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The study on tribological properties of Co-TiC powder alloys

Tribological properties of Co-Cr-Fe-Al powder alloys strengthened with TiC particles have being studied. The alloy has good wear resistance at high temperature fretting wear conditions. For alloy with 50% (vol) of TiC with the long time operation is possible if ambient temperature not acceeds 850 °C

Introduction. Modern aviation industry is one of the largest consumers of newest technologies and materials. The development of this industry is significantly restrained by the insufficient development of material science. A large number of technologies of their surface strengthening have been developed, which provided a significant improvement of GTE hot section parts.

Particular attention has always been paid to the working blades of GTE – top shrouds, as far as wear of their contact faces is one of most common reason for the blade to fail. One of good methods to improve their wear resistance – is soldering of protective layer made of alloy XTH-61 and XTH-62. Their use provides a blades service life up to 12 thousand hours. The further development of this technology are Co-TiC cemented cadbides.

Materials and the methods. A sintered cobalt-based alloy developed jointly with the Institute for Metal Physics of the National Academy of Sciences of Ukraine has being studied. Cabalt matrix was alloyed by aluminiun, iron (their content in the alloy is 2-2.5% wt.) and chromium (15-16% wt). As a reinforcement phase, titanium carbide is used in an amount of 36% wt/50% vol. The size of TiC particles is 1-10 μm. Powder ingredients were milled in a planetary mill. The microstructure of the alloy is shown in Fig. 1

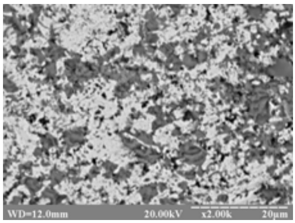


Figure 1. Micristructure of composite sintered cobalt-based alloy containing 50% vol. of TiC. Light phase – cobalt matrix, dark phase – TiC grains

Tribological tests were conducted using wear test machine MFK-1, which is additionally equipped with a circular electric furnace providing temperature up to 1200 °C. Specific load in contact – 30 MPa, fretting amplitude – 120 μm at a frequency of – 30 Hz. Test temperature 450-1050 °C Test time –50 hours, corresponding to 5×10^6 of fretting cycles.

Microstructural examinations have being performed using raster electron microscope REM-106I equipped with EDS, and a light microscope MIM-7.

Results and discussion. Tests at high-temperature fretting conditions confirmed the high wear resistance of composite cobalt-based alloy (Fig. 2). So, after testing at a temperature of 1050 °C, the average linear wear did not exceed 150 microns. The alloy equally wears over a wide range of temperatures, and only at its highest values there is a significant intensification of wear, which, however, is small, if compared with the results obtained by a other of authors earlier, the wear resistance of a wide range of materials used to apply The contact surfaces of the tramline shafts of the turbine blades of the GTE in various ways.

Preliminary investigations of the composite alloy of the Co-TiC system in high-temperature fretting conditions emphasize the possibility of plastic deformation [1-2], which was previously associated with a increase of wear at temperatures above 950 °C, which is why it was for these samples that a material analysis was performed under the friction surface.

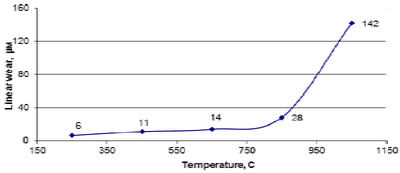
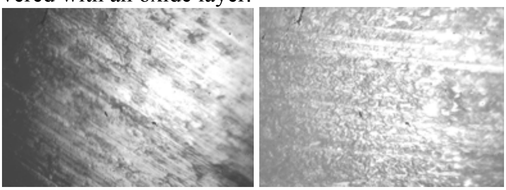


Fig. 2. Mean linear wear of 50% vol. Co-TiC cemented carbides

At low temperatures the alloy components (matrix and filler), as well as in the initial period of friction, the oxide layer is formed on a surface that occupies about 0.2-0.3 (Fig. 3, a) from the sample area, which is approximately equal to the actual contact area [10].

At a temperature of 450 °C, the surface is covered with oxides to higher extent: 85-90% (Fig. 3, b). It can be argued that under these conditions the friction surface is completely covered with an oxide layer.



a b

Fig. 3. Wear surface of the alloy: a – temperature 250 °C, ×200, b – temperature 450 °C, ×200

At temperatures 650 and 850 °C, a change in the nature of the relief of wear track is observed (Fig. 4). On the surface there are visible ploughings in friction direction; this is particularly well seen in Fig. 6, a. It should also note the presence of colored areas on the surface, which may indicate their dissimilar chemical composition.

According to Fig. 2, the average linear wear of the alloy in this temperature range remains low, this indicates the stability of friction process.

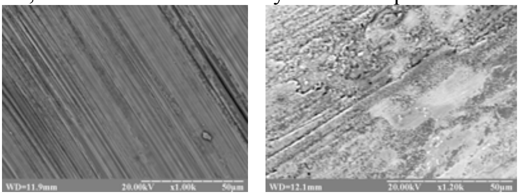
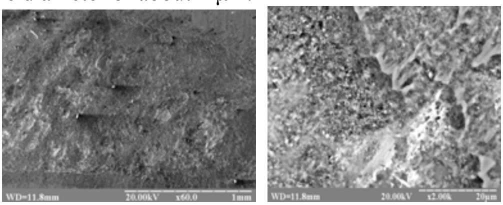


Fig. 4. Topography of wear surface of the alloy: *a* – 650 ^{o}C, ×200; *б* – 850 ^{o}C, ×1200

The increase in temperature to the maximum within value 1050 °C leads to a significant increase in linear wear of the material. In Fig. 5, it is well seen the separation of wear surface into light and dark areas. In the center of the fig. 5, a large particles of 50 microns in diameter are visible.

In Fig. 5, b it can be seen that the wear products, which are mainly accumulated on the surface, have diameter of about 1 μm.



a b

Fig. 5. Top view of wear track at temperature 1050^{o}C: *a* – general view, ×60; *b* – wear debries, ×2000

The results of X-ray analysis of light and dark areas are given in Fig. 6. They confirm the different chemical composition of the dark and light areas formed on the wear surface of Co-TiC cemented carbides after fretting-wear test at temperature of 1050 °C. In particular, in light areas there is an increased content of chromium that exceeds its initial value in the alloy, while the content of cobalt is much lower. Along with the presence of a significant amount of oxygen, iron, cobalt and aluminum, it can be argued that a white section is formed predominantly from chemical elements that are part of a matrix alloy. On the dark areas, on the contrary, the concentration of the elements of matrix alloy is reduced, while the proportion of titanium significantly increases. Oxygen content is also high. This is explained by the oxidation of titanium carbide, as well as the oxidation of other chemical elements.

The size of darker areas is 200-300 microns. By comparing this value with the magnitude of fretting amplitude (120 μm), it becomes clear that they are contour portions of the contact of contiguous surfaces. In the process of wear, carbide grains appear on the actual contact place. Under these conditions, a large proportion of the load falls on the carbide phase. As a result, fine wear debries (Fig. 5, b), whose chemical composition corresponds to titanium oxides are formed.

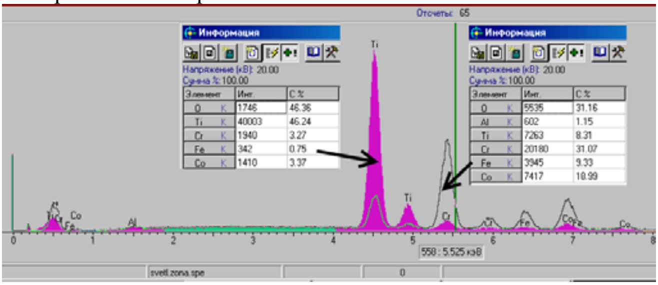
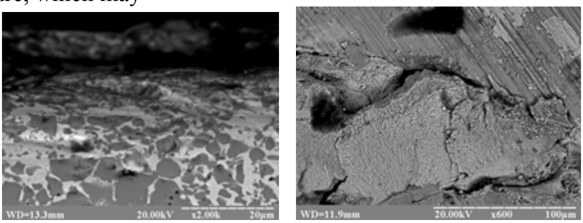


Fig. 6. X-ray analyses of oxide layer, temperature 1050 °C. Contour specter – light area, solid specter – dark area (from fig. 7, a)

Significant growth of wear at temperature 850-1050 °C could be explained by the intensification of the processes of surface deformation of the material. In Fig. 7, a, a structure below wear track is shownted below the friction path. It can be seen that the mutual arrangement of strengthening phase differs little from the original microstructure, which may



a b

Fig. 7. Microstructure of the alloy, *a* – under the wear track, *b* – place of local destruction of oxide layer and its healing by wear debries. Temperature *T* =1050 °C.

indicate plastic deformation of the surface layer. The matrix phase is closely adjacent to the TiC grains, there are no cracks and separation of carbide phase from wear surface. This indicates either strong adhesion with the matrix phase, and optimal distribution of stresses in the material.

Fig. 7, b shows the location of the local destruction of oxide layer. Analysis of chemical composition of oxide layer around the destruction area indicates that chromium and oxygen predominates. The composition of the powder product, by which the damaged area is filled (Fig. 7, b) includes all components of alloy and oxygen, with the amount of titanium and chromium higher than in the alloy (24 and 62% wt., respectively), while cobalt - much less (about 7% wt.).

In the whole range of test temperatures, the surface structure is homogeneous, with weakly marked traces of destruction. A stable layer of chromium oxides is formed, and they are selectively covered with titanium oxides. The formation of titanium oxides and their accumulation on a more solid sublayer can be accepted as another proof that carbide grains are placed in the areas of direct contact between two contiguous surfaces. The generated layer corresponds to the rule of a positive gradient of mechanical properties, since the hardness of titanium oxides is much less than the hardness of chromium oxide. In addition, particles of titanium oxide powder can play the role of solid lubricant in the friction zone, softening the wear process. The accumulation of the powdered wear products in the places of oxide film local destruction prevents seizing of contiguous surfaces, since the areas of microwelding during the topographic analysis of wear track have not being found.

Conclusions. The investigated material has a uniform wear throughout the range of temperatures. The structure of the material contributes to the formation of small compacted wear products and forms a secondary triboinduced structure whose mechanical properties correspond to the rule of a positive gradient. The formed powders of titanium oxides can also play the role of solid lubricant. At temperatures up to 850 °C, the wear of the material is insignificant and the destruction of the protective oxide layer is not observed. The incremant of wear has linear character. It can also be argued that in this range of temperatures, the alloy has uniform wear rate increment, what is especially important for the elements of GTE hot section.

References

1. Дослідження зносостійкості композиційних сплавів на основі кобальту [10-й міжнар. симпозіум українських інженерів-механіків у Львові], (м. Львів, 25–27 травня 2011р) Нац. ун-т «Львівська політехніка», М-во освіти і науки, молоді та спорту України.– 2011. – С. 297–298

2. Тісов О.В. Дослідження зносостійкості композиційних сплавів на основі кобальту / О.В Тісов // Вісник двигунобудування. – 2012. – №1. – С. 191-195.