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Wear Performance of TiC-Base Cermets

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Some carbide composites – WC hardmetals and TiC-base cermets with Ni-alloy and Fe-alloy binders – were investigated in different wear conditions. For the simulation of the adhesion wear conditions during blanking of sheet steel, the original method was used. The results of these tests were compared with the results obtained from sliding wear and abrasive wear. Relations between wear performance, microstructure and mechanical characteristics were found. It was shown that the surface failure of carbide composite during adhesion starts preferably in the binder phase. This is a combined process of microcutting, extraction and extrusion and depends on the amount of carbide phase and its composition. Cermets on basis of TiC bonded with Fe- alloy (steel) binder showed superiority over TiC base composites bonded with Ni alloy in all wear conditions.

Keywords: cermet; hardmetal; carbide composite; abrasive wear; adhesive wear; sliding wear.

1. INTRODUCTION

Tungsten carbide based hardmetals are the most widely used materials for different wear conditions. This is because of their excellent combination of fair strength and high wear resistance [1].

Tungsten free hardmetals on basis of TiC cemented with nickel alloys and alloyed steels have been developed [2 – 5] to replace the hardmetals due to a shortage of tungsten and some deficiency of its physical properties (oxidation, corrosion resistance). These reasons restrict the application of hardmetal. In general, TiC-base composites are at some disadvantage in respect to strength and abrasive and erosion resistance. Recent developments in technology (sinter/HIP, HIP) resulting in substantial improvement of performance of carbide composites have created a renewed interest to TiC-base cermets [6, 7].

The present study is focused on the wear behaviour of some carbide composites, in particular TiC-base cermets with nickel steel binder developed for metalforming [6]. In metalforming the adhesion (wear in blanking, wear in sliding) prevails. The wear performance is related to their mechanical properties and microstructure.

2. MATERIALS TESTED AND EXPERIMENTAL DETAILS

2.1. Materials

Tungsten and titanium-carbide base carbide composites in particular composites prospective for metalforming (carbide fraction up to 85 vol.% and properties: Rockwell hardness HRA ≥ 86.5, transverse rupture strength TRS ≥ 2000 MPa) were investigated.

Porosity of all materials tested was less than 0.2 vol.% and average grain size 1.9 µm – 2.2 µm.

The materials were produced through the ordinary vacuum sintering technology of compacted powders. Some of grades (T80/14, T75/14) were sintered both by vacuum sintering and by the sinter/HIP techniques (under gas compression of 50 Bar at sintering temperature) [7, 8]. The composition and mechanical properties of the composites investigated are presented in Table 1.

2.2. Experimental details

The adhesive wear tests were performed by a special cutting method (by turning mild steel at low speed) simulating wear of blanking tools – wear in conditions with prevalence of adhesion [6, 8]. The wear resistance was determined as the length of cutting path L_1, when height *h* of the wear land at specimen (tool) nose achieved 1 mm.

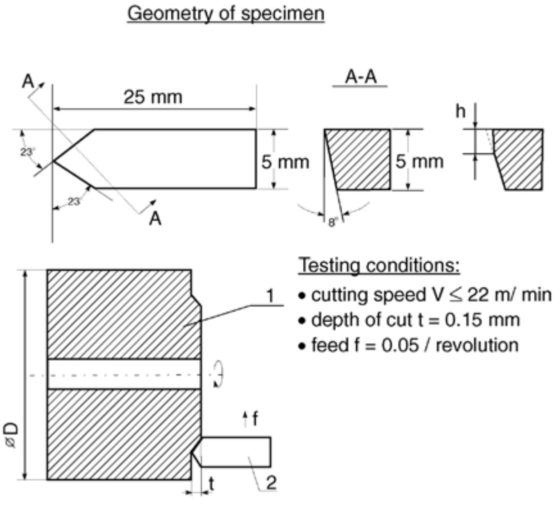

Fig. 1. The adhesive-wear testing conditions and geometry of specimen

The abrasive wear tests were performed by the rubber-rimmed rotary wheel machine (modified method) as follows: abrasive – quartz sand (amount – 3 kg with a

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Table 1. Structural characteristics and properties (hardness HV, transverse rupture strength R_{TZ}, modulus of elasticity E, proof stress $R_{C0.1}$) of carbide composites

Grade	Carbide content, vol.%	Binder composition, structure	HV	R_{TZ}, GPa	E, GPa	$R_{C0.1}$, GPa
H10	WC, 83.5	Co (W)	1350	2.3	610	2.9
H13	WC, 79.9	Co (W)	1300	2.8	590	2.9
H15	WC, 76.0	Co (W)	1150	2.9	560	2.5
H20	WC, 69.0	Co (W)	1000	3.1	510	2.0
T80/14	TiC, 86.5	14Ni-steel, austenite-bainite	1450	1.5/2.1*	420	3/3.2
T75/14	TiC, 83.0	14Ni-steel, austenite-bainite	1350	1.8/2.4*	410	2.8/2.9
T70/14	TiC, 79.0	14Ni-steel, austenite-bainite	1250	2.3	400	2.5
T60/14	TiC, 74.0	14Ni-steel, austenite-bainite	1050	2.4	380	1.9
T60/8	TiC, 74.0	14Ni-steel, martensite	1200	2.2	390	2.3
TN30	TiC, 81.0	Ni:Mo (2:1)	1400	1.7	380	2.3
TN40	TiC, 74.0	Ni:Mo (2:1)	1260	1.9	360	2.0
TN40	TiC, 74.0	Ni:Mo (4:1)	1050	2.2	360	1.8
TN50	TiC, 65.0	Ni:Mo (2:1)	1000	2.2	340	1.7

*increase after sinter/HIP.

particle size of 0.1 mm – 0.2 mm and hardness $HV = 1100$), velocity of the wheel – 0.24 m/s, diameter of the steel wheel – 80 mm, wear distance – 144 m, testing time – 10 min and load – 3 N. The wear was estimated as the volume loss V in mm^3 and wear resistance as $1/V$, mm^{-3}.

The sliding wear tests were performed in accordance with ASTM standard B611-85 (without abrasive). The wear rate was calculated as a volume loss W, mm^3.

As an additional characteristic the proof stress $R_{CO.1}$, featuring the resistance of a material to plastic strain and the shearing strength (resistance to microcutting) of composites were determined. The proof stress was determined in a uniaxial compression test [7].

3. RESULTS AND DISCUSSION

3.1. Adhesive wear

Fig. 2 shows the adhesive wear (cutting adhesive wear) resistances of the test materials plotted against their composition (carbide volume fraction). It can be seen that the increase in volume fraction of carbides (decrease in binder) leads to a monotonous improvement of wear performance of all composites independent of their carbide and binder composition.

According to the results there is a clear relation between the wear performance of alloys and their composition. At equal carbide (binder) fraction, WC-base hardmetal and TiC-cermet cemented with nickel steel show a remarkable superiority over ordinary TiC-based cermet cemented with nickel alloy.

The ordinary characteristic and measure of material wear resistance is hardness. In Fig. 3 the wear resistances of test materials are plotted against their hardness. It is definitively confirmed by the results that there exists the inconclusive influence of hardness on adhesive wear, as also revealed for carbide composites tested in erosion, abrasion and blanking wear conditions [7, 9, 10].

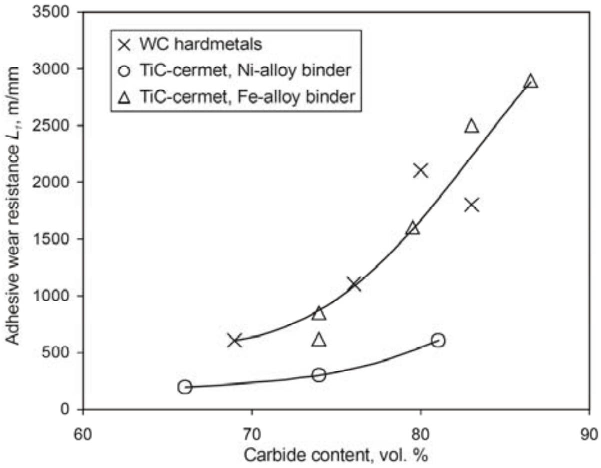

Fig. 2. Adhesive wear resistance of carbide composites vs. carbide fraction in alloy

In Fig. 4 the adhesive wear performance of test materials is opposed to their proof stress. The relationships refer to the dependence of wear on proof stress: the increase in proof stress improves monotonously the wear resistance. The results obtained are in accordance with the wear theories of hardmetals and cermets described [10 – 14]. On the basis of these studies it may be concluded that the removal of material during adhesive wear has a selective nature – it starts preferably in the binder mainly by microcutting and extraction. As a precondition for removal extrusion of binder and its adhesive interaction has to occur. Shortly, for wear composites binder must be subjected to elastic and plastic strain. The elastic strain – elastic compression of carbide skeleton results in extrusion of binder, while plastic strain induces frustration of oxide films, protecting composites surface and hindering formation of physical contact (juvenile surfaces) – precondition for adhesion.

Increase in composite resistance to elastic strain (modulus of elasticity) and plastic one (proof stress) results in improvement of wear performance.

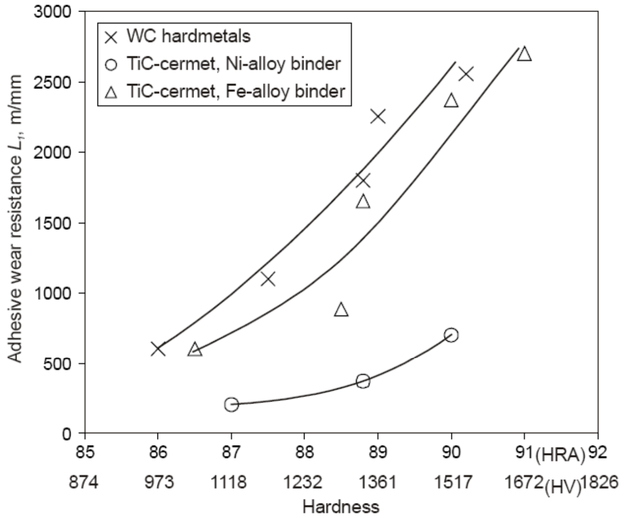

Fig. 3. Adhesive wear resistance of carbide composites vs. hardness

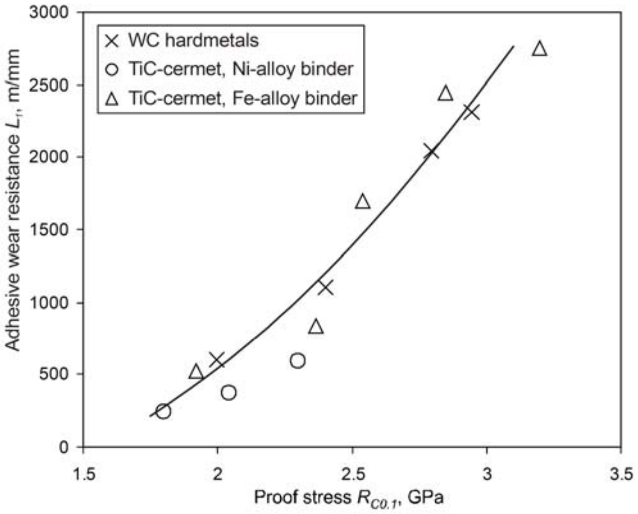

Fig. 4. Adhesive wear resistance of carbide composites vs. proof stress

The high wear resistance of WC-hardmetals and TiC-cermets with steel binder (compared with cermets with nickel binder) appears to be resulted from their higher rigidity (WC-hardmetal) and higher binder strength (steel binder with austenitic-bainitic structure).

3.2. Abrasive wear

In Fig. 5 abrasion rates of the test materials are plotted against their hardness. The results confirm an inconclusive influence of hardness on the abrasive wear performance of materials reported before. At equal hardness the abrasive wear of alloys of different composition may vary up to four times.

The fact that no correlation between the abrasion performance and hardness exists may be attributed to higher structural sensitivity of the wear resistance of the composite in relation to hardness and differences in the stress states during wear and hardness test [5, 8].

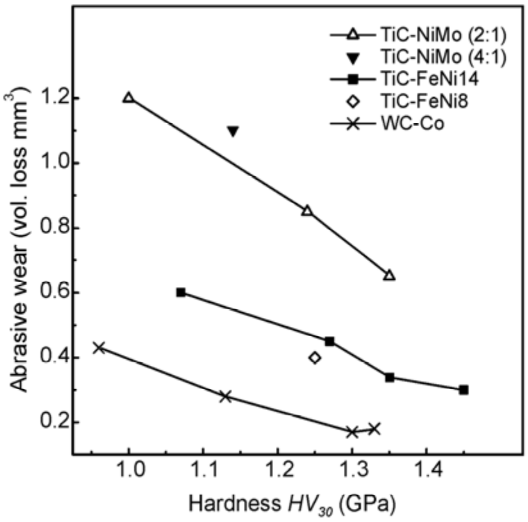

Fig. 5. Abrasive wear of carbide composites vs. Vickers hardness

The results suggest that the wear of the test material depends on its composition (composition of the carbide and that of the binder). At equal hardness level tungsten carbide-base composites demonstrate a superiority over TiC-base ones. TiC-cermets with steel binder are in advantage over those with nickel-alloy.

3.3. Sliding wear

In Fig. 6 the sliding wear rates of test materials are plotted against their composition.

From Fig. 6 it is obvious that the WC-base hardmetal has superiority over tungsten free ones and cermet with steel binder over composite with nickel of alloy binder. Also the monotonous decrease in wear with increase in carbide fraction in alloy is demonstrated. In general these relationships repeat those revealed for cutting adhesive wear (Figs. 2 – 4).

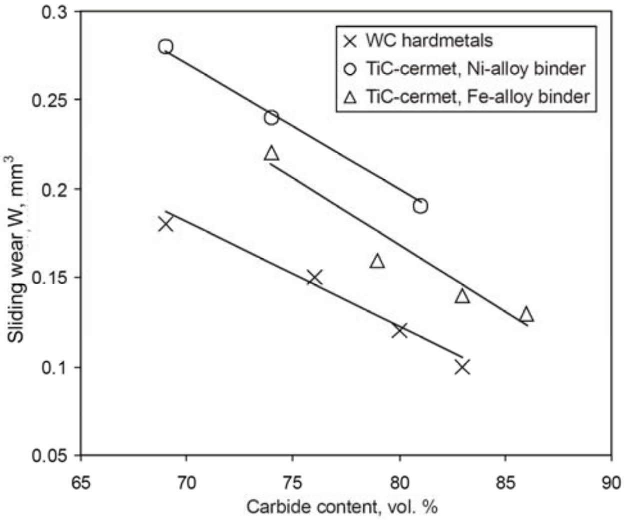

Fig. 6. Sliding wear of carbide composites vs. carbide fraction in alloy

In contrast to adhesive wear and to abrasive one the sliding wear of carbide composites demonstrated a relatively low sensitivity to composition and mechanical properties. Increase in carbide fraction from 69 vol.% – 90 vol.% in WC-hardmetal results in improvement of its performance in wear conditions with prevalence of adhesion up to 4 times and in sliding wear less than 2 times (compare Fig. 2 with Fig. 6).

During sliding wear formation of thin tribofilms has been observed [15]. These films – a result of binder extrusion and adhesive interaction, – result in decrease of wear and sensitivity to alloy composition.

4. CONCLUSIONS

1. At equal carbide volume fraction WC-base hardmetals and TiC-base cermets with steel binder are at an advantage over ordinary TiC-cermets with nickel (nickel-alloy) binder in wear conditions with prevalence of adhesion.
2. The performance of a carbide composite in wear conditions with prevalence of adhesion (in cutting adhesive wear and sliding wear) is controlled by resistance to local plastic strain (measured by the proof stress) and depends first on the amount and properties of its binder.
3. The tungsten–based composites outperform tungsten-free cermets in abrasive wear conditions (at the same level of hardness). TiC-base cermets with a steel binder are superior to those with nickel-alloy.
4. In sliding wear conditions formation of thin tribofilms with protective-lubricating effect has been observed. It results in reduce of wear and in remarkable decrease of its sensitivity to alloy composition and properties.

Acknowledgments

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