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High Temperature Oxide Resistant Components of Perspective High Strength Intermetalceramic Composite Coatings

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Abstract

The work represents the results of the experiments associated with the development of a fundamentally new composite intermetallic ceramic coating for hot section parts of gas turbine engines. It was determined that the combination of arc-jet and magnetron methods gives opportunity to expand the scope of sputtering when creating heat-resistant coatings in vacuum. In such a way obtained coating differs by the absence of a "drop" phase and, subsequently, by higher thickness and smoothness. In such a case, the best coating properties can be achieved by separate gas feeding into working chamber.

Keywords

Multicomponent coatings, ion-plasmous sputtering, gas turbine blades.

Introduction

The products of general and transport machine-building in many cases work under the conditions of high temperatures and in aggressive environments. Common examples of such products are parts of the hot section of modern gas turbine engines (GTE) [1]. Thus, for instance, GTE turbine blades operate under high temperatures (up to 950 - 1050°C) being exposed to the effect of high temperature corrosion and erosion. During the maintenance process, in the surface part of the blades there take place the accumulation of oxygen and sulphur from the gas flow of the burnt fuel as well as the formation of oxides and sulphides. Such formations result in the destruction of the blades. Widely known protective coatings for GTE products operating in the environment of high-temperature corrosion and erosion as, for example, aluminized and zirconium-aluminium ones have comparatively poor durability. This is mainly connected with their diffusion 'penetrability' [2].

The paper deals with the creation of

fundamentally new functional multicomponent coatings applying the technologies of ion-plasmous sputtering.

Results and Discussion

Turbine blades of GTE compressor were used as the subject of the research (Fig. 1); they were made of fusion which had the following content in percents: 0,1 *C*; <0,3 *Mn*; 0,6 *Li*; < 1,5 *Fe*; (5,4…6,2) *Al*; (6…7,5) *W*; (6,5…8) *Mo*; (8,5…10,5) *Cr*; (11…13) *Co*; 56 *Ni* (base).

Figure 1. Turbine blades of GTE compressor.

The functional intermetalic-ceramic IMCER coating is sputtered by applying vacuum installation (Fig. 2). The coating is formed in plasma from the fusions based upon aluminium and titanium (Fig. 3). The maximum thickness of the coating reaches 40 μm .

Further blades tests for heat resistance are conducted in air – in an electric furnace and in the environment of glowing chlorine sulphide ash (from suspension: Na2SO4 + NaCl + H2O). During the tests the heat resistance was quantitatively assessed accordingly to a factual weight increment at the expense of oxidation; there was used an analytical balance.

The study of microstructure was carried out by means of a focused-beam microscope.

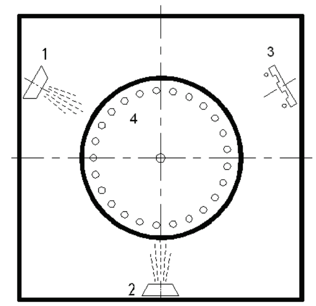

Figure 2. Vacuum ion-plasmous sputtering installation scheme: 1, 2 – cathode (arc evaporator); 3 – magnetron; 4 – worked parts.

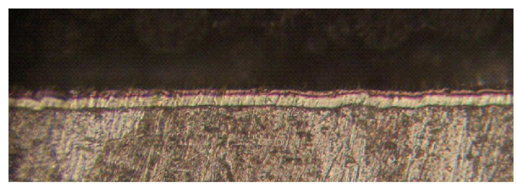

Figure 3. The functional intermetalic-ceramic IMCER (x460).

The first stage of the test involved a high-temperature annealing of the blades in furnace atmosphere under the temperature of 950°C in the course of 200 hours (Fig. 4).

The test results obtained (Fig. 5) revealed a considerable increase in the heat resistance of the IMCER coating in comparison to that of the zirconium-aluminium (5…15 times higher, depending on the duration of temperature action).

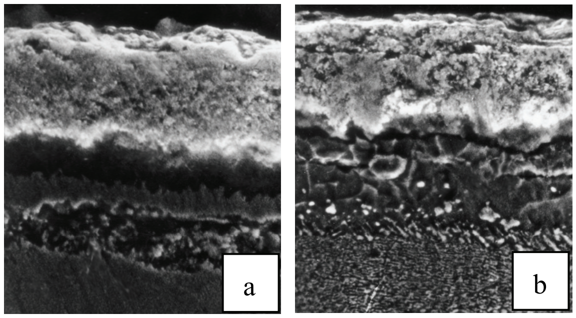

Figure 4. Microstructure of heat-resisting coating after heat resistance testing under temperature 9500 C, x1000: a – during 30 hours; b - during 200 hours.

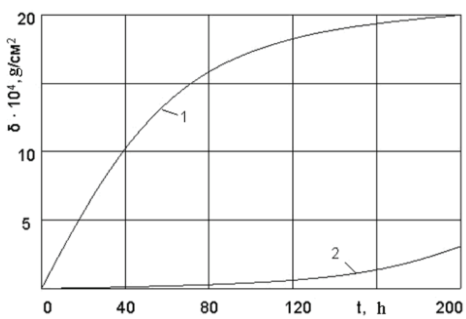

Figure 5. Heat resistance tests results in furnace atmosphere under the temperature of 950°C: 1 - zirconium-aluminium coating; 2 – IMCER coating.

There has also been studied the distribution of the substrate basic elements (cobalt, tungsten, nickel, chrome) contained in the created coating after the tests.

The distribution of the substrate basic elements is represented in figure 6. The coating section two peaks of the increased microhirdness are connected with the increase of the cobalt and tungsten content in the given area. In the area of the cobalt and tungsten maximum concentration, the nickel has a null with the formation of a maximum along with their consequent decrease.

It was also found that the external ceramic layer not only held its initial properties after 200 hours of tests but also showed a compression capacity owing to the penetration of chrome into it. After the monotonous content decrease in the coating, the chrome has its own moderate maximum in the ceramic layer, the presence of which can be explained by its oxidation and holdup in the ceramics. The process of filling the ceramics with the chrome apparently results in the compression of the ceramic constituent of the coating. This, in its turn, should promote the decrease of gas oxygen penetration inside the product material and subsequently result in the coating heat resistance increase in general.

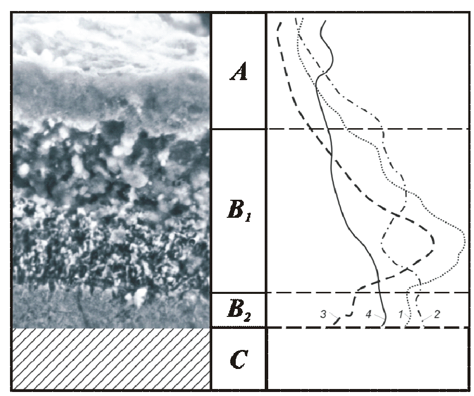

Figure 6. Distribution of the basic elements of fusion substrate within the intermetalic-ceramic coating after thermal testing (200 hours): A – ceramic area; B1, B2 – diffusion areas; C – substrate; 1,2,3,4 – distribution accordingly Co, Ni, W, Cr.

An earlier research carried out with the aim to study the process of GTE combustors burner wear showed that the sulphur educed from the fuel has a high diffusive mobility in comparison to the gas oxygen. It brings to the structural alteration of the material as well as to its embrittlement. Thermal testing of the blades of various categories in the environment of glowing chlorine sulphide ash also confirmed the efficiency of the offered protective coating. Fig. 7 shows that in the result of testing in the aggressive environment there was observed a substantial damage of the coatings which entails a subsequent fast-moving destruction of the blades basic material.

It was found that the IMCER coatings have 2…3 times higher heat resistance in the aggressive environment in comparison to the standard aluminized ones.

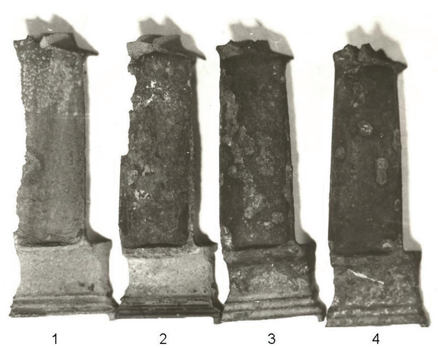

Figure 7. Outward appearance of blades with the coatings after the thermal testing in the environment of glowing chlorine sulphide ash: 1 – standard aluminizing; 2 – standard aluminizing and annealing (900°C, 2 hours); 3 – zirconium aluminizing; 4 – IMCER coating.

The characteristics of microhardness distribution within the coating are represented in fig. 8. A substantial microhardness decrease in the medium area of the coating can be obviously explained by the paramount content of the nickel in it when compared to the tungsten, cobalt and chrome.

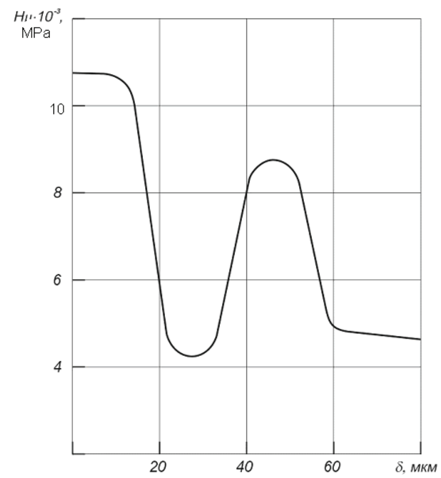

Figure 8. Distribution of microhardness in the intermetalic-ceramic coating after gas corrosion testing in chlorine sulphide ash, 900°C – 18 hours.

Conclusion

Testing of various category products on heat resistance in scorching chlorine sulphurous ash environment also confirmed the effectiveness of the offered protective coating. IMCER coatings differ with 2…3 times higher heat resistance in comparison to aluminized ones.

Distinguishing features:

– coating gives opportunity of 2…3 time increasing the resource of products working under high temperatures and aggressive environments;

- possibility of obtaining the coating of variable composition, structure, thickness taking into consideration acting temperatures and voltages;
- high plasticity and heat resistance of the composition product material - coating;
- simplicity, stability and availability of coating sputtering technological process in conditions of serial production.

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