Functional plasma sprayed coatings on magnesium ceramic substrates.

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Abstract. The possibility of improving the quality of the titanium articles using ceramic molds with improved surface layer. The improvement is achieved by reducing a porosity of by plasma sprayed Al2O3.

1. Introduction

In the aviation and marine industries widely used products from titanium alloys. These products meet high requirements on quality and reliability, so the improvement of technologies for their production is an urgent task.

For the manufacture of titanium alloy parts using molds. They can be made of various materials such as graphite or ceramic-based MgO. Graphite dust that is formed during the manufacture and operation by graphite forms causes irreparable damage to human health, it is one of the most dangerous by the degree of its impact on the respiratory organs and provokes a many diseases. An alternative to graphite casting forms are ceramic molds, based on MgO, however, such molds have a porous surface, which contributes to preservation a residual gas on stage of evacuating.

| Element | Weight % | Atomic % |
|---------|----------|----------|
| C K     | 20.28    | 36.28    |
| O K     | 28.83    | 38.73    |
| Na K    | 0.53     | 0.49     |
| Mg K    | 1.77     | 1.56     |
| Al K    | 1.83     | 1.46     |
| Si K    | 1.19     | 0.91     |
| Cl K    | 0.35     | 0.21     |
| K K     | 0.29     | 0.16     |
| Ca K    | 0.34     | 0.18     |
| Ti K    | 44.60    | 20.01    |

Figure 1. The spectra of the surface of titanium samples manufactured in ceramic forms.
2. Analysis
As shown at the spectral analysis of composition of the surface layer of a casting (Figure 1), an amount titanium and oxygen atoms in the layer approximately rated as 1:2. It is formed on the surface the layer, composed mainly of TiO$_2$ with high values of hardness and microhardness, which leads to disruption of strength characteristics of products. One of reducing methods of penetrating gases during casting processes is an application of plasma coatings [1-12] on molds (Figure 2).

3. Experiment and results
Series of experiments of Al$_2$O$_3$ deposition was carried out. Spraying was performed by arc plasma torch. The sprayed layer has formed a thermal barrier coating. The melting temperature of Al$_2$O$_3$ is 2345 K, and the dissociation temperature about 4000 K, which is significantly higher than the melting temperature of the titanium. Sputtering was carried out using natural gas, and as a result, particles of Al$_2$O$_3$ reached the surface of the casting mold in a molten state. The composition of the casting, produced in a ceramic mold with Al$_2$O$_3$-coating, was investigated by X-ray spectral analysis, which showed decreased number of oxygen atoms and other impurities in the casting surface. The content data of TiO$_2$ are consistent with the values of hardness and microhardness, which allowed carrying out a comparative analysis of the properties of titanium casting for selected sections.

The experiments were performed on ceramic samples, which are constituent elements of complex casting molds. They were exposed at temperature 600 K within an hour, and then cooled off 2-3 degrees per minute speed, to ambient temperature under the conditions excluding H$_2$O ingress of the environment. At first the sample was exposed in a plasma flow for processing after which immediately was produced spraying. Upon receipt of casting the camera volume was pre-evacuated to a pressure of 1-2 Pa, then filled with technically pure argon.

Figure 3 shows a comparative analysis results of changes in the relative hardness of castings produced in the same conditions in magnesite forms, curve 1 - with Al$_2$O$_3$ coating and curve 2 - without, where R - section radius, r - distance from the casting center, Hs - surface hardness, H - material hardness. In the region I, closer to the center of a sample, values of the curve - 2 lies below than values of the curve - 1, that indicating higher value Hsu of castings made in a traditional way. In region II is seen
decreased value of the curve 1 due to the lower content of TiO$_2$. In both cases, content of TiO$_2$ in the surface layers increased, so the area III is characterized by a sharp increase of the relative hardness.

Figure 3. The results of the comparative analysis of changes in the relative hardness of the castings.

4. Conclusion
The proposed method of plasma spraying to magnesite forms can improve the strength properties of titanium articles by reducing of TiO$_2$ content in the casting volume. It is also possible to reduce the wear of the cutting and milling instruments on stage of preparation of the titanium articles.

References
[1] Fayrushin I, Kashapov N and Dautov I 2014 J. Phys.: Conf. Ser. 567 012009
[2] Kashapov L N, Kashapov N F and Kashapov R N 2013 J. Phys.: Conf. Ser. 479 012011
[3] Kashapov L N, Kashapov N F and Kashapov R N 2014 J. Phys.: Conf. Ser. 567 012025
[4] Zaripov R G, Kashapov N F, Tkachenko L A and Shaydullin L R 2016 J. Phys.: Conf. Ser. 669 012053
[5] Denisov D G, Kashapov N F and Kashapov R N 2015 IOP Conference Series: Materials Science and Engineering 86 012005
[6] Gavrilova V A, Kashapov N F and Kashapov R N 2011 Biomedical Engineering 45 198–200
[7] Saifutdinov A I, Fairushin I I and Kashapov N F 2016 JETP Lett. 104 180–185
[8] Galyautdinov R T and Kashapov N F 2003 Svarochnoe Proizvodstvo (3) 27–31
[9] Azarov A I, Kashapov N F and Osipova O P 2003 Liteinnoe Proizvodstvo (11) 30–31
[10] Abdullin I Sh, Galyautdinov R T and Kashapov N F 2001 Inzhenerno-Fizicheskii Zhurnal 74 104–107
[11] Luchkin A G, Kashapov N F and Luchkin G S 2013 J. Phys.: Conf. Series 479 012019
[12] Kornienko E E, Lapushkina E J, Kuzmin, V I, Vaschenko S P, Gulyaev I P, Kartaev E V, Sergachev D S, Kashapov N, Sharifullin S, Fayrushin I 2014 Journal of Physics: Conf. Series 567 012010