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Advances and Trends in
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Preface

I wish to express my sincere gratitude to all delegates of the OTTAWA'2015 AES-ATEMA 22nd International Conference for their valuable contributions which made this Conference outstandingly successful. I trust that all delegates have had a unique experience by participating in this Conference, both scientifically and culturally.

The AES-ATEMA Conference Series is sponsored and administered by Advanced Engineering Solutions [AES. COM], in cooperation with "Advanced Engineering Solutions International", within the mission of "AES Technical Reviews International Journal Series - ISSN 1915-5409. In this regard, I wish to express my full indebtedness to Advanced Engineering Solutions International and also to the members of the International Editorial Board of "AES Technical Reviews International Journal Series".

I hope that the valuable scientific and engineering contributions presented on / in this CD-ROM / book proceedings will provide guidance to Science and Engineering students, educators and researchers who are working in the pertinent fields. I hope also that these proceedings will be of significant value to scientists and engineers who are involved in the production, processing of engineering materials and the study of their properties, in addition to all other pertinent fields.

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CONTENTS

Conference Presentations

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Conference Presentations

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Corrosion and Wear Resistant Nanostructured Metal Coatings Characteristics Analysis

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Abstract

One of the most efficient technologies for improving durability of a product is applying different coatings on the effective area. Due to their flexibility ion-plasma methods of applying corrosion and wear resistant coatings are becoming more widely used in modern industry. Methods differ with high controllability of the process; capability of getting chemical compounds and alloys of given composition including films with better adhesion to the surface, etc.

Keywords

Corrosion, wear resistance, coatings.

1 Introduction

The analysis of the losses that are caused due to corrosion is an important input in the economy of Latvia and the European Union. The corrosion of the metal and equipment accounts for a considerable proportion of the total corrosion losses, thus it is the impetus for further investigation and developments for protection from corrosion, providing the transport systems and industry with corrosion preventive materials and tools. Protection of metals from corrosion is a particularly topical issue, which affects all areas of the global economy. The growing world economic growth leads to increase the number of transport vehicles and hence different systems and mechanisms unit increases that are subject to aggressive environmental influences and the various processes that cause metal corrosion.

Damage caused by corrosion could be prevented by reducing either by choosing the appropriate metal at a fixed location, either by using metal coating. The topic deals with corrosion processes occurring under certain

operating conditions. The analysis of operating characteristics of the research object and the parameters associated with the surface layer characteristics is carried out.

During the experiment there has been developed corrosion-resistant coating theoretical model. As a result of experiment there has been obtained versatile multi-layer corrosion resistant and abrasion resistant coating for carbon steel products.

2 Thermodynamics of corrosion process

Corrosion is one of the most common naturally occurring processes that have been studied by thermodynamics – including oxidation process, metal disruption, and its chemical and electrochemical effects under environment influence.

Corrosion mechanism is the basic set of processes, which are determined by the reaction of metals with the environment. It determines the stages of the process and corrosion processes, distinguishes elementary processes, thus enabling to look for ways to control this process. There are 2 types of mechanisms – chemical and electrochemical corrosion. [1, 2, 5]

Chemical corrosion is an arbitrary process of metal exposure to corrosive environment, when metal oxidation and environmental oxidation components regeneration take place simultaneously. It occurs in dry gasses, liquid electrolytes and non-electrolytes. Chemical corrosion mechanism in electrolytes is not discussed in this paper, because electrolytes, in which corrosion mechanism is observed, are not used in ship building, operation and maintenance On seagoing vessels, various elements of power plants, fuel combustion products discharged into the system, oil tanks, fuel tanks and other structures are subject to chemical corrosion. In shipbuilding and ships repairing the metal constructions which are processed in high temperatures (e.g., welding, cutting) is the subject of corrosion [3, 5].

Electrochemical corrosion is an arbitrary process of metal exposure to corrosive environment (electrolyte), when metal oxidation and environmental oxidation component regeneration do not take place simultaneously – their regeneration speed depends on electrolyte potential.

3 Kinematics of corrosion process

The kinematics of corrosion process significantly changes the external (composition, temperature, pressure, physical state environmental) and internal (chemical and phase composition, structure, physical and mechanical metal chemical) properties. Corrosion rate [4] – quantity of metal that is ionized in time unit dependable from area unit and is characterized by

$$K = \frac{W_0 - W_1}{S\tau}, \quad (1)$$

K – corrosion rate, *g/(mm^{2}h);*

W_0 – sample weight before corrosion process started, *g*;

W_1 – sample weight after corrosion removed, *g*;

S – corroded area, *mm^2*;

τ – duration, *h*.

4 Research object and test procedure

One of the most important characteristics of coatings for any purpose is adhesion. Ion-plasma coating were produced by the upgraded vacuum unit NNV-6, 6-I1 [4]. For the experimental research two sources of metallic plasma were used – the electric arc vaporizer and magnetron. During sputtering with the electric arc vaporizer electromagnetic movement stabilization, focus of the cathode spot on the face of the evaporated cathode and separation of the flow of the sputtered material from the droplet phase were provided.

The argon pressure in the chamber was 0,133…0,399 ·10-3 MPa the nitrogen pressure - 0,026…0,266·10^{-3} MPa. The microhardness of the coatings was measured by nanoindentation by means of the micro-durometer PMT-3M. Hitachi S-3000N scanning electron microscope was used for analysis of chemical composition of the obtained compound [7]. Research was made around two protective coatings on the basis of (TiAl)N and Ti-Al-N conglomerate coatings.

5 Potential determination

Prior to initiating any measures against corrosion metal potential is determined in order to choose the appropriate metallic coating. In order to determine the potential platinum electrode should be used which is immersed in sulphuric acid electrolyte (Figure 1).

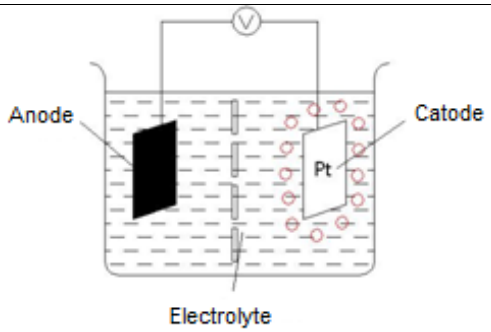

Figure 1. Potential electrode determination scheme with standard hydrogen electrode. V – Potentiometer [6].

Platinum electrode, the hydrogen ions, is a benchmark for determining the potential, but during the experiments authors use a simpler option for determining the potential. Authors use self made potential measuring device. Basic electrode (copper) in the potential detection device is constant so all measurements should be done against the copper [6]. Potential Measurement for (TiAl)N coatings is done with self-made copper electrode potential measuring device. Potential values are relative to the Cu electrode. (Figure 2).

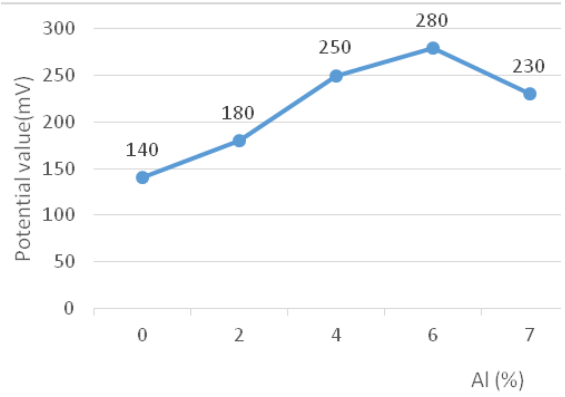

Figure 2. Electrode potential depending on the Al quantum in (TiAl)N coating.

It can be concluded that most potential value for (TiAl)N coating is when Al composition is relatively 6%, when the magnetron current is 6A, (it depends on the Al coating composition). The smallest metal potential value is when Al composition in coating is least, respectively, when a current is 0A. When Al composition increases from 0 to 6, potential of coating is growing reaching its maximum value, then decreasing.

6 Corrosion rate experimental detection using gravimetric method

The method includes detection of the mass change of the sample. Two couples of samples are taken - one of the sample is raw (ST-3), the other is from the first experimental group - titanium aluminum nitride (TiAl)N.

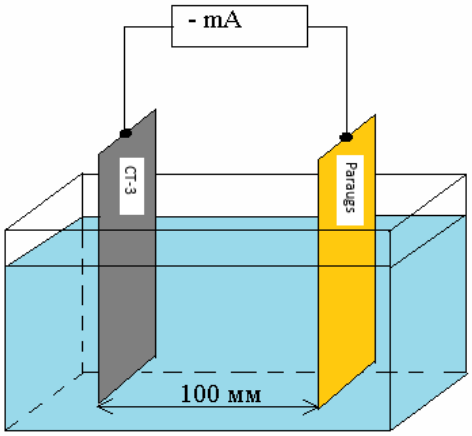

Figure 3. Primary cells corrosion current detection circuit (left) and samples before the experiment.

Both samples are placed in a 10% NaCl electrolyte solution see (Fig.3) and submerged at a depth equal to the uniform contact area electrolyte. For electrochemical reaction they are connected with copper wire. The distance between the two samples is 100 mm. Samples are kept in the NaCl solution for 72 hours. Every 24 hours samples are removed from the solution, washed in running water and drained (see Fig. 4). After sample weight is determined using analytical scales RADWAG AS 160 / X with an accuracy of 0,00001g.

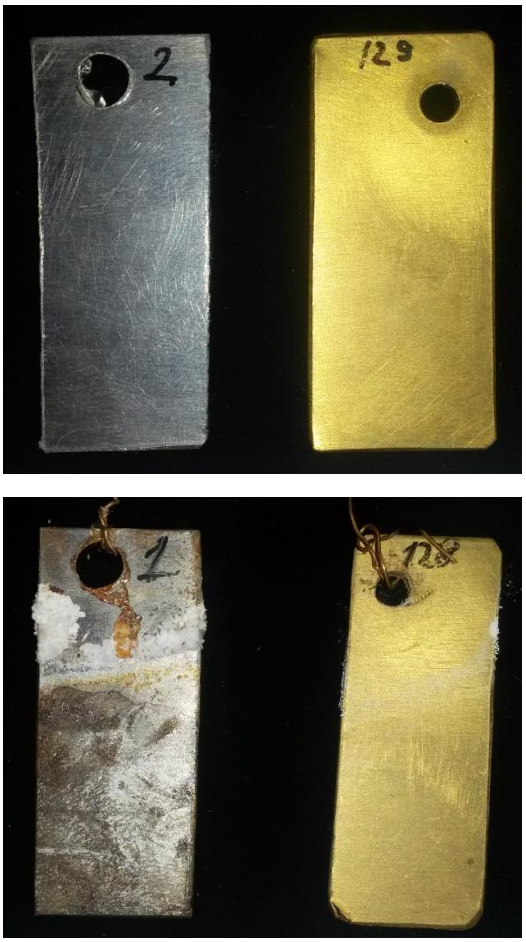

Figure 4. Samples (with and without coating) before the experiment (left) and after 72 h of an experiment.

It is registered that coated samples after 72 hours have not corroded (Fig.4). Also it proved that chosen chemical composition of Al for the samples shown is optimal.

Sample weight taken after each 24 h is summarized in comparative graph of sample

pairs ST-3 uncoated sample and the sample with (TiAl) N coating (Fig.5).

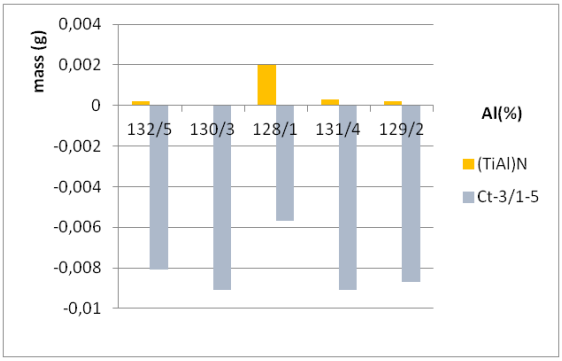

Figure 5. Change of mass in 72h time period.

After 72 h it is registered that samples made from ST-3 have lost weight. In Fig.5 it is shown that mass losses for every sample pair differ. It proves that mass losses depend on Al chemical composition in the coating, also different corrosion speed is registered for samples.

Calculating corrosion rate after weight loss for raw ST3 sample with corrosion area of 368 mm2 is K= 103,3 mg/(mm2per year). Results for all samples are shown in table 1.

Table 1. The change of mass during the experiment (in 10% NaCl electrolyte).

Sample Nr.	Duration, h				Δm(g)	Δm,(g/cm²)	Comments
	0	24	48	72			
1	9,4197g	9,4172g	9,4150g	9,4140g	-0,0057	-0,0015	ST-3 without coating
2	9,4268g	9,4247g	9,4223g	9,4181g	-0,0087	-0,0027	
3	8,6295g	8,6274g	8,6254g	8,6204g	-0,0091	-0,0025	
4	9,8295g	9,8273g	9,8249g	9,8204g	-0,0091	-0,0024	
5	8,7573g	8,7556g	8,7531g	8,7492g	-0,0081	-0,0024	
128	8,0722g	8,0732g	8,0731g	8,0742g	0,0020		(TiAl)N I=4A
129	9,4256g	9,4254g	9,4254g	9,4258g	0,0002		(TiAl)N I=7A
130	8,3937g	8,3938g	8,3938g	8,3937g	0		(TiAl)N I=2A
131	8,1366g	8,1362g	8,1363g	8,1369g	0,0003		(TiAl)N I=6A
132	7,7086g	7,7089g	7,7087g	7,7088g	0,0002		(TiAl)N I=0A

As per graph (Fig.6.) it is shown that only ST3 steel uncoated sample have lost weight, but the rest of the samples mass loss values are positive, that means that weight is gained.

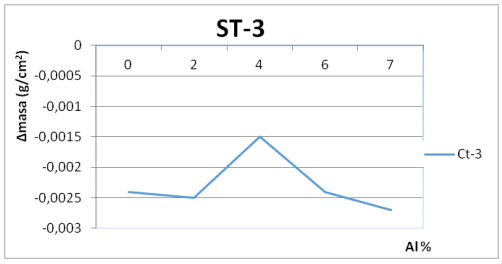

Figure 6. ST-3 samples without coating change of mass, g/cm^2.

This kind of mass gains could be explained by imperfect sample cleaning from corrosion products, but it would be correct if steel ST3 mass increased, but it did not happen. So it is assumed that the protective coatings were sub coated by oxide film (passivation film) which increased mass of the sample.

7 Conclusions

Damage caused by corrosion could be prevented by reducing either by choosing the appropriate metal at a fixed location, either by

using metal coating. Research was made around two protective coatings on the basis of (TiAl)N and Ti-Al-N conglomerate coatings.

Experiments were conducted placing samples in a 10% NaCl electrolyte solution. Samples were kept in the NaCl solution for 72 hours. Every 24 hours samples are removed from the solution, washed in running water and drained. Experiment proved that developed (TiAl)N coating with an optimal Al composition relatively 6% protects sample for at least 72 hours in comparison with uncoated sample. In 72 hours coated sample have no corrosion products on it surface.

Acknowledgments

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AUTHOR'S INDEX