EFFECT OF SURFACE PREPARATIONS ON THE ADHESION AND CORROSION BEHAVIOUR OF Zn-0.5Al COATING ON HIGH CARBON STEEL

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For my dearest family, Prof Esah and friends

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ABSTRACT

The corrosion of steel is one of the primary causes for premature failure. The ideal way to overcome this problem is to provide corrosion protection right at the time of manufacturing by hot-dip galvanizing. Conventionally, pure zinc (Zn) galvanizing provide a poor adhesion coating due to formation of brittle intermetallic of Fe–Zn; whilst single layer Zn–0.5 wt% Al alloy coating has a poor adhesion due to lack of suitable fluxes. This project is aimed to investigate the effects of various surface preparation treatments of high carbon steel plate on the adhesion and corrosion behaviour of Zn-0.5Al coating. Surface preparation prior to coating is thus crucial in order to obtain better coating adhesion and improve corrosion resistance. In this project, sand blasting and sand grinding were conducted together with chemical pretreatment on the steel substrate prior to Zn-0.5Al coating. The sand blasted, sand ground together with chemical pretreated steel samples were coated with Zn-0.5Al coating by dipping process. Adhesion property was examined on the coated samples by using pin on disc test. Electrochemical and salt spray tests were performed on the coated steels following the ASTM standard. Analysis has been carried out on the samples by using standard material characterization techniques namely optical microscopy, scanning electron microscopy and X-ray diffractometer. From this project, it was found that sand blasting followed by chemical pretreatment gave the best coating performance in terms of both adhesion and corrosion protection. This is due to the effect of high surface roughness from sand blasting which led to good mechanical interlocking effect for improved adhesion strength between Zn-0.5Al coating and steel substrate. Subsequently, corrosion protection also improved because Zn-0.5Al alloy coating did not peel off easily during corrosion tests. Sand ground galvanized steel gave the intermediate coating performance and conventional chemical pretreatment galvanized steel had a low coating performance in terms of both adhesion and corrosion protection. It can be concluded that surface roughness has significant effect on the coating adhesion and corrosion protection of galvanized coating.

ABSTRAK

Kakisan keluli adalah salah satu punca utama kegagalan pra-matang. Cara yang sesuai untuk mengatasi masalah ini adalah untuk memberi perlindungan kakisan semasa pencelupan panas penggalvanian. Sebelum ini, salutan zink (Zn) menyediakan lapisan lekatan yang lemah kerana pembentukan antara logam Fe-Zn yang rapuh; manakala lapisan Zn-0.5 %berat Al salutan aloi mempunyai lekatan yang lemah kerana kekurangan fluks yang sesuai. Projek ini bertujuan untuk mengkaji kesan pelbagai jenis rawatan permukaan pada keluli karbon tinggi ke atas lekatan dan kelakuan kakisan salutan Zn-0.5Al. Penyediaan permukaan sebelum salutan adalah penting untuk mendapatkan lapisan lekatan yang lebih baik dan meningkatkan perlindungan kakisan. Dalam projek ini, pembagasan pasir dan pengisaran pasir telah dijalankan bersama-sama dengan pra-rawatan kimia pada substrat keluli sebelum salutan celup panas Zn-0.5Al. Semua sampel kemudiannya disalut dengan salutan Zn-0.5Al melalui proses celupan panas. Kualiti lekatan telah diperiksa pada sampel bersalut dengan menggunakan mesin pin pada cakera. Ujian elektrokimia dan semburan garam telah dijalankan ke atas keluli bersalut berdasarkan standard ASTM. Analisis telah dijalankan ke atas sampel dengan menggunakan teknik pencirian bahan iaitu mikroskop optik, mikroskop pengimbasan elektron dan pembelau sinar-X. Daripada projek ini, telah didapati bahawa pembagasan pasir diikuti dengan pra-rawatan kimia memberikan prestasi salutan yang terbaik dari segi lekatan dan perlindungan kakisan. Ini adalah disebabkan oleh kesan kekasaran permukaan yang tinggi daripada pembagasan pasir yang membawa kepada kesan cengkaman mekanikal yang baik untuk kekuatan lekatan yang lebih baik antara lapisan Zn-0.5Al dan substrat keluli. Selepas itu, perlindungan kakisan juga bertambah baik kerana salutan aloi Zn-0.5Al tidak mudah menggelupas semasa ujian kakisan. Pengisaran pasir pada substrat keluli memberikan prestasi salutan yang sederhana dan konvensional pra-rawatan kimia keluli salutan Zn-0.5Al mempunyai prestasi salutan yang lemah dari segi lekatan dan kakisan perlindungan. Ia boleh disimpulkan bahawa kekasaran permukaan mempunyai kesan yang besar ke atas lekatan salutan dan perlindungan kakisan salutan tergalvani.

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LIST OF SYMBOLS AND ABBREVIATIONS

Zn	- Zinc
Al	- Aluminium
Cl	- Chlorine
Fe	- Steel
%	- Percentage
ºC	- Degree Celsius
m	- Meter
g	- Gram
l	- Litre
R_a	- Average roughness
SEM	- Scanning Electrode Microscope
FESEM	- Field Emission Scanning Electron Microscope
EDX	- Energy Dispersive X- Ray Analysis
XRD	- X-Ray Diffractometer
H_2O	- Water
H_2SO_4	- Sulphuric Acid
HNO_3	- Nitric Acid
HCl	- Hydrogen Chloride (Chloride Acid)
NH_4Cl	- Ammonium Chloride
$ZnCl_2$	- Zinc Chloride

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CHAPTER 1

INTRODUCTION

1.1 Introduction

High carbon steel is used widely in the applications which require high strength property especially in the offshore corrosive environment, uncoated high carbon steel will be rendered useless due to corrosion failure. Hence, in order to solve this problem, galvanized coating was applied onto high carbon steel for barrier and cathodic protection. However, the effectiveness of the coating depends on the environment condition to which the Zinc (Zn) coating is exposed. The corrosion resistance ability of Zn in mild chloride environment is good but it has inferior resistance in aggressive chloride environment and thereby reduces the service life of the high carbon steel (Ahmad Z, 2006).

Furthermore, ductility of pure Zn coating is found to be inferior due to the presence of brittle Fe-Zn phases such as gamma, gamma1, delta and zeta. Therefore, additional of Aluminium (Al) is proposed by researchers in order to impede the formation of the brittle interlayer phases of Fe-Zn. Adhesion is another very important property for coating process. In this study, galvanized coating was investigated in terms of their adhesion and corrosion performance on high carbon steel.

1.2 Problem Statement

Over the pass decades, offshore industry has been developing extensively due to the depletion of the onshore resources and the possibly huge profits promised by the oil and gas offshore resources. Hence, vessels, offshore plants and cranes are widely used for the extractions and production of the oil and gas resources. In order to maintain the stability and forestall the free movement of the production system on the seawater, wire ropes are used as the major part in the mooring system. With recent exploration in the subsea with depths beyond 1500 meters, wire ropes showed a few limitations towards both operation system and the environment. One of the most detrimental factors which cause the steel wire to fail in the subsea environment is corrosion problem. Several conditions such as salt (and chlorine) content, dissolved oxygen, wind and wave flow erosion and temperature difference will result in premature failure of the mooring system and possible financial lost for the production system (Chaplin, C.R., 1999).

To solve the problem, galvanizing on steel wire ropes has been used extensively in the offshore industry over the centuries due to its excellent corrosion resistance. Generally galvanizing on steel wire ropes can provide two types of corrosion protection, i.e., cathodic protection and barrier protection. However, in some circumstances, pure zinc galvanizing has proven to have corrosion problem as well despite the excellent two types of protection given. The proposed research project is therefore aimed at investigating the corrosion behavior of galvanized steel ropes for offshore mooring system and introducing a new set of parameters with Zn-Al bath for better corrosion resistance.

1.3 Objective of the Research

A study on the possible corrosion mechanisms and how to minimize the corrosion actions are required. Therefore, the main objective of the research is to investigate the effects of various surface preparation treatments of high carbon steel plate on the adhesion and corrosion behaviour of Zn-Al coating.

1.4 Scope of Study

1. Selection of various surface treatments suitable for high carbon steel plates.
2. Hot dip galvanizing process of Zn-Al on surface treated high carbon steel plates.
3. Microstructural evolutions will be characterized by optical microscopy, XRD, AFM and FESEM.
4. Pin on disc test will be performed to determine adhesion property.
5. The corrosion resistance will be investigated by electrochemical test and salt spray test.

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