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RESEARCH OF CORROSION RATE OF ADDITIVE ALLOY VT20

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ABSTRACT

An important problem in the additive manufacturing of high-tech industry parts is the provision of performance properties, which can be attributed to corrosion resistance. Additive technologies have a number of features that set a mark on the performance of these properties. The formation of alloy layers from different thickness technological layers of the powder, due to the different fractional composition of the latter can lead to a decrease in performance.

The aim of this work was to investigate the corrosion behavior of additives from domestic powders of VT20 alloy, which had non-spherical shape of particles, fused by additive technology.

Corrosion rate in 20% aqueous hydrochloric acid was investigated and electrochemical studies were performed. The highest corrosion rate was established in the fusion zones of the VT20 and VT1-0 alloys, which exceeds the corrosion rate of the zones of the VT20 alloy powder deposited and the deformed VT1-0 titanium. Corrosive damage to the surface of different areas of the sample was selective. Potentiodynamic polarization curves are typical of passivation-prone alloys for all zones of the sample obtained by additive technology.

KEY WORDS: *additive technologies, powders, corrosion rare, corrosion behavior, fractional composition.*

INTRODUCTION

Production of competitive machines is connected with the development of new materials and the enhancement of their properties. This can be achieved by improving production technologies. The same material with the same chemical composition but obtained by different technologies has differences in structure and properties.

The need to introduce resource-saving methods of production has led to the emergence of 3D printing technologies with metallic powders (additive technologies). Additive technologies (AT) have occupied a special place in the industry and now can be classified in a separate category of formation. Every year their market penetration is rising more and more and as a result replacing classic technologies of components' manufacturing. This is driven be the possibility of obtaining a finishing surface with the necessary tolerances for one cycle of cultivation. The main raw material in such technologies is powder.

Equally important in the additive manufacturing of high-tech industry components is the maintaining of performance properties, which can be attributed to corrosion resistance. Additive technologies have a number of features that set a mark on the performance of these properties. The formation of alloy layers from different thickness of powder technological layers, due to the different fractional composition of the latter can lead to a decrease in performance. Powders are the main drivers of the properties of the final products. Nowadays, the corrosion behavior of alloys obtained by additive technologies is poorly learnt.

The aim of this study was to investigate the corrosion behavior of samples fused by additive technology from domestic powders of VT20 alloy, which had non-spherical particle shape.

MATERIALS AND METHODS

For this purpose, samples were obtained on the equipment, with the implementation of AT by electron beam fusion of VT20 alloy powders onto a substrate of VT1-0 alloy. To obtain samples of additive surfacing used titanium alloy powders obtained by prospective HDH technology of domestic production [1]. HDH process was performed on sintered billets of alloy VT20. The chemical compositions of the powder were within the requirements of GOST 19807-91. The fractional composition of the used powder was in the range -150 + 100 µm. Technological characteristics: Fluidity (∅ 5mm) 11.7 sec., Density 1.8 g/cm^3. The surfacing works were carried out in the conditions of the Institute of Electric Welding named after. E.O. Paton on the installation of electron beam welding [2]. Metallographic studies were performed on an optical microscope of reflected light "Neophot 32". Surfaces for research were made from the middle part of the sample by sequential grinding.

Corrosion tests were performed in a 20% aqueous solution of HCl acid. The corrosion rate of the different zones of the alloy obtained by additive technology was calculated by gravimetric method by changing the weight of the samples (GOST 9.908-85) after exposure in an aggressive environment (504 h) under free access of air and room temperature.

RESULTS AND DISCUSSION

Figure 1 *a, b* shows the scheme of sample separation by characteristic zones. Metallographic changes in the structure in different zones were established. This can be the result of redistribution of the alloying elements in the VT20-VT1-0 fusion zones.

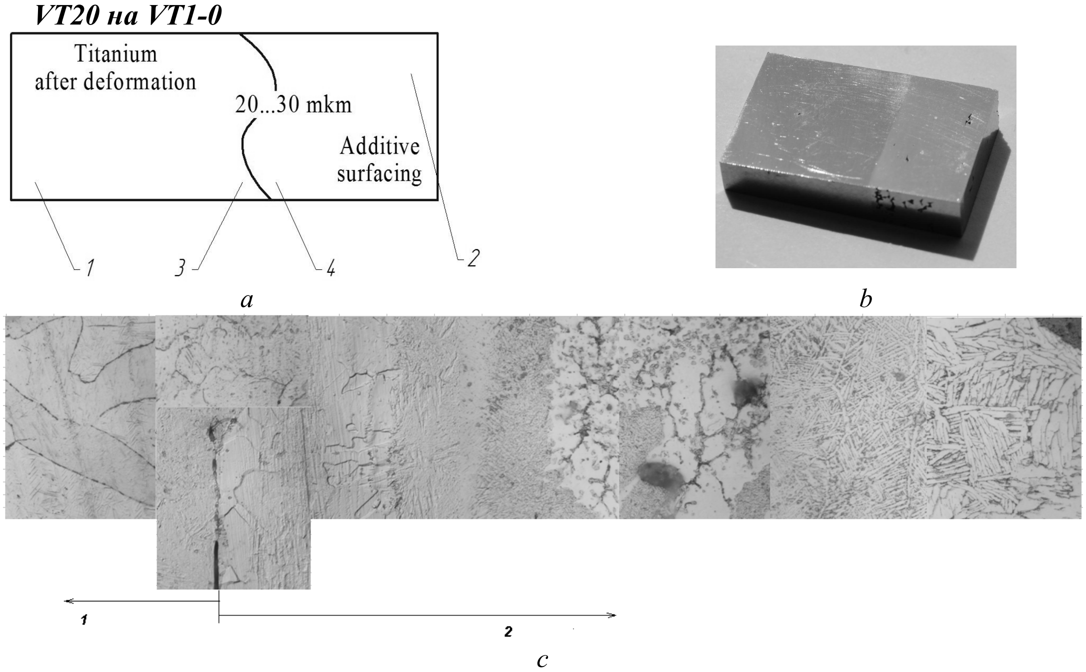


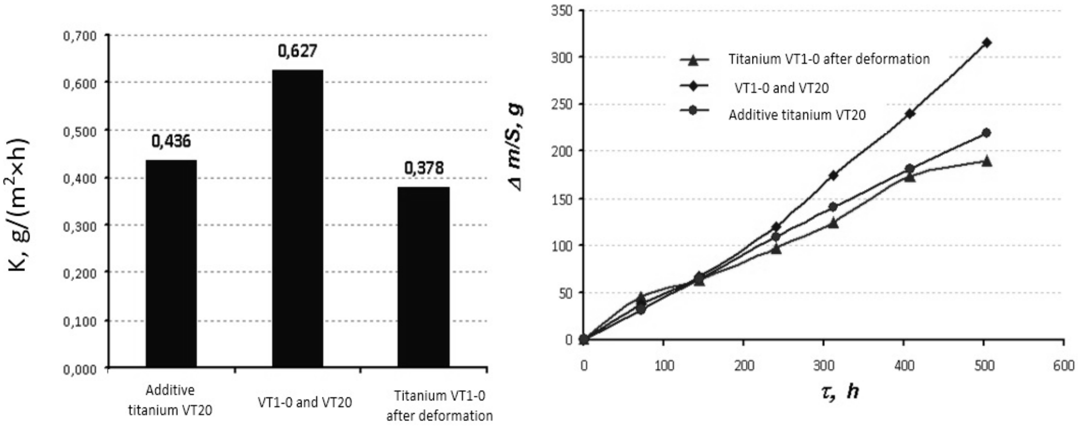
Fig. 1. Structure of alloy powder-like VT20 - VT1-0 is deformed, got on additive technology. *a*) layout of zones chart; *b*) general view; *c*) structure.

The corrosion rate of the different zones of the sample obtained by additive technology is shown on the Fig. 2, *a*. The highest corrosion rate (0.627 g/(m^2 × h) is common to the alloy zone, which is 1.4 and 1.7 times higher than the corrosion rate of the zones of the deposited VT20 alloy powder (zone 2 in the scheme of Fig. 1 *a*) and deformed titanium VT1-0 (zone 1 in the scheme of Fig. 1, *a*), respectively, which is obviously related to the structural heterogeneity of the fused zone, the presence of non-fusion areas at the junction of the deposited powder and deformed materials (Fig. 3, *c*).

Corrosive damage to the surface of different zones of the alloy surfaced from VT20 powder - deformed VT1-0 are selective (Fig. 3), which is related both to the structural features of the composite alloy components and to the technology of its production.

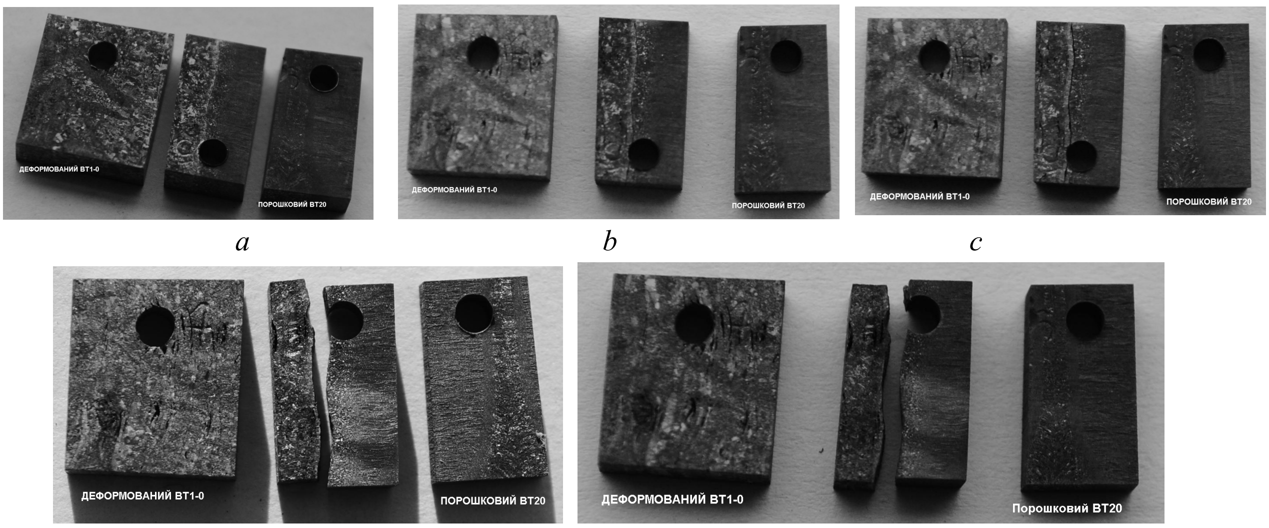
With the prolongation of the residence time of the alloy in the aggressive environment, corrosion begins to intensify at the junction of the deposited powder and deformed material (Fig. 3 *b*, *c*), both due to the nature of this zone and due to its imperfection (Fig. 3 *c*), which after 312 hours of exposure leads to a complete stratification of the fused zone (Fig. 3, *d, e*).

Electrochemical studies were performed using the potentiostat of IPC-pro in the potentiodynamic mode. Corrosion potential and streams were determined graphically by Tafel extrapolation.



a *b*

Fig. 2. Speed of corrosion on 504 h to the base (*a*) and kinetics of corrosive dissolution (*b*) of different zones of alloy powder-like VT20 - VT1-0 is deformed, got on additive technology.



a *b* *c*

d *e*

Fig. 3. Surface of different zones of alloy additive from powder of VT20 - VT1-0 is deformed, got on additive technology, after self-control in 20%- water solution of chlorous acid.
a) – 72 h; *b*) – 240 h; *c*) – 312 h; *e*) – 408 h; *d*) - 504 h.

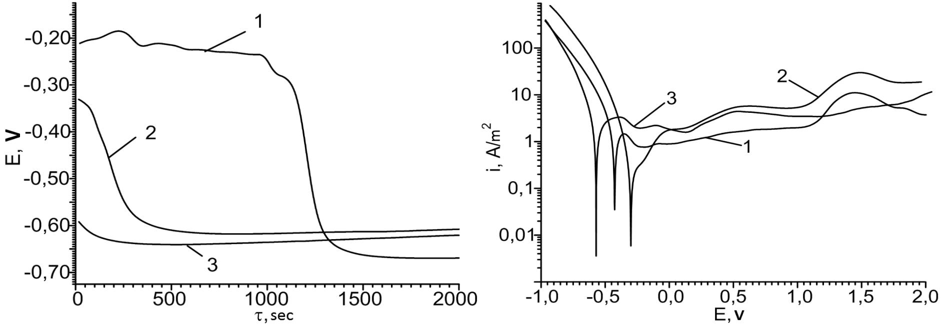
Potentiodynamic polarization curves are typical for passivation-prone alloys for all zones of VT20 alloys obtained by additive technologies (Fig. 4 *b*).

Two passive sections are observed on the anode branch of the polarization curve taken from the area of the deposited VT20 powder (Fig. 4 *b*, curve 1). In the potential range -0.088 ... 0.024 V, the first passive region is observed, the passivation stream is 0.88 A/m^2. At potentials 0.67 ... 1.03 V, the second passive region is observed, the passivation stream is 1.92 A/m^2. Corrosion stream 1,49 A/m^2, corrosion potential -0,430 V.

The anode branch of the polarization curve, taken from the deformed titanium VT1-0 zone (Fig. 4 *b*, curve 2), shows a significant slowdown of the anodic dissolution process: the corrosion stream decreases by an order of magnitude relative to the powder sintered VT20 zone (Table 1). The corrosion potential (-0279 V) is refined (Table 1). On the anode branch of the polarization curve, two waves of anodic dissolution are clearly expressed and there are regions of the passive state at potentials of -0.022 ... 0.11 V and 0.52 ... 1.05 V with a passivation stream of 1.82 A/m^2 and 5.48 A/m^2 respectively. The stepwise growth of the anode stream obviously reveals changes in the mechanisms of anodic reactions upon polarization.

The anode branch of the polarization curve, taken from the fused zone (Fig. 4 *b*, curve 3), begins with active dissolution, the current increases to the maximum critical current of passivity

(3.27 A/m^2) at the potential of onset of passivation -0.39 V with subsequent slow decline to smaller values, remaining constant in the range of -0.26 ... -0.093 V. Stream density in the passive state is 1.98 A / m2. The second wave of titanium anode dissolution is observed at potentials of 0.13… 0.52 V and secondary current stabilization (3.87 A/m^2) occurs in the potential range from 0.52 to 1.25 V. For the fused zone, the corrosion current increases (to 1.57 A/m^2, Table 1) compared to other zones of additively obtained alloy, and the corrosion potential takes the most negative value (-0.56 V, Table 1), which indicates the lowest corrosion-electrochemical characteristics of this zone of the alloy.



a *b*

Fig. 4. Kinetics of electrode potential (*b*) and polarization curves of different zones of alloy powder-like VT20 - VT1-0 is deformed, got on additive technology, in 20%-ому water solution of chlorou acid :
1 - powder-like VT20; 2 - VT1-0 is deformed; 3 is the alloyed zone.

The low electrochemical characteristics of the welded zone of VT20 powder, and especially of the fused zone of the additively obtained alloy, are largely due to their structural heterogeneity, including in the place of fusion of the substrate and powder metals (Fig. 1), which contributes to the activation of anode processes.

Table 1. Parameters of corrosion of different zones of standard powder-like VT20 - VT1-0 is deformed, got on additive technology

Material	$E_{cor.}$, mV	$I_{cor.}$, A/m^2
Powder VT20	- 0,430	1,49
Deformed VT1-0	- 0,279	0,202
VT1-0 – VT20	- 0,560	1,57

CONCLUSIONS

1. Speed of corrosion is investigational in 20%- water solution of chlorou acid and undertaken electrochemical studies.
2. It is set that the greatest speed of corrosion (0,627 gs/(of m^2×h) has zone of alloy of alloys of VT20 and VT1-0, that in 1,4 and 1,7 times exceeds speed of corrosion of zones of additive powder of alloy of VT20 and deformed titan of VT1-0 accordingly.
3. The corrosive defeats of surface of different zones to the standard carry selective character.
4. For all zones of the standard got after additive technologies, polarization curves are typical for alloys apt to passive state. For additively deposited VT20, two passivation regions are observed at -0.088 ... 0.024 V with flow 0.88 A/m^2 and at 0.67 ... 1.03 V with flow 1.92 A/m^2. Corrosion flow is 1.49 A/m2, which is 7 times higher than that of deformed VT1-0, and the corrosion potential is 0.430 V, which is 1.5 times higher than that of deformed VT1-0. In the fusion zone, the corrosion characteristics are slightly higher than in the zone of additive VT20. This can be explained by the redistribution of alloying elements.

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