

Temperature Effects on Stainless Steel 316L Corrosion in the Environment of Sulphuric Acid (H₂SO₄)

by I Gusti Ayu

Submission date: 22-Jun-2019 12:50PM (UTC+0700)

Submission ID: 1146027249

File name: international_conference_IOP_scopus_1.pdf (434.27K)

Word count: 2907

Character count: 14870

PAPER • OPEN ACCESS

Temperature Effects on Stainless Steel 316L Corrosion in the Environment of Sulphuric Acid (H_2SO_4)

To cite this article: I.G. Ayu Arwati *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **343** 012016

View the [article online](#) for updates and enhancements.

Related content

- [Study of solvent debinding parameters for metal injection moulded 316L stainless steel](#)
M F F A Hamidi, W S W Harun, N Z Khalil et al.
- [Effect of concentration of hyaluronic acid and NaCl on corrosion behavior of 316L austenitic stainless steel](#)
Ankur V Bansod, Nilay N Khobragade, Karansagar V Giradkar et al.
- [Serrated Flow Behavior of Aisi 316L Austenitic Stainless Steel for Nuclear Reactors](#)
Qingshan Li, Yinzhong Shen and Pengcheng Han

Temperature Effects on Stainless Steel 316L Corrosion in the Environment of Sulphuric Acid (H₂SO₄)

I.G. Ayu Arwati^{1,2*}, Edy Herianto Majlan¹, Wan Ramli Wan Daud¹, Loh Kee

Shyuan¹, Khuzaimah Binti Arifin¹, Teuku Husaini¹, Sagir Alfa², and Fakhruddien Ashidiq²

¹Fuel Cell Institute, National University of Malaysia, 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia.

²Mechanical Engineering Program, Engineering Faculty, Mercubuana, 1160, Indonesia

arwatiayu@yahoo.com

Abstract. In its application, metal is always in contact with its environment whether air, vapor, water, and other chemicals. During contact, chemical interactions emerge between metals and their respective environments such that the metal surface corrodes. This study aims to determine the corrosion rate of 316L stainless steel sulphuric acid environment (H₂SO₄) with weight loss and electrochemical methods. The corrosion rate (CR) is value of 316L stainless steel by weight loss method with sulfuric acid (H₂SO₄) with concentration of 0.5 M. The result obtained in conjunction with the increase of temperature the rate of erosion obtained appears to be larger, with a consecutive 3 hour the temperature of 50°C is 0.27 mg/cm²h, temperature 70°C 0.38 mg/cm²h, and temperature 90 °C 0.52 mg/cm²h. With the electrochemical method, the current value increases by using a C350 potentiostat tool. The higher the current, the longer the time the corrosion rate increases, where the current is at 90 °C with a 10-minute treatment time of 0.0014736 A. The 316L stainless steel in surface metal morphology is shown by using a Scanning Electron Microscope (SEM).

1. Introduction

Metal is generally used as a support tool given its several advantages compared with other materials [1]. Certain types of metal are used as design/construction materials to create equipment, such as bipolar stack PEM fuel cells. One type of stainless steel used is 316L stainless steel the type of steel that is easy to rust. Corrosion is a metal material damage caused by a reaction between metals and their respective environments, thereby resulting in metal oxide, metal sulphide, or other reactions, such as calcification. From a chemical point of view, corrosion is essentially a metal reaction to ions on the metal surface that directly contacts aqueous and oxygen environments [1]. In its application, metal is always in contact with its environment whether air, vapour, water, and other chemicals. When metals come in contact with their respective environments, interactions between them happen. As a result, the metal surfaces connecting form anode and cathode regions. In the anode region, metals release electrons to the cathodes captured, thereby forming a hydroxyl group, which then reacts with the metal ions that



Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd

have released the electrons [2].

Stainless steel is a corrosion-resistant alloy steel, which is widely used in chemical, fertiliser, food and beverage industries and is related to seawater and all industries that require corrosion resistance [3]. Corrosion is the decline in the quality of metals due to the electrochemical reaction with their respective environments that are directly related to open air, which is generally referred to as atmospheric corrosion. Almost all corrosion products are caused by the atmospheric environment. One reason is that most metals are always associated with open air where humidity and pollutant contents may affect metal leakages. Factors such as temperature, humidity and chemical content in the air determine the degree of corrosion. Meanwhile, metal composition, metallurgical structure, and metallurgical processes also accelerate corrosion. Corrosion is a difficult metal problem, dangerous and very expensive if not treated. Generally, corrosion is a metal deterioration due a reaction between metals and the surrounding environments. The important types of corrosion are uniform, galvanic, crack, current-assisted, intragranular and high temperature corrosions. Corrosion results from a low pH effect of water in which H^+ ions react with electrons in cathodes. The factors that can cause corrosive metals are, pH, oxygen content, air, metal and temperature [4] [3]. Corrosion prevention in metal can be done in several ways, such as cathodic protection, coating and can use also use inhibitor. Inhibitor use green is the new trend in corrosion control [6][8]. Corrosion can be defined as an electrochemical event between metals or metal alloys and their respective environments, with the following components as the conditions of occurrence: (1) anode, as the cover of oxidation reaction., (2) cathode as closed the occurrence of reduction reaction, (3) media electrolyte as the conductor of electric current and (4) the emergence of electric current between the anode and the cathode. factors that can affect the corrosion process, among others. (I) Temperature—The rise in temperature results in an increase in the rate of corrosion reaction. This scenario happens because the high temperature of the kinetic energy of the reacting particles increases such that it exceeds the magnitude of the price of activation energy. Consequently, the rate of reaction corrosion also accelerates, and vice versa. (II) Fluid flow velocity or speed stirring—The corrosion rate tends to increase as the rate or velocity of fluid flow increases. This scenario happens because the contact between reactants and metals is significant such that the number of metal ions increases and Abu-Dalo [7] more loose so that the metal will experience the fragility (corrosion). (III) Concentration of corrosive material—This activity is related to the pH or acidity and alkalinity of a solution. The acidic solution is highly corrosive to the metal where the latter in the acid solution medium will rapidly corrode due to the anode reaction. Meanwhile, an alkaline solution may cause corrosion in the cathode reaction because such a reaction is always in conjunction with the anode reaction. (IV) Oxygen—Oxygen in the air can be in contact with moist metal surfaces. So the chances of becoming more corrosion. In water (open environment), the presence of oxygen causes corrosion.

Corrosion velocity can be calculated by weight gain union time unity can also be calculated by the thickness of oxidation formed time unity. Corrosion designation is generally made by adding or removing the weight graph as a function of time. The calculation of the corrosion rate (CR) uses the equation below for Abu-Dalo [7]:

$$CR = \frac{m1 - m2}{A t}$$

where m_1 and m_2 are the weight losses (mg) before and after the immersions in the test solutions, respectively, A is the surface area of the specimens (cm^2) and t is the exposure time (hour).

2. Methods

In this study, SS 316L metal, with $1 \times 1 \text{ cm}^2$ metal size in 0.5 M sulfuric acid environment, was tested at room temperature, 50°C , 70°C and 90°C using immersion times 1, 2 and 3 hours. Before the metal test was cleaned using sandpaper from grade 800 to grade 1200, the metal was then cleaned with aquades DM and alcohol. For testing, the corrosion rate was determined in this study using weight loss and electrochemical methods with potentiostate. The morphology and surface of 316L stainless steel specimens were examined after polishing and after exposure to 0.5 M sulphuric acid using scanning electron microscopy (SEM).

3. Results and Discussion

To see the corrosion rate was carried out by preparation of 316L stainless steel cutting with size $1 \times 1 \text{ cm}^2$, then immersion with sulfuric acid (H_2SO_4) with 0.5. Figure 1 shows that the 316L stainless steel metal in the sulfuric acid environment (H_2SO_4) with a concentration of 0.5 M at a temperature of 50°C , 70°C , and 90°C , at a temperature of 50°C at a resistance of 1 hour 0.24mg, while in the immersion for 3 hours there was a reduction of 0.66. With the rise in a temperature rate of 70°C in 1 hour, a weight loss of 0.66 mg and M concentration for 1, 2 and 3 hours with the variation of temperatures 50°C , 70°C and 90°C occurs. The weight loss (1.14 mg) in the 3-hour immersion was significant. If the temperature rate increased to 90°C in a 1-hour immersion with a weight loss of 0.88 mg, then in 3 hours, a high weight loss of 1.14 emerged. From the data obtained it can be concluded that the longer time and temperature the higher the heavy metal 316L stainless steel means that the metal is clearly corrosive.

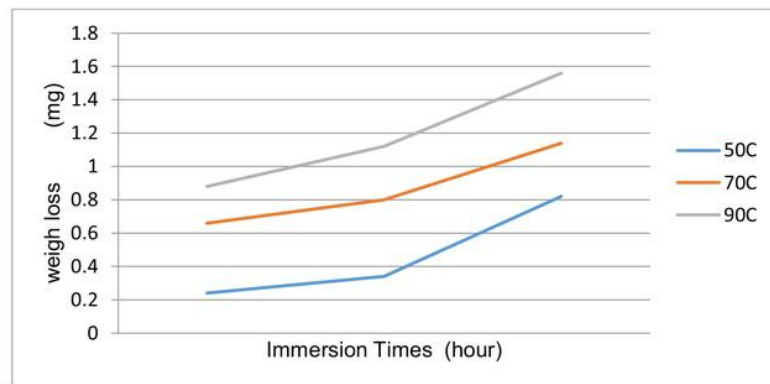


Figure 1. Graph of 316L stainless steel weight loss by immersion in acid sulphate (H_2SO_4) at concentration 0.5 M in 1, 2 and 3 hours with temperature variations of 50°C , 70°C and 90°C .

From the data of corrosion rate calculation to immersion with sulfuric acid 0.5 M for 1 hour at temperature 50°C , is $0.24 \text{ mg/cm}^2\text{h}$. Figure 2 illustrates the highly detailed CR for 2- and 3-hour smearing. Evidently, the temperature increased, and the length of immersion times reduced the corrosion rate. After calculating a rust rate of 0.5 M in a 3-hour immersion at 90°C , 316L stainless steel has a $0.52 \text{ mg/cm}^2\text{h}$ rust CR content. From the data of corrosion rate

calculation to immersion with sulfuric acid 0.5 M for 1 hour at temperature 50°C is 0.24 mg/cm²h. Figure 2 exhibits the highly detailed CR for 2- and 3-hour smearing. Apparently, the temperature increased, and the length of immersion times reduced the corrosion rate. 316L stainless steel after calculating corrosion rate (CR) content of 0.5 M in a 3 hour immersion at 90°C has a 0.52 mg/cm²h corrosion. Corrosion rate decreases with increasing time. The higher the temperature and the soaking time the corrosion rate decreases. With temperature rise and immersion period in the yield at 50°C by immersing the corrosion rate of 3 hours 0.18 mg/cm²h, at 70°C temperature with 3 hours immersion 0.38 mg/cm²h, at 90°C with 3 hours immersion of 0.52 mg/cm²h.

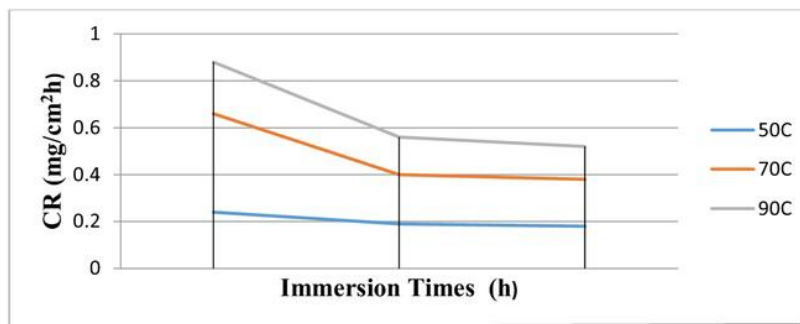


Figure 2. Graph of the average corrosion rate calculation of each 316L stainless steel test sample

Figure 3 depicts the analysis results and the usage of the potentiostat tool to determine the relationship of wear (I) vs time (s) for 30 seconds. Evidently, at a temperature rate of 50 °C, the current decreased from 0.0012675 A to 0.0012453 A; at temperature rate 70 °C, the current decreased from 0.0011972 A to 0.0011744 A and at a temperature rate of 90 °C, the current decreased from 0.0014458 A to 0.0014114. Hence, within 30 seconds, the 316L stainless steel metal environment sulphuric acid at a concentration of 0.5 M visible current decreased, meaning on the surface of this 316L stainless steel formed a passive layer means the surface of the metal has not been corroded. (For additional details, see the figure graph below.) Based on Figure 3, the current current graph with regard to the third time temperature variation is 50°C, 70°C, 90°C can be seen that at 50°C the starting point of the current value is 0.0012675 A, at 70°C temperature of the starting point of the current value is 0.0011792 A, and at point temperature 90°C initial value current is 0.0014458 A. Therefore, the higher the temperature, the higher the current value, which leads to the onset of corrosion. This test was carried out for 30 seconds, and on the graph shows that graphic upwards and downwards unstable on the surface of the 316L stainless steel metal begins to damage the pitting corrosion in certain areas that have been oxidised.

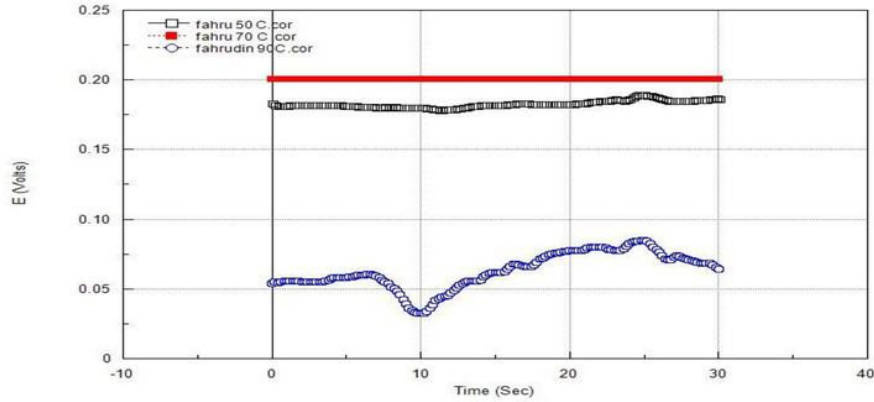


Figure 3. Graphic potential relationship (V) with time (s); 316L stainless steel in medium sulphuric acid (H₂SO₄) with temperature variations of 50 °C, 70 °C and 90 °C.

To view the surface morphology of AISI 316L stainless steel test material before immersion and after immersion is done using SEM photo. From the pictures shown, the immersion test material shown in Figure 4 does not suffer from smoother corrosion damage from the test material after immersion in photo Figure 5 of the metal surface seen in some locals experiencing damage to the passive layers in the form of pitting (corrosion pitting) in certain areas that have undergone previous oxidation may occur as the locals are initiated by metal defects or defects, so that the first region is subject to damage due to corrosive sulphuric acid environment, while in certain local local passive properties 316L stainless steel metal still protects wells metal.

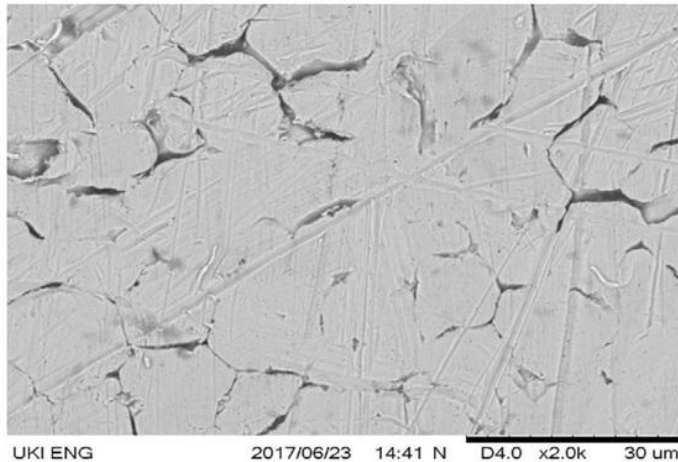


Figure 4. Photo SEM magnification 5000x, 316L stainless steel metal without immersion

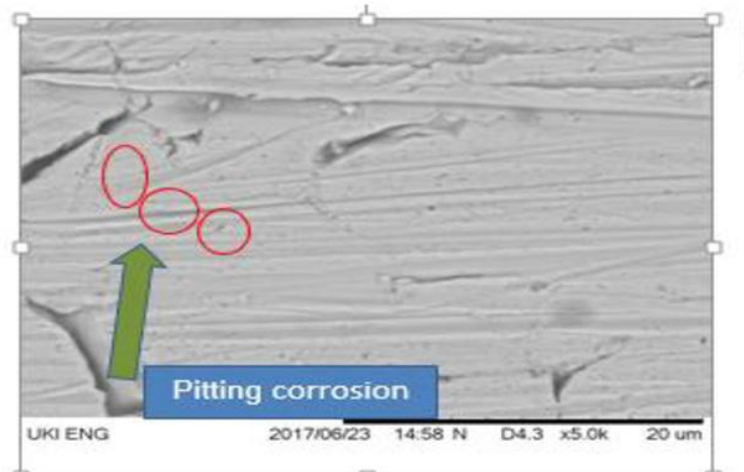


Figure 5. Photos of SEM magnification 5000 \times , 316L stainless steel metal corrosion pitting with the immersion 0.5 H₂SO₄ result for 3 hours and a temperature rate of 90 °C

4. Conclusion

Corrosion analysis using the weight loss method of 316L stainless steel metal after immersion with sulphuric acid (H₂SO₄) 0.5 M concentration with variation of temperature 50°C, 70°C, and 90°C having the largest weight loss was at 90°C with immersion for 3 hours with a decrease weight of 1.56 mg, while the least weight loss occurs at 50°C by immersing for 1 hour with an average weight loss of 0.24 mg. This means that higher temperatures and duration of immersion will be found to lower the weight of the higher the start of corrosion. The corrosion analysis using the electrochemical method of 316L stainless steel metal for 30 seconds corroborated that an increase in current at 50 °C temperature of 0.00108762 A, at 70 °C temperature of 0.00115587 A and at 90°C temperature of 0.00141139 A emerged. Using the tool SEM with 5000 \times magnification can see the surface morphology of AISI 316L. The stainless steel test material before soaking appears to be smooth surface while after 3 hours of absorption is seen on the surface of metal pitting corrosion.

Acknowledgment

The author would like to thank Mercubuana University (UMB) for facilities and support.

5. References

- [1] Ornelasari, R. (2015). *Analisa laju Korosi Pada Stainless Steel 304 menggunakan Metode ASTM G31-72 pada Media Air Nira Aren*. JTM Volume 01 nomor 1 Tahun 2015.
- [2] Seitovirta, M. (2013). *Handbook of Stainless Steel (Outokumpu)*. 11-20.
- [3] Raharjo, R. (2015). *Tingkat Kekerasan Permukaan Stainless Steel 316L Akibat Tekanan Steelballpeening*. Proceeding Seminar Nasional Tahunan Teknik Mesin XIV(SNTTM XI)

- [4] R. V. M, S. K. N, and R. Balaji, "A Review on Corrosion of Metallic Bi-Polar Plates for Proton Exchange Membrane (PEM) Fuel Cells," vol. 11, no. 6, pp. 83–99, 2015.
- [5] N.Guerrero, M. Cisneros, D. Gervasio, J. Francisco, and P. Robles, "Approaches to polymer electrolyte membrane fuel cells (PEMFCs) and their cost," *Renew. Sustain. Energy Rev.*, vol. 52, pp. 897–906, 2015.
- [6] T.Sutharssan, D. Montalvao, Y. Kang, W. Wang, C. Pisac, and H. Elemara, "A review on prognostics and health monitoring of proton exchange membrane fuel cell," *Renew. Sustain. Energy Rev.*, vol. 75, no. November 2015, pp. 440–450, 2017.
- [7] M. A. Abu-Dalo1, A. A.-R. (2012). *Exudate Gum from Acacia Trees as Green Corrosion Inhibitor*. Int. J. Electrochem. Sci, 1-5.
- [8] A. S. Fouda and L. E. Lamloum, "Study on corrosion inhibition efficiency of some quinazoline derivatives on stainless steel 304 in hydrochloric acid solutions †," no. 2, pp. 112–131, 2016.
- [9] Azar, V. (2010). *The Effect Of Shot Peening on FatiGue And Corrosion Behavior Of 316L Stainless Steel in Ringer's Solution*. Departement Of Material Science And Engineering, Shiraz University, Shiraz, Iran.
- [10] Fontana, Mars G. (1987). *Corrosion Engineering (Third Edition)*. Singapore: McGraw-Hill Book Company.

Temperature Effects on Stainless Steel 316L Corrosion in the Environment of Sulphuric Acid (H₂SO₄)

ORIGINALITY REPORT

20%

SIMILARITY INDEX

14%

INTERNET SOURCES

17%

PUBLICATIONS

%

STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

6%

★ Hongliang Yang, He Xue, Jianlong Zhang. "Effect of Crack Length on Mechanical Field of Stress Corrosion Crack Tip of Cold Working 316L Stainless Steel", IOP Conference Series: Materials Science and Engineering, 2018

Publication

Exclude quotes Off

Exclude matches Off

Exclude bibliography Off