THE EFFECT OF ALKALI TREATMENT ON THE PHYSICAL AND MECHANICAL PROPERTIES OF CURAUA FIBERS

Alexandre GOMES*, Koichi GODA** and Junji OHGI**
*Graduate School of Science and Engineering, Yamaguchi University, Japan
**Department of Mechanical Engineering, Yamaguchi University, Japan

ABSTRACT

Alkali treatment has been performed on the surface of curaua fibers in order to improve their mechanical properties. The fibers were dipped into 5%, 10% and 15% concentrated sodium hydroxide solutions for 1hr and 2hrs, and the effects of both solution's concentration and treatment time on the physical and mechanical properties of curaua fibers were investigated. Tensile tests of untreated and alkali treated curaua fibers were carried out. The results showed that tensile strength of the treated fibers decreased as compared with untreated fibers, while fracture strain of the treated fibers increased largely comparing to that of untreated fibers. It is expected that such improvement of the fiber fracture strain could provide an increase in fracture toughness of the composite reinforced by the treated fibers.

KEYWORDS: Curaua, Natural fibers, Single fiber test, Alkali treatment, Tensile strength, Fracture strain.

INTRODUCTION

There has been an increase in the number of ecological aware studies and their practical applications, such as the use of green materials. Therefore, natural fiber composites, using kenaf, sisal and coir, have already been applied for several industrial products, such as interior parts of automobiles. Natural fibers are not only light and strong, but also low price, renewable and eco-friendly.

Curaua (Ananas erectifolius), a plant in Amazon forest, has a possibility of being the highest strength in natural fibers[1)]. Curaua fibers are abundantly available and can easily be taken from its leaves. Thus, curaua fibers are highly expected as a reinforcement of natural fiber composites. In this study the physical and mechanical properties of as-supplied and alkali-treated curaua fibers have been investigated by tensile tests and scanning electron microscope observations. And the effect of alkali treatment on the properties of curaua fibers has been discussed.

EXPERIMENTAL PROCEDURE

Curaua fibers (supplied from POEMA of Para Federal University, Brazil) were employed as a test material in this study. Alkali treatment has been applied on the surface of curaua fibers to improve their mechanical properties. The treatment was carried out by dipping small bunches of fibers into 5wt%, 10wt% and 15wt% concentrated sodium hydroxide (NaOH) solutions. Then, the treatment time was done for 1hr and 2hrs. Such different concentrations of solutions have been used for investigating the effect of alkali concentration on the mechanical properties of curaua fibers. After alkali treatment, the fibers were washed for a few minutes by using a 1% concentrated acetic acid solution. Finally, the fibers were washed by water and dried at room temperature. In addition, densities and losses of weight of 5%, 10% and 15% treated fibers were measured.

In order to carry out the tensile test, single fibers were extracted from the untreated and treated bunches of curaua fibers. The single fiber was bonded to a paper with a rectangular hole of 10mm length, as shown in Fig.1. Then, twenty single fiber specimens for each condition, i.e. untreated, 5%, 10% and 15% treated fibers, have been prepared, following the testing method of carbon fibers (Japan Industrial Standard, R 7601). The gage length for each specimen was 10mm. The diameter of each specimen was measured using an optical microscope. The cross-head speed of tensile testing machine was 0.8 mm/min and the tensile load and displacement were then measured by using a load-cell and laser system, respectively.

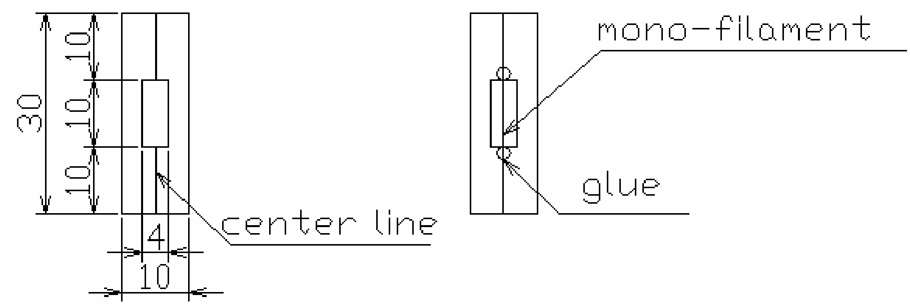

Fig.1. Tensile-test specimen.

RESULTS AND DISCUSSION

Mechanical properties

The results of untreated and alkali-treated specimens tensile-tested are shown in Table 1, in which the values are all averages. The results showed that the tensile strength of curaua fibers obviously decreased by alkali treatment. This fact could be due to damage on the fibers caused by chemical reaction with sodium hydroxide during treatment. On the other hand, fracture strain of treated fibers increased largely as compared with untreated fibers. Regarding the alkali solution's concentration, the tensile strength of treated fibers decreases with an increase in the content of sodium hydroxide; hence the tensile strength of 5% treated fibers is higher than that of 10% treated fibers, followed by that of 15% treated fibers. However, fracture strain increases with an increase in the content of sodium hydroxide. The fracture strains of fibers treated in 5%, 10% and 15%NaOH for 2h reached 0.0571, 0.0686 and 0.0868, respectively. The Young's modulus of treated fibers decreased compared to untreated fibers. Fibers treated by the same concentration of sodium hydroxide, showed higher tensile strength for 1hr treatment than that treated for 2hrs, while 2hrs treatment provided higher fracture strain than 1hr treatment.

Table 1. Mechanical properties of untreated and alkali-treated curaua fibers.

Treatment time (hrs)	0	1			2		
NaOH concentration (wt%)	0	5	10	15	5	10	15
Fiber diameter (μm)	66.0	58.4	62.9	55.6	94.3	45.8	54.8
Tensile strength (MPa)	913	736	597	539	842	551	523
Fracture strain	0.0398	0.0474	0.0636	0.0781	0.0571	0.0686	0.0868
Young's modulus (GPa)	30.3	26.8	22.4	18.9	24	22.1	18.4

Stress-Strain diagrams

Stress-strain diagrams of 1hr and 2hrs alkali-treated curaua fibers are shown in the Fig. 2 and Fig. 3, respectively. Through these diagrams we can see the influences of both treatment time and alkali solution's concentration on the mechanical properties of treated fibers. It is clear that slopes of the stress-strain curves of the treated fibers decrease in comparison with that of the untreated fiber. The decrease in slope of the stress-strain diagram brings decreases in tensile strength and young's modulus. However, as mentioned above, the fiber fracture strains increase drastically after alkali treatment. It should be noted that fracture strain of fibers treated at 2hrs and 15% sodium hydroxide reached nearly 0.09, which is more than the double of the fracture strain of the untreated fiber. In addition the stress-strain behavior of the treated fibers is nonlinear, similarly to a plastic deformation behavior. Therefore, there is an expectation, that any improvement on the fiber fracture strain could generate an increase in fracture toughness of the composite reinforced by such treated fibers.

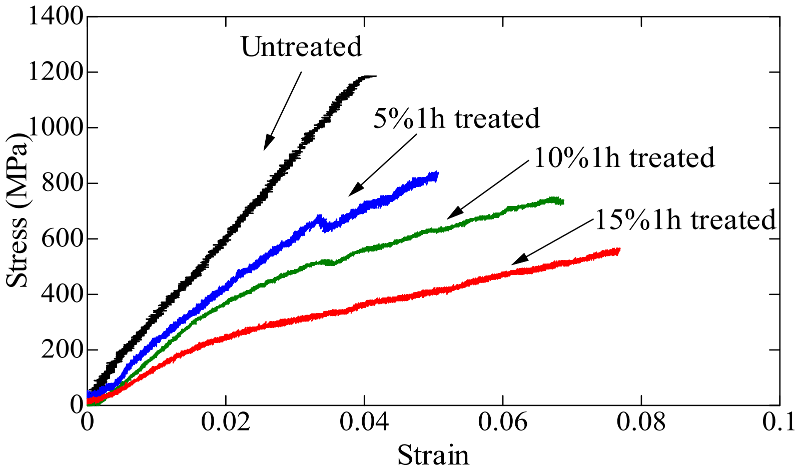

Fig.2.Stress-strain diagram of 1h alkali treated curaua fibers.

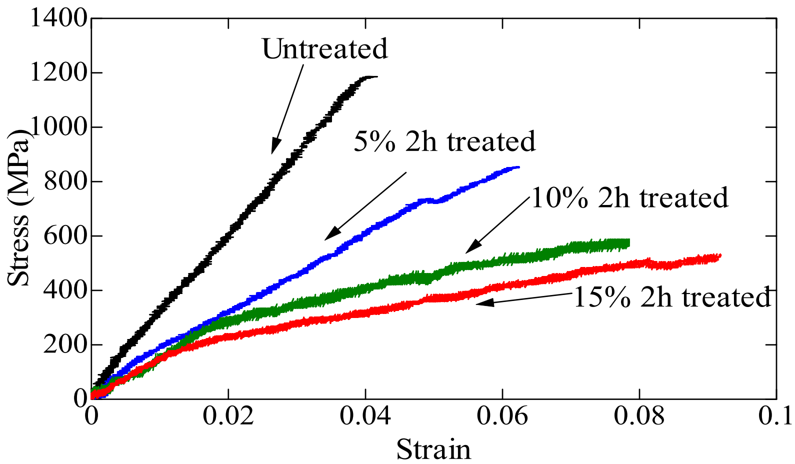

Fig.3.Stress-strain diagram of 2h alkali treated curaua fibers.

Physical and morphological properties

The surfaces of untreated and treated fibers have been observed through a scanning electronic microscope. Figures 4 (a) and (b) show SEM photographs of the surfaces of untreated and 15% and 2hrs treated fibers. Observations on the treated fiber surface revealed that the fiber is not truly a monofilament, but a bundle of real monofilaments bonded and covered by lignin. Then, it can be understood that alkali treatment provoked a removal of a great content of lignin from the surface of the untreated fiber. The existence of a considerable amount lignin on the untreated fiber gives it a rougher surface than that of treated fibers. Figure 5 shows a schematic of a morphological change in the fiber caused by alkali treatment. The fiber structure is originally an apparent single fiber, which is composed of monofilaments bonded to a great amount lignin, similar to a structure of fiber-reinforced composites. After alkali treatment the structure is changed into a bundle structure, which is composed of monofilaments barely bonded each other by a very little content of lignin. The removal of lignin caused a loss of weight and a consequently reduction in density of alkali-treated fibers. Table 2 shows changes of weight and density of the fiber. It is shown from the table that both the fiber's weight and density decrease with an increase in the alkali solution's concentration.

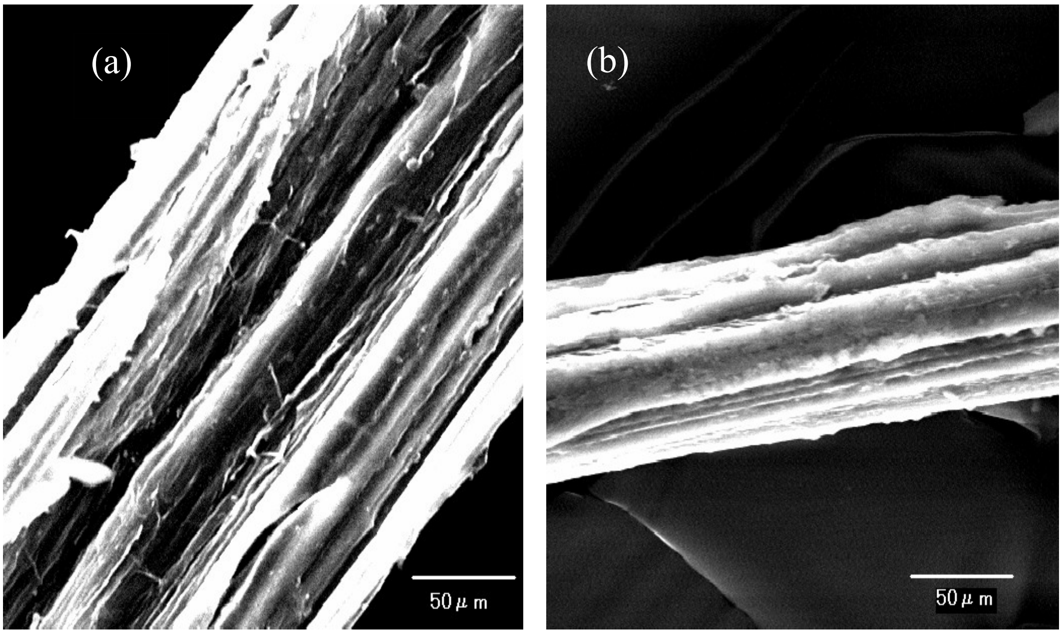

Fig.4. SEM photographs of surfaces of (a) untreated and (b) 15% and 2hrs alkali treated curaua fibers.

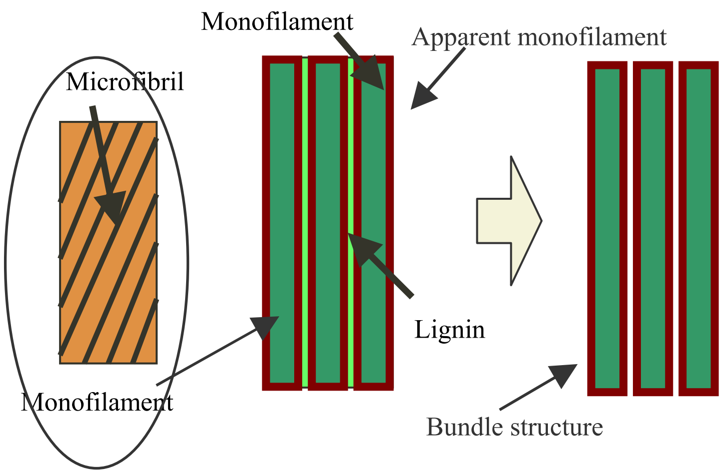

Fig.5. Effect of alkali treatment on the morphological structure of curaua fibers.

Table 2. Density and loss of weight of treated and untreated curaua fibers.

NaOH concentration (wt%)	0	5	10	15
Loss of weight (%)	-	14.0	20.0	27.0
Density (Mg/m^3)	1.38	1.187	1.104	1.007

Curaua fibers and glass fibers

From the properties of untreated and alkali-treated curaua fibers, it is possible to discuss the possibility of replacing glass fibers for curaua fibers as the reinforcement of composites. Figure 6 shows strength and specific strength of three types of glass fibers and untreated, 5%, 10% and 15% alkali-treated curaua fibers. The strength level of all types of glass fibers is much higher than that of any type of curaua fibers. However, the specific strengths of untreated and 5% alkali treated curaua fibers are clearly higher than that of alkali resistance glass fibers. The good performance on specific strength of curaua fibers plays a very important role in reducing the weight of composites reinforced by them as compared with glass fiber reinforced plastics composites (GFRP). Furthermore, GFRP are not decomposed easily and its reclamation process generates a large environmental load. Also, it is difficult to establish a suitable method of discarding

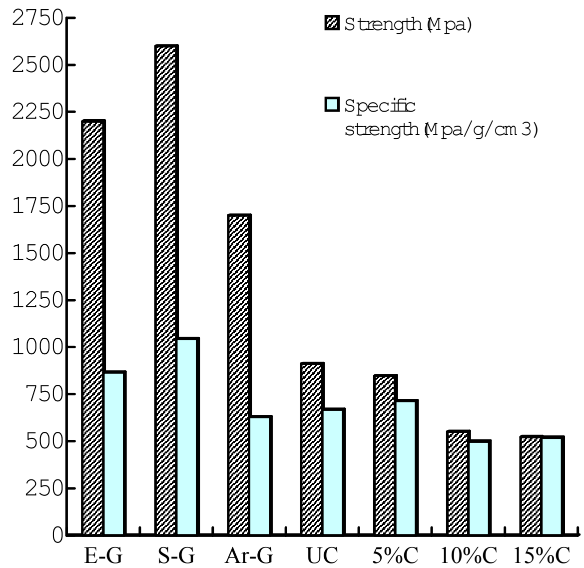

Fig.6. Strength and specific strength of electric fiber glass (E-G), high strength and stiffness fiber glass (S-G), alkali resistant fiber glass (Ar-G), untreated curaua fibers (UC), 5% alkali treated curaua fibers (5%C), 10% alkali treated curaua fibers (10%C) and 15% alkali treated curaua fibers (15%C).

for these materials. Incineration of GFRP generates many problems such as damages to the incinerator, generation of a lot of black smoke and bad smells. Industrial workers who produce glass fibers and assemble GFRP components, often suffer skin irritations and respiratory diseases caused by the inhalation of glass fibers dust. Thus, the use of curaua fibers reinforced composites may solve various problems inherent in GFRP.

CONCLUSIONS

(1) Curaua fibers had been treated by 5%, 10% and 15% sodium hydroxide solution for 1hr and 2hrs. The mechanical properties of untreated and alkali treated curaua fibers were investigated through tensile tests. The tensile strength of the treated fibers decreased compared to that of the untreated fiber, while the fracture strain of the treated fibers increased largely. The fracture strain of fibers treated for 2hr in 15%NaOH solution reached nearly 0.09 that represents about 2 times more than that of untreated fibers (0.0398).

(2) SEM observations revealed the structure of untreated and treated curaua fibers. The structure of an untreated single fiber was actually a bundle composed of some single fibers bonded and covered by lignin (composite's structure). The addition of alkali treatment changes the original structure into a bundle of single fibers (bundle structure) barely bonded by a very little quantity of lignin.

(3) Untreated and 5% alkali treated curaua fibers have shown higher specific strength than alkali resistance glass fibers. The good performance on specific strength of curaua fibers can provides a reduction of weight of composites reinforced by them in comparison with GFRP.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Electric Technology Research Foundation of Chugoku who gave a financial support on the travel expenses to one of the authors, Alexandre Gomes.

REFERENCES

1) **Thomas G. Schuh**, *Proc. First Int. Sympo. Lignocellulosic Composites*(1996)

2) **M.Z.Rong and M.Q.Zhang**, *Com. Sci. Tec.*, **61** (2001), 1437-1447.

3) **F. L. Mathews and R. D. Rawlings**, *Composite Materials: engineering and science*, (1999), *WoodHead Publishing Limited*, p.40.

4) **S. Hill**, *New Scientist*, 1 Feb. (1997) 36.

5) **H.Takagi**, **W.Winoto and A.Netravali**, *Proc. First Int. Workshop on Green Compo*, 4-7, Japan (2002).

6) **K.Goda**, **T.Asai and T.Yamane**, *Proc. First Int. Workshop on Green Compo*, 8-11, Japan (2002).
7) **K.Goda**, **T.Kaji and Junji Ohgi**, *Proc. Second Int. Workshop on Green Compo*, 101-103, Japan (2002).).
8) **K.Joseph**, **S. Thomas and C.Pavithran**, *Polymer*, **37** n.23, pp 5139(1996).
9) **P.Wambua**, **J.Ivens and I.Verpoest**, *Com. Sci. Tec*, (2003), **63**, 1259-1264