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Complex refurbishment of titanium turbine blades by applying heat-resistant coatings by direct metal deposition

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ABSTRACT

The paper presents a comprehensive approach to the refurbishment of titanium turbine blades by direct laser deposition. Coatings based on titanium carbide with the introduction of boron carbide and tungsten carbide particles for airfoil shroud platform and based on the commercially pure Ti with the addition of fine particles of aluminum oxide for the turbine airfoil are proposed.

It is shown that large refractory particles with a hardness of 1384 $HV_{0.1}$ ÷ 5108 $HV_{0.1}$ are crystallization centers and reinforcing particles, and melting fine particles form high-temperature phases of TiB and Ti_3Al in the coating metal with a hardness of 520 $HV_{0.1}$.

1. Introduction

The modern aircraft turbojet engine – is, as it is known, the heart of the aircraft, and with its help, it takes the air, but possible troubles for the engine start from the ground.

The turbojet engine consumes a lot of air during its operation. Until the aircraft did not get enough speed all the air is sucked into the engine from the surrounding environment and, along with it, the objects, that somehow find themselves in critical proximity near the air intake, can also get into the engine duct.

In the case of unfavorable conditions, this will lead at least to considerable financial losses – this is the removal and subsequent refurbishment of the engine at the manufacturing plant or repair enterprise.

Blades are the main elements exposed to wear and, in particular, the blade foot and butt end of the blade airfoil. The refurbishment of blades made of different materials has peculiarities [1–7], related to the materials application uniformity, blade metal protection, material choice and etc. For example, the refurbishment of the titanium alloys blades by laser cladding methods has some features related to the cladding zone protection from oxidation [8–9].

In some cases, the laser deposition technology of wear-resistant coatings is accompanied by the addition of a small number of particles based on heat-resistant alloys into materials with a prevailing particle quantity with significantly lower melting point to increase the heat resistance [10–15].

The efficiency of critical parts of aerospace engines increases with increasing the operating temperatures. A higher temperature level can be achieved by creating new heat-resistant alloys operating at higher temperatures.

The most optimal in this regard is titanium aluminide. High melting point, low density, high elasticity modulus, increase in yield strength with increasing the temperature, resistance to oxidation and ignition, high strength/density ratio, heat resistance – all this creates favorable conditions for the application of this material as a constructive one for a new generation of aerospace engines.

Concurrently, borides and other refractory boron compounds are increasingly used in industry and engineering. The high heat resistance of some borides makes them promising components for high-temperature alloys, especially composite materials reinforced

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Table 1
Chemical composition of the titanium alloy VT8, %.

Alloy blades	Ti	Al	Mo	Si	Fe	C	N	Zr	O	H
VT8	Осн.	6,5	3,3	0,2	0,2	0,1	0.05	0.5	0.1	0.01

with boride fibers or dispersion-strengthened borides. In this case, borides increase hardness and, as a consequence, the wear resistance of coatings is increased [16,17].

The creation of wear-resistant and heat-resistant coatings on the butt end of the blade airfoil is an urgent task, at that the issue of reducing the engine weight or at least maintaining the weight when applying a solid heat-resistant coating is equally significant.

The use of inexpensive materials based on titanium carbide with the addition of small portions of solid heat-resistant metal particles will allow finding solutions for the development of new heat-resistant coatings for blade shroud platform. In this paper, we propose a comprehensive approach for solving the problem of refurbishing worn turbine blades which affects the most important engine-building problems, such as the refurbishment of the blade foot and the missing elements of the blade airfoil.

2. Materials and methods

For the research, we selected the blade of the compressor's 5th stage of gas turbine engine made of a titanium alloy VT8. Table 1 presents the chemical composition of the blade material.

The most characteristic sections exposed to considerable wear and requiring the refurbishment were cut from the blade for the study (Fig. 1a, b). The CT scanner XViewTM series model H5000 was applied to detect pores and cracks in the received samples due to the fact that most of the blades can have hidden defects (Fig. 1b).

The bimodal structure of the VT8 alloy is represented by the primary α-phase and the β-transformed matrix (Fig. 1). The size of α-grains is 3–6 μm.

The blades were refurbished using a laser cladding plant, which includes an IPG Photonics fiber laser with a power of up to 10 kW, with a radiation wavelength of 1064 nm. Powder material of a titanium alloy was supplied through the coaxial nozzle into the cladding zone.

We used the TiC powder with a particle size of 20–100 μm (50 μm – 70%) with the addition of the WC part with a particle size of 50–150 μm and the BC with a particle size of 50–150 as the basis for the laser cladding of the shroud platform, and powders of commercially pure Ti with a particle size 20–50 and Al_2O_3 with a particle size ≈1 μm for refurbishment of the blade airfoil. Fig. 2 shows the powder particles.

The cladding process was carried out using a constant (Fig. 3a), and a pulse (Fig. 3b) laser operation modes. The mixing of the powders was carried out in a tabletop machine Turbula Model T2F shaker.

After the blades refurbishment by laser cladding method, they were cut, and microsections were prepared for metallographic analysis.

Samples were filled with epoxy resin successively ground with a set of diamond grinding discs (120 grit, 220 grit, 500 grit) and polished using diamond suspensions (9 μm, 3 μm). Macro- and microstructure of the metal was identified by chemical etching in a prepared reagent HF – 15 cm^3, HNO_3–35 cm^3, H_2O – 200 cm^3, glycerin – 100 cm^3.

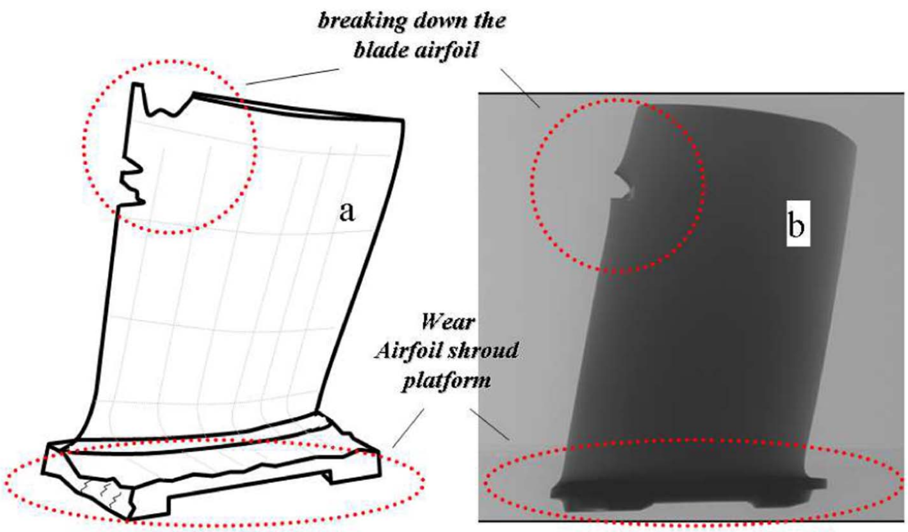

Fig. 1. The appearance of damaged blades a – schematic representation, b – image obtained using an X-ray tomography.