CORROSION PERFORMANCE OF Zn-Al-Mg COATED STEEL WIRE ROD FOR OFFSHORE APPLICATION

MOHD NAIF HANIS BIN MOHD SOKRI

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Universiti Teknologi Malaysia

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Specially dedicated to my beloved family

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ABSTRACT

The increase demand on improvement corrosion protection in steel structure for offshore industry lead to development on the hot-dip galvanizing process and the coating material alloy. It is crucial to provide long service life for all this structure to minimize cost of operation, time saving, and workload. This research project focusing on evaluating the Zn-Al-Mg alloy coated on steel wire rod. Prior to Zn-Al-Mg alloy coating, the steel wire rod was coated with pure Zn followed by Zn-Al coating for comparison purposes. This is to determine effect of the intermediate layer of coating on the performance of Zn-Al-Mg coating. Electrochemical test and salt spray test were done to evaluate corrosion performance of the steel wire after Zn-Al-Mg coating. The samples before and after corrosion test were analyzed with optical microscopy, scanning electron microscopy to obtain microstructure image and Energy Dispersive Spectrometry (EDS) for elemental analysis. It was found that iron diffusion increases with multiple galvanizing process. It was also found that Zn-Al-Mg corrosion performance is good due to the presence of Magnesium (Mg) which forms protective oxide. The result shows that the Zn-5Al wire coated with Zn-5.3Al-2Mg gives better corrosion performance compared to pure Zn coated wire which were coated with Zn-2.3Al-2Mg coating.

ABSTRAK

Penambahan permintaan terhadap peningkatan perlindungan kakisan dalam struktur keluli bagi industri pesisir pantai membawa kepada pembangunan proses penggalvanian dan bahan salutan aloi. Jangka hayat perkhidmatan yang panjang untuk semua struktur ini adalah penting untuk meminimumkan kos operasi, penjimatan masa, dan mengurangkan beban kerja. Projek penyelidikan ini memberi tumpuan kepada menilai salutan aloi Zn-Al-Mg pada rod dawai keluli. Sebelum proses salutan aloi Zn-Al-Mg, rod dawai keluli disalutkankan dengan Zn tulen diikuti oleh lapisan Zn-Al untuk tujuan perbandingan. Ini adalah untuk menentukan kesan salutan lapisan pertengahan pada prestasi lapisan Zn-Al-Mg. Ujian elektrokimia dan ujian penyemburan garam dilakukan untuk menilai prestasi kakisan dawai keluli selepas salutan Zn-Al-Mg. Sampel sebelum dan selepas ujian kakisan dianalisis menggunakan mikroskop optic dan mikroskop imbasan electron (SEM) untuk mendapatkan imej mikrostruktur. Spektrometri tenaga serakan (EDS) digunakan bagi analisis unsur. Kajian mendapati bahawa penyerapan besi meningkat dengan proses penggalvanian berganda. Ia juga mendapati bahawa prestasi kakisan Zn-Al-Mg lebih baik atas kehadiran Magnesium (Mg) yang membentuk lapisan oksida. Hasilnya menunjukkan bahawa rod keluli bersalut Zn-5Al yang kemudiannya dilapisi dengan Zn-5.3Al-2Mg memberikan prestasi kakisan yang lebih baik berbanding dengan rod keluli bersalut Zn tulen yang kemudiannya disalut Zn-2.3Al-2Mg.

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LIST OF SYMBOLS

°C	Degree Celsius
K	Kelvin
µm	Micron
l	liter
M	Mega
Pa	Pascal
Å	Angstrom
H	Hydrogen
O	Oxygen
SO	Sulphur dioxide
Zn	Zinc
Fe	Ferrous
Al	Aluminum
Mg	Magnesium
NaCl	Sodium Chloride
CO2	Carbon dioxide
t	Time (min)
H2O	Water

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wire rope have been used widely in many applications worldwide as support system for heavy structures such as crane rope, mining rope, elevator, bridge, and offshore platform. The wire rope consist of several strands of metal wire laid (twisted) into a helix. This component are prone to corrosion in corrosive environment such as sea and polluted environment which will contribute to degradation of component material and lead to early failure. However, such problem can be mitigated by metal coating process on components which act as isolator between the substrate with the surrounding environment. Figure 1.1 and 1.2 shows examples on the application of wire ropes.

Figure 1.1: Wire rope used for suspension bridge

Figure 1.2: Wire rope used for offshore application

Coating process have been used in industry for so many years to change the surface property of material in order to serve many purpose such as increasing wettability, corrosion resistance, or wear resistance. Basically it is used to enhance the ability of materials to withstand interaction with multiple specific environments that might induce from the weather, environment exposure and application of the material itself.

One of the most used coating on steel is Zinc known as galvanized steel. This is done by applying Zn on substrate which normally use hot-dip galvanizing process. This method has been applied years ago for the purpose of inhibiting corrosion against the substrate metal. Galvanized coat will act as a galvanic protector to the substrate as zinc element is more anodic to most of metal and alloy especially steel. The coating will promote protective layer on the substrate and corrosion process will take place on zinc first before it affecting the substrate thus it will slow down the corrosion process on the metal. Figure 1.3 shows a typical hot-dipping galvanizing process.

Figure 1.3: Steel wire rod ready to be hot-dipped in galvanizing bath

The hot dip galvanizing method has been continuously being researched all over the world by means to create a better galvanizing process in term of cost whether it is direct and indirect, simplification, and time saving process. Also at the same time creating Zn alloy coating that have the best corrosion protection in the specific environment where the material are used. The Zn coated materials are being widely used in many applications such as street furniture, building frameworks, balconies and also in oil and gas industries where the structures are exposed in very extreme corrosive environment. Researchers actively studying on producing Zn coated alloy to increase service life of these structures and components.

About 30 years ago, researchers have develop a combination of aluminum and magnesium in zinc-based alloy coating with various composition which has been proven to give better corrosion protection to the steel substrate. These alloys have been continuously investigated to obtain the best alloy composition for the coating and to optimize the coating process.

Recently, a wire rope producing company (Kiswire Sdn. Bhd) has successfully produced Zn-Al-Mg coating on their products, however the faced difficulty in stabilizing dross formation on top of the molten bath. The dross basically is a scum that formed whether due to dissolution of iron where it will react with molten bath material, or the oxidation of bath alloy itself. The dross will float on top of the alloy molten bath due to its low density and adheres to the coated substrate and compromise coating quality and integrity by inducing crack initiation and also reduce corrosion protection performance of the coating. Figure 1.4 shows the dross formation which covering surface of Zn-alloy molten bath while Figure 1.5 shows pimples developed on galvanized steel surface due to dross interaction during galvanizing process.

Figure 1.4: Dross formation covering surface of Zn-alloy molten bath

Figure 1.5: Pimples developed on galvanized steel surface due to dross interaction

1.2 Objective of the study

The main objectives of this research project are as follows;

1. To investigate the microstructural features of the various coating layer.
2. To determine the effect of elements on the composition of the coating alloy.
3. To investigate the corrosion performance of the newly developed Zn-Al-Mg coating.

1.3 Scope of the study

1. Obtaining samples of Zn-Al-Mg alloys from Kiswire Sdn. Bhd.
2. Microstructural study on the Zn-Al-Mg samples using optical, SEM, and EDS.
3. Identification of metallic element that can improve on the stabilization of the molten Zn-Al-Mg alloy.
4. Corrosion test on coated samples using salt spray and electrochemical method.

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