Test Standards for the Global Advanced Ceramics Market – Needs, Challenges, and Responsibilities

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OUTLINE

Why Standards?

The Global Situation for Advanced Ceramic Standards

ASTM C28 Committee

- Scope, History, Organization, and Standards
- The ASTM Standards Process
- New C28 Work Efforts in Ceramic Applications

ISO TC 206 Committee

- Scope, Organization and Status
- Current TC 206 Activities

Interaction of C28 and ISO TC206

- Responsibilities and Tasks
- Current Challenges
- Action Proposals

Silicon Nitride Turbocharger Rotors

PW-119-PW100 Engine for F22 with Thrust Diverters

Standards for Testing and Measuring

Why Test and Measure??

For material and structural development
Design data
Engineering/ production specifications
Product characterization and quality control
Failure Analysis

If you can't test and measure it accurately and reliably, you can't control it.

The challenge is to develop consensus-based test standards that we all can use with confidence and reliability within our ceramic producer-user-research community.

BENEFITS OF STANDARDS

Technical Benefits

- Accurate/complete test methods for broad use
- A common terminology
- Tests support critical material and/or application performance criteria
- Well-defined formats and complete requirements for data exchange
- Broadly accepted means of benchmarking new materials and processes

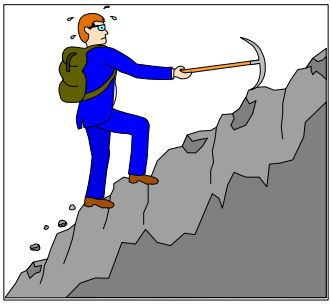
Market Benefits

- A basis for design codes, QC requirements, and regulatory action
- Reduce testing redundancy, increase efficiency, and reduce costs in development
- Speed the transition of new materials from laboratory to commercial markets
- Support the establishment of a strong, stable supplier base
- Assist in the establishment of high quality products

WITHOUT STANDARDS !!!!

AT BEST!!!

- Confusion over terminology, test procedures, protocols, and data requirements.
- Conflicting and/or incomplete data comparison
- Multiple test requirements from multiple users and developers.



AT WORST!!!

- **BAD TESTS** with invalid, unreliable, irreproducible, and incomplete test data.

The Global Situation for Advanced Ceramics Standards

- **Wide variety of national standards for advanced ceramics** *[ASTM - 47, CEN (European Union)-66, Japan- 95, China -10, Korea - 34]* covering the full range of mechanical, thermal, physical, electrical properties, and specifications.
- **ISO (International Standards Organization) has a technical ceramics committee (TC 206)** with 33 published standards and 27 standards in progress or proposed.

QUESTIONS --

1. *What standards are needed for the global market ?*
2. *Which standards will the ceramics customer specify?*
3. *How "good" are the different standards?*
4. *Should and how can standards be harmonized?*

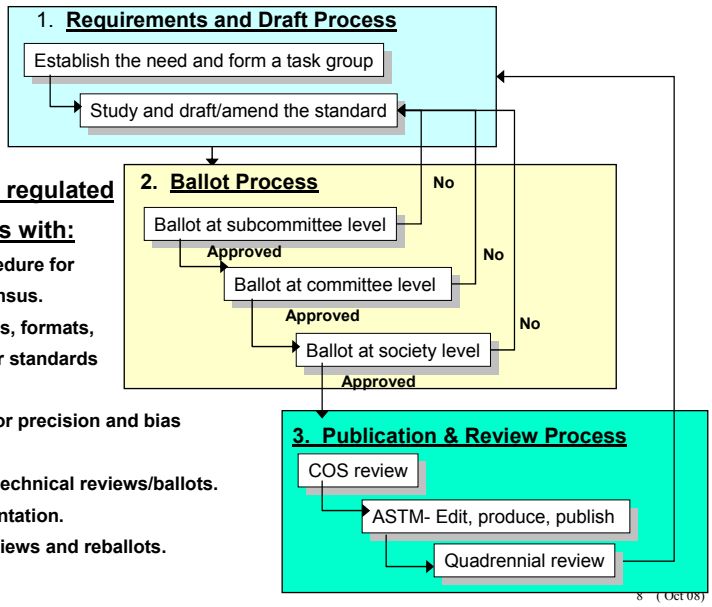
ASTM International

- ***The largest U.S. based international voluntary consensus standards writing organization***
- ***32,000 Members from 100 Countries***
- ***11,000 Full Consensus Standards***

ASTM MISSION -- To be the foremost developer and provider of voluntary consensus standards, related technical information, and services having globally recognized quality and applicability that:

- promote public health and safety, and the overall quality of life;
- contribute to the reliability of materials, products, systems and services;
- facilitate international, regional, and national commerce.

The ASTM Standards Process



An organized and regulated volunteer process with:

- **A defined procedure for reaching consensus.**
- **Extensive guides, formats, and methods for standards development.**
- **Requirements for precision and bias determination.**
- **Three levels of technical reviews/ballots.**
- **Formal documentation.**
- **Quadrennial reviews and reballots.**

History of ASTM C28 Advanced Ceramics

- **Mid 80s -- The start of the advanced ceramics technology wave!!**
  - ***Structural applications in aerospace, automotive, energy-production, electronics, wear/abrasion, and environment control.***

- **Standards were needed for advanced ceramics, but this was outside the scope ASTM C21-Whitewares and ASTM C8-Refractories.**

1986 - ASTM C28 Advanced Ceramics was established

2008 - Over 45 advanced ceramic test standards developed and published in ASTM Vol 15.01.

C28 Advanced Ceramics Committee

C28 Scope –

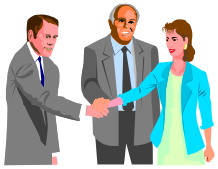
The promotion of knowledge, stimulation of research, and the development of standards *(classifications, specifications, nomenclature, test methods, guides, and practices*) relating to processing, properties, characterization, and performance of advanced ceramic materials.

C28 Membership and Organization

Committee Membership -- 97 Members (Jan 2008)

- Industry, Government, Academic, International (24%)

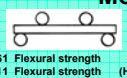
- **Six Technical Subcommittees**
  - C28.01 - Mechanical Properties and Reliability – 20 Standards
  - C28.03 – Physical Properties and NDE – 9 Standards
  - C28.04 – Ceramic Applications –3 Standards
  - C28.07 - Ceramic Composites – 11 Standards
  - C28.91 - Terminology – 1 standard
  - C28.94 – ISO TAG TC206
- **Four Administrative Subcommittees**
  - C28.90 - Executive Committee
  - C28.92 - Awards
  - C28.93 – Education and Outreach
  - C28.95 – Long Range Planning
- **Two Meetings A Year –**
  - Daytona Beach (January) and Web-Tele Conference (July)



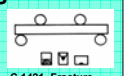
C28 Advanced Ceramic Standards - Today

Visit the C28 website (http://www.astm.org/COMMIT/COMMITTEE/C28.htm) to purchase standards or join the C28 committee.

Monolithics

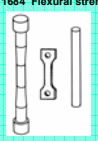


C 1161 Flexural strength
C 1211 Flexural strength (High Temp)
C 1368 Slow Crack Growth (Dynamic Fatigue)
C 1465 Slow Crack Growth (High Temp)
C 1576 Slow Crack Growth (Stress Rupture)
C 1684 Flexural strength (Rods)



C 1421 Fracture Toughness

C 1322 Fractography
C 1678 Fracture Mirror

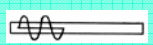


C 1424 Compression strength

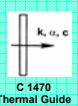
C 1273 Tension strength
C 1366 Tension strength (High T.)
C 1291 Creep, Creep Rupture
C 1361 Cyclic fatigue

C 1326 Knoop hardness
C 1327 Vickers hardness

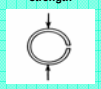
C 1499 Biaxial strength



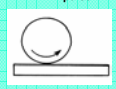
C 1198 Elastic Modulus - continuous
C 1259 Elastic modulus - impulse



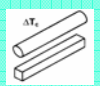
C 1470 Thermal Guide



C 1323 C-ring strength



C 1495 Grinding

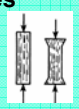


C 1525 Thermal shock

Composites

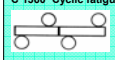
C 1275 Tension strength
C 1359 Tension strength (High Temp)
C 1337 Creep, Creep Rupture
C 1360 Cyclic fatigue

C 1468 Tension Trans thickness



C 1358 Compression

C 1557 Tensile strength and Elastic modulus



C 1469 Joint strength

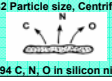
C 1341 Flexure strength

C 1292 Shear strength
C 1425 Shear strength (High T.)

C 1624 Coatings – Scratch Adhesion

Powders

C 1251 Particle size, BET Guide
C 1274 Particle size, BET
C 1282 Particle size, Centrifugal Sed.



C 1494 C, N, O in silicon nitride

Subcommittees
.01 Mech. Prop. + Reliability
.03 Physical Prop. + NDE
.04 Applications
.07 Ceramic Matrix Composites
.91 Terminology
.94 ISO TAG

NDE and Design

C 1239 Weibull

C 1683 Weibull Scaling

C 1212 Seeded voids
C 1336 Seeded inclusions

C 1175 NDE Guide

C 1331 Ultrasonic velocity
C 1332 Ultrasonic attenuation

Terms, Workshops, Education

STP 1201 Life Prediction
STP 1309 Composites
STP 1392 Composites
STP 1409 Fracture

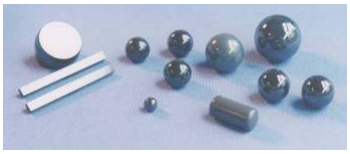
C 1145 Terminology

ASTM C28 standards are found in Vol. 15.01.

Standardization: The Tangible Benefits

F 2094 (2001) Standard Specification for Silicon Nitride Bearing Balls

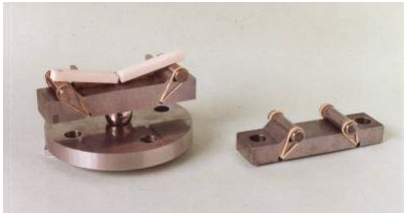
ASTM Committee F34 on Rolling Element Bearings

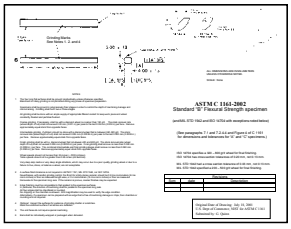


- C 1161 Flexure Strength
  "Average values for room temperature rupture strength for a minimum of 20 individual determinations shall exceed the minimum values given in Tale 3. Either 3 or 4-point methods may be used …..
- C 1327 Vickers hardness
  "The hardness (HV) shall be determined by the Vickers method ….."
- C 1421 Fracture Toughness
  "Fracture resistance shall be measured by either an indentation technique or by a standard toughness tests method. Average values for hardness and fracture resistance shall exceed the minimum of values for the specified material class ….."
- C 1198 Elastic Modulus
  "Minimum 270 Pa, maximum 330 GPa."
- C 1239 Weibull Distribution Parameters
  "Weibull modulus for each test series shall also exceed the minimum permitted values given in Table 3."

Standardization: The Tangible Benefits

C1161 -- Flexure Strength of Advanced Ceramics

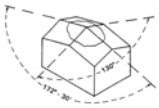


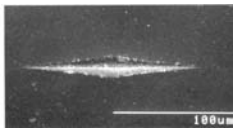


- Prior to standardization, a myriad of procedures which produced conflicting data were in use.
- MIL STD (in 1983), ASTM (in 1990), and ISO (in 2000) standards were prepared. They are in harmony. Fixture and specimens sizes and preparation procedures were specified.
- The outcome is that users around the world are able to obtain high quality test data, suitable either for design or routine characterization. There is immediate data acceptance and credibility.
- Another benefit was lower cost test specimens. They cost $12 -$20 each prior to standardization. Inflation adjusted they would cost $25 - $40 now. They actually cost $12 - $15 each.
- Another benefit is that users can acquire test fixtures off-the-shelf.

Standardization: The Tangible Benefits

C1326 -- Vickers Hardness Testing of Advanced Ceramics





NIST

ISO

The Knoop diamond pyramid indenter. A Knoop indentation in a ceramic. NIST SRM 2830

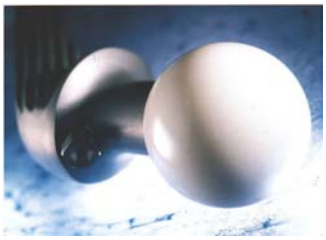
- Hardness standards for metals such as ASTM E 384 were often applied to ceramics. E 384 features Knoop and Vickers microindentation hardness. This led to problems since cracking and the indentation size effect in ceramics caused users to vary the testing conditions dramatically. As a result, it was very difficult to compare ceramic hardness values. This was a severe problem since material specifications were being written for ceramics with hardness requirements.
- Furthermore, the Harmonized Tariff Schedule of the United States classified imported ceramic wares in part by hardness, but with the archaic Mohs mineralogical scratch test.
- ASTM Knoop and Vickers ceramic hardness tests were adopted in 1996. An ISO test was adopted in 2000. The procedures are harmonious.
- NIST developed ceramic Knoop and Vickers hardness SRM's that complement the test method standards. Confusion has been eliminated and data quality has improved dramatically.
- The US Customs service acquired two Knoop SRM's disks and is working through NAFTA to replace the Mohs specifications with modern Knoop hardness specifications.

Standardization: The Tangible Benefits

F 1973 (1998) Standard Specification for High Purity Dense Yttria Tetragonal Zirconium Oxide Polycrystal (Y-TZP) for Surgical Implant Applications

ASTM Committee F-04, Surgical and Medical Devices and the U.S. Food and Drug Administration used 5 Generic C-28 Advanced Ceramics for their new standard:

- **C 1161-90 Flexure Strength**
  "The average flexural strength shall be 800 MPa or greater by 4 point bending in accordance with ASTM C 1161."
- **C 1198-91 Elastic Moduli by Sonic Resonance, or**
- **C 1259-94 Elastic Moduli by Impulse Excitation of Vibration**
  "The minimum elastic modulus shall be 200 GPa in accordance with C 1198 or C 1259."
- **C 1239-93 Weibull Strength Parameters**
  "If Weibull modulus is tested, it shall be tested in accordance with C 1239."
- **C 1327-96 Vickers Hardness**
  "The minimum Vickers hardness shall be 1200 HV in accordance with C 1327."

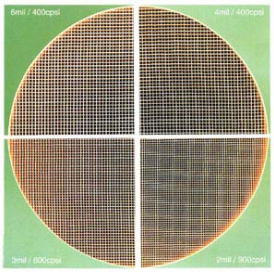


Current C28 Activities

Update and Improved Current Standards

Current Efforts

Fracture Toughness
BET Surface Area
C-Ring Testing
Powder Sizing



Write and Publish New Standards

Published in 2008

- Flexure Testing of Cylindrical Rods
- Weibull Size Scaling for Tensile Strength
- Fractographic Analysis of Fracture Mirrors
- Flexure Testing of Ceramic Honeycombs

New Initiatives

- Nanomechanics Test Methods
- Round Robin Evaluation of Honeycomb Flex
- Double Torsion Fracture Toughness
- Standards for Nuclear CFCC Ceramics
- Button Configuration Fuel Cell Test

Opportunities

Ceramic Armor
Photocatalytic Ceramic Coatings
Thermoelectric Ceramics

Questions for the Audience

- What C28 standards are you and your customers using and citing?
- What new standards are needed for advanced ceramics in the global market?
- Should your company be active on the C28 committee?

ISO TC 206 – Fine Ceramics

Established in 1994 –

Scope: Standardization in the field of fine ceramic materials and products in all forms: powders, monoliths, coatings, and composites, intended for specific functional applications including mechanical, thermal, chemical, electrical,magnetic, optical and combinations thereof.

The term "fine ceramics" is defined as "a highly engineered, high performance, predominantly nonmetallic, inorganic material having specific functional attributes".

Participating (voting) Members – 15 countries,
Japan(Secretariat Austria, Belgium, Canada, China, France, Germany, Indonesia, Italy, Japan, Republic of Korea, Malaysia, Russian Federation, Ukraine, United Kingdom, USA

Observing (non-voting) Members – 14 countries
Cuba, Czech Republic, Ecuador, Egypt, Norway, Philippines, Poland, Serbia, Slovakia, Spain, Switzerland, Thailand, Turkey, Venezuela

One Annual Meeting –
Korea (2008), Germany, (2007), Indonesia (2006), Hawaii (2005)

ISO TC 206 – Status

Twenty-two Active Working Groups

ISO TC206 Standards Status As of Nov 2007	Published	In-Progress	Proposed	5-year Review
Powders	7	-	1	1
Monoliths – Mech, Thermal, etc	16	1	-	3
Composites - Mech, Thermal, etc	4	-	4	-
Coatings	3	3	1	-
Photocatalytic Ceramics	1	7	-	-
Porous Ceramics	-	2	-	-
Ion-Conducting Ceramics	-	-	3	-
Specification	-	1	-	-
Other	2	-	-	-
Total	**33**	**14**	**9**	**4**

ASTM C28 and ISO TC 206

ASTM C28 is the US representative (Technical Advisory Group) to the ISO TC206 committee and has been active since the start, particularly on TC206 standards based on C28 standards.

Participating Member Responsibilities and Tasks

- Review, comment, and vote on ballot items at each development stage.
- Attend and participate in the annual meeting.
- Organize work groups where appropriate.

Observer Member Responsibilities and Tasks

- Review and comment on ballot items as appropriate.
- Attend and participate in the annual meeting as an observer.

TC 206 TAG Leadership and Committee Tasks

1. **Review, comment, and vote on ballot items at each development stage.**
   - Receive, organize, maintain, and reply to admin and ballot items.
   - Find US technical experts for review and comment on new ballot items.
   - Send out ballot items, coordinate and collect reviews from technical experts for the TAG subcommittee.
   - Submit reviews and obtain vote on specific items from the C28 TC206 TAG subcommittee.
   - Submit ballot votes to TC206 secretariat.
   - Develop and maintain records on ballot items.
2. **Attend and participate in the annual meeting.**
   - Obtain travel funding for the international meeting.
   - Prepare and organize information and briefings for the annual meeting.
   - Attend and participate in the 5 day meeting.
   - Work the action items after the meeting.
3. **Organize work groups where appropriate.**
   - Find expert volunteers to lead the work groups.
   - Support and encourage the work group
   - Liaison between the work group leader and the Secretariat.

Current Challenges for the C28 TC206 TAG

The C28 committee hasn't able to fully meet the obligations of TC206 membership for the last 5 years

1. **Full participation on the ballot actions is more than a volunteer can do in his spare unpaid time.**

2. **The travel costs and time commitment for the annual meeting are too much for a volunteer to cover.**

Four Options on the Table

- **Give up the TC206 TAG**
- **Drop to observer status.**
- **Participate at limited activity level.**
- **Full participation.**

Options for the TC206 TAG Activity

TC206 Participation Options	Risk and Questions	Cost
Give up ISO TC 206 Membership	NO US participation in the TC 206.	No Cost
Switch to Observer Status (TAG Leader watches ballot actions)	Observer only. No input on any ballot item. ***What do we do on critical items?***	$600 membership 40 volunteer hours/year
Limited participation, but only respond to high priority standards (2 per year). No annual meeting attendance	Very limited participation and no coverage on new items. ***What do we do if a big issue comes up?***	$600 membership 100 volunteer hours a year BETTER – 100 **paid** hours/year.
Full participation (10 items/year) with annual meeting attendance	Full coverage of revisions and new standards efforts	$600 membership + 650+ hours/year paid time+ $2.5K travel

TC 206 TAG Task Estimates

1. **Review, comment, and vote on ballot items at each development stage.** *(10 ballot actions a year = 550 hours a year)*
   - **Receive, organize, maintain, and reply to admin and ballot items.** *(8 h /month)*
   - **Find US technical experts for review and comment on new ballot items.** *(25 h /new item)*
   - **Send out ballot items, coordinate and collect reviews from US technical experts for the TAG subcommittee.** *(20 h /ballot item)*
   - **Submit reviews and obtain vote on specific items from the C28 TC206 TAG subcommittee.** **(***8h /ballot item)*
   - **Submit ballot votes to TC206 secretariat.** (*3h /ballot item)*
   - **Develop and maintain records on ballot items.** (*3h /ballot item)*

2. **Attend and participate in the annual meeting.** *($2.5K + 90 hours a year)*
   - **Obtain travel funding for the international meeting.** *($2.5K)*
   - **Prepare and organize information and briefings for the annual meeting.** (*30 hours)*
   - **Attend and participate in the 5 day meeting.** (*40 hours)*
   - **Work the action items after the meeting.** (*20 hours)*

3. **Organize work groups where appropriate.** *(120 hours a year)*
   - **Find expert volunteers to lead the work groups.** (*30 hours)*
   - **Support and encourage the work group** (*50 hours/year)*
   - **Liaison between the work group leader and the Secretariat.** (*50 hours/year)*

Closing Questions

The C28 committee has been wrestling with this TC206 issue for 4 years, as the TC 206 workload grows and volunteer resources diminish.

- **We have polled our members and resources and $ are not available at that level.**

KEY QUESTIONS

1. **How vital and important is US participation in ISO TC206 to the US advanced ceramic industry and market?**
   - **What are the risks of not participating?**
2. **Which users/suppliers/agencies can provide resources and support the C28 TC206 TAG?**
3. **What level of resources are available to support what level of participation?**