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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for tensile strength of monolithic ceramics at room temperature

Céramiques techniques — Méthode d'essai de résistance à la traction des céramiques monolithiques à température ambiante

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15490 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

This second edition cancels and replaces the first edition (ISO 15490:2000), which has been technically revised.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for tensile strength of monolithic ceramics at room temperature

1 Scope

This International Standard specifies the test method for determining the tensile strength under uniaxial loading of monolithic fine ceramics and whisker or particulate-reinforced ceramic composites at room temperature. This test method, in which parasitic bending is minimized, may be used for material development, material comparison, quality assurance, characterization and design data generation.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3611:1978, *Micrometer callipers for external measurement*

ISO 7500-1:2004, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
tensile stress
value of tensile force applied to a test specimen divided by the original cross-sectional area of the gauge part of a test specimen

3.2
tensile strength
maximum tensile stress applied to a test specimen during a tensile strength test

3.3
maximum tensile force
maximum force applied to a test specimen during a tensile strength test

3.4
gauge section
parallel portion of the test specimen having the same cross-section as its middle part

3.5
gripped region
end part of a test specimen which is held by the gripping device of a tensile test machine

3.6
gripping device
device to hold a test specimen and to transfer a force to a test specimen during a tensile test

3.7
bending strain component
value of bending strain generated on the surface of the gauge part of a test specimen by axial misalignment, divided by the average strain

3.8
percent bending
bending strain component times 100

3.9
strain
fractional increase in length when a test specimen is loaded in tension

3.10
breaking force
force at which fracture occurs

4 Principle

The test consists of applying a tensile force to a test specimen by uniaxial loading until fracture, for the purpose of determining the tensile strength.

5 Apparatus

5.1 Tensile testing machine

The testing machine used for the tensile test shall conform to the requirements of ISO 7500-1:2004, Class 1.

5.2 Gripping devices

Every endeavour shall be made to ensure that test specimens are held in such a way that the force is applied as axially as possible (see 7.2). For this purpose, various types of gripping device may be used.

NOTE The gripping devices that have been applied to measuring tensile strength of monolithic ceramics and their advantages/disadvantages are shown in ASTM C 1273.

6 Test specimen

6.1 Shape and dimensions

The shape and dimensions of the test specimens depend on several factors, including the purpose of the tensile test itself, the gripping devices, and the shape and dimensions of the ceramic products whose tensile strength is to be determined. Therefore, various shapes and dimensions may be used.

The shapes and dimensions, however, shall be determined so that the tensile stress is applied uniformly in the gauge section (see 7.2). Also, it shall be ensured that stress concentrations which could lead to undesired fractures outside the gauge section are minimized. In addition, the cross-section of the gauge section shall be uniform, with a dimensional accuracy greater than ± 0,5 %.

The test specimens that have been applied to testing fine ceramics are shown in Annex A.

6.2 Test specimen preparation

Surface finishes in the gauge section of the order of average roughness Ra 0,2 µm to 0,4 µm (measured in the longitudinal direction) are recommended in order to avoid surface-roughness-related fracture.

Unless it is part of an exercise to determine the effects of grinding methods, it is highly recommended that the final grinding operation in the gauge section be performed along the longitudinal direction of the test specimen, in order to ensure that grinding marks are parallel to the applied tensile stress.

Care shall be taken in storage and handling of finished test specimens to avoid the introduction of random and severe flaws.

NOTE In some cases, the final surface finish might not be as important as the subsurface damage produced during the grinding process. This damage is not readily observed or measured.

6.3 Number of test specimens

As a general rule, a minimum of ten tests is required for the purpose of estimating a mean, and thirty or more tests are needed to estimate the strength distribution parameters, such as Weibull modulus and characteristic strength

Tests with fractures outside the gauge section shall not be included in the calculation of the mean or standard deviation, but may be included in the calculation of Weibull statistics as censored tests.

NOTE The number of test specimens needed for the test depends on the precision required for estimating the parameters of strength properties.

7 Procedures

7.1 Test specimen dimensions

The diameter or thickness and width of the gauge section of each test specimen shall be determined to within 0,02 mm. Measurements on at least three different cross-sections in the gauge section shall be made. The average of the multiple measurements shall be used in calculating the cross-sectional area.

7.2 Axial alignment

The testing system shall be verified using the following procedures.

Three or four strain gauges are equally spaced around the circumferences on two cross-sectional planes. The strain gauge planes shall be symmetrically located about the longitudinal midpoint of the gauge section, and shall be separated by at least 3/4 of the length of the gauge section. When the gauge section is not long enough to have two strain gauge planes, one plane may be used. In this case, the location shall be the longitudinal midpoint of the gauge section. When axial strain gauges are mounted, the gauge axis shall be aligned with the stress axis, so that the deviation is less than 0,035 rad (2°).

Ideally, the verification shall be made for all the individual test specimens to be tested. However, if this is not possible or desired, a permanent strain-gauged “dummy” test specimen may be used, provided that the test specimen to be tested has exactly the same shape as the “dummy” one. It is most preferable that it be of the same material as that to be tested.

Mount the test specimen in the gripping device and apply a load so as to give an average strain of one half of that expected at fracture. Measure the amount of strain as a function of average strain, and calculate the percent bending using the following equation:

$$B = 2 \times \frac{[(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_4)^2]^{1/2}}{\varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4} \times 100$$

for four gauges and

$$B = 2 \times \frac{(\varepsilon_1{}^2 + \varepsilon_2{}^2 + \varepsilon_3{}^2 - \varepsilon_1\varepsilon_2 - \varepsilon_2\varepsilon_3 - \varepsilon_3\varepsilon_1)^{1/2}}{\varepsilon_1 + \varepsilon_2 + \varepsilon_3} \times 100$$

for three gauges,

where

B is the percentage bending;

ε_1, ε_2, ε_3 and ε_4 are the strain readings for strain gauges.

When alignment is verified for the individual test specimens, percentage bending shall not exceed 7,5 % at an average strain of one-half that expected at fracture. Alignment with a percentage bending of 5 % or less is required when the testing system is verified using a permanent strain-gauged "dummy" test specimen, since this will minimize the contribution of the testing system to percentage bending in the actual test specimens.

This verification shall be made at least at the beginning and end of each test series. Verification is highly recommended for all the test specimens.

Care shall be taken to avoid placing the strain gauges too near geometric transitions in the gauge section which can cause strain concentration and inaccurate measurements of the strain in the uniform gauge section.

NOTE Information on bending in tensile strength tests is available in ASTM C 1273-05, Annex.

7.3 Test mode and rates

Various test modes, including force, displacement (of the test machine cross-head) and strain control may be used. Sufficiently rapid testing rates are recommended so that final fracture is reached in less than 10 s in order to minimize environmental effects and thus obtain the intrinsic value of the ultimate tensile strength. In the case of evaluating rate effects, lower rates can be used. In all cases, the test mode and rate shall be reported.

The most common test mode is displacement control. In this case, cross-head speeds greater than 0,008 33 mm/s (0,5 mm/min) are recommended. For force control, stress rates greater than 20 MPa/s are recommended. Generally, these conditions satisfy the above requirements if the testing assembly is sufficiently rigid during the last half of the duration of the test.

7.4 Recording

After conducting the test, the breaking force shall be read to an accuracy of 1,0 % and noted for the report, and the fracture location shall be identified. If required, examine the fracture surface with a microscope to determine the position and nature of the fracture origin.

8 Calculation

8.1 Tensile strength

The following formula shall be used for calculating the tensile strength for each test.

$$R_m = \frac{F_m}{A}$$

where

R_m is the tensile strength;

F_m is the maximum tensile force;

A is the cross-sectional area.

8.2 Mean and standard deviation

The mean and standard deviation for each test series shall be calculated as follows.

$$X_m = \frac{\sum X_i}{n}$$

$$\mathrm{SD} = \left[\frac{\sum (X_i - X_m)^2}{n-1} \right]^{1/2}$$

where

X_m is the mean deviation;

X_i is the measured value;

n is the number of valid tests;

SD is the standard deviation.

9 Report

9.1 Test set

The following information shall be reported for each test set:

a) shape and dimensions of test specimen;

b) testing machine (in the case of a commercial testing machine, report the manufacturer and the model number);

c) gripping device (in the case of a commercial gripping device, report the manufacturer and the model number);

d) number of test specimens tested in a valid fashion (fractured within the gauge section);

e) total number of test specimens tested;

f) all material data, including vintage data or billet identity data;

g) test-specimen-preparation procedure, including all stages of machining;

h) heat treatments, or pre-test exposures, applied to the as-processed material or to the as-fabricated test specimen;

i) test environment, including relative humidity, ambient temperature, and atmosphere (e.g. in air, nitrogen, vacuum, silicon oil, etc.);

j) test mode (force, stress, displacement or strain control) and test rate (force, stress, displacement or strain rates);

k) percentage bending and corresponding average strain measured in the axial alignment verification;

l) the number of the strain gauges used for each of the verifications;

m) mean tensile strength and standard deviation;

n) strength distribution parameters (Weibull modulus and characteristic strength), if calculated;

o) any significant deviations from the procedures and requirements of this International Standard.

9.2 Individual test specimen

The following information shall be reported for each specimen tested:

a) pertinent overall test specimen dimensions, if measured;

b) average cross-sectional dimensions of the gauge section;

c) average surface roughness, if measured, of the gauge section measured in the longitudinal direction;

d) breaking force;

e) calculated tensile strength;

f) fracture strain, if measured;

g) force-strain curve, or force-time curve, if recorded;

h) fracture location relative to the gauge-section midpoint (positive is toward the top of the test specimen as marked, and negative is toward the bottom of the test specimen as marked, with 0 being the gauge-section midpoint);

i) result of fractography (type and location of fracture origin), if conducted;

j) any significant deviations from the procedures and requirements of this International Standard.

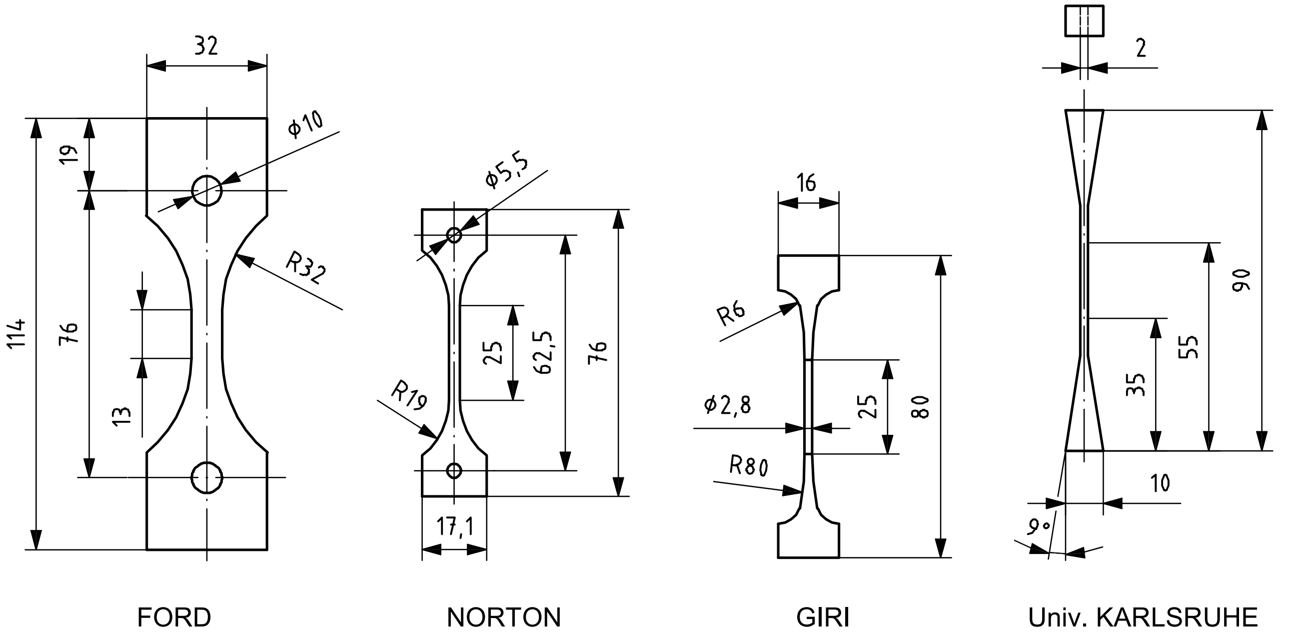
Annex A
(informative)

Shape and dimensions of test specimen

The shape and dimensions of tensile test specimens are limited by several factors. When a tensile test is performed for the purpose of knowing the tensile strength of an as-fabricated component, the dimensions of the possible test specimen are limited by the dimension of the component. If it is desired to evaluate the effects of inherent flaw distributions for a particular material, the test specimen should reflect the desired volume or surface area to be sampled. Also, gripping devices may restrict the design of the test specimen shape. For these reasons, this International Standard does not specify fixed shapes and dimensions of test specimens. The range of possible tensile-test-specimen shapes that have been used for advanced ceramics is illustrated in Figure A.1 (after Reference [1] in the Bibliography).

One of the significant features of the tensile test is the advantage of determining strength from a large effective volume in comparison with the flexural test. It is, therefore, highly recommended to use a test specimen with a gauge section of ample dimensions. The shape and dimensions of a gauge section provided by JIS R 1606 [2] and KSL 1599 [3], as shown in Figure A.2, are good examples of this. Many of the test specimens used to date, including NPL, WESTINGHOUSE, WESTINGHOUSE/ASAHI-GLASS, ORNL, NGK and SoRI shown in Figures A.1 b) and A.1 c), have gauge sections whose shape and dimensions are close to those shown in Figure A.2. It has also been observed that gauge sections very frequently have a circular cross-section and their diameters are less than one-fifth of their lengths.

Dimensions in millimetres



a)

Key

FORD: Ford Motor Co., U.S.A.

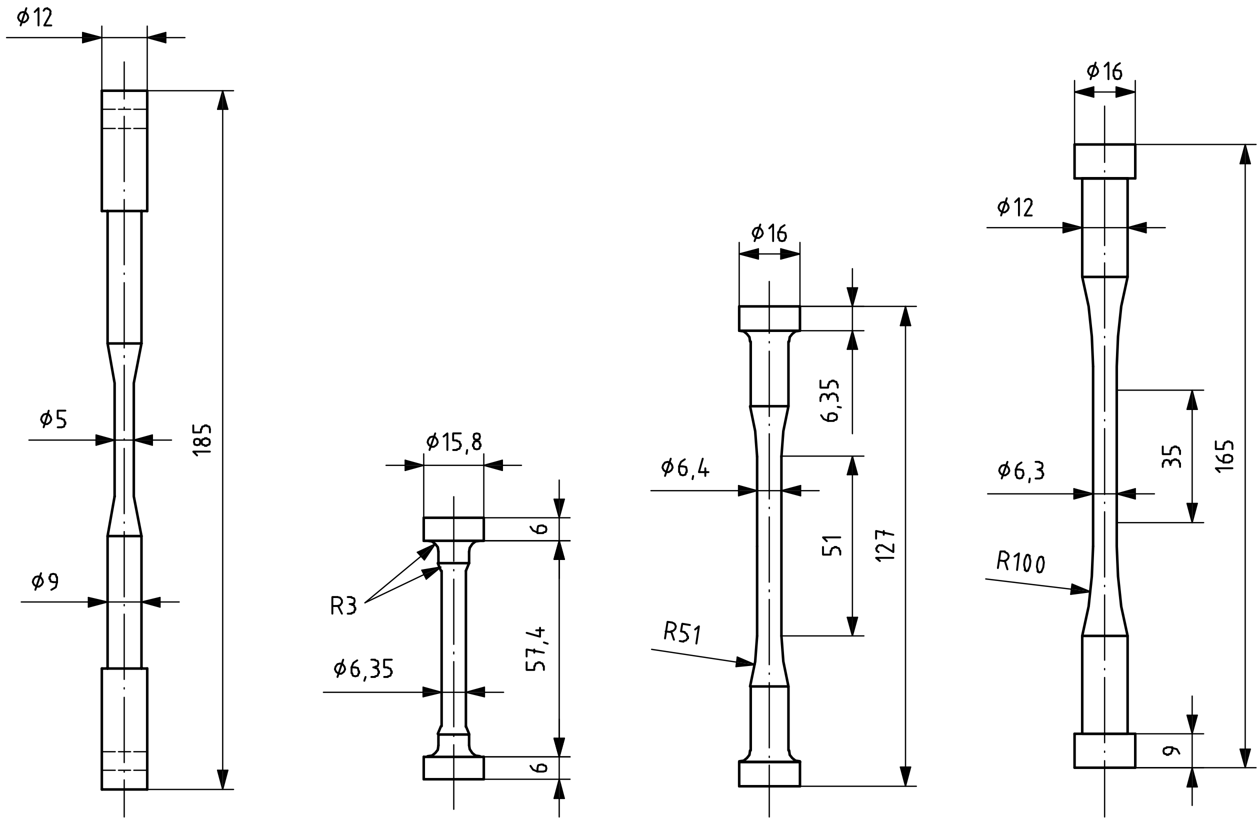
NORTON: Norton Co., U.S.A.

GIRI: Government Industrial Research Institute, Japan

Univ. KARLSRUHE: University of Karlsruhe, Germany

Figure A.1 — Variety of tensile test specimen shapes used for advanced ceramics
(after Reference [1] in the Bibliography)

Dimensions in millimetres



NPL WESTINGHOUSE WESTINGHOUSE/ASAHI-GLASS ORNL

b)

Key

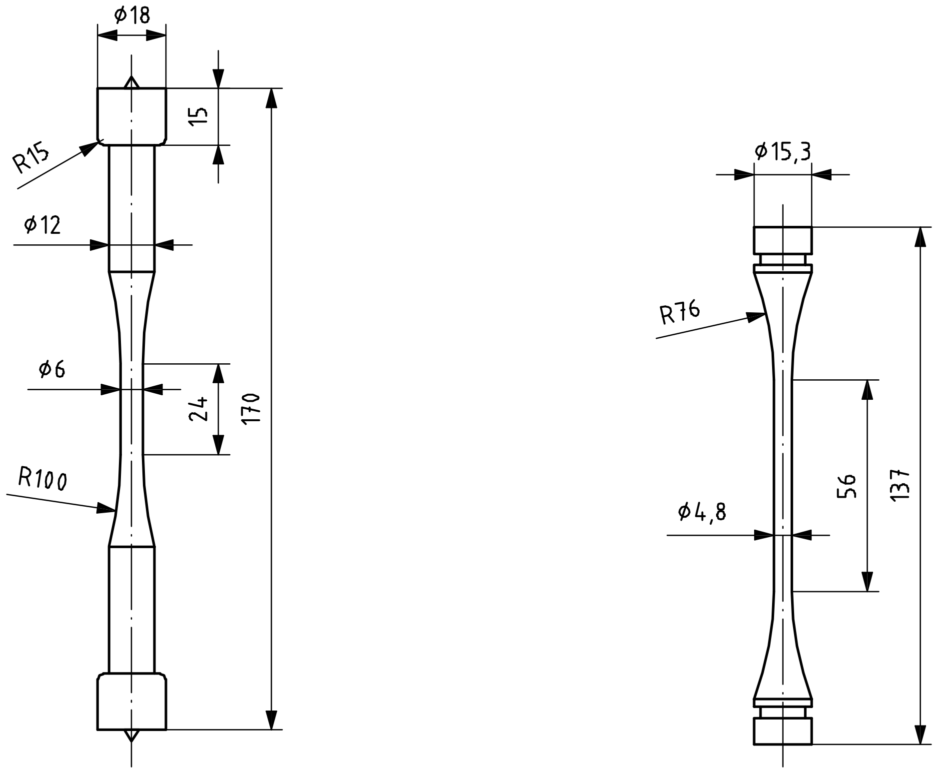
NPL: National Physical Laboratory, U.K.

WESTINGHOUSE: Westinghouse Research Labs., U.S.A.

ASAHI-GLASS: Asahi Glass Co., Japan

ORNL: Oak Ridge National Laboratory, U.S.A.

Figure A.1 (*continued*)



NGK

SoRI

c)

Key

NGK: NGK Insulators Co., Japan

SoRI: Southern Research Institute, U.S.A.

Figure A.1 (*continued*)

Dimensions in millimetres

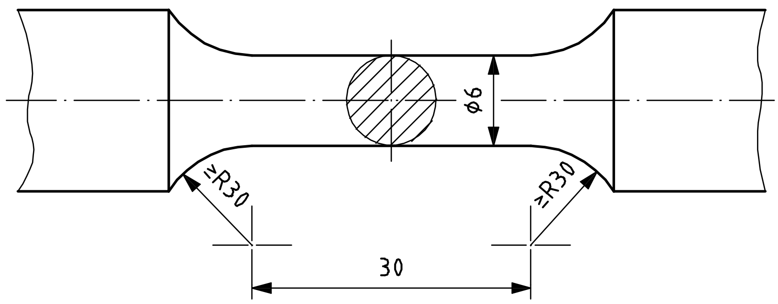


Figure A.2 — Shape and dimensions of test specimen in accordance with JIS R 1606 [2] and KSL 1599 [3]

Bibliography

[1] ASTM C 1273-05, *Standard Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures*

[2] JIS R 1606, *Testing methods for tensile strength of high performance ceramics at room and elevated temperature*

[3] KSL 1599, *Testing methods for tensile strength of high performance ceramics at room and elevated temperatures*

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