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Adhesive wear performance of hardmetals and cermets

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ABSTRACT

This work focuses on the performance of some carbide composites, in particular alloys designed for metalforming in wear conditions with prevalence of adhesion. Wear tests were performed by a special metal cutting method which consisted of turning of mild steel at low speed. The results were compared with those obtained in the sliding wear tests and related to the mechanical properties and microstructure studied by SEM and XRD. It was shown that the surface failure starts preferably in the binder by a combined process (extraction, microcutting) and is preceded by the plastic strain taking place in both phases—in the ductile binder and in the brittle carbide. WC–Co composites and cermets on the basis of TiC, bonded with Fe-alloys demonstrated their noticeable superiority over TiC-base composites bonded with Ni-alloys.

1. Introduction

Combination of desirable properties is met in multiphase materials, including carbide composites (hardmetals and cermets). Composites are prospective for use under the conditions of two or more bodies interacting, e.g. tribological applications.

Tungsten carbide base hardmetals are the most widely used materials for different wear applications owing to their excellent combination of high wear resistance and strength-toughness [1,2]. Major applications of tungsten carbide based hardmetals cover metal removal cutting tools, rock- and earth drilling tools and sheet metal forming tools [2]. Shortage of tungsten and deficiency of some properties (oxidation, corrosion resistance, and low weldability with steel) result in some restriction of hardmetal applications. For these reasons tungsten free carbide composites on the basis of TiC cemented with nickel alloys and alloyed steels have been developed [2–5].

In general, TiC-base composites are at some disadvantage in respect of strength and abrasive and erosive wear resistance. Application areas of the cermets are still quite restricted. However, recent developments in technology-sintering in combined atmospheres [6], application of gas compression during sintering (HIP and sinter/HIP) [7] that have substantially improved the performance of carbide composites—have created a renewed interest in TiC-base cermets.

This paper focuses on the wear behaviour of some carbide composites, in particular TiC-base cermets with nickel steel binder developed for metalforming [1,7] in the conditions where adhesion (sliding wear and cutting adhesive wear) prevails. The wear performance was related to their mechanical properties and the microstructure was studied by SEM and XRD.

2. Materials tested and experimental details

2.1. Materials

Studies focused on tungsten and titanium carbide-base carbide composites, in particular composites prospective for metalforming (carbide fraction 74–85 vol.% and properties: Rockwell hardness HRA ≥ 86.5, transverse rupture strength $R_{TZ} \geq 2000$ MPa) [1].

Fig. 1 shows the microstructures of the composites with carbide fraction ≈75 vol.%. The microstructure of WC-composites consists of WC grains mainly of angular shape embedded in the binder phase. The shape of TiC grains is more rounded. Porosity of carbide composites was <0.2 vol.% for all materials and the average grain size was 2–2.3 μm.

The materials were produced by means of the conventional vacuum sintering technology of pressed powders [1]. Some grades (cermets T80/14, T75/14) were sintered by the sinter/HIP techniques (under gas compression of 50 Bar at the sintering temperature) [7]. A review of the composition and mechanical properties of the composites investigated is presented in Table 1.

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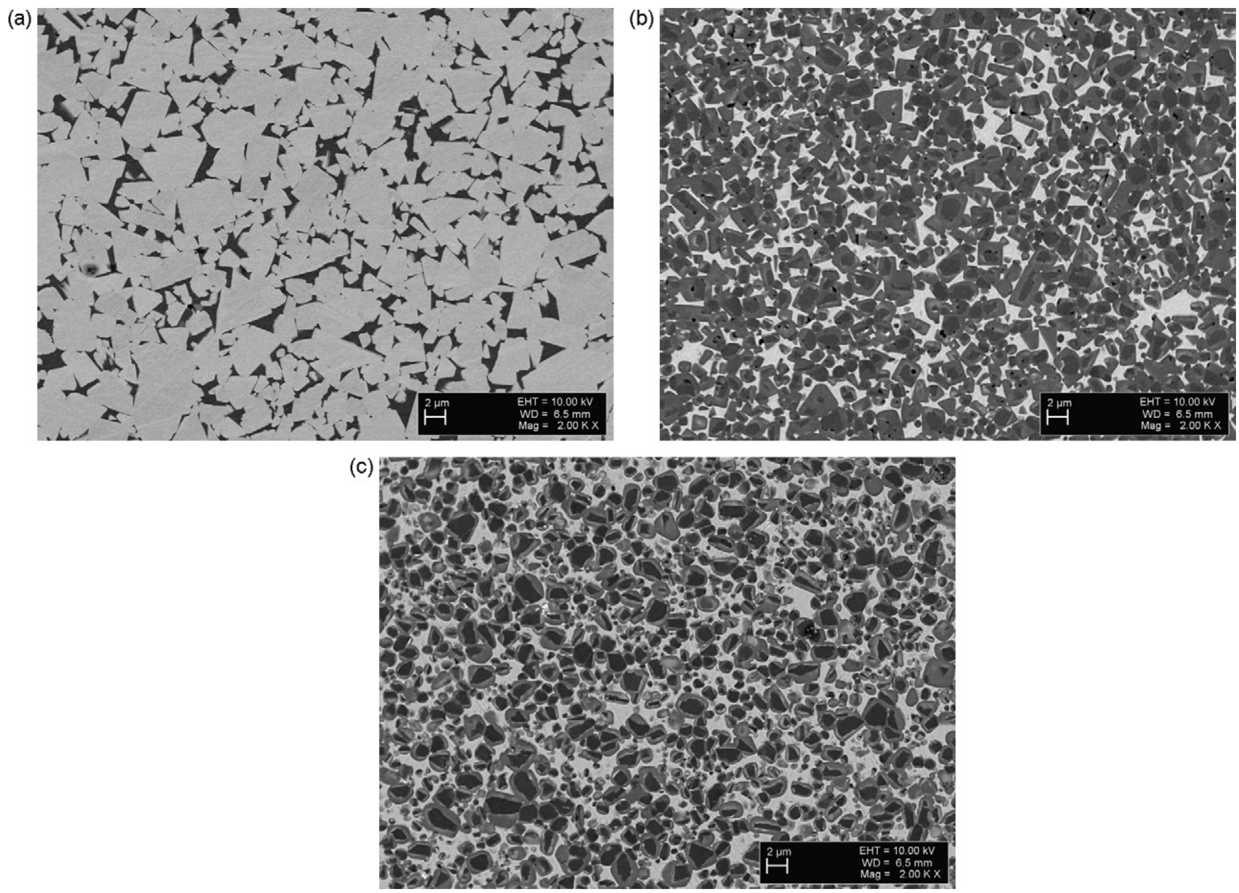

Fig. 1. SEM micrographs of the carbide composites studied: (a) hardmetal, grade H15, (b) cermet TiC–FeNi, grade T70/14; (c) cermet TiC–NiMo, grade TN30 (see Table 1).

2.2. Experimental details

Adhesive wear tests were performed by a special cutting method (by turning mild steel at low speed), simulating the wear of blanking tools—wear in the prevalence of adhesion [6,8]. The wear resistance was determined as the length of cutting path L_1, when the height h of the wear land at the specimen (tool) nose achieved 1 mm (Fig. 2). An excellent correlation between the wear resistance determined by this method and blanking die wear was reported in [1,7].

Sliding wear tests were performed in accordance with the ASTM standard B611–85 (without abrasive). The wear rate was calculated as a volume loss W, mm^3. Transverse rupture strength R_{TZ} was determined in accordance with the ISO 332/7 method (using specimen B) and Vickers hardness in compliance with EN-ISO6567. As an additional characteristic, the proof stress $R_{CO.1}$, featuring the resistance of a material to the plastic strain and the shear-strength (resistance to microcutting) of all composites, was determined. The proof stress was determined in a uniaxial compression test using a specimen of a diameter of 10 mm and a length of 18 mm [8].

Examinations were complemented by SEM and XRD investigations performed on the scanning electron microscope Zeiss EVO MA15 and diffractometer Bruker D 5005, respectively. The line broadening and decrease in the intensity of X-ray reflections (measure of local plastic strain) from the composites phases were

Table 1
Structural characteristics and properties (hardness HV, transverse rupture strength R_{TZ}, modulus of elasticity E, and proof stress in compression $R_{CO.1}$) of carbide composites.

Grade	Carbide, content (vol.%)	Binder composition, structure	HV (GPa)	R_{TZ} (GPa)	E (GPa)	$R_{CO.1}$ (GPa)
H10	WC, 83.5	Co (W)	13.5	2.3	610	2.9
H13	WC, 79.9	Co (W)	13.0	2.8	590	2.9
H15	WC, 76.0	Co (W)	11.5	2.9	560	2.5
H20	WC, 69.0	Co (W)	10.0	3.0	510	2.0
T80/14	TiC, 86.5	14Ni–steel, austenite–bainite	14.5	1.5/2.1[a]	420	3/3.2[a]
T75/14	TiC, 83.0	14Ni–steel, austenite–bainite	13.5	1.8/2.4[a]	410	2.8/2.9[a]
T70/14	TiC, 79.0	14Ni–steel, austenite–bainite	12.5	2.3	400	2.5
T60/14	TiC, 74.0	14Ni–steel, austenite–bainite	10.5	2.4	380	2.0
T60/8	TiC, 74.0	8Ni–steel, martensite	12.2	2.2	390	2.4
TN20	TiC, 86.5	NiMo (2:1)	14.0	1.45	410	2.5
TN30	TiC, 81.0	NiMo (2:1)	13.5	1.7	380	2.4
TN40	TiC, 74.0	NiMo (2:1)	12.6	1.9	360	2.0
TN50	TiC, 65.0	NiMo (2:1)	10.0	2.1	340	1.7

[a] Sinterhipped.