FEATURES OF CERAMIC-METAL COMPOSITES RESPONSE ON EROSIVE PARTICLE IMPACT.

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1 Introduction

Ceramic-metal composites are the materials of interest in applications in aggressive environments such as erosive; erosive-corrosive medium and at high temperatures. The most known cermets are the cemented carbides, which are composed of extremely hard particles of a refractory carbide ceramic such as tungsten carbide, titanium carbide or chromium carbide, embedded in matrix of a metal such as cobalt, nickel or steel. These materials possess superior stiffness as compared to metals, simultaneously having better toughness and structural integrity compared to monolithic ceramics.

Discussing the composites reliability in working conditions, hardness and fracture toughness are often mentioned. However, it was shown that materials possessing the similar measured bulk mechanical properties, such as hardness, fracture toughness, modulus of elasticity, and having the same microstructural characteristics, such as grain size and porosity, may reveal a different behavior when subjected to an impact loading [1]. Previously, the development of so-called wear sheets under abrasion of composites was revealed [2]. Formation of surface layer consisting of deformed binder metal, detached small carbide grains, damaged large carbides, mixed with additional phases such as wear debris of counterparts, crushed abrasive, parts of oxidation scales, etc, may play an extremely important role in materials tolerance to impact.

There are no published data on mechanically mixed layer developing in cermets in conditions of erosive particle impact. Because of above, the main aims of this study are (i) detailed characterization of surface and subsurface areas of the worn ceramic-metal composites (cermets) and (ii) investigation of MML formation during erosive wear of chromium, titanium and tungsten carbide based materials.

2 Materials and experimental procedure

Materials chosen for this study were WC-, TiC-, and Cr_3C_2 – based cermets with 12 vol.% of binder metals, carbide particles mean size of 3 μm and porosity of 1 %. Some large elongated grains were found in Cr_3C_2 –Ni cermet.

Specially elaborated high temperature tester [3] was used for materials impacting by silica particles of 0.3 μm in diameter. Two particle velocities and impact angles were applied. Velocity of 20 m/s is in the range of used at gas pipes and heat exchangers of power plants while the velocity of 80 m/s is close to the working conditions of turbine. The behavior of material at angle of 30º shows the ability to sustain extensive cutting and ploughing action of abrasive particles and is typical for gas transport pipes. The behavior of material under the impact angle of 90º shows the ability to sustain sufficient tensile stresses that is specific for elbows or heat exchangers. Temperature of 600º was chosen as the maximum temperature at which the conventional WC-Co cermets can operate. Experiments for all grades were made simultaneously to avoid any difference in tests conditions.

3 Results and discussion

Typical curves of indentation tests of undamaged materials held at 600º C are presented in Fig. 1. All tested cermets exhibited lower hardness after holding at 600ºC as compared to as-received and polished materials. This can be attributed to the low hardness of oxide films formed on the cermets surface at high temperature.

Specimens were polished step-by-step to remove materials from damaged surface. Hardness changes in the subsurface layer were revealed for all materials subjected to impact. The mean hardness variation is plotted in Fig.2 for TiC-Ni composite. Polishing depth shows the distance from surface.

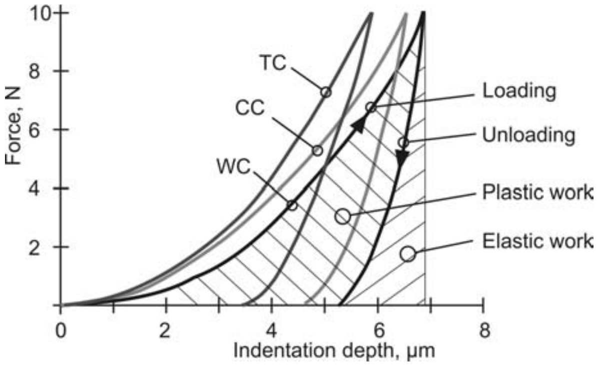

Fig. 1. Typical curves of universal hardness testing: WC – WC-Co; CC - Cr_3C_2 –Ni; TC – TiC-Ni cermets.

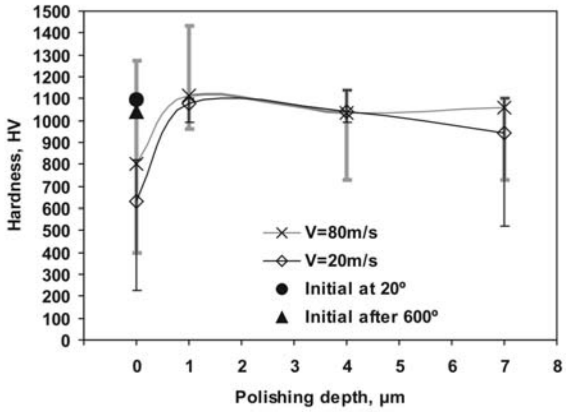

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Fig. 2. Hardness variation through the subsurface layers in TiC-Ni system at impact angle 90^0

The erosion at 30º has less pronounced effect on modification of surface layer. After the erosion at impact angle of 90º the depth of the modified layer is deeper. The depth of layer within which the properties are changed, or in other words, the thickness of MML for CC and TC cermets is not larger than 4-5 µm while for WC grade it is about 7 µm. The example of subsurface cracking and MML presence is shown in Fig. 3 for Cr_3C_2 –Ni cermet.

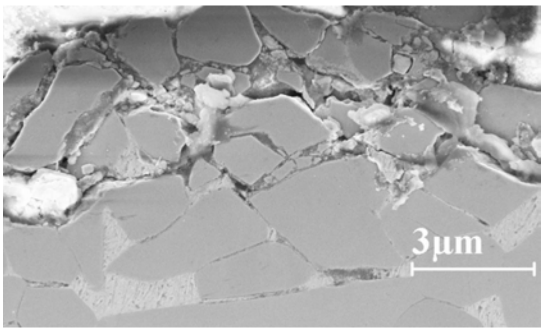

Fig. 3. Cross-section of Cr_3C_2 –Ni.

Testing the erosion resistance at high temperatures shows the advantage of TiC-Ni composites over other cermets.

The pronounced MML formation is possible when particle velocity reaches some threshold value. In this study the velocity of 20 m/s may be considered as a threshold. Composites with low binder metal hardness are more susceptible to MML formation during impact. The oxidation resistance is of high importance at high temperature testing. Cobalt binder in the MML being oxidized and removed leaves the carbide grains unprotected that leads to extensive cracking to as deep as about 5 grains distance (15 µm). The contact between carbide grains in case of Cr_3C_2 based cermets also provoke cracks formation due to the shifting of ceramic grains at impact site. The core-rim structure of TiC cermets provide some damping ability. This material has higher percent of elastic work during the indentation.

4 Conclusions

- Experimental observations indicate that during erosion of ceramic-metal composites the mechanically mixed layer is formed. The erosion resistance of cermet is the result of interaction of MML with abrasive particles and with bulk cermet. The removal of thick MML is responsible for the high erosion rate.
- The properties of MML differ from properties of bulk materials and characteristics of MML strongly correlate to microstructural features of materials.
- Erosive behavior of non-homogeneous materials possessing similar mechanical properties, binder contents and grain sizes can be explained on the basis of formation and fracture of MML. Erosion resistance is dependant on thickness and hardness of MML as well as on applied conditions.

References

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