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QUANTITATIVE FRACTOGRAPHY OF SINTERED CARBIDES

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ABSTRACT

Three grades of sintered carbides ("Baildonit" Co Ltd) with diversified tungsten carbide size (0.5-8.0 μm) and cobalt binder (6-9.5 wt.%) were investigated. The specimens were fractured using three points bending device mounted in scanning electron microscope. Values of bending strength and deflection measured this way were used in further fractography analysis. The fractures exhibited gradual change of certain features (from the coarse to fine grained specimens): decrease in transcrystalline fracture fraction, decrease in secondary cracks and WC particles cracks frequency.
Confocal laser microscopy (TSC 4D Leica Laser Technik) was used to obtain 3D topography of the fractures and main fractography parameters - average arithmetic profile deviation from the average line (R_a), surface roughness (R_s) and fractal dimension.

Key words: sintered carbides, confocal microscopy, fractography

INTRODUCTION

During last 75 years sintered carbides become, apart from high-speed steels, the most important tool material. At the beginning of 90' fraction of tools made of sintered carbides (in respect of chips' mass during turning, milling, drilling and planing) amounts as much as 80%. Sintered carbides are also used for production of tools for plastic forming (rolls, punches, dies, drawing dies) and other products of elevated hardness and wear resistance.
The main directions of these materials development are both increase of hardness (controlling maximum cutting speed) and fracture toughness (controlling cutting speed and depth) (Schedler 1988). Therefore the aim of the work is to determine influence of structural factors of sintered carbides decohesion using quantitative fractography methods (Lea et al. 1981, Coster 1991).

MATERIAL

Three grades of sintered carbides ("Baildonit" Co Ltd) with diversified carbide particles' mean diameter (0.5-8.0 μm) and cobalt binder content (6-9.5 wt.%) were investigated (Table 1).

Table 1. Characteristic of the investigated sintered carbides.

Grade	Chemical composition [wt.%]			Carbides mean diameter d [μm]
	WC	Co	W dissolved	
B23G	90.5	9.5	3.5-5.3	3.0-8.0
G10	94.0	6.0	2.3-4.6	2.0-4.0
H30	91.0	9.0	2.6-4.2	0.5-2.0

EXPERIMENTAL

The specimens' microsections were observed using both light and scanning electron microscopy (SEM) - Fig. 1.

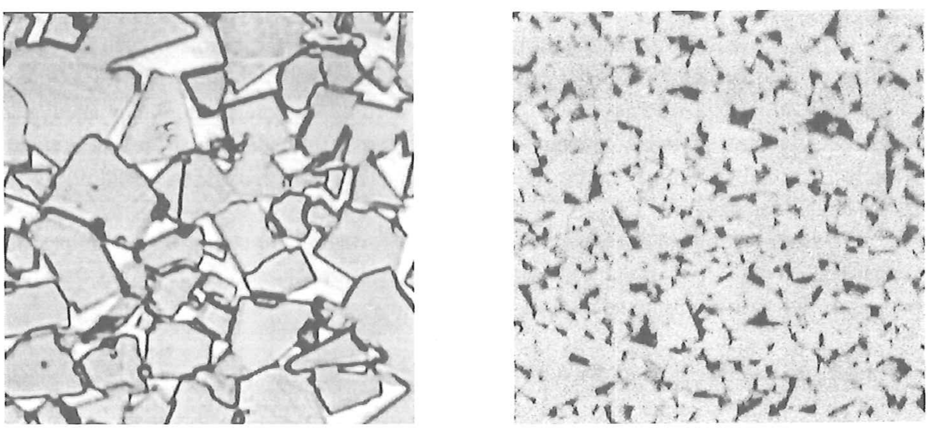

Fig. 1. Examples of the sintered carbides microstructure:
B23G grade, light microscopy x2000 (left)
H30 grade, SEM, BSE mode x5000 (right)

"In situ" bending test (Roebuck and Bennett 1995) enables direct observation of deformation and decohesion processes and recording basic mechanical properties. Specimens (48x5x2 mm) were fractured using Kammrath & Weiss three points bending device (Fig. 2) mounted in SEM's specimen chamber. During the tests load-deflection curve was registered (Fig. 3). The following parameters were available:

- bending speed	0.2-0.5 μm/s
- reliving speed	20 μm/s
- maximal load	500 N
- maximal deflection	5000 μm

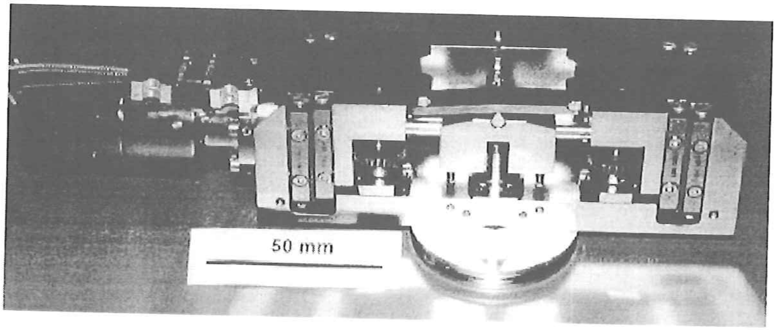

Fig. 2. Three points "in situ" bending device.

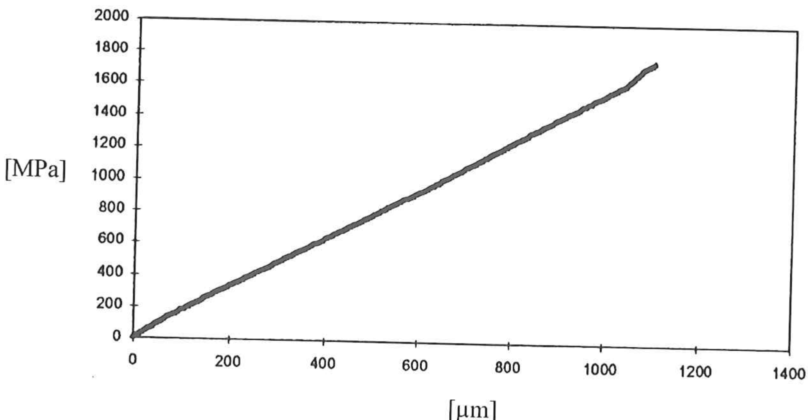

Fig. 3. Example (G10 grade) stress-deflection curve recorded during the three points bending test.

The results obtained through the bending tests, together with other mechanical and physical properties are collected in Table 2.

Table 2. Results of the mechanical testing.

Grade	Density [g/cm^3]	Hardness [HV30]	Bending strength [MPa]	Total deflection [µm]
B23G	14.53-14.55	1089-1119	1700-1850	1100-1300
G10	14.86-14.88	1395-1405	1800-1950	1000-1200
H30	14.54-14.55	1489-1509	1100-1300	600-750

Surfaces of the fractured specimens were observed using SEM (Fig. 4).

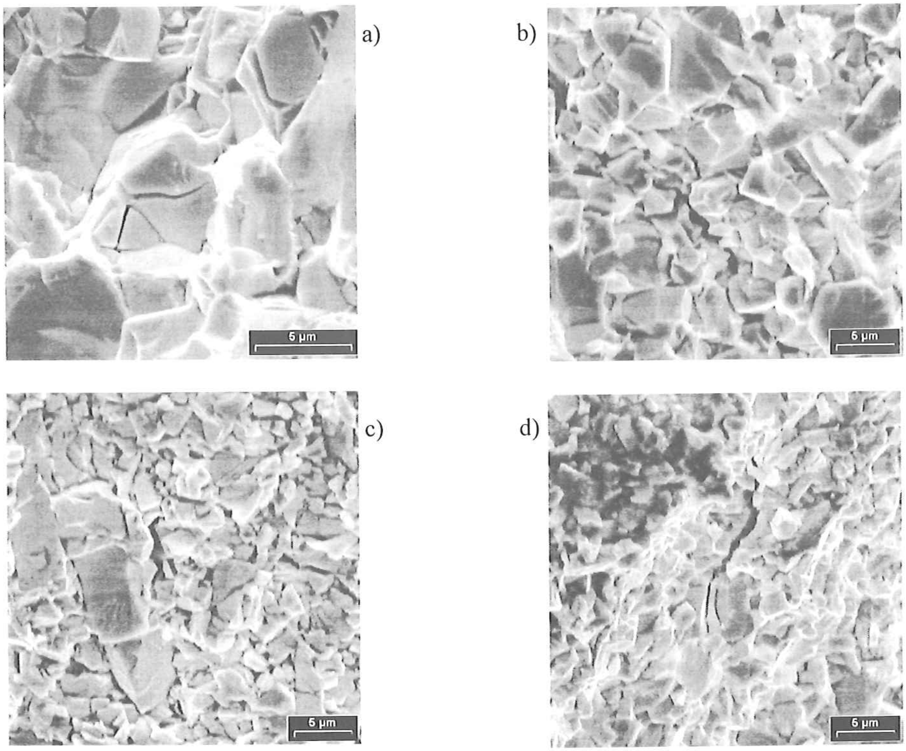

Fig. 4.SEM images of the sintered specimens subjected three points bending tests
a) B23G grade, cracking of WC carbide particle
b) B23G grade, secondary cracks
c) G10 grade, secondary, intercrystalline crack
d) G10 grade, secondary, transcrystalline crack.

Confocal laser microscope (TSC 4D Leica Laser Technik) was used to obtain 3D topography of the fractured specimens and main fractography parameters - average arithmetic profile deviation from the average line (R_a), surface roughness (R_s) and fractal dimension (D).
The basic principle of this microscopy technique (Grasserbauer and Werner 1991), in comparison with conventional light and SE microscopy, is filtration and extinguishing of light reflected from elements lying beyond focal plane. Consequently, only light reflected from points lying on the focal plane reaches a detector. Scanning procedure is repeated after each step change of the focal plane's position. From given series of such "confocal cuts" set of pixels along "z" axis taking maximal intensity of the reflected laser light are determined. Obtained this way topographical maps (Fig. 5) contain information on three coordinates of each point of the examined nonplanar surface and value of "z" (height of given point of the surface) is represented by greyness intensity of corresponding pixel of the topographical map.

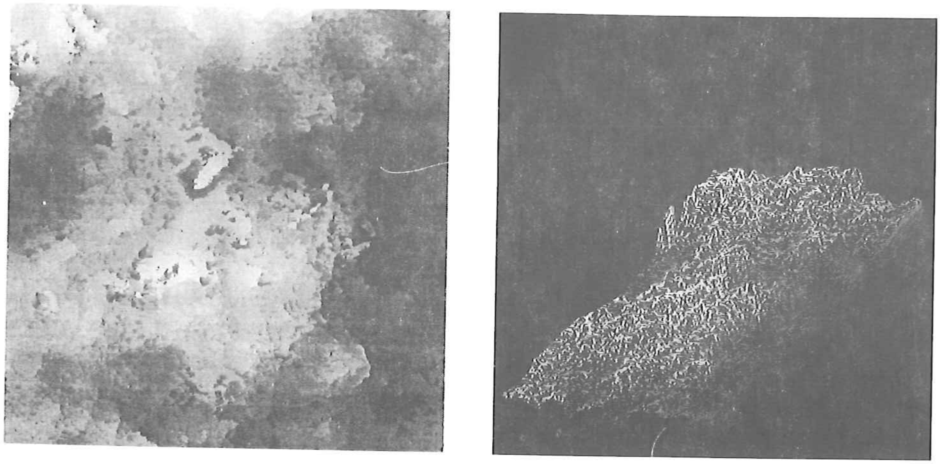

Fig. 5. Examples of topographical (left) and pseudo-3D map of B23G grade fracture (right).

The available software enabled determination of numerous parameters of quantitative fractoghraphy - average arithmetic profile deviation from the average line (R_a),surface roughness (R_s=surface area/projected area) and fractal dimension ($D=2\text{-}\log R_s/\log\varepsilon$, where ε is a measuring 'yardstick' (Mandelbrot 1983, Mandelbrot et al.1984) (Table 3). Unlike in case of conventional profilometry, these parameters were obtained on the basis of data from whole scanned surfaces of the fractures, hence not dependently from profile position and thus statistically more reliable.

Table 3. Quantitative description of the sintered carbides fractures.

Grade, specimen number	R_a	R_s	D
B23G-1	3.065	3.217	2.186
B23G-2	3.400	4.545	2.246
G10-1	1.552	2.265	2.170
G10-2	5.420	4.830	2.162
H30-1	0.500	1.283	2.094
H30-2	0.785	1.507	2.097

DISCUSSION

The results obtained through three points bending and hardness measurements, confirmed well known relations concerning grain size effect upon hard materials' mechanical properties - grade with the finest carbide particles (H30) exhibited maximum hardness at the smallest deflection (conversely in case of coarse grained B23G grade). Results for G10 grade of intermediate grain size did not comply this regularity - it revealed the largest value of bending strength. It was probably caused by visible grain size inhomogeneity (Fig. 4c) and by slight different than in the other investigated grades content of the binding phase.

Stress-deflection curves (Fig. 3) has shown that in the investigated sintered carbides up to 9.5 % of cobalt the course of cracking is of typically brittle nature.

It was found that with decreasing carbide particles size fraction of transcrystalline fracture, degree of fractured surface development, frequency of secondary cracking and cracking of individual tungsten carbide particles decrease.

The quantitative description of the fractures using the confocal laser microscopy revealed the following correlation: specimens with the largest grain size and toughness (B23G) exhibited maximum values of average arithmetic profile deviation from the average line, surface roughness and fractal dimension. Because of the above mentioned reasons (grain size inhomogeneity and cobalt content) R_a, R_s and D parameters obtained for the G10 grade did not reveal similar relation and (besides the fractal dimension) vary several times within this grade's framework.

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