Effects of microfibrillated cellulose addition and water absorption on mechanical properties of jute/PLA composites

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Abstract

In this study, the effects of microfibrillated cellulose (MFC) addition and water absorption on mechanical properties of jute fiber reinforced composites were investigated. Plain woven jute fiber cloth was used as reinforcement. Polylactic acid (PLA) was used as matrix. Additions of MFC are conducted to matrix or reinforcement. Specimens were fabricated by the compression molding method. Static flexural and izod impact tests of composites were conducted. As a result, the following conclusions are obtained. The addition of MFC was effective for an improvement of flexural property. But, when the amount of MFC is too much, the mechanical properties decreased. The reason is thought that the interfacial adhesion was decreased by MFC addition. In addition, the interfacial adhesion was decreased by absorbing water. The water absorption rate increased with an increase of immersion time and adding MFC. Flexural strength decreases by water absorption, but impact strength can be improved. Impact strength with emulsion PLA almost did not change after immersion.
Keywords: biodegradable resin, microfibrillated cellulose, natural fiber, water absorption, flexural, impact.

1 Introduction

Composite materials with high specific strength and high specific stiffness have attracting attentions from a wide variety of fields. However, the solution of the global warming is a major issue in the industrial society. Therefore, natural fiber reinforced plastics (NFRP) composed by natural fiber and biodegradable resin is focused as environmentally-friendly materials [1–3]. However, mechanical properties of NFRP are inferior to glass fiber reinforce plastics. The

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improvement of mechanical properties is important issue for the development of NFRP.

Therefore, MFC (Microfibrillated cellulose) of nano-sized cellulose was focused in this study. There is some reports that mechanical properties were improved by adding MFC in resin [4–8]. MFC which was derived from plant cellulose is environmentally-friendly materials and having a great deal of resources. In this study, the effectiveness of adding MFC to resin or fiber was examined. MFC was not much used as a reinforcement of composite material, because the cost of MFC is so high.

Cellulose is potentially hydrophilic because of the presence of hydroxyl group. This hydrophilicity affects mechanical properties of NFRP. In addition, increase of cellulose content in specimen by MFC addition probably influences water absorption and mechanical properties. In this study, effects of MFC addition and water absorption on mechanical properties of jute/PLA composites were investigated.

2 Specimen

2.1 Molding method

Plain woven jute fiber cloth was used as reinforcement. Polylactic acid (PLA) was used as matrix. Sheet type PLA (Unitika Ltd., Terramac SS300,) and emulsion type PLA (Miyoshi Oil and Fat Co., Ltd., PL-1000) were used as matrix. The specimens were fabricated by the compression molding method using hot press facility for 10 min at 185°C. The fiber content of specimens was approximately 40wt %.

2.2 Addition method of MFC

In this study, MFC (Daicel Fine Chem, Ltd., Celish KY-100S) was used as reinforcement of NFRP. About the method of MFC addition to resin, MFC and emulsion PLA were stirred by homogenizer. About the method of MFC to fiber, MFC and water were stirred in homogenizer first, and it was added to jute fiber cloth by a filter device, then it was dried in oven.

The addition amounts of MFC are 0.5wt% and 1.0wt% for the specimen.

3 Experimental method

3.1 Water absorption test

Before water absorption test, the specimen was dried in drying oven. Temperature and time were 50°C and 1 day respectively. Distilled water was used for water absorption test. The specimens were immersed in distilled water whose temperature is 25°C. The immersion time was 1 day. The weight of specimen was measured after wiping surfaces of the specimen. The water absorption rate was calculated by the following equation.

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$$c = \frac{m_1 - m_0}{m_0} \times 100 \quad (1)$$

where, c is water absorption rate, m_0 is a weight before immersion, m_1 is a weight after immersion. The specimens were dried at 50°C for 4 days after water absorption.

3.2 Static flexural test

The static flexural test was conducted by using universal testing machine (Shimadzu Co., Ltd., Autograph (AG-IS)). The dimensions of static flexural test specimen were referred to JIS (Japanese Industrial Standard) K 7017. The length, width and thickness of the specimens were 80mm, 10mm and 4mm respectively. The crosshead speed was 2 mm/min.

3.3 Izod impact test

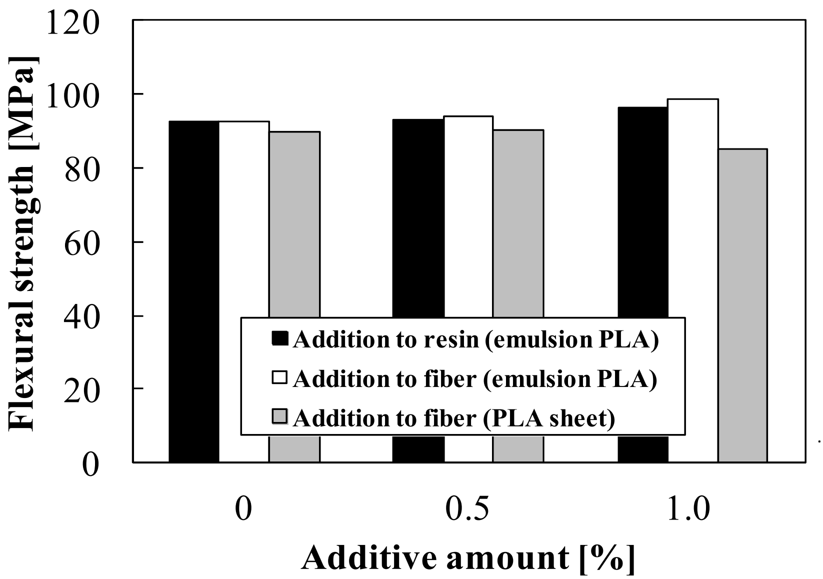
The izod impact test was conducted by using shock machine (Toyo seiki seisaku-sho, Ltd., Digital impact tester (DG-IB)). The dimensions of the specimen were referred to JIS K 7110. The length, width and thickness of the specimens were 80 mm, 10 mm and 4 mm, respectively. The notch was not applied to the specimen.
After flexural and izod impact tests, the fracture mode of composites was investigated by using optical microscope.

4 Results and discussion

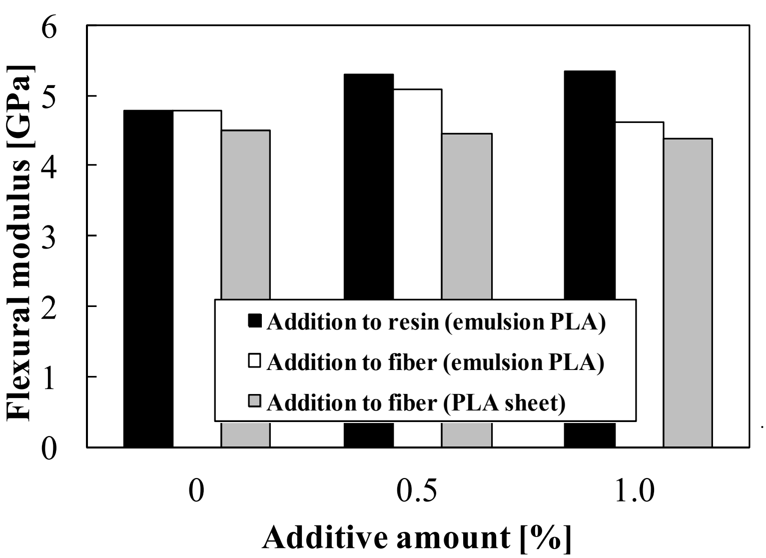
4.1 Flexural property of composite using MFC addition

Figure 1 shows the relationships between flexural property and additive amount of MFC in each molding condition. In case of emulsion PLA, the addition of MFC was effective in improving flexural property of composite. Flexural strength in 1.0wt% at addition to fiber increased 7% compared with that of virgin composite. The flexural modulus in 1.0wt% at addition to resin increased 12% compared with that of virgin composite. The flexural modulus of composite was the highest when MFC was added to resin. The reason is that MFC was suppressed for crack resistance in the resin.

In case of PLA sheet, the flexural property of the composite at MFC 1.0wt% was significantly decreased. The flexural strength and modulus decreased 7% and 11% respectively compared with that of virgin composite. The resin impregnation to fiber was insufficient in the molding method. Therefore, interfacial adhesion between fiber and PLA probably decreased by addition of MFC to fiber.



(a) Flexural strength.



(b) Flexural modulus.

Figure 1: Relationship between flexural property and additive amount of MFC.

Figure 2 shows the relationships between impact strength and additive amount in each molding condition.

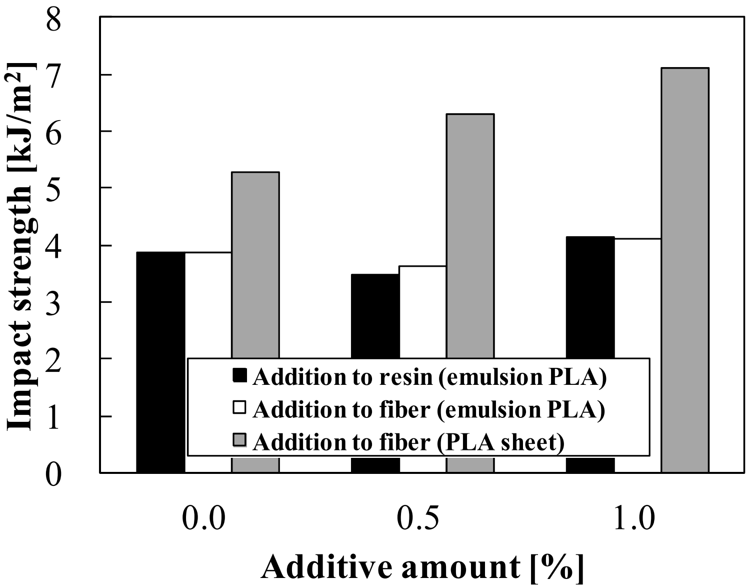


Figure 2: Relationship between impact strength and additive amount of MFC.

In case of emulsion PLA, effect of impact strength could not be seen significant difference between addition to resin and addition to fiber.

In case of PLA sheet, impact strength of composites increased with increasing addictive amount of MFC. The increasing rate is almost constant.

4.2 Flexural property and impact strength of composites after water absorption

Table 1 shows the relationship between molding method and water absorption rate. The water absorption rates increased sharply to approximately 10% in a day. In case of addition to emulsion PLA, water absorption rate is small because absorbing water was probably caused by jute fiber.

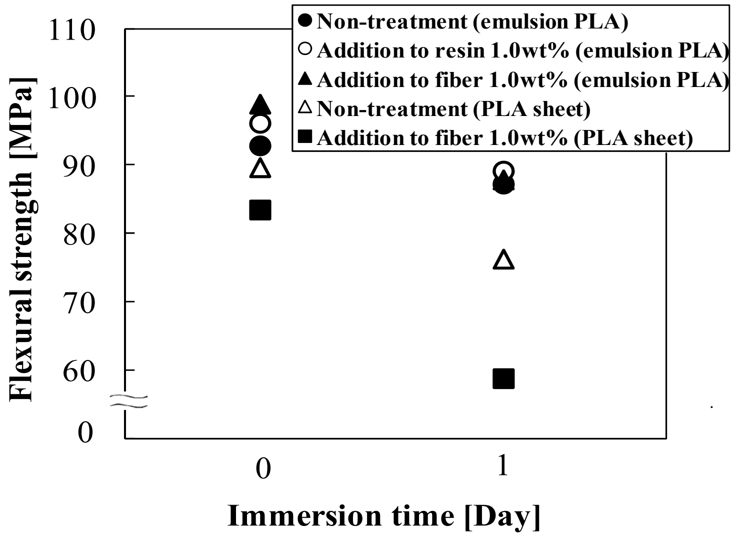
Table 1: Relationship between molding method and water absorption rate.

Molding method	0wt%	0.5wt%	1.0wt%
Addition to resin (emulsion PLA)	10.2%	10.1%	9.4%
Addition to fiber (emulsion PLA)	10.2%	11.4%	10.3%
Addition to fiber (PLA sheet)	8.5%	10.4%	14.4%

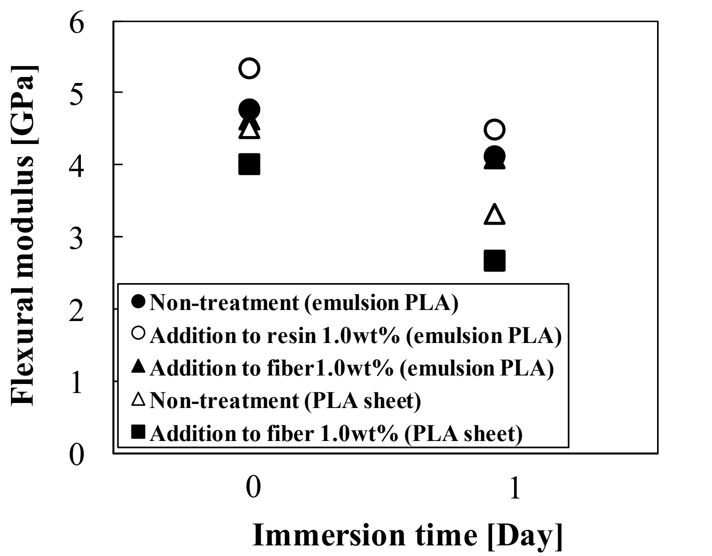
In the case of PLA sheet, impregnation of PLA to jute fiber was disturbed by increasing of additive amount of the MFC, therefore the water absorption rates increased.

Figure 3 shows the flexural property of composites after water absorption. Flexural properties were decreased by absorbing water.

Flexural property of composite using PLA sheet rapidly decreased after immersion. This result implied that flexural property of the composites using PLA sheet was affected due to interfacial adhesion.



(a) Flexural strength.



(b) Flexural modulus.

Figure 3: Flexural property of composites after immersion.

Figure 4 shows the relationship between impact strength and immersion time in each molding condition. Impact strengths of composites using emulsion PLA almost did not change after immersion. On the other hand, that of composite using PLA sheet increased. Their results implied that impact energy was acted in the direction of interfacial debonding. The combinations of water absorption and increasing additive amount have a tremendous effect on interfacial adhesion.

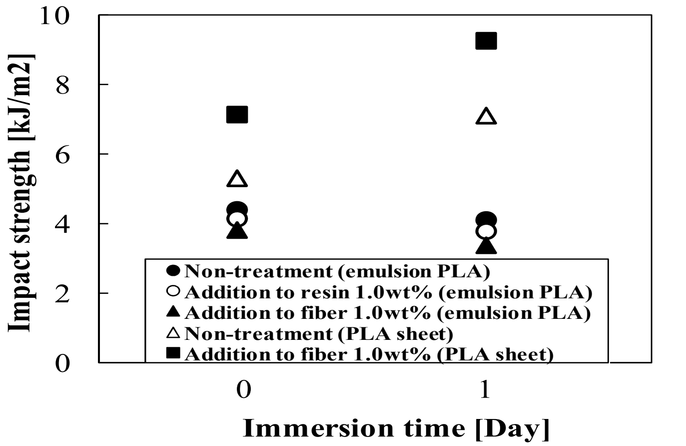
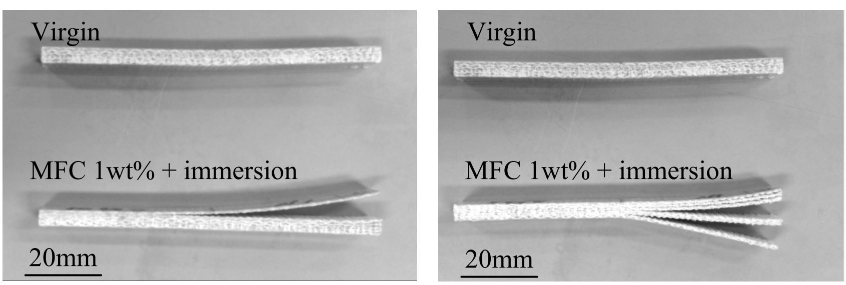


Figure 4: Relationship between impact strength and immersion time.

4.3 Fracture mode of composite after flexural and izod impact tests

Figure 5 shows the fracuture modes of composites after flexural and impact tests. Delamination of composite using PLA sheet and addition to fiber was found after immersion. This implied that delamination of the composite using PLA sheet was occurred due to water absorption at the interface. Therefore, interfacal adhesion of composite using PLA sheet and fiber was probably decreased.



(a) Static flexural test. (b) Izod impact test.

Figure 5: Fracture mode of composite using PLA sheet.

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5 Conclusions

In this study, the effects of microfibrillated cellulose addition and water absorption on mechanical properties of jute/PLA composites were investigated. Following conclusions were obtained.

(1) Type of PLA affected on difference of impregnation resin to jute fiber. Addition of MFC improved flexural properties when impregnation of resin was sufficient. Excess addition of the MFC causes an interfacial adhesive decline due to impregnation of resin.

(2) When the amount of MFC addition is small, water absorption rate of composite has not a big influence. The water absorption has a big influence on mechanical properties in 1day.

(3) Impact strengths of composites using emulsion PLA almost did not change after immersion but that of composites using PLA sheet increased.

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