SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion it is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluid) with Honours"

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INVESTIGATION OF CORROSION RATE OF SS316 PLATE INSIDE AN ALKALINE ELECTROLYZER

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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and questions which have been duly acknowledged."

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Special dedication to my mother, Siti Mariam Binti Shaari, thank you for the love and attention, for the help and educate, for the supports and hear complaints.

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ABSTRACT

Alkaline electrolysis is considered to be a basic technique for hydrogen production. Many researchers have investigated the alkaline electrolysis in order to promote the electrochemical reaction. In most of the metal corrosion will occurs via electrochemical reaction at the interface of the metal and an electrolyte solution. While the corrosion will occur on metal but the different metal have different rate of corrosion depend on the composition of the metal. This paper studies about the corrosion rate of Stainless Steel type 316 with different thickness into potassium hydroxide (KOH) electrolyte alkaline (pH14). The aim for this investigation is to obtain the corrosion rate of stainless steel plate in an alkaline electrolyte and to study the corrosion rate of stainless steel with different thickness. The stainless steel will be soaked into Potassium Hydroxide because of Potassium Hydroxide is a highly corrosive chemical. The investigation covered the effects of current, solution concentration, and thickness of stainless steel on the characteristics of alkaline electrolysis. The study was carried out under atmospheric pressure using stainless steel electrodes. It will involve the flow process in electrolysis. Besides that, this project also needs the rolling mill machine to reduce the thickness of stainless steel. In this experiment, the plate of stainless steel was cut into pieces in size 5 cm x 5 cm and the range of thickness is 0.2 mm to 0.5 mm. The result shows that by reducing the plate thickness of stainless steel will increase the corrosion rate. In conclusion, the corrosion rate for thickness 0.2 mm is higher than 0.5 mm and thickness 0.5 mm longer good for low corrosion rate.

ABSTRAK

Elektrolisis alkali dianggap sebagai teknik asas untuk pengeluaran hidrogen. Ramai penyelidik telah menjalankan kajian elektrolisis alkali bagi mepromosikan tindak balas proses elektrokimia. Kebanyakan logam terkakisan melalui tindak balas elektrokimia di antara permuka logam dan larutan elektrolit. Walaupun kakisan akan terhasil pada semua logam tetapi logam yang berbeza mempunyai kadar yang berbeza bergantung kepada kakisan komposisi logam. Kajian ini mengkaji mengenai kadar kakisan daripada keluli tahan karat jenis 316 dengan ketebalan yang berbeza ke dalam Kalium Hidroksida (KOH) elektrolit alkali (pH14). Tujuan penyiasatan ini adalah untuk mendapatkan kadar kakisan plat keluli tahan karat dalam elektrolit alkali dan mengkaji kadar kakisan daripada keluli tahan karat dengan ketebalan yang berbeza. Keluli tahan karat akan direndam ke dalam Kalium Hidroksida kerana Kalium Hidroksida adalah bahan kimia yang sangat menghakis. Kajian ini juga meliputi kesan arus elektrik, kepekatan larutan, dan ketebalan keluli tahan karat pada ciri-ciri elektrolisis alkali. Kajian ini telah dijalankan di bawah tekanan atmosfera menggunakan elektrod keluli tahan karat. Ia akan melibatkan proses aliran dalam elektrolisis. Selain itu, projek ini juga memerlukan rolling mill mesin untuk mengurangkan ketebalan keluli tahan karat. Dalam percubaan ini, plat jenis keluli tahan karat dipotong menjadi kepingan bersaiz 5 cm x 5 cm dan pelbagai ketebalan adalah 0.2 mm hingga 0.5 mm. Hasil kajian menunjukkan bahawa dengan mengurangkan ketebalan plat keluli tahan karat akan meningkatkan kadar kakisan pada plat tersebut. Kesimpulannya, kadar kakisan untuk ketebalan 0.2 mm lebih tinggi berbanding 0.5 mm dan ketebalan 0.5 mm adalah sesuai dan lebih baik untuk kadar kakisan yang sedikit.

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CHAPTER I

INTRODUCTION

1.0 INTRODUCTION

Stainless steels are iron base alloys that contain approximately 11% Cr, the amount needed to prevent the stainless steel from the formation of rust in unpolluted atmospheres. Few stainless steel contains more than 30% Cr or less than 50% Fe (Davis, 1999). For the stainless steel type 316, the minimum Cr is 16 % and maximum Cr is 18 %, while stainless steel type 304, the minimum Cr is 18% and maximum is 20% (Nandishwar, 2010). Stainless steel type 316 has high corrosion resistance and can be easily formed and welded, making it an ideal material for many applications (Li, Dong, Xiao, Yao, & Li, 2014). A common misconception, stainless steel will not be affected by corrosion process.

Corrosion will be defined as an impairment of the properties of material due to interactions between the material and environment. Corrosion process can be separated into 8 types of corrosion that will be impacted on stainless steel. The type of corrosion is Uniform Attack, Crevice Corrosion, Pitting, Galvanic Corrosion, Intergranular Corrosion, Selection Leaching, Erosion Corrosion and Stress Corrosion. Corrosion can be defined as the degradation of a material due to a reaction with its environment. Degradation implies deterioration of physical properties of the material.

This experiment will investigate of corrosion rate by using the type 316 stainless steel with different thickness. These investigations have been made using other materials of alloy steel and carbon steel. The material is dissolved under solution sodium chloride (Mehdipour, Naderi, & Markhali, 2014). For this experiment will be carried out using the stainless steel 5cm x 5cm and the range of thickness is 0.2 mm to 0.5 mm. A 3mm thickness plate for the hydrogen production process has been researched by Mahrous (Mahrous, Sakr, Balabel, & Ibrahim, 2010)("HHO Dry Cell Kits," 2009). Recent studies showed that the different specimen size will get the different corrosion rate and reasonable for us to reduce the specimen size in order to attain excellent corrosion resistance (Wu et al., 2014)(Mirzaee Sisan, Abdolahi Sereshki, Khorsand, & Siadati, 2014).

For this experiment a 3.5 A of current will be used to test the corrosion with different thickness. The material of stainless steel will be soaked into potassium hydroxide (KOH) electrolyte alkaline (pH14) for a day to investigate the corrosion rate. The results of the study will give the suitable thickness to get the smaller corrosion rate.

1.1 PROBLEM STATEMENT

Corrosion is a process through which metals in manufactured states return to their natural oxidation states. This process is a reduction-oxidation reaction in which the metal is being oxidized by its surroundings. The corrosion will occur on metal but the different metal have different rate of corrosion depend on the composition of the metal. Corrosion will reduce the metal thickness lead to loss of mechanical strength and surface characteristic.

The problem statement of this project is about the corrosion rate for stainless steel. This project will be investigated the corrosion rate of stainless steel type 316 with different thickness and identify the suitable thickness to reduce the weight of the product. But due to plate type 316 cannot be obtained as soon as possible, stainless steel type 304 was be replaced as a material for this experiment. Each product has a thickness that will effect to the weight of the product.

So, to reduce the weight, the thickness will be reduced, but the corrosion rate can control. The stainless steel will be soaked into Potassium Hydroxide because of Potassium Hydroxide is a highly corrosive chemical. Therefore, the Potassium Hydroxide will increase the rate of corrosion process.

1.2 OBJECTIVE

There are two objectives of this experiment. The objectives are:

i. To obtain the corrosion rate of stainless steel plate type 316 in an alkaline electrolyte.
ii. To study the corrosion rate of stainless steel type 316 with different thickness.

1.3 SCOPE OF RESEARCH

There are a few scopes need to follow for this experiment in order to achieve the experiment objective. The scopes of the project area:

i. To study the corrosion rate by using alkaline electrolysis experiment.
ii. To use the stainless steel type 316 as the material and the range of thickness is 0.1mm to 0.5mm.
iii. Soaking of different plate thickness in a KOH solution at the same time interval

1.4 THESIS OUTLINES

This thesis contains five chapters which are the Chapter 1 is an introduction, Chapter 2 is a literature review, Chapter 3 is a methodology and Chapter 4 is results and discussion and lastly Chapter 5 is a conclusion of this project. In the first chapter contains the introduction, problem statement, objectives and scope of the project. In the second chapter, the literature reviews of this report are explained. This chapter generally explained about stainless steel, corrosion process, electrolysis process, potassium hydroxide and corrosion rate. Next, chapter 3 explain about the project methods and how to conduct the project. In the next chapter which is chapter 4, all the result that obtained from experiment is recorded in this chapter and all the result and problem throughout this project are discussed. Lastly, chapter 5 is a conclusion that concludes the entire project and describe on the result. In this chapter also included the several recommendations are proposed for further research.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

The literature review has been carried out about the corrosion of stainless steel. Besides that, it will involve the flow process in electrolysis. Furthermore, analysis of resulting of the different thickness effect of corrosion. Corrosion rate monitoring aims to state the suitable thickness and compare it with the previous experiment.

2.1 STAINLESS STEEL

Based on the market, the Stainless Steel Quarto will be rolled in flat condition to a specific thickness. The available thickness range is from 5mm and above (Vijesh Kumar Jain, 2012) and Stainless Steel Coil Plate thickness are 13mm for the hot rolled and 8mm for cold rolled application (Vijesh Kumar Jain, 2012). While, some of company manufacturing of stainless steel 316 produce the thickness 0.3mm to 200mm (Nandishwar, 2010)("Samir Steel Syndicate," 2014).

All types of stainless steel have a high resistance to the corrosion. The low alloyed grades resist corrosion in atmospheric condition. While the highly alloyed grades can resist corrosion in more condition such as most acids, alkaline solution, and chloride bearing environment, even at elevated temperature and pressures.

The stainless steel has many benefits for example, some of the grades will resist scaling and maintain high strength at very high temperature. The majority of stainless steel can be cut, formed, welded, machined and fabricated easily. Moreover, for the cold work hardening properties of many Stainless steels can be used in design to reduce material thicknesses, weight and cost. Other of Stainless Steel may be heat treated to make very high strength components.

According to the MIL HDBK-73S and Japanese Industry Standard (JIS), there are different stainless steel grades with different corrosion resistance and mechanical properties (Fong-yuan ma, 2012). For Stainless Steel Grades 300 Series are non-magnetic and have an austenitic structure. The basic Stainless Steel Grades 300 alloys contains 18% chromium and 8% nickel. These alloys are subject to crevice corrosion and pitting corrosion. They have a range of incubation times in seawater ranging from essentially zero in the case of the free machining grades such as Type 303, to 6 months to 1 year for the best alloys such as Type 316. **Figure 2.1** shows the plate of Stainless Steel type 316.

They have been widely used in facilities with mixed results. If used in an application where chloride levels are low or where concentration cell corrosion has been prevented through design, they are likely to perform well. When chloride levels are high and where concentration cells can occur, the performance of these alloys has been often poor.

Figure 2.1: Stainless Steel 316 Plates

The commercial 316 stainless steel was used as metallic substrate material and the composition for 316 of stainless steel is given in **Table 2.1** (Nandishwar, 2010).The composition of Type 316 stainless steel includes slightly increased nickel content and the presence of 2%-3% of molybdenum, which significantly increases the metal's corrosion resistance.

Table 2.1: Composition for 316 of Stainless Steel (Nandishwar, 2010)

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
316	Min	-	-	-	0	-	16.0	2.00	10.0	-
	Max	0.08	2.0	0.75	0.045	0.03	18.0	3.00	14.0	0.10

Stainless steel type 304 has no significant difference with type 316. The only different between of 2 type stainless steel are chromium and nickel value. The chromium in type 304 is higher than type 316 and nickel is lower. The composition for 304 of stainless steel as shown in **Table 2.2** (Nandishwar, 2010) and **Figure 2.2** shows the plate of Stainless Steel type 304.

Table 2.2: Composition for 304 of Stainless Steel (Nandishwar, 2010)

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
304	Min	-	-	-	0	-	18.0	-	8.0	-
	Max	0.08	2.0	0.75	0.045	0.03	20.0	-	10.5	0.10

Figure 2.2: Stainless Steel 304 Plates

2.2 CORROSION PROCESS

Corrosion is the destructive attack of a material by reaction with its environment (Roberge & Pierre, 2000). The corrosion process shows the characteristics of the time and variant corrosion rate, and the corrosion process can be divided into four phases (Yuan, Jiang, & Peng, 2010). **Figure 2.3** shows the corrosion loss in steel under seawater immersion (Y.Kawasaki, M. Kitaura, 2012). In Phase 1, the onset of corrosion is initiated. The activity of the corrosion process is dominated by the rate of penetration of oxygen and water. Then a corrosion loss decreases at Phase 2, because the flow of oxygen is eventually inhibited by corrosion product.

The corrosion process increases again at Phase 3, because the corrosion penetrates inside and the expansion of corrosion progresses at an almost constant speed at Phase 4. Thus, the phenomenological model is referred to as two transition stage of the onset of corrosion and the growth of corrosion products.

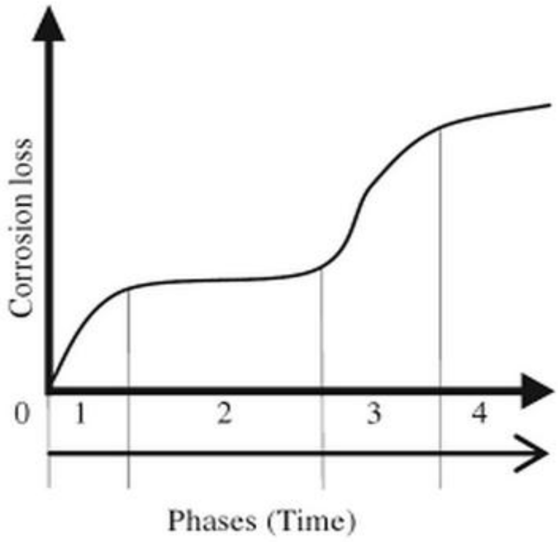

Figure 2.3: The Corrosion Loss in Steel under Seawater Immersion
(Y.Kawasaki, M. Kitaura, 2012)

There are three main components necessary for corrosion to occur which is metal, an oxygen and an electrolyte. Many metals used in production occur naturally in an ore and therefore must be separated out, leading to reduced stability. Corrosion can be separated into 8 types of corrosion, but not all types of corrosion occur in stainless steel. The most common forms of corrosion in stainless steel are pitting corrosion, crevice corrosion, general corrosion, stress corrosion, intergranular corrosion and galvanic corrosion (British Stainless Steel Association, 2014)

Pitting corrosion is a localized phenomenon confined to smaller areas. Pitting factor can be used to evaluate severity of pitting corrosion which is usually observed in passive metals and alloys. Concentration cells involving oxygen gradients or ion gradients can initiate pitting through generations of anodic and cathodic areas. Chloride ions are damaging to the passive films and can make pit formation auto-catalytic (Natarajan, 2014).

Crevice corrosion is a localized attack on a metal adjacent to the crevice between two joining surfaces, whether two metals or non-metal crevices. The corrosion is generally confined to one localized area to one metal. This type of corrosion can be initiated by concentration gradients may be due to ions or oxygen.

Various factors influence crevice corrosion such as materials, environmental conditions such as pH, oxygen concentration and temperature, geometrical features of crevices or surface roughness (Natarajan, 2014).

Uniform or general corrosion is a very common form found in ferrous metals and alloys that are not protected by surface coating or inhibitors. A uniform layer of ruston the surface is formed when exposed to corrosive environments Atmospheric corrosion is a typical example of this type (Natarajan, 2014).

Galvanic corrosion occurs if two dissimilar metals are in contact with each other and with an electrolyte e.g. water or other solution, it is possible for a galvanic cell to be set up. This is rather like a battery and can accelerate corrosion of the less 'noble' metal. Other environmental factors contribute to corrosion such as pH, salt concentration, and oxygen concentration, along with the velocity of the water and temperature (British Stainless Steel Association, 2014).

Stress corrosion or stress corrosion cracking refers to failure under simultaneous presence of a corrosive medium and tensile stress. Two classic examples of stress corrosion cracking are caustic embrittlement of steels occurring in riveted boilers of steam-driven locomotives and season cracking of brasses observed in brass cartridge cases due to the ammonia in the environment. While intergranular corrosion is common in stainless steel welded structures and is referred to as weld decay. Intergranular attacks can occur in other alloys as well (Natarajan, 2014).

In the electrolysis, the possible corrosion will occur are pitting corrosion, crevice corrosion and galvanic corrosion. The three types of corrosion related to oxygen concentration.