MECHANICAL PROPERTIES AND TEST METHODS OF ADVANCED CERAMICS

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23 June 2021

Turkish Ceramic Society Lecture

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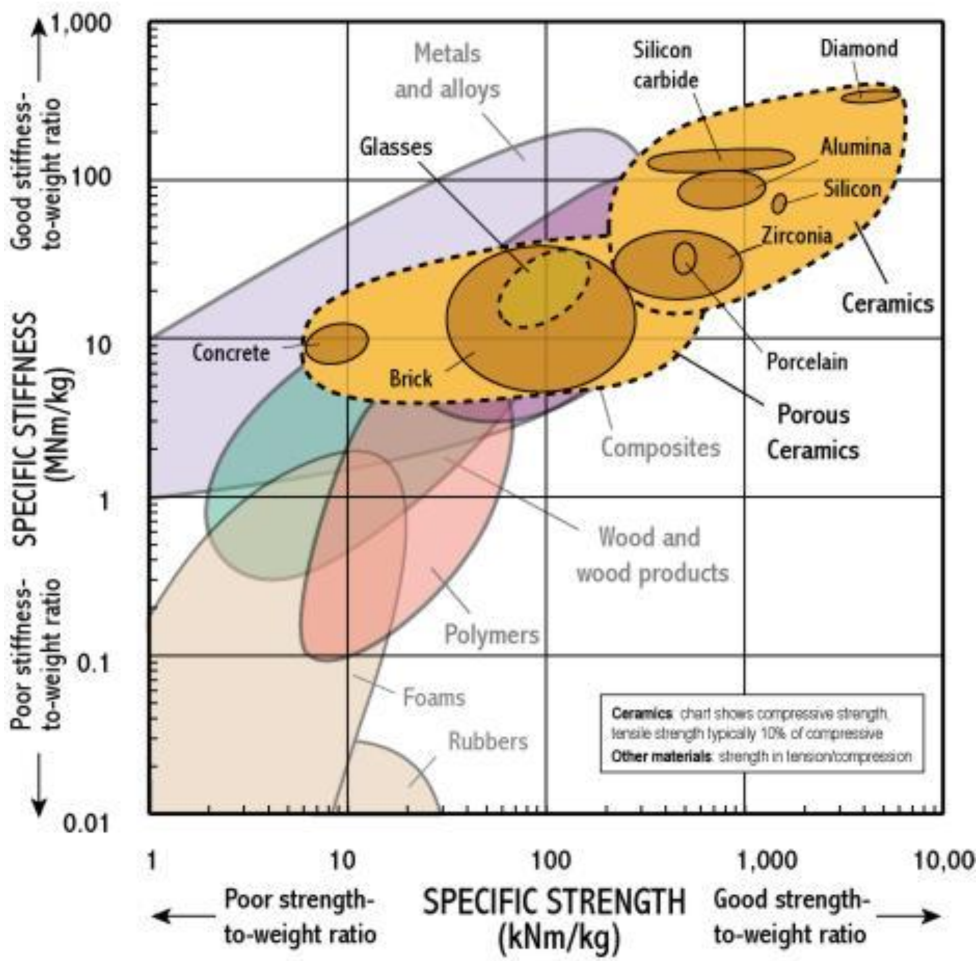
CERAMICS

- Always composed of more than one element (e.g., Al_2O_3, SiC, SiO_2)
- Bonds are partially or totally ionic, can have combination of ionic and covalent bonding
- Generally hard and brittle
- Generally low density (compared to steel)
- Generally electrical and thermal insulators
- Can be optically opaque, semi-transparent, or transparent
- Traditional ceramics – based on clay (china, bricks, tiles, porcelain), glasses.
- Structural ceramics – “New ceramics” for electronic, computer, aerospace industries.

WHY CERAMICS



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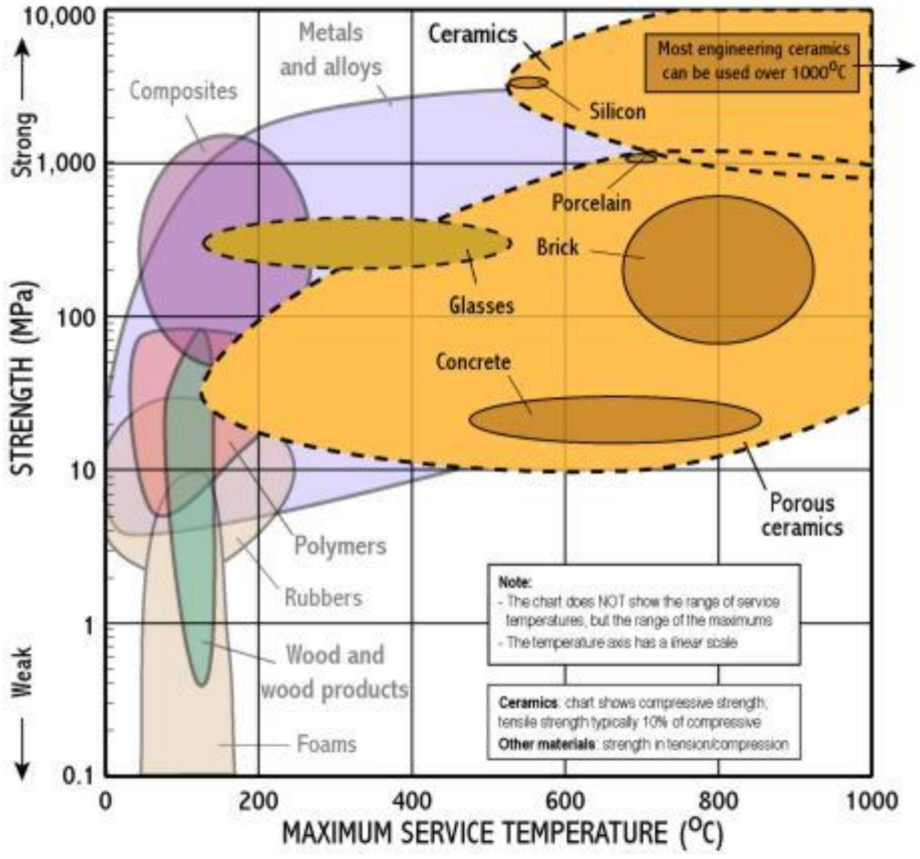
WHY CERAMICS



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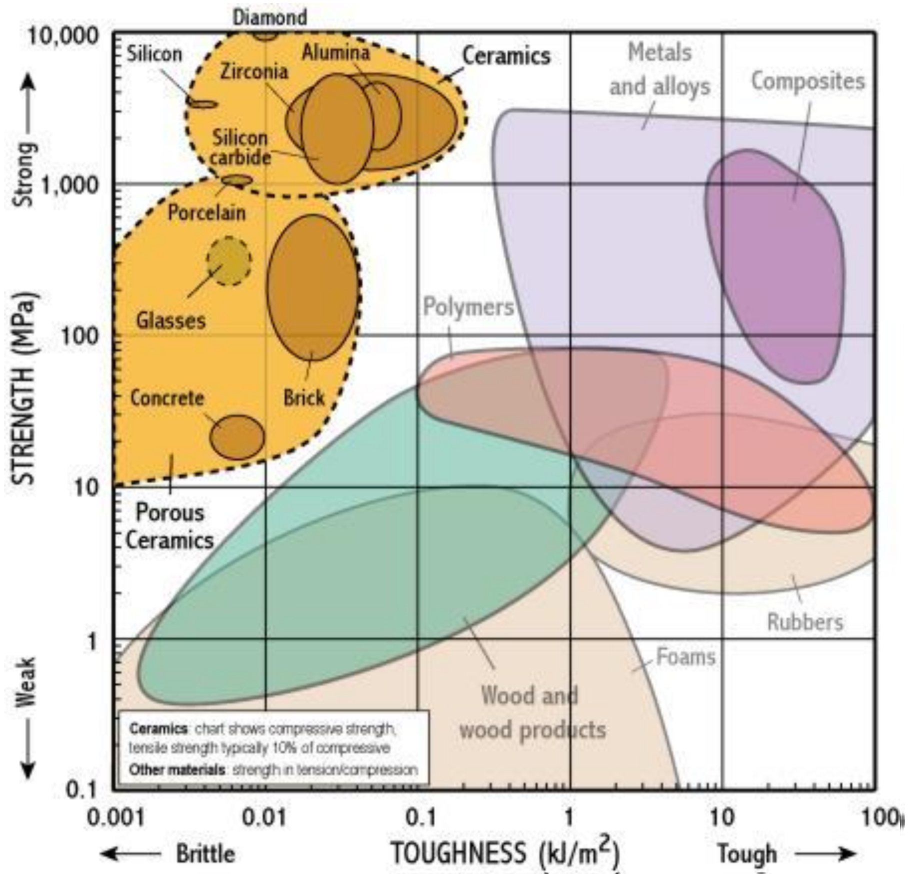
WHY NOT CERAMICS



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SERVICE ADVERTISED ON THE WEB

Mechanical Characterization of Ceramics, Brittle Materials and Components: Materials

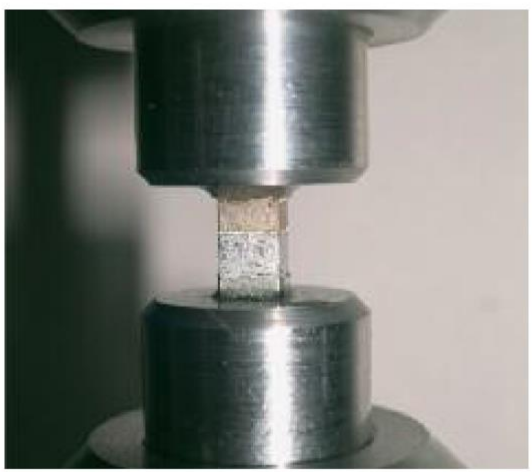
Ceramics
- monolithic
- reinforced (with particles, whiskers, fibers, nano-fibers, CNT)
- conductive, non-conductive, piezo-electric

Composites
- ceramic-ceramic (CMC)
- metal-ceramic (MMC)

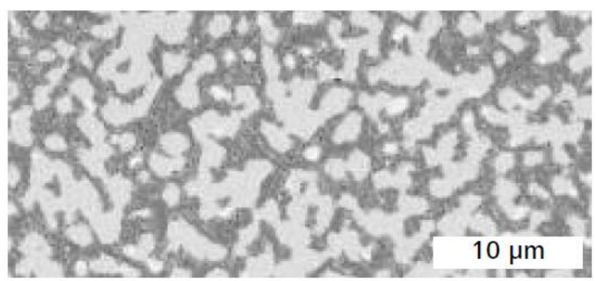
Ceramic laminates
- macro (e.g. wear parts)
- micro (e.g. sensors)
- coatings

Joined materials (brazed, glued)
- ceramic with ceramic
- ceramic with metal

and many more, e.g.
- porcelain (e.g. isolator)
- glass (e.g. accessories, controls, instruments)
- long fibers
- porous bodies and foams
- green-bodies



Tensile strength test of a Metal-Ceramic joint



BSE: Si_3N_4-$MoSi_2$ composite

Ceramic laminate. The white outer layers have a thickness of ~50 µm.

swiss federal laboratories for materials science and technology
https://www.empa.ch/documents/55877/235502/Mechanical+Characterization.pdf/

SERVICE ADVERTISED ON THE WEB

Mechanical Characterization of Ceramics, Brittle Materials and Components: Properties

Strength up to 1500°C
- 3-point and 4-point bending
- biaxial flexural (ring on ring)
- ball-on-three-ball (small discs)
- C-ring
- shear

Fracture toughness
- SEVNB: Single Edge V-Notched Beam up to 1500°C
- SCF: Surface Crack in Flexure
- SEPB: Single Edge Pre-cracked Beam
- edge chipping

Young's modulus, Shear modulus, Poisson's ratio
- natural frequency up to 1000°C
- bending up to 1500°C (Young's modulus)
- instrumented indentation (Young's modulus)

Hardness
- Vickers and Knoop
- dynamic hardness

and many more, e.g.

Lifetime, e.g. subcritical crack growth under
- static or cyclic load
- constant stress rate

creep resistance up to 1600°C
- tensile load

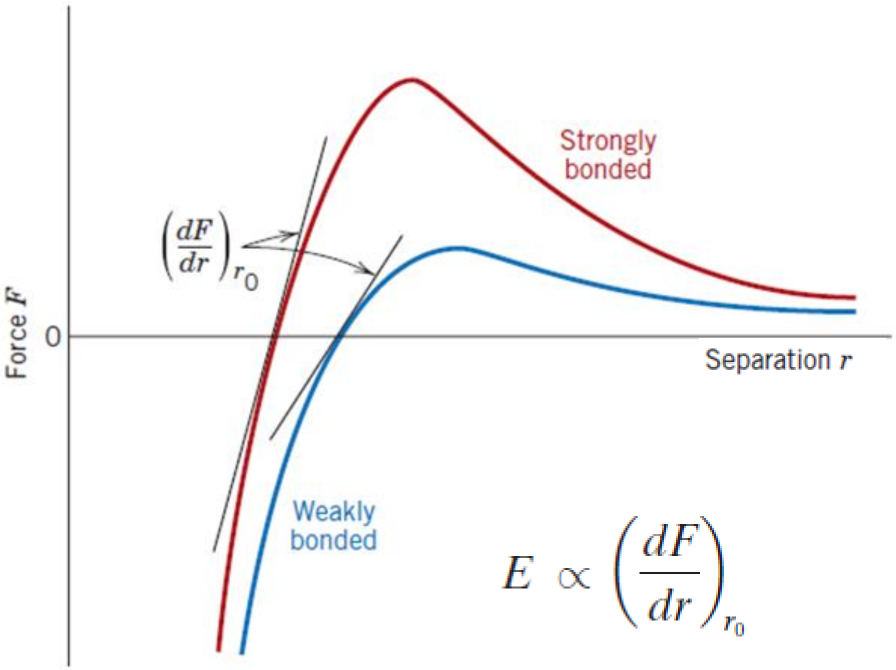
thermal shock resistance

Thermo-mechanical characterization of Solid Oxide Fuel Cell component

swiss federal laboratories for materials science and technology
https://www.empa.ch/documents/55877/235502/Mechanical+Characterization.pdf/

ELASTIC MODULUS OF CERAMICS

Elastic modulus depends on the microstructure and interatomic bonding forces.



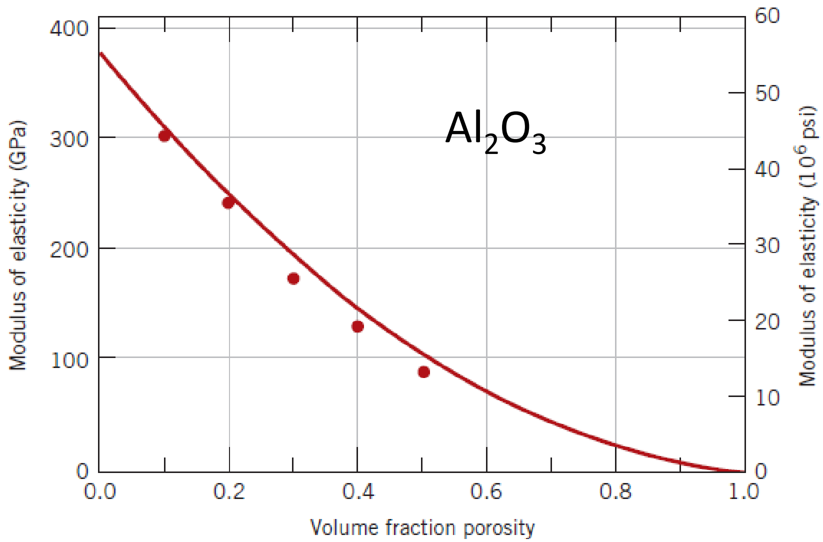
Ceramics, glasses,:	(GPa)	Melting Temp. (C)
Diamond (C)	1000	
Tungsten Carbide (WC)	450 -650	2870
Silicon Carbide (SiC)	450	
Aluminum Oxide (Al_2O_3)	390	2072
Berylium Oxide (BeO)	380	
Magnesium Oxide (MgO)	250	
Zirconium Oxide (ZrO)	160 - 241	
Mullite ($Al_6Si_2O_{13}$)	145	
Silicon (Si)	107	
Silica glass (SiO_2)	94	
Soda-lime glass (Na_2O - SiO_2)	69	
Metals:		
Tungsten (W)	406	3400
Low Alloy Steels	200 - 207	
Stainless Steels	190 - 200	
Cast Irons	170 - 190	
Copper (Cu)	124	1084
Titanium (Ti)	116	
Brasses and Bronzes	103 – 124	
Aluminum (Al)	69	660

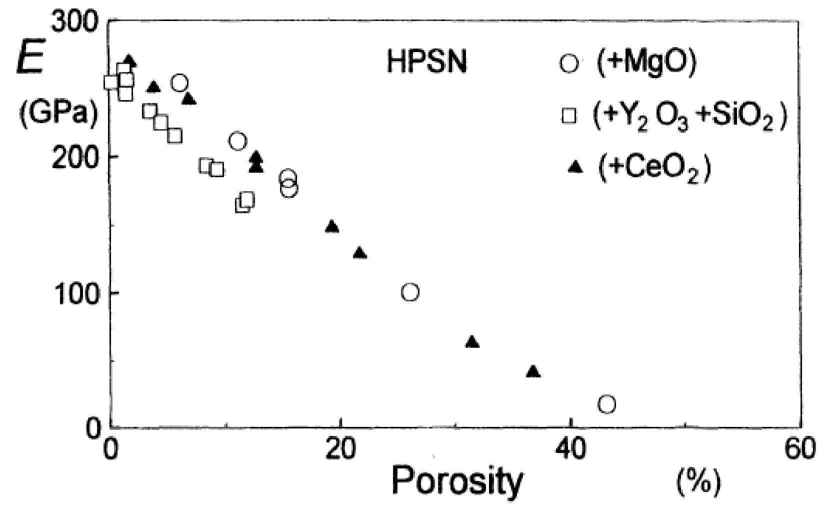
The values given are indicative only

Callister, Materials Science and Engineering

ELASTIC MODULUS OF CERAMICS

For many ceramic fabrication techniques, the precursor material is in the form of a powder. During the ensuing heat treatment some residual porosity will remain.





$$E = E_0(1 - 1.9P + 0.9P^2)$$

$$E = E_0\, e^{-bP} \text{ where b} \approx 4$$

$E = E_0(1 - aP)$
$E = E_0(1 - aP + bP^2)$
$E = E_0(1 - aP)^b$
$E = E_0[1 + aP/(1-(a+1)P)]$
$E = E_0 \exp(-aP)$
$E = E_0 \exp[-(aP + bP^2)]$

Callister, Materials Science and Engineering

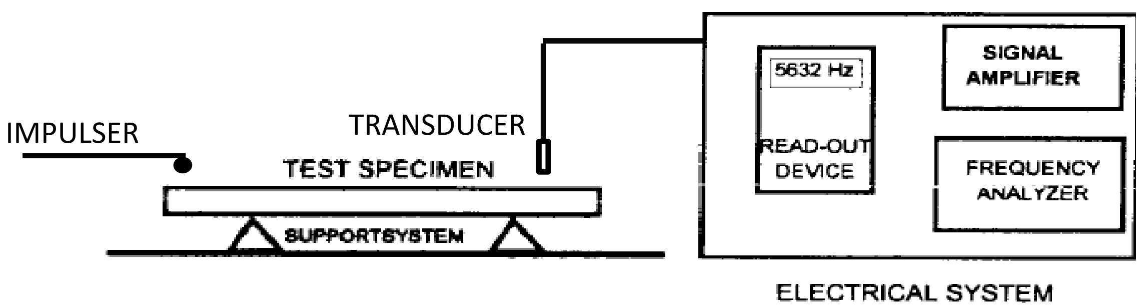
Munz and Fett, Ceramics

ELASTIC MODULUS OF CERAMICS

The elastic modulus can be measured by the **impulse excitation of vibration method** (ASTM C 1259) .

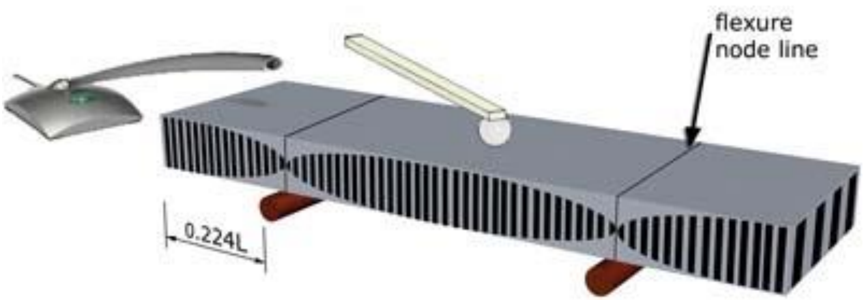
This test method measures the fundamental resonant frequency of test specimens of suitable geometry by exciting them mechanically by a singular elastic strike with an impulser.

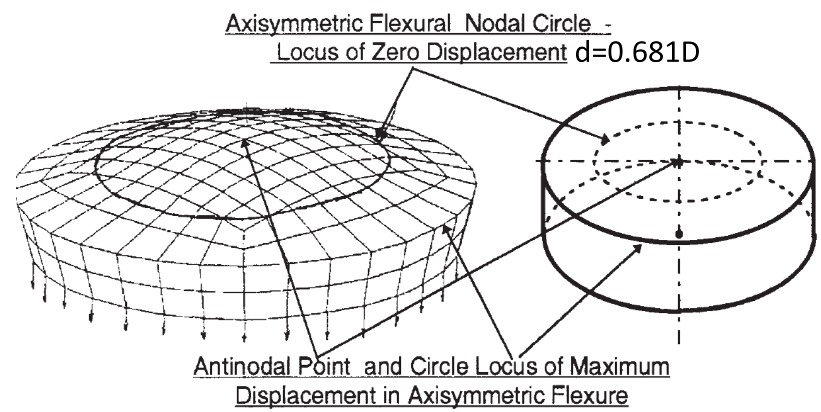
A transducer senses the resulting mechanical vibrations of the specimen, which provides a numerical reading that is (or is proportional to) either the frequency or the period of the specimen vibration.



ELASTIC MODULUS OF CERAMICS

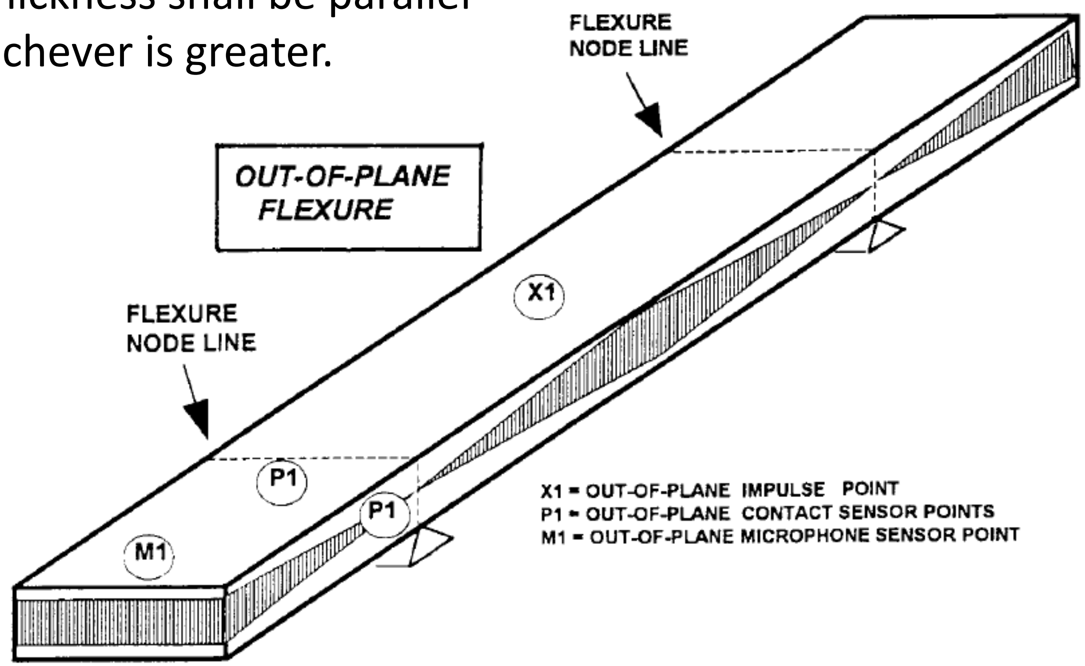
An impulse-excited solid might be expected to vibrate at several resonant frequencies simultaneously. However, for simple shapes, such as beams and plates, it is possible to support them and excite them in such a way that only one mode of vibration is prevalent. The sample is struck at one of the antinodes, and the frequency of vibration is then measured at another antinode using a microphone and frequency analyzer





ELASTIC MODULUS OF CERAMICS

All surfaces on the rectangular specimen shall be flat. Opposite surfaces across the length and width shall be parallel within 0.01 mm or 0.1 %, whichever is greater. Opposite surfaces across the thickness shall be parallel within 0.002 mm or 0.1 %, whichever is greater.



$$E = \frac{0.9464 m f_f^2 L^3}{b t^3} T_1$$

where

E= Young's modulus (Pa)

m= mass of the bar (g)

b=width of the bar (mm)

L= length of the bar (mm)

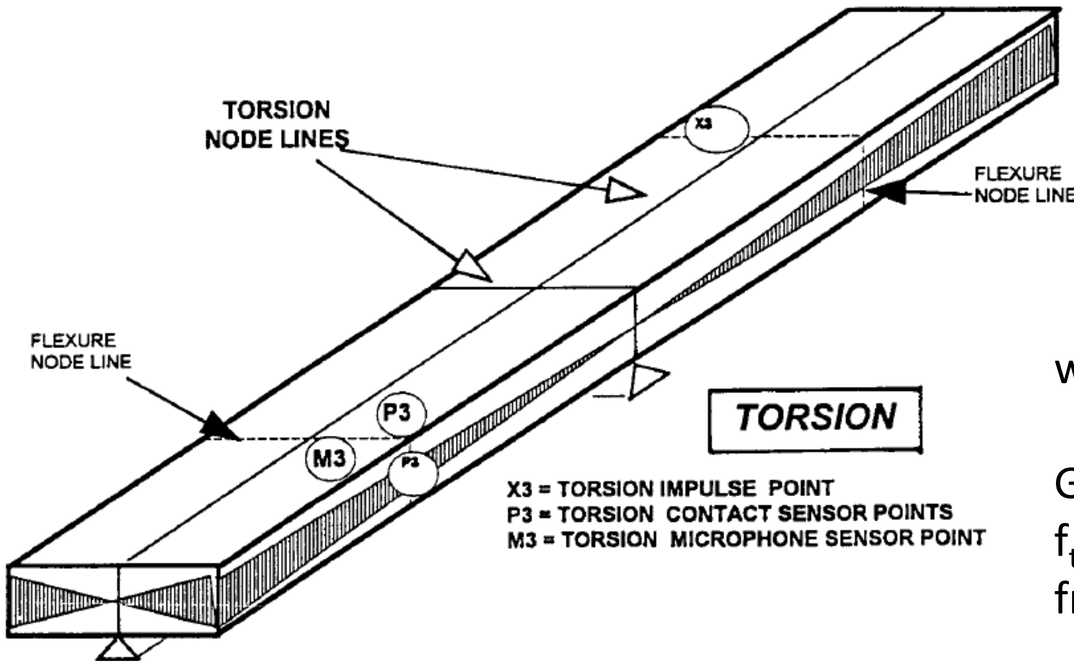
t= thickness of the bar (mm)

f_f= fundemental resonant frequency of bar in flexure (Hz)

T_1= correction factor for fundemental flexural mode to account for finite thickness of bar, Poisson's ratio, etc.

ASTM C 1259

ELASTIC MODULUS OF CERAMICS



$$G = \frac{4 m f_t^2 L}{bt} \mathrm{B}$$

where

G = shear modulus (Pa)

f_t= fundemental resonant frequency of bar in torsion (Hz)

$$\mathrm{B} = \frac{b/t + t/b}{4\left(t/b\right) - 2.52\left(t/b\right)^2 + 0.21(t/b)^6}$$

ASTM C 1259

ELASTIC MODULUS OF CERAMICS

More detailed information on measuring elastic modulus of ceramics can be found in:

ASTM C 1259 Test Method for Dynamic Young’s Modulus, Shear Modulus, and Poisson’s Ratio for Advanced Ceramics by Impulse Excitation of Vibration

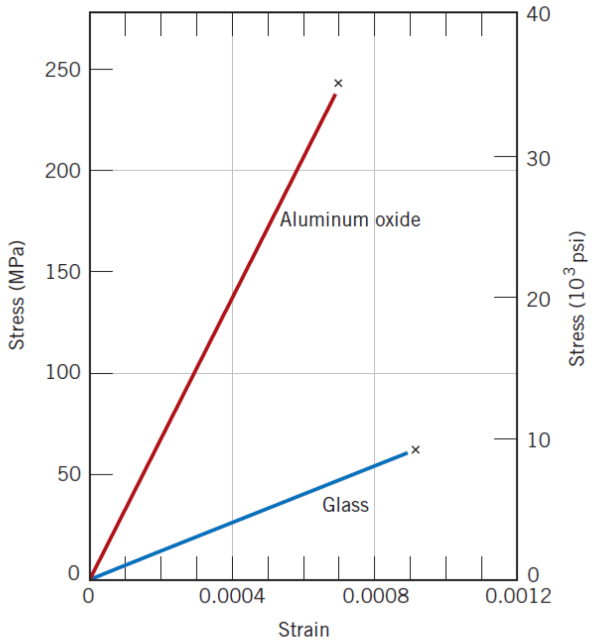
ASTM C 1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance

STRENGTH OF CERAMICS

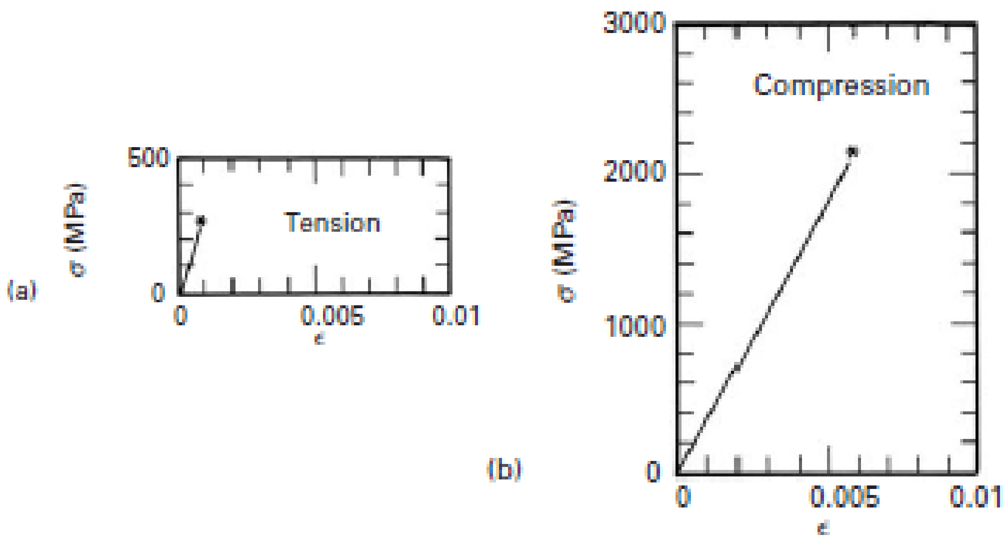
Theoretical strength is ~E/10.

We would expect strength of ceramic materials at the order of 10 GPa.

In practice, strength of ceramic materials are much lower in tension.



Typical stress-strain behavior for aluminum oxide and glass.



(a) Tensile strength and (b) compressive strength of aluminum oxide

Callister, Materials Science and Engineering

Meyers and Chawla., Mechanical Behavior of Materials,

STRENGTH OF CERAMICS

Ceramic materials usually fail by brittle fracture.

Strength is a function of the fracture toughness and the defect size

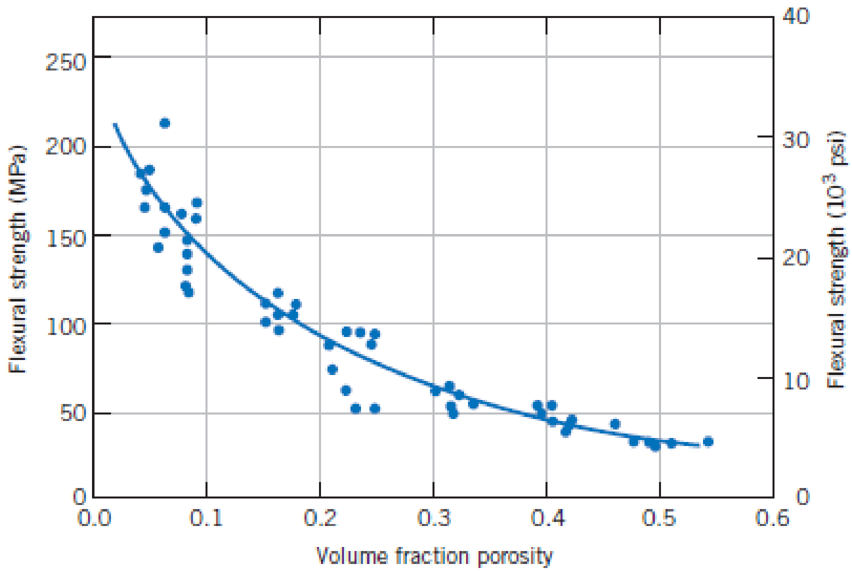
$$\sigma_f = \frac{K_{Ic}}{Y\sqrt{\pi c}}$$

For a given toughness, an increase in the defect size results in a decrease in the strength of the material.

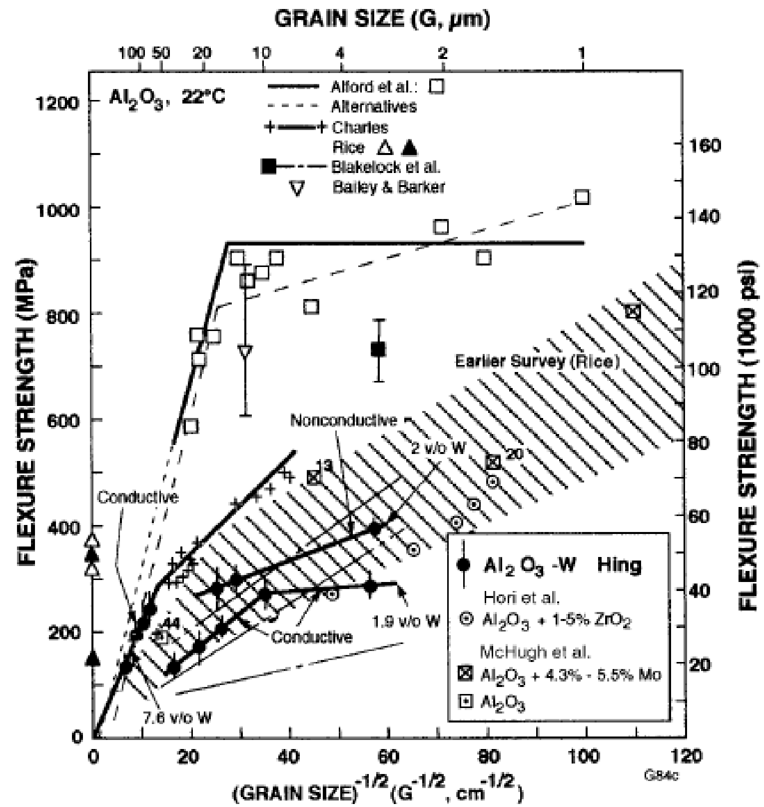
Defect size $\uparrow$ Strength $\downarrow$

STRENGTH OF CERAMICS

Strength of a ceramic material depends on the size of the largest defect present in the structure.



The influence of porosity



The influence of grain size

Callister, Materials Science and Engineering

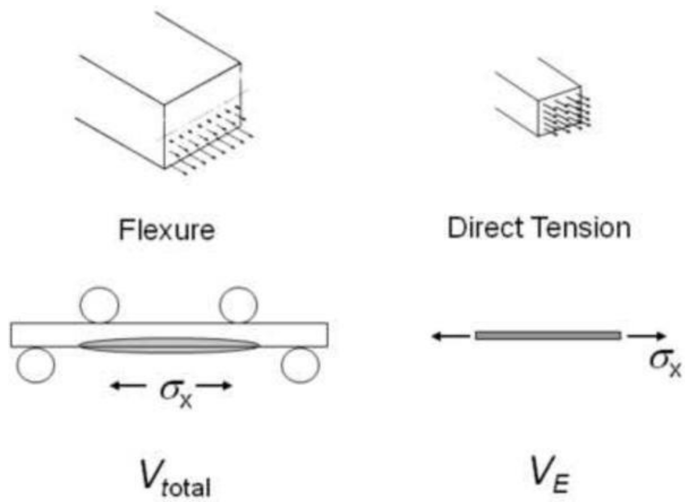
Rice, Mechanical properties of ceramics and composites

STRENGTH OF CERAMICS

As the volume of the ceramic material subject to stress decreases, probability of the presence of a larger defect also decreases; therefore strength increases.

Specimen size $\downarrow$	Probability of larger defects $\downarrow$	Strength $\uparrow$

Volume effected by maximum stress $\downarrow$	Strength $\uparrow$



Only part of the total volume, *V*, of the flexure specimen on the left is in tension. Only a smaller fraction of this region (depicted by the shaded area) is subjected to higher stresses.

STRENGTH OF CERAMICS

	Tensile strength (MPa)	Flexural strength (MPa)	Compressive strength (MPa)
Silicon Nitride	350–415	930	2100–3500
Silicon Carbide	390–450	634	1035–1725
Aluminum Nitride	–	200	1400–2100
Tungsten Carbide	344	1930	2683
Titanium Oxide	51.6	137	688
MgO stabilized Zirconia	352	620	1750
Aluminum Oxide (98%)	150	300	2500
Aluminum Oxide (99%)	180	400	3000
Zirconia toughened alumina (ZTA)	–	912	–
Boron Carbide	–	450	470
Titanium Diboride	–	277	470
Zirconia	–	800–1200	2000

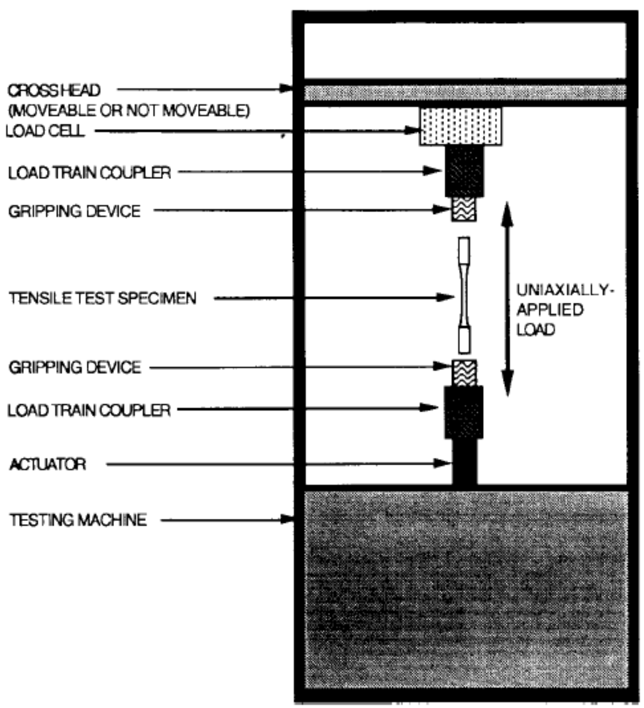
The values given are indicative only

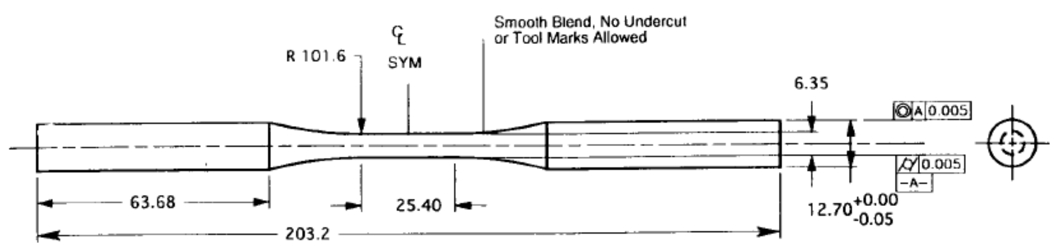
Meyers and Chawla., Mechanical Behavior of Materials,

STRENGTH OF CERAMICS

Tensile Strength Test (ASTM C 1273) requires

- a very careful alignment of the load train.
- a uniform interface between the grip components and the gripped section of the specimen
- a special geometry



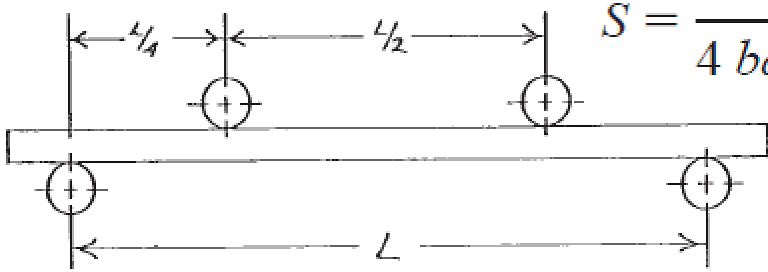


Number of specimens****

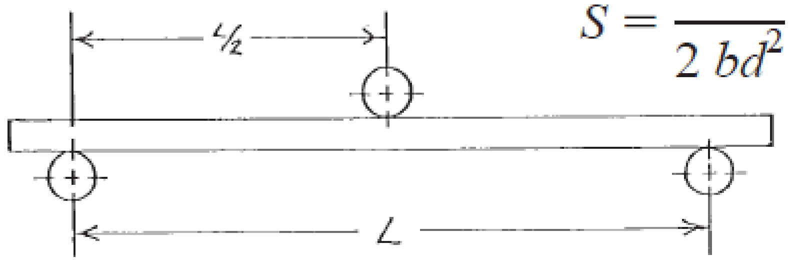
STRENGTH OF CERAMICS

Flexural Strength Test (ASTM C 1161)

$$S = \frac{3\,PL}{4\,bd^2}$$



$$S = \frac{3\,PL}{2\,bd^2}$$



NOTE 1—Configuration:
A: L = 20 mm
B: L = 40 mm
C: L = 80 mm

TABLE 1 Fixture Spans

Configuration	Support Span (L), mm	Loading Span, mm
A	20	10
B	40	20
C	80	40

TABLE 3 Specimen Size

Configuration	Width (b), mm	Depth (d), mm	Length (L_T), min, mm
A	2.0	1.5	25
B	4.0	3.0	45
C	8.0	6.0	90

TABLE 4 Crosshead Speeds for Displacement-Controlled Testing Machine

Configuration	Crosshead Speeds, mm/min
A	0.2
B	0.5
C	1.0

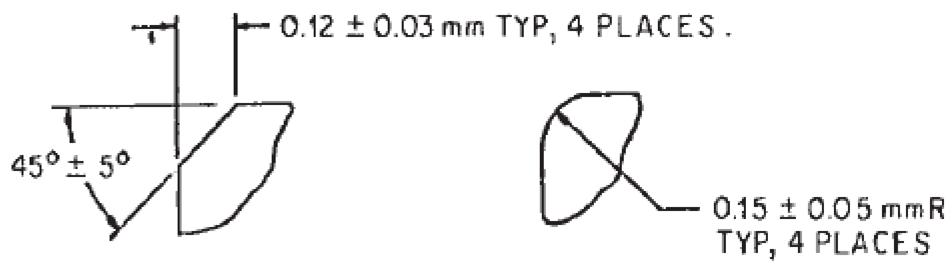
ASTM C 1161

STRENGTH OF CERAMICS

Specimen Preparation—Depending upon the intended purpose specimens can be tested As-Fabricated or Polished

Cross-sectional dimensional tolerances are ± 0.13 mm for B and C specimens, and ±0.05 mm for A. The parallelism tolerances on the four longitudinal faces are 0.015 mm for A and B and 0.03 mm for C.

The four long edges of each specimen shall be uniformly chamfered at 45°, a distance of 0.12±0.03 mm. They can alternatively be rounded with a radius of 0.15±0.05 mm. Edge finishing must be comparable to that applied to the specimen surfaces. Strength correction factors are provided in the standard.



DETAIL A

DETAIL A
ALTERNATE METHOD

ASTM C 1161

STRENGTH OF CERAMICS

ASTM C 1273 Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures

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

ASTM C1323 Test Method for Ultimate Strength of Advanced Ceramics with Diametrally Compressed C-Ring Specimens at Ambient Temperature

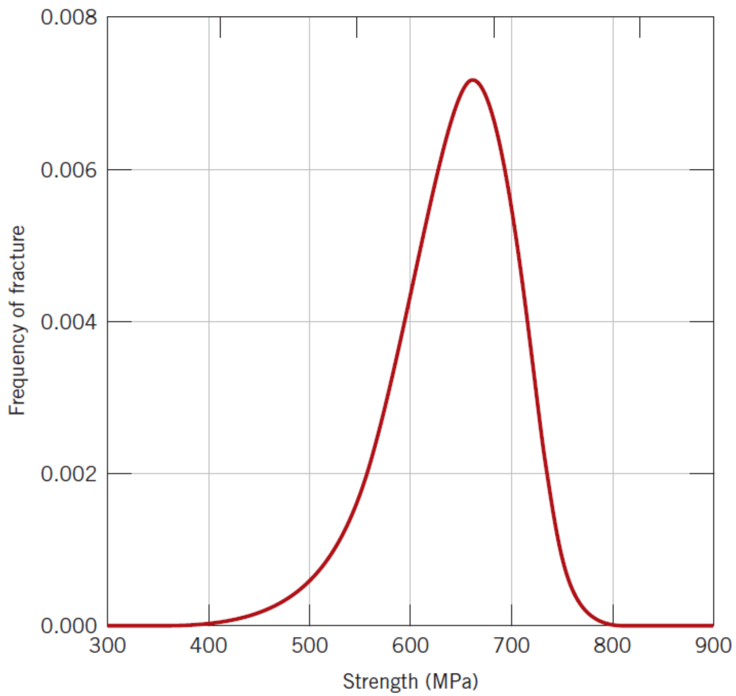
ASTM C1499 Test Method for Monotonic Equibiaxial Flexural Strength of Advanced Ceramics at Ambient Temperature

- Also known as ‘ring on ring test’

ASTM C1424 Test Method for Monotonic Compressive Strength of Advanced Ceramics at Ambient Temperature

STATISTICAL ANALYSIS OF STRENGTH

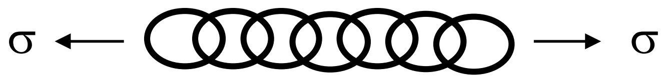
There is usually considerable variation and scatter in the fracture strength of ceramic materials.



The frequency distribution of observed fracture strengths for a silicon nitride material.

Callister, Materials Science and Engineering

WEIBULL ANALYSIS



The chain fails if the weakest link fails (Weibull, 1939)

Survival probability of one link: $P_s=[1-(\sigma/\sigma_0)^m]$

m: Weibull modulus

σ_0*: Weibull strength*

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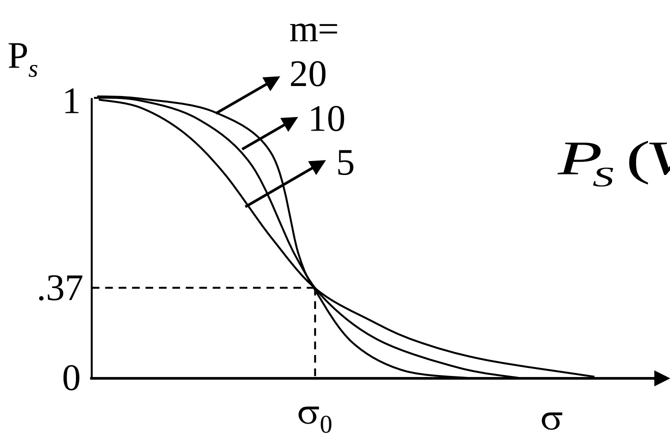
Survavival probability of a specimen with volume V_0:

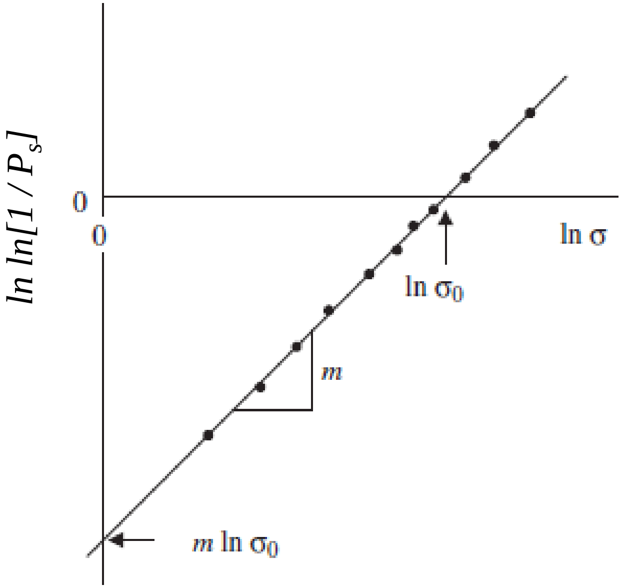


$$P_S(V_o) = \exp\left[-\left(\frac{\sigma}{\sigma_o}\right)^m\right]$$

WEIBULL ANALYSIS

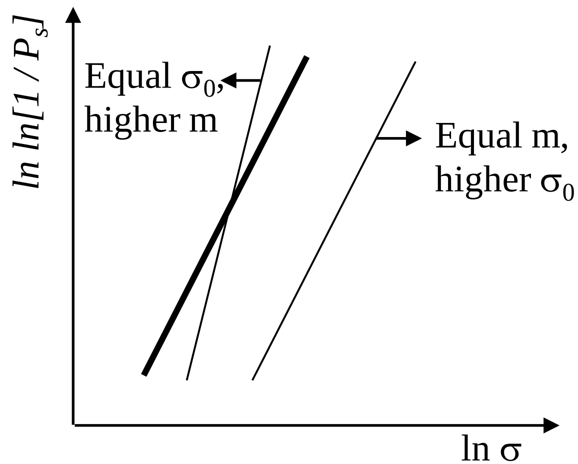
$$P_S(V_0) = \exp\left[-\left(\frac{\sigma}{\sigma_0}\right)^m\right] \Rightarrow \ln\ln\left(\frac{1}{P_s}\right) = m\ \ln\left(\frac{\sigma}{\sigma_0}\right)$$

$$\Rightarrow \ln\ln\left(\frac{1}{P_s}\right) = m\ \ln(\sigma) - m\ln(\sigma_0)$$

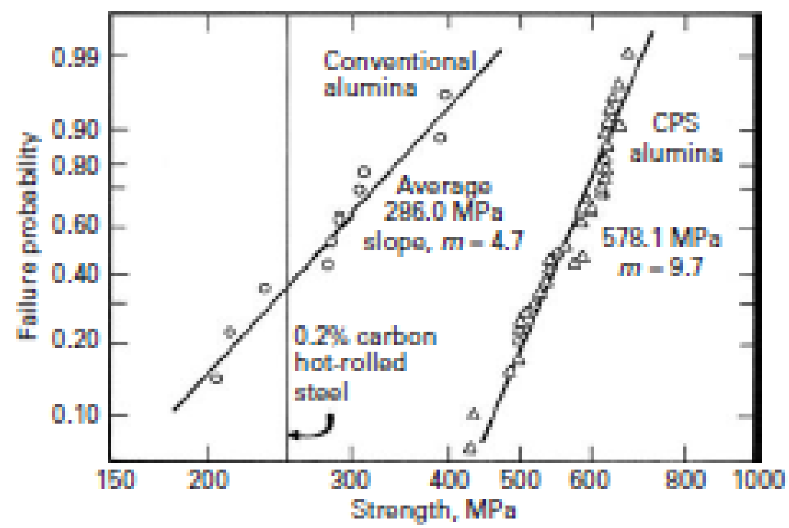


Watchman, Mechanical properties of ceramics

WEIBULL ANALYSIS



Material	m
Traditional Ceramics:	
Brick, Pottery, Chalk	<3
Engineered Ceramics:	
SiC, Al_2O_3, Si_3N_4	5–10
Metals:	
Aluminum, Steel	90–100



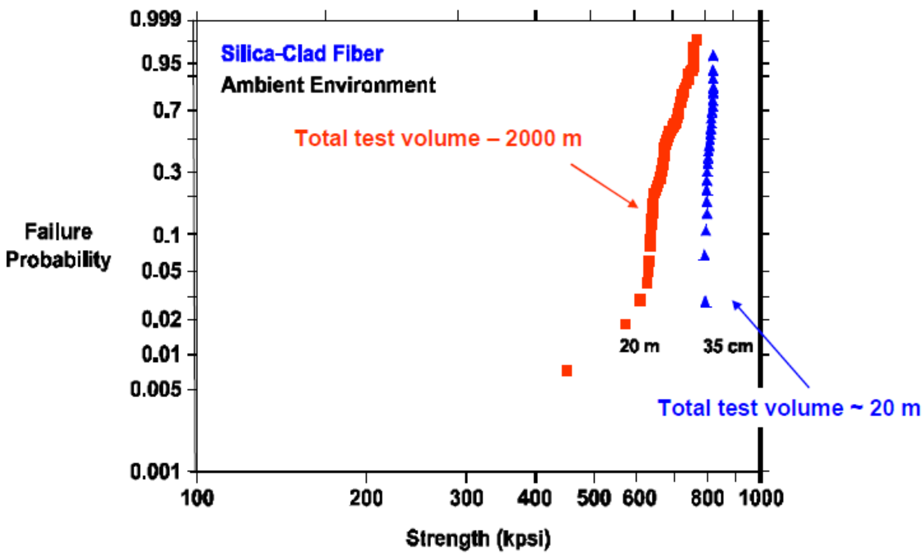
Meyers and Chawla., Mechanical Behavior of Materials,

WEIBULL ANALYSIS

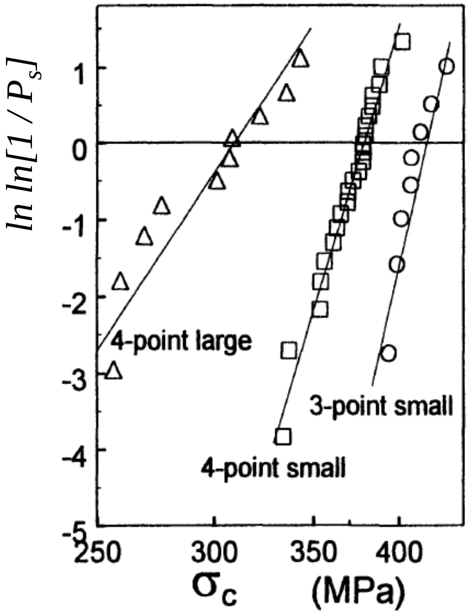
the generalized strength distribution law can be given by:

$$P_S(V) = \exp\left[-\frac{V}{V_0}\left(\frac{\sigma}{\sigma_0}\right)^m\right]$$

where V_0 is the reference volume



Testing a longer Gauge Length on Strength Distribution gives the illusion of lower strength because a greater sample volume is tested, exposing more lower strength flaws



Weibull plots for strength data of sintered alumina measured with different specimen sizes

John A. Jay, Corning, Optical fiber

Munz and Fett, Ceramics

WEIBULL ANALYSIS

More detailed information on statistical analysis of strength can be found in:

ASTM C 1239 Standard Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics

ASTM C 1683 Standard Practice for Size Scaling of Tensile Strengths Using Weibull Statistics for Advanced Ceramics

HARDNESS OF CERAMICS

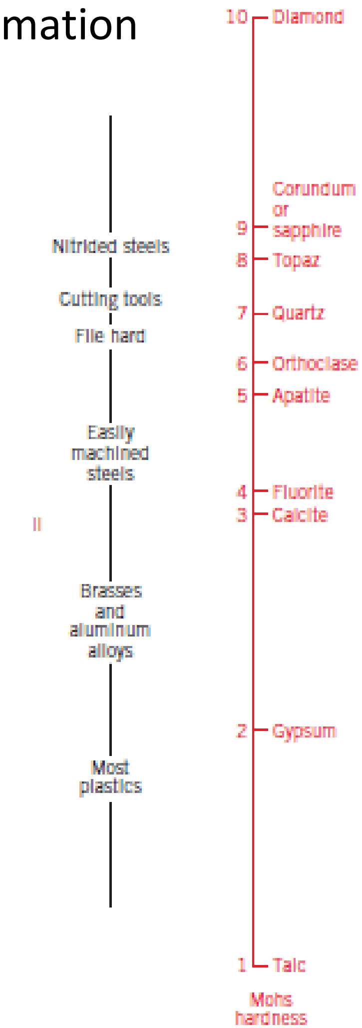
Hardness: The measure of a material's resistance to deformation by surface indentation or by abrasion.
Ceramics hardness is much higher than metals.

For Steel

Vickers HV	Approximate Tensile Strength (MPa)
660	2199
620	2061
580	1923
540	1792
500	1655
460	1517
420	1379
380	1241
340	1110
300	972
260	834
220	696
200	634
180	579
160	517
140	455

For Ceramics

	Hardness (HV)
Silicon Nitride	1800
Silicon Carbide	2300
Aluminum Nitride	1110
Tungsten Carbide	1600
Titanium Oxide	800
MgO stabilized Zirconia	1200
Aluminum Oxide (98%)	1800
Aluminum Oxide (99%)	1800
Zirconia toughened alumina (ZTA)	1500
Boron Carbide	2700
Titanium Diboride	2700
Zirconia	1200



The values given are indicative only

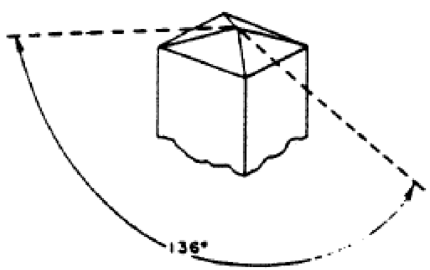
Meyers and Chawla., Mechanical Behavior of Materials,

Callister, Materials Science and Engineering

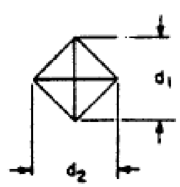
HARDNESS OF CERAMICS

Knoop hardness (ASTM C 1326) and Vickers hardness (ASTM C 1327) are preferred hardness measurement methods.

Vickers indenter is a square-based pyramidal-shaped diamond indenter with face angles of 136° .



Vickers hardness is generally given as the applied force on the indenter divided by the area between the four faces of the pyramid indenter and the surface (measured after the indenter is removed)

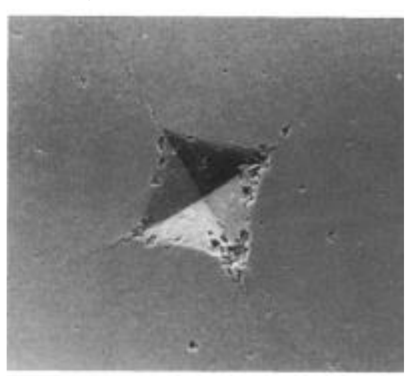


Hence, the Vickers hardness number is computed by

$$HV = 1.8544\,\frac{P}{d^2}$$

P= load, kgf

d= average length of the two diagonals of indentation, mm



The hardness symbol HV shall be supplemented by a number indicating the test force used (in kgf)

Ex: HV1 means Vickers hardness for an applied force of 1 kg (9.81 N)

ASTM C 1327

HARDNESS OF CERAMICS

*The Vickers hardness reported with units of **GPa** is determined as follows:*

$HV = 0.0018544\,\frac{P}{d^2}$

ASTM C 1327

P= load, N

Some in the ceramic community use the projected area in defining the Vickers hardness. In this case, hardness reported with units of GPa is determined as follows:

$H = 0.002\,\frac{P}{d^2}$

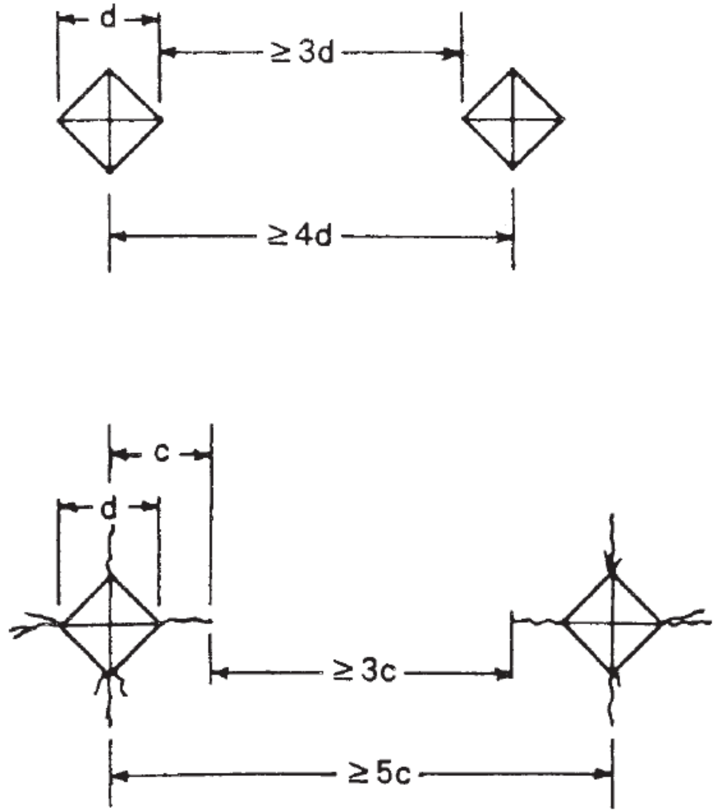
B. Lawn, Fracture of Brittle Solids

P=load, N

In reporting Vickers hardness it would be useful to state whether the projected area or the contact area is used since there is a 7.9 % difference in hardness values.

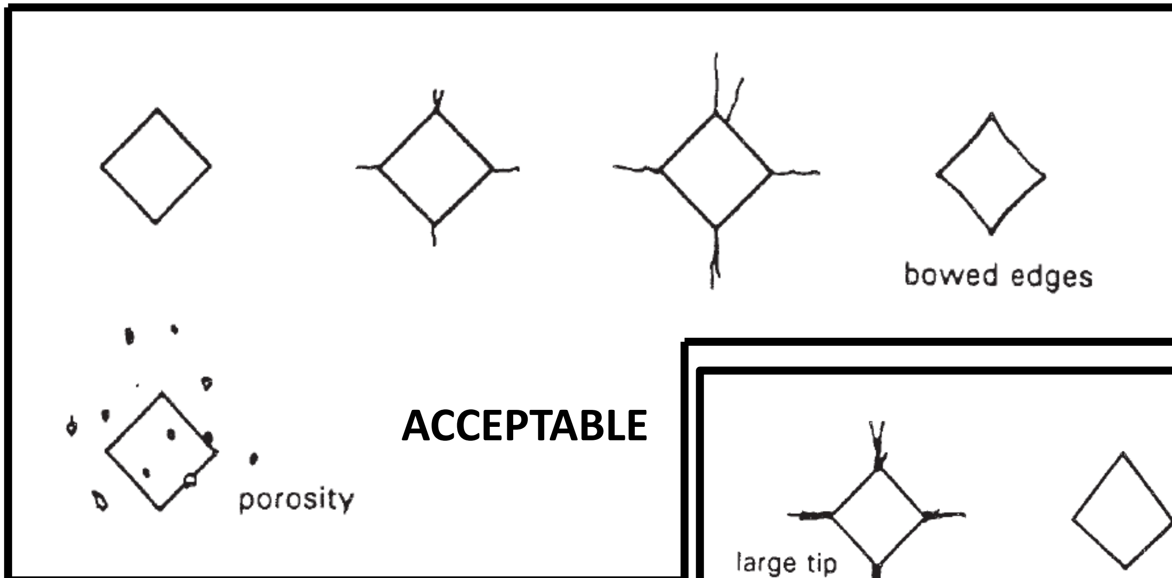
HARDNESS OF CERAMICS

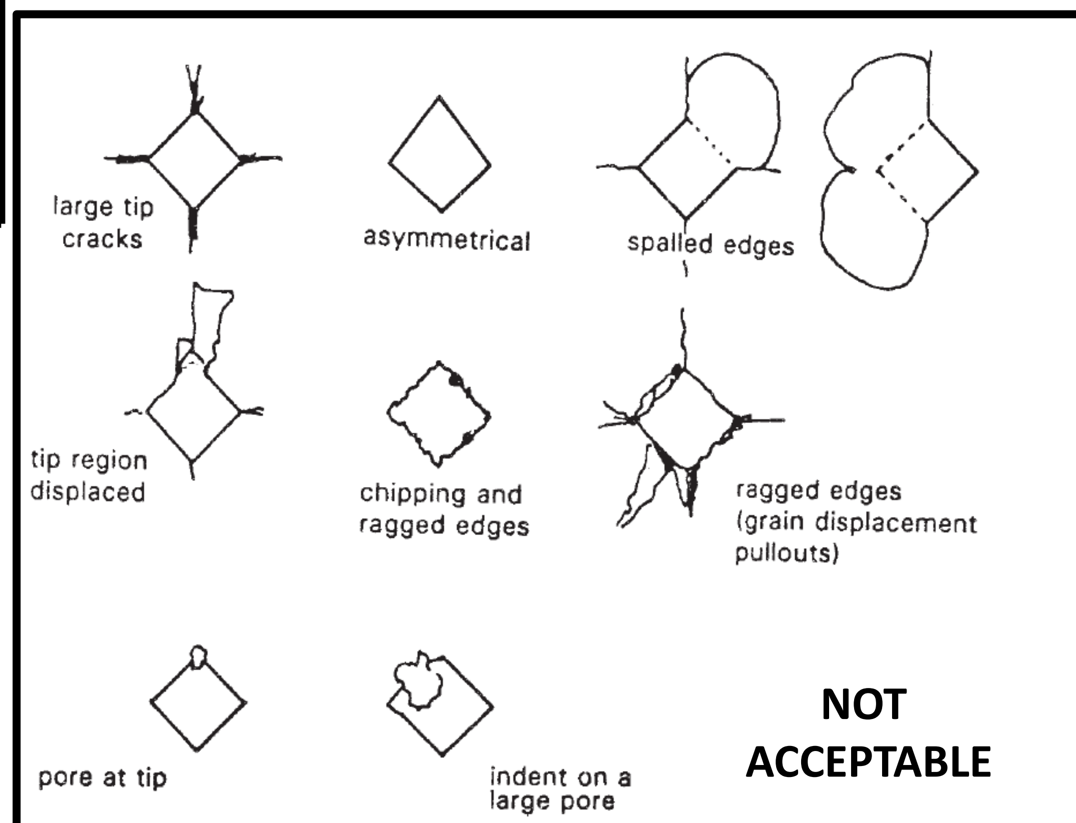
Closest permitted spacing between Vickers indentations



ASTM C 1327

HARDNESS OF CERAMICS



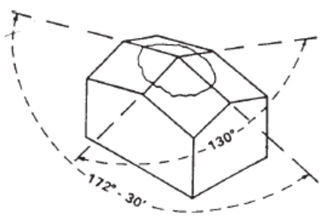


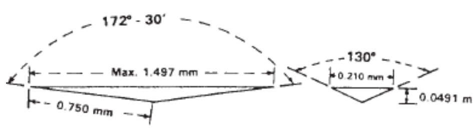
At least five and preferably ten acceptable indentations shall be made.

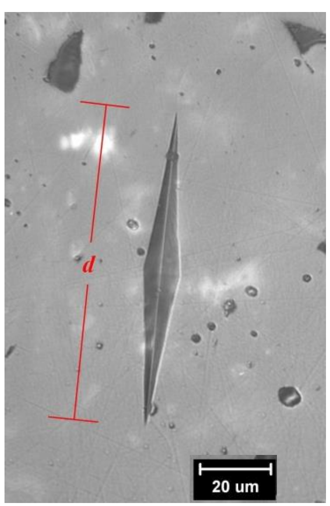
ASTM C 1327

HARDNESS OF CERAMICS

Knoop indenter is a rhombic-based pyramidalshaped diamond indenter with edge angles of 172° 30’ and 130° 00’.







Knoop hardness is obtained by dividing the force applied to the Knoop indenter by the projected area of the permanent impression made by the indenter.

Hence, the Knoop hardness number is computed by

$$HK = \frac{P}{d^2\, C_p}$$

P= load, kgf

d= length of the long diagonal of the indentation, mm

C_p=correction factor related to the shape of the indenter, ideally 0.070279

The Knoop hardness reported with units of ***GPa***

$$HK = 0.001\left(\frac{P}{d^2\, C_p}\right)$$

P= load, N

d and C_p as defined above.

ASTM C 1326

HARDNESS OF CERAMICS

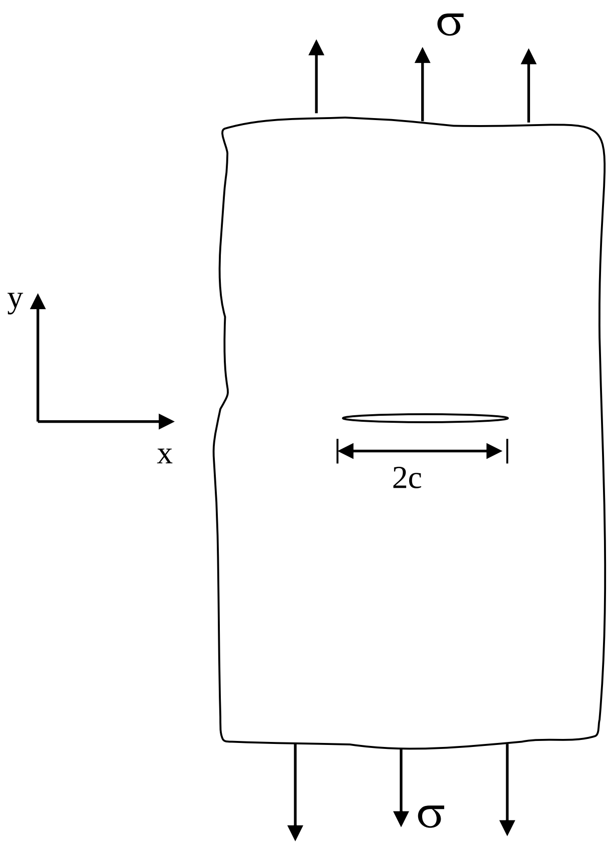
More detailed information on measurement of hardness of ceramics can be found in:

ASTM C 1326 Test Method for Knoop Indentation Hardness of Advanced Ceramics

ASTM C 1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics

TOUGHNESS OF CERAMICS

Linear elastic fracture mechanics



Stress near the crack tip $\sigma_y = \frac{\sigma\sqrt{\pi c}}{\sqrt{2\pi r}} f(\theta)$

$$K_I = Y\sigma\sqrt{\pi c}$$

$K_I > K_{IC}$ ⇒ crack propagation

K_I : stress intensity factor $(MPa\sqrt{m})$
K_{IC} : Critical stress intensity factor (toughness)
σ : Applied stress (MPa)
2c : Crack length (m)
Y : Stress intensity factor coefficient

TOUGHNESS OF CERAMICS

The fracture toughness of ceramic materials are low because they do have limited energy dissipation mechanisms.

	Fracture toughness (MPa $m^{1/2}$)	
Silicon Nitride	6	→ Grain bridging
Silicon Carbide	4.3	
Aluminum Nitride	3	
Tungsten Carbide	–	
Titanium Oxide	3.2	
MgO stabilized Zirconia	11	→ Transformation toughening
Aluminum Oxide (98%)	4	
Aluminum Oxide (99%)	4	
Zirconia toughened alumina (ZTA)	6.9	
Boron Carbide	3.0	
Titanium Diboride	6.9	
Zirconia	6–8	

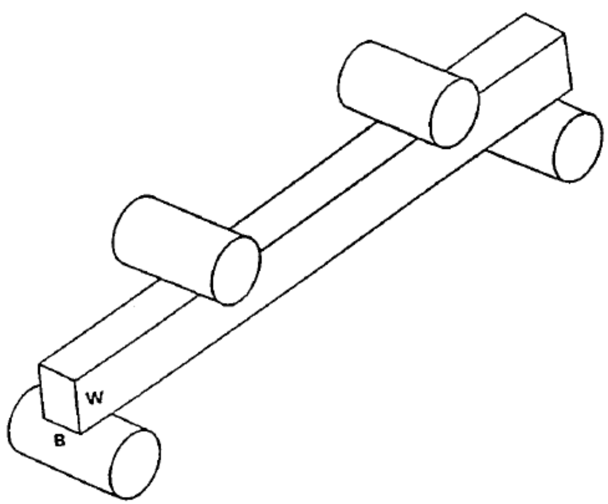
The values given are indicative only

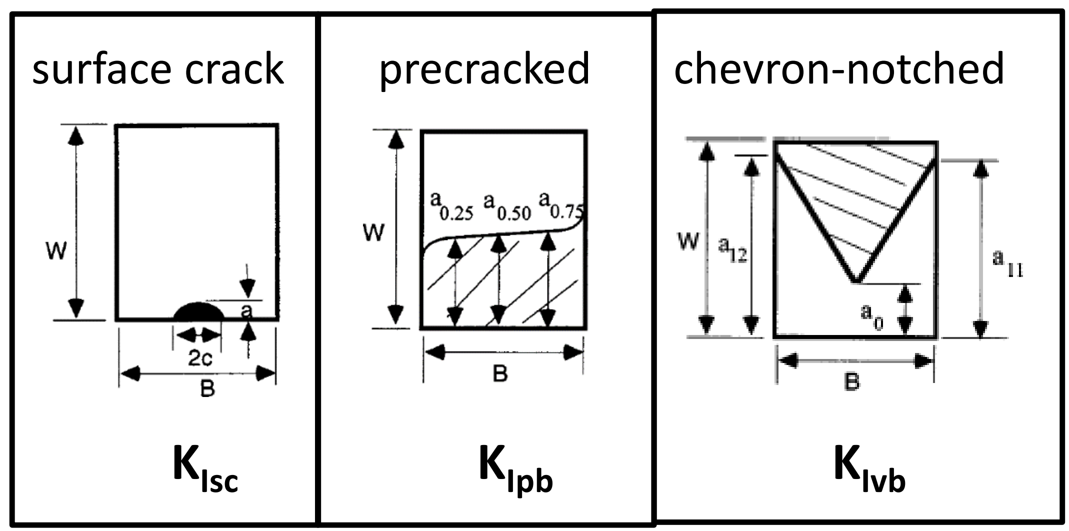
Meyers and Chawla., Mechanical Behavior of Materials,

TOUGHNESS OF CERAMICS

ASTM C 1421 covers the determination of fracture toughness of advanced ceramics at ambient temperature

The fracture toughness values are determined using beam test specimens with a sharp crack. The crack is either a semi-elliptical surface crack, a straight through crack, or it is propagated in a chevron notch.



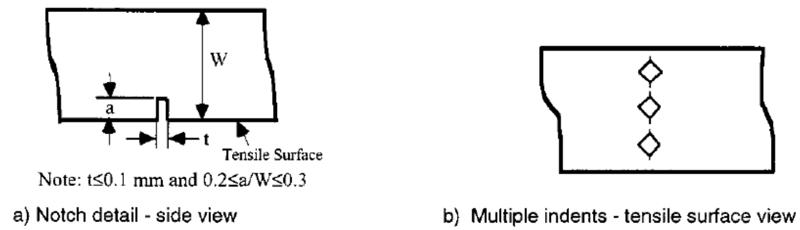


The precrack must be on the tension (bottom) surface.

TOUGHNESS OF CERAMICS

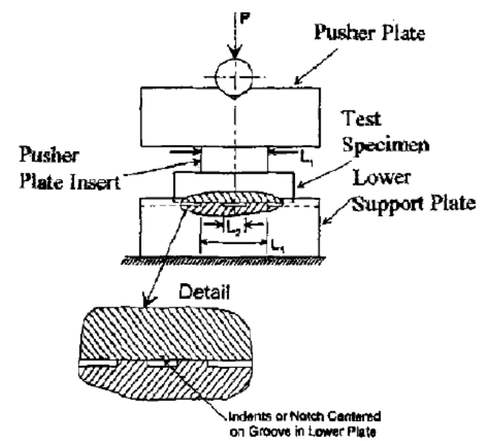
The Precracked Beam Method

Either the machined notch, a Vickers indent, or a series of Vickers indents act as the crack starter.



Precracked Beam Precracking Arrangement

Place the test specimen in the compression fixture with the surface containing the notch or indent(s) over the groove Load the test specimen in the compression fixture until a distinct pop-in sound is heard and/or until a pop-in precrack is seen.



Suggestion for Bridge Compression Fixture

The fracture force of the test specimen is determined in flexure test and the fracture toughness, K_{Ipb}, is calculated from the fracture force, the test specimen size, and the measured precrack size.

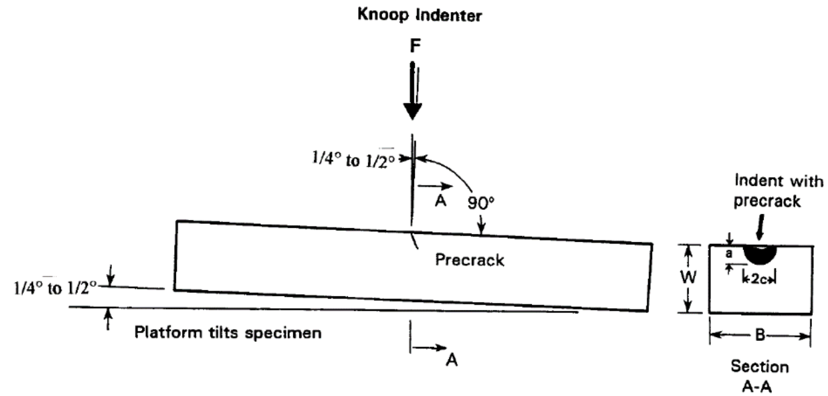
$$K_{Ipb} = f\left[\frac{P_{\max}[S_o - S_1]10^{-6}}{BW^{3/2}}\right]\left[\frac{3[a/W]^{1/2}}{2[1-a/W]^{3/2}}\right]$$

f=f(a/W)

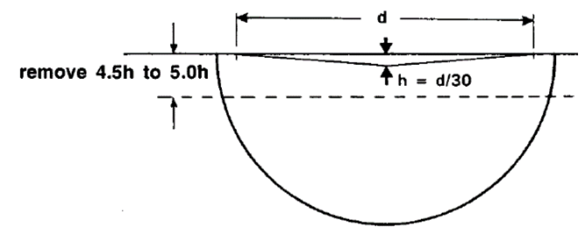
TOUGHNESS OF CERAMICS

Surface Crack in Flexure Method

A beam test specimen is indented with a Knoop indenter. Specimen is tilted to make crack more visible in post fracture measurement.



It is polished (or hand ground), while maintaining surface parallelism, until the indent and associated residual stress field are removed.



The fracture force of the test specimen is determined in flexure test and the fracture toughness, K_{Isc}, is calculated from the fracture force, the test specimen size, and the measured precrack size.

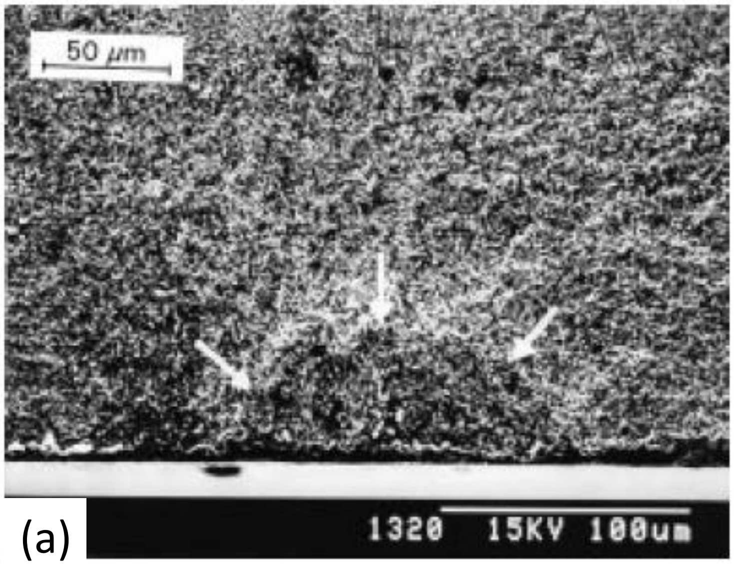
$$K_{Isc} = Y\left[\frac{3P_{\max}[S_o - S_i]10^{-6}}{2BW^2}\right]\sqrt{a}$$

Y=Y(a/c,a/W)

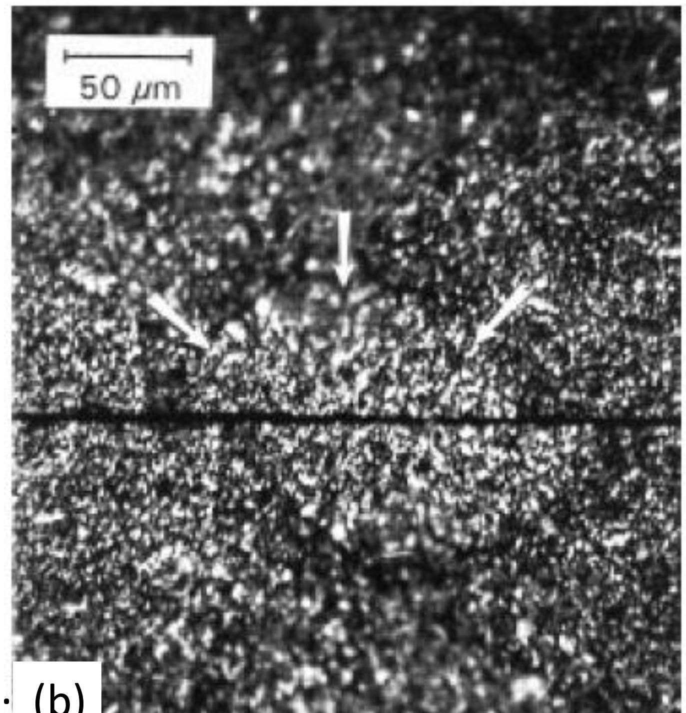
TOUGHNESS OF CERAMICS

Measuring precrack size after the fracture:

Fractographic techniques and fractographic skills are needed for this step.
The optimum procedure will vary from material to material.
Either an optical microscope or a scanning electron microscope can be used.



(a)



(b)

(a) SEM and (b) optic microscope images of Knoop Indent Precrack in SiN.

Dye penetration procedures may be beneficial and are permitted by these test methods. Considerable caution should be exercised in the use of these test methods, since it is difficult to completely penetrate the small, tight cracks in ceramics.

TOUGHNESS OF CERAMICS

More detailed information on measurement of toughness of ceramics can be found in:

ASTM C 1421 Standard Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature

Thanks for listening!
Q & A

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SERAMİK Journal of the Turkish Ceramics Society

Seramik - Journal of the Turkish Ceramics Society, 1 (1) 1-5 (2020)

Özgün Araştırma Makalesi / Original Research Article

Mangan Katkısının 94($Na_{0.5}Bi_{0.5}$)TiO_3-6$BaTiO_3$ Çok Katmanlı Piezoelektrik Seramiklerin Elektriksel Yorulma Davranışına Etkisi

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Makale Bilgisi / Article Info
Sunulma / Received : 15/01/2020
Düzeltme / Revised : 12/02/2020
Kabul / Accepted : 01/03/2020

Destekleyen Kuruluş / Funding Agency
Afyon Kocatepe Ünv. BAP Birimi
Proje No: 17.FEN.BİL.71 ve
Eskişehir Teknik Ünv. BAP Birimi
Proje No: 1705F199 ve 1605F333

Anahtar Kelimeler
Kurşunsuz
piezoelektrik
çok katmanlı
elektriksel yorulma
mangan

Keywords
Lead-free
piezoelectric
multilayer
electrical fatigue
manganese

Özet

Piezoelektrik çok katmanlı seramikler eyleyici uygulamalarında yüksek mekanik dayanım ve deplasman özellikleri nedeniyle kullanılmaktadırlar. Bu uygulamalarda çok fazla elektriksel çevrime maruz kalan malzemelerin elektriksel tepkileri, çevrim sayısına bağlı olarak düşmektedir. Buna elektriksel yorulma denmektedir. Eyleyici olarak kullanılacak olan malzemelerin yorulma davranışının belirlenmesi ve mümkünse dayanımının artırılması gerekmektedir. Eyleyici uygulamalarında genellikle kurşun içerikli PZT tabanlı malzemeler kullanılmaktadır. Kurşunsuz piezoelektrik malzemeler ise kapasitör uygulamalarında sıklıkla kullanılmaktadır. Toksik etkileri sebebiyle RoHs standartları gereği kurşun içerikli malzemelerin tüm endüstriyel ürünlerde sınırladırılması istenmektedir. Bu sebeple tüm dünyada kurşunsuz piezoelektrik malzemeler geliştirilmektedir. Eyleyici uygulamalarında kullanılmak üzere geliştirilen kompozisyonlardan bir tanesi de 94($Na_{0.5}Bi_{0.}$5)TiO_3-6$BaTiO_3$ kısaca NBT-6BT kompozisyonudur. Bu çalışmada kurşunsuz NBT-6BT kompozisyonuna Mangan ilavesi yapılmış, çok katmanlı seramik üretilmiş ve katkısız NBT-6BT kompozisyonu ile karşılaştırılmıştır. Bu sayede Mangan katkısının NBT-6BT çok katmanlı seramiklerin elektriksel yorulma davranışlarına etkisi araştırılmıştır. Kurşunsuz çok katmanlı seramikler su çözelti sistemiyle ve gümüş-paladyum (Ag-Pd) elektrot kullanılarak 1115-1120°C sinterleme sıcaklığı ve 2-4-6 saat olmak üzere farklı sinterleme sürelerinde sinterlenerek üretilmiştir. Mangan katkısının kalıcı polarizasyon değerini artırdığı, histeris eğrisinin kareselliğindeki bozulma oranını düşürdüğü belirlenmiştir.

Effect of Manganese Additive on Electrical Fatigue Behavior of 94($Na_{0.5}Bi_{0.5}$)TiO_3-6$BaTiO_3$ Multilayer Piezoelectric Ceramics

Abstract

Piezoelectric multilayer ceramics are used in actuator applications related to high mechanical strength and actuating performances. In these applications, the electrical response of materials decreases depending on the number of applied cycles. This is called electrical fatigue. Fatigue behavior of the materials must be determined if possible fatigue strength increased to be used as actuators. PZT based materials with lead content are generally used in actuator applications. Lead-free piezoelectric materials are frequently used in capacitor applications. Due to its toxic effects, it is desirable to limit lead containing materials in all industrial products as required by RoHs standarts. Therefore, lead-free piezoelectric materials are being developed all over the world. One of the compositions developed for use in actuator applications is 94($Na_{0.5}Bi_{0.5}$)TiO_3-6$BaTiO_3$, in short NBT-6BT. In this study, manganese was added to lead free NBT-6BT composition, multilayer ceramics were produced and compared with NBT-6BT multilayer ceramics. Thus, the effect of manganese additive on the electrical fatigue behaviour of NBT-6BT multilayer ceramics was investigated. Lead-free multilayer ceramics were produced with water-based tape casting slurry system and Ag-Pd electrode by sintering at 1115C-1120°C sintering temperature and 2-4-6 hours at different sintering times. It has been observed that manganese additive increases the permanent polarization value, decreases the deformation ratio of squareness of hysterisis.

TÜRK SERAMİK DERNEĞİ
Bilim-Teknoloji Webinerleri

Prof. Dr. Servet TURAN

Eskişehir Teknik Üniversitesi
Malzeme Bilimi ve Mühendisliği

Problem Çözümünde Farklı Mikroskop Tekniklerinin Stratejik Kullanımı

Malzeme ve yaşam bilimlerinde farklı mikroskopların kullanımları yüzyıllardır devam etmekte olup en önemli buluşlarda ve gelişmelerde mikroskoplar çok önemli yer tutmuş ve bu buluşların birçoğu Nobel ödülü ile taçlandırılmıştır. Mikroskoplarla İlgili bilmek istediğiniz ama sormaya çekindiğiniz her türlü soruyu sorabileceğiniz (her sorunuza cevap veremeyebiliriz!) bir ortamda geçecek olan bu seminerde mikroskop tekniklerinin çalışma prensipleri ile ilgili kısa bir bilgi verildikten sonra farklı problemlerin çözümünde stratejik olarak hangi tekniğin ne zaman ve nasıl kullanılması gerektiği ve elde edilen sonuçların anlamlandırılmasında dikkat edilmesi gereken unsurlar farklı örnek problem çözümleri ile anlatılacaktır. Mikroskopta elde edilen her gördüğümüz sonuca inanacak mıyız?, Gördüğüm şey doğru mudur?, Doğruyu nasıl buluruz?, ana ekseni üzerinden hareketle doğru bilinen yanlışlar örneklerle anlatılacaktır.

28 Temmuz 2021 Çarşamba 14:00