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BEHAVIOUR OF HARD ALLOYS IN SLIDING AND EROSION WEAR CONDITIONS

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Abstract
The wear behaviour of some carbide composite differing in composition and structure (WC hardmetals, TiC-, Cr_3C_2-cermets) in a set of wear trials (erosion-, sliding wear)were investigated. Comparative trials in these conditions with tool steels, complemented by SEM studies were performed. It was shown that in erosion as well as in sliding wear conditions the performance of hard alloy (carbide composite, tool steel) is controlled primarily by its carbide phase (its amount in alloy and properties).
Key words: *abrasive-erosion, sliding wear, cemented carbides, tool steels.*

1. INTRODUCTION

Of P/M materials, ceramic and metal composites – hardmetals and cermets – and high speed steels are most widely used for wear applications. Hardmetals and high speed steels are used in all types of wear performance, including abrasive wear, sliding wear and erosive wear.
Major categories of applications of tungsten carbide-based hardmetals cover metal removal cutting tools, rock and earth drilling tools, sheet metal forming tools, etc (Brookes, 1992). Cermets – commonly used to describe TiC-NiMo and TiCN-NiMo alloys – are used in restricted application areas. Steel-bonded composites are also well known among titanium carbide based composites (Komac & Novak, 1985; Kübarsepp, Reshetnyak & Annuka, 1994). Selection of a composite reliable in given working conditions is difficult because of inadequate information about the wear resistance of ceramic and metal composites. Furthermore, information available is quite contradictory. Quite contradictory are also results of the influence of structural and mechanical characteristics on the resistance to wear. Influence of the size of carbide grain on the abrasive wear resistance is an example (O'Quigley, 1997; Engqvist, 2000; Montgomery, Hara & Ikeda, 1970; Larsen-Basse, 1973).
No systematic information is available about the wear resistance of different wear resistant materials, particularly cemented carbides and tool steels, in different wear conditions. Therefore, the aim of this study was to test (and map) wear resistance of different powder composites – cemented carbides – and tool steels in different wear condition, particularly in abrasive-erosive and sliding wear.

2. EXPERIMENTAL DETAILS

2.1 Materials

Tungsten-, titanium- and chromium carbide-based cemented carbides were invested. Composition, structural characteristics and main mechanical properties of such composites are shown in Table 1. Composition and some properties of thermally treated tool steels investigated are given in Table 2.

Cermet	%	Compo-sition	*d*, µm	*HV*	R_{TZ} GPa	$R_{co.1}$ GPa
H8	92	Co(W)	2.2	1470	2.0	3.3
H10	90	Co(W)	2.1	1350	2.4	3.0
H15	85	Co(W)	2.15	1140	3.0	2.3
H20	80	Co(W)	2.25	960	2.9	1.8
H12F	88	Co(W)	1.75	1320	3.0	3.0
H15F	85	Co(W)	<1.0	1380	3.5	3.4
T60/FeNi8	60	Fe+8%Ni,	2.2	1210	2.4	2.4
		martensiit				
T70/FeNi8	70	Fe+8%Ni,	2.2	1360	1.9	2.5
		martensiit				
T60/FeNil4	60	Fe+14%Ni,	2.1	1100	2.3	1.5
		austeniit				
T70/FeNil4	70	Fe+14%Ni,	2.2	1260	2.2	2.2
		austeniit				
TN 30 TN40 TN50	70 60 50	Ni:Mo=2:l Ni:Mo=2:l Ni:Mo=2:l	2.0 2.1 2.1	1420 1260 1000	1.6 2.0 2.2	2.3 1.6 1.3
C10	90	Ni:Mo=2:l	5.0	1420	1.2	3.3
C20	80	Ni:Mo=2:l	4.5	1300	0.8	2.9
C30	70	Ni:Mo-2:l	4.1	1110	0.6	2.7

Table 1. Composition, grain size of carbides *d* and properties (Vickers hardness number *HV*, transverse rupture strength R_{TZ} and proof stress $R_{co.1}$) of cemented carbides.

Steel	Compostion					*HV*	R_{TZ} GPa	$R_{co.1}$ GPa
Uddeholm	C	Cr	W	Mo	V			
Calmax	0.6	4.5	-	0.5	-	780	3.8	2.0
Arne	1.0	0.5	0.6	-	-	820	4.2	2.3
Rigor	1.0	5.1	-	1.0	0.2	800	4.4	2.6
Sverker	1.5	12	-	0.8	0.8	800	4.5	2.7
ASP23	1..3	4.2	6.5	5.0	3.0	900	4.7	3.0
ASP60	2.3	4.0	6.5	7.0	10	1100	4.8	3.3
Vanadis 4	1..5	8.0	-	1.5	4.0	800	5.5	2.7
Vanadis 6	2.3	8.0	-	1.5	6.0	960	6.0	3.2

Table 2. Composition and properties (Vickers hardness number *HV*, transverse rupture strength R_{TZ} and proof stress $R_{co.1}$) of tool steels.

2.2 Testing conditions

Transverse rupture strength R_{TZ} was tested in accordance with the standard ISO332 using specimens B. Proof stress $R_{co.1}$ was tested in compression, using cilindrical specimens ground from both flat sides with a diameter of 10 mm and length of 15 mm. Vickers hardness was determined in accordance with the standard EN-ISO6507-1. Wear behaviour was studied in abrasive-erosion and sliding wear conditions. The abrasive-erosion was tested using a centrifugal accelerator in accordance with the Russian standard GOST 23.201-78, using silica sand (particle size 0.1...0.3 mm) as abrasive. The velocity of abrasive jet was 80 m·s^{-1}, angle of attack 30^{o}. Erosive wear *K* was considered as volumetric wear in mm^3 per 1 kg of abrasive. Relative wear resistance *X* was calculated relative to normalized carbon steel (0.45%C). The number of specimens per testing point was 4.

Sliding wear in dry conditions without abrasive was tested in accordance with the ASTM standard B611-85. Wear rate was considered as volumetric wear in mm^3 generated during the sliding distance of 4000 at loading F=40V.

3. RESULTS

3.1 Abrasive-erosion wear

Results of testing show a shortcoming of hardness as a characteristic used for wear resistance prognostication. Wear resistance between cemented carbides based on different carbides may differ up to three times (Figure 1). Results confirm advantages of tungsten carbide-based composites over tungsten-free cermets (Reshetnjak & Kübarsepp, 1994).

Despite the difference in the composition of carbide (titanium or chromium carbide) and metal phase (FeNi-steels, Ni-Mo alloy), no pronounced difference exists in the wear resistance at the same hardness of tungsten-free cermets. The higher the hardness (and content of carbides), the higher is the advantage of wear resistance of WC-based hardmetals over titanium and chromium carbide cermets.

As expected, the erosion resistance of tool steels has a considerable disadvantage over the erosion resistance of cemented carbides. Low effectiveness of the alloying degree of steels should be pointed out. The advantage of high-alloyed high speed steels ASP60 over the low-alloyed tool steel ARNE is only 1.8 times (Figure 2).

Thus, our results show a prevailing influence of content and properties of carbide phase on the wear resistance of carbide composites. The influence of binder characteristics is of minor importance (see Figure 1).

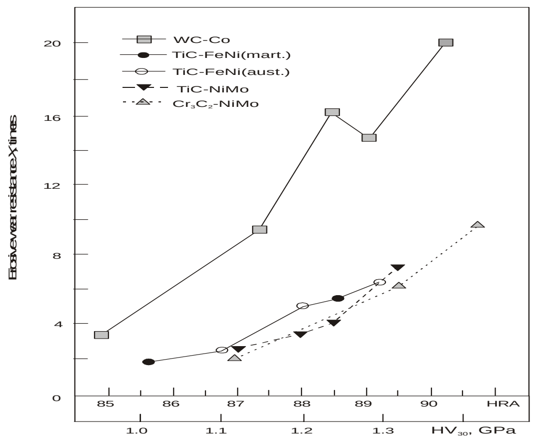

Figure 1. Abrasive-erosive wear resistance vs hardness of TiC-, WC- and Cr_3C_2-base cemented carbides.

Stiffness (characterized by the modulus of elasticity) of carbide phase and that of carbide composite and steel seems to be of crucial importance when erosive wear is considered. A good correlation between the modulus of elasticity and erosive wear resistance of the alloys considered proves the conclusion mentioned (see Figure 3).

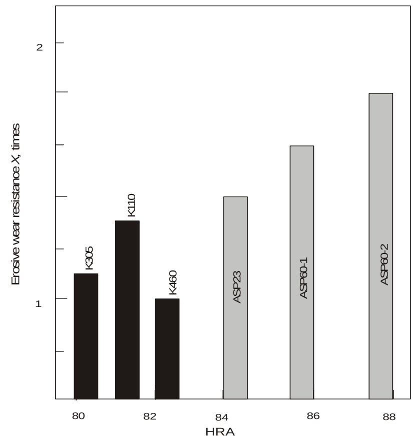

Figure 2. Abrasive-erosive wear resistance vs hardness of tool steels.

Attempts have been made to find a relationship between abrasive-erosion wear resistance and fracture toughness K_{1c} of brittle ceramic materials. Such a relationship has not been found when ceramic and metal composites are considered.

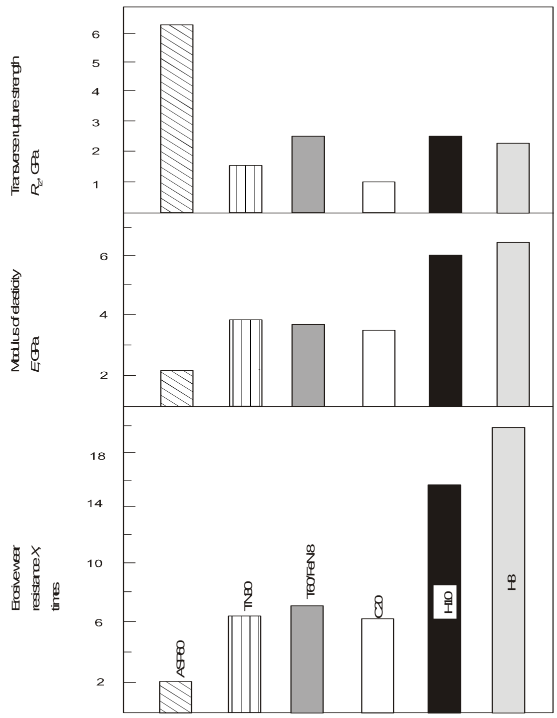

Figure 3. Transverse rupture strength R_{TZ}, modulus of elasticity *E* and abrasive-erosive wear resistance *X* of some carbide composites based on TiC, WC, Cr_3C_2 and high speed steel ASP60.

3.2 Sliding wear

Testing results in sliding wear conditions are somewhat similar to these in abrasive-erosion wear – hardness has limitations as a characteristic used for the assessment of wear rate (and wear resistance). Results in Fig. 4 confirm the advantage of WC-based hardmetals over tungsten-free cermets. However, the superiority of tungsten-carbide based composites do not exceed 1.7 times over titanium carbide-based cermets.

Characteristically, the influence of an increase in the carbide content (and hardness) of WC- and TiC-based cermets on the wear rate (and wear resistance) is much lower than in the conditions of erosive wear. Additional characteristic of sliding wear is extremely low wear resistance of chromium carbide-based cermets. It is of importance to point out that wear resistance of such alloys decreases when carbide content and hardness increase (see Fig. 4).

It is also of importance that TiC-FeNi steel cermets, unlike in abrasive-erosion wear conditions, have advantage over TiC-NiMo ones.

Sliding wear resistance of tool steels is at a disadvantage in relation to sliding wear resistance of WC- and TiC-based ceramic and metal composites. However, unlike in abrasive-

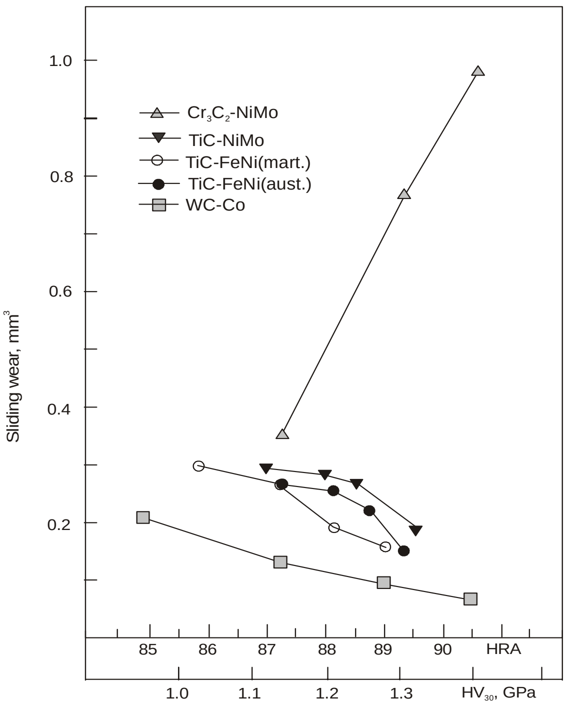

Figure 4. Sliding wear rate vs hardness of TiC-, WC- and Cr_3C_2-base cemented carbides.

erosion conditions, the degree of alloying has a marked influence on the wear resistance of tool steels. The difference in the wear rate of low- and high-alloyed steels exceeds six times (in abrasive erosion only 1.8 times). High-alloyed high speed steels in the sliding wear resistance have a substantial advantage over chromium carbide-based cermets.

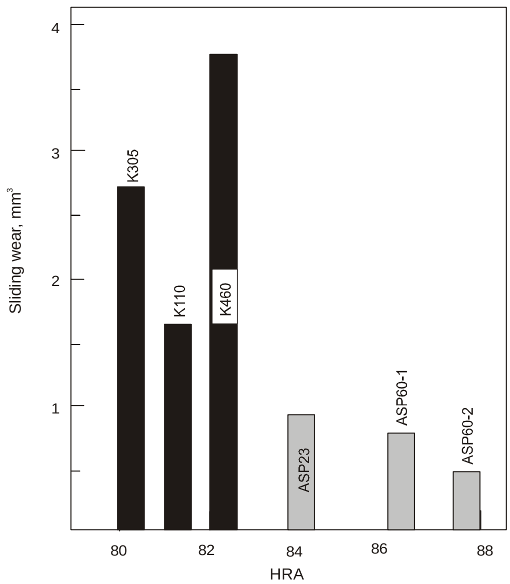

Figure 5. Sliding wear rate vs hardness of tool steels.

4. CONCLUSIONS

1. WC-base cemented carbides have advantages over tungsten-free cermets both in abrasive-erosion (up to 3 times) and sliding wear (up to 1.7 times) conditions.
2. Prognostication of wear resistance on the basis of hardness as a mechanical characteristic can bring pronounced mistakes when ceramic and metal composites and tool steels of different composition are considered.
3. Titanium and chromium carbide-based cermets bonded with Ni-Mo alloy are in a par with TiC-FeNi cermets in abrasive erosion and in disadvantage in sliding wear conditions.
4. Tool steels compare unfavourably with tungsten, titanium and chromium carbide composites in abrasive-erosion wear. High alloyed high speed steels have advantages over chromium carbide-based cermets and have wear resistance close to titanium carbide-based ones in sliding wear conditions.

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