Standard Specification for Silicon Nitride Cylindrical Bearing Rollers[1]

This standard is issued under the fixed designation F2730/F2730M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the establishment of the basic quality, physical/mechanical property, and test requirements for silicon nitride rollers Classes I, II, and III to be used for cylindrical roller bearings.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *Order of Precedence:*

2.1.1 In the event of a conflict between the text of this document and the references herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 *ASTM Standards:*[2]

C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature

C1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature

2.3 *ASME Standard:*[3]

B 46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

2.4 *JIS Standards:*[4]

R 1601 Testing Method for Flexural Strength (Modulus of Rupture) of High Performance Ceramics

R 1607 Testing Method for Fracture Toughness of High Performance Ceramics

2.5 *CEN Standards:*[5]

EN 843-1 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 1, Determination of Flexural Strength

ENV 843-5 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 5, Statistical Analysis

2.6 *ISO Standard:*[6]

Hardmetals-Metallographic determination of porosity and uncombined carbon

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *ceramic second phase, n*—sintering additive based phases, for example yttria and alumina, which appear darker or lighter than the silicon nitride matrix but are not highly reflective in nature when viewed under reflected light microscopy and bright field illumination.

3.1.2 *chips, n*—break-outs of material greater in extent than 0.25 mm [0.1 in.] typically at the corner chamfers or the junction of the chamfers with the cylindrical surface or end face.

3.1.3 *color variation, n*—an area that appears lighter or darker than the surrounding area under reflected light microscopy but with no discernible physical discontinuity associated with it.

3.1.3.1 *Discussion*—Color variation is often not visible under scanning electron microscopy (SEM) examination.

3.1.4 *cracks, n*—irregular, narrow breaks in the surface of the roller typically having a visible width of less than 0.002 mm. [0.00008 in.]

3.1.4.1 *Discussion*—Most cracks are formed after densification but occasionally may be present as material faults. Some cracks may not be visible with normal white light microscopy and may only show up under ultraviolet light after processing with a suitable fluorescent penetrant.

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[1] This specification is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.01 on Rolling Element.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Japanese Standards Organization (JSA), 4-1-24 Akasaka Minato-Ku, Tokyo, 107-8440, Japan, http://www.jsa.or.jp.

[5] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.5 *cuts, n*—short linear or circumferential grooves having a width of more than 0.005 mm [0.002 in.] and a length of more than 0.20 mm [0.008 in.]. Cuts are normally assessed under roller surface appearance but large or numerous cuts, or both can be considered defects.

3.1.6 *flats, n*—flat bands running along the length of the cylindrical part of the roller, usually caused by a stop in rotation of the roller during machining.

3.1.6.1 *Discussion*—Flats can also be formed at one end only by incorrect approach into a machining operation.

3.1.7 *grooves, n*—shallow machining marks having a width of more than 0.005 mm [0.002 in.] extending more than one quarter of the circumference on the cylindrical surface or having a length of more than one quarter of the roller diameter on the end faces.

3.1.8 *inclusion, n*—any discrete imhomogeneity in the microstructure that is not intended to be included in the material.

3.1.8.1 *Discussion*—Inclusions typically consist of foreign material as a result of unintended external powder contamination and resulting reaction product after sintering.

3.1.9 *material lot, n*—single process lot of a blended powder (blended with additives), produced from a single lot of silicon nitride or silicon metal raw powder received from a material supplier.

3.1.9.1 *Discussion*—What constitutes a "single process lot" of blended powder can vary depending on the standard practices of the vendor and the requirements of the customer and application. For example, for many customers/applications, combining multiple mill charges from one raw material lot into a single material lot is acceptable while for others, each mill charge would be considered a separate material lot. It is difficult, if not impossible, for a single definition of material lot to apply to all applications. The material lot should be defined such that application-appropriate traceability is maintained and adequate testing appropriate for the intended application is performed to ensure that the chemistry and material properties of densified parts meet specifications. The material lot requirements should be discussed and agreed between the vendor and customer.

3.1.10 *mean roller diameter, n*—one half the sum of the largest and smallest of individual diameters measured in a single radial plane.

3.1.11 *mean roller length, n*—one half the sum of the largest and smallest lengths measured on a roller.

3.1.12 *metallic phase, n*—material phase that is highly reflective when viewed by reflected light microscopy and bright field illumination.

3.1.13 *metallic smears, n*—metallic material from machining or measuring equipment transferred onto the roller surface.

3.1.14 *pits, n*—voids or cavities in the roller surface.

3.1.14.1 *Discussion*—Pits can be formed by severe material pullout during roller finishing. Pits can also be a result of the breakout of inclusions during machining.

3.1.15 *porosity, n*—small, closely spaced voids permeating a region of the roller surface or the whole roller.

3.1.16 *pressing defects, n*—the result of cracks in roller preforms prior to densification.

3.1.16.1 *Discussion*—Some pressing defects heal more or less completely on densification resulting in a region of material with slightly different composition and optical characteristics than the rest of the roller. These are known as healed or partially healed pressing defects. Unhealed or open pressing defects can have the appearance of cracks or fissures.

3.1.17 *raw material lot, n*—single process lot of raw silicon nitride or raw silicon metal powder received from a material supplier.

3.1.18 *scratches, n*—narrow, linear, shallow abrasions on the surface.

3.1.19 *snowflakes, n*—regions of microporosity in the grain boundary phase that often display a dendritic appearance.

3.1.19.1 *Discussion*—Snowflakes show up as white dendritic features when viewed with oblique illumination or with ultraviolet light after processing with a fluorescent penetrant. The individual micropores are often submicron in size and the snowflakes can range in size from less than 10 µm [.00039 in.] to over 1,000 µm [.039 in] in extreme cases.

3.1.20 *steps, n*—regions at the edge of a roller end face that have been machined to a lower depth than the rest of the end face.

3.1.21 *surface roughness, Ra, n*—surface irregularities with relative small spacings, which usually include irregularities resulting from the method of manufacture being used, other influences, or both.

3.1.22 *tears, n*—circumferential machining marks associated with lateral surface cracks.

3.1.23 *unfinished areas, n*—regions on the roller surfaces that should be machined but have not been machined at all, or have not been completely machined and finished, because of either faults in blank geometry or errors in the machining process.

4. Classification

4.1 Silicon nitride materials for bearing applications are specified according to the following material classes:

4.1.1 *Class I*—Highest grade of material in terms of properties and microstructure and suitable for use in the most demanding applications. This group adds high reliability and durability for extreme performance requirements.

4.1.2 *Class II*—General class of material for most bearing applications. This group addresses the concerns of roller defects as is relative to fatigue life, levels of torque, and noise.

4.1.3 *Class III*—Lower grade of material for low duty applications only. This group of applications primarily takes advantage of silicon nitride material properties (for example, light weight, chemical inertness, lubricant life extension because of dissimilarity with race materials, and so forth.).

4.1.4 A material grade approved as a Class I material may be supplied where Class II or III is specified and, similarly, a Class II material for a Class III.

5. Roller Dimensions

5.1 Cylindrical rollers are generally identified using a nominal diameter (*D*) and nominal length (*L*) where the first value is that of nominal diameter (for example, 9 × 9 mm, 18 × 21 mm).

5.2 Rollers are normally manufactured to millimetre dimensions with *D* equal to *L*. However, many variations exist where *L* is larger or smaller than *D*. There may be a practical limitation to this as *L* becomes significantly larger than *D* because of pressing limitations. In these cases, the roller blank supplier should be consulted.

5.3 There should be sufficient stock allowance on the roller blank so that all surface skin effects are removed during machining.

5.4 Silicon nitride rollers should be machined entirely over the diameter and end face surfaces. Corner chamfers need not be machined providing the corners are uniform and have a smooth transition from the diameter to the end face.

6. Material

6.1 Unless otherwise specified, physical and mechanical property requirements will apply to all material classes.

6.2 To be classified as Class I, silicon nitride rollers shall be produced from either silicon nitride powder having the compositional limits listed in Table 1 or from silicon metal powder, which, after nitridation, complies with the compositional limits listed in Table 1.

6.3 Composition is measured in weight percent. Testing shall be carried out by a facility qualified and approved by the supplier. Specific equipment, tests, and/or methods are subject to agreement between suppliers and their customers.

6.4 Compounds may be added to promote densification and enhance product performance and quality.

6.5 Iron oxides may be added to promote densification with the total iron content for the final product not to exceed 1.0 weight %.

6.6 Precautions should be taken to minimize contamination by foreign materials during all stages of processing up to and including densification.

6.7 A residual content of up to 2 % tungsten carbide from powder processing is allowable.

6.8 Final composition shall meet and be reported according to the specification of the individual supplier.

6.9 Notification will be made upon process changes.

TABLE 1 Compositional Limits for Starting Silicon Nitride Powders or Silicon Powder Converted to Silicon Nitride for Class I Materials[A]

Constituents	Limits (wt %)
Silicon nitride	97.0 min
Free silicon	0.3 max
Carbon	0.3 max
Iron	0.5 max

[A] Other impurities or elements such as sodium, potassium, chlorine, and so forth individually shall not exceed 0.02 wt % max.

6.10 Specific requirements such as specific material grade designation, physical/mechanical property requirements (for example, density) or quality or testing requirements shall be established by specific application. The special requirements shall be in addition to the general requirements established in this specification.

6.11 Typical mechanical properties will fall within the range listed in Table 2. Individual requirements may have tighter ranges. The vendor shall certify that the silicon nitride material supplied has physical and mechanical properties within the range given in Table 2. In the case of properties indicated by (+), the provision of the data is not mandatory.

7. Physical Properties

7.1 The following physical properties shall be measured, at a minimum, on each material lot.

7.1.1 Average values for room temperature rupture strength (bend strength/modulus of rupture) for a minimum of 20 individual determinations shall exceed the minimum values given in Table 3. Either 3-point or 4-point test methods may be used for flexural strength, which should be measured in accordance with Test Method C1161 (size B), EN 843-5, or JIS R 1601. Weibull modulus for each test series shall also exceed the minimum permitted values given in Table 3. If a sample set of specimens for a material lot does not meet the Weibull modulus requirement in Table 3, then a second sample set may be tested to establish conformance.

7.1.2 The hardness (HV) shall be determined by the Vickers method (see Annex A1) using a load of at least 5 kg [11 lbs] but not exceeding 20 kg [44 lbs]. Fracture resistance shall be measured by either an indentation technique (see Annex A1) or by a standard fracture toughness test method. Average values for hardness and fracture resistance shall exceed the minimum of values for the specified material class given in Table 4.

7.1.3 Microstructure constituents visible at magnification in the range ×100 to ×200 shall not exceed the maximum values given in Table 5 for the specified material class.

7.1.4 The number inclusions observed in transverse sections shall not exceed the limits given in Table 6.

7.1.5 Macrostructure variation visible at 1× on a polished section is not permissible.

TABLE 2 Typical Mechanical Properties[A]

Properties	Minimum	Maximum
Density, g/cc [lb/ft^3]	3.0 [187]	3.4 [212]
Elastic modulus, GPa [ksi]	270 [39 150]	330 [47 850]
Poisson's ratio	0.23	0.29
Thermal conductivity, W/m-°K [Btu/h-ft-°F] – @ 20°C (room temp.)	20 [11.5]	38 [21.9]
Specific heat, J/kg-°K [Btu/1bm-°F]	650 [0.167]	800 [0.191]
Coefficient of thermal expansion, ×10 ^{6}/°C (room temp, to 500°C)	2.3	3.4
+ Resistivity, Ohm-m	10^{10}	10^{16}
+ Compressive strength, MPa [ksi]	3000 [435]	

[A] Special material data should be obtained from individual suppliers.

TABLE 3 Minimum Values for Mean Flexural Strength and Weibull Modulus

	Unit	Material Class I	II	III
Transverse-rupture strength[A] 3 point $\sigma_{3,40}$ ($\sigma_{3,30}$)	MPa	900 [920]	800 [825]	600 [625]
Weibull modulus		12	9	7
Transverse-rupture strength[A] 4-point $\sigma_{4,40}$ ($\sigma_{4,30}$)	MPa	765 [805]	660 [705]	485 [530]
Weibull modulus		12	9	7

[A] The flexural strength equivalents are based on Weibull volume or surface scaling using the value of m for each cell and are rounded to the nearest 5 MPa [0.7 ksi].

$\sigma_{n,L}$ = denotes the flexure strength, *n* = 3 or 4 point, on spans of size L.

$\sigma_{4,40}$ = 660 MPa [96 ksi] means the four point flexure strength, on 40 mm [1.6 in.] spans is 660 MPa [96 ksi] as per Test Method C1161 (size B) and EN EN 843-1.

$\sigma_{4,30}$ = 705 MPa [102 ksi] means the four point flexure strength, on 30 mm [1.2 in.] spans is 705 MPa [102 ksi] as per JIS R 1601.

TABLE 4 Minimum Values for Hardness and Toughness

Property	Unit	Load	Material Class I	II	III
Hardness					
HV5	kg/mm²	5 kg	1500	1400	1350
HV10		10 kg	1480	1380	1325
HV20		20 kg	1460	1360	1300
Indentation Fracture Resistance, IFR (or “TP”) (Annex A1)	MPa√m		6.0	5.0	5.0
Fracture Toughness, K (Test Methods C1421 or JIS R 1607)	MPa√m		6.0	5.0	5.0

TABLE 5 Maximum Limits for Microstructural Constituents

	Material Class I	II	III
Porosity: Size (µm)	10	10	25
Volume Rating / ISO 4505	0.02	0.06	0.06
Metallic Phases: Size (µm)	10	10	25
Ceramic 2nd Phases: Size (µm)	25	25	25

TABLE 6 Maximum Number of Inclusions per cm² of Transverse Section

Maximum Extent (µm)	Material Class I	II	III
200	0	0	1
100 to <200	0	1	2
50 to <100	1	2	4
25 to <50	4	8	16

7.1.6 Density variation from the mean value of a sample of at least ten pieces taken from a batch of components manufactured under the same conditions shall not exceed the values for three times the standard deviation (3 × sigma) given in Table 7, according to the volume of the component after any finishing operations and the specified material class.

8. Inspection and Verification

8.1 The intent of this section is to list potential observable indications and methods of inspection of finished rollers. The type of observable indications, methods of inspection, and limits should be agreed upon by the customer and vendor to meet the specific requirements for a given application.

TABLE 7 Maximum Allowable Density Variation (3 × Sigma) Within a Single Lot

Component Volume (cm³)	Density Variation (g/cm³) Material Class I	II	III
0.005 to <0.1	0.010	0.015	0.020
0.1 to <0.5	0.008	0.010	0.015
0.5 to <2.0	0.005	0.008	0.012
2.0 to 20.0	0.005	0.005	0.010

8.2 Unless otherwise specified, all dimensional and form inspections shall be performed under the following conditions:

8.2.1 *Temperature*—Room ambient 20 to 25°C [68 to 77°F].

8.2.2 *Humidity*—50 % relative, maximum.

8.3 Certain manufacturer to manufacturer or lot to lot variation in color is acceptable. Color variation within a single roller should be investigated per 8.4.

8.4 There may exist in silicon nitride bearing rollers the observable indications listed in 8.4.1, which may be inspected for using the methods in 8.4.2 as required.

8.4.1 *Types of observable indications:*

8.4.1.1 *Material origin:*

(1) Color variation

(2) Inclusions,

(3) Porosity,

(4) Pressing defects, and

(5) Snowflakes.

8.4.1.2 *Processing origin:*

(1) Cuts,

(2) Flats,

(3) Grooves,

(4) Metallic smears,

(5) Scratches,

(6) Steps, and

(7) Tears.

8.4.1.3 *Material or processing origin:*

(1) Chips,

(2) Cracks,

(3) Pits, and

(4) Unfinished areas.

8.4.2 *Methods of Inspection:*

8.4.2.1 Visual white light (unaided eye and magnification-aided eye);

8.4.2.2 Black light (unaided eye and magnification-aided eye);

8.4.2.3 Fluorescent penetrant inspection (FPI) (unaided eye and magnification-aided eye); and

TABLE 8 Lot Variation—Roller Diameter

Roller Diameter	Total Lot Variation, µm [µin.][A]
>3 ≤26 mm	2 [79]
>26 ≤40 mm	3 [118]

[A] Difference between the mean diameter of the largest roller and the smallest roller in the lot.

TABLE 9 Lot Variation—Roller Length

Roller Length	Total Lot Variation µm [µin.][A]
>5 ≤8 mm	8 [315]
>48 ≤56 mm	12 [472]

[A] Difference between the mean length of the largest roller and the smallest roller in the lot.

TABLE 10 End Face Axial Runout

Roller Diameter	Runout µm [µin.][A]
>3 ≤6 mm	6 [236]
>6 ≤10 mm	7 [276]
>10 ≤18 mm	8 [315]
>18 ≤30 mm	10 [394]
>30 ≤40 mm	12 [472]

[A] Fixed point and gage point equidistant from roller axis and 0.25 mm [0.1 in.] inside of max. chamfer breakout. Will provide twice the true runout value.

TABLE 11 Diameter Taper

Roller Diameter	Taper µm [µin.][A]
>3 ≤26 mm	0.8 [32]
>26 ≤40 mm	1.2 [47]

[A] Measured at ends of the cylindrical portion.

TABLE 12 Straightness of Cylindrical Portion

Roller Diameter	Concavity µm [µin.]	Convexity µm [µin.]
>5 ≤11 mm	0.38 [15]	0.64 [25]
>11 ≤21 mm	0.5 [20]	1.0 [40]
>21 ≤40 mm	0.75 [30]	1.5 [60]

TABLE 13 Roundness of Cylindrical Portion

Roller Diameter	Two-Point Variation µm [µin.]	Three-Point Variation µm [µin.]
>5 ≤11 mm	0.25 [10]	0.64 [25]
>11 ≤21 mm	0.38 [15]	1.15 [45]
>21 ≤40 mm	0.5 [20]	1.5 [60]

TABLE 14 Waviness of Cylindrical Portion

Roller Diameter	Low Band (4-17 Waves/Revolution) µm [µin.][A]	High Band (18-330 Waves/Revolution) µm [µin.][A]
>5 ≤11 mm	0.025 [1.0]	0.0064 [0.25]
>11 ≤21 mm	0.38 [1.5]	0.0127 [0.5]
>21 ≤40 mm	0.5 [2.0]	0.02 [0.75]

[A] Waviness values are RMS. With probe tip radius of 0.78 mm [0.03 in.].

8.4.2.4 Ultrasonic inspection (the following methods are currently in development and may require extensive evaluation to be applicable):

(1) Resonant inspection (resonant ultrasound spectroscopy),

(2) Rayleigh wave, and

(3) Acoustic microscopy.

8.5 *Dimensional and Form:*

TABLE 15 Surface Roughness (Roughness Average–Ra)

Roller Diameter	Diameter Finish µm [µin.]	End Face Finish µm [µin.]	Chamfer (Corner) Finish µm [µin.]
>3 ≤26 mm	0.1 [4]	0.1 [4]	0.8 [32]
>26 ≤40 mm	0.14 [5.5]	0.1 [4]	0.8 [32]

8.5.1 *Tolerances for Individual Rollers and Tolerances for Lots of Rollers*—Acceptable methods of measurement should be agreed upon by both finished roller supplier and customer.

8.5.2 Whenever possible, silicon nitride master rollers should be used for gage setting.

8.6 The diameter and length tolerance of roller lots shall be as specified in the contract or purchase order. If this is not specified, tolerance limits shall be in accordance with Tables 8 and 9.

8.7 The nominal diameter and length of individual rollers shall be as specified in the contract or purchase order. Unless otherwise specified, tolerance limits for size variations and form deviations shall be in accordance with Tables 10-14.

8.8 The surface roughness of the roller surfaces shall not exceed the value specified in Table 15. Surface roughness shall be in accordance with ASME B 46.1.

9. Certificates of Quality and Material Certification

NOTE 1—This section contains information of a general or explanatory nature which may be helpful but is not mandatory.

9.1 When specified in the contract or purchase order, certificates of quality (conformance) supplied by the manufacturer of the roller blanks may be furnished in lieu of actual performance of such testing by the manufacturer, provided the lot identity has been maintained and can be demonstrated to the customer. The certificate may include:

9.1.1 Name of the customer,

9.1.2 Contract or purchase order number,

9.1.3 Name of the manufacturer or supplier,

9.1.4 Name of the material,

9.1.5 Lot number,

9.1.6 Lot size.

9.1.7 Sample size,

9.1.8 Date of testing,

9.1.9 Test method,

9.1.10 Individual test results, and

9.1.11 Specification requirements.

9.2 Contract or purchase order requirements other than those specified within this specification will have authority over this document.

10. Packaging

10.1 For acquisition purposes, the packaging requirements shall be as specified in the contract or order.

10.2 Preservatives are not required.

10.3 *Special Handling*—It is recommended that all finished rollers should be packaged to prevent roller to roller contact.

11. Keywords

11.1 bearing rollers; ceramic; roller bearings; silicon nitride; Si_3N_4

ANNEX

(Mandatory Information)

A1. VICKER'S HARDNESS AND NIIHARA'S TOUGHNESS MEASUREMENTS

A1.1 Measurements for hardness and toughness are made on a polished cross-section.

A1.2 Indentations for toughness measurement are made using a Vicker's indenter under the following conditions:

Load	20 kgf
Dwell Time	30 s

A1.3 Hardness and toughness are calculated as follows (see Fig. A1.1):

A1.3.1 Measure both diagonals of each hardness impression as "2*a*" values according to orientation except when impressions are placed on separate pieces.

A1.3.2 Measure visible tip-to-tip crack lengths associated with the hardness impressions as "2*c*" values according to orientation except when impressions are placed on separate pieces.

A1.3.3 Calculate the mean values of $2a = (2a_1 + 2a_2)/2$ and $2c = (2c_1 + 2c_2)/2$ in microns.

A1.3.4 Calculate the Vickers hardness value as follows:

$$HV = 1\,854\,400\,P/(2a)^2 \quad (A1.1)$$

where:

HV = Vicker's hardness number; the symbol should be written with the indentation load in kilograms denoted in parentheses (for example, HV(20) for a 20-kgf load),
P = the applied load in kilogram force, and
$a(2\,a/2)$ = the mean half length diagonal value in microns.

A1.3.5 Calculate the indentation fracture resistance by Niihara's method as follows:

$$IFR = 10.4(E^{0.4})(P^{0.6})(a^{0.8}/c^{1.5}) \quad (A1.2)$$

where:

IFR = the indentation fracture resistance in megapascals-square root metre,
E = the elastic modulus in gigapascals,
P = the applied load in kilogram force,
a = the mean half diagonal value in microns, and
c = the mean half tip-to-tip crack length in microns.

A1.4 Alternative formulas or calibration constants for indentation fracture resistance may be used by mutual agreement of customer and vendor.

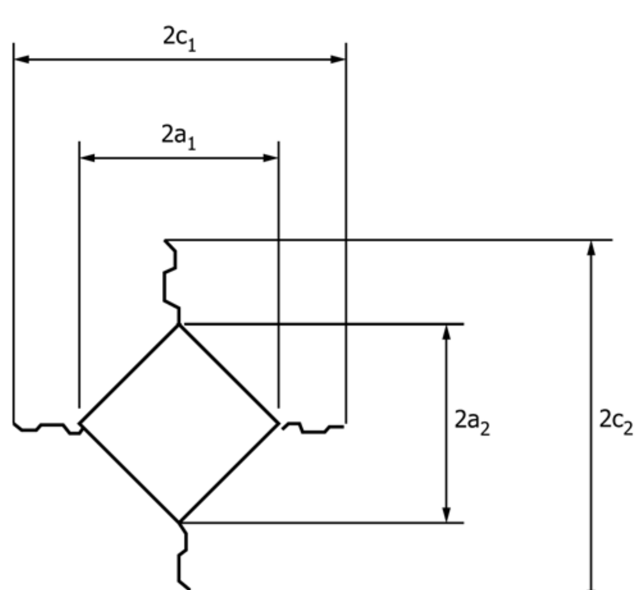

FIG. A1.1 Hardness and Toughness Calculation

NOTE A1.1—The within-laboratory (repeatability) consistency of results by this method may be acceptable, but the between-laboratory (reproducibility) consistency is often poor because of variations in the interpretation of the crack length arising from microscopy limitations as well as operator experience or subjectivity.

RELATED MATERIAL

ASTM Standards[4]
- C373 Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products
- C1198 Test Method for Dynamic Youngs Modulus, Shear Modulus, and Poissons Ratio for Advanced Ceramics by Sonic Resonance
- C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
- C1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics
- E165 Test Method for Liquid Penetrant Examination
- E384 Test Method for Microindentation Hardness of Materials
- E831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- E1417 Practice for Liquid Penetrant Testing

ANSI Standards:[6]
- ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes
- ANSI B89.3.1 Measurement of Out-of-Roundness

ABMA Standard: Replaced by ISO standard.

DIN Standard: Nothing applicable to rollers.

ISO Standard:[6]
- 1132-1 Rolling Bearings—Tolerances--Part 1: Terms and Definitions

JIS Standards:[4]
- R 1602 Testing Method for Elastic Modulus of High Performance Ceramics
- R 1603 Methods for Chemical Analysis of Fine Silicon Nitride Powders for Fine Ceramics
- R 1610 Testing Method for Vicker's Hardness of High Performance Ceramics

CEN Standards:
- EN 843-2 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 2, Determination of Elastic Moduli
- ENV 843-4 Advanced Technical Ceramics—Monolithic Ceramics—Mechanical Properties at Room Temperature, Part 4, Vickers, Knoop and Rockwell Superficial Hardness Tests
- EN 623-2 Advanced Technical Ceramics—Monolithic Ceramics—General and Textural Properties—Determination of Density and Porosity
- EN 821-2 Advanced Technical Ceramics—Monolithic Ceramics—Thermo-physical Properties—Part 2: Determination of Thermal Diffusivity by the Laser Flash (or Heat Pulse) Method
- EN 821-1 Advanced Technical Ceramics—Monolithic Ceramics—Thermo-physical Properties—Part 1: Determination of Thermal Expansion