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Application News

No. i260

Material Testing System

Three-point Bending Flexural Test for Plastics

Introduction

Based on their thermal properties and light weight, plastics have recently come to be used in a variety of applications and sectors, from small gears to airplane fuselages. A variety of tests must be performed to evaluate these materials, from tensile tests to flexural tests and compression tests. Of these, a flexural test is performed to examine material characteristics when flexed by an external force. Because components subject to an external force will flex in reaction to a bending moment, the flexural test is one of the most basic tests used to evaluate materials.

Previous testing standards that define a three-point bending flexural test for plastics did not require the deflection-measuring system. As a result, tests detected specimen, instrument deflection and indenter depression together as a total, which is a method not suited to accurate measurements of flexural modulus of elasticity. Amended standards (ISO178:2010, Amd.1:2013 and JIS K 7171:2016) have been amended and include either use of a deflection-measuring system with "ISO 9513 Class 1" absolute accuracy of within 1 %, or use of compliance correction to remove testing machine deflection. A three-point bending flexural test was performed on PC, PVC, and GFRP specimens in compliance with the amended standards, where the flexural modulus of elasticity of each plastic was calculated using crosshead displacement, compliance correction and the deflection measuring instrument.

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Measurement System

Measurements were performed using an AGS-X Table-Top Type Universal Testing Instrument and the deflection-measuring system with a measurement accuracy of within 3.4 µm. The requirements of the amended standards when mean specimen thickness is 4 mm are shown in Fig. 1. The value relevant to flexural modulus calculation is 341 µm, where a deflection measuring instrument with absolute accuracy of 1 % of this value (3.4 µm) is required (Fig. 1 shows the flexural modulus of elasticity calculated based on the slope at two points, though the flexural modulus of elasticity could also be calculated based on the linear regression of the curve).

Table 1, 2 and 3 show details of the instruments, specimens, and test conditions used. Fig. 2 shows the test apparatus layout. The amended standards describe a method A that uses a constant test speed, and a method B that increases the test speed after flexural modulus measurement. Test method A was used with GFRP that has a small maximum flexural strain, and test method B was used with PC and PVC that have a large maximum flexural strain, and the test speed changeover point was set at 0.3 % flexural strain. Furthermore, since the proportion of external force accounted for by shearing force increases when the span between supports is small[*1], standards recommend the span between specimen supports is 16 ± 1 times the mean specimen thickness.

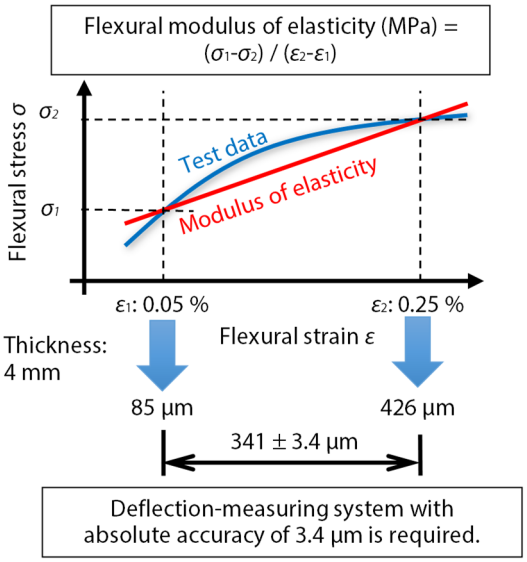

Fig. 1 Amended Standards Requirements

Table 1 Equipment Details

Testing machine	AGS-X
Load cell	1 kN
Deflection-measuring system	Deflection measuring device
Bending jigs	Loading edge R5, supports R5

Table 2 Specimen Information

Dimensions	80 mm × 10 mm × 4 mm
Material	PC, PVC, GFRP (short fibre)

Table 3 Test Conditions

Test speed	2 mm/min
Test speed after measurement of flexural modulus of elasticity	100 mm/min (method B)
Span between specimen supports	64 mm

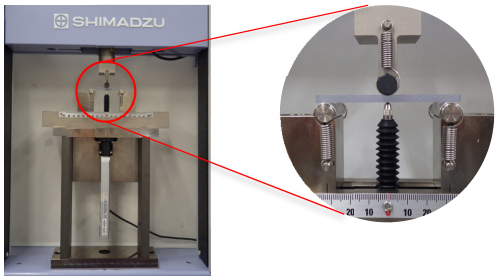

Fig. 2 Attachment of Deflection-Measuring System to Testing Machine

Test Results

Fig. 3 shows a flexural stress/flexural strain curves. Flexural strain on the horizontal axis was calculated based on results measured using the deflection-measuring system. The curve shows a sudden decrease in flexural stress with GFRP, but no sudden decrease in flexural stress with PC and PVC as these specimens did not break suddenly. Table 4 shows the results obtained for flexural strength and flexural modulus of elasticity for each material.

Table 5 shows the comparison of flexural modulus of elasticity calculated based on the crosshead displacement, compliance correction and the deflection-measuring system. The results show that the flexural modulus of elasticity is higher in order of the crosshead displacement, the compliance correction, and the deflection-measuring system.

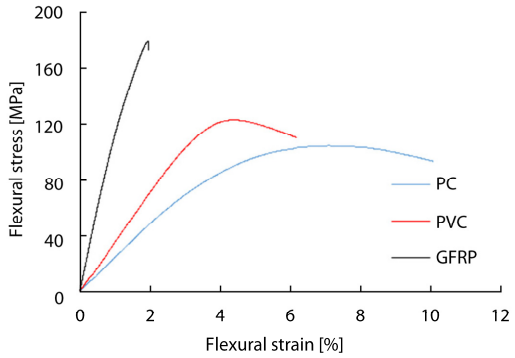

Fig. 3 Test Results

Table 4 Test Results

	Flexural strength [MPa]	Flexural modulus of elasticity [GPa]
PC	104.4	2.44
PVC	123.0	3.48
GFRP	179.4	12.1

Table 5 Comparison of Flexural Modulus of Elasticity Results by Measurement Method Deflection [GPa]

	PC	PVC	GFRP
Crosshead displacement	2.41	3.39	11.5
Compliance correction	2.42	3.41	11.7
Deflection-measuring system	2.44	3.48	12.1

Flexural strains are compared in Fig. 4, which are calculated from the crosshead displacement and compliance correction, and the deflection-measuring system at the initial period of test of GFRP. The blue line shows the measurement of crosshead displacement, the red line shows that with compliance correction and the black line shows that with the deflection-measuring system. The graph shows that there are differences at the initial period of test.

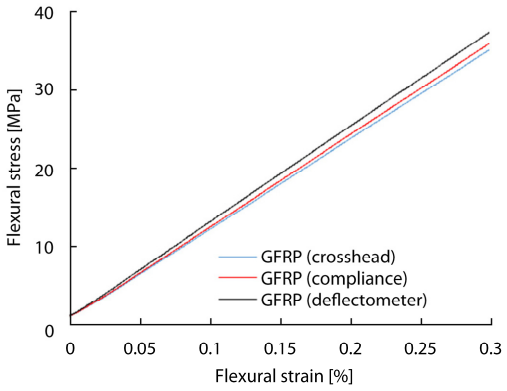

Fig. 4 Flexural Stress/Flexural Strain Curve of GFRP (Flexural Strain 0 % to 3 %)

Summary

Plastics were subjected to a three-point bending flexural test with a method compliant with amended standards (ISO178:2010, Amd.1:2013 and JIS K 7171:2016). Results showed the higher the flexural modulus of elasticity of material in order of the measurement with the crosshead displacement, the compliance correction, deflection-measuring system. Furthermore, results showed that this difference becomes larger for specimens with higher flexural modulus of elasticity. Exact measurement of displacement with a deflection-measuring system is required for a proper evaluation of materials in compliance with the amended standards.

The equipment setup employed in this article can be used to perform three-point bending flexural tests of plastics in compliance with the amended standards.

References

*1 Takashi Murakami, Shimadzu Review Vol. 71, issue 3/4 (2014)

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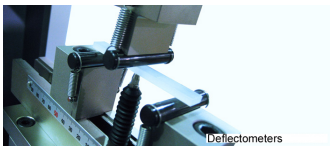

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