UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Engineering Materials

Electrodeposition of Nickel Coatings on Aluminium Alloy 7075 through a Modified Single Zincating Process

by

Intan Sharhida Othman

Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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Electrodeposition on aluminium alloy substrates often is often difficult in producing a coating with good adhesion when compared to other metals. This is due to the rapid formation of oxide layers on the substrate's surface when exposed to air and water, preventing metallic bonds from forming between the nickel coating and the aluminium alloy substrate which in turn resulting in poor adhesion. Adhesion of the coating on the substrate influences the quality of the coating. To overcome this problem, a series of critical surface pre-treatment procedures are required for a successful electrodeposition process with a strong coating adhesion. The pre-treatment process consists of mechanical grinding and polishing, alkaline and acidic cleaning, zincating and activation process. This study focuses on the zincating process to obtain a strong adherence coating on the substrate.

An aim of this study was to replace the complex double zincating process. To this end, modification has been made to a conventional single zincating process, as the process results in a non-homogenous deposition of zinc particles on the substrate which leads to a poor adhesion of the coating. The modified process, for which the duration of the single zincating process was extended from 1 to 20 minutes, was based on the electrochemistry measurements of aluminium alloy 7075 substrate in the zincating

solution. For comparison, nickel coatings prepared using a double zincating process at 60/10, 60/20, 60/30, 60/40 and 60/50 seconds were also produced in this study.. By replacing the double zincating with a modified single zincating process, two pre-treatment steps of double zincating process will be eliminated. Thus, the waste disposal problem in terms of the chemical used in the zincating solution is reduced. In addition, copper activation was applied before the single zincating process in order to overcome the high dissolution of the substrate in the zincating solution.

The surface pre-treated samples were characterized after alkaline cleaning, acid cleaning, zincating process and copper activation at various immersion durations by scanning electron microscopy (SEM), energy dispersive X-ray (EDX) and atomic force microscopy (AFM). The modified single zincated samples were found to contain larger zinc particles, as compared to the conventional single and double zincated samples. The modified single zincating process also showed an increasing trend in the nucleation density and size of zinc particles with time. A gradual decrease in the surface roughness values with the extension of the modified single zincating duration was also observed.

Then, the influence of multiple zincating processes (conventional and modified single zincating with and without copper activation, and double zincating) at various durations on the coating adhesion was investigated using scratch adhesion test. Scratch failure modes were analysed using acoustic emission signals, frictional force, and microscopy observation. The conventional single zincating and double zincating processes resulted in poor adhesion of the nickel coatings to the substrate, as both the cohesive and adhesion failures occurred during the scratch test. The adhesion of the coating to the substrate was improved by extending the single zincating duration from 1 to 5, 10, 15 and 20 minutes, with only cohesive failure found for the samples. This result was supported by the number of acoustic emission activity (N_{AE}) events recorded during the test, which showed the highest N_{AE} at about 130 for the sample produced from the conventional single zincating process. An increase in the zincating duration to 5 minutes resulted in a drastic reduction of the N_{AE} to 30. The similar adhesion behaviour was also observed on modified single zincated samples with copper activation.

The corrosion tests were carried out by immersing the coatings in a 3.5 wt. % NaCl solution at room temperature. It was found that a modified single zincating process at a longer duration provided a significant enhancement of corrosion resistance as compared to the conventional single zincating process, due to the increase in corrosion potential and decrease in corrosion current density of the conventional single zincated sample.

These much improved performance of coating adhesion and corrosion resistance may be explained by homogenous distribution of zinc particles and good coverage of the zinc particles on the aluminium alloy substrate.

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DECLARATION OF AUTHORSHIP

I, **Intan Sharhida Othman**

declare that the thesis entitled

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and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

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Date: 29 April 2016

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