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Application News

No. i273

Precision Universal Testing Machine

Tensile Test of Carbon Fiber

Carbon fiber has excellent functional properties such as corrosion resistance, chemical resistance, and heat resistance, but its most important features are extremely high specific strength and specific stiffness. Nevertheless, carbon fiber is almost never used as a single fiber. Rather, it is normally used in composite materials in which it is embedded in a matrix of resin (matrix resin) or other material. Composite materials in which carbon fiber is used as a reinforcement material are called carbon fiber reinforced plastic (CFRP), and display extremely high specific strength and specific stiffness. For this reason, they are used in the structural materials of aircraft and other transportation equipment in order to improve fuel efficiency by weight reduction. The mechanical properties of these composite materials are generally considered to be influenced by the mechanical properties of the reinforcing fiber and the matrix resin, and by the interfacial strength between the fiber and the resin. For this reason, understanding the strength of a single carbon fiber filament is important for the development of composite materials. In this article, a tensile test of a single carbon fiber filament was conducted in accordance with JIS R 7606:2000, Carbon fibre – Determination of the tensile properties of the single-filament specimens (ISO 11566:1996).

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Measurement System

The test was conducted using an AGS-X Series table-top precision universal testing machine. The grips were easily-attached 1N clip type grips (rubber-coated teeth). Table 1 shows the specification of the test system used, and Fig. 1 shows the test conditions.

Table 1 Specification of Test System

Instrument	: AGS-5NX
Grip	: 1N clip type grip
Grip face	: Rubber-coated teeth
Software	: TRAPEZIUM™ LITE X

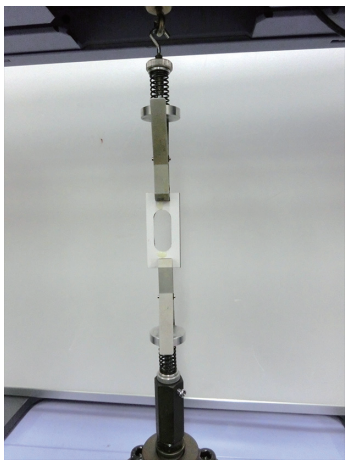

Fig. 1 Condition of Test

Measurement Conditions

Because carbon fibers have a small diameter of approximately 7 µm, they are difficult to grasp as-is. Therefore, in JIS R 7606, a fiber is attached to the grips after fixing the specimen on a specimen mount prepared from a sheet of paper, metal, or resin having a maximum thickness of 0.1 mm as shown in Fig. 2. After attachment, a cut section is cut with scissors or the like, and the test is performed. The test speed in the JIS standard is described as 1 to 5 mm/min. In this experiment, the test was conducted at 1 mm/min.

Because the stress-strain curve of a single filament is not linear, the elastic modulus is expressed by the chord modulus, which is obtained from the slope between the two gauge marks. When tensile elasticity is to be obtained, it is necessary to obtain system compliance prior to the test. For this purpose, tests are performed with mounts having lengths of 5 mm, 10 mm, 20 mm, 30 mm, and 40 mm. Two tensile elasticity calculation methods are provided, method A, in which the stress between the two gauge marks is used as a standard, and method B, in which the elongation between the two gauge marks is used as a standard. In this test, tensile elasticity was obtained by using method B, which is calculated by equation (1). With method B, the calculation range of the elastic modulus differs depending on the elongation at the time of rupture. Table 2 shows the test conditions.

$$E_{fB} = \frac{\left(\frac{\Delta F_B}{A_f}\right)\left(\frac{L}{\Delta L_B}\right)}{1 - K\left(\frac{\Delta F_B}{L}\right)} \times 10^{-3} \qquad (1)$$

E_{fB} : Tensile elasticity [GPa]
ΔF_B : Increment of test force in elongation of 0.1 % to 0.6 % [N]
A_f : Section area of single filament [mm^2]
L : Test length [mm]
ΔL_B : Increment of elongation in elongation of 0.1 % to 0.6 % [mm]
K : System compliance [mm/N]

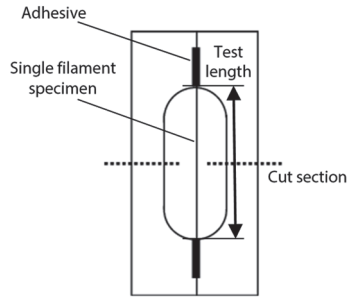

Fig. 2 Mount with Attached Specimen

Table 2 Test Conditions

Test speed	: 1 mm/min
Gauge length	: 25 mm
Number of tests	: n = 3
Specimen diameter	: 6.8 µm
Elongation range in calculation of elastic modulus	: 0.1% to 0.6%

Measurement Results

Tests were conducted with the test lengths of 5 mm, 10 mm, 20 mm, 30 mm, and 40 mm to obtain the elastic modulus. Fig. 3 shows the relationship between ΔL/ΔF and the test length for obtaining system compliance. Here, ΔL and ΔF show the increment of stroke and the increment of test force, respectively, in the elongation range for calculation of the elastic modulus. System compliance *K* is the extrapolated value at the test length of 0 in Fig. 3. The system compliance obtained from Fig. 3 was 0.2586.

Fig. 4 shows the test force-stroke (strain) curve, and Table 3 shows the test results. The tensile strength, tensile elasticity, and breaking elongation of the carbon fiber were 4,250 MPa, 233 GPa, and 1.81%, respectively.

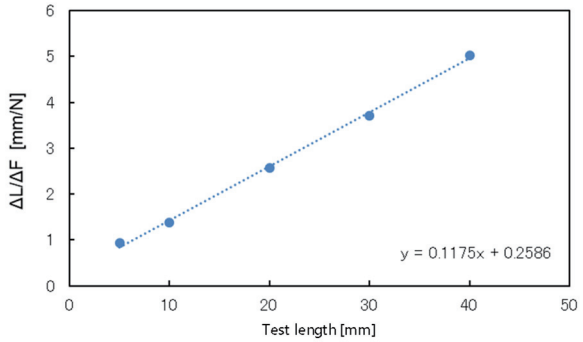

Fig. 3 Method for Obtaining System Compliance

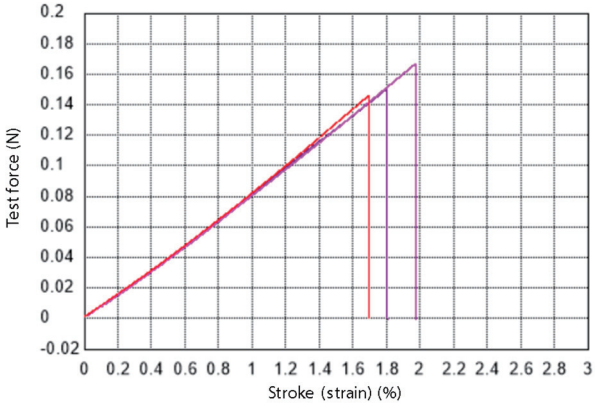

Fig. 4 Test Force-Stroke (Stain) Curve

Table 3 Test Results

Specimen No.	Tensile strength [MPa]	Tensile elasticity [GPa]	Breaking elongation [%]
1	4016	236	1.69
2	4140	230	1.77
3	4593	232	1.97
Average	4250	233	1.81

Conclusion

This article introduced an example of a tensile test of a carbon fiber conforming to JIS R 7606:2000 (ISO 11566). Because carbon fibers have a small diameter and are difficult to grasp as-is, the test was conducted with the fiber pasted to a mount. In setting the specimen in the testing machine, 1N clip type grips were used, as specimens can be gripped easily.

By using the AGS-X Series table-top precision universal testing machine and the 1N clip type grips, it was possible to evaluate the tensile strength and tensile elasticity of a single filament of carbon fiber in the tensile test.

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