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Fatigue property of natural fiber after alkali treatment

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Abstract

Generally, interfacial adhesion between natural fiber and biodegradable resin can be improved by alkali treatment. The effect of alkali concentration of treatment on fatigue property of natural fiber as reinforcement should be examined to assure the use of structural material using green composite. The purpose of this study is to examine fatigue properties of 1% and 15% alkali treated natural fiber. Jute fiber was used as specimen. Alkali treatments were conducted in distilled water with NaOH 1% and 15%. X-ray diffraction measurement of alkali treated jute fiber was conducted. Fatigue tests and damage observations of non and alkali treated jute fibers were conducted. As a condition of fatigue test, the stress ratio was 0.1 and the frequency was 10Hz. As a result, following conclusions were obtained. Peaks of diffraction intensities of 1% and 15% alkali treated jute fiber appeared at 22.8° and 22°, respectively. This phenomenon indicated that cellulose in constitution materials of 15% alkali treated jute fiber changed cellulose I to cellulose II. Fatigue strengths of non, 1% and 15% alkali treated jute fiber decreased with an increase of number of cycle. Fatigue strengths at 10^6 cycles of non, 1% and 15% alkali treated jute fibers were 280MPa, 320MPa and 181MPa, respectively. The number of crack in surface of jute fiber at 10^3 cycles increased with an increase of alkali concentration of treatment. Therefore, fatigue property and damage of jute fiber was affected by alkali concentration of treatment.
Keywords: natural fiber, fatigue property, alkali treatment, alkali concentration, crack, cellulose.

1 Introduction

Recently, green composite using biodegradable resin and natural fiber is used as interior component of automotive SAI [1]. Mechanical properties [2–5] and molding method [6–8] of the green composite have been studied. Specific stiffness of natural fiber as reinforcement of green composite is similar to that of glass fiber [9]. Ren *et al.* [10] reported on tensile property of green composite using unidirectional sliver for wider application. The Young's modulus of unidirectional sliver reinforced green composite was similar to that of glass fiber reinforced plastics. Fatigue property of the green composite should be investigated to assure the use of structural material using green composite.

Katogi *et al.* [11] reported that fatigue property of unidirectional jute spun yarn reinforced green composite resembled that of glass fiber reinforced plastics. However, interfacial adhesion natural fiber and biodegradable resin is low. So, mechanical properties of green composites were improved by alkali treatment [12, 13]. In addition, there are some reports about tensile property of alkali treated natural fiber [14–17]. Reddy *et al.* [16] reported that tensile strength of alkali treated borassus fruit fine fiber increased compared with that of virgin material. Fatigue property of natural fiber as reinforcement should be investigated for a long term safety. Silva *et al.* [18] reported that sisal fiber had superior fatigue property. Katogi *et al.* [19] reported on fatigue property of jute fiber. Fatigue strength at 10^6 cycles of jute fiber was 50% of tensile strength. However, there is few report about effect of alkali concentration of treatment on fatigue property of jute fiber.

In this study, fatigue properties of 1% and 15% alkali treated jute fibers was investigated.

2 Specimen

2.1 Material

The jute fiber was used as specimen. The jute fiber consists of elementally fibers. Structure of elementary fiber in jute fiber consists of lumen, primary wall, secondary walls and intercellular layer. Main constituent materials of the elementary fiber are cellulose (63%), lignin (14%) and hemicellulose (22%) [15]. Specific gravity of jute fiber was 1.3 [9].

2.2 Alkali treatment

Jute fiber was treated by alkali treatment. The alkali treatment was conducted in distilled water with 1% and 15% concentrations at room temperature for 2 hours. The alkali treated jute fiber was dried at 50°C for 24 hours.

3 Testing method

3.1 Measurement of cross sectional area

Diameters of non and alkali treated jute fiber at seven points from 45° and 135° were measured by optical microscope (SZX7, OLYMPUS Co., Ltd.). After that, cross sectional areas of non and alkali treated jute fiber were estimated by elliptical approximation using their diameters at 45° and 135°. The number of specimen was ten.

3.2 X-ray diffraction measurement

X-ray diffraction measurements of non, 1% and 15% alkali treated jute fibers were conducted by X-ray diffractometer (RINT-Ultima III, Rigaku Co., Ltd.). Powders of non, 1% and 15% alkali treated jute fibers were used as specimen.

3.3 Fatigue test

Fatigue tests of non and alkali treated jute fiber were conducted by fatigue testing machine (FRDS50, Asahi Seisakusyo Co., Ltd.). The maximum stress was from 50% to 80% of tensile strength. The stress ratio was 0.1 and the frequency was 10Hz. The maximum number of cycle was 10^6 cycles. The gauge length of specimen was 10mm. Environmental temperature was room temperature.

3.4 Damage observation

Damage observations of non and alkali treated jute fiber were conducted by scanning electron microscope (VE-7800, KEYENCE Co., Ltd.). The maximum stress was 60% of tensile strength. The stress ratio was 0.1 and the frequency was 10Hz. The maximum number of cycle was 10^3 cycles. Crack in surface of jute fiber at 10^3 cycles was measured. The gauge length of specimen was 3mm. The number of specimen was two. Environmental temperature was room temperature.

4 Results and discussion

4.1 Measurement of cross sectional area

Figure 1 shows cross sectional areas of jute fibers before and after alkali treatment. Cross sectional area of jute fiber decreased with an increase of alkali concentration of treatment. Hemicellulose in constituent materials of jute fiber mainly dissolves in alkali solution at low concentration [20]. Hemicellulose and lignin in constituent materials of jute fiber mainly dissolve in alkali solution at high concentration [14]. So, cross sectional area of jute fiber was probably decreased due to dissolution of hemicellulose and lignin by concentration of alkali solution.

4.2 X-ray diffraction measurement

Figure 2 shows X-ray diffraction patterns of jute fibers before and after alkali treatment. Peaks of diffraction intensities of non and 1% alkali treated jute fiber appeared 22.8°. The peak of diffraction intensity of 15% alkali treated jute fiber appeared 22°. Generally, peaks of diffraction intensities of cellulose I and cellulose II appear around 23° and 22°, respectively [20]. Therefore, main constituent materials of 1% and 15% alkali treated jute fibers consisted of cellulose I and cellulose II, respectively.

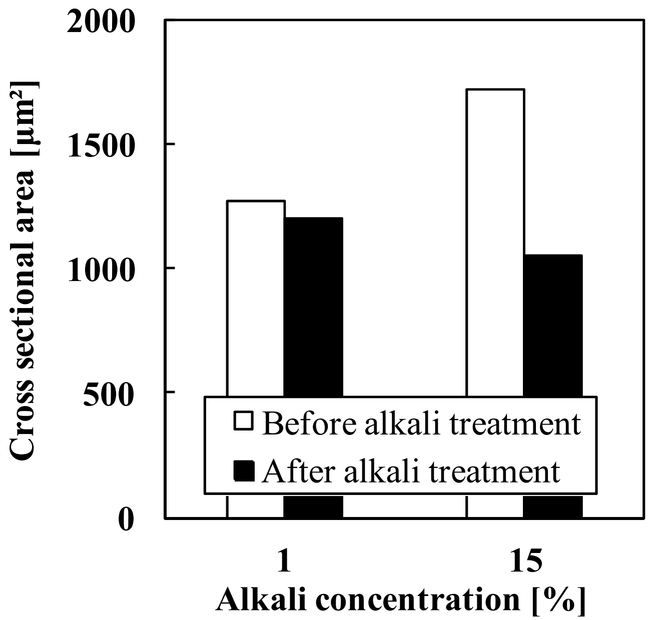


Figure 1: Cross sectional areas of jute fibers before and after alkali treatment.

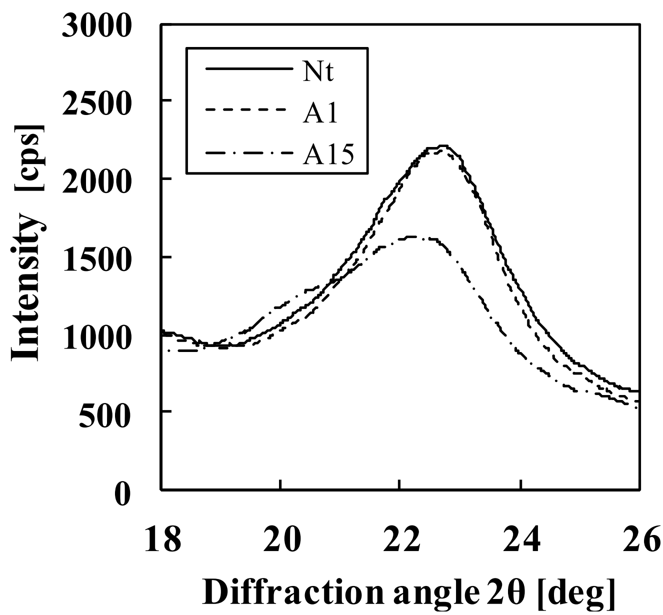


Figure 2: X-ray diffraction patterns of jute fiber before and after alkali treatment.

4.3 Fatigue test

Figure 3 shows S–N diagrams of non and alkali treated jute fibers. Fatigue strengths of non and alkali treated jute fibers decreased with an increase of number of cycles. Fatigue strength of 1% alkali treated jute fiber increased compared with that of non and 15% alkali treated jute fiber. But, fatigue strength of 15% alkali treated jute fiber decreased compared with that of non and 1% alkali treated jute fiber. Fatigue strengths at 10^6 cycles of non, 1% and 15% alkali treated jute fibers were 260MPa, 320MPa and 181MPa, respectively. In case of 1% concentration of treatment, cellulose rate in jute fiber may be increased by decrease of cross sectional area. Therefore, fatigue property of jute fiber was improved by 1% concentration of treatment. But, fatigue property of 15% alkali treated jute fiber decreased compared with that of non and 1% alkali treated jute fiber because cellulose I in constituent materials of 15% alkali treated jute fiber changed to cellulose II.

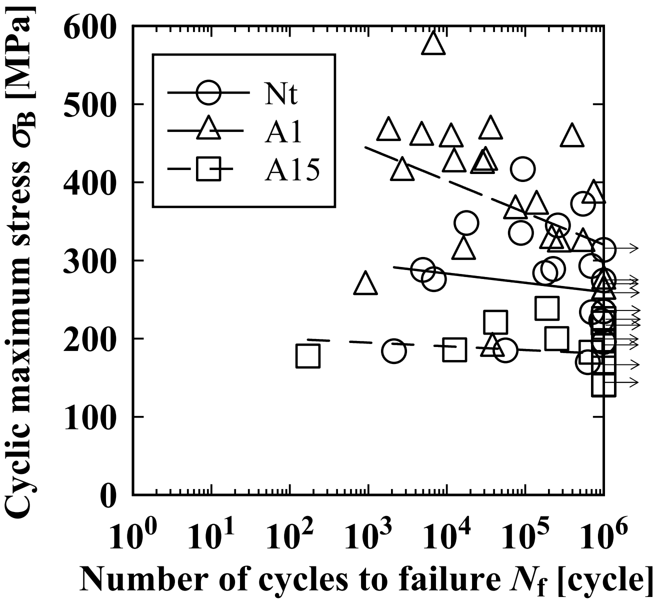
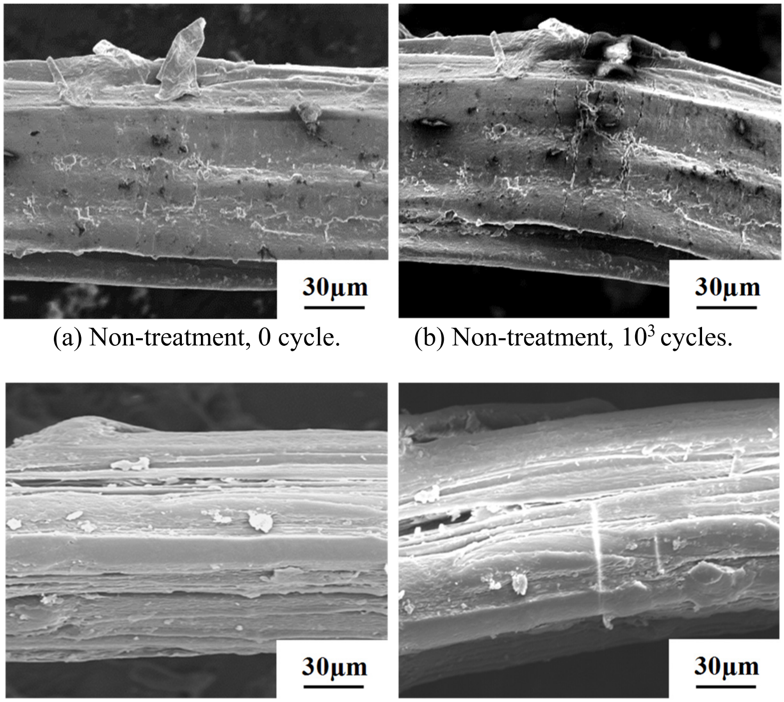


Figure 3: S–N diagrams of non and alkali treated jute fibers.

4.4 Damage observation

Figure 4 shows damage observations of non and 15% alkali treated jute fibers. Figure 5 shows number of crack in surface of jute fiber at 10^3 cycles. Crack initiations in surfaces of non and alkali treated jute fiber were found after cyclic loading. And, number of crack in surface of jute fiber increased with an increase of alkali concentration of treatment. Therefore, crack initiation in surface of alkali treated jute fiber was mainly affected by dissolution rate of lignin and hemicellulose of constituent materials.



(a) Non-treatment, 0 cycle. (b) Non-treatment, 10^3 cycles.

(c) Alkali treatment 15%, 0 cycle. (d) Alkali treatment 15%, 10^3 cycles.

Figure 4: Damage observations of non and 15% alkali treated jute fibers ($0.6\sigma_B$).

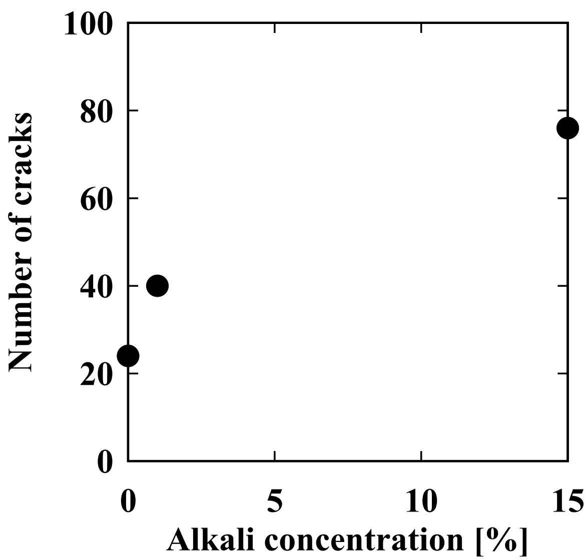


Figure 5: Number of cracks in surface of alkali treated jute fiber at 10^3 cycles.

5 Conclusions

In this study, fatigue properties of 1% and 15% alkali treated jute fibers were investigated. As a result, following conclusions were obtained.

1. In case of 1% concentration of treatment, fatigue property of jute fiber improved compared with than that of non and 15% alkali treated jute fiber because of increase of cellulose rate in constituent materials of jute fiber. But, fatigue property of 15% alkali treated jute fiber decreased compared with that of non and 1% alkali treated jute fiber because cellulose I in constituent materials of 15% alkali treated jute fiber changed to cellulose II.
2. Crack initiations in surfaces of non and alkali treated jute fiber were found after cyclic loading. The number of crack in surface of jute fiber at 10^3 cycles increased with an increase of alkali concentration of treatment. Therefore, crack initiation in surface of alkali treated jute fiber was mainly affected by dissolution rate of lignin and hemicellulose in alkali solution.

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