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**JIS R 1673** : 2007  
(JFCA/JSA)

**Test method for compressive behavior  
of continuous fiber-reinforced ceramic  
matrix composites at room  
temperature**

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## Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal of establishing a Japanese Industrial Standard from Japan Fine Ceramics Association (JFCA)/Japanese Standards Association (JSA), with a draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

This Standard has been made based on **ISO 20504: 2006** *Fine ceramics (advanced ceramics, advanced technical ceramics)—Test method for compressive behaviour of continuous fibre-reinforced composites at room temperature* for the purposes of making it easier to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of an International Standard which is based on Japanese Industrial Standard.

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# Test method for compressive behavior of continuous fiber-reinforced ceramic matrix composites at room temperature

**Introduction** This Japanese Industrial Standard has been prepared based on the first edition of ISO 20504 *Fine ceramics (advanced ceramics, advanced technical ceramics) —Test method for compressive behaviour of continuous fibre-reinforced composites at room temperature* published in 2006 with some modifications of the technical contents.

The portions given sidelines or dotted underlines in this Standard are the matters different from the International Standard. A list of modifications with the explanations is given in Annex 2 (informative).

**1 Scope** This Standard specifies procedures for determination of the compressive behaviour of continuous fibre-reinforced ceramic matrix composites and carbon fibre-reinforced carbon matrix composites at room temperature. This method applies to compression tests for all ceramic matrix composites with a continuous fibre reinforcement, uni-directional (1D), bi-directional (2D) and tri-directional ( $x$ D, with  $2 < x \leq 3$ ), tested along one principal axis of reinforcement. In this standard, two cases of testing are distinguished: a) compression between platens and b) compression using grips.

NOTES 1 When the reinforced fibre in the out-of-plane direction is not vertical against the in-of-plane direction, tri-direction may be referred to as  $x$  direction ( $2 < x \leq 3$ ).

2 The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and JIS are IDT (identical), MOD (modified) and NEQ (not equivalent) according to ISO/IEC Guide 21.

ISO 20504:2006 *Fine ceramics (advanced ceramics, advanced technical ceramics)—Test method for compressive behaviour of continuous fibre-reinforced composites at room temperature* (MOD)

**2 Normative references** The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 7502 *Micrometer callipers*

NOTE : ISO 3611 *Micrometer callipers for external measurement* is equivalent to the said standard.

JIS B 7721 *Verification and calibration of the force measuring system of the tension/compression testing machines*

NOTE : ISO 7500-1 *Metallic materials—Verification of static uniaxial testing machines—Part 1: Tension/compression testing machines—Verification and calibration of the force-measuring system* is equivalent to the said standard.

JIS B 7741 *Verification of extensometers used in uniaxial testing*

NOTE : ISO 9513 *Metallic materials—Calibration of extensometers used in uniaxial testing* is equivalent to the said standard.

JIS K 7018 *Fiber-reinforced plastic composites—Determination of compressive properties in the in-plane direction*

NOTE : ISO 14126 *Fibre-reinforced plastic composites—Determination of compressive properties in the in-plane direction* is equivalent to the said standard.

JIS R 1600 *Glossary of terms relating to fine ceramics*

JIS Z 8401 *Guide to the rounding of numbers*

ASTM E 1012 *Standard Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application*

**3 Principle** A test specimen of specified shape and dimensions is loaded in compression. The compression test is usually performed at a constant cross-head displacement rate or at a constant deformation rate.

NOTES 1 Constant force rate is only allowed in the case of linear stress-strain behaviour up to fracture.

2 For cross-head displacement tests, a constant rate is recommended when the test is conducted to fracture. The force and longitudinal deformation are measured and recorded simultaneously.

**4 Terms and definitions** For the purposes of this Standard, the definitions given in JIS R 1600 and the following terms and definitions apply.

- a) **uniform gauge length,  $l$**  length of the uniform gauge (parts with a minimum cross-section area) of a test specimen
- b) **initial gauge length,  $L_0$**  initial distance between reference points (two optional points) on the test specimen in the gauge section before initiation of the test
- c) **initial cross-sectional area,  $A_0$**  initial area of the gauge section's cross-section
- d) **longitudinal deformation,  $\Delta L$**  change (contraction) of the initial gauge due to the application of a uniaxial compressive force

The longitudinal deformation corresponding to the maximum force is denoted as  $\Delta L_{c,m}$ .

- e) **compressive strain,  $\varepsilon$**  relative change in the gauge length defined as the value of the longitudinal deformation divided by the initial gauge length,  $\Delta L/L_0$

The compressive strain corresponding to the maximum force is denoted as  $\varepsilon_{c,m}$ .

- f) **compressive stress,  $\sigma$**  compressive force supported by the test specimen at any time in the test divided by the initial cross-sectional area
- g) **maximum compressive force,  $F_{c,m}$**  greatest uniaxial compressive force applied to a test specimen when tested to failure
- h) **compressive strength,  $S_{c,m}$**  greatest compressive stress applied to a test specimen when tested to failure
- i) **proportionality ratio or pseudo-elastic modulus  $E_p$ , elastic modulus  $E$**  slope of the linear region of the stress-strain curve

Examination of stress-strain curves for ceramic matrix composites allows definition of the following cases.

- For material with a linear region in the stress-strain curve, the proportionality ratio or pseudo-elastic modulus  $E_p$  is defined by Equation (1).

$$E_p(\sigma_1, \sigma_2) = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \dots \dots \dots (1)$$

where,  $(\varepsilon_1, \sigma_1)$  and  $(\varepsilon_2, \sigma_2)$  lie near the lower and the upper limits of strain and stress of the linear region of the stress-strain curve as shown in Annex A figure 1. As shown in Annex A figure 2, when linearity is seen from the area close to the origin, pseudo-elastic modulus becomes elastic modulus  $E$ .

- For material with non-linear region in the stress-strain curve, only relation of stress-strain couples is shown in the stress-strain curve, and proportionality ratio can not be defined.
- j) **axial strain** average of the longitudinal strain measured at the surface of the test specimen at specified locations (see Annex B)
- k) **bending strain** difference between the longitudinal strain at a given longitudinal location on the test specimen surface and the axial strain at the same location (see Annex B)
- l) **percent bending (%)** percent expression of a value of bending strain divided by the value of axial strain (see Annex B)
- m) **initiation buckling force,  $F_b$**  force when the longitudinal strain measured on the surface of the test specimen turns from increase to decrease in accordance with increase of force

## 5 Apparatus and devices

**5.1 Test machine** The machine shall be equipped with a system for measuring the force applied to the test specimen that shall conform to Class 1 in accordance with JIS B 7721.

**5.2 Load train** The load train is composed of movable and fixed cross-heads, the loading rods and the grips or platens. Load train couplers may additionally be used to connect the grips or platens to the loading rods.

The load train shall align the test specimen axis with the direction of force application without introducing bending or torsion in the test specimen. The misalignment of the specimen shall be verified and documented in accordance with the procedure described in Annex B. The maximum percent bending shall not exceed 5 % at an average axial strain of  $500 \times 10^{-6}$ .

There are two alternative means of force application.

- a) Compression platens are connected to the force transducer and the moving cross-head. The parallelism of these platens shall be better than 0.01 mm, in the loading area and the faces of the platens shall be perpendicular to the force application direction.

**NOTES** 1 The use of platens is not recommended for compression testing of 1D and 2D materials with small thicknesses because of buckling.

2 A compliant interlayer material (composed only of paper or cardboard), between the test specimen and platens, can be used for testing macroscopically inhomogeneous materials to ensure uniform contact pressure.

3 When the dimensions of the test specimen are such that buckling may occur, it is recommended to use anti-buckling devices similar to those described in **JIS K 7018** or **ISO 14126**. However, these devices should not introduce parasitic stresses during loading of the test specimen.

- b) Grips are used to clamp and load the test specimen. The grip design shall prevent the test specimen from slipping and the grips shall align the test specimen axis with that of the applied force.

**NOTE :** The concrete methods for the details of alignment are shown in Annex B.

**5.3 Strain measurement** For continuous measurement of the longitudinal deformation as a function of the applied force, either strain gauges or a suitable extensometer may be used. Measurement of longitudinal deformation over a length as long as possible within the gauge section length of the test specimen is recommended.

**5.3.1 Strain gauges** Strain gauges are used for the verification of the alignment on the test specimen. They may also be used to determine longitudinal deformation during testing. In both cases, the length of the strain gauges shall be such that the readings are not affected by local features on the surface of the specimen, such as fibre crossovers. Care shall be taken to ensure that the strain gauge readings are not influenced by the surface preparation and the adhesive used.

The gauges shall be generally long enough to cover 2 or more construction unit cells for both 2D and 3D materials. The strain gauges, surface preparation and adhesives should be chosen to provide adequate performance on the subject materials. Also, suitable strain-conditioning and recording equipment should be used.

**5.3.2 Extensometer** The linearity tolerance of the extensometer shall be less than 0.15 % of the extensometer range used. Extensometers shall meet the requirements as specified in JIS B 7741.

**5.3.2.1 Mechanical extensometer** For a mechanical contact type extensometer, the gauge length corresponds to the longitudinal distance between the two locations where the extensometer contacts the test specimen. Mounting of the extensometer to the test specimen shall prevent slippage of the extensometer at the contact points and shall not initiate failure under the contact points. Any extensometer contact forces shall not introduce bending greater than that allowed in 5.2.

**5.3.2.2 Electro-optical extensometer** Electro-optical measurements of strain require reference marks on the test specimen. For this purpose, fiducial marks such as rods or flags are attached to the test specimen surface perpendicular to the longitudinal axis of the test specimen. The initial gauge length corresponds to the longitudinal distance between the two fiducial marks.

NOTE : The use of integral flags as part of the test specimen geometry is not recommended, because of stress concentrations induced by such features.

**5.4 Data recording system** A calibrated recorder may be used to record force-deformation curves. The use of a digital data recording system combined with an analog recorder is recommended.

**5.5 Dimension measuring devices** Devices used for measuring linear dimensions of the test specimen shall be accurate to  $\pm 0.1$  mm or superior. Micrometers shall be in accordance with JIS B 7502.

**6 Test specimens** The shape of test specimens shall be chosen depending on the nature of the material and of the reinforcement structure and test method. The ratio between the length of the test specimen subject to buckling and the thickness of the test specimen, in addition to the stiffness of the material, will influence the resistance of the test specimen to buckling. If buckling occurs, it may be necessary to modify the dimensions of the test specimen or alternatively to use an anti-buckling device.

The anti-buckling device includes fixed lateral guides pressed against the test specimen so as to freely allow longitudinal motion while simultaneously suppressing transverse motion.

The volume in the gauge length shall be representative of the material. Two types of test specimens can be distinguished as follows.

- As-fabricated test specimens, where only the length and the width are machined to the specified size. In this case, the two faces of the test specimen may present irregular surfaces while the two edges present regular machined surfaces.
- Machined test specimens, where the length and the width, as well as the two faces of the test specimen, have been machined and present regular machined surfaces.