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Effect of Fiber Length on Tensile Properties of Jute Fiber Composite

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Abstract

Natural fibers have recently become attractive 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 synthetic fibers. In this work, an investigation is carried out on jute fiber. As a natural fiber, jute has gained interest in the composite field due to its superior specific properties compared to manmade synthetic fibers. The present work describes the development of natural fiber based composites consisting of jute fiber as reinforcement and polystyrene resin as matrix material. For the development of polystyrene based composites 5 wt. % jute fibers of lengths 1mm, 10mm and 20mm respectively were used as reinforcement. The composites were fabricated using hand lay-up molding technique. Test specimens were prepared according to standard specification and tensile tests were conducted using universal testing machine (UTM). The results show a decrease in tensile strength for composites compared to pure polystyrene. However, significant improvement in young's modulus was seen for the composites. The effect of jute fiber length on the tensile fracture modes were also observed and discussed.

Keywords: Natural fiber, Jute fiber, Polystyrene, Composites, Tensile strength.

1. Introduction

In modern day engineering and development works, materials with conflicting and unusual properties are often required that cannot be met by tradition materials available such as metals, polymers, etc. To meet these property requirements, composites are being developed. A composite material is made by combining two or more materials, often ones that have very different properties than the constituents. The two materials combine to give the composite unique properties required in new technologies. Among the various types of composites that are being developed, fiber reinforced composites posses a great importance. A fiber reinforced polymer (FRP) is a composite material consisting of a polymer matrix imbedded with high-strength fibers [1]. In the recent decades, natural fibers as reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional fibers as carbon, glass, etc [3]. These natural fibers include flax, hemp, jute, sisal, coir, kapok, banana, henequen and many others. The various advantages of natural fibers over man-made glass and carbon fibers are low cost, low density, comparable specific tensile properties, non-abrasive to the equipments, non-irritation to the skin, reduced energy consumption, less health risk, renewability, recyclability and bio-degradability. These composite materials are suitably applicable for aerospace, construction, sport, automotive industries, etc. [2].

One of the most trending natural fibers to be used in recent composite developments is jute fiber. Due to its ease of availability and increasing demand as environmental friendly material, jute fiber has become important in composite engineering. It has relatively low density and higher strength and modulus than plastic and is a good substitute for conventional fibers in many situations [4]. Due to its remarkable properties and also easy availability, we use jute as composite fiber in this research.

The matrix material used here is Polystyrene (PS) resin. Polystyrene is one of the most widely used plastics and an inexpensive resin. It is a thermoplastic polymer and used in making protective packaging, containers, bottles, cutleries, etc. However polystyrene is very slow to degradation. Recycling of plastic results in partial degradation and loss of mechanical properties due to environmental conditions like sunlight, humidity and temperature. The incorporation of natural fibers in plastic materials is done in order to rescue the reduced properties [13]. Another critical issue in polystyrene is the poor mechanical resistance to cracks which might be improved with the addition of reinforcements.

There are many factors that can influence the performance of natural fiber reinforced composites. The strength of natural fiber reinforced composites is very low compared to glass which is often a result of the incompatibility between the hydrophilic fiber and the hydrophobic polymer matrix. Also natural fibers have water absorption tendencies from the environment due to the presence of hydroxyl groups which results in decreased strength [5]. To improve the fiber-matrix interface, coupling agents can be used. This shows an improvement in composite mechanical properties [14, 15].

In general, high fiber content is required to achieve high performance of the composites. Therefore, the effect of fiber content on the properties of natural fiber reinforced composites is particularly significant. It is often observed that the increase in fiber loading leads to an increase in tensile properties [6]. Suitable processing techniques and parameters are also required in order to yield the optimum composite products with desired properties and characteristics.

The tensile properties of composites are markedly improved by adding fibers to a polymer matrix since fibers have much higher strength and stiffness values than those of the matrices. In a study in 1996 it has been shown that strength of short fiber reinforced composite increases rapidly with the increase of the mean fiber length (in the vicinity of the critical fiber length, L_c) and approaches a plateau level as the mean fiber length increases for the cases of large mean fiber lengths ($>5L_c$) [7]. In 2012 Raghavendra et al studied that the tensile properties of banana fiber reinforced epoxy composite showed an increasing trend as the fiber length was increased but the elongation at break of the composite was not affected significantly by the fiber length. The optimum of fiber length in epoxy resin to obtain the highest tensile strength was found at 4 mm in fiber length [8]. Sankar et al in 2014 worked with *Sansevieria trifasciata* fiber reinforced polyster resin composites and found out that the tensile strength showed an increasing trend as the fiber length was increased but the elongation at break of the composite was not affected significantly by the fiber length. The optimum of fiber length in polyester resin to obtain the highest tensile strength was found at 10 mm in fiber length [9]. In 2014 Offora et al used some animal materials such as feather, hide and hoof as natural fillers for polystyrene matrix composite and found significant improvement in mechanical properties that are advantageous to polystyrene [16].

The present study deals with the development of jute fiber reinforced polystyrene composite with the hand lay-up method. The fiber lengths of the fabricated composites were varied. The effect of fiber lengths on the tensile properties was studied and the fracture modes for different composites were analyzed.

2. Materials and Experimental Procedure

Materials

The main matrix material in this experiment was commercial Polystyrene (PS) resin collected from local market of Dhaka. The jute fiber used was also collected locally which was produced and processed in Rangpur. Lastly hardener material was collected from local market.

Experimental Procedure

The jute fibers were washed with clean water to remove any kind of dirt, silt, etc. Then they were naturally dried followed by oven drying at 80° C for 6 hours. Natural fibers were cut into lengths 1mm, 10mm and 20mm respectively.

For the hand lay-up method of composite fabrication, a mold of 160mm×160mm was prepared. Appropriate amount of Polystyrene resin needed for each casting was measured and then it was vacuum treated to remove dissolved gasses for 15 minutes. After that, 5% wt. of jute fibers of desired fiber length was mixed with the composite. The jute fibers were preheated to remove any undesirable moisture. Then it was again vacuum-treated for 15 minutes followed by the addition of 1% hardener and mixing. The mix was quickly poured in the mold followed by proper spreading. A roller was used for further spreading and also for smoothing of the top surface. It was kept like this for 1 day to harden and transform into desired composite. This procedure was used to fabricate composites using fiber lengths of 1mm, 10mm and 20mm respectively. The pure polystyrene sample was also fabricated in this method.

From the fabricated composites, tensile specimens were prepared according to standard specification. Tensile tests were performed using a Universal Testing Machine of model INSTRON 3369 and at a cross-head speed of 2mm/min. Tests were conducted according to ASTM D 638-01 and for each test and type of composite, several replicate samples were tested and the average values were reported. The fractured surfaces of the tensile specimens were visually analyzed.

3. Results and Discussion

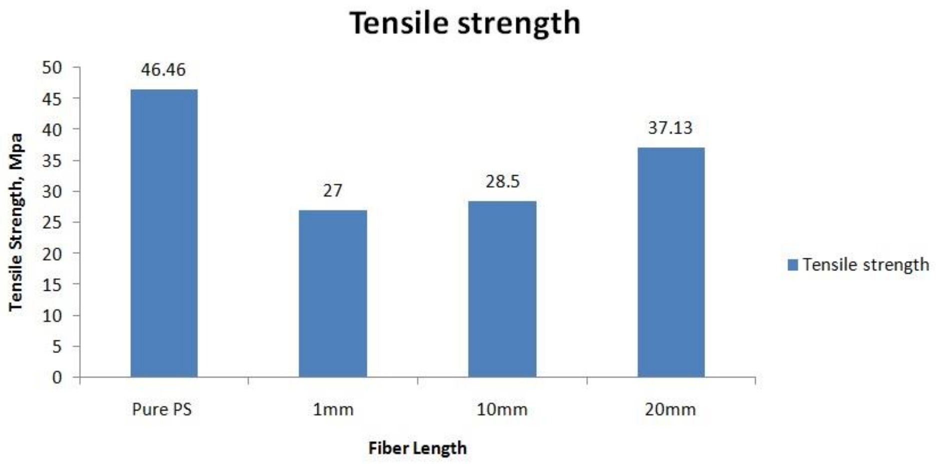

Fig. 1. Tensile Strength

The tensile strengths are compared in Fig. 1. It can be seen that the tensile strength varies with the addition of jute of different fiber lengths. The addition of 1mm fiber length of jute results in a decrease in tensile strength. However with the increase in fiber length to 10mm and 20mm respectively, the tensile strengths increased compared to 1mm jute fiber composite. The decrease in tensile strength might be due to the poor interfacial adhesion between the hydrophobic polymeric matrix and the hydrophilic fibers, which does not allow efficient stress transfer between the two phases of the material [5]. Generally, the filler fibers tie polymer chain bundles together by filling interstitial voids, thereby restricting molecular slippage on application of tensile force. At the same time, the filler particles assist in distributing any induced stress more equitably [10]. However in our case it can be said that the fillers do not perform accordingly which might be due to the poor adhesion between filler fibers and the matrix.

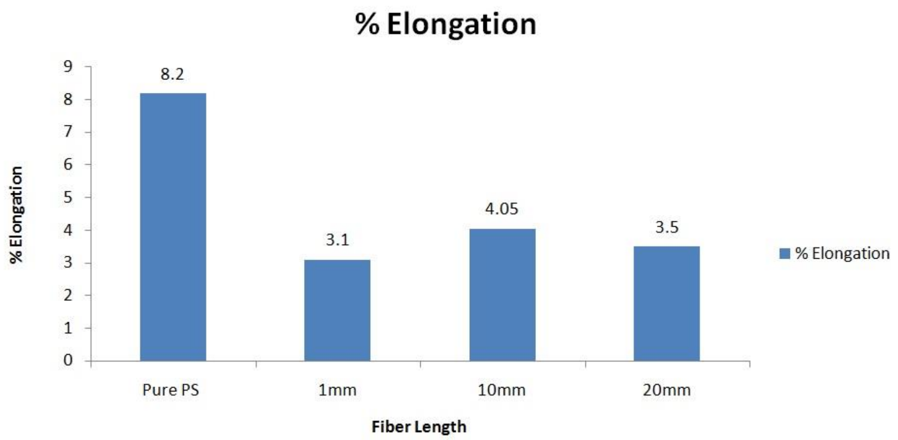

Fig. 2. % Elongation

The elongation at break follows the same trend as the tensile strength. This is shown in Fig. 2. Elongation for pure polystyrene sample is 8.2%, whereas elongation for composites decreased with the increase in fiber length. This decline in elongation on filler addition is because the fibers in the matrix restrict the plastic flow of the polymer [11]. As a result brittle like fracture is observed for the composites with very little elongation.

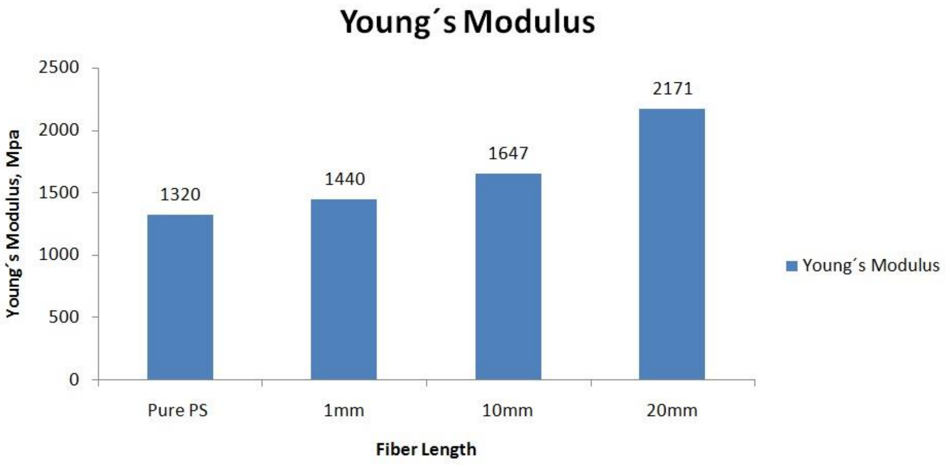

Fig. 3. Young´s Modulus

Fig.3. shows the young´s modulus of composites compared to pure polystyrene. It can be seen that the young´s modulus increases with the addition of jute fibers. There is a gradual increase in young´s modulus with the increase in fiber length. The addition of the rigid fibers into the soft PS matrix results in increased stiffness. This is because the poor interfacial bonding creates partially separated micro-spaces between the filler and matrix polymer thereby obstructing stress propagation during tensile stress loading [12]. In our case the significant increase in stiffness for 20mm jute fiber composite indicates less stress propagation and hence poorer interfacial bonding. For 1mm and 10mm jute fiber composites, the change is negligible.

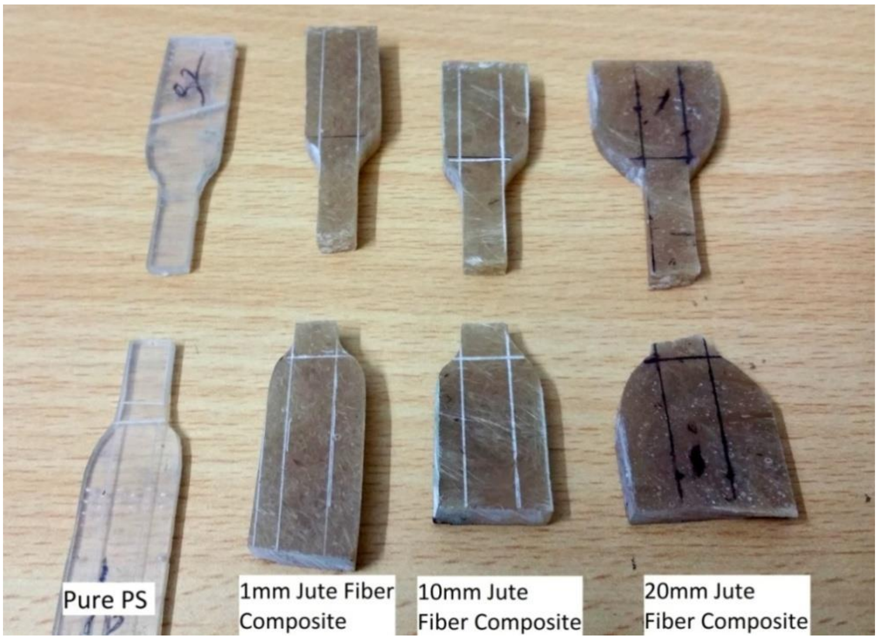

Fig. 4. Fractured tensile samples

Fig. 4 shows the tensile specimen of Pure PS and fabricated composites after failure. The fracture surface of pure PS is a characteristic of ductile failure whereas for the composites the fracture mode is brittle failure. The reason behind the brittle failure might again be explained by the poor adhesion between the filler fibers and the matrix phase which results in poor stress transfer. The plastic flow of the matrix is restricted by the fillers. Again it can be seen that the fracture location for the composites are deviated largely from the middle of the samples. This might be due to the presents of voids, pores or blowholes in the samples causing stress concentrations which might result in brittle failure [17].

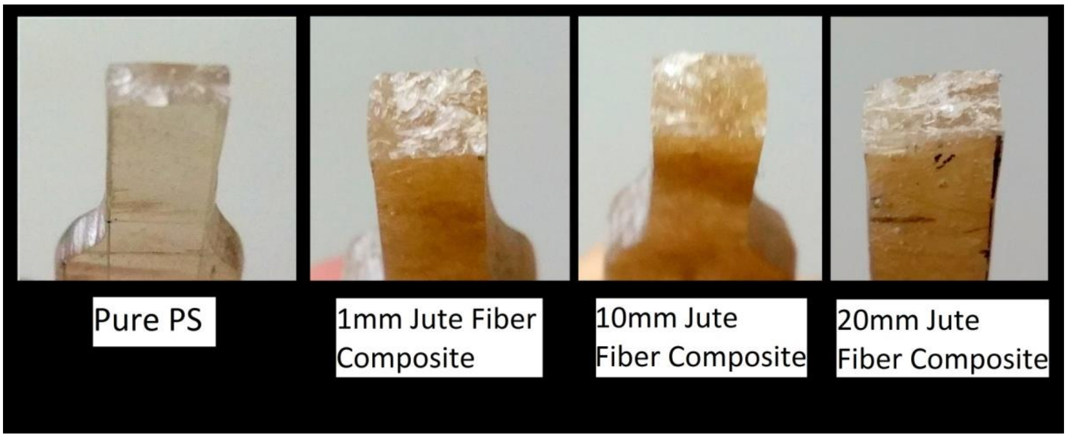

Fig. 5. Fracture surface of the tensile samples

The fracture surfaces of the tensile samples are shown in detail in Fig. 5. The surfaces show mixed characteristics. There is a mixture of rough areas and some smooth areas in the surface. This indicates that the matrix can plastically deform until the fillers restrict the deformation since there is no proper stress transfer due to lack of proper adhesion. Also the smooth areas in the surfaces indicate brittle failure which might be due to the presence of voids, pores, blowholes, etc. [17, 18].

4. Conclusion

The use of jute fibers of different lengths as reinforcement for polystyrene composite has significant effects on the tensile properties. The addition of jute fibers resulted in the decrease of tensile strength and elongation of the composites compared to pure PS. This is due to the poor adhesion between the hydrophilic jute fiber fillers and hydrophobic polystyrene matrix resulting in inferior stress transfer between the fiber and matrix. Another reason might be the presence of interstitial voids and pores which were not filled properly by the jute fibers and hence resulted in the brittle fracture of the composites. The poor stress propagation resulted in higher stiffness in the composites which is evident from the experiment.

The poor mechanical adhesion between filler and matrix can be improved by the use of suitable coupling agent. Further research is suggested to find a suitable coupling agent for jute fiber-polystyrene composites. Also the voids, pores and blowholes in the fabricated composites can be overcome by suitable vacuum molding processes.

5. References

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