EFFECT OF HEAT TREATMENT ON THE INTERLAYER AND CORROSION BEHAVIOR OF Zn AND Zn-0.5%Al COATED HIGH CARBON STEEL FOR MARINE APPLICATION

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Specially dedicated to

my beloved family and supervisor

for their support and inspiration

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ABSTRACT

Hot dip galvanizing has been an important technique for corrosion protection in the industry. In recent years, longer service life for hot dip galvanized steel is thus crucial to offset the rapid rises in cost of maintenance in service. This project is aimed to investigate the effects of heat treatment on the intermetallic and corrosion behaviour of Zn and Zn-0.5%Al coated high carbon steel wire rope for marine application. A total of nine set of heat treatment parameters with heating time one, three and five hours at temperatures 250, 350, 400°C respectively were conducted onto Zn and Zn-0.5%Al coated high carbon steel substrate (0.87%C). These parameters were to evaluate the effects of heat treatment time and temperature on the microstructural evolution and formation kinetics of the coating. The coated steels had undergone corrosion tests namely salt spray test and electrochemical test. The samples before and after corrosion test were analyzed with optical microscopy, scanning electron microscopy, energy dispersive X-ray and X-ray diffractometer The result shows that heat treatment affects the coating thickness and weight loss due to powdering effect. Besides, by increasing heat treatment time and temperature, it was observed that the gamma layer for Zn-coated steel was increased. However, the growth rate of gamma layer for Zn-0.5%Al galvanized wire rope was slow. It was also observed that heat treatment affects the corrosion rate of Zn and Zn-0.5%Al coated samples. The optimum heat treatment parameter for Zn coated samples was heating at temperature 350ºC for 3 hours which gives the lowest corrosion rate. Optimum heat treatment parameter for Zn-0.5%Al coated samples was heating at temperature 400°C for 5 hours.

ABSTRAK

Celup panas penggalvanian merupakan satu teknik yang penting untuk perlindungan kakisan dalam industri. Sejak kebelakangan tahun ini, jangka masa perkhidmatan yang panjang daripada keluli bergalvani adalah penting untuk mengimbangi peningkatan pesat dari segi kos penyelenggaraan. Projek ini bertujuan untuk menyiasat kesan-kesan rawatan haba pada kelakuan antara logam dan prestasi kakisan salutan Zn dan Zn-0.5% Al pada tali dawai keluli karbon tinggi untuk kegunaan marin. Sejumlah sembilan set parameter rawatan haba dengan masa pemanasan satu, tiga dan lima jam pada suhu 250, 350, 400°C masing-masing telah dijalankan ke atas salutan Zn dan Zn-0.5% Al pada substrat keluli karbon tinggi (0.87% C). Parameter ini adalah untuk menilai kesan masa dan suhu rawatan haba ke atas evolusi mikrostruktur dan kinetic pembentukan lapisan. Salutan keluli tersebut telah diuji dengan ujian kakisan iaitu ujian semburan garam dan ujian elektrokimia. Sampel sebelum dan selepas ujian kakisan dianalisis dengan mikroskop optik, pengimbasan elektron mikroskop, penyerakan tenaga sinar-X dan pembelau sinar-X. Hasilnya menunjukkan bahawa kesan rawatan haba mempengaruhi ketebalan lapisan dan kehilangan berat badan disebabkan oleh kesan powdering. Selain itu, dengan peningkatan masa rawatan haba dan suhu, ia telah diperhatikan bahawa ketebalan lapisan gamma untuk keluli salutan Zn meningkat. Walau bagaimanapun, kadar pertumbuhan lapisan gamma adalah lambat untuk salutan Zn-0.5% Al pada keluli tali dawai, Ia juga diperhatikan bahawa rawatan haba mempengaruhi kadar kakisan sampel salutan Zn dan Zn-0.5% Al. Parameter yang optimum untuk rawatan haba sampel salutan Zn ialah rawatan haba pada suhu 350ºC untuk 3 jam yang memberikan kadar kakisan yang terendah. Rawatan haba yang optimum untuk sampel salutan Zn-Al 0.5% ialah rawatan haba pada suhu 400°C selama 5 jam.

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LIST OF SYMBOLS AND ABREVIATIONS

°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
NaCl	Sodium Chloride
CO_2	Carbon dioxide
t	Time (min)
H_2O	Water

CHAPTER 1

INTRODUCTION

1.1 Introduction

Corrosion has been a major problem encountered by many industries and causes RM 500 million annually since 1981. Thus, many researches have been done in order to yield a better way to prevent and control against corrosion.

Hot dip galvanizing is one of the oldest and most important zinc (Zn) coating process. It has been applied for over 200 years and widely used in industry for corrosion protection of steels. The steel is protected by the Zn coating through a barrier effect and a galvanic effect, in which Zn acts as the sacrificial anode while steel acts as the cathode. In most atmospheric environments, Zn corrodes much less than steel, by a factor of 10 to 100 times (X. G. Zhang, 1996) due to the formation of a protective layer consisting of a mixture of Zn oxide, Zn hydroxide and various basic Zn salts depending on the nature of the environment. Thus the protection of steel by a Zn coating is mainly through the barrier effect. However, at the places where the Zn coating is damaged and the steel underneath is exposed, such as at cuts or at scratches, the galvanic action between steel and Zn can protect the exposed steel from corrosion.

In recent years, with the increasing requirements of industry for a longer service life for hot dip galvanized steel to offset the rapid rises in cost of maintenance in service, a need for investigating the effect of heat treatment on the interlayer and corrosion behavior of Zn-Al coated High Carbon Steel for Marine application.

In this work, an investigation into the effect of heat treatment on the Zn, Zn-0.5%Al coating to observe the changes on intermetallic layer will be carried out.

1.3 Problem Statement

Galvanized wire ropes are exposed to seawater for a long period of time. Thus corrosion occurs and causes enormous losses. There are many methods to improve on the corrosion resistance of galvanized steel such as coating thickness, coating quality or perform heat treatment on the coating material. In this research, a study on the effect of heat treatment on the galvanized steel has been carried out in order to obtain better corrosion resistance of the coated layer.

1.4 Objectives of the Research

To investigate the effects of heat treatment of galvanized high carbon wire rope on the interlayer and corrosion behaviour of Zn and Zn-0.5%Al coated high carbon steel for marine application.

1.5 Scopes of the Study

The scopes of the study are based on the followings:

1. Selection of heat treatment parameters for coated high carbon steel wire ropes.
2. Perform heat treatment on the coated samples using high temperature furnace.
3. Microstructure evolutions were characterized by optical microscopy, X-Ray Diffraction, Field Emission Scanning Electron Microscopy (FESEM) and Energy Dispersive X-Rays (EDX), elemental analysis.
4. The corrosion behavior were investigated by potentiodynamic polarization the on the coated and uncoated steel wire ropes.

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