BRITISH STANDARD

BS ISO
26602:2009

Fine ceramics (advanced ceramics, advanced technical ceramics) — Silicon nitride materials for rolling bearing balls

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Foreword

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INTERNATIONAL STANDARD **ISO 26602:2009(E)**

Fine ceramics (advanced ceramics, advanced technical ceramics) — Silicon nitride materials for rolling bearing balls

1 Scope

This International Standard specifies the requirements for preprocessed silicon nitride materials for rolling bearing balls.

This International Standard provides a classification defining physical and mechanical properties of silicon nitride preprocessed bearing ball materials. The materials are classified in three categories by the specification of characteristics and microstructures. Methods for sample preparation and observation of microstructures are provided in Annex A.

NOTE The silicon nitride product means the sintered body of which the main component is silicon nitride material.

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 14704, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature*

ISO 14705, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for hardness of monolithic ceramics at room temperature*

ISO 15732, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture toughness of monolithic ceramics at room temperature by single edge precracked beam (SEPB) method*

ISO 17561, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance*

ISO 17562, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for linear thermal expansion of monolithic ceramics by push-rod technique*

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

ISO 20501, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Weibull statistics for strength data*

ISO 20507, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Vocabulary*

ASTM F2094, *Standard Specification for Silicon Nitride Bearing Balls*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20507 and the following apply.

3.1
fracture resistance
$K_{I, IFR}$
fracture resistance measured in accordance with the indentation fracture (IF) method specified in ASTM F2094, Annex

3.2
material class
specific combination of physical and mechanical properties of the silicon nitride material

3.3
preprocessed ball
densified unit of material from a material lot before final shaping and finishing

3.4
material lot
defined quantity of raw material ready for the shaping and densification of ball shapes and/or test items

3.5
inclusion
region that differs from the normal silicon nitride microstructures

3.6
fracture toughness
$K_{I,SEPB}$
measured critical stress intensity factor in accordance with the single edge precracked beam (SEPB) method specified in ISO 15732

4 Physical and mechanical properties

Typical ranges of physical and mechanical properties of a preprocessed ball are given in Table 1. Physical and mechanical properties shall be measured in accordance with 6.1 to 6.4. Values for thermal conductivity, specific heat and electrical resistivity are subject to agreement between the parties concerned.

Table 1 — Physical and mechanical properties

Properties	Minimum	Maximum
Density (g/cm^3)	3,0	3,6
Elastic modulus (GPa)	270	330
Poisson's ratio	0,23	0,29
Coefficient of thermal expansion, $\times 10^{-6}$/°C (applicable range: room temperature to 500 °C)	2,0	3,7

5 Material classification

Silicon nitride materials for rolling bearing balls are divided into three classes according to the physical and mechanical properties of the material (see Annex B).

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6 Test

6.1 Density

Preprocessed balls shall be used as the test specimens.

The test shall be conducted in accordance with ISO 18754.

6.2 Elastic modulus

Test pieces shall be fabricated from the same material lot as the preprocessed balls.

The test shall be conducted in accordance with ISO 17561.

6.3 Poisson's ratio

Test pieces shall be fabricated from the same material lot as the preprocessed balls.

The test shall be conducted in accordance with ISO 17561.

6.4 Coefficient of thermal expansion

Test pieces shall be fabricated from the same material lot as the preprocessed balls.

The test shall be conducted in accordance with ISO 17562.

6.5 Flexural strength and Weibull modulus

Test pieces shall be fabricated from the same material lot as the preprocessed balls.

Average values for flexural strength at room temperature and Weibull modulus shall be evaluated in accordance with ISO 14704 and ISO 20501. Either 4-point or 3-point test methods may be used for flexural strength.

6.6 Hardness

Polished sections of the preprocessed balls shall be used for the test.

Average values for Vickers hardness shall be evaluated in accordance with ISO 14705. The test force shall be HV5, HV10 or HV20.

6.7 Indentation fracture resistance

6.7.1 The polished sections of the preprocessed balls shall be used for the indentation fracture (IF) method. The surface finishing shall be carried out to avoid residual stress.

6.7.2 Average values for fracture resistance in the indentation fracture (IF) method shall be evaluated in accordance with ASTM F2094, Annex.

If necessary, test pieces for the single edge precracked beam (SEPB) method shall be fabricated from the same material lot as the preprocessed balls. Average values for fracture toughness determined by the single edge precracked beam (SEPB) method shall be evaluated in accordance with ISO 15732.

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6.8 Microstructure

Polished sections of the preprocessed balls shall be used for microstructure inspection. Sample preparation and observation shall be conducted as described in Annex A.

7 Classification of materials

According to the values obtained from the test on a material sample, the material lot shall be classified as Class 1, Class 2 or Class 3 (see Table B.1).

8 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) the date of the test;

c) the raw powder lot;

d) the test results:

   1) density;

   2) elastic modulus;

   3) Poisson's ratio;

   4) coefficient of thermal expansion;

   5) average flexural strength and average Weibull modulus;

   6) Vickers hardness (test conditions, average hardness);

   7) average fracture toughness and fracture resistance (test method, average fracture toughness or fracture resistance);

   8) microstructure (sizes and numbers of pores and inclusions);

e) the material class;

f) any additional information relevant to the evaluation.

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Annex A
(normative)

Microstructure observation procedure

NOTE This annex describes general methods for sample preparation and the observation methods for silicon nitride bearing ball materials. However, because there is no formally standardized ISO procedure and definitive methods for microstructure observation are not available, some aspects of evaluation may need to be agreed between parties.

A.1 Sample preparation

Sections of silicon nitride balls shall be prepared by cutting, grinding and lapping. The sections shall be polished using either of the following two methods.

a) After rough polishing with diamond powders of less than 50 μm in diameter, the sections shall be polished using abrasive powders such as alumina or diamond with sizes of less than or equal to 1 μm.

b) After rough polishing with diamond powders of less than 50 μm in diameter, the sections shall be chemically polished with abrasive powders such as cerium oxide, chromium oxide, or iron oxide.

In either case, the sections shall be polished until grinding scratches disappear, and shall then be ultrasonically cleaned.

A.2 Observation

The section shall be placed on the stage of an optical microscope. The observation area and portion shall be determined between related parties. Pores and inclusions shall be searched for with a 100x to 200x magnification. The number and size of any pores and inclusions found shall be determined, and the pore size and inclusion size shall be identified by their maximum size in the section. Alternatively, the size and number of pores and inclusions may be determined by a scanning electron microscope (SEM), secondary electron image, or reflection electron image, as necessary.

A.3 Additional remarks

The observed portion depends on the size of the ball and the application condition of the bearing; it may be recommended that these be determined between parties to the characterization.

Colour variation is a very difficult problem to be clarified which may also require discussion between suppliers and their customers. If the volume rating of porosity is required, it is recommended that the methodology in ISO 4505 for hard metals be adopted. Observation of the macrostructure at lower magnification may be useful for reviewing visible cracks and defects.

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Annex B
(normative)

Material classification for silicon nitride materials

Table B.1 provides the specification of physical and mechanical properties and of the microstructure of the classified silicon nitride bearing ball materials in three categories, Classes 1, 2 and 3.

Table B.1 — Material classification

			Class 1	Class 2	Class 3
1.	Average flexural strength (MPa) [a]				
a)	4-point test method				
	i) Average strength:	40 mm (span of supports)	min. 760	min. 660	min. 480
		30 mm (span of supports)	min. 800	min. 700	min. 530
	ii) Weibull modulus		min. 12	min. 9	min. 7
b)	3-point test method				
	i) Average strength:	40 mm (span of supports)	min. 894	min. 798	min. 595
		30 mm (span of supports)	min. 915	min. 817	min. 629
	ii) Weibull modulus		min. 12	min. 9	min. 7
2.	Average Vickers hardness (GPa) [b]		min. 14,2	min. 13,3	min. 12,7
3.	Average indentation fracture resistance (MPa $\sqrt{m}$)				
	$K_{I,\ IFR}$ (indentation fracture resistance)		min. 6,0	min. 5,0	min. 5,0
4.	Microstructure				
a)	Pore size (µm)		max. 10	max. 10	max. 25
b)	Inclusion (number/cm^2)				
	Size (µm)	> 25 to ⩽ 50	⩽ 4	⩽ 8	⩽ 16
		> 50 to ⩽ 100	⩽ 1	⩽ 2	⩽ 4
		> 100 to ⩽ 200	0	⩽ 1	⩽ 2
		> 200	0	0	⩽ 1

NOTE If it is required to determine the true fast fracture toughness of the test material, the indentation fracture resistance calculated above is not an equivalent number. It is recommended that $K_{I,SEPB}$ be determined by the single edge precracked beam method (ISO 15732) or equivalent method.

[a] Either test method may be used.

[b] The test force shall be HV5, HV10 or HV20.

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