Application of Plasma Electrolytic Oxidation for Repair of Details of Marine Technique

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ABSTRACT

Thermal oxidation (TO) of shipbuilding details and products is one of the well-known methods of formation of protective coatings on the surface of metals and alloys. Nevertheless, thermal oxidation has several major drawbacks: high energy consumption, labor-intensity and the duration of the process, as well as lack of restoration of the coatings on the details, which already were in operation. One of the most effective alternative methods of application of protective coatings on the surface of the ship fittings and tools made of titanium, magnesium, aluminium and low-carbon steel is plasma electrolytic oxidation (PEO).

The scientific field and practical applications areas for this study – are corrosion and wear protection, formation and repair of protective coatings on constructional and functional materials. The main goal of this research was to improve and restore the protective properties of the damaged coatings using PEO.

The quality of protective properties of surface layers was evaluated by electrochemical and tribological modern methods.

KEY WORDS: Offshore structures, Magnesium alloys, Steel, Protective coatings, Plasma electrolytic oxidation, corrosion, Electrochemical impedance spectroscopy

INTRODUCTION

The plasma electrolytic oxidation method is used for fabrication of coatings that improve the surface properties of various metals and alloys (titanium, aluminium, magnesium alloys and steel) for Offshore Structures and Marine Engineering (Minaev et al. 2014, Yerokhin et al. 1999). The porous coatings are produced by high voltage AC, DC or bipolar polarization of the substrate in appropriate electrolyte solutions. The plasma discharges occur at the electrode surface during the PEO-process and lead to the formation of coatings similar to ceramic ones. The frictional, corrosive, electrical, and thermal properties of these coatings have generated interest in view of their possible use in mechanical, aerospace, aircraft, and automobile industry, engineering equipment components, and biomedical devices. The coatings obtained by the PEO-method have the unopened porosity and are characterized by low corrosion currents (Ic) and high values of polarization resistance (Rp) and impedance modulus (|Z|) (especially in low frequency range) (Sinebryukhov et al. 2012). Formation of coatings at the surface of metals and alloys by the PEO-method enables one to expand substantially the field of their practical application. However, in case of a mechanical impact during improper or careless transportation or operation, there is a possibility of disruption of the surface layer, which inevitably results in deterioration of protective properties of the coating (Sinebryukhov et al. 2010). In view of this, the development of the methods of deposition of coatings, which are not only corrosion-stable and wearproof, but also have antifriction properties, is of an extreme importance, since this would significantly reduce the probability of the mechanical damage in the process of exploitation. PEO-coatings having a good adhesion to the substrate and developed surface can serve as the basis for the creation of composite layers (Gnedenkov, Sinebryukhov, 2009). Moreover, one of the methods of surface modification is the embedding of polymer and inorganic nanoparticles in the electrolyte for the plasma electrolytic oxidation or in PEO pretreated surface layer (Boinovich et al. 2012). It allows improving the practically important physical-chemical properties of the PEO-coatings such as anticorrosion- and wear-resistance, hardness (Imshinetskiy et al. 2014). The main problem in the preparation of such suspensions for PEO is the achievement of sufficiently sedimentative and aggregative stability. In this work as substrates for PEO-coating formation, the carbon steel and magnesium alloys were chosen.

EXPERIMENTAL

Rectangular plates (40 mm × 8 mm × 1 mm and 20 mm × 30 mm × 1.5 mm) of low-carbon steel (99.2 Fe; 0.4 Mn; 0.2 Si; 0.2 C at. %), and MA8 wrought magnesium alloy (1.5 – 2.5 Mn; 0.15 – 0.35 Ce, mass %), respectively, were used as samples. Prior to oxidation the samples were polished with sandpapers (the final one is P1200 grit size) and degreased with acetone. Low-carbon steel was oxidized in silicate-containing electrolyte (20 g/l Na2CO3 + 30 g/l NaN3O·nSiO2 (m/n = 2). Oxidation was performed in bipolar PEO-mode with voltage raising from 30 up to 300 V at the rate of 0.45 V/s in anodic period and a constant cathodic voltage of 30 V. Magnesium alloy was treated in 15 g/l Na2SiO3·5H2O + 5 g/l NaF aqueous solution. The coating formation process was performed using the bipolar mode. The anodic component