A Review on mechanical properties of natural and artificial fiber reinforcedpolymer composites

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Abstract
Natural fibres have attracting the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement for fibre reinforced polymer composites, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics. In this point of view, a brief review has been carried out to make use of natural fibres (such as abaca, banana, bamboo, cotton, coir, hemp, jute, pineapple, sisal etc) abundantly available in India. Glass Fibre Reinforced Polymers are mixing with natural fibres to increase Engineering and Technology applications. This paper presents a review on the mechanical properties of natural-glass fibre reinforced polymer composites.Natural fiber replaces the synthetic fiber dueto its superior properties for example high specific strength, small weight, and low cost, moderately good mechanical property, nonabrasive recyclable and bio-degradable features. But the mechanical properties of natural fibre composites are less than that of synthetic composite like glass fiber reinforced polymer (GFRP). In present study the natural fiber polymer composites mix with the glass fiber, to enhance the mechanical property of composite.This paper presents a review on the mechanical properties of natural fiber reinforced polymer composites.Composites of polypropylene (PP) reinforced with short glass fibers were prepared with extrusion compounding and injection molding techniques. The tensile properties of these composites were investigated. It was noted that an increase infiber volume fraction led to a decrease in mean fiber length as observed previously.

Keywordsglass fiber reinforced polymercomposite, natural fiber, fiber reinforced polymer composite

Introduction

A fiber reinforced polymer (FRP) is a composite material consisting of a polymer matrix imbedded withhigh-strength fibers, such as natural fiber or synthetic fiber.A composite is a structural material that consistsof two or more material that is combined at a macroscopic level and is not soluble in each other. Thematerial which is embedded is called reinforcementand another one in which it is embedded is called the matrix. Generally, polymer can be classified into two classes, thermoplastics and thermosetting. Thermoplastic materials currently dominate, as matrices for bio fibers, the most commonly used Thermoplastics for this purposeare polypropylene (PP), polyethylene, and poly vinyl chloride (PVC); while phenol, epoxy and polyester resins are the most commonly used thermosetting matrices [1].The increasing demand of high strength and earth friendly material day by day cause to developed the compositematerials and their related design and manufacturing technologies. In order to obtain low cost, easily disposable, Research and engineering interest has been shifting from huge materials to Natural fiber reinforced polymeric materials.In the previous year, natural fibers as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibers. These natural fibers include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others[2]. Most of the composites materialsare been suitable for aerospace, engineering and space shuttles. The roll of natural fibers is improved remarkably due to the fact that the field of application is improved day by dayespecially in automotive industries. Mixingof natural fiber with another natural fiber does not give superior mechanical property as given by glass fiber [2].

In present day's natural fibers such as sisal and jute fiber composite materials are replacing the glass and carbon fibers due to their easy availability and cost. Natural fibers may play an important role in developing biodegradable composites to resolve the current ecological and environmental problems. Natural fibers are lighter and cheaper, buttheyhave low mechanical properties than glass fibers. The combined use of these two fibers may solve this problem.

Most of the studies on natural fibers are concerned with single reinforcement. The adding together of natural fiber to the glass fiber canmake the composite hybrid which is relatively cheaper and easy to use. Natural fibers are selected asreinforcement because they can reduce the tool wear when processing, respiratory irritation and serving as alternativesfor artificial fiber composites in the increasing global energy disaster and ecological risks. A fiber reinforced polymerhybrids composites are more than one reinforcing phase and a single matrix phase or single reinforcing phase withmultiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as comparedto single fiber containing composites [3]. Hybrid composites are includes multiple reinforcing such as natural aswell as synthetic fiber. The natural fibers involved coir, jute,sisal, banana, bamboo, and abaca. The effects ofhybridization of coir-jute, sisal-jute and coir-sisal fiber with polyester resins were analyzed. The result showshybridization play important role for improving mechanical properties of composites [4]. Hybrid compositesmay replace or reduce utilization of synthetic fibers in application of automotive, building industries, aircraft.Jute-coir hybrid composites find into railway coaches for sleeper berth backing, for building interiors, doors andwindows besides in transportation sector as backings for seat and backrest in busesMany authors have reported the mechanical properties of natural fiber reinforced composites. But less efforthas been focused on Natural hybrid fiber reinforced polymers. So this paper provides overview of Natural sisal-glass fiber reinforced polymers.

Short-fiber reinforced polymer (SFRP) composites are very attractive because of their ease of fabrication, economy and superior mechanical properties. Extrusion compounding and injection molding processes are frequently employed to make SFRP composites [1–27]. In general, a high fiber content is required in order to achieve a high performance SFRP composite. Therefore, the effect of fiber content on the mechanical properties of SFRP composites is of particular interest and significance. However, for injection molded SFRP composites, fiber breakage takes place during processing. Fiber breakage results from fiber–polymer interaction, fiber– fiber interaction, and fiber contact with surfaces of processing equipment [27,28].

proposed in previous studies. Freiman's crack growth model was imposed to determine crack growth to failure of glass fiber under the stress or load applied [6]. Under the wet environment and constant loading, the strength of glass fibers decreases and it fails as placed for a long time span. This behavior is known as stress corrosion [7–9]. Table 2 shows a composition of E-glass which facilitates durability to glass fiber under stress corrosion [10]. The coating of alkaline facilitate oxide shield to composite. Furthermore, coating of Mg, Al, Si, Ni or Zn improves durability of glass fiber [11, 12]. E-22 and woven glass fibers were frequently used in previous studies. E-glass fiber has high density with high elongation which provides superior elastic strength. Low Young's modulus provides durability against failure [13].

The mechanical as well as chemical stability of matrix-reinforcement interface is investigated from many years. Interfacial stability of glass fiber composites directly depends upon type of glass fiber, reinforcement and bonding agent. Investigators [14, 15] designed the experiments by varying the volume percentages of resin and reinforcement for achieving the desired mechanical, microstructural, thermal and electrical properties. The reinforcements used in previous studies are metallic, natural and polymeric. Polymeric and metallic reinforcements are applicable in high scale industry whereas natural fibers are used in small and medium scale industry

1.1. Epoxy/Glass Fiber Composites

Initially the fibers are treated with epoxy resins only. This type of composites is known as epoxy/glass fiber composites. The direct interfacing between fibers through binding agent is the only medium which provided the strength to composite [17–27]. Table 4 shows the epoxy resins that have been used in past studies for fabrication of epoxy/glass fiberncomposite. The fabrication of this type of composite is done by injection molding or simple hand layup technique. The sol gels are also used in place of epoxy resins. Aerosol gels are commonly used sol gels because of their thermal insulating property and having highly porosity [28].

1.2. Epoxy/Metallic Foil/Glass Fiber Composites

Metallic foils are helpful for improving the durability of composite under mechanical loading e.g. aluminium, titanium and tin foils. But the use of metallic foil matrix with glass fiber composite is quite limited.

1.3. Epoxy/Synthetic Fibers/Glass Fiber Composites

Epoxy/Synthetic fibers/glass fiber composites involve the interfacing of polymeric or thermoplastics matrix with glass-fiber reinforcement via epoxy resins. Recently, the continuous advancement in thermoplastics has attracted the researchers to use it in composite applications. The use of thermoplastics in glass-fiber composite is aid to increase in its melting point at the interface. Table 5 shows the chemical structure of polymer and agent used in glass fiber composite [29]. Flexural strength of thermosets is found relatively high as compare to tensile strength.

FABRICATION METHODS

A limited number of methods are observed in literature to fabricate the composites which are described below.

2.1. Hand Layup Method

Simple hand layup method is applied for natural as well as synthetic fiber to fabricate the composite. Figure 3 represents the schematic diagram of hand layup method. Firstly, a releasing agent is sprayed on top and bottom of mold for achieving surface finish. Then, the bonding agent is poured on the glass fiber sheet and uniform loads are applied by means of roller. Roller removes the air present in the reinforcement and matrix interface. This process again repeated for next layer and repeated over and over again until the required thickness doesn't achieved [31, 22]. Epoxy and polyester resins are used by different researchers for composite fabrication.

2.2. Compression Molding

In this method, mold with application of high pressure is used to fabricate the composite. Two match plate mold contains one stationary and one movable plate in which reinforcement and matix placed at high pressure and temperature. The amount of pressure and temperature decides the size of composite product. The composite is cured at room temperature and after curing composite product is taken out [29]. Automotive parts, panels and structures are developed by compression molding.

2.3. Injection Molding

Injection molding is used to fabricate the polymer/glass fiber composites in which molten polymeric material injected into closed matched molds under the pressure [20-26]. Anisotropic property was observed reduced in case of injection molding. Injection molding was found defect free technique in literature [30, 22]. Powder injection molding is a modern approach to fabricate the polymer/glass composite [14].

2.4. Vacuum Assisted Methods

These are the modern methods in composite manufacturing industry. Different vacuum assisted techniques are discussed below. Firstly impregnation in which epoxy resin is used in two glass sheets to directly impregnate with each other with help of vacuum generator The Vacuum assisted resin infusion technique (VARIM) in which glass fibers are blended into the mixture enclosed in a vacuum bag to produce high quality fiber products e.g. aircraft parts There were several vacuum bagging methods available in literature such as vacuum bag resin transfer molding, vacuum assisted resin transfer molding, vacuum assisted resin infused repairing.

2.5. Pultrusion

This process is used for manufacturing of uniform sectional products for example structural shapes, pipe, beams, tubes, rods etc. In this process glass fiber is pulled from Simple hand layup technique had been preferred in many investigations because of its easier fabrication procedure. Belingardi et al. had found the vacuum infusion as an alternative of hand layup technique due to cleaner and environment friendly process. Yuhazri et al. evaluated that vacuum infusion technique provided better mechanical properties over hand layup. Resin infusion molding was found faster among other processes as presented in Figure 8 [10]. Hayward et al. [21] observed that VRTM provided better flexural strength over RTM. Composite fabricated with RTM process has a considerable porosity which results in bubble formation within resin, it contribute in failure of composite near resin injection points. Figure 9 represents a comparison of different fabrication methods on the basis of energy consumption. Pultrusion consumed lowest energy among all processes. Vacuum assisted molding processes have been suggested in this study. From literature it can be observed that there was a lack of accuracy in hand layup and compression molding [18]. Moreover, Resin transfer and infusion molding processes are valid only for polymer/glass fibers because these follows powder metallurgy.

2. Characterization of Natural-Glass Fiber Reinforced Polymers Composite

2.1 Natural fibers

Natural fibers are materials that belong to a class of hair like materials which are in the form of continuousfilaments. Natural fibers are classified into two types, as plant (vegetable) fibers and animal fibers. Plant fibers namely cotton, flax, hemp, abaca, sisal, jute, kenaf, and coconut are widely used. They are preferred mostly since they are eco-friendly, and also available inLesscost.Most of the Researchers are putting more efforts to utilize the properties of these naturally occurring lignocelluloses fibers. Natural fibers offer a wide range of advantages like low cost, abundant availability, biodegradability, non toxic nature etc. Natural fibers offer a wide variety of fibers as different fibers comes from different parts of plants, fibers made of minerals and animals. Natural fiber based polymer composite offer many advantages like low cost, biodegradability etc, but there are some disadvantages like they do not offer high strength, stiffness. Also causes poor bonding of reinforcement with the matrix. [1]**.** Synthetic fiber reinforced composite offers some solution to the case of synthetic fiber there are two main drawbacks: high manufacturing cost and non biodegradability.

2.2 Chemical Composition of natural fibre

2.4 Glass/synthetic fiber

In the table 2 Synthetic fibbers are made from synthesized polymer or small molecules. The compound used to make this fibre come from raw material such as petroleum based chemicals or petro chemicals. There are many types of synthetic fibbers like polyester, nylon, acrylic, glass fibbers etc.In present time Glass fibbers are commonly used fibre for various polymer composites. It offers various advantages like high strength, chemical resistant, good insulation, and elasticity. There are various types of glass, table 2, fibbers like a glass, S glass, E glass, D glass etc. Among these types E glass and S glass are commonly used due to their High tensile strength. Commercially available Glass fibbers are in the form of woven cloth, chopped fibbers and long continuous fibbers. Woven cloths are made of long fibre woven in perpendicular directions. In chopped strands long fibbers are cut into small pieces and arranged in form of bundle [3].E-glass fibre is mainly used where cost of development is restricted as in household products like glass fibre doors, window frames and sports products etc. when strength to the component is more important than the cost in that case S glass fibbers are used. Components made of S glass fibbers are used in ship hull, tail wings of airplane,vessels, vehicle components etc [4]

Application

Electronics: GRP has been widely used for circuit board manufacture (PCB's), TVs, radios, computers, cell phones, electrical motor covers etc.

*Home and furniture:*Roof sheets, bathtub furniture,windows, sun shade, show racks, book racks, tea tables, spa tubs etc.

*Aviation and aerospace:*GRP has been extensively used in aviation and aerospace though it is not widely used for primary airframe construction, as there are alternative materials which better suit the applications. Typical GRP applications are engine cowlings, luggage racks, instrument enclosures, bulkheads, ducting, storage bins and antenna enclosures. It is also widely used in ground-handling equipment.

Boats and marine: Its properties are ideally suited to boat construction. Although there were problems with water absorption, the modern resins are more resilient and they are used to make the simple type of boats. In fact, GRP is lower weight materials compared to other materials like wood and metals.

Medical: Because of its low porosity, non-staining and hard wearing finish, GRP is widely suited to medical applications. From instrument enclosures to X-ray beds (where X-ray transparency is important) are made up of GRP.

Automobiles: GRP has been extensively used for automobile parts like body panels, seat cover plates, door panels, bumpers and engine cover. However, GRP has been widely used for replacing the present metal and non-metal parts in the variousapplications and tooling costs are relatively low as comparedwith metal assemblies.

Conclusion

The mechanical, dynamics, tribological, thermal and water absorption properties of GFRP composites have been discussed. The important application of these composites has highlighted.The various preparation technologies were used for preparing the GRP composites with various environmental conditions.Ultimate tensile strength and flexural strength of the fiber glass polyester composite increased with increase in the glassfiber and natural fiber weight fractions. The elastic strain of the composite increased with the fiber glass up to 0.25, and then subsequently decreased with further increase in glass fiber. The Young's modulus of elasticity of the composite increased with the glass fiber.The damping properties of GRP were improved by increasing the GF content in composite and the natural frequency was measured for all conditions. The water absorption was analyzed for various environmental conditions with different time period. The water absorption decreased the mechanical properties of the composites.The coefficient of friction at various sliding distances and loading condition were analyzed with various fiber orientations like random, woven mat, longitudinal, P/AP chopped GF. The lower wear was found for more fiber incorporated in the polymers. For improving the composites properties, the fibers were treated with various chemicals and matrix blend with suitable chemical for making the GRP composites. This may improve the mechanical, thermal, tribologicalproperties of the GRP composites.

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