

Chapter 28

Nanostructured Intermetal-Ceramic Coatings for Blades of Gas Turbine Engines

A. Urbahs, K. Savkovs, M. Urbaha, and I. Kurjanovičs

Abstract The paper deals with the creation of fundamentally new functional multicomponent coatings applying the technologies of ion-plasmas sputtering. The results of the conducted experimental research showed the high efficiency of the elaborated multicomponent intermetal-ceramic (IMCER) coating for the protection of gas turbine engines (GTE) blades in their maintenance process. The coating is formed in plasma from the fusions based upon aluminium and titanium. The maximum thickness of the coating reaches 40 μm .

Keywords Coating • Ion plasma • Gas turbine engines blades

28.1 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 GTE [1]. The increase of GTE effectiveness is related to the growth of parameters of their gas-dynamic cycle and, first of all, to the growth of gas turbine entry temperature and compressor pressure ratio. Thus, if to compare the first serial GTE (Jumo 109-004, BMW 109-003, W.2B/23 Welland I) with contemporary turbfans (Pratt&Whitney 4000, General Electric GE90, Rolls-Royce Trent, etc.), their gas turbine entry temperatures have increased from 800–900 K to 1,600–1,750 K while the compressor pressure ratio has increased from 3–5 to 35–40 and even more [1–5].

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Fig. 28.1 GTE turbine blade

Analyzing the main technical solutions for increasing gas turbine entry temperatures, it is necessary to point out that initially there were attempts to solve this problem by applying new high-temperature materials. Then special protective coatings started to be used [6]; in addition, air cooling systems were developed and new technologies for engine hot part elements manufacturing were applied.

Thus, for instance, GTE turbine blades operate under high temperatures being exposed to the effect of high temperature corrosion and erosion (Fig. 28.1). During the maintenance process, the accumulation of oxygen and sulphur from the gas flow of the burnt fuel take place on the surface part of the blades, 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-plasmas sputtering.

28.2 Experiment Techniques

Turbine blades of GTE compressor have been used as the subject of the research; they are made of fusion with the following content in percent: 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).

The functional intermetallic-ceramic IMCER coating based on aluminium and titanium is sputtered by applying vacuum installation (Fig. 28.2).

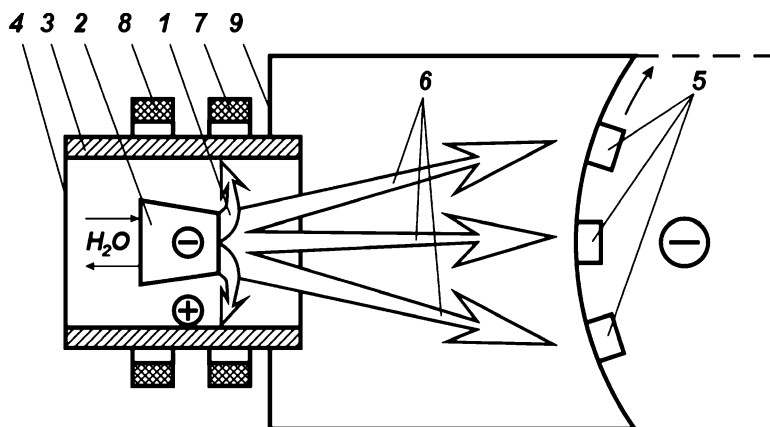


Fig. 28.2 Vacuum ion-plasma sputtering installation scheme: 1 plasma, 2 cathode (arc evaporator), 3 circular anode, 4 gun, 5 worked parts, 6 sputtered material, 7 focusing magnetic coil, 8 regulating magnetic coil, 9 vacuum chamber

Further, blades tests for heat resistance are conducted in the air – in the electric furnace and in the environment of the glowing chlorine sulphide ash (from suspension: $Na_2SO_4 + NaCl + H_2O$). During the tests the heat resistance was quantitatively assessed according to the factual weight increment at the expense of oxidation; the analytical balance was used there.

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

28.3 Results and Discussion

The coating (Fig. 28.3) is formed in plasma from the fusions based upon aluminium and titanium. The maximum thickness of the coating reaches 40 μm .

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 h.

The obtained test results (Fig. 28.4) have revealed a considerable increase in the heat resistance of the IMCER coating in comparison with that of the zirconium-aluminium (5–15 times higher, depending on the duration of temperature action).

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

The distribution of the substrate basic elements is represented in Fig. 28.5. The coating section two peaks of the increased microhardness are connected with the increase of cobalt and tungsten content in the given area. In the area of cobalt and

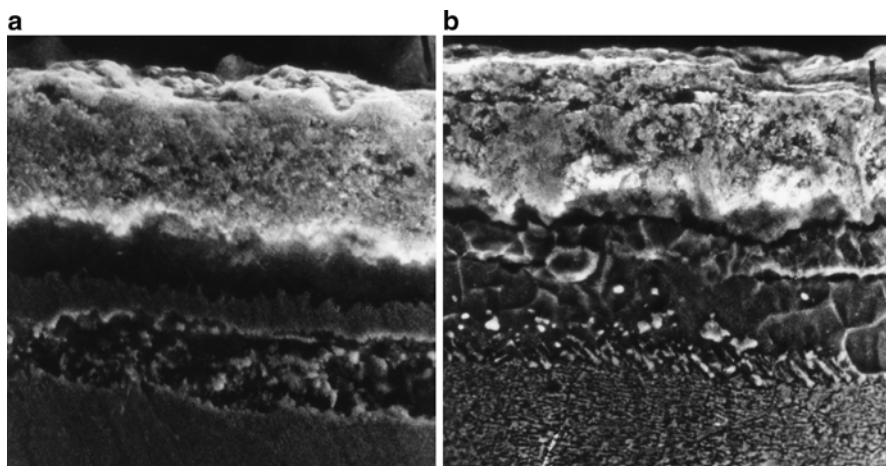


Fig. 28.3 Microstructure of heat-resisting coating after heat resistance testing under temperature 950°C, $\times 1,000$: (a) during 30 h; (b) during 200 h

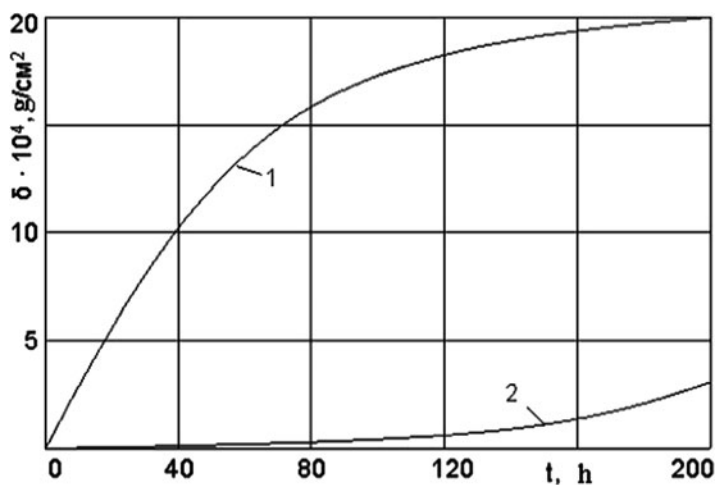


Fig. 28.4 Heat resistance tests results in furnace atmosphere under the temperature of 950°C: 1 zirconium-aluminium coating; 2 IMCER coating

tungsten maximum concentration, nickel has a null with the formation of the maximum along with their consequent decrease.

It has also been found that the external ceramic layer can not only preserve its initial properties after 200 h of tests but also show a compression capacity owing to the penetration of chrome into it. After the monotonous content decrease in the

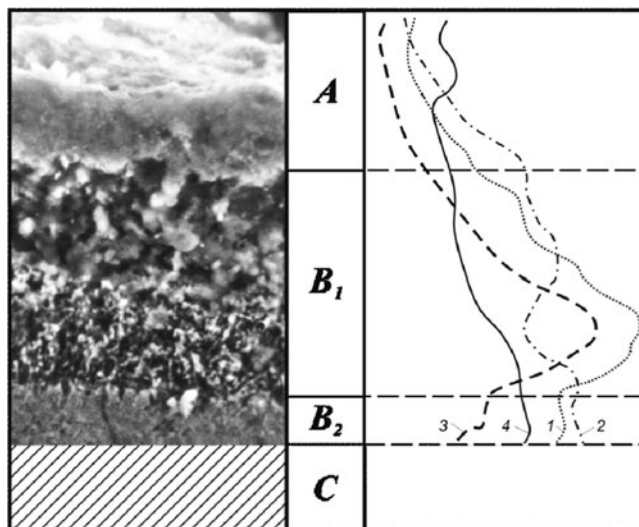


Fig. 28.5 Distribution of the basic elements of fusion substrate within the intermetallic-ceramic coating after thermal testing (200 h): *A* ceramic area; *B₁*, *B₂* diffusion areas; *C* substrate; 1, 2, 3, 4 distribution accordingly Co, Ni, W, Cr

coating, 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 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.

The earlier research carried out with the aim of studying the process of GTE combustors burner wear showed that the sulphur educed from the fuel has a high diffusive mobility in comparison with the gas oxygen [2]. It leads 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 the glowing chlorine sulphide ash also confirmed the efficiency of the offered protective coating. Figure 28.6 shows that as a result of testing in the aggressive environment, there was a substantial damage of the coatings observed, which entails a subsequent fast-moving destruction of the blades basic material.

It has been found that the IMCER coatings have 2–3 times higher heat resistance in the aggressive environment in comparison with the standard aluminized ones (Figs. 28.7 and 28.8).

The characteristics of microhardness distribution within the coating are represented in Fig. 28.9. A substantial microhardness decrease in the medium area of the coating can be obviously explained by the paramount content of nickel in it when compared to tungsten, cobalt and chrome.

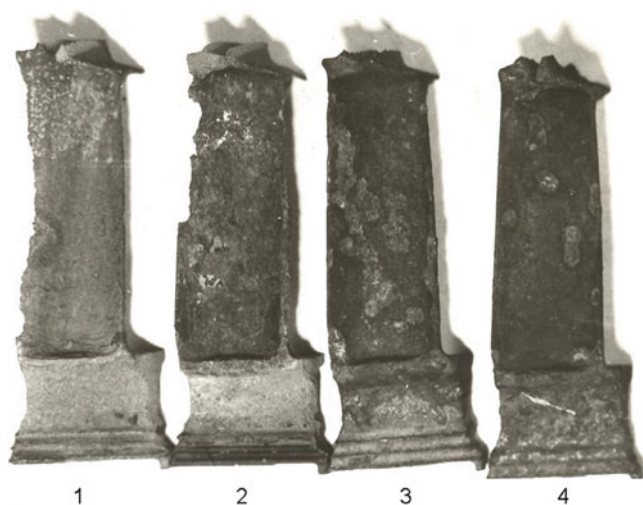


Fig. 28.6 Outward appearance of blades with the coatings after the thermal testing in the environment of glowing chlorine sulphide ash: 1 standard aluminizing; 2 standard aluminizing and annealing (900°C, 2 h); 3 zirconium aluminizing; 4 IMCER coating

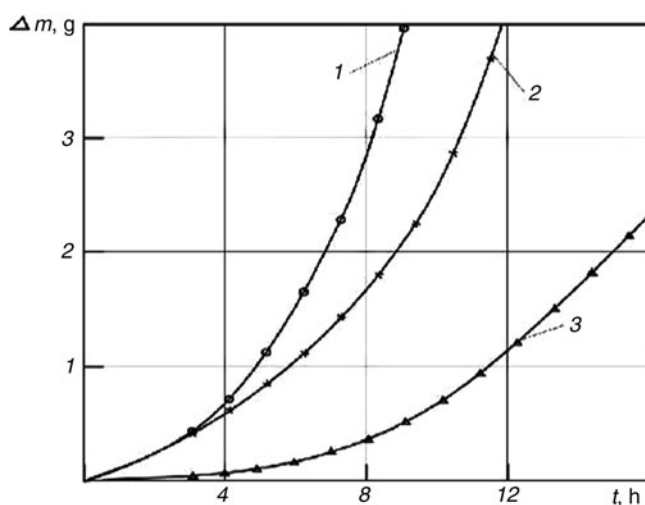


Fig. 28.7 Thermal testing results of the GTE turbine blades in artificial ash, 900°C – 18 h: 1 standard aluminizing; 2 standard aluminizing and annealing 900°C – 2 h; 3 intermetallic-ceramic coating and annealing in furnace: 900°C – 2 h

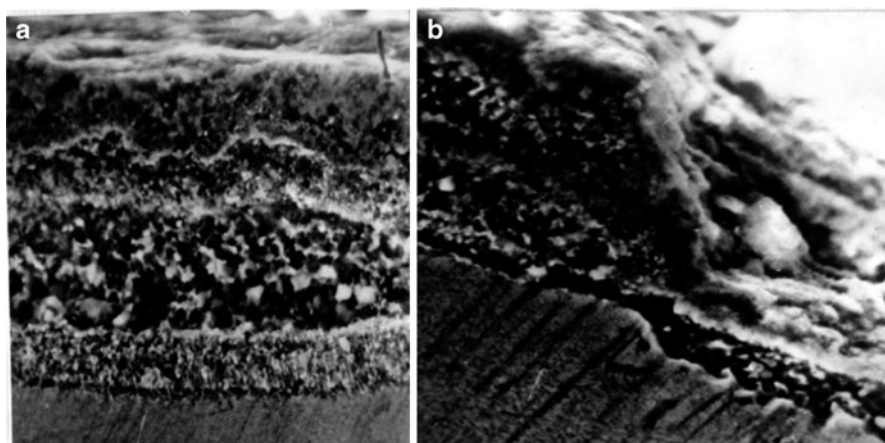


Fig. 28.8 Microstructure of the heat-resistant IMCER coating after the thermal testing in the environment of glowing chlorine sulphide ash: (a) without defect; (b) with defect

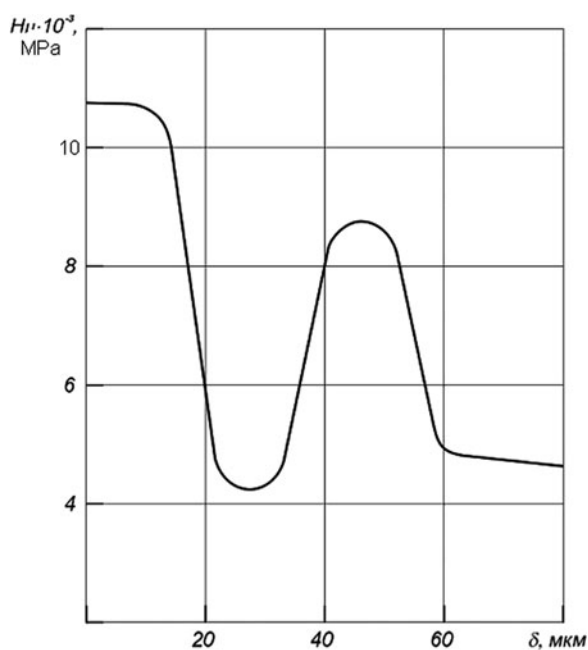


Fig. 28.9 Distribution of microhardness in the intermetallic-ceramic coating after gas corrosion testing in chlorine sulphide ash, 900°C – 18 h

28.4 Conclusion

The testing of various categories of products on heat resistance in the scorching chlorine sulphurous ash environment has also confirmed the effectiveness of the offered protective coating. IMCER coatings differ with 2–3 times higher heat resistance in comparison with aluminized ones.

The distinguishing features include:

1. the coating gives the opportunity of 2–3 times increasing the resource of products working under high temperatures and aggressive environments;
2. the possibility of obtaining the coating of various composition, structure, thickness taking into consideration acting temperatures;
3. high plasticity and heat resistance of the composition product material – coating;
4. simplicity, stability and availability of the coating sputtering technological process in conditions of serial production.



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