polymers are often used matrix materials. Polypropylene (PP) is the most often

used resin substance among these. In light of this, current efforts have been made to create a sample to test the tensile and compressive strengths of composites made of polypropylene with reinforcement from sisal and jute fibers. Here, the procedure creates a polymer composite consisting of polypropylene and sisal and jute fibers.. The process used for the production of polymer composite is shown in Fig.1.

5.2 Process layout

Figure.1 shows the process layout of Fiber Reinforced Polymeric Composites (FRP) and its classifications.

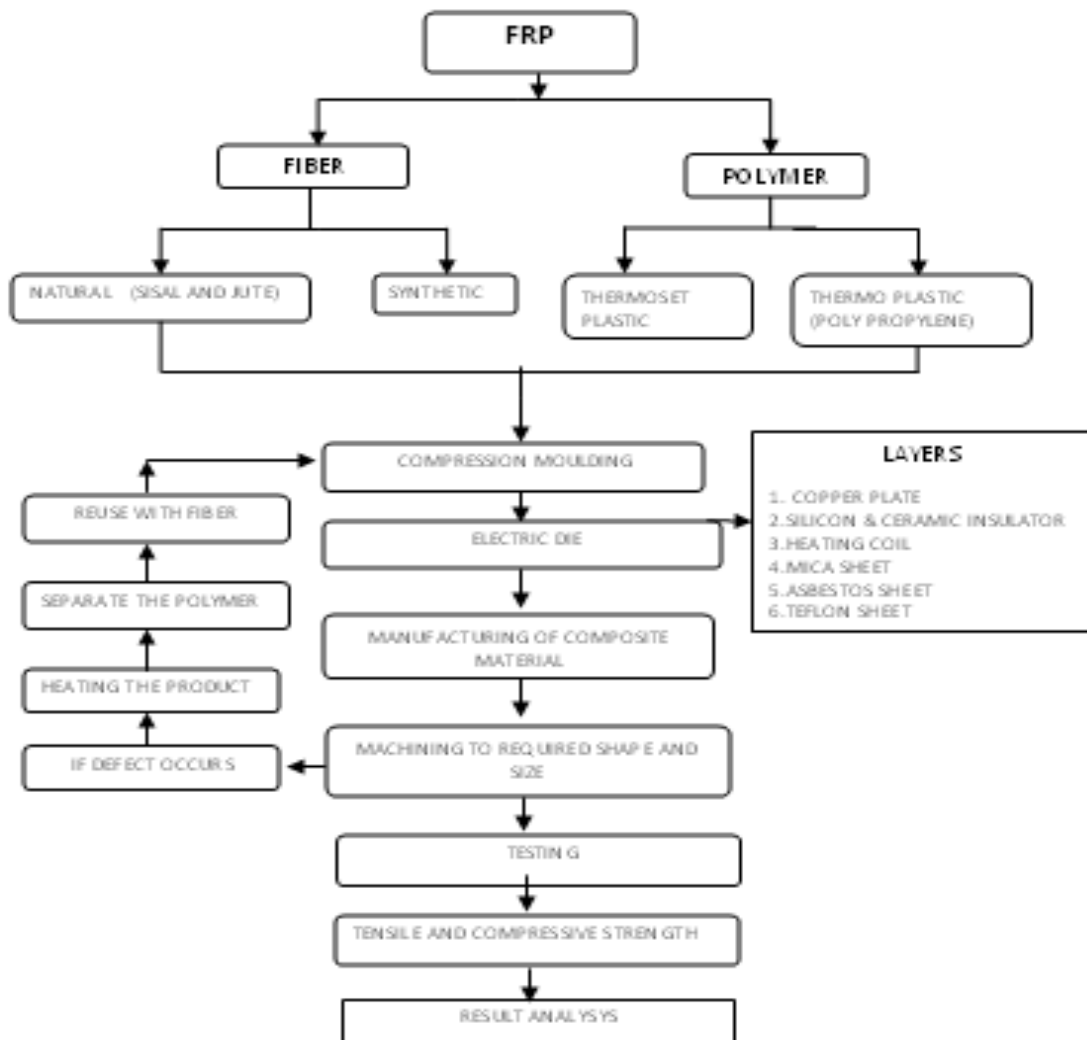


Fig.1 Process layout of FRP

5.3 Compression molding

As seen in Fig. 2, the compression molding process involves inserting a hot polymer that has been warmed into an open mold chamber. After sealing the mold with a top plug, pressure is used to push the material into every crevice of the mold. Pressure and heat are kept constant during the procedure until the polymer cures. Although thermosets and thermoplastics can both be used in the compression molding process, thermoset polymers are now used in the majority of applications. Compression molding of advanced composite thermoplastics can also be done using chopped strand, woven textiles, unidirectional tapes, and randomly orientated fiber mats. Compression molding is a plastic molding technique that utilizes large volume and high pressure, making it appropriate for creating intricate and robust items. Moreover, its brief cycle period and high production rate, many organizations in the automotive industry have chosen compression molding to produce parts.

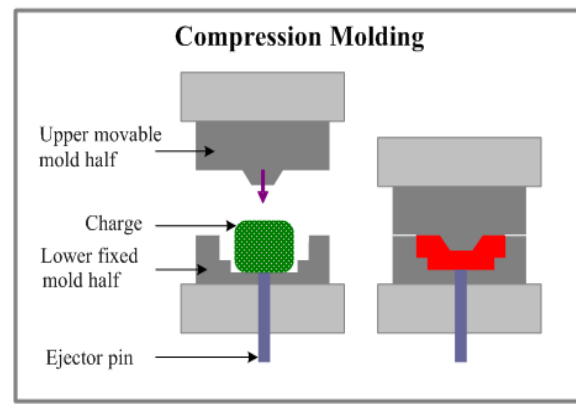


Fig.2 Compression molding process

5.4 Electric Die:

The Joule effect, or Joule's first law, is a physical law that describes the relationship between the amount of heat produced by a current running through a conductor. It is the basis for the operation of this electric die, which has a heating coil inserted into both the male and female dies. Layers of fibers and resin are layered atop one another, crushed, and sealed. Because pressure and heat are applied simultaneously, strength and durability will both increase. Additionally, this die has a thermostat to control the temperature. Between the coil and the material, a copper plate serves as the heat transmission medium. Asbestos is used as heat absorber, an insulator between the copper plate and coil, while mica is utilized as the insulator to prevent the heat flow to other sides.

6. TEST PROCESS

The test specimen, which measures 8 x 0.75 x 0.25 inches, is placed within the testing apparatus and strain is gradually applied to it at a rate of 1 mm per minute until it cracks. The gauge section's elongation is measured in relation to the applied force as tension is applied. To ensure

that the results are independent of the test sample's geometry, the data is altered. The following formula is used to determine the engineering strain, ϵ , based on the elongation measurement

$$\epsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

Where,

ΔL is the change in gauge length,

L_0 is the initial gauge length,

L is the final length.

The force measurement is used to calculate the engineering stress, σ , using the following equation:

$$\sigma = \frac{F_n}{A}$$

Where,

F -force,

A is the cross-section of the gauge section,

The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.

7. RESULTS

The following results show the variation in tensile and compressive strength with regard to change in temperature, fiber treatment, and volume fraction.

1. Untreated Sisal Fiber

TEMPERATURE	TENSILE STRENGTH (MPa)	COMPRESSIVE STRENGTH (MPa)
140	227	224
150	239	237
160	251	253
170	264	262
180	280	278
190	269	265

Table.3 change in Properties wrt Sisal processing temperature

2. Untreated Jute Fiber

TEMPERATUE	TENSILE STRENGTH (MPa)	COMPRESSIVE STRENGTH (MPa)
120	212	214
130	224	219
140	237	235
150	250	251
160	264	268
170	255	257

Table.4 change in Properties wrt Jute processing temperature

3. Treated Sisal Fiber

TEMPERATUE	TENSILE STRENGTH (MPa)	COMPRESSIVE STRENGTH (MPa)
140	260	258
150	276	276
160	294	290
170	318	315
180	344	340
190	324	319

Table.5 change in Properties wrt Treated Sisal processing temperature

4. Treated Jute Fiber

TEMPERATUE	TENSILE STRENGTH (MPa)	COMPRESSIVE STRENGTH (MPa)
120	242	239
130	256	258
140	270	276

150	284	287
160	291	293
170	282	286

Table.6 change in Properties wrt Treated Jute processing temperature

5. Treated Sisal Fiber

%VOLUME OF FIBER	TENSILE STRENGTH(MPa)	COMPRESSIVE STRENGTH(MPa)
35	268	267
40	279	276
45	297	295
50	328	324
55	344	340
60	329	328

Table.7 change in Treated sisal Properties wrt change in fiber volume

6. Treated Jute Fiber

%VOLUME OF FIBER	TENSILE STRENGTH(MPa)	COMPRESSIVE STRENGTH(MPa)
35	245	242
40	254	256
45	269	267
50	278	277
55	287	285
60	294	292

Table.8 change in Treated jute Properties wrt change in fiber volume

CONCLUSION

The hydrophilicity of the natural fiber is reducing in the reinforcement and there is increase in bond with the matrix in the reinforcement due to surface treatment. Surface treatment provides the better increment in mechanical, adhesion, and hydrophobicity property of the natural fiber composite. The physical and mechanical properties of these NFPCs can be further enhanced



through the chemical treatment, while moisture absorption of the NFPCs can be reduced through surface modification of fibers such as alkalization and addition of coupling agents.

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