AN INVESTIGATION ON EXTERNAL CORROSION OF TEMPERED DUAL PHASE STEEL WELDED PLATE IN NaCl SOLUTIONS

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in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Investigation On Structural Vibration Problem At MARS Building UTeM" is the result of my own work except as cited in the references

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

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DEDICATION

For my beloved family and my friend,

who give all the encouragements, supports and stand by my own side no matter how over the years.

ABSTRACT

The upgrading of new steel that has stronger properties is needed to make sure the enhancement of industry development nowadays. According to the situation, dual phase steel is another substitute to low carbon steel because of its characteristics of low yield strength, excellent elongation, and good formability.Therefore, the effect of quenching and tempering process on the microstructure,hardness and corrosion rate of carbon dual-phase steel has been studied. The low carbon steel has been intercritically annealed at 800°C and 850°C followed by rapid water quenching to get different microstructure of martensite and matrix ferrite.The dual phase steel then tempered in the range of 200–400°C. This study also investigates the corrosion rate of welded of dual phase steel in 3.5% concentration of NaCl solution. The method of welding that used in this study was Shielded metal arc welding (SMAW) technique. The hardness and weight loss of metal is measured and the microstructure of dual phase steel is investigated by using Optical microscope and Scanning electron microscopy (SEM).This study has shown that the hardness and corrosion rate increase after annealing and quenching process while the ductility and the corrosion resistance increase after tempering process.The corrosion rate of the dual phase steel depends on the volume of martensite,which is the dual phase steel that through the heat treatment by the annealing process at 850°C (850DPS) has the higher corrosion rate than the dual phase steel annealed at 800 °C (800DPS).

ABSTRAK

Menaik taraf keluli baru yang mempunyai ciri-ciri yang lebih kuat amat diperlukan sesuai dengan peningkatan pembangunan industry pada masa kini. Bagi memenuhi kehendak tersebut, keluli dwi fasa di cipta sebaga salah satu lagi gantian untuk keluli karbon rendah kerana memiliki ciri-ciri kekuatan yang rendah tegangan luluh bawah, kadar kelenturan yang tinggi dan sifat mampu bentuk bahan logam yang baik. Oleh itu, kesan proses rendaman untuk menghilangkan haba dan pemanasan semula proses keatas mikrostruktur, kekuatan dan tahap karat keluli dwi fasa telah dikaji. Keluli karbon rendah telah dipanaskan pada suhu 800°C dan 850°C kemudian di rendam di dalam air untuk menghilangkan haba untuk mendapatkan mikrostruktur yang berbeza jumlah martensit dan matrik ferit. Kemudian, keluli dua fasa di panaskan semula dalam julat 300°C. Kajian ini juga mengkaji kadar karat keluli dwi fasa yang telah dikimpal kemudian direndam dalam 3.5% kepekatan larutan NaCl. Kaedah kimpalan yang digunakan dalam kajian ini ialah kaedah arka logam kimpalan teknik .Tahap kekuatan besi dan kehilangan berat logam diukur dan mikrostruktur keluli dwi fasa di kaji dengan menggunakan mikroskop optik dan mikroskop elektron pengimbas. Kajian ini menunjukkan bahawa kekuatan dan tahap karat meningkat selepas proses rawatan haba manakala kemuluran dan rintangan terhadap karat meningkat selepas proses pemanasan semula. Kadar karat keluli dwi fasa hala bergantung kepada jumlah martensit, keluli dua fasa yang melalui rawatan haba pada suhu 850°C (850DPS) mempunyai kadar karat yang lebih tinggi daripada keluli dwi fasa yang di panaskan pada suhu 800°C (800DPS).

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LIST OF ABBEREVATIONS

^oC	Degree Celsius
Cl	Cloride
CM	Confocal Microscope
DPS	Dual Phase Steel
EDS	Electron Dispersive Spectroscopy
Fe	Iron
GMAW	Gas Metal Arc Welding
GTAW	Tungsten Inert Gas
H20	Water
HAZ	Heat affected zone
HCl	Hydrochloric Acid
NaCl	Sodium chloride
OH	Hydroxide
OM	Optical Microscope
SEM	Scanning Electron Microscope
SMAW	Arc Welding

LIST OF SYMBOLS

γ	=	beta
α	=	alpha

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Nowadays, the industry's demands for low carbon steel increase particularly in construction and marine structure industry. The upgrading of new steel that has stronger properties is needed to make sure the enhancement of industry development. According to the situation, dual phase steel is another substitute to low carbon steel because of its characteristics of low yield strength, excellent elongation and good formability. Dual phase steel is transmuted from low carbon steel by annealing process at the region present of austenite and alpha ferrite above the eutectoid line, then go along with water quenching process (Hüseyin U. & Emrah Ö. , 2013) Dual-phase steel (DPS) is high-strength steel that has a ferrite and martensitic microstructure. Martensite plays an important role towards the properties of dual phase steel. The strength of dual phase steel is known to increase the amount of martensite increased within the microstructure. However, with the increment percentage of martensite the ductility of dual phase steel making it decrease. To reduce the hardness of the martensite the tempering process can be applied to dual phase steel by lowering some of the internal stresses that were created during phase transformation of annealing (G.Ylva , 2010).

The phase of heating and cooling that occurs during the welding process affects the microstructure and surface composition of welds and adjacent base metal. Consequently, the welded area is likely to become more expose to steel corrosion attack than basis plate

(S.S.Ng et al., 2013). Among many possibilities of corrosion attack on steel, pitting corrosion is considered as detrimental since it cause a fracture in elements. There are several factors that are affecting corrosion attack such as the presence of water, amount of oxygen dissolved in the water, the temperature and the presence of electrolytes in the water as sodium chloride (NaCl). Sodium chloride environment is one source of corrosion in steel(Mustafa A., Hayrettin A. and Fatih H. , 2013). Corrosion on steel was discovered to be a factor of failures of ships industry, oil and gas industry and other marine equipment. On offshore platforms the expense for replacement of broken equipment is large, and this cause loses in production. The selection of dual phase steel that more resist to corrosion will lower the risk of breakdown equipment.

In this study, corrosion of welded dual phase steel that undergoes tempering process from different annealing temperature will be investigated to compare its effect on the martensite microstructure eventually, looking at the effect of microstructural changes towards its susceptibility to corrosion.

1.2 PROBLEM STATEMENT

Dual phase steel has been introduced as an alternative to low carbon steel due to its superior strength, its susceptibility to corrosion is not yet to be fully understood. In this study, investigation of welded dual phase steel that undergoes tempering process will be done to look at the corrosion attack, especially along the weldment. Furthermore, for corrosion purpose the steel will be immersed in a NaCl solution which one the most corrosion environment for steel.

1.3 OBJECTIVES

The objectives of this research are as follows:

1. To conduct heat treatment and tempering process to produce dual phase steel from low carbon steel.
2. To conduct the immersion corrosion test of dual phase steel in 3.5 % concentration of sodium chloride.
3. To conduct hardness test of dual phase steel before and after the corrosion test.
4. To investigate the corrosion product on dual phase steel after the corrosion test.

1.4 SCOPE OF PROJECT

The scopes of this research are:

1. Use SMAW on butt joint to weld two pieces of the specimen.
2. Use different of heating temperatures to get different of martensite percentage.
3. Temper the specimens in the temperature range of 200°C to 400°C.
4. Check, compare and record the weight loss of the specimens before and after the corrosion test.
5. Conduct a corrosion test by immersing the specimens in 3.5% concentration of Sodium Chloride, NaCl for a period of time.
6. Use Optical Microscope (OM) and Confocal Microscope (CM) to study the microstructure of the specimens after the corrosion test.

7. Use Scanning Electron Microscope (SEM) and Electron Dispersive Spectroscopy (EDS) to investigate the specimens further in terms of specific elements and its chemical composition after the corrosion test.

CHAPTER 2

LITERATURE REVIEW

2.1 STEEL

Steel is alloys made up from the iron mixed with carbon and other elements. These alloys differ both in the method they are made and in the amounts of the materials added to the iron. The properties of carbon steel depend on the amount of carbon it contains and basically carbon steel has a carbon content of less than 1.5% along with small percentages of silica, Sulphur, phosphorus and manganese. Particularly, steel is a crystalline alloy of iron, carbon and several other elements which through hardening proces above its critical temperature (Seblin.B *et al.* 2005). Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans. In fact, there are three types of steel were categorized based on the percentage of carbon they contain, which are mild, medium and high carbon steel (Handbook 2007) .

a) Low carbon steel or mild steel- contain 0.05%-0.25% carbon,it is a low-cost material that is easy to shape. While not as hard as higher-carbon steels, heat treatment can increase its hardness.

b) Medium Carbon Steel - contain 0.29%-0.54% carbon, with. Medium carbon steel is ductile and strong, with long lasting structure.

c) High Carbon Steel – contain 0.55%-0.95% carbon. It is very strong and hard to shape.

That is important to differentiate the amount of carbon content in steel to determine their hardness, brittleness, and ductility. By increasing the carbon content in the steel it increasing their hardness and decreasing their ductiliy properties.

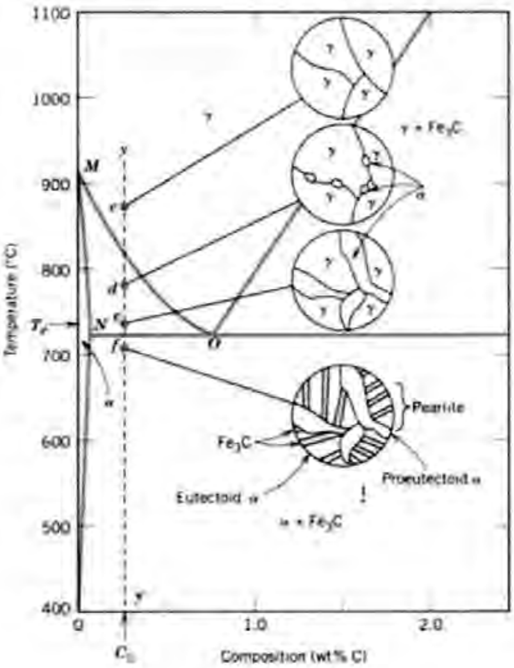

Figure 2.1 : Carbon phase diagram.(Nadlene *et al.* 2011)

By considering to the Figure 2.1,The microstructure of steel above the eutectoid temperature consists of pearlite and ferrite. At low carbon content about 0.2% there are consist of 25 % pearlite and 75% proeutectoid ferrite. When the volume of carbon increase to 0.8% the steel contain fully pearlitic structure condition. Nevertheless, in gradually cooled carbon steels, the hardness and ductility of the steel are showed by the quantity of the soft, ductile ferrite and the hard, brittle cementite. The increase of cementite, increase the hardness and lower the ductility of steel.(Kempaiah *et al.* 2001)

For marine applications, mild steel is the most important metal for constructional demands of quality of relatively low cost, mechanical strength and ease of fabrication. However, mild steel corrodes easily in seawater and except effectively protected by a coating. According to that, to prevent loses strength which may affect in structural failure the dual phase steel has been created. Dual phase steel that has higher strength properties and good formability can lower the risk of failure in the structure.(Park *et al.* 2009)

2.2 Dual phase steel.

The low carbon steel is experienced annealing process which changes the microstructure of metal to the two phase field of austenite and ferrite. Austenite is changing to martensite by the proses quenching, hardening and adequate cooling time. The steel produced is microstructure with soft continuous ferrite with fixed hard martensite particles. (Granbom n.d.)

The microstructure of dual phase steel that produced from the annealing at a lower temperature is a form of fibrous shape which is gray uniform fibrous ferrite and dark colored martensite. However, the microstructure of dual phase steel that produced from higher temperature consists of islands of martensite in a ferrite matrix. The tensile strength of dual phase steel is increase with the increasing of martensite structure ,but the ductility of dual phase steel decreases. (Uzun 2013)

A similar study of dual phase steel by (Ejovwoke 2014) and (Enrique and Moreno 2014) show that dual phase steel microstructure generally mixed of ferrite and martensite.

To get the dual phase steel microstructure ,the pearlite phase must be decreased, with the austenite being stimulated to procedure martensite by rapid cooling during the water quenching method (Enrique and Moreno 2014).The dual phase steel hardness increase with the increasing of volume of matensite (Uzun 2013).The volume of martensite is effect the strength level and the refinement of the martensite particles size also affect the hardening rate.(Ejovwoke 2014)

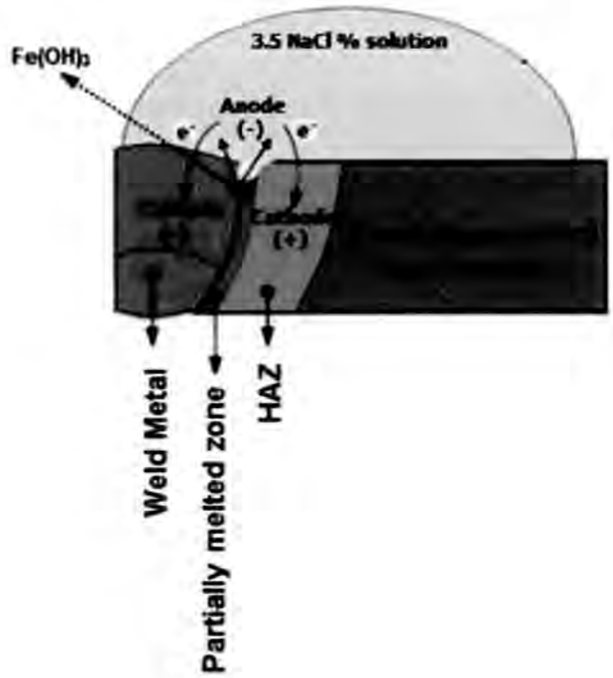

Figure 2.2 : Corrosion of dual phase steel

From the Figure 2.2 It is predictable that the galvanic couple caused pitting reaction on the corrosion of dual-phase steel joints. It is detected that the corrosion attack at the weld area specially begins in the inside part melted zone in the middle of weld metal and heat affected zone (HAZ), and extended near the HAZ. Therefore, HAZ may corrode quicker than the weld metal. This is recognized, the two galvanic couples are started between two areas either between the weld metal and the partially melted zone or between HAZ and the partially melted zone.

In 3.5% NaCl solution, sodium and chlorine ions are decomposed and then reacted with ferrous ions, thus the pH value decrease (Uzun 2013). Therefore, the corrosion failure of steels increases. In addition, the decreasing of pH (the acidity of sodium chloride is increased) will increase the corrosion rate.(Arjmand and Adriaens 2012).There is similar study by Prawoto from the journal of Effect Of Ph And Chloride Concentration On The Corrosion Of Duplex Stainless Steel stated that corrosion rate will increase with the decreasing of pH value.

On the other hand, it was observed a micro corrosion couple and two macro corrosion couples at the dual-phase steel joints. Macro corrosion couples are formed between the weld metal and the partially melted zone, between HAZ (cathode) and the partially melted zone (anode). The micro corrosion couple is formed between ferrite (anode) and martensite (cathode).

2.3 Corrosion reaction

In the corrosion of dual-phase steels in 3.5% NaCl solution, following corrosion reactions occur simultaneously.

Anodic reaction : $Fe \rightarrow Fe^{2+} + 2e$ (1)

Cathodic reaction: $Fe^{+2} + 2OH^{-} \rightarrow Fe(OH)2$ (2)

In 3.5% NaCl solution, sodium and chlorine ions are decomposed and then reacted with ferrous ions,

$NaCl \rightarrow Na^{+} + Cl^{-}$ (3)

$Fe^{+2} + 2Cl^{-} \rightarrow FeCl2$ (4)

$Fe^{+3} + 3Cl^{-} \rightarrow FeCl3$ (5)