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Application News

No. i284

Material Testing System

Evaluation of Temperature-Dependent Flexural Properties of Fiber Reinforced Resin

Cellulose is the main component of plant cell walls and fibers. It is also the most abundant carbohydrate on earth and has been used as a raw material for paper and cotton since antiquity. Recently, cellulose nanofiber (CNF) has been the focus of attention as a new material in which the functionality of cellulose is enhanced by defibration to the nano level. CNF has ″5 times the strength of steel while weighing only 1/5 as much″, and also has numerous other desirable properties, including “transparency,” “low thermal expansion and high heat resistance,” “gas barrier property,” and “thickening property and thixotropy,” and as a plant-derived substance, it is also a low environmental impact material. For these reasons, it has attracted interest as a new material following carbon fiber.

In particular, in the transportation equipment field, light weight components fabricated with CNF combined with resin are of interest when applied to the automotive field, as they contribute to CO_2 emissions reduction (1). However, considering the environments in which automobiles are used, it is necessary to clarify the material properties of CNF not only at room temperature, but also across a wide temperature region from low to high temperatures.

In this article, bending tests were conducted to evaluate the temperature dependence of flexural strength and the flexural modulus of nylon 6 (PA6) strengthened with CNF and with glass fiber (GF).

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Measurement System

Table 1 shows the test configuration. In these measurements, the tests were conducted with a Shimadzu AGX™-V precision universal testing machine (Fig. 1). Fig. 2 shows the condition of the test, and Table 2 lists the test conditions. The room temperature tests were conducted with a 3-point bending test jig for plastic, as shown in Fig. 2 (a), and the test in a thermostatic chamber were carried out with an extension rod and a box-type jig (Fig. 2 (b)). The box-type jig converts the tensile load applied by the testing machine into bending load on the specimen, preventing unwanted buckling of the extension rod caused by compression loads. Considering the use environments of automobiles, the tests were carried out under temperature conditions from -30 °C to 80 °C. A total of 7 types of test specimens were prepared, including PA6 without fiber addition and CNF/PA6 and GF/PA6 composites with three different wt% levels of fiber concentration (3, 5, 10 wt%), respectively. The specimens were fabricated following the guidelines of the ISO 178 regulation, and the tests were conducted with n = 3 of each specimen type.

* Samples were provided by the Kyoto Municipal Institute of Industrial Technology and Culture.

Fig. 1 AGX™-V Precision Universal Testing Machine

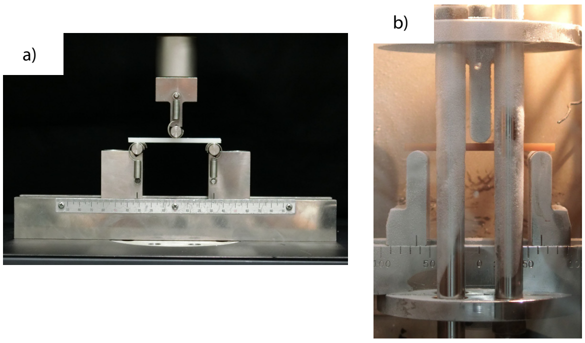

Fig. 2 Condition of Test
(a: Room Temperature, b: In Thermostatic Chamber)

Table 1 Test Configuration

Precision universal testing machine	: AGX-V
Load cell	: 1 kN
Thermostatic chamber	: Refrigerator Thermostatic Chamber TCR1WF
Test jigs	: 3-point bending test jig for plastic (room temperature) Box-type jig (in thermostatic chamber)
Distance between supports	: 64 mm
Support radius, punch radius	: R5 mm
Software	: TRAPEZIUM™ X (single)

Table 2 Test Conditions

Specimen dimensions	: Length 80 mm × width 10 mm × thickness 4 mm
Test speed	: 1 mm/min (strain < 0.3 %) 20 mm/min (strain ≥ 0.3 %)
Test temp. (℃)	: 5 temperature conditions (-30, 0, RT, 60, 80)
Specimen type	: PA6 CNF/PA6 (3 wt%, 5 wt%, 10 wt%) GF/PA6 (3 wt%, 5 wt%, 10 wt%)
Number of tests	: n = 3

Test Results

Fig. 3 shows the results for -30 °C, room temperature, and 80 °C as an example of the test results. Specimens tested at room temperature and high temperatures showed ductile behavior as the stress decreased gradually after the point of maximum stress and rupture did not occur. However, at low temperatures, the specimens displayed brittle behavior, as the rupture occurred immediately after the maximum stress was reached and the rupture was followed by an instantaneous stress decrease. Fig. 4 shows the correlation between the flexural strength and temperature for each specimen. As shown in Fig. 4, both CNF/PA6 and GF/PA6 displayed temperature dependence, in that flexural strength decreased as the temperature increased. Moreover, although the strength values tended to increase as the fiber content percentage became higher, there were also specimens in which the strength of GF/PA6 was lower than that of PA6, depending on the temperature. Fig. 5 shows the correlation between the flexural modulus and temperature for each specimen. For both reinforcing fibers, the flexural modulus increased as the fiber content percentage became higher, and the flexural modulus of the CNF reinforced composites was higher than that of the GF reinforced specimens regardless of the fiber percentage content. In comparison with flexural strength, the temperature dependence of the flexural modulus was less evident, and there was almost no change in the flexural modulus in the range from -30 °C to room temperature and in the range from 60 °C to 80 °C. However, the flexural modulus decreased greatly from room temperature to 60 °C. It is estimated that the physical properties of the specimens changed at around the glass transition temperature (50 °C) of PA6, which was the matrix resin.

Conclusion

In this article, bending tests of two types of fiber reinforced resins (CNF- and GF-reinforced) were conducted under a wide range of temperature. The results revealed that flexural strength and the flexural modulus differed depending on the test temperature.

The temperature characteristics of materials can be clarified by conducting tests using the instrument composition in this article.

<References>
(1) Ministry of the Environment, Japan, NCV (Nano Cellulose Vehicle) Project
http://www.env.go.jp/press/103177.html
(2) Takeshi Semba, Nanocellulose Symposium 2018, Abstracts, 319-320 (2018)

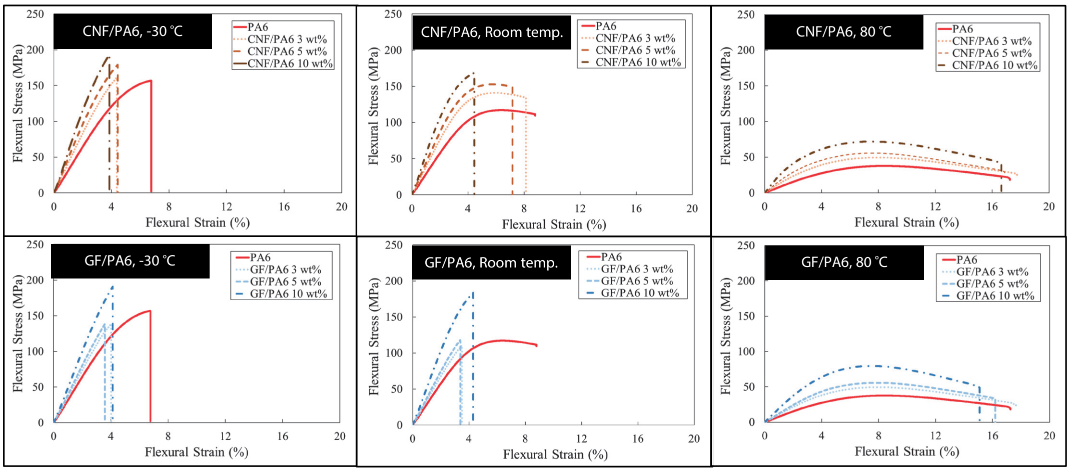

Fig. 3 Test Results

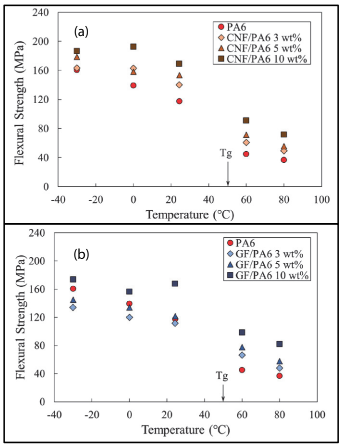

Fig. 4 Correlation of Flexural Strength and Temperature
(a) CNF/PA6 (b) GF/PA6

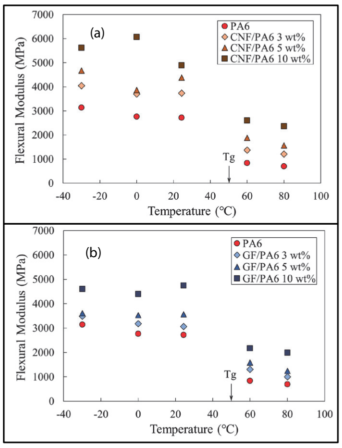

Fig. 5 Correlation of Flexural Modulus and Temperature
(a) CNF/PA6 (b) GF/PA6

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