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THERMAL RESISTANT COATING OBTAINED FROM ZIRCONIUM AND ALUMINUM OXIDES BY DETONATION METHOD

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The aim of this work was to study coatings deposited by the detonation method on the surface of stainless steel 12X18H10T. CCDS detonation complex, Xpert Pro X-ray analysis (U = 40 kV, I = 30 mA CuKα), Phenom ProX scanning electron microscope (SEM) and DuraScan-20 microstructure detection methods were used. The surface of the steel was covered by Al_2O_3 and ZrO_2 powders in 500 and 1100 μm thick. The thickness of the coating was measured and the elemental analysis was performed. Based on literary reviews and research, it was found that the covering of the metal with different coatings increases the physico-mechanical and tribological properties.

INTRODUCTION

For reinforcing products and improving the physico-mechanical properties of metals and alloys, protective coatings with high physico-mechanical and chemical parameters are used: hardness, resistance to aggressive environment and wear, low thermal and electrical conductivity, and so on. This can substantially increase the resource and reliability of the structural components. The CCDS detonation complex equipped with high-speed valves enables gas supply (oxidizer, fuel, cleansing gas) and accurate and constant dosing and acceleration of particles of impact powders. Currently, the surface of the working blades of gas turbine engines (GTE) is exposed to corrosion by high temperatures due to aggressive external environment, intense heat and mechanical stress [1–4]. At the same time, the need to increase the efficiency of different types of GTE requires the increase of temperature of the nickel-based heat-resistant alloys, limited to the melting temperature. The most effective means of protecting the working blades of GTE is heat-resistant coatings, as their application can significantly reduce the operating temperature of the mill (100 °C or more) or increase the working gas temperature before turbine [5]. In recent years, new materials for ceramic coating (CC), capable of replacing ZrO_2-8% Y_2O_3 (YSZ) system, are under consideration. It should be noted that in order to achieve the best performance of the TRC system it is necessary to look for new components for heat-resistant coatings [6, 7]. Therefore, the aim of this study was to obtain heat-resistant coating based on zirconium and aluminum oxides by the detonation method.

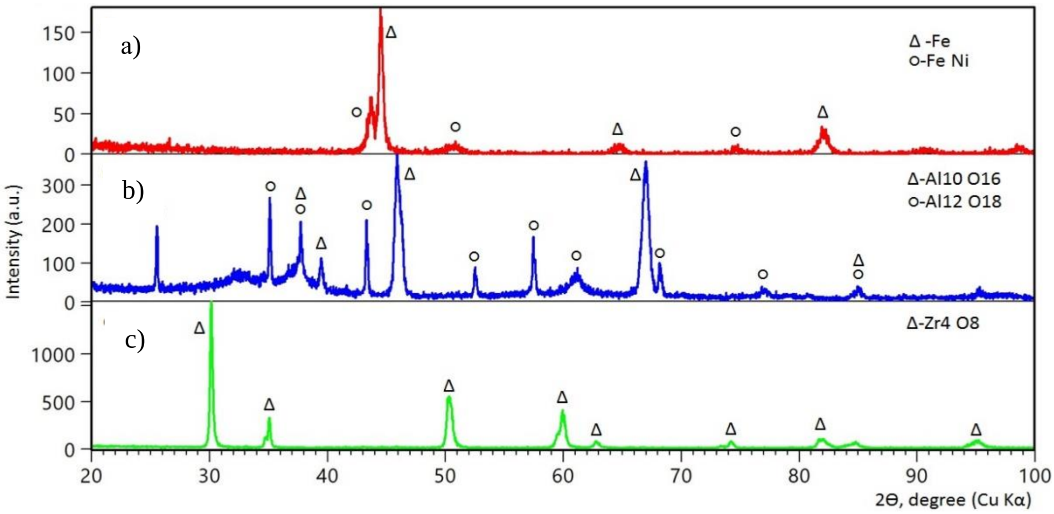
EXPERIMENTAL

12X18H10T stainless steel was used as a research material, and the surface was covered by a detonation method. The main element of 12X18H10T alloy is iron (Fe). In addition, it contains Cr – 17–19%, Ni – 9–11%, Ti – 0.8%, Si – less than 0.8%, S – less than 0.02%, Mn– less than 2%, Cu – 0.03%, P – 0.035% and C – less than 0.12%. Stainless steel is widely used in cryogenic technology (up to −269 °C) and for steam, heat exchangers, high pressure pipes and steam boilers up to + 600 °C. CCDS detonation complex, Xpert Pro X-ray analysis (U = 40 kV, I = 30 mA CuKα), Phenom ProX scanning electron microscope (SEM) and DuraScan-20 were used determine the structure and microhardness of the studied material.

Figure 1, a shows that 12X18N10T stainless steel consists of γ-Fe and (FeNi) tetragonal lattice, and coatings of Al_2O_3 (500 μm) and ZrO_2 (500 μm) form hexagonal and tetragonal lattice (Figure 1, b, c).

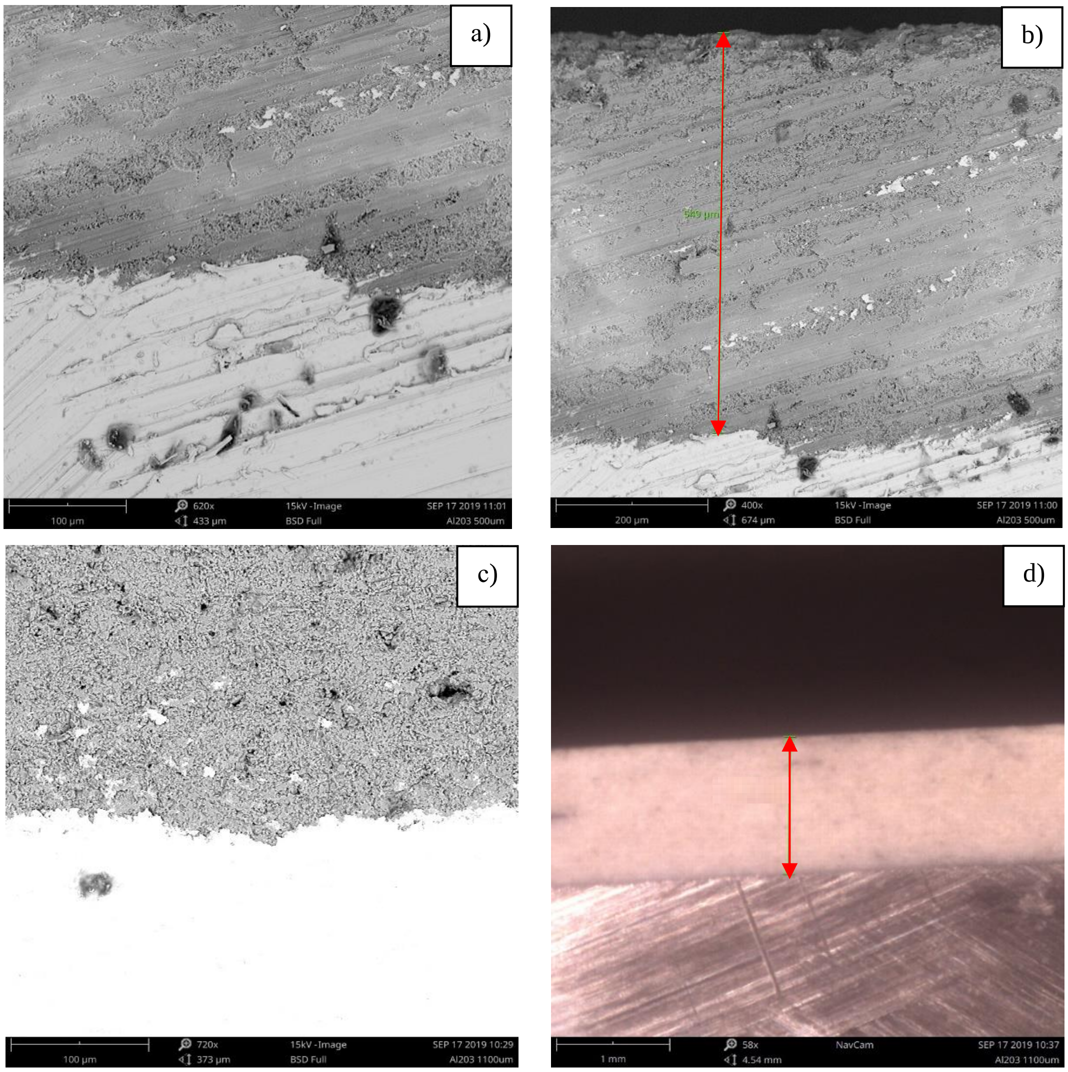
YSZ coating has a number of properties, under the influence of which is currently the best heat-resistant ceramic coating. Also, YSZ coating has a relatively high temperature coefficient of linear expansion ($11 \cdot 10^{-6}$ K^{-1}), as the result of the thermal expansion of the ceramic coating and metal rod, which helps to reduce surface tension. In order to avoid damaging ceramics causing an increase in the thermal conductivity coefficient, the maximum operating temperature of the surface of the coating should not exceed 1200 °C for a long time [8]. To achieve heat protection, ceramic layer of ~150 μm should be applied at 100 °C, resulting in the increased weight characteristics of the turboprop engine (TPE) working blades (~1 kg per square meter). With the help of TRC it is possible to reduce the mass of the blades and increase the gas-air passage of the engine along the turbine section. This can only be achieved by reducing the thickness of the surface layer and reducing the thermal conductivity of the ceramic layer [9, 10].

Selected Al_2O_3 and ZrO_2 powders were coated by the detonation method onto the surface of 12X18H10T steel, with a thickness of 500 μm and 1100 μm of powder (Figure 2). In addition, the elemental analysis of the main metal and the coating has been made in the lateral structure. From figure 2, the metal and coatings can be traced to one another and the homogeneity of the coating structure can be observed, and there is a small number of cavities. 12X18H10T + Al_2O_3 (500 μm) and 12X18H10T + ZrO_2 (500 μm) samples were heated in SUOL-0,4,4-12 oven at 900 ºC, 1000 ºC and 1100 ºC (1 hour) in vacuum.



(a) – 12X18H10T steel; (b) – Al_2O_3 (500 µm) coating; (c) – ZrO_2 (500 µm) coating

Figure 1 – X-ray-phase analysis results



(a), (b) – Al_2O_3 (500 µm); (c) – Al_2O_3 (1100 µm); (d) – cross section of coating

Figure 2 – Microstructure of the studied coating based on Al_2O_3

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	70.73	57.58
13	Al	Aluminium	28.97	39.77

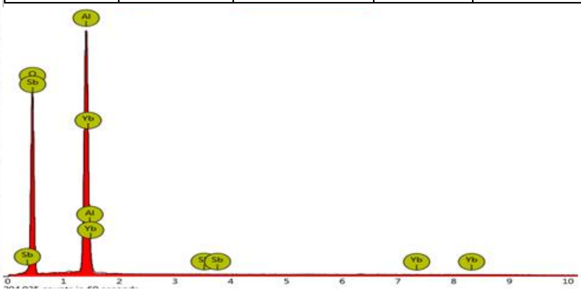
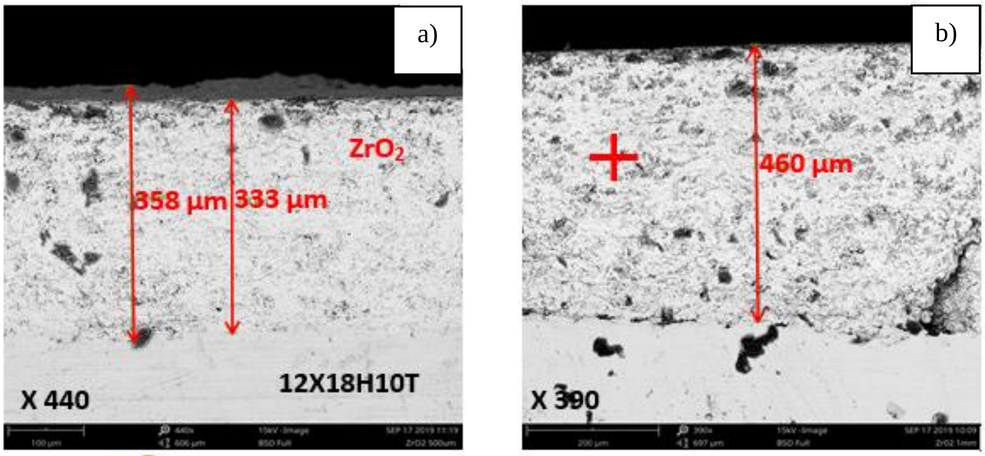
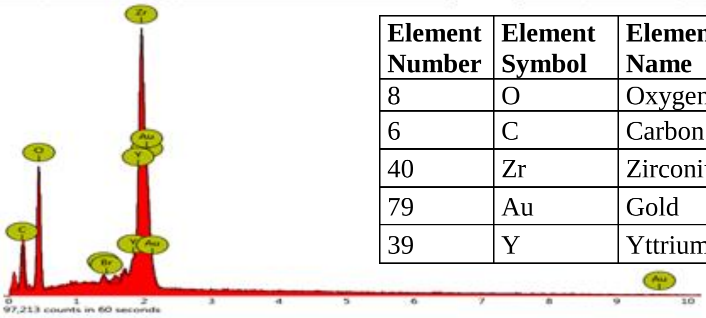


Figure 3 – The results of element analysis of coating





Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	41.15	16.23
6	C	Carbon	37.50	11.11
40	Zr	Zirconium	10.39	23.38
79	Au	Gold	9.52	46.21
39	Y	Yttrium	1.07	2.35

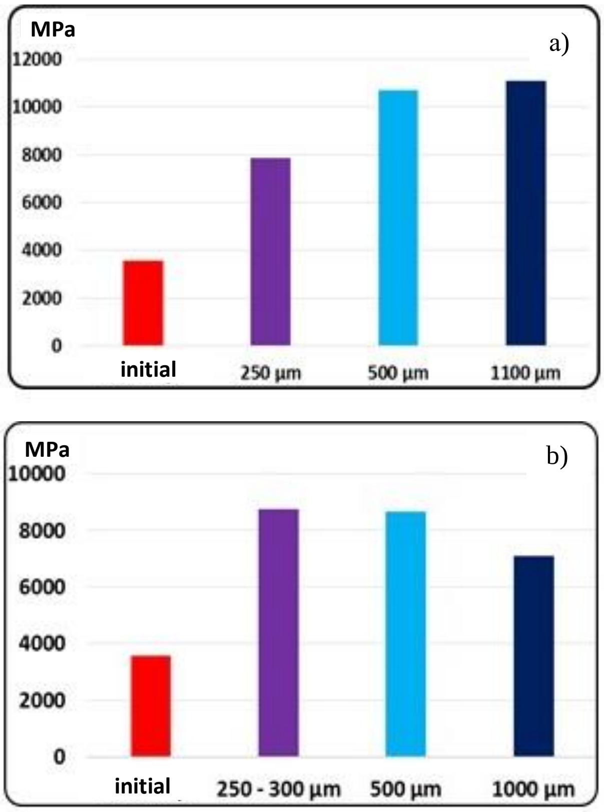
(a) – ZrO_2 (500 μm); (b) – ZrO_2 (1 mm)

Figure 4 – Microstructure and elemental analysis of the sample

The sample was cooled for 30 minutes in a vacuum, the main metal and coating was divided into two parts, because of the fact that the thermal expansion coefficient of coating with steel is different.

Figure 4 shows that 12X18H10T surfaces were coated with ZrO_2 powder for up to 500 μm and 1 mm thick. Cross section electron microscopy of the sample revealed the boundary of contact with the main metal surface, the thickness was measured from the slab coating and elemental analysis was performed from the burned part (Figure 3).

Figure 5, a shows that the initial microhardness of 12X18H10T steel was 3580 MPa. After coating with Al_2O_3 powder it was 7860 MPa, at 500 μm – 10700 MPa and at 11080 MPa – 1100 μm, i.e. 3 times more than the initial steel. As the thickness of the coating increases, it increases with microhardness. In Figure 5, b it seems like coating with ZrO_2 powder increases the microhardness up to 8750 MPa at 250 μm, up to 8650 MPa at 500 μm, and up to 7100 MPa at 1000 μm, i.e. 2 times more than the original state of steel. Here, as the thickness of the coating increases, the microhardness decreases slightly.



(a) – 12X18H10T+Al_2O_3; (b) – 12X18H10T+ZrO_2

Figure 5 – Changes in the microhardness of the coating

By comparing the two types of coatings, it can be noted that the microhardness does not change significantly depending on the thickness of ZrO_2 powder coating because ZrO_2 belongs to the rare metal type, and it can be used for alloying or as a coating to achieve the highest quality.

CONCLUSION

Finally, using the detonation method, the coating of 12X18H10T steel surfaces with Al_2O_3 and ZrO_2 significantly increased the mechanical properties, while coating thickness increased from 250 to 1100 μm for Al_2O_3 coating increased by 3 times accordingly. When the coating thickness of ZrO_2 coating is increased from 250 to 1000 μm, the microhardness did not change significantly due to the thickness of the coating layer, the reason is that the rare metal powder has a positive effect on the microhardness. Therefore, based on these results, it is assumed that two of the above powders will be mixed together in a different layered coating.

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ДЕТОНАЦИЯЛЫҚ ӘДІСПЕН ЦИРКОНИЙ ОКСИДІ ЖӘНЕ АЛЮМИНИЙ ОКСИДІ НЕГІЗІНДЕ ЖЫЛУДАН ҚОРҒАҒЫШ ЖАБЫН АЛУ

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Бұл мақалада осындай материалдардың бірі ретінде 12Х18Н10Т тотбаспайтын болаты таңдалып және оның бетіне детонациялық әдіспен жағылған жабынды зерттеу негізгі мақсат етілді. CCDS детонациялық жабындау кешені, Xpert PRO рентген-фазалық талдау (U = 40 kv, I = 30 mA CuKα), Phenom ProX сканерлеуші электрондық микроскобы (SEM) және DuraScan-20 микроқаттылығы анықтау әдістері қолданылды. Болаттың бетіне детонациялық әдіспен, 500 µm және 1100 µm қалыңдықта Al_2O_3 және ZrO_2 жабыны алынды. Жабынның қалыңдығы өлшеніп, элементтік талдау жүргізді. Әдеби шолулар мен зерттеулер негізінде металдың түрлі жабындармен қапталуы физико-механикалық және трибологиялық қасиеттерін арттыратыны анықталды.

ПОЛУЧЕНИЕ ТЕПЛОЗАЩИТНОГО ПОКРЫТИЯ НА ОСНОВЕ ОКСИДА ЦИРКОНИЯ И ОКСИДА АЛЮМИНИЯ ДЕТОНАЦИОННЫМ МЕТОДОМ

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Целю данной работы являлось исследование покрытий, нанесенных детонационным методом на поверхность нержавеющей стали 12Х18Н10Т. Для нанесения детонационных покрытий использовался комплекс CCDS, а для определения структуры и микротвердости покрытия – установка рентгеноструктурного анализа Xpert PRO (U = 40 кВ, I = 30 мА CuKα), сканирующий электронный микроскоп (SEM) Phenom ProX и микротвердомер DuraScan-20. На поверхности стали детонационным методом было получено покрытие Al_2O_3 и ZrO_2, толщиной 500 мкм и 1100 мкм. Измерялась толщина покрытия и проводился элементный анализ. На основании литературных обзоров и исследований было установлено, что нанесение различных покрытий на металлы повышает их физико-механические и трибологические свойства.