Effect of Processing Conditions on Mechanical Properties of PLA-Jute Composite

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1. INTRODUCTION

Recently, the biodegradable polyesters are paid attention as petroleum based polymer alternative. Polylactic acid(PLA) is a kind of linear aliphatic bio-based polymers produced from renewable resources. It has good mechanical properties, thermal plasticity, processing properties and biocompatibility and has been proposed as renewable and degradable plastic[1]. The mechanical properties of PLA can be modified by reinforcement. But, the reinforcement like glass fiber and synthetic fiber with PLA decrease the biodegradability of PLA and circumscribe its end-use applications. Natural fiber such as jute, ramie, bamboo and kenaf as a reinforcement material are paid the same attention[2,3], because of their outstanding biodegradability.

Some papers on the mercerization of jute fibers report the removal of lignin and hemicelluloses that affects the tensile characteristics of the fibers. The improvement of single fiber tensile could improve the tensile properties of composite.

Though a great deal of theoretical work has been carried out to predict mechanical properties of fiber reinforced composites, some of the models are quite sophisticated to use for composites[4]. Here, a modified form of rule of mixture and Halphin–Tsai equations are used to predict elastic modulus of jute-PLA composites as they used both volume fraction and aspect ratio of jute fibers to predict modulus of the composites. In case of rule of mixture, it is assumed that both jute fiber and PLA are very well-bonded, equally strained and jute fibers are homogeneously distributed within PLA matrix.

2. EXPERIMENTAL

2.1 Mercerization

With pretreatment, alkali treatment was conducted by treating the fiber samples with NaOH concentrations at 10 wt% for 6 hours at room temperature followed by washing the fibers in distilled water, neutralization with 2 wt% acetic acid, washing again, and drying in oven for 24 hours.

2.2 Materials and sample production

Composites containing 5, 10 and 15% jute fibers by weight were produced using a film-stacking procedure.

2.3 Measurement and observation

The surfaces and cross-section of selected tensile test specimens were examined using a scanning electron microscope (SEM). Tensile tests of single jute fibers were measured in accordance with ASTM D 3822-07.

3. RESULTS AND DISCUSSION

3.1 Microstructure

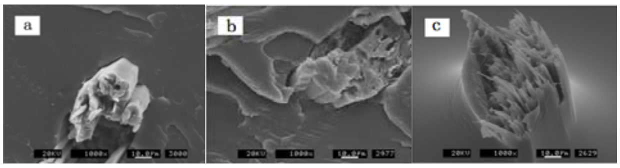

Figure 1. SEM micrographs of the fractured surface after tensile test: (a) processing temperature was 200℃, (b) processing temperature was 210℃, processing temperature was 220℃.

Fig. 1 compares SEM micrographs of composites in different processing conditions. At the interface between PLA and jute fibers cavities are clearly seen when processing temperatures were 200℃ and 210℃, indicating the poor bonding between jute fibers and PLA. Conversely, no void space is observed between PLA matrix and jute fibers phase when processing temperature was 220℃ in Fig. 1c. Where, the fiber protruding almost perpendicularly from the fracture surface appears to be in close contact with the polyester along its whole perimeter.

3.2 Mechanical properties

The results of mechanical properties of composite are shown in table1. The tensile strength and modulus of PLA/jute fibers composite increase with increase in contents of jute fibers up to 15% in 200℃, 210℃ and 220℃. It was shown that strength was decreased with temperature increasing

Table 1. Mechanical properties of samples

Process temperature	Jute contents (wt%)	Tensile strength (MPa)	Tensile modulus (MPa)
200℃	5	23.63	504.16
	10	38.16	705.58
	15	44.78	791.14
210℃	5	24.60	568.61
	10	35.68	731.32
	15	44.62	886.63
220℃	5	23.74	476.45
	10	28.73	638.80
	15	38.14	733.01

3.3 Mercerization

The comparison of experimental and theoretical values of modulus is shown in Fig. 2, where a linear increase of modulus with volume fraction of jute fibers is observed.

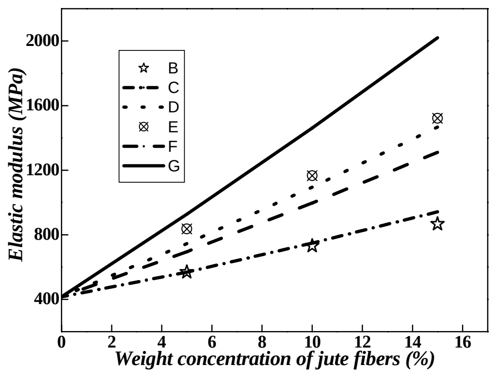

Figure 2. Comparison between experimental and theoretical values of elastic modulus of jute-PLA composites. B: measured un-mercerized fibers reinforced composite, C: calculated un-mercerized fibers reinforced composite based on the modified form of rule of mixtures, D: calculated un-mercerized fibers reinforced composite by Halpin–Tsai equations, E: measured mercerized fibers reinforced composite, F: calculated mercerized fibers reinforced composite based on the modified form of rule of mixtures, G: calculated un-mercerized fibers reinforced composite by Halpin–Tsai equations.

The comparison between experimental and Halpin–Tsai model gives an accordant trend that the modulus increase with the increasing of volume fraction of jute fibers. But the elastic modulus by measured is lower than calculated the maximum relative error of 40% and 25% as un-mercerized and mercerized, respectively. This indicates that the assumptions made to derive these equations were not closely agreeing with experimental conditions. First, the decentralization of jute is not exactly homogeneous. Jute fiber and PLA are not perfectly bonded, at the same time, there are different wetting condition at the different processing conditions. The different modulus between calculated and measured indicate it can be improved that the interface between jute fiber and PLA matrix.

In case of modified of rule of mixtures for series equation, the experimental results are closely following the predicted values within the maximum relative error of 8% and 7% as un-mercerized and mercerized, respectively. However, the relative error increases with jute fibers concentration but it is well within agreeable limits. Thus, it is suggested that modified of rule of mixtures for series equation more suitable to predict elastic modulus of jute fibers-PLA composites than Halpin–Tsai model. A linear increase of modulus with volume fraction, as shown in Fig. 2, and its value is 2.93GPa, 3.01GPa and 3.37GPa at aspect ratio is 32.6 for un-mercerized condition. Correspondingly, for mercerized condition, the value is 5.34GPa, 5.57GPa and 5.72GPa at aspect ratio is 71.6. Thus, the condition that jute fibers after mercerization closer to the assumptions demanded by Halpin–Tsai equations. This indicates that there is a good load transfer effect and an interface link between jute fibers and PLA after mercerization.

4. CONCLUSION

There is a best interface condition at 220℃. The highest tensile strength was obtained at 200 ℃ contain15% jute fibers. The highest tensile modulus of PLA/jute composite was shown at 210℃.

Mercerization can large improve the mechanical properties both of single jute fiber and jute fiber-PLA composite. The modulus of single jute fiber and jute fiber-PLA composite was increased 29% and 76%, respectively.

Modified of rule of mixtures for series equation more suitable to predict elastic modulus of jute fibers-PLA composites than Halpin–Tsai model. And the relative error is less than 8%.

5. REFERENCES

[1] S. Jacobsen, H. Z. Fritz, P Degee, *Industrial Crops and Products, j.*, 11, 265-275 (2000).
[2] J. B. Naik, S. Mishra, *Journal of Applied Polymer Science, j.*, 106, 2571-2574 (2007).
[3] S. Shibata, Y. Cao, I. Fukumoto, *Composites, Part A,j.*, 39, 640-646 (2008).
[4] C. L. Tucker, E. Liang, *Compos Sci Technol j.*, 59, 655-671 (1999).