Application News

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Material Testing System

Three-Point Bending Flexural Test of Plastics (ISO 178, JIS K 7171)

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 described 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. New standards (ISO178:2010, Amd.1:2013 and JIS K 7171:2016) have been revised 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 new standards, where the flexural modulus of elasticity of each plastic was calculated using compliance correction and the deflection-measuring instrument.

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 new 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 new 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.

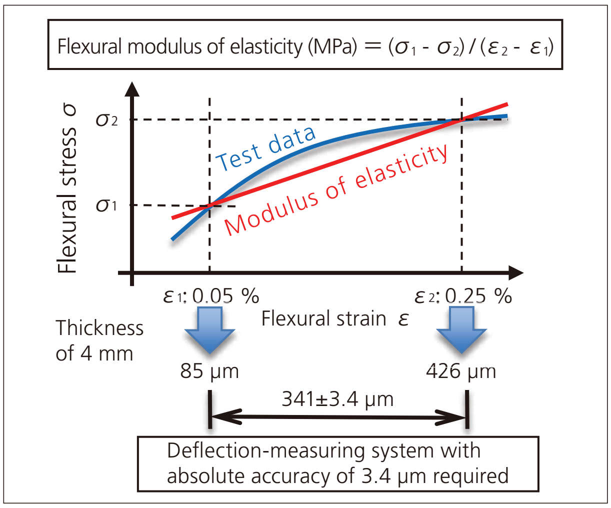

Fig. 1 New Standard Requirements

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
Type	: PC, PVC, GFRP (short fiber)

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

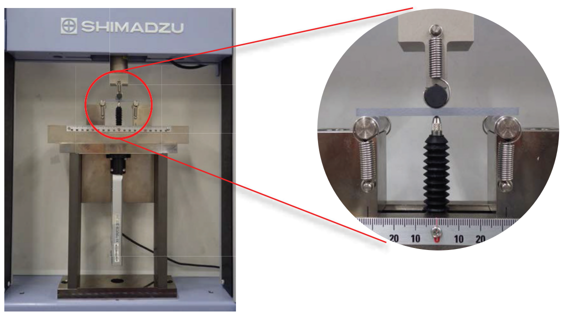

Fig. 2 Attachment of deflection-measuring system to Testing Machine

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 difference in flexural modulus when calculated based on the deflection-measuring system and compliance correction. The results show a difference of around 1 to 2 % for plastics like PC and PVC with a flexural modulus of elasticity of 2 to 3 GPa, and a difference of around 3 % for specimens like GFRP with a high flexural modulus of elasticity.

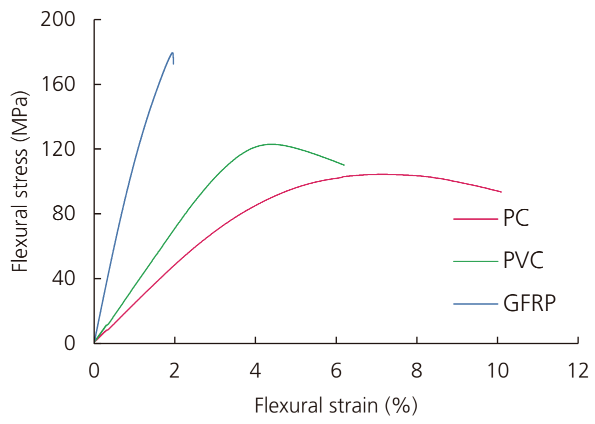

Fig. 3 Test Results

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 Difference in Flexural Modulus of Elasticity Results Using Compliance Correction and Deflection-Measuring System

	Flexural Modulus of Elasticity [GPa] Deflection-Measuring System	Flexural Modulus of Elasticity [GPa] Compliance Correction	Difference (%)
PC	2.44	2.42	1.1
PVC	3.48	3.41	2.1
GFRP	12.1	11.7	3.3

Deflection according to compliance correction and the deflection-measuring system is compared in Fig. 4, which shows deflection obtained by each method during the initial period of the test of GFRP. Results obtained from the deflection-measuring system are represented by the solid line, and results obtained by compliance correction are represented by the dotted line. The graph shows the difference between the lines.

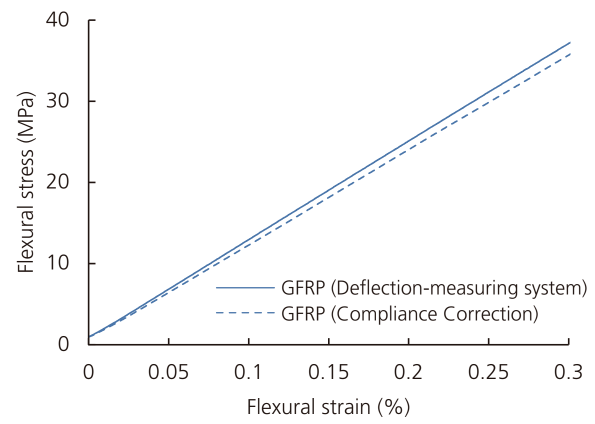

Fig. 4 Flexural Stress/Flexural Strain Curve of GFRP (Flexural strain 0 % to 0.3 %)

Conclusion

Plastics were subjected to a three-point bending flexural test with a method compliant with new standards (ISO178:2010, Amd.1:2013 and JIS K 7171:2016). Results showed the higher the flexural modulus of elasticity of a material, the larger the difference between the flexural modulus of elasticity calculated using a deflection-measuring system and compliance correction. Exact measurement of displacement with a deflection-measuring system is required for a proper evaluation of materials in compliance with the new standards.
The equipment setup employed in this article can be used to perform three-point bending flexural tests of plastics in compliance with the new standards.

Reference
1) Takeshi Murakami, Shimadzu Review Vol. 71, Issue 3/4 (2014)

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