Characterization of the Impact Properties of Jute Fiber Mats Reinforced Unsaturated Polyester Matrix Composites

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Jute fiber mats-reinforced unsaturated polyester matrix composites having different fiber weight contents (11, 22, 2 wt%) were fabricated by modifying the hand lay-up technique with resin pre-impregnation into the jute mats in a vacuum. This modification showed a better impregnation of resin throughout the jute mats and lower voids contents in the composites. Two types of impact tests, swing pendulum (Izod) and drop weight (impulse), were carried out to evaluate the effect of fiber contents on the impact properties of above-mentioned composites. The impact properties of these composites were compared with those of neat unsaturated polyester resin material. The fracture behavior of the composites that yielded from the impact tests was characterized by observation of the composites microstructure using scanning electron microscopy (SEM). The Izod impact strength increases as the fiber content increases and the improvement in the impact strength of the composites compared to that of the neat resin occurs at 32 wt%. Moreover, the fracture surface has demonstrated single matrix crack with complete fiber pull-out at a fiber content of 11 wt%, while single matrix crack with partially fiber pull-out mechanism was confirmed at fiber contents of 22 wt% and 32 wt%. The fiber contents has a positively large effect on the impulse total impact energy of the composites, e.g. the total energy increases with fiber contents of 11 and 22 wt% to about three times, whereas the total energy increases at 32 wt% to about four times compared to total energy of neat resin. Multiple matrix cracking and fiber pull-out mechanisms were revealed from the impulse impact test of the composites. Finally, this study showed that both izod and impulse impact properties can be improved by adding 32 wt% of jute fiber mats as reinforcements to unsaturated polyester matrix composites.

1 INTRODUCTION

Strict environmental regulations and increased interest in the preservation of natural resources have forced the composite industry to find alternative reinforcement and resin systems that are environmentally friendly to produce “eco-friendly” composites. Composites reinforced with natural fibers have been subject of intense study because of the advantages that these fibers provide over the conventional fiber reinforcements such as low cost, renewability, biodegradability, low specific gravity, abundance, and high specific strength [1-5]. So the development of jute fiber composites has been a subject of interest for the past few years. However, certain drawbacks such as incompatibility with the hydrophobic polymer matrices, the tendency to form aggregates during processing, and poor resistance to moisture absorption greatly reduce the mechanical properties of the composites.

Generally plant or vegetable natural fibers are used for the preparation of reinforced plastic materials. The utilization of light weight, low cost, and recyclability of natural fibers offer the potential to replace a large segment of the glass and mineral fillers in numerous automotive interior and exterior parts [6-9] and extensive applications in building and civil engineering [10].

Amongst the natural fiber, jute constitutes large area of investigation. Several authors have studied the mechanical properties of unidirectional jute composites [11,12], and some authors have studied the mechanical properties of short jute fiber composites manufactured by injection molding technique [13,14] and by continuous extrusion compounding [15]. Some authors have studied the mechanical properties of hybrid composites of glass/ jute fiber reinforced unsaturated matrix composites manufactured by hand lay-up technique [16].

It is known that the used jute bags will be waste at the end of their longevity, and during the production of the jute cloth in jute cloth industry, short jute slivers are remained. Used jute bags are minced and are mingled with short jute slivers, then the blend is compressed to form jute mats. So, this work aims to recycle the used jute and reuse of the jute slivers by using jute mats for the fabrication of jute fiber mat-reinforced unsaturated polyester matrix composites using a modified hand lay-up technique, and to study the effect of fiber weight contents on the impact properties of these composites.

2 EXPERIMENTAL

2.1 Preparation of the Composites Jute fiber mats consisting of 50% jute slivers and 50% recycled jute were prepared by Yano Co.LTD, Japan. Unsaturated polyester, Rigorac™ was obtained from Showa Denko K.K., Japan and the curing agent is Methyl ethyl ketone peroxide (PERMEK® N) obtained from NOF Corporation, Japan.

Jute fiber mats-reinforced unsaturated polyester composites have been fabricated using a modified vacuum-assisted hand lay-up technique. In this method, jute mats were dried for 6
hours at 100°C and were completely submerged in unsaturated polyester resin, after that the jute mats were degassed in a vacuum for 20 minutes to remove the entrapped air bubbles. The surface air bubbles were removed from the jute mat through the hand-lay-up technique using squeegees or rollers. Then the jute mats were compressed under a pressure of about 15 kg/cm² at room temperature with the presence of a 6 mm spacer to keep the same thickness for the composites for different fiber contents. The composite was cured at room temperature for 24 hrs followed by post curing in at 100°C for 2 hrs. Sheets were prepared with different fiber contents (11, 22, 32 wt%) and the specimens of required dimensions were cut from the sheets and used for testing.

2.2 Mechanical Characterization Izod impact test on unnotched specimens with dimensions 62×12.7×6 mm was done according to ASTM D 256-05 using an IS.5J digital pendulum impact tester, TOYOSEIKI, Japan. Impulse impact test was done with sample dimension 102×102 mm using instron dynatup 9250 HV. The fracture behavior of the composites of the different mechanical tests was studied using a JEOL-5200 scanning electron microscope (SEM).

3 RESULTS AND DISCUSSIONS

The impact strength of the composites depends mainly on two factors, the toughening properties of the fibers, and the interface properties between the fibers and the matrix and the more energy absorbed by the material the more toughness the material will be. The impact strength is highly affected by the interface strength between the fibers and the matrix, and it is known that very strong interface between the fibers and the matrix has the negative effect on the impact strength [17, 18]. The effect of the fiber content on izod impact strength is shown in Fig.1, it can be observed that as the fiber content increases the impact strength increases. The impact strength was decreased by 51% compared to the value of the neat resin at 11 wt% fiber content, because the fiber content is very low and so the interface between the fiber and the matrix is very weak as shown in Fig.2(a). In this figure, most of the fibers are completely pulled out from the matrix indicating the very weak interface between the fiber and the matrix, and the fracture surface is mainly smooth and level indicating that the fracture is brittle and mainly occurred through the brittle matrix and so the toughness is very low.

As the fiber content increases to 22 wt%, the value of the impact strength was improved and is nearly equal to that of the neat resin, so the fiber content is not sufficient to improve the impact strength of the composites. As the fiber content increases to 32 wt%, the impact strength was improved by 20% more than that of the neat resin. The nature of the natural fiber is porous and can be considered as a composite of hollow cellulose fibrils held together by a lignin and hemicelluloses, this nature displays absorbing mechanism for the impact energy. Single matrix crack with partially fiber pull-out mechanism was confirmed at fiber contents of 22 wt% and 32 wt% with uneven fracture surface as shown in Fig.2(b,c) respectively. By increasing the fiber content to 32 wt%, the fracture surface became more uneven and bumpy indicating that the energy was increased and so the composites have higher toughness to withstand the sudden loads compared to that of the neat resin.
However, the addition of the jute fiber to the unsaturated polyester resin has a positively large effect on the impulse total impact energy. Load-deflection and energy-deflection curves of the composites for different fiber contents and neat resin are indicated in Fig.3. The total impulse impact energy is the area under the load-displacement curve, which starts brittle and changed to ductile and failure at the end.

Fig.3 Load-displacement and Energy-displacement curves of impulse impact test of the composites for (a) neat resin (b) 11 wt%, (c) 22 wt%, (d) 32 wt%, and

Fig.4 SEM micrographs of impulse impact fracture surface of the composites (a) 11wt% (b) 22 wt% and (c) 32 wt%.

Fig.5 Effect of fiber weight content on total impulse impact energy.
It can be observed that the neat resin is brittle material with very little ductility and so it has low value of total energy as shown in Fig.3(a). By the addition of the fiber, the load-displacement curve for different fiber contents is corrugated for the three regions as shown in Fig.3(b, c, d). These figures show that the area of plastic region of the composites of different fiber contents is larger than that of the neat resin, so this will lead to improvement of the impact energy and thus the toughness of the composites compared to that of neat resin. This was also reflected from the fracture surface of the composites when examined under SEM as shown in Fig.4(a, b, c). Multiple matrix cracking and fiber pull-out mechanisms were revealed for different fiber contents and the fracture surface is uneven and bumpy for different fiber contents indicating that the energy was increased and so the composites have higher toughness to withstand the sudden loads compared to that of the neat resin.

As a result of that, the addition of the jute fiber to the unsaturated polyester resin enhanced significantly the impulse total impact energy of the jute composites as shown in Fig.5. This figure indicates the effect of fiber contents on the impulse total impact energy, the total energy was increased with the addition of 11 wt % and 22 wt % fiber content to about three times, while at 32 wt % fiber content the total energy was increased to about four times compared to the value of the neat resin.

Finally, it can be concluded from this study that both izod and impulse impact properties can be improved by adding 32 wt% of jute fiber mats as reinforcements to unsaturated polyester matrix composites.

4 CONCLUSIONS

Jute fiber mats-reinforced unsaturated polyester matrix composites having different fiber weight contents (11, 22, 32 wt%) were fabricated by a modified hand lay-up technique. Izod and impulse impact tests were carried out to evaluate the effect of fiber contents on the impact properties of these composites. The Izod impact strength increases as the fiber content increases and the improvement in the impact strength of the composites compared to that of the neat resin occurs at 32 wt%. Moreover, the fracture surface has demonstrated single matrix crack with complete fiber pull-out at a fiber content of 11 wt%, while single matrix crack with partially fiber pull-out mechanism was confirmed at fiber contents of 22 wt% and 32 wt%. The total energy increases to about three times at 11 and 22 wt% fiber contents, whereas the total energy increases to about four times at 32 wt% fiber content compared to total energy of neat resin. The fracture surface indicated that multiple matrix cracking and fiber pull-out mechanisms were revealed from the impulse impact test of the composites. This study showed that the effect of the jute fiber on the improvement of the impulse total impact energy is much better than that of izod impact strength and both izod and impulse impact properties can be improved by adding 32 wt% of jute fiber mats as reinforcements to unsaturated polyester matrix composites.

REFERENCES