IMPACT PROPERTIES OF JUTE AND JUTE HYBRID REINFORCED COMPOSITES

Ying YU[1]*, Yuqiu YANG[1], H. Hamada[1]
[1] Division of Advanced Fibro-Science, Kyoto Institute of Technology, Kyoto, Japan,
* Corresponding author (**yuying_yoyo@hotmail.com**)

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The use of natural fiber reinforced composites has continuously increased during recent years due to their low density, low cost and environmental friendliness. At current study, a preliminary investigation on the impact properties and morphologies of unsaturated polyester reinforced by jute woven fabric from the used coffee bags with different moisture contents were carried out. Additionally, the effects of the hybridization with glass woven fabric laminated structures were also investigated.

Jute/Jute laminated composite, Jute/Glass/Jute and Jute/Jute/Glass laminated hybrid composites had been fabricated by hand lay up method and compared the impact properties by dropped and Izod impact tests. In particularly, the influences of moisture content and different structures of the jute and glass hybrid composites on the impact properties were discussed.

Results showed the strength and elongation of the jute yarn decreased with the decrease of the moisture content and affected the mechanical properties of composites consequently. For the hybrid composites, the mechanical properties were affected by the structure dominantly, in details, for natural dried hybrid composites, the Jute/Jute/Glass hybrid composite achieved about 66.7% higher Izod impact energy than that of Jute/Glass/Jute hybrid composites. In particularly, for the dropped impact tests, the jute layer which directly stuck up by the tup (Jute/Jute/Glass) was 46% higher than that the composites with the glass cloth layer exposed to impact (Glass/Jute/Jute) and 68% higher than the Jute/Glass/Jute hybrid composites.

1. Introduction

Since the 1980s, natural fiber reinforced polymer composites have been investigated extensively. This has led to the application of various natural fibers, like jute, flax, hemp, sisal, wood and fibers likewise in many polymer reinforced composites in a wide range of applications. Natural fibers as a substitute for traditional synthetic fibers such as glass fiber in composite components have gained renewed interest during recent years due to their low cost, renewability, biodegradability, high specific strength and also, their abundance. Meanwhile, carbon dioxide neutrality of natural fibers is particularly attractive. Burning of substances derived from fossil products releases enormous amounts of carbon dioxide into the atmosphere. This phenomenon is believed to be the root cause of the greenhouse effect and by extension the world's climatic changes. Recently, plenty of the attempts have been made to use natural fiber composites in place of glass fiber mostly in non-structural applications. Demands for natural fiber reinforced plastics is forecast to has risen fastest of all composites materials with a growth rate of 25% annually in American. However, unlike man-made fibers, natural fiber is hydrophilic in natural and owns good moisture absorptions which usually tend to affect the bonding between fiber and matrix since moisture or other mechanicals will be able to diffuse into the material and thereby cause the structure to leak or even trigger an earlier failure [1-6].

On the other hand, for glass fiber, although glass fibers are the most widely reinforcements used in the fiber reinforced plastic fields for their high strength, stiffness, corrosion resistance and low cost. However, advantages of the glass fiber are significantly reduced because of its susceptibility to the impact damage [9]. With the purpose of improving the impact property of glass fiber reinforced composites, several approaches have been taken to improve the penetration resistance and damage tolerance of glass fiber reinforced composites. One of the possible ways appears to be very important is the fiber hybridization by combining two or more different types of fibers in a common matrix to get a range of properties that can not be obtained with a single kind of reinforcement. Therefore, from the foregoing, it is clearly to understand that the production of glass/plant fiber hybrid laminates has been explored during recent years, trying to obtain materials with sufficient impact properties and other better mechanical properties, which also maintains a reduced cost and a substantial environmental gain [10-11].

At current study, a preliminary investigation on the impact properties and morphologies of unsaturated polyester reinforced by jute woven fabric from the used coffee bags with different moisture contents were carried out. Additionally, the effects of the laminated structures of hybrid with glass woven fabric were also investigated based on the dropped impact test and Izod impact test.

2. Experimental

2.1. Materials

Unsaturated polyester (Showa High Polymer Co., Ltd., Japan), jute cloth (from the waste coffee bags collected from Coffee Making Company Japan) and glass cloth (Nitto Glasstex

Co., Ltd., Japan) were used to fabricate the composite. Polymer was mixed with the hardener MEKPO (PERMEK N; NOF Corporation) in a ratio of 100:0.7.

2.2. Tensile test on jute yarns

60 jute yarns were taken from the several pieces of jute clothes randomly and underwent the different dry conditions to determine the effect of moisture content on the jute yarn itself. In details, 20 jute yarns were dried naturally in the room and the rest were dried in the oven at 100 ℃ for 4 hours. Firstly, the tensile tests of 20 jute yarns with normal moisture content were carried out at 10 mm/min on an Instron Universal Testing Machine (Type 4466) one by one. For the oven dried ones, half of them i.e. 20 jute yarns were taken from the oven and carried out tensile test immediately. In order to investigate whether the oven dried fibers suffered damage during the heat drying process, another 20 lines of the jute yarns after oven dried were put in experiment room for about 24h to let the jute yarns reabsorb the moisture (it is noticeable that the temperature and humidity of the experiment room was 20 ℃ and 50HR%), the tensile strength on reabsorbed moisture jute yarns had also been evaluated.

2.3. Fabrication of composites

The composite were fabricated by hand lay up molding method. Firstly, jute cloth was washed by water and dry naturally in room temperature to remove the smudge (Room: 50%RH,20℃). Prior to the hand lay up process, one was deal with further dry conditions i.e. 100℃ (4 hours).

After that, jute fabrics were impregnated into resin and two layers laminated by hand lay-up method within 2-3 minutes to keep the water absorption ratio. The thickness of the composites was controlled from 2.6~2.9mm to get a volume fraction of jute fiber around 20%. After keeping in the room temperature 24 hours to cure the resin, they were dried at 100℃ (2 hours) for post-cure.

Additionally, hybrid composites were also made (Since compared with the jute fiber, glass fiber do not absorb the moisture greatly, therefore, only the moisture content of the jute cloth was discussed in this study). Two kinds of structures of the hybrid composites were fabricated with a laminated structure of Jute/Glass/Jute or Jute/Jute/Glass.

2.4. Dropped impact test of composites

For the composites, dropped impact test was conducted on an Instron Dynatup Machine (Type 9250HV) under the impact energy of 30J. The tup size was 12.7mm and the fixing size was 76mm. No fewer than three specimens were repeated.

2.5. Izod impact test of composites

Additionally, Izod impact test was performed on the Impact tester (Toyoseiki) pendulum 5.5 J. Test was carried in accordance with ADTM D 256-05. The size of the specimen was 10×60mm with a V- notch (depth of the notch was 2mm). No fewer than eight specimens were repeated.

2.6. Optical microscopy and scanning electron microscopy (SEM)

Post failure cross sectional observations were carried out on the selected test specimens using an optical microscope and a field emission scanning electron microscope (Hitachi, S-4200). Gold was sputtered onto the specimens for electron conductivity before SEM observation.

3. Results and discussion

3.1. Dry processing of the jute cloth and name method of composites

A relationship between weight of jute cloth and drying time is shown in Figure. 1. A drastic decrease ratio of weight was seen within 15 minutes and then the decrease of ratio of weight was very slowly, the final weight of the jute cloth was around 92.5wt% which means the moisture content of the jute cloth was about 7.5wt%. It can be found that the jute cloth attained final weight after 240 minutes of drying. In this study, two dry conditions were performed on the jute cloth before hand lay up molding to make two kinds of composites. One was 100 ℃ (4 hours), and the other one was without further dry. Therefore, the moisture contents for these two jute clothes could be known as the results of approximately 0wt% for 100 ℃ (4 hours) named as deeply dried cloth, and 7.5wt% for without further dry named as natural dried cloth, respectively. Although glass cloth didn't dry in an oven, hybrid composites were also divided into natural and deeply dried series.

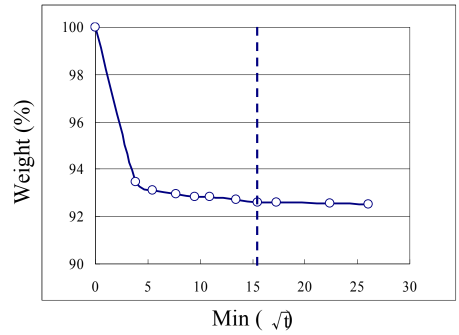


Fig.1. Relationship between weight of jute cloth and square of drying time

In this study, two different hybrid composites were fabricated. Both of them were laminated by 2 layers of jute cloth and one layer of glass cloth. However, one of them, the glass layer was laminated insert of two jute layers which named as Jute/Glass/Jute hybrid composite. The other one, the glass layer was laminated on the top of the two jute layers was named as Glass/Jute/Jute or Jute/Jute/Glass hybrid composite. In particularly, for the dropped impact test, although the structure of the Jute/Jute/Glass and Glass/Jute/Jute hybrid was the same, the hybrid which with two jute layers directly stuck up by the tup was named as Jute/Jute/Glass, while for the one with glass layer exposed to impact tup was named as Glass/Jute/Jute hybrid composite.

3.2 Effect of moisture content on jute yarns

Figure.2. displays the load-displacement curves of the jute yarns after tensile test. The breaking strength per linear density of the jute yarns with different moisture content was 0.78 ±0.12 cN/dtex (Deeply dried, 0wt%), and 0.98±0.09 cN/dtex (Natural dried, 7.5wt%) respectively. The strength of natural dried jute yarn was 25.6 % higher than that of the deeply dried one.

The breaking strength per linear density of moisture reabsorbed one was 1.03±0.11 cN/dtex which was similar to that of natural dried yarn because of 5% value difference only. It is considered that the heat during oven drying process did not damage the yarns strength significantly. The deeply dried fibers were only deprived of moisture during the heat drying process.

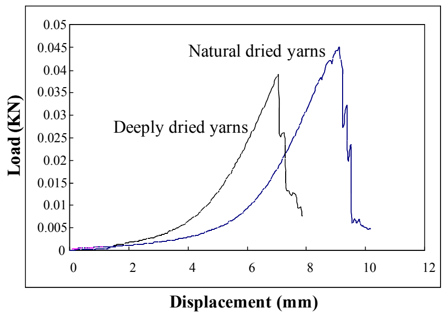


Fig.2. Load-displacement curves of jute yarns

3.3 Morphology of the composites

Optical image of the structure of the 2 jute layers composite was shown in Figure.3. It is noteworthy that there were some voids in the composites made from the jute fabric without further dry. Enlarged photographs show that the voids exist in either warp or weft fiber bundle. It is considered that moisture of jute fabric were evaporated during post cure process and led to such voids in the fiber bundles of composite. Here it should be noted that those voids did not exist in the space between fiber bundles and resin.

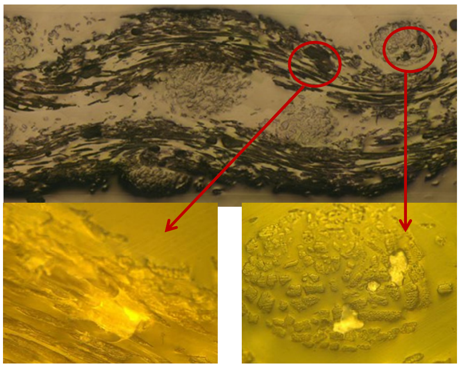


Fig.3. Reflection-Type Optical Microscope of the composites made by natural dried jute woven

3.4 Effect of moisture content on the mechanical properties of composites

Figure.4. presented the dropped impact and Izod impact properties with different moisture contents of the jute cloth reinforced composites and hybrid composites. It could be noted that for the above tests, almost the natural dried composites showed comparable high value to the deeply dried ones. It is considered that it could be due to the high breaking strength per liner density of the natural dried yarns and also the higher elongation of the natural dried layer at break compared to the deeply dried one.

Based on the cross-section observation shown in Figure.5., jute fibers were pulled out along loading direction and the glass layers were delaminated with the matrix for the natural dried composites. While for the deeply dried one, the glass layers were still tightly bended to the matrix. In particularly, for the hybrid composites, compared with the deeply dried ones, it was clearly that the natural dried ones experienced larger deformation especially for the Jute/Jute/Glass hybrid composite. It is considered to the higher elongation of the natural dried layer at break compared to the deeply dried one and lead to a better impact resistance.

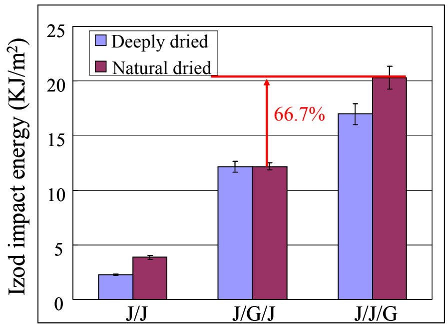
Fig.6. showed the fracture surface observations after Izod impact test, for the Jute/Jute composite, the ruptured fiber was still tightly bended to the matrix and a thin layer of the matrix was found on the loose fiber surfaces in the deeply dried composite. While for natural dried one, fiber bundle pull-out at the fractured surface was observed leaving behind large holes. Therefore, it is considered that the bonding between jute fiber/jute bundle and matrix was better for the composite with low moisture content in deeply dried composite.

3.5 Effect of different position of the glass layer on the mechanical properties of the hybrid composites

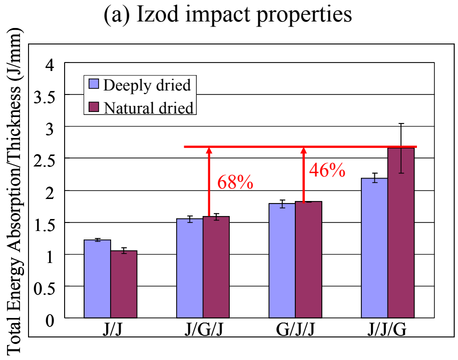
From the mechanical properties showed in Fig.4., it could be noted that the mechanical properties of the hybrid composites were affected by the structure dominantly, in details, for natural dried hybrid composites, the Jute/Jute/Glass one achieved about 66.7% higher Izod impact energy than that of Jute/Glass/Jute hybrid composites. Moreover, for the dropped impact tests, the jute layer which directly stuck up by the tup (Jute/Jute/Glass) was 46% higher than that the composites with the glass cloth layer exposed to impact (Glass/Jute/Jute) and 68% higher than the Jute/Glass/Jute composites. It suggested that in general for hand lay up molding product, the sandwich configuration can be considered a suitable way to provide a higher impact resistance. Moreover, these results also mean that the stacking sequence of composite affects the impact behavior of the hybrid composites significantly.

Based on the observations showed in Fig.5., it is noted that the Jute/Jute composites were fractured completely and leaded to a localized damage area which may the reason resulted in low impact energy of the Jute/Jute composites. While for the hybrid composites, compared with the Jute/Glass/Jute hybrid composites and Glass/Jute/Jute ones, it was clearly that the jute layer at the impact surface (Jute/Jute/Glass) experienced larger deformation, it is considered that was attributed to the higher elongation of the jute layer at break compared to the glass layer which may the reason leading to larger deformation which is considered leading to a better impact resistance consequently. In particularly, from the figures, it is also noted that the glass layer in hybrid composite is effective in extending the break area and may result in better impact resistance and damage tolerance compared to the Jute/Jute composites.

The SEM micrographs of hybrid composites have also been showed in Fig.6. From these photos, it is not easily to find the differences between Glass/Jute/Jute hybrid composite and Jute/Glass/Jute one from the fracture surface at the transverse direction. Therefore, the digital photographs showing the fracture surface of natural dried hybrid composites form longitudinal direction after Izod impact test have been displayed in Fig.7. It is easily to observe that there was obvious delamination between glass layer and matrix in the Glass/Jute/Jute hybrid composite. It is considered that might the reason resulted in the higher Izod impact energy of the Glass/Jute/Jute hybrid composite compared to the Jute/Glass/Jute one.



(a) Izod impact properties



(b) Dropped impact properties

Fig.4. Mechanical properties

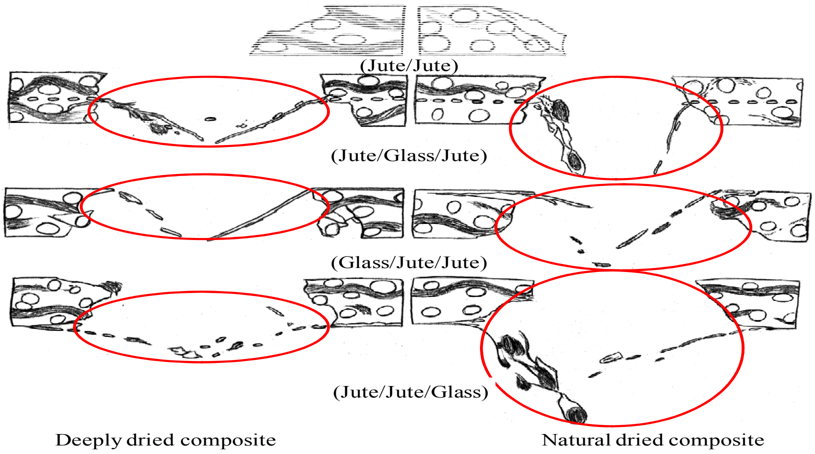


Fig.5. Schematic Representation of Reflection-Type Optical Microscope of the fracture after dropped impact test (The red circle indicated the fracture area after dropped impact test)

From the results illustrated above, it could be concluded that although deeply dried composites own comparably better interfacial properties, it seems the fiber strength and elongation were more influential on the mechanical properties of the composites.

4. Conclusion

At current study, the jute cloth from recycled coffee bags was used to fabricate ecologically friendly composites. The effect of the moisture content on the mechanical properties of the composites were discussed, additionally, the effects of the hybridization with glass woven fabric laminated structures were also investigated.

It is found that the strength of jute yarn without the moisture decreased and the elongation also decreased which then affected the mechanical property of the composites consequently. Moreover, the optical images of the fracture after dropped impact test indicated that the deeply dried composite owns a better interfacial property while for the natural dried composites experienced larger deformation which is considered due to the higher elongation of the natural dried jute layer. In the other hand, for the hybrid composites, it could be noted that the glass layer was effective to blunt the crack propagation and increase the impact resistance.

The addition of glass layer to jute layer increase the impact resistance of the composite not only due to the higher strength of the glass fiber but also, the glass layer can increase the deformation of the composite during impact. Additionally, the position of the glass layer result in variations in the impact behavior of hybrid composites. When the glass layer was at the bottom of the impacted surface, the composite exhibited highest impact energy than those glass cloths on top or middle layer

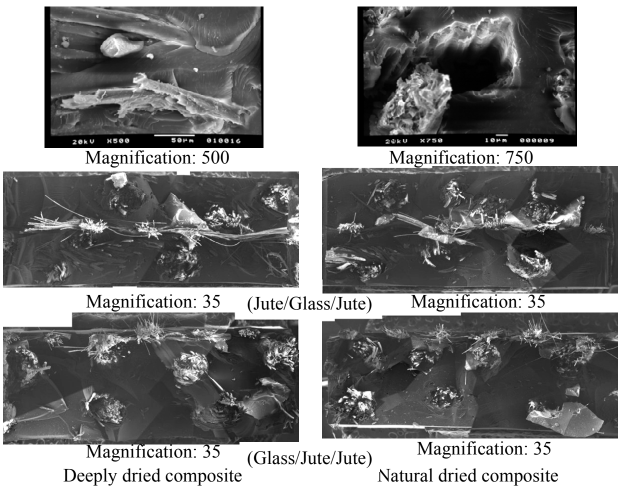


Fig.6. SEM micrographs after Izod impact test

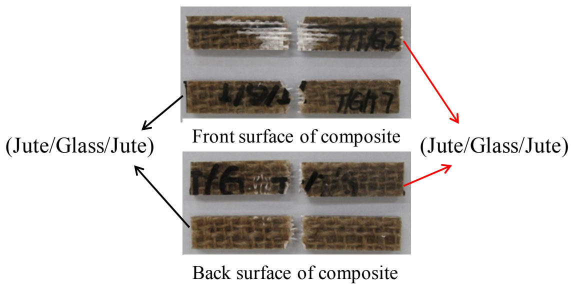


Fig.7. Photographs showing fracture surface of natural dried hybrid composites after Izod impact test

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