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A STUDY OF THE EFFECTS OF PLASMA GAS NITRIDING PROCESS UPON THE CORROSION RESISTANCE OF TITANIUM ALLOYS

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Key words*: titanium alloys, plasma gas nitriding process, corrosion resistance*
Abstract: *The article submits results obtained from research into the effects of plasma gas nitriding process upon the corrosion resistance of titanium alloys Ti-8Al-1Mo-1V and Ti-6Al-4V. The analysis of these results will give a clear idea about the ability of these alloys to resist corrosive impacts of aggressive media at different temperatures.*

Corrosion resistance is one of the biggest advantages of titanium alloys in comparison to all others used in shipbuilding and ship repair. This property has been widely studied, with the use of a variety of aggressive media at different temperatures [2,7,8,9,10,11]. The aim of the research is to study the impact of the process of plasma gas nitriding with indirect plasmatron on the corrosion resistance of aluminum Ti-8Al-1Mo-1V and Ti-6Al-4V by means of the weighing method.

There is a plethora of contradictory data on the corrosion resistance of titanium alloys and hence the need to quantitate the effects of the corrosive medium at different temperatures after the above mentioned chemo-thermal treatment [1, 3, 4, 5, 6]

The results of the study are needed to expand the use of titanium alloys in marine engineering and shipping practice. The alloys examined in this report have a different chemical composition. This implies that they react differently in the conditions of the aggressive media used in experiments. Corrosion of titanium alloys Ti-8Al-1Mo-1V and Ti-6Al-4V has been determined experimentally at various temperatures for the period of 1500 hours.

Experimental procedures and results.

Samples of Ti-8Al-1Mo-1V and Ti-6Al-4V titanium alloys with dimensions 4x8x15 mm were used in the study. Some of them were subjected to plasma gas nitriding with an indirect plasmatron PN 20; power - 20KW, time - 10 minutes; the input parameters are following:

- voltage - 60V;
- plasma-forming gas consumption Ar - 20l / min;
- distance from the nozzle end to the sample - 100mm;
- Plasma-forming gas consumption N2 - 0,1l / min with 99,998% purity.

When nitriding of the samples had been completed, they all were tested for corrosion resistance, by means of the weight method, in the medium of sodium chloride (NaCl), hydrochloric acid (HCl) and sulfuric acid (H_2SO_4). Temperatures of the three aggressive media are 40 ºC and 80ºC.

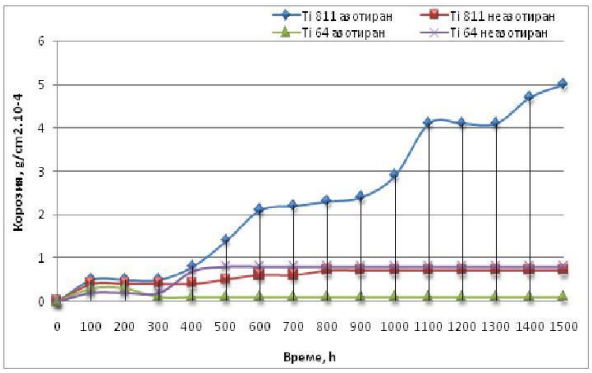

Fig. 1. The results for corrosion resistance of non-nitrided and plasma gas nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V in NaCl corrosive medium at 40ºC.

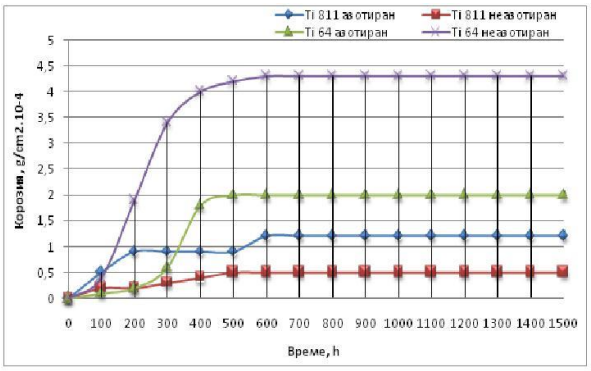

Fig. 2. The results for corrosion resistance of non-nitrided and plasma gas nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V in NaCl corrosive medium at 80ºC.

The results for Ti-8Al-1Mo-1V and Ti-6Al-4V alloys in NaCl corrosive medium at 40 ºC and 80ºC are shown in Fig. 1 and 2: at 40ºC the Ti-6Al-4V alloy demonstrates better corrosion resistance, this being manifested to a greater extent in the nitrided sample. The higher temperature of the aggressive NaCl medium (80ºC) adversely affects the corrosion resistance of Ti-6Al-4V. The loss of weight increases to a large extent in the sample that has not been nitrided (Fig. 2). The results in Fig. 1 and 2 show that the plasma gas nitriding process with indirect plasmatron decreases the corrosion resistance of Ti-8Al-1Mo-1V in NaCl medium at the two temperatures used. This process has a positive effect on the study conducted with the other alloy, Ti-6Al-4V. Despite these differences in the behavior of the two alloys in aggressive NaCl media, they exhibit excellent properties with or without the use of plasma gas nitriding as a method of improving surface properties. The corrosion of Ti-8Al-1Mo-1V and Ti-6Al-4V in NaCl medium does not exceed 5.10^{-4}g / cm^2 after 1500 hours of testing for both temperatures.

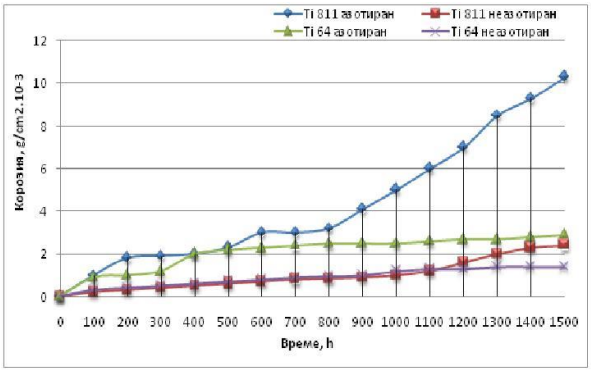

Fig. 3. The results for corrosion resistance of non-nitrided and plasma gas nitrided Ti-8Al-1Mo-1V and Ti-6Al-4V in HCl corrosive medium at 40ºC.

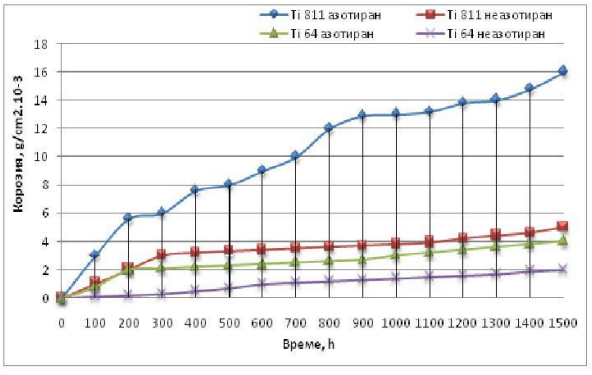

Fig. 4. The results for corrosion resistance of non-nitrided and plasma gas nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V in HCl corrosion medium at 80ºC.

The results of the corrosion resistance tests of Ti-8Al-1Mo-1V and Ti-6Al-4V in HCl corrosive medium at 40 ºC and 80ºC are shown in Fig. 3 and 4, respectively. They show that the weight loss/corrosion rate for all specimens increases with time and temperature of the

medium. The exception is the non-nitrided Ti-6Al-4V alloy. The figures show that the temperature of the HCl medium has no significant influence on its corrosive properties. Ti-6Al-4V alloy samples show better corrosion resistance, with loss of weight for non-nitrided samples being similar for both alloys at 40ºC.

The results of this experiment show that plasma gas nitriding with indirect plasmatron adversely affects the corrosion resistance of the alloys tested in HCl medium. This negative influence is more pronounced in titanium alloy Ti-8Al-1Mo-1V. The aggressive HCl medium destroys the surface layer and deeply corrodes the studied samples, resulting in a significant increase in body loss (corrosion).

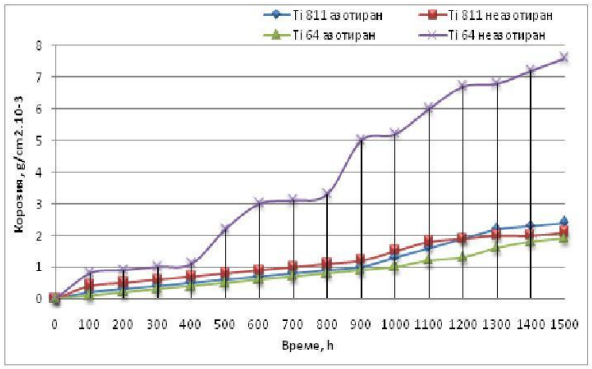

Fig. 5. The results for corrosion resistance of non-nitrided and plasma gas nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V in H_2SO_4 corrosive medium at 40ºC

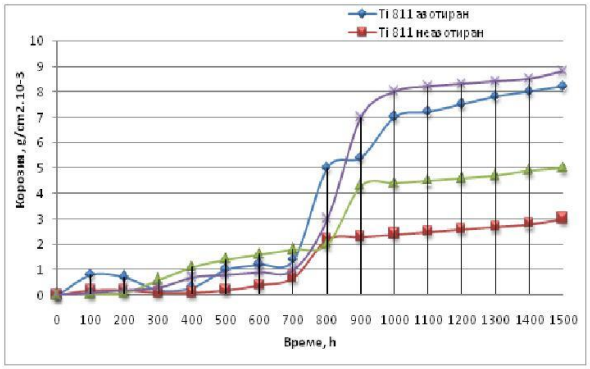

Fig. 6. The results for corrosion resistance of non-nitrided and plasma gas nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V in H_2SO_4 corrosive medium at 80ºC

The data obtained for the corrosion resistance of Ti-8Al-1Mo-1V and Ti-6Al-4V in aggressive medium of H_2SO_4 at 40 ºC and 80ºC are shown in Fig.5 and 6, respectively. The results show that plasma gas nitriding decreases the corrosion resistance of the Ti-8Al-1Mo-1V nitrided alloy in H_2SO_4 medium at 80ºC. At 40ºC, the results for the nitrided and non-nitrided samples are identical. The exception is the non-nitrided Ti-6Al-4V alloy, where the weight loss increases significantly at both temperatures. The process of plasma gas nitriding improves the corrosion resistance of Ti-6Al-4V alloy in H_2SO_4 medium in the temperature range 40-80ºC due to the obtained surface layer.

For the nitrided Ti-8Al-1Mo-1V alloy, weight loss increases with time and temperature of the corrosive medium in the temperature range of 40-80ºC. The results show that the process of plasma gas nitriding decreases its corrosion resistance in H_2SO_4 medium in the temperature range of 40-80°C.

The samples of nitrided titanium alloy Ti-6Al-4V sample show better corrosion resistance than those of Ti-8Al-1Mo-1V in aggressive H_2SO_4 medium. For the non-nitrided samples of the two alloys, the trend is the opposite.

The impact of the aggressive medium

The chemical composition of the aggressive medium is a major factor affecting the corrosion resistance of the alloys examined. The results of the studies show that titanium alloys Ti-8Al-1Mo-1V and Ti-6Al-4V are of high corrosion resistance in alkaline medium (NaCl) and are more sensitive in acidic aggressive media (HCl, H_2SO_4).

At 40ºC, the Ti-8Al-1Mo-1V alloy exhibits good corrosion resistance in NaCl medium. It decreases in H_2SO_4 medium. The nitrided sample shows large weight losses in HCl medium. Similar trends are also observed at of 80°C.

Titanium alloy Ti-6Al-4V has significantly better corrosion resistance properties in aggressive media of NaCl, HCl and H_2SO_4 at the temperatures tested (40°C and 80°C). This

trend is more pronounced in the nitrided specimens. The value of weight loss in NaCl medium is negligible compared to those determined in the other two corrosive media.

The impact of temperature in aggressive media

The corrosion resistance of titanium alloys is influenced to a large extent by the temperature and concentration of the aggressive media. When they exceed certain values, the possibility of the protective layer being destroyed increases. This leads to a significant reduction in corrosion resistance.

The results show that in HCl corrosive medium, weight losses are identical for all tested samples at 40ºC. Their value increases with temperature (80 °C). A similar trend for the corrosion of the studied samples is also observed in aggressive H_2SO_4 medium. Serious changes in the weight of the samples for both media were observed at 80°C. The breakdown of the protective layer is probably due to its local degradation in the aggressive environment, resulting in deep penetration and intensification of the corrosion in the spin matrix.

Corrosion of titanium alloys Ti-8Al-1Mo-1V and Ti-6Al-4V has been experimentally determined in three different aggressive media at various temperatures during the time period of 1500 hours. For both alloys tested, the corrosion resistance decreases when the temperature rises from 40°C to 80°C. The highest degree of corrosion was observed with the nitrided Ti-8Al-1Mo-1V alloy sample in HCl medium at 80ºC/$15.8.10^{-3}$, g/cm^2/.

The research has been carried out with the purpose of extending the fields of application of titanium alloys to marine engineering and of choosing a suitable alloy for the construction of parts, machines and equipment operating in aggressive media.

The results obtained in the present experiment in an alkaline (NaCl) and two acidic media (HCl, H_2SO_4) at temperatures of 40 ºC and 80ºC and time period of 1500 hours with nitrided and non-nitrided samples of Ti-8Al-1Mo-1V and Ti-6Al-4V alloys yield the following results:

- the weight losses determined in the test of the samples in NaCl medium indicate that the plasma gas nitriding process does not significantly affect the corrosion resistance of Ti-8Al-1Mo-1V and Ti-6Al-4V alloys;

- deterioration of the anticorrosive properties is registered in the two alloys after plasma nitriding in HCl medium at all temperatures and in the Ti-8Al-1Mo-1V sample at 80ºC in H_2SO_4 medium;

- the process of plasma gas nitriding improves the corrosion resistance of Ti-6Al-4V alloy in H_2SO_4 medium at all temperatures.

- Ti-6Al-4V alloy showed better corrosion resistance than Ti-8Al-1Mo-1V, with weight losses increasing with time and the temperature rising from 40 ºC to 80ºC.

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ИЗСЛЕДВАНЕ ВЛИЯНИЕТО НА ПРОЦЕСА ПЛАЗМЕНО ГАЗОВО АЗОТИРАНЕ ВЪРХУ КОРОЗИОННАТА УСТОЙЧИВОСТ НА ТИТАНОВИ СПЛАВИ

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Ключови думи: *Титанови сплави, плазмено газово азотиране, корозиона устойчивост, titanium alloys, plasma gas nitriding process, corrosion resistance*

Резюме: *Настоящата статия представя резултати от изследвания, свързани с определяне влиянието на процеса плазмено газово азотиране с индиректен плазмотрон върху корозионната устойчивост на титанови сплави Ti-8Al-1Mo-1V и Ti-6Al-4V. Анализът на тези резултати ще даде ясна представа за влиянието на процеса върху способността на тези сплави да се издържат на корозионните въздействия на различни агресивни среди при различни температури.*