EFFECT OF pH, TEMPERATURE AND CHLORIDE CONCENTRATIONS ON THE CORROSION BEHAVIOUR OF WELDED 316L STAINLESS STEEL

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ABSTRACT

The aim of this work is to determine the effect of pH, temperature and chloride concentrations on the corrosion behavior of welded 316L stainless steel. An electrochemical, immersion and salt spray tests were employed. Corrosion behavior of welded 316L stainless steel in acidic and alkaline solutions at different concentrations and temperatures was investigated. The results showed that the weld metal (WM) zone was the most critical zone for pitting corrosion in alkaline (pH=7.64) and acidic (pH=1.83) conditions at temperature of 50°C. The results correlated well to the microstructural features of the metal studied. While, in the immersion test the results indicated that the highest corrosion rate was observed in stainless steel sample tested in 10% $FeCl_3$ at 50°C for both 72 and 144 hours (40.6453 mm/yr and 40.8592 mm/yr). It was also found that the salt spray test had no considerable effect on the weldment of 316L SS probably due to the limited time of testing. Field Emission Scanning Electron Microscopy (FESEM) and Optical Microscopy (OM) were used to examine the microstructure features of the tested samples in order to determine the extent of corrosion attack and type of corrosion.

ABSTRAK

Tujuan kajian ini adalah untuk menentukan kesan pH, suhu dan kepekatan klorida terhadap kelakuan kakisan kimpalan keluli tahan karat 316L. Ujian elektrokimia, rendaman dan semburan garam telah dijalankan dalam kajian ini. Kelakuan kakisan di dalam larutan asid dan alkali yang mempunyai kepekatan dan suhu yang berbeza telah dikaji melalui teknik ini. Teknik ini menunjukkan zon kimpalan adalah kawasan yang paling kritikal untuk kakisan bopeng didalam keadaan alkali (pH=7.64) dan asid (pH=1.83) pada suhu 50°C. Ini berhubung kait dengan mikrostruktur sampel yang dikaji. Manakala untuk ujian rendaman, keputusan menunjukkan kadar kakisan yang tertinggi adalah untuk keluli tahan karat didalam 10% $FeCl_3$ pada suhu 50°C untuk 72 dan 144 jam. Turut didapati ujian semburan garam tidak memberi sebarang kesan ke atas kimpalan 316L keluli tahan karat disebabkan had masa yang singkat untuk tindak balas. Mikroskop Imbasan Elektron dan Mikroskop Optik telah digunakan untuk pemeriksaan ciri mikrostruktur bagi menentukan serangan kakisan dan jenis kakisan.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

Austenitic stainless steels are widely used in industrial applications, mainly due to their good corrosion resistance. 316L stainless steel is one of the most popular austenitic stainless steel used for offshore structures. The material used in this study is 316L SS supplied by Sarawak Shell. Due to the low carbon content, 316L stainless steel has become widely used in welding applications. Welding is a reliable and efficient metal-joining process widely used in the industry. However, during the welding process, due to the intense heat input, many problems arise from the process. Since joint is generally the weakest part in the components, therefore specific attention must be taken to avoid any damage especially due to corrosion. In the environment containing chloride solution such as a sea water, chloride induced corrosion may adversely affect the material performance. In this situation, stainless steels are more susceptible to pitting corrosion, crevice and stress corrosion cracking. The research done by C. Garcia *et al.* showed that the heat affected zone or HAZ is the most critical zone for pitting corrosion for AISI 304 and 316L stainless steels.

1.2 Objectives of the Research

The main objective of the present study is to investigate the effect of pH, temperature and chloride concentrations on the corrosion behaviour of welded 316L stainless steel used as off-shore structure provided by SARAWAK SHELL.

1.3 Scopes of the Research

(a) Literature study on the welded 316L stainless steel and its corrosion behaviour.

(b) Welding process of 316L stainless steel using TIG method.

(c) Corrosion test measurement by:
(i) Immersion test (ASTM G48)
(ii) Electrochemical test (ASTM G5) and
(iii) Salt spray test (ASTM B117).

(d) Corrosion performance and analysis of samples.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusion points can be deduced from the present study:

i. Welding of 316L SS showed four distinct regionst; base metal (BM), weld metal (WM), heat affected zone (HAZ) and fusion line (FL).

ii. Electrochemical test results showed that the highest corrosion rate was obtained in sample tested in acidic solution (pH=1.83) at 50°C and the most critical zone attacked was the weld metal zone. The low to high order of corrosion penetration rate was found in specimens tested in alkaline solution (pH=7.64) at room temperature, alkaline solution at 50°C, acidic solution (pH=1.83) at room temperature and acidic solution at 50°C.

iii. Results for immersion test, at room temperature, indicated that the corrosion rate of 316L SS is significantly lower (0.3588 mm/yr for) compared to the high temperature environment (0.7183 mm/yr) for sample in 1% $FeCl_3$

iv. $FeCl_3$ solution has a detrimental effect on 316L SS compared to the solution with an addition of 5% HCl. It is due to the role of $FeCl_3$ which acts as an excellent corrosion accelerator.

v. High concentration of chloride ion (Cl^-) gives high corrosion rates and degradation of the metal surface. Corrosion penetration rate increases as the time extended from 72 to 144 hours. pH of solution, temperature and solution containing chloride concentration affect the corrosion behavior of welded 316L SS.

vi. No significant effect was observed when the specimen was tested using salt spray test. It was due to properties of 316L stainless steel which exhibits excellent corrosion resistance as the time of reaction provided was limited.

vii. Inter-dendritic attack in the weld metal zone and sensitized grain boundaries in the heat affected zone are the most relevant microstructural factors.

6.2 Recommendations for future work

Further study can be carried out to enhance the current study and the following areas are recommended for further investigation:

i. Use micro-electrochemical methods to study the mechanisms of localized corrosion processes on small areas of passive metals.

ii. Conduct salt spray test for long period to investigate the corrosion behavior of 316L stainless steel

iii. Study on other type of stainless steels and welding techniques

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