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SLIDING WEAR OF CHROMIUM CARBIDE BASED CERMETS UNDER DIFFERENT WEAR CONDITIONS

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Abstract: *Present paper considers the sliding wear properties of chromium carbide based cermets, produced by different methods and with different chemical compositions (10-30% of Ni), under different wear conditions. Sliding wear properties depend on the chemical composition and microstructure of cermets and although on wear conditions. Sliding wear under normal load 40 N is surprising, sliding wear coefficient decreases in increase of binder content. Under higher normal loads wear coefficient increases in increase of binder content. Wear coefficient is highest for pure water conditions; wear coefficient in case of artificial seawater is lower than for dry and pure water conditions. Better wear resistance exhibited cermets produced by reactive sintering. Wear mechanism of chromium carbide based cermets is mainly dependent on thermal cracking and fatigue related crushing of large carbide grains and carbide framework and also adhesion.*
Key words: Chromium carbide, cermets, sliding wear, wear coefficient, wear mechanism.

1. INTRODUCTION

Chromium carbide based cermets are perspective materials to operate in corrosive and abrasive environments [1-5]. Those cermets exhibited great hardness, good surface polishing qualities and heat expansion factor close to the steel, as well as high corrosion resistance in aggressive environments and at high temperatures. In this reasons chromium carbide based cermets could be successfully used for producing sleeve gaskets and bearings especially if they operate in corroding environments. Main disadvantages of these cermets are their relatively low mechanical properties and wear resistance mainly because of their coarse-grained structure (the carbide grain size is usually over 4 µm).

Wear is one of the most common causes for the failure of engineering materials [6,7]. Sliding wear is the most complex type of wear due to the way of different materials responds to the sliding conditions [6,7].

Wear coefficient of materials is predicted by Lancaster model [8]. Wear coefficient k is indicated the material wear rate under giving wear conditions, it is different for different materials and it is material characteristic similar to hardness, in this reason it is applicable to compare wear rates of different materials in the same wear conditions.

The sliding wear of chromium carbide based cermets is investigated in [9-12]. Because there is a lack of information on sliding wear properties of chromium carbide based cermets the aim of present work was to study the sliding wear properties of chromium carbide based cermets, with different chemical compositions and made by different technologies, under different normal loads and in different environments.

2. MATERIALS & EXPERIMENTAL

Investigated chromium carbide based cermets were fabricated at Tallinn University of Technology by a new

method reactive carburizing sintering [9]. Reference cermets were produced using conventional PM methods [9]. The structure of the cermets is composed of chromium carbide grains in a metal binder with the mean grain size about 2 μm for reactive sintered cermets and about 4 μm for cermets, produced by conventional technology.
Sliding wear tests were conducted on a modified block-on ring test device according to ASTM B611-85 [13]. The specimens of different chromium carbide based composites with the size of 23x14x5 mm were clamped in a holder and held rigidly against the rotating steel wheel under normal loads of 20, 180 or 320 N. The rotation speed of steel wheel was 235 rpm (linear speed 2.8 m/s). Sliding distance was 4000 m for each test. Tests wear carried out in different environments: dry sliding conditions and wet sliding conditions in pure water and in artificial seawater. The blocks were finished to a surface roughness of about 1 μm prior to each test. Each specimen was weighed before and after testing with an accuracy of 0.1 mg. Weight loss was converted into the volume loss. Specimen's temperature was measured according to [10]. The surface of the specimens after the wear tests was observed with scanning electron microscope JEOL JSM 840A.

3. RESULTS

3.1. Volume loss and wear coefficient

Figures 1 and 2 cover volumetric wear of chromium carbide based cermets, made by different technologies under different normal loads. Volumetric wear depends on the chemical composition, applied load and cermet producing technology. Volumetric wear of chromium carbide based is surprising, because low binder content cermets with greater hardness rate exhibited lower wear resistance than cermets with bigger binder content. Volumetric wear increases in increase of normal load.

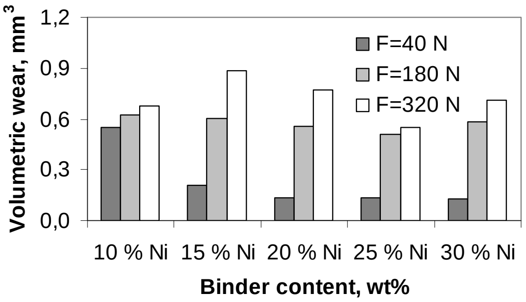


Fig.1. Volume loss of reactive sintered chromium carbide based cermets under different normal loads in dry sliding conditions

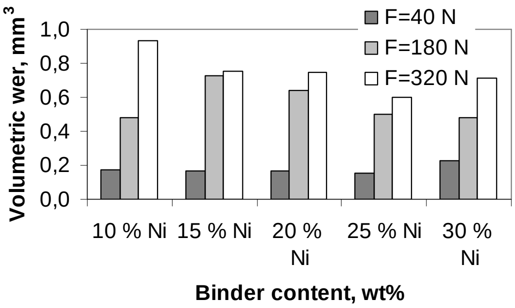


Fig.2. Volume loss of chromium carbide based cermets, made by conventional technology under different normal loads in dry sliding conditions

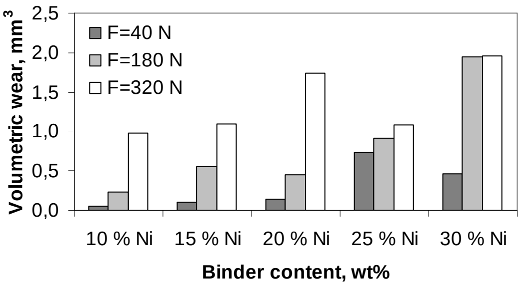


Fig.3. Volume loss of reactive sintered chromium carbide based cermets under different normal loads in wet sliding wear conditions

Under higher normal loads the influence of binder content decreases, but the main trend preserve.
Volume loss in pure water environment depends on binder content, applied normal load and cermets producing technology

(figures 3 and 4). Wear increases in increase of binder content and normal load. Higher wear resistance show cermets made by reactive sintering.

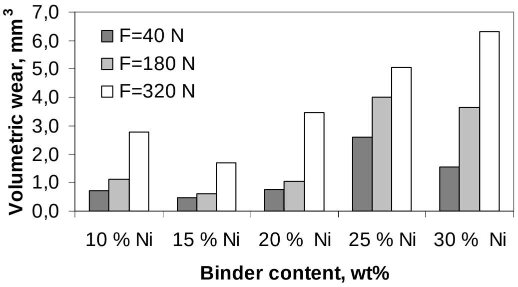


Fig.4. Volume loss of chromium carbide based cermets, made by conventional technology under different normal loads in wet sliding wear conditions

Figures 5 and 6 covers sliding wear coefficient of chromium carbide based cermets in different environments under normal load 320 N. Wear coefficient depends on chemical composition, environment and cermets producing technology. Wear coefficient exhibited highest values for pure water environment and increases in increase of binder content for pure water and artificial seawater environments.

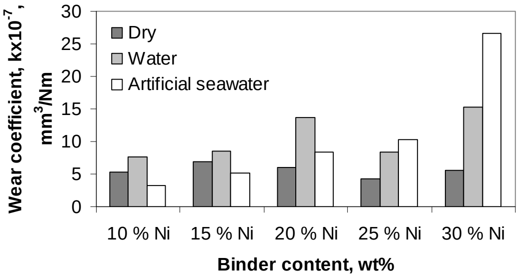


Fig.5. Wear coefficient of reactive sintered chromium carbide based cermets in different wear environments under normal load 320 N

Wear coefficient shows, an average, lowest values for dry sliding conditions. For artificial seawater environment the wear resistance is higher than for pure water environment. In comparison with dry sliding conditions than for low binder content materials the wear coefficient is lower for artificial seawater conditions and for high binder content materials for dry sliding conditions.

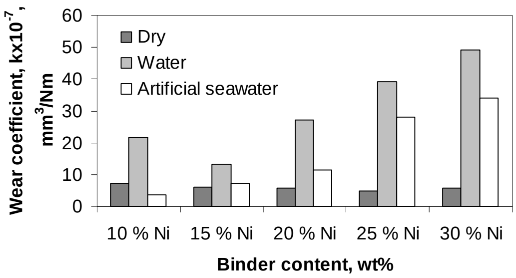


Fig.6. Wear coefficient of chromium carbide based cermets, made by conventional technology in different wear environments under normal load 320 N

3.2. Temperature

As seen in figure 7 the temperature arises abruptly for the first 100-200 m of sliding distance in case of normal load 40 N and reaches a constant value in sliding distance of 1000 m. In case of higher normal loads temperature increases abruptly for he first 100-200 m of sliding distance and then became to increase more slightly.

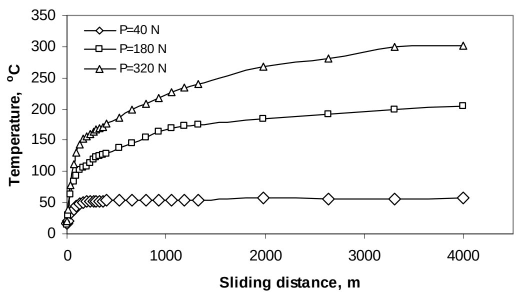


Fig.7. Temperature of chromium carbide based cermets under different normal loads.

Temperature increases in increase of normal load and show highest values in case of normal load 320 N. It may be presume that the temperature of the material surface is slightly higher than in measurement point, but changes in the material surface do not take place at such temperatures.

3.3 Wear mechanism

Wear mechanism of chromium carbide based cermets is investigated in [10-12]. Wear mechanism of chromium carbide based cermets was examined by SEM images.

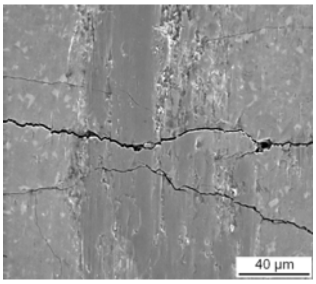
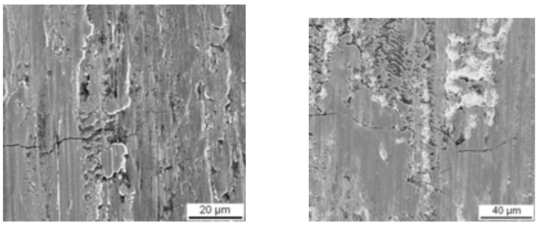


Fig.8. Microcracks in the surface of Cr_3C_2-20%Ni cermet after testing in dry sliding conditions under normal load 320 N and for sliding distance 1000 m



a) b)

Fig.9. Microcracks in the surface of Cr_3C_2-20%Ni cermet after testing in dry sliding conditions under normal load 320 N and for sliding distances10 m (a) and 1000m (b)

In case of dry sliding conditions macrocracks is formed in materials surface transversely to the sliding direction (figures 8 and 9). It could be explained by the high thermal expansion coefficient of chromium carbide based cermets combined wit low thermal conductivity, due to this reason friction causes great internal tensions. The material is detaches in the layers when cracks meet together and its leaves holes in the material surface. Thermal shock and friction forces affected the materials surface to exceed its tensile strength, its causes rupturing of the material and detachment of fragments from the surface. In case of normal load 40 N, when the binder content increases then the brittleness of the material is decreases and although the volume wear is decreases. Under higher normal loads the influence of applied load equilibrates the influence of brittleness and due to that the influences of binder content to the volume wear decreases.

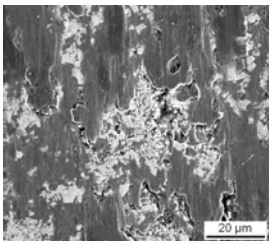


Fig.10. Worn surface of Cr_3C_2-20%Ni cermet after testing in wet sliding conditions under normal load 320 N and for sliding distance 1000m

Figure 10 exhibited the worn surface of Cr_3C_2-20%Ni cermet in wet sliding conditions. Sliding wear mechanism of chromium carbide based cermets in pure water and artificial seawater environment does not correspond to general knowledge. If the wear results in dry sliding conditions are accountable, then why the volume loss in dry sliding conditions are lower than in case of wet conditions has not clear response by the moment. It could be explained by the microstructure of the material (fine and coarse grained materials) and lubrication properties of the artificial seawater. Although, the higher temperature in case of dry sliding wear affect the volume loss compared to artificial seawater environment.

4. CONCLUSIONS

The following conclusions can be drawn from the experimental study:

1. Volume loss depends on chemical composition, sliding conditions and cermets producing technology;

2. Volume loss for dry sliding conditions is surprising, volume loss decreases in increase of binder content and decrease of bulk hardness, volume loss for pure water and artificial seawater environments increases in increase of binder content;
3. Wear coefficient is highest for pure water conditions; an average the wear coefficient is lower for dry sliding conditions;
4. Temperature depends on applied normal load; temperature exhibited highest values for normal load 320 N;
5. Study of the wear mechanism shows macrocracks formation in the surface transversely to the sliding direction due to the brittleness and high thermal expansion coefficient combined with low thermal conductivity of Cr_3C_2, wear mechanism in wet environments need continuous examination.

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