Application News

No. i275

High-Speed Impact Testing Machine

High-Speed Tensile Test of CNF-Reinforced Plastic

Cellulose is the main component of plants. It is also the most abundant carbohydrate on earth and has been used as raw materials of paper and textiles since antiquity. In recent years, cellulose nanofiber (CNF) with higher functionality realized by defibrating cellulose to the nano level has attracted considerable attention. CNF has low environmental impacts, as it is a plant-derived material, and possesses a variety of desirable functions, including low linear expansion, a gas barrier property, and transparency. It is also lightweight, weighing only 1/5 as much as steel, and displays high specific strength 5 to 8 times stronger than ferrous materials. For these reasons, research aimed at developing composite materials with a combination high strength and light weight by adding CNF to thermoplastic resins is currently in progress, and application in various fields is expected. One such field is the automotive industry, where the ultimate purpose is to improve fuel efficiency by reducing auto body weight. However, considering the use conditions of automobiles, it is essential to clarify not only the static mechanical properties of materials, but also their impact properties, fatigue characteristics, and thermal characteristics.

In this article, the tensile strength of CNF-reinforced plastic was evaluated at various test speeds (strain rates) by using a Shimadzu testing machine and high-speed impact testing machine. The fracture surfaces of the specimens after the tests were also observed by using an electron probe microanalyzer (EPMA) [1].

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Measurement System

Fig. 1 shows the condition of the static tensile test and the high-speed tensile test. An AGS-X table-top type universal testing machine was used in low-speed tests, and an HITS™-TX high speed impact testing machine was used in high-speed tests. An optical microscope and an EPMA™-8050G electron probe microanalyzer were used to observe the fracture surfaces of the specimens after the tests. Table 1 shows the test equipment used in this study.

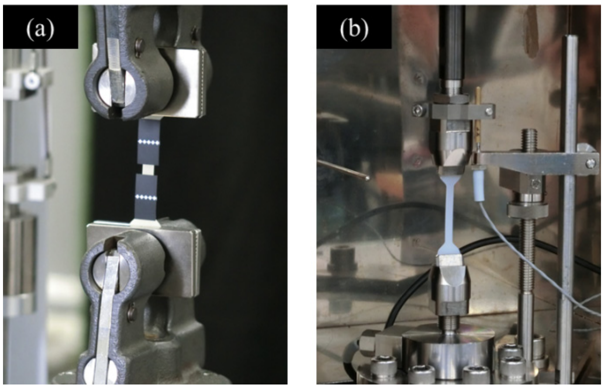

Fig. 1 Condition of Tests
(a) Static Tensile Test, (b) High-Speed Tensile Test

Measurement Results

Two types of specimens were prepared, one using high density polyethylene (HDPE) and the other, HDPE reinforced with 10% CNF (CNF10%/HDPE). Table 2 shows the test conditions and the specimen information.

Fig. 2 shows examples of the stress-displacement curves of the HDPE and CNF10%/HDPE at various strain rates. From Fig. 2, both materials exhibited lower tensile strength as the test speed decreased and higher tensile strength at higher test speeds. Moreover, the slopes of the stress-displacement curves also became larger as the test speed increased.

Table 1 Test Equipment

Testing machines	: AGS-X (static tensile tests) HITS-TX (high-speed tensile tests)
Load cell	: 1 kN (AGS-X) 2 kN (HITS-TX)
Grip	: Pneumatic flat grip (AGS-X) Grip for plate specimens (HITS-TX)
Fracture surface observation	: EPMA-8050G

Table 2 Test Conditions and Specimen Information

Test speed	: 0.0001, 0.001, 0.01, 0.1 /s (AGS-X) 0.1, 1, 10, 100 /s (HITS-TX) (0.000004 - 4 m/s)
Test temperature	: Room temperature
Number of tests	: n = 3
Specimens	: HDPE, CNF10%/HDPE
Specimen dimensions	: T1 mm × W5 mm, parallel part 40 mm

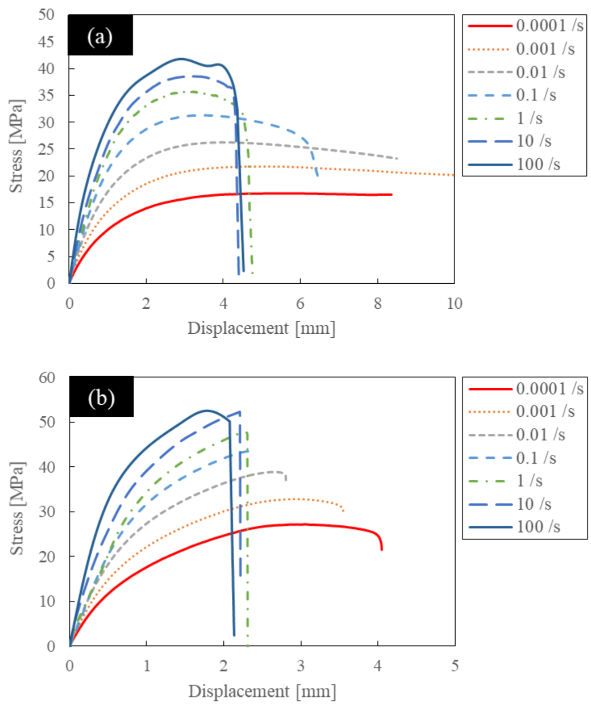

Fig. 2 Stress-Displacement Curves
(a) HDPE, (b) CNF10%/HDPE

Fig. 3 shows the relationship between the strain rate and tensile strength. From the results in Fig. 3, CNF10%/HDPE displayed larger tensile strength under all strain rate conditions. The tensile strength also increased at higher test speeds.

Fig. 4 shows images of the lateral surfaces of the specimens after the test photographed with the optical microscope. The left side of the images is the fracture surface. Figs. 4(b), (c), and (d) show that whitening has occurred around the fracture surfaces. From this, the fracture mode is considered to be ductile fracture. In Fig. 4(b), a diagonal whitish stripe appeared. On the other hand, because Fig. 4(a) shows virtually no traces of whitening, it is thought that brittle fracture occurred in this specimen.

Fig. 5 shows images of the fracture surfaces after the test photographed with the optical microscope. Fig. 6 shows the EPMA images of the parts indicated by the white frames in Fig. 5. Fig. 6(a) shows a condition in which fracture occurred in fibers in which defibration had not progressed. In contrast, fracture of the fibers was not observed in Fig. 6(b), and a condition of ductile elongation could be seen in the resin containing CNF. The image in Fig. 6(c) is the result of observation of the most elongated part in Fig. 5. Ductile elongation of the resin could be observed in this figure. Elongation of the resin was also observed in Fig. 6(d).

Conclusion

As described in this article, a high-speed tensile test of CNF10%/HDPE and HDPE was conducted. As a result, it was found that tensile strength changed depending on the test speed. Furthermore, the fracture surfaces after the tests were observed, clarifying the fact that different fracture surfaces had occurred. Since it is possible to set a wide range of strain rates as test conditions by using the HITS-TX and AGS-X, these testing machines can be useful in evaluating the strain rate dependency of resins.

<Reference>
(1) Fumiaki Yano, Yuki Kamei, Takeshi Senba, and Kazuo Kitagawa, Abstracts of the Symposium on Polymer Processing ’19 (2019)

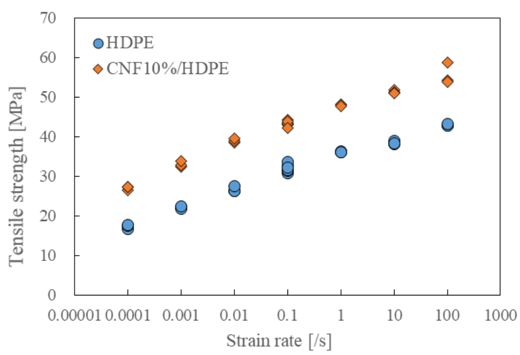

Fig. 3 Relationship Between Strain Rate and Tensile Strength

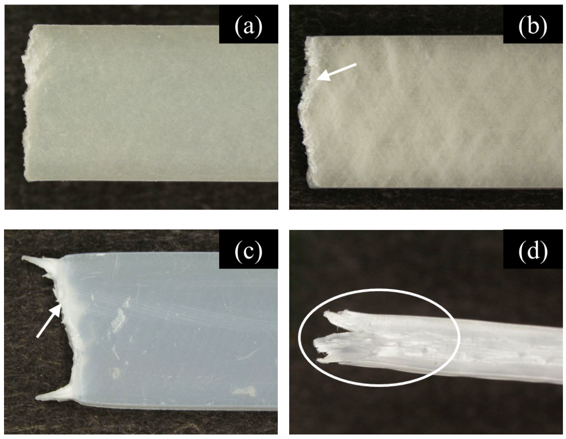

Fig. 4 Images of Lateral Surfaces of Specimens after Test
(a) CNF10%/HDPE, 100 /s, (b) CNF10%/HDPE, 0.0001 /s, (c) HDPE, 100 /s, (d) HDPE, 0.0001 /s

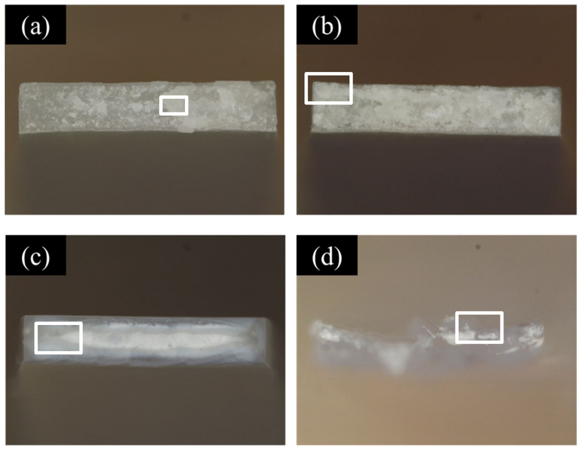

Fig. 5 Images of Fracture Surfaces of Specimens after Test
(a) CNF10%/HDPE, 100 /s, (b) CNF10%/HDPE, 0.0001 /s, (c) HDPE, 100 /s, (d) HDPE, 0.0001 /s

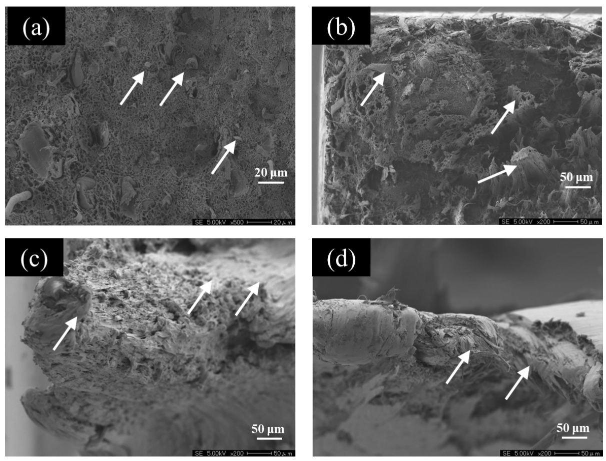

Fig. 6 EPMA Observation Images of Fracture Surfaces
(a) CNF10%/HDPE, 100 /s, (b) CNF10%/HDPE, 0.0001 /s, (c) HDPE, 100 /s, (d) HDPE, 0.0001 /s

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