Fracture Toughness of Ceramics using the SEVNB Method; Round Robin

Jakob Kübler[1]*

Introduction

Numerous methods are currently in use to measure the fracture toughness of ceramic materials. However, methods based on widely accepted theories are often difficult to realise, unreliable, or expensive. A simple and cost-saving method, the single-edge-V-notched beam (SEVNB) method, was recently reintroduced. With this method, a saw cut is tapered by hand or with a simple machine (Fig.1) to a sharp V-notch (Fig.2) using a razor blade sprinkled with diamond paste. In an international round robin, the fracture toughness was measured with the SEVNB method (Fig.3) on five ceramic materials.

Experimental procedure

In the round robin, five ceramic materials with varying fracture toughness measurability were used. Each participant was required to test a coarse-grained alumina-998 and a gas-pressures sintered silicon nitride (GPSSN). Optional were a fine-grained alumina-999, a silicon carbide (SSiC) and a submicron-grained yttria-stabilised tetragonal zirconia (Y-TZP). Participants who volunteered received additional specimens to measure the fracture toughness using their preferred method, e.g. chevron notch.

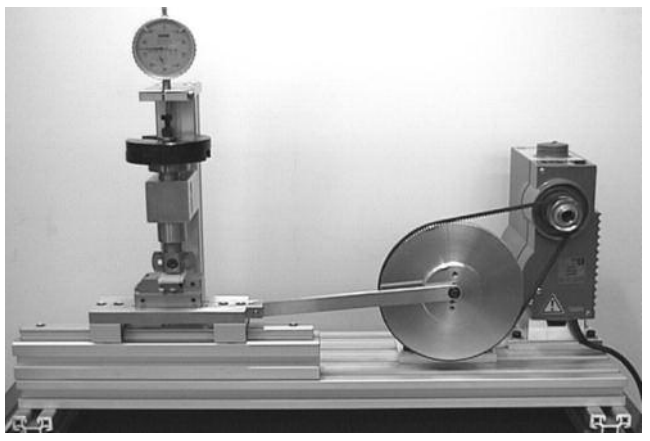

Fig. 1: Simple machine to polish V-notches

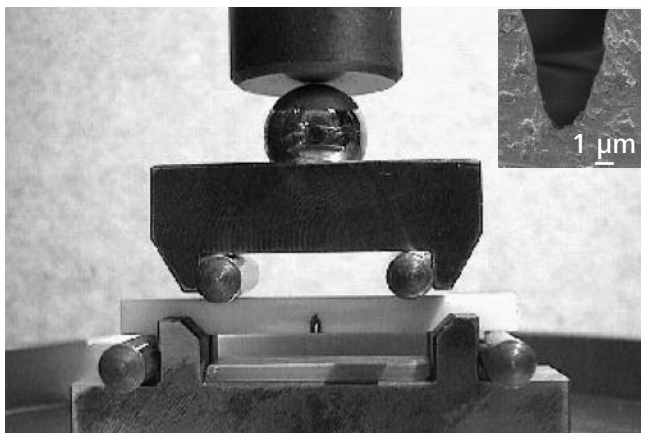

Fig. 2: V-notch tip on a silicon nitride bend bar (insert)
Fig. 3: SEVNB test with notched bend bar (marked black for better visibility)

Results and discussion

Consistent to very consistent results were obtaine for the alumina-999, the GPSSN, the SSiC, and the alumina-998 (Fig.4). As predicted, less consistent results were obtained for the Y-TZP due to its grain size in the submicron range. The round robin showed that the repeatability and reproducibility of the SEVNB method was very good (Table 1) and that the results compared well with results from other methods (Fig.5). Further, the method proved to be forgiving and robust with respect to notch preparation (Fig.6) for ceramics having a major microstructural feature greater than about 1 µm in size. Most participants had no difficulties conducting the measurements and rated the SEVNB method as user-friendly, easy and cheap to conduct, reliable, accurate, and worthwhile for standardisation.

Material	Participants / specimens	G.P.Avg. ± Std.Dev. MPa √m	Repeatability Std.Dev. MPa √m	Repeatability CV %	Reproducibility Std.Dev. MPa √m	Reproducibility CV %
alumina-998	28 / 135	3.57 ± 0.22	0.17	4.6	0.22	6.1
alumina-999	21 / 102	3.74 ± 0.40	0.23	6.2	0.40	10.7
GPSSN	27 / 129	5.36 ± 0.34	0.28	5.3	0.34	6.3
SSiC	12 / 56	2.61 ± 0.18	0.12	4.5	0.18	6.8
Y-TZP	7 / 35	5.34 ± 0.65	0.33	6.2	0.68	12.7

Table 1: Grand population average with standard deviation, repeatability (within-lab), and reproducibility (between-lab)

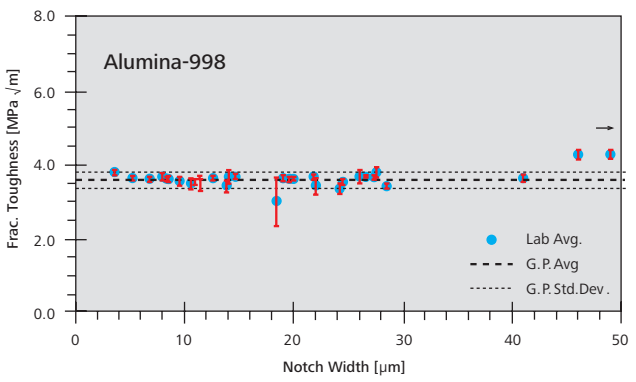

Fig. 4: Master result graph for alumina-998.

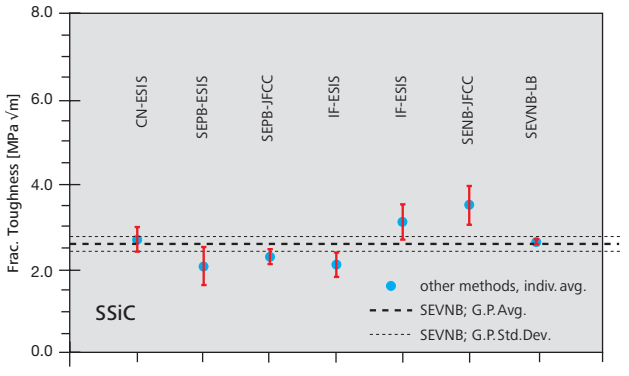

Fig. 5: Comparison of SEVNB fracture toughness values with values measured with other methods.

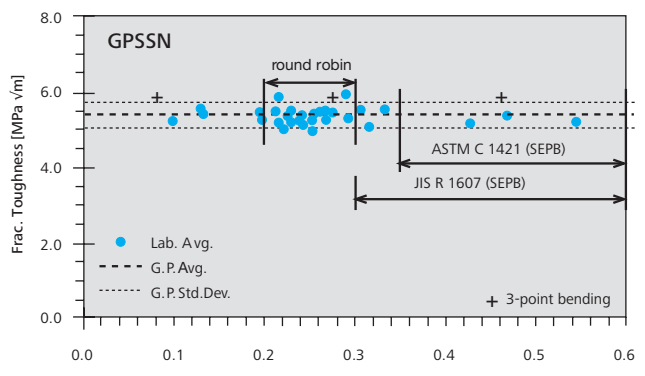

Fig. 6: Influence of V-notch depth ratio a/W on fracture toughness

Conclusions

With the SEVNB method very consistent fracture toughness results can be obtained. Repeatability and reproducibility of the method are equal or better than those of other methods. Participants unfamiliar with the SEVNB method in general had no difficulty performing the measurements. An ESIS/ VAMAS recommended practice has been written which serves as basis for a new CEN standard.

Acknowledgements

The author wishes to thank all participants for joining in this successful round robin and Metoxit, Switzerland, for supplying the alumina-999.

Participants

M.J. Anglada	Univ. Politèc. Catalunya, Spain	G. De Portu	CNR-IRTEC, Faenza, Italy	V. Knoblauch	Bosch, Stuttgart, Germany	Y. Nagano	JFCC, Nagoya, Japan	H. Richter	CeramTech, Plochingen, Germany
S. Barinov	Acad. Sciences, Moscow, Russia	P. Descamps	B.C.R.C., Mons, Belgium	M. Kuntz	Univ. Bremen, Germany	J. Y. Pastor	Univ. Politèc. Madrid, Spain	J. Rödel	TH Darmstadt, Germany
K. Breder	ORNL, Oak Ridge, USA	J. Dusza	Acad. Sciences, Kosice, Slovakia	M. Labanti	ENEA-CRNM, Faenza, Italy	G. Quinn	NIST, Gaithersburg, USA	E. Rudolph	BAM, Berlin, Germany
S.R. Choi	NASA, Cleveland, USA	G.A. Gogotsi	Acad. Sciences, Kiev, Ukraine	H.A. Lindner	CFI, Rödental, Germany	G. Rauchs	Univ. Karlsruhe, Germany	S. Sakaguchi	NIRIN, Nagoya, Japan
Da Costa Neto	Univ. Fed. Rio de Janeiro, Brazil	M. Hoffman	Univ. New South Wales, Australia	F. Meschke	Lehigh Univ., Bethlehem, USA	M. Reece	Queen M&W Col., London, UK	M. Steen	EC-JRC Petten, Netherlands
R. Damani	Montanuniv. Leoben, Austria	K. Keller	BASF, Ludwigshafen, Germany	R. Morrell	NPL, Teddington, UK	T. Reich	FhG-IKTS, Dresden, Germany	R. Westerheide	FhG-IWM, Freiburg, Germany

References

- J. Kübler, Fracture Toughness of Ceramics using the SEVNB Method: From a Preliminary Study to a Standard Test Method, Fracture Resistance Testing of Monolithic and Composite Brittle Materials, ASTM STP 1409, J.A. Salem, M. G. Jenkins, and G.D. Quinn, eds. American Society for Testing and Materials, West Conshohocken, PA, 2001
- J. Kübler, Fracture Toughness of Ceramics using the SEVNB Method: Round Robin, VAMAS Report No. 37 (ISSN 1016-2186) and ESIS Document D2-99, published by Empa-Dübendorf Switzerland, Sept. 1999

* jakob.kuebler@empa.ch
[1] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for High Performance Ceramics, Ueberlandstrasse 129, 8600 Duebendorf, Switzerland.
VAMAS: Versailles Project on Advanced Materials and Standards, ESIS: European Structural Integrity Society, CEN: European Committee for Standardisation