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SLURRY EROSION WEAR OF TiC-NiMo AND WC-Co CERMETS

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Abstract *There is increasing demand for adequate materials to handle in erosive slurries. Titanium carbide based cermets, due to their corrosion resistance, are perspective material to use in corrosive and abrasive environments. Present paper covers slurry erosion corrosive wear properties of titanium carbide based cermets with different binder contents and different Ni to Mo ratios. Widely used WC-Co cermets are used as reference material. It is shown that titanium carbide based cermets exhibited superior wear resistance compared to WC-Co cermets. Wear mechanism was investigated by SEM images of worn surfaces. The wear mechanism is mainly characterized by the removal of binder phase followed by carbide grain detachment.*
Keywords: TiC-NiMo, WC-Co, cermets, slurry erosion wear, wear mechanism

1. INTRODUCTION

TiC - base cermets are known for their outstanding corrosion- and high-temperature wear resistance; they are most commonly used in metal cutting tools, but their unique combination of properties offer wide scope to the materials design engineer [1]. However, TiC-based cermets present some disadvantages, such as low toughness and bending strength compared with that of cemented carbides [2]. Even today best TiC-base cermets still possess poor erosive and wear resistance compared with WC-Co cemented carbides [3,4].

Slurry erosion of liquid carrying solid particle impingement is one of the main sources of failure of some components such as pumps, valves and pipelines, which are subjected to extremely severe impact and wear damages [5]. There is increasing demand for adequate materials to handle in erosive slurries. Wear and corrosion can involve number of mechanical and chemical processes. Combined abrasive wear and corrosion can significantly increase total material losses in aggressive environments, thus producing synergistic effect.

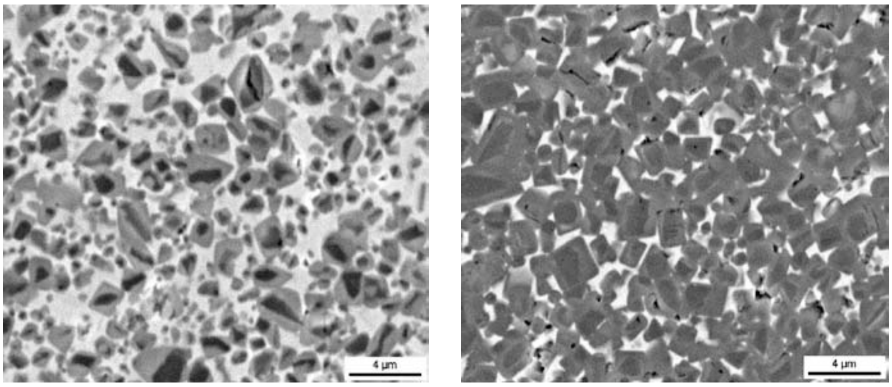
Corrosion is a chemical or electrochemical process in which surface atoms of a solid body react with a substance in contact with the exposed surface [6]. Usually the binder metal only corrodes during process of chemical interaction of cermet and substance. Binder metal is generally dissolved from the surface of the material leaving surface covered by ceramic grains. Loosing their support grains can be easily removed from the surface. The amount and rate of corrosion may change considerably with changes in such factors as concentration and temperature of the corrosive fluid and exposure time [7].

The corrosion rate of nickel in salt water is approximately 10 times lower than that of cobalt and at least 50 times lower than that of low alloyed steel. In case of Ni and Co some local attacks (pitting) may be expected where salt and deposits set up corrosion cells [8, 9].

However there is a lack of information about the erosion corrosion properties of TiC-NiMo cermets. The aim of present work were (1) to study the slurry erosion wear behaviour of titanium carbide based cermets with different binder contents in slurry of distilled water and abrasive and (2) to clarify the mechanism of material removing in solid liquid impingement conditions.

2. INVESTIGATED MATERIALS AND EXPERIMENTAL DETAILS

Investigated titanium carbide based cermets with binder content 20-60 %NiMo and Ni to Mo ratios 4:1, 2:1 and 1:1 and reference WC-Co cermets with binder content 5, 8 and 15 %Co were produced at Tallinn University of Technology using conventional powder metallurgy route. TiC, Ni and Mo or WC and Co powders were mixed together, ballmilled for 72 hours, then plasticized and pressed into green compacts and sintered in temperatures 1380 - 1480 ^{o}C for 30 minutes under vacuum. The microstructure of the titanium carbide based cermets consists of so called core rim structure, TiC core, (Ti, Mo)C ring around the core and binder consisting of Ni, Mo and Ti (figure 1). The compositions, densities and hardness of investigated TiC–NiMo cermets are exhibited in Table 1.



a b

Fig.1 Investigated TiC-NiMo cermets
a – 20%NiMo (Ni:Mo 4:1), b – 60%NiMo (Ni:Mo 2:1)

TiC, wt%	Ni, wt%	Mo, wt%	Density, g/cm^3	HV_{10}
80	16	4	5.47	1400
80	13	7	5.5	1515
80	10	10	5.54	1650
70	24	6	5.74	1300
70	20	10	5.77	1415
70	15	15	5.68	1590
60	32	8	6.04	1170
60	26	14	6.02	1270
60	20	20	6.03	1360
50	40	10	6.4	990
50	34	16	6.42	1150
50	25	25	6.34	1340
40	48	12	6.5	810
40	40	20	6.54	950
40	30	30	6.62	1180

Table 1. Chemical compositions, densities and hardness of TiC-NiMo cermets

Slurry erosion test were carried out in test device exhibited in figure 2. The stainless steel pot 2 was filled with slurry of water and silica sand as abrasive. When the rotor 5 rotates the slurry is lifted up from the bottom and flows throw the caps between the rotor's blades and attacks the specimens 3 mounted on a specimen holder 4 because of the centrifugal forces.

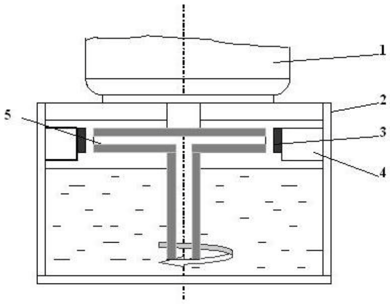


Fig.2. Principal scheme of slurry erosion test device
1 – electrical motor, 2-stainless steel pot, 3- specimen, 4- specimen holder, 5- rotor

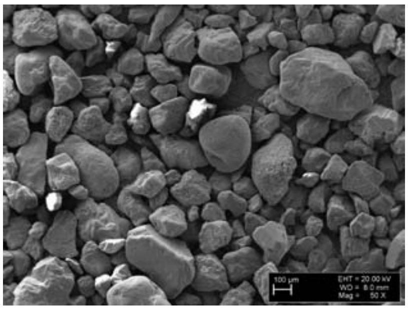


Fig.3. Silica sand abrasive used in tests

The slurry erosion tests were carried out in following conditions: distilled water + 5% silica sand as abrasive; the impact angle was close to 60^o, the impact velocity was 14 m·s^{-1}. In figure 3 is exhibited the silica sand (SiO_2) abrasive used in tests. The hardness of silica sand is 1100HV and the abrasive particles size is between 0.1–0.3mm. The specimens were washed in distilled water, dried in warm air and weighted to accuracy 0.1 mg before and after each test. There were 5 specimens per each investigated composition tested together in the same conditions. The weight loss was converted into the volume loss. The duration of each test was 24 hours. To study the wear mechanism the surface of the specimens after the wear tests was observed with scanning electron microscope JEOL JSM 840A.

3. RESULTS AND DISCUSSION

3.1. Wear rate

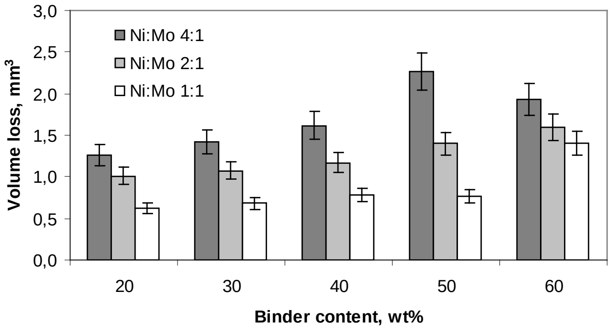


Fig.4. Volume loss of TiC-NiMo cermets in the flow of the slurry of distilled water and silica sand, depending on the chemical composition

In figure 4 is covered the slurry erosion resistance of titanium carbide based cermets in the slurry of distilled water and abrasive. In case of the slurry of distilled water and abrasive the volume loss increases in increase of binder content. When the softer binder content, which is more sensitive to erosion factor, increases the volume loss although increases; lower wear exhibited cermets with higher molybdenum amount in the composition, due to the higher bulk hardness of those cermets. In figure 5 is compared the volume loss of titanium carbide based cermets with Ni to Mo ratio 2:1 to widely used WC-Co cermets as reference material; the volume loss of WC-Co based cermets increased in increase of binder content and exhibited higher volume loss, compared to titanium carbide based cermets, due to the fact that cobalt base binder is more susceptible to corrosion compared to Ni binder in TiC-NiMo cermets. The importance of the corrosion resistance of the binder has significant role when the corrosion effect play dominant role in wear process. In case of TiC-NiMo and WC-Co cermets the corrosion-erosion process is mainly depend on the corrosion resistance of binder phase.

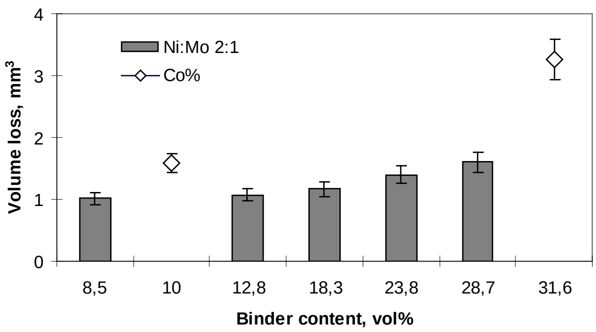


Fig.5. Volume loss of TiC-NiMo (NiMo ratio 2:1) cermets compared to WC-Co cermets in the flow of slurry of distilled water silica sand

3.2. Wear mechanism

The removal of material, during slurry erosion wear, occur mainly throw the binder loss followed by carbide grain pullout; therefore the ability of binder phase to resist removal by improved corrosion resistance is fundamental to improve slurry erosion resistance of cermet materials. In Figure 6 is exhibited the SEM images of worn surfaces of TiC-50%NiMo and WC-15%Co cermets. The same area before and after slurry erosion in distilled water and abrasive slurry for 6, 12, and 18 hours are exhibited. The binder phase is removed preferentially to the carbide phase. In case of abrasive is involved into the wear process the slurry erosion is a balance between the erosion by solid particles and the corrosion of the target; the corrosion resistance of binder material plays significant role in process when the corrosion aspect is dominant or the rate controlling factor. The removing of the carbide grains crumbling out by abrasive particles exposes new areas of binder phase to the corrosive abrasive influence. Consequently in case of WC-Co materials under corrosive abrasive environment wear resistance depends not on the content of harder tungsten carbide phase but dominantly on the content on less corrosion resistant binder phase. Comparing the titanium carbide based cermets where binder material is more corrosive resistant nickel with WC-Co materials it is evident than in case of materials with more corrosion resistant binder material the damages are decreased.

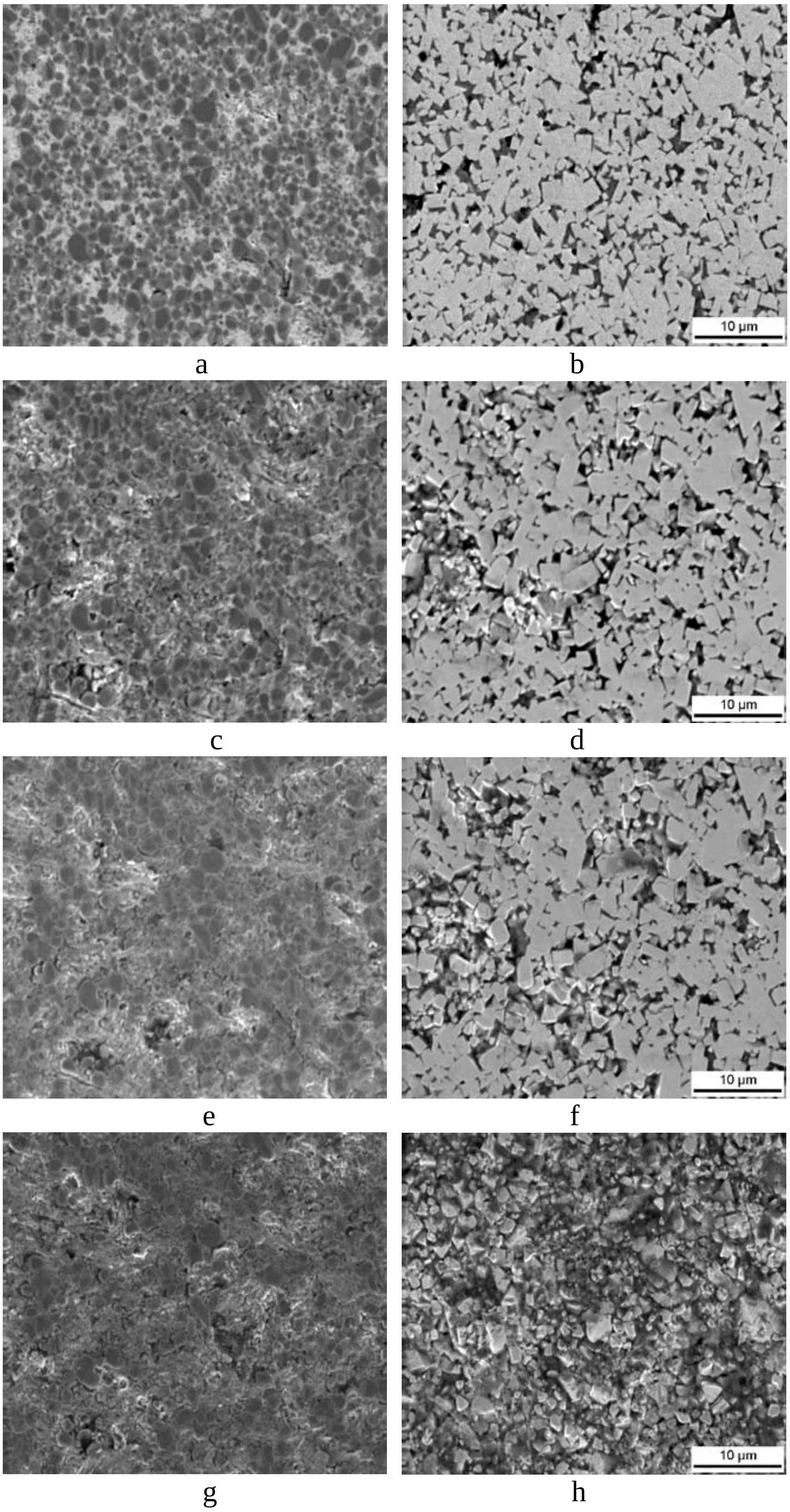


Fig.6. Worn surface of TiC-NiMo cermets before (a) and after the same area erosion after 6 (c), 12 (e), 18 (g) hours and WC-Co cermets before (b) and after the same area erosion after 6 (d), 12 (f) and 18 hours (h)

CONCLUSIONS

1. The slurry erosion wear of TiC-NiMo cermets, in case of slurry of distilled water and abrasive depends, on NiMo content; when NiMo content increases the volume loss although increases, higher wear resistance exhibited cermets with higher Mo amount in the chemical composition. TiC-NiMo cermets exhibited superior wear resistance compared to less corrosion resistant WC-Co cermets;
2. The main wear mechanism is characterized by the removal of binder phase followed by carbide grain detachment; therefore the slurry erosion wear depends mainly on the corrosion resistance of binder phase.

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