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Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of friction and wear characteristics of monolithic ceramics by ball-on-disc method

Céramiques techniques — Détermination des caractéristiques de frottement et d'usure des céramiques monolithiques par la méthode «bille sur disque»

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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.

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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.

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ISO 20808 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of friction and wear characteristics of monolithic ceramics by ball-on-disc method

1 Scope

This International Standard specifies a procedure for and provides guidance on the determination of the coefficient of friction and the specific wear rate for monolithic ceramics. In this method, the materials are tested in pairs, in a ball-on-disc configuration, under dry, non-abrasive conditions.

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 31-0, *Quantities and units — Part 0: General principles*

ISO 1101, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 3599, *Vernier callipers reading to 0,1 and 0,05 mm*

ISO 3611, *Micrometer callipers for external measurement*

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 18754*, Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of density and apparent porosity*

3 Terms and definitions

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

3.1
wear
progressive mass removal from the surface of solid material due to relative motion with a contacting substance or substances

3.2
wear test
method of evaluating the friction and wear performance of materials in sliding contact

3.3
ball-on-disc method
one of the wear test methods in which the sliding contact is brought about by pushing a ball specimen on to a rotating disc specimen under a constant load

3.4
friction force
resisting force tangential to the interface between two bodies, when one body moves or tends to move relative to the other under the action of a normal force pressing these bodies together

3.5
coefficient of friction
μ
dimensionless ratio of the friction force, F_f, to the applied normal force, F_p
$\mu = F_f/F_p$

3.6
specific wear rate
W_s
rate of material removal by wear, expressed by means of the wear volume, V, per unit applied normal force, F_p and unit sliding distance, L where $W_s = V/(F_p \times L)$

4 Significance and use

This International Standard gives guidance on conducting a sliding friction and wear test in a ball-on-disc configuration. It shall be used to determine the wear resistance and friction generated in uniaxial sliding contacts between ceramics.

It should be noted that there are many parameters in sliding contact that affect the magnitude of friction and wear. The aim of performing any wear test is to simulate, as closely as possible, the conditions that occur in the real application. As the deviation between the test conditions and the application conditions becomes larger, the test results become less relevant. To add credence to the test results, the appearance of the worn surfaces from the test samples shall be compared with the appearance of the worn surface from the actual worn component in order to ensure that similar wear mechanisms have taken place in each case.

The recommended test conditions suggested in this International Standard shall be used when the application conditions are not well defined but general comparison among materials is required.

5 Test materials and specimen preparation

5.1 Materials

This test method can be applied to a variety of materials. The only requirement is that ball and disc specimens having the dimensions specified below can be prepared, and that they shall withstand the stresses imposed during the testing without failure or excessive flexure. In principle, the ball and disc specimen should be from the same material, but ball and disc specimens from different materials can also be tested by this method. Any pertinent details of the materials such as their dimensions, surface finish, material type, composition, microstructure and processing treatments shall be supplied.

5.2 Ball specimen

The ball specimen shall be a true sphere of more than 5 mm diameter, or a straight rod whose end part is machined to a spherical cap. The recommended diameter of the sphere is 10 mm. The surface roughness of the specimen shall be not more than 0,1 µm Ra as specified in ISO 4287.

5.3 Disc specimen

The disc specimen shall be more than 3 mm in thickness and be large enough to enable the testing surface to contain a sliding circle of more than 30 mm diameter. The surfaces of the disc shall be flat and parallel to within 0,02 mm as specified in ISO 1101. The roughness of the test surface shall be not more than 0,1 μm Ra as specified in ISO 4287.

6 Apparatus

6.1 Ball-on-disc method testing apparatus.

The testing apparatus shall consist of:

— the disc holder, for securing a disc specimen;

— the drive system for rotating the disc;

— the ball holder for gripping a ball specimen;

— the loading mechanism for pushing the ball specimen on to the disc specimen;

— the equipment for measuring the friction force and the linear wear;

— the equipment for controlling the testing atmosphere;

— the ancillary devices for the above.

a) The disc holder shall rotate in a horizontal or vertical plane. The eccentricity of rotating axis shall be less than 0,02 mm and the fluctuation at the contact point in the direction perpendicular to the disc shall be less than 0,05 mm.

b) The drive system shall be capable of giving a controllable sliding speed that is stable under the influence of the friction forces that are generated. The drive system shall be fitted with a revolution counter or equivalent device.

c) The ball holder shall firmly grip the ball specimen and have a high rigidity with respect to the stress generated at the contact point with the disc specimen.

d) The loading mechanism shall apply a controlled load to the ball holder directly or through a lever-arm device with attached weight, or by a hydraulic or pneumatic system.

e) The friction force shall be measured by means of mechanisms, such as a load cell, distortion of a leaf spring or measurement of rotational torque. The measurement should not affect the frictional condition. The accuracy of friction measurement shall be ± 1 % or better of the applied load. A device for measuring the linear wear is optional, but when provided it should have a sensitivity of 2,5 μm or better.

f) The testing atmosphere shall be controlled to within ± 2 °C of the set temperature and the relative humidity to 50 % ± 10 %. Alternatively, the testing apparatus itself can be placed in a room with conditions controlled to these limits.

g) If the specification of testing apparatus is different from the above, it shall be described in the test report.

6.2 Balance, capable of measuring the mass of the specimen to the nearest 0,01 mg.

6.3 Micrometer calliper, capable of measuring as specified in ISO 3611 or equivalent or better.

6.4 Vernier calliper, having a resolution of 0,05 mm as specified in ISO 3599 or equivalent or better.

6.5 Micrometer microscope, capable of reading to the nearest 0,01 mm.

6.6 Contact stylus profilometer, as specified in ISO 3274 or at least equal thereto in precision.

7 Testing procedure

7.1 Determination of specimen density

Measure the diameter of the ball specimen and the diameter and thickness of the disc specimen using a micrometer calliper (6.3), vernier calliper (6.4) or equivalent, and calculate the density of the specimen from the mass measured in accordance with 7.3. The density value measured by another method having equivalent or superior precision can also be used, e.g., density determination in accordance with ISO 18754.

7.2 Treatment of specimen before test

Wash specimens ultrasonically in high purity acetone for 10 min or longer, with the testing surface downwards in the case of the disc specimen. Without allowing them to dry, the specimens should be rinsed with high purity hexane and then dried for 30 min or longer in an oven set at 120 °C. Acetone and/or hexane can be replaced with other solvents or deionized water as long as clean specimen surfaces are produced at the end of the procedure. The specimens shall be stored in the same atmosphere as that used for the wear testing apparatus until required.

7.3 Measurement of mass before test

Measure the mass of each specimen by weighing it with a balance (6.2) immediately before the wear test.

7.4 Preparation of wear test

Clamp the ball and disc specimen firmly in position in their respective holders and bring them gently into contact, then apply the set load. After the testing atmosphere has stabilized for at least 30 min, start the test by rotating the disc at the set condition.

7.5 Testing conditions

Recommended test conditions are listed below, but can be changed to suit the particular needs of the measuring process. All test conditions shall be described in the test report.

a) **Applied load**: 10 N.

b) **Sliding speed**: 0,1 m/s; the diameter of the sliding circle should be more than 30 mm and the rotational velocity of disc holder be determined from

$$v_r = v/2\pi R.$$

where

v_r is the rotational velocity, in rotations per second (s^{-1});

v is the sliding speed, in metres per second;

R is the sliding circle radius, in metres.

c) **Sliding distance**: 2 000 m.

d) **Testing atmosphere**: air at room temperature; the temperature should be controlled to within ± 2 °C and the relative humidity to within 50 % ± 10 %.

7.6 Measurement of friction force

Measure the friction force continuously during the test and record it by using a data logger or other recording device. An appropriate system for averaging the fluctuation with rotation period shall be adopted. Before the test starts, the zero of the friction force measurement device should be checked with the specimens not in contact with one another.

7.7 Measurement of mass after test

After the wear test has been completed, give the specimens the same cleaning treatment as in 7.2, and then measure the mass using the same balance as in 7.3. The wear debris on the disc specimen shall be carefully collected for further analysis before this treatment.

7.8 Measurement of wear scar on ball specimen

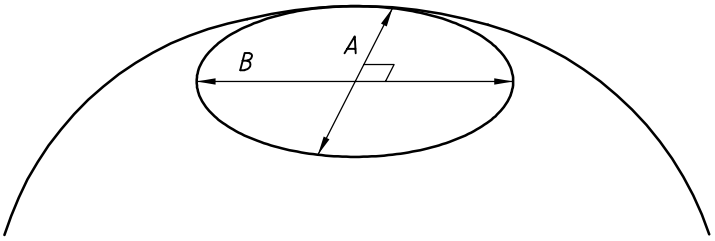
On completion of the test there will be a roughly circular scar on the ball specimen, as shown in Figure 1. Measure the minimum diameter, A, and the diameter in a direction perpendicular to it, B, by using the micrometer microscope (6.5).

7.9 Measurement of wear track on disc specimen

On completion of the test there will be a wear track on the disc specimen, as shown in Figure 2. Measure the cross-sectional profile of the wear track at four places (S_1 – S_4) at intervals of 90° using a contact stylus profilometer (6.6) or similar instrument and calculate the cross-sectional area of the wear track at each position.

7.10 Number of test repeats

Repeat the wear test at least three times under the same testing conditions.

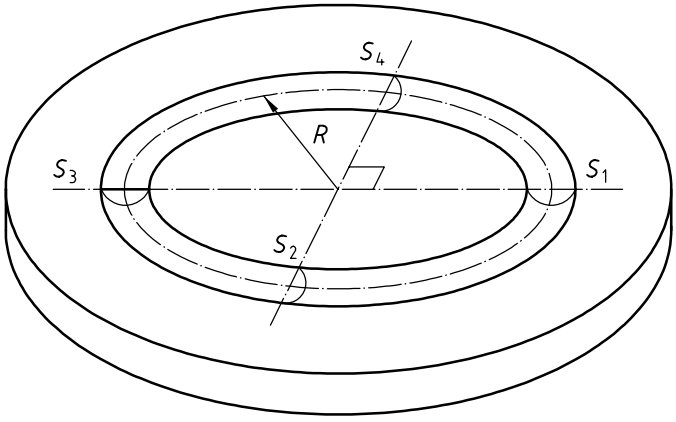


Key

A minimum diameter

B perpendicular diameter

Figure 1 — Wear scar on ball specimen



Key

R radius

S_n cross-sectional profiles where n is 1, 2, 3 or 4

Figure 2 — Wear track on disc specimen

8 Calculation of test results

8.1 Specific wear rate of ball specimen

8.1.1 Specific wear rate according to wear volume

Calculate the wear volume of the ball specimen using Equation (1) from the minimum diameter of wear scar and the diameter in a direction perpendicular to it, which were measured in 7.8.

$$V_{\text{ball}} = \frac{\pi A^3 B}{32D} \tag{1}$$

where

V_{ball} is the wear volume of ball specimen, in cubic metres;

A is the minimum diameter of wear scar, in metres;

B is the diameter in direction perpendicular to minimum diameter, in metres;

D is the diameter of ball specimen, in metres.

When the shape of the wear scar is warped because of the large groove of wear track on the disc specimen ($B > 1{,}5\,A$), this formula shall not be applied and the wear volume can be obtained by profiling the wear scar accurately with a profilometer or similar instrument.

The specific wear rate of the ball specimen shall be obtained from V_{ball} in Equation (1) by means of Equation (2).

$$W_{\text{s(ball)}} = \frac{V_{\text{ball}}}{F_{\text{p}} \times L} \tag{2}$$

where

$W_{\text{s(ball)}}$ is the specific wear rate of ball specimen, in square metres per newton;

F_{p} is the applied load (normal force), in newtons;

L is the sliding distance, in metres.

8.1.2 Specific wear rate according to mass loss

The specific wear rate shall be calculated from the difference due to wear between the mass of the ball specimen before and after the test, by means of Equation (3).

$$W_{\text{s(ball)}} = \frac{m_{\text{before}} - m_{\text{after}}}{F_{\text{p}} \times L \times \rho_{\text{ball}}} \tag{3}$$

where

$W_{\text{s(ball)}}$ is the specific wear rate of ball specimen, in square metres per newton;

m_{before} is the mass before test, in kilograms;

m_{after} is the mass after test, in kilograms;

ρ_{ball} is the density of ball specimen, in kilograms per cubic metre.

If the mass loss is very small compared with the total mass or is not detectable [$(m_{before} - m_{after})/m_{before} < 0{,}000\ 1$] the specific wear rate from the mass loss shall not be used.

8.2 Specific wear rate of disc specimen

8.2.1 Specific wear rate according to wear volume

Calculate the wear volume of the disc specimen from the cross-sectional area of wear track, which was measured as described in 7.9, by means of Equation (4).

$$V_{disc} = \frac{\pi \times R(S_1 + S_2 + S_3 + S_4)}{2} \tag{4}$$

where

V_{disc} is the wear volume of disc specimen, in cubic metres;

R is the radius of wear track, in metres;

S_1 to S_4 represent cross-sectional areas at four places on wear track circle in square metres.

If the ratio of the maximum to the minimum cross sectional area exceeds 1,5, Equation (4) shall not be applied.

The specific wear rate of the disc specimen shall be obtained from V_{disc} in Equation (4) by means of Equation (5).

$$W_{s(disc)} = \frac{V_{disc}}{F_p \times L} \tag{5}$$

where

$W_{s(disc)}$ is the specific wear rate of disc specimen, in square metres per newton;

F_p is the applied load, in newtons;

L is the sliding distance, in metres.

8.2.2 Specific wear rate according to mass loss

The specific wear rate shall be calculated from the difference due to wear between the mass of the disc specimen before and after the test, by means of Equation (6).

$$W_{s(disc)} = \frac{m_{before} - m_{after}}{F_p \times L \times \rho_{disc}} \tag{6}$$

where

$W_{s(disc)}$ is the specific wear rate of disc specimen in square metres per newton;

m_{before} is the mass before test, in kilograms;

m_{after} is the mass after test, in kilograms;

ρ_{disc} is the density of disc specimen, in kilograms per cubic metre.

If the mass loss is very small compared with the total mass or is not detectable [$(m_{\text{before}} - m_{\text{after}})/m_{\text{before}} < 0{,}000\ 1$] the specific wear rate from the mass loss shall not be used.

8.3 Coefficient of friction

Calculate the coefficient of friction from the applied load and the average value of friction force by means of Equation (7).

$$\mu = \frac{\bar{F}_{\text{f}}}{F_{\text{p}}} \tag{7}$$

where

μ is the coefficient of friction;

$\bar{F}_{\text{f}}$ is the average value of friction force, in newtons;

F_{p} is the applied load, in newtons.

As the coefficient of friction usually changes with sliding distance, initial, steady-state, maximum and minimum values shall be determined and reported, when available.

8.4 Rounding off of numerical values

The specific wear rate and the coefficient of friction shall be stated to two significant digits in accordance with ISO 31-0.

9 Test report

The test report shall contain the following information.

a) description of material or materials tested;

b) specification of wear testing apparatus (disc driving method, orientation of disc rotation, loading method, friction force detecting method, atmosphere control method, etc.);

c) testing conditions (applied load, sliding speed, diameter of sliding circle, rotational velocity of disc, sliding distance, etc.);

d) the following items shall be reported for each individual test:

   1) testing temperature, humidity and their ranges;

   2) initial mass, dimension and density of ball specimen and disc specimen;

   3) wear volume and/or mass loss of ball specimen and specific wear rate calculated from them;

   4) wear volume and/or mass loss of disc specimen and specific wear rate calculated from them;

   5) coefficient of friction at initial, steady-state, maximum and minimum, when available;

   6) other matters to be written especially with regard to the state of test and the specimen after test.

If, for the specific wear rate, a representative value under the same testing conditions is required, the arithmetic mean of each value shall be used, and for the coefficient of friction, the arithmetic mean of each steady-state value shall be used.

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