A New Fracture Toughness Test for Ceramic Discs and Plates

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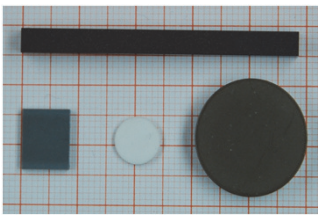
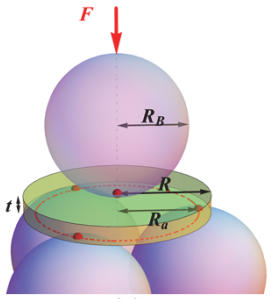
Motivation

Standard 4-point bending specimen



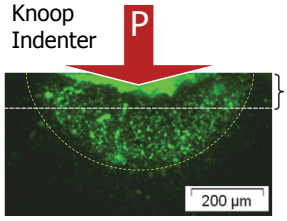
Components and specimens for B3B-KIc-test

- Components or specimens produced during material development are often too small to machine standard specimens for K_{Ic}-testing ($3 \times 4 \times 45$ mm³) out of them.
- Material properties of ceramics depend on consolidation and sintering conditions. On large specimens (often fabricated seperately) differing properties are determined.
- **WANTED**: a test method for fracture toughness applicable to small material pieces



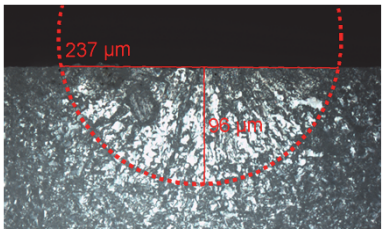
Test set-up of the B3B-KIc-test

Experimental Method



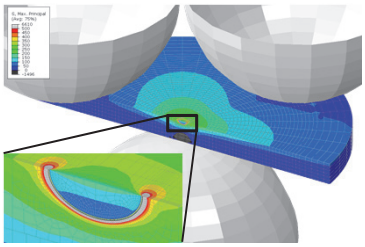
Fracture surface with Knoop indentation crack, fluorescent dye

- Introduce starter crack with Knoop indenter
- Grind off deformed zone
- Fracture specimen in B3B-test
- Calculate fracture stress σ_{B3B} from maximum force
- Measure crack size (a, c) on fracture surface
- Calculate Max(Y_A, Y_C)
- Evaluate K_{Ic}



Measurement of dimensions of the starting crack

Parametric Evaluation of the Stress Intensity Factor



FEM model

$$K_{Ic} = \sigma_{B3B} Y \sqrt{\pi a} \quad \text{with} \quad \sigma_{B3B} = \frac{F}{t^2} \cdot f\left(\frac{t}{R}, \frac{R_a}{R}, \nu\right)^*$$

$$Y_{A,C} = Y_{A,C}\left(\frac{a}{c}, \frac{a}{t}, \frac{t}{R_a}, \nu\right)$$

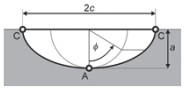
crack shape $\frac{a}{c}$: 0,4 … 0,8

crack size $\frac{a}{t}$: 0,05 … 0,2

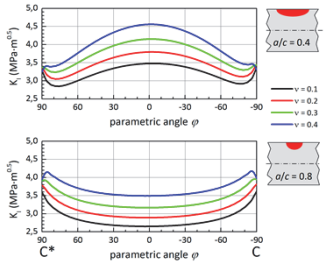
disc thickness $\frac{t}{R_a}$: 0,1 … 0,3

Poisson's ratio ν: 0,1 … 0,4

→ fitted expression for Y_A and Y_C



* http://www.isfk.at/de/960/



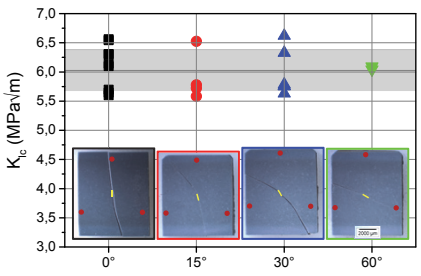
Stress intensity factor along the crack front

Verification

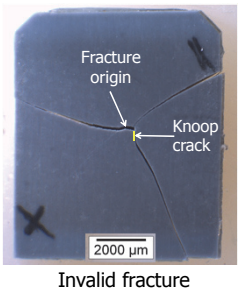
Material	R mm	R_B mm	t mm	ν	a µm	c µm	B3B-K_{Ic} MPa m$^{1/2}$	Reference MPa m$^{1/2}$
Rubalit 708S (Al_2O_3)	4	2.75	0.545 ± 0.003	0.23	85 ± 7	110 ± 5	**3.5 ± 0.1**	**3.5 ± 0.2** (SEVNB)
FSNI (Si_3N_4)	9.6	7.5	1.802 ± 0.012	0.27	74 ± 16	140 ± 15	**5.0 ± 0.3**	**5.1 ± 0.2** (SCF) **5.0 ± 0.2** (SEVNB)

Sources of Error

Crack orientation



Crack location



Invalid fracture

Conclusions

- Small measurement error
- Precise evaluation of Y using FEM
- Formula for K_{Ic} evaluation available [1]
- Variable specimen sizes, also small specimens possible
- Variable specimen shape possible: round discs or rectangular plates
- Can be applied directly to components (electrical resistors, PTCs, …) or to specimens taken from components

Publications:

[1] T. Lube, S. Rasche, T.G.T. Nindhia: "B3B-KIc fracture toughness test – geometric function formulae for semi-elliptical surface cracks in bi-axial bending", *JACS* **99** [1] (2016), 249–256, http://www.dx.doi.org/10.1111/jace.13842

[2] S. Strobl, S. Rasche, C. Krautgasser, E. Sharova, T. Lube: "Fracture toughness testing of small ceramic discs and plates", *J. Eur. Ceram.Soc.* **34** [6] (2014), 1637-1642

[3] S. Rasche, S. Strobl, M. Kuna, R. Bermejo, T. Lube: "Determination of strength and fracture toughness of small ceramic discs using the small punch test and the ball-on-three-balls test", *Proc. Mat. Sci.* **3** (2014), 961-966

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