



World Conference on Technology, Innovation and Entrepreneurship

## Corrosion Behavior of Eutectic Molten Salt solution on Stainless Steel 316L

Fuzieah Subari<sup>a</sup>, Hafizul Faiz Maksom<sup>a</sup>, Aiman Zawawi<sup>a,\*</sup>

<sup>a</sup>Faculty of Chemical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

### Abstract

The effect of eutectic molten salt on the corrosion behavior of a stainless steel 316L was investigated. To be used as thermal energy storage fluid, low melting point is one of the utmost important thermal properties amongst other. Eutectic salt was defined as a combination of two or more salt at different composition producing lower melting point than of it purest form. Four types of salts, sodium chloride (NaCl), potassium nitrate (KNO<sub>3</sub>), lithium nitrate (LiNO<sub>3</sub>), and sodium nitrate (NaNO<sub>3</sub>) were used to form fifteen mixtures of different composition to be tested on SS316L. The composition based on weight ratio was generated using response surface methodology (RSM). Eutectic composition of molten salt used as thermal energy storage fluid can possibly affect the corrosion occurrences due to the existence of Cl<sup>-</sup> ion and thereby influence the lifespan of the 316L stainless steel. This study indicates that the compositional different of eutectic mixture significantly affected the lifespan of the 316L stainless steel against corrosion. Two types of approaches are used in describing the corrosion behavior, which are resistance potential, Rp and corrosion rate. After test of 24 hours in total immersion condition, 316L stainless samples have developed a scale of corrosion products made up of multiple oxides. Highest proportion of NaCl salt inhibits higher corrosion rate in eutectic molten salt as observed in resistance potential value and corrosion rate. Morphology of the stainless steel SS316L was further investigated under scanning electron microscope (SEM).

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).  
Peer-review under responsibility of Istanbul Univeristy.

**Keywords:** Corrosion; eutectic molten salt; pitting corrosion; thermal energy storage; stainless steel 316L.

\* Corresponding author. Tel.: +603-55448011; fax: +603-55436300.  
E-mail address: [fuzieahsubari@salam.uitm.edu.my](mailto:fuzieahsubari@salam.uitm.edu.my)

## 1. Introduction

Solar energy is currently being studied for further use as one of the renewable energy sources. Therefore, a study of the material that is capable to store the excessive electricity generated from the solar power plant is carried out. Salt are commonly known has a capability of storing a large amount of electricity, the thermal energy is then possible to be stored. These applications require a thermal storage and a heat transfer material with higher density and low melting point in order to improve power output. The word "Molten salt" refers to the term of melted salt or fused salt. Sodium chloride can be one of the examples of molten salt where a large amount of heat above the melting point of 120°C to 400°C is needed to changes its phase. Because of these special properties they have higher heats of fusion and relatively good thermal conductivities and they are not expensive (Raade, 2011). Any mixture of materials that crystallize into two distinct materials when they are solidified one of the components will be formed and the other. This kind of system is called a simple eutectic. Eutectic molten salt proved to store energy efficiently but must be incorporated with economic viability as well. The cost of fabrication was known contribute to the major investment of chemical plant. The study on the effect of eutectic molten salt towards steel used provides useful information on designing equipment, which can resist or at least reduce the effect of corrosion. Hence, cost of fabrication and production can be minimizing during plant maintenance and operation. Corrosion is defined as the destruction or deterioration of material due to the exposure of its surrounding environment. The corrosion is possibly due to the chemical or electrochemical process that takes part on the surface of the material. The electrochemical reaction that involves is reduction and oxidation or can be simplifies as redox couple reaction (Ebner & Sharpe, 2010). Several methods of study are available in dividing the corrosion types. For corrosion that influences by the temperature, it is best sub-divided into high and low temperature condition. For high temperature condition, the type of corrosion that takes place is the dry type corrosion. Meanwhile, the low temperature condition reflects that the corrosion is wet type corrosions; means there are presence of water molecules. The 316L stainless steel commonly used by most chemical plant due to mainly its durability, minimum cost of material and resistance towards chemical fluids which eventually caused corrosion. In previous application, the using of eutectic molten salt for heat storage material has been widely employed. However, it causes bad effects to the equipment such that corrosion problem occur where the protective oxide layer of the steel was clearly destroyed and the steel started to oxidize in an uncontrolled manner (Jongenotte, 2007). Pitting type corrosion occurs on the material of construction mainly due to the presence of halides that blocks the penetration of oxygen to recover the damaged surface. Pitting corrosion of 316L stainless steel can be a critical form of corrosion in engineering structure if it cause perforation of equipment especially energy storage tank. Most equipment fabricated from stainless steel failed due to pitting corrosion, which in caused by chloride ions (Fontana and Green, 1967). But, it can be altered with nonaggressive anions that reduce the pitting corrosion of stainless steel in chloride solution include sulfate, chromate, bicarbonate, and phosphate ions. In addressing corrosion behaviour, two parameters were observed namely polarization resistance and corrosion rate. Polarization is a deviation of the electrochemical process from equilibrium due to an electric current passing through the galvanic cell. Polarization resistance ( $R_p$ ) is the transition resistance between the electrodes and the electrolyte. The chemical reaction that takes place at the electrodes results an increase in resistance to the flow of current in the respective voltaic cell. Polarization results in a reduction of the electric potential across the voltaic cell. An electrode is polarized when its potential is forced away from its value at open circuit or corrosion potential. The current is forced to flow since the electrodes were polarized. This is a natural occurring condition where electrochemical reaction is drives by the induced electrode surface. Polarization may occur either at the cathode (cathodic polarization) or at the anode (anodic polarization). High  $R_p$  of a metal implies high corrosion resistance and low  $R_p$  implies low corrosion resistance. Thus, polarization resistance is the ratio of the applied potential and the resulting current response. This "resistance" is inversely related to the uniform corrosion rate. Polarization resistance behaves like a resistor and can be calculated by taking the inverse of the slope of the current potential curve at open circuit or corrosion potential. During the polarization of an electrode, the magnitude of the current is controlled by reaction kinetics and diffusion of reactants both toward and away from the electrode.

## 2. Literature Review And Hypotheses

The application of thermal energy storage (TES) requires the use of heat transfer fluid. Currently, TES is using the mixture of organic compounds, di-phenyl oxide and bi-phenyl oxide in the collector field (Bradshaw & Siegel, 2008). The direct use of the mixture is considered expensive. Therefore there is been discovered to replace the organic mixture with other inorganic fluids. Some of the advantages of using inorganic fluids are having an upper temperature limit in a range of 500°C. This is favourable since the TES require a solution that works at high temperature range for a long duration of time. Inorganic fluid also serving a much lower unit cost compared to the organic fluid. In term of vapour pressure, inorganic fluid only produces a few of Pascal value when being used at high temperature. The pressure is important to be monitored since the fluid will be placed inside a closed container. The inorganic fluid is therefore showing all of the criteria needed for any fluid to be purposes as a heat exchanger fluid for TES application.

The inorganic fluids that intended to be used for the study consist of Nitrogen, which is in a form of nitrite and nitrate. Nitrogen gas acts as a covering gas to prevent the conversion of nitrite to nitrate. Therefore, the inorganic fluid must be protected from air to prevent the reverse reaction of the above reaction. The reverse reaction results on the decrease of nitrite level,  $\text{NO}^{3-}$  thus increase the melting point of the fluid. The melts that contains nitrate such as Ammonium Nitrate or Silver Nitrate will respectively decompose at low temperature and prohibitively expensive. Therefore metallic nitrate was proposed due to the reasons that the miscibility of the metallic nitrate is low or poor therefore it can protect itself from undergoing the reverse reaction mentioned earlier. Greater potential stability when contact with air is therefore established without the supply of nitrogen gas as the protective layer. Metallic nitrates are therefore very suitable to be use as the eutectic combination solution (Bradshaw & Siegel, 2008).

Four types of inorganic fluid originates from nitrates family is chosen, which are calcium nitrate,  $\text{CaNO}_3$ , lithium nitrate,  $\text{LiNO}_3$ , sodium nitrate,  $\text{NaNO}_3$  and potassium nitrate,  $\text{KNO}_3$ . These four types of salts are chosen because all binary combination of these nitrate salts displays melting point depression, which means the eutectic solution, remains on its liquid state. The eutectic properties of the salts after combined are experimentally convenient to be use for high temperature condition. The combination of the salts also give a ternary system for the solution which is therefore increase and improve their chemical and physical properties as a solution. The use of eutectic combination using the salt mentioned earlier also undergoing any reaction forming insoluble product (Bradshaw & Siegel, 2008). Molten nitrate/nitrite salts can be used for storage medium for concentrated solar power plant. The molten nitrate/nitrite salts is therefore act as high temperature fluid for heat transfer for solar energy system. Molten nitrate/nitrite salt is chosen due to several characteristics such as having a high density, showing good melting enthalpy and forming an anhydrous mixture of nitrite. These characteristics enable nitrate/nitrite eutectic to store high volumetric heat capacity up to  $70\text{kWhm}^{-3}$ .

Salt system is characterize and selected by several factor such as their low melting point (Ebner & Sharpe, 2010). This is to prevent the salt become solid state while being use. Another factor is having a low vapor pressure at operating temperature. High vapour pressure may cause the storage container to burst up since the operating temperature is generally high for solar power plant. The most crucial factor is their ability as thermal conductivity. A good thermal conductivity is preferable to prevent the temperature gradient build up on the salt system. The temperature gradient is believes to be one of the contributors of corrosion on the salt system. However, there are still several issues to be considered before using the salt system such as their stability and their compatibility with regards to the storage container. The storage container is generally metals or alloys. The structural of storage container might not fit to the salt system since there will be reaction that takes part on the salt system.

Determination of thermophysical and thermochemical properties of each eutectic salt can be done using related equipment. However, based on  $\text{NaNO}_3$ - $\text{NaNO}_2$ - $\text{KNO}_3$  salt system, the thermophysical and thermochemical properties are changing with temperature such that the salt property is a function of temperature. The properties that intended to be identified such as density, viscosity, surface tension, specific heat capacity, and thermal conductivity.

These properties is important for the formulation of eutectic salt since eutectic salt must have high density, high heat capacity, low viscosity, good heat conductivity and must compatible with common metal of construction.

Corrosion is a condition that derives from electrochemical reaction, which takes place on the metal surface, and its surrounding. The electrochemical reaction that involves is reduction and oxidation or can be simplifies as redox couple reaction (Ebner & Sharpe, 2010). The oxidation occurs on the less noble anodic material while the reduction occurs on the more cathode material. The redox couple reaction results in the formation of oxides or salts. Corrosion that takes place on the surface or inside the alloy or metals are generally cause by the air, water and/or acid. A metal or alloy, which comes into contact with air or water, will generally undergo the formation of oxide layer on the surface of the respective metal or alloy. The oxide layer that form is responsible to protect the surface or to retard the diffusion of oxidant to the reaction interface of metal or alloy (Ebner & Sharpe, 2010). However, this ability to form oxide layer is only present on certain metal or alloy or specially constructed material. The protective oxide layer can only be formed by any metal or alloy that consists of significant levels of chromium ion, aluminium ion, or other elements. For the material that has chromium and aluminium ions, they tend to form  $\text{Cr}_2\text{O}_3$  and  $\text{Al}_2\text{O}_3$  as their protective oxide layer.

The corrosion that takes place on the storage material for eutectic molten salt is possibly due to the chemical reaction that occurs on the molten salts. Therefore it is state that the molten salts can support corrosion in the thermal energy storage system (Cabeza & Mehling, 2003). Molten salts are ionic and form electrically conducting fluids on its molten state. This reaction is positively producing a free energy gradient towards the metal storage surface. Molten salts also are good solvents for metals salts. There are three major types of molten salt used for thermal energy storage, which are fluoride salts, chloride salts, and nitrate/nitrite salts. The corrosion that sponsored by the any fluoride molten salts seems to cause destruction of protective oxide layer that already present on the surface of the metal or alloy (Ebner & Sharpe, 2010). The salt that formed by the reaction also undergoes dissolution. However, the characteristic is not showed when the fluoride molten salts are changed with chloride molten salts or nitrate/nitrite molten salts. Both chloride and nitrate/nitrite molten salts seem to be stable with the passivating oxide layer on metals or alloys.

There are several types of corrosion that takes place on metals and alloys. The corrosion that occurs is divided into two major classes which are based on the solution that contribute to the corrosion which are aqueous solution and molten salts. The passive metal/alloy surface can only be susceptible to pitting corrosion if two condition is fulfilled which is the presence of aggressive anions and the presence of pitting potential. The aggressive anions will promote the dissolution of passive protective surface of the metal/alloy. Meanwhile, the pitting potential is a result of higher equilibrium potential of material if compared to the materials characteristic potential. In this paper, corrosion behaviour of the eutectic molten salt on stainless steel 316L was observed based on the corrosion parameter that is resistance potential and eventually determined the corrosion rate.

### **3. Methodology**

#### *3.1. Research Goal*

The study was conducted to determine the corrosion behavior of eutectic molten salt to the SS316L. It will be further observed using scanning electron microscope (SEM) for its morphology changes when the corrosion takes place.

#### *3.2. Sample and Data Collection*

The chemicals used in this experiment were sodium nitrate ( $\text{NaNO}_3$ ) (99%, Fluka), sodium chloride ( $\text{NaCl}$ ) (99%, Fluka), lithium nitrate ( $\text{LiNO}_3$ ) (98%, Bendosen) and potassium nitrate ( $\text{KNO}_3$ ) (98%, Bendosen). Table 1 shows

the composition by weight ratio of eutectic molten salts. The ratio was generated using Response Surface Methodology (RSM) software.

#### A. Effect on corrosion

The SS316L were cut into 2cm x 2cm dimension and soldered well to Nickel-Chromium wire, which have been grinded for ease of soldering. Moulding cups are prepared and well known its half volume of it. The soldered SS316L are placed on respective moulding cup. Moulding solution is prepared using epoxy resin and hardener with ratio of 15:2 respectively. The total prepared moulding solution is determined by the previous calculation on the  $\frac{1}{2}$  of the moulding cup. The sample is left hardening for 24 hours and 48 hours for total harden. The moulded SS316L undergoes the grinding and polishing process such that its surface should not be tarnish by any unknown debris or its own oxide layer. The percentage of clearness is observed such that the surface will able to reflect any image or light clearly.

Eutectic mixture is a combination of two or more phases at composition with a significantly lower melting point compared to the pure phases (Mahjour, 2009). Optimization on the composition on the eutectic salt in done by Response Surface Methodology (RSM). The series as depicted in Table 1 shows 15 sets of solution sample which having different composition on the different salts. Each of the samples is made to become 1M of eutectic salt solution. The compositional values are assumed to be taken as percentage of each salt inside the eutectic salt solution. The amount of each salts were then determined. The salt solution is prepared at 1M fresh prior to the run. Voltalab PGZ202 is used in determining the Resistance potential (Rp) and the corrosion rate in mmPY. Two types of electrode, which are the auxiliary and reference, is cleaned using respective procedure prior used. The moulded SS316L is clamped and connected as the working sample. The auxiliary electrode and the working sample are located approximately 0.5 to 1.0 cm from each other, and all the electrodes is placed levelly.

Table 1: The series of eutectic molten salts

Sample No	Eutectic Molten Salts Composition (%)			
	NaCl	K <sub>2</sub> NO <sub>3</sub>	Li <sub>2</sub> NO <sub>3</sub>	NaNO <sub>3</sub>
1	70	10	10	10
2	40	20	20	20
3	30	20	20	30
4	60	10	10	20
5	50	20	20	10
6	80	5	5	10
7	56	11	22	11
8	77	6	11	6
9	56	11	22	11
10	44	33	11.5	11.5
11	30	20	30	20
12	20	20	20	40
13	30	50	10	10
14	20	50	10	20
15	20	10	20	50

#### B. Analysis by SEM

The corrosion analysis was assessed using immersion tests in salt solution at different composition. Corrosion tests of 316L stainless steel were carried out on samples with dimensions 2x4 cm. Before starting the analysis the samples were washed in distilled water, ultrasonically cleaned in acetone and finally cleaned in 95.6% ethanol. The time of the test for the stainless steel was equal to 24 hours for each sample. All the samples were dipped entirely to

compare the performance of each sample. After the tests the samples were weighed to measure loss due to corrosion process measured. SEM indicates the shape of the surface on the metal.

### 3.3. Analyses and Results

#### A. Resistance potential, $R_p$

Generally, Fig. 1 shows that all samples tested at different composition by weight ratio of NaCl,  $K_2NO_3$ ,  $Li_2NO_3$  and  $NaNO_3$  increase monotonously for all curves as resistance potential ( $R_p$ ) passes 60 minutes. At 10 minute, sample 15 and 14 increase sharply to  $350 \text{ k.ohm.cm}^2$  and  $250 \text{ k.ohm.cm}^2$  respectively by 60 minutes test time leave behind others at value less than  $150 \text{ k.ohm.cm}^2$ . Therefore it clearly observed that the maximum  $R_p$  achieved by Set 15, followed by Set 14, Set 5 and Set 6. Yang et al, (2013) stated that the resistance potential of the metallic system involving oxide film formation is less susceptible to be charged and has higher resistance to corrosion. This indicates that SS316L least prone to corrode when immersed in Set 15 comprise of 20% NaCl, 10%  $K_2NO_3$ , 20%  $Li_2NO_3$  and 50%  $NaNO_3$ . Set 15 consists of 20% of NaCl, which is the least NaCl composition amongst of all test samples.

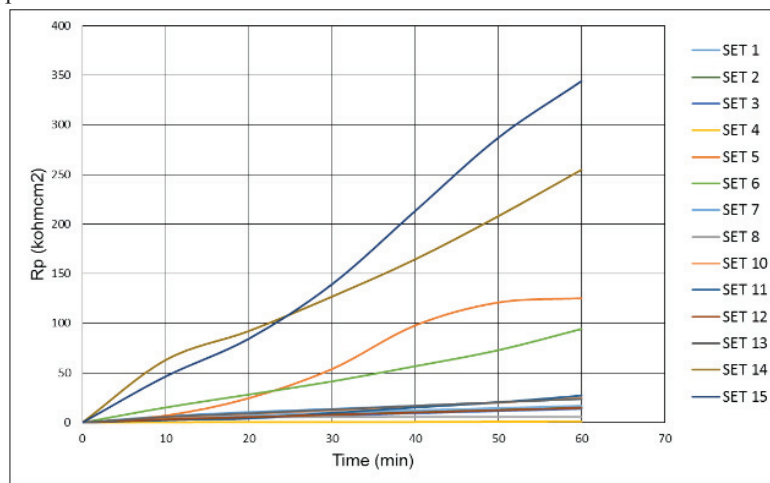


Fig. 1. Resistance potential of eutectic molten salt.

#### B. Corrosion rate

According to Fig. 2, the corrosion stages can be easily determine since the plot of each slope showing a decline phase followed by constant rate region. The decline phases indicate the hydrogen evolution while the constant regions indicate the minimum corrosion rate respectively. The minimum corrosion rate is achieved since the corrosion rate is equal to the protective oxide layer self-regeneration. Water chemistry factors, which can cause interruption or breakdown of the protective oxide film on the surface of the metal, are acidity, low dissolved oxygen concentrations and high concentration of chloride in solution (Ma, 2012). From the experiment conducted, all the data is collected and interpreted as Fig. 2. The data then undergo simplification by calculating each of the slopes of the curve in order to determine a single rate for each eutectic salt solution composition. Taking the initial rate which being considered as the early stage of corrosion occurrence does the slope calculation. Table shows the calculated corrosion rate using the gradient of graph from Fig. 2. The negative value indicates the depletion of thickness of the stainless steel. According to Table 1, it can be clearly shows that the highest corrosion rate on SS316L can be achieved by having Set 4 composition. Set 3, Set 12, Set 5 and Set 11 follow the highest corrosion rate. Generating the ranks on corrosion rate, it is proved that the theory on polarization resistance,  $R_p$  is inversely proportional to the corrosion rate. This conclusion accompanied by Fig.3 that is comparing two set having the highest  $R_p$  value and the highest corrosion rate.

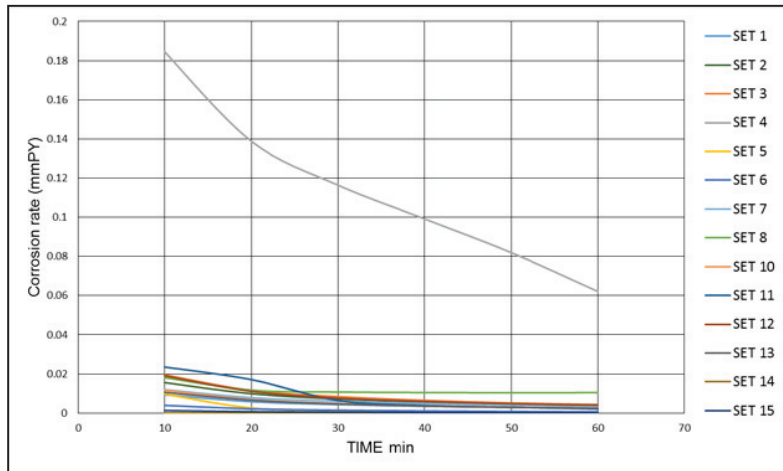


Fig. 2: corrosion rate of the eutectic molten salt.

Table 2: Corrosion rate by slope estimation with ranks for each eutectic salt solution composition.

Set	Corrosion Rate (mmPY x 10000)	Rank
1	-3.5580	11
2	-5.7020	7
3	-8.0300	2
4	-45.8000	1
5	-7.1450	4
6	-1.7830	12
7	-4.1250	9
8	-6.3800	6
10	-4.7720	8
11	-6.4500	5
12	-8.0100	3
13	-4.0000	10
14	-0.0003	14
15	-0.5865	13

From Fig. 3 it can be clearly seen that Rp value is inversely proportional to the rate of corrosion. Set 15 which having the highest Rp value, and increase gradually with time showing the lowest corrosion rate which nearing zero or precisely having corrosion rate of -0.000059mmPY. Meanwhile, Set 4 is determined to have the highest corrosion rate is showing the lowest value of Rp. There are three main factors that involve Cl- ions in corrosion rate. The factors are the ability of the Cl- ion to breakdown the protective oxide film, the properties of the protective oxide film on the metal surface and the evolution from homogeneous to localized corrosion (Taltavull et al, 2014) or hydrogen evolution as being mentioned earlier. Selection of set of eutectic mixture is done in comparing the effect of NaCl percentage inside the solution. This is mainly due to the irregular or inconstant amount of other material or chemical in the solution. Therefore, it can be assumed that the corrosion that takes part on the steel use will have a high corrosion rate at the beginning and the rate is slightly reduced through time elapsed (Wang, 2012), which already being implemented on previous section. The corrosion rate then becomes constant or can be classified as minimum corrosion rate.

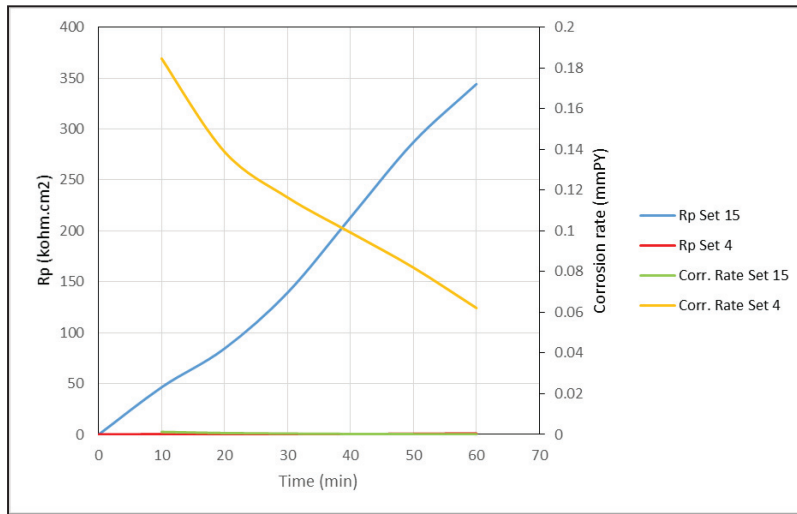


Fig. 3: Comparison of sets having the highest Rp value and the highest corrosion rate.

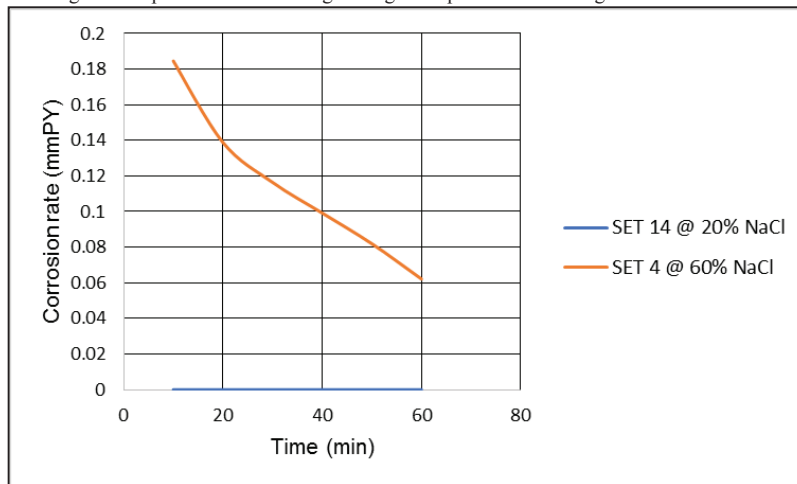


Fig. 4: Comparison on corrosion rate between Set 14 and Set 4.

For the comparison purpose only on the NaCl composition, Set 14 and Set 4 are chosen. The amount of  $\text{LiNO}_3$  and  $\text{NaNO}_3$  are being constant or maintained for this sets, which is at 10% and 20% respectively. This left the  $\text{KNO}_3$  to change with changes in NaCl percentage. Increase in NaCl percentage will therefore force the reduction in the  $\text{NaNO}_3$  percentage. Fig. 4 shows the collected result on Set 14 and Set 4. Set 14 is having 20% of NaCl on the solution which makes the  $\text{KNO}_3$  only consists of 50% of the solution. Meanwhile, Set 4 is having a 60% of NaCl composition, making the  $\text{KNO}_3$  percentage at 10%. From Fig. 4, it can be clearly shows that Set 4 is having a greater corrosion rate from the beginning of the test duration until the end of the test duration, which is at about 60 minutes. The greater corrosion rate is contributed by the higher number of NaCl percentage (Temur & Yildiz, 2006) which is 60% for Set 4. The corrosion rate is increased with chloride ion concentration which mainly contributes by the NaCl (Taltavull et al, 2014).



### C. Morphology of the 316L Stainless steel

Fig. 5 and Fig. 6 shows the corrosion morphologies of sample 1 and sample 14 of the 316L stainless steel respectively under 2000x magnification of SEM. Figures indicate that the surface containing high density of pits due to higher concentration of NaCl. The steel inhibit oxygen depolarization in chloride solution enhance corrosion process.

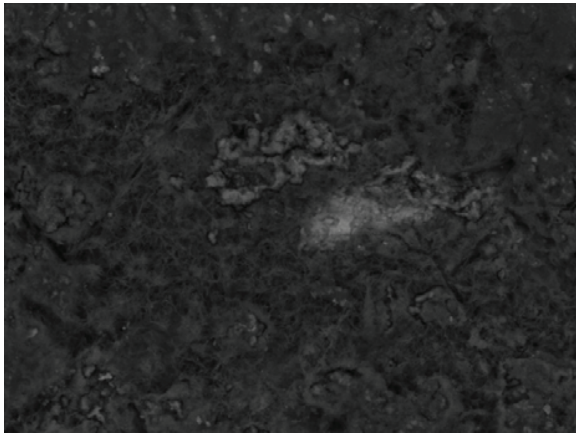


Fig. 5. SEM of the 316L stainless steel surface after treated in sample 4 at 2000x magnification

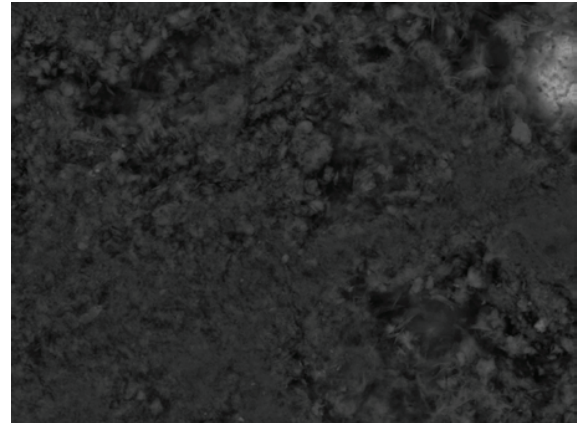


Fig. 6. SEM of the 316L stainless steel surface after treated in sample 14 at 2000x magnification

A low magnification SEM image of open crack rupture surface is shown in Figure 7 in which 1000x magnification SEM image of an open crack clearly resolves the exhaustion detention marks near the outer surface. The increased magnification SEM images in figures 8 reveal intergranular corrosion morphology along the edge of the surface. A characteristic of weakness in the cyclic nature of crack growth. The morphology of a surface of the 316L stainless steel samples after immersion in 80wt% composition of NaCl showed at various characters of corrosion products. There are lot of corrosion pits of various sizes can be observed after immersion in the sample 6. The amount and size of pits are very high and they are formed along the whole surface of the samples.

### 4. Conclusion

The nonaggressive anions in aqueous solution play an important role in the passivation process that reduces the pitting corrosion of stainless steel in highly concentrated  $\text{Cl}^-$  solution. Sodium nitrate and potassium nitrate have recognized to be an efficient inhibitor for general and pitting corrosion of 316L stainless steel in salt solution. The efficiency of the inhibitor is increased due to increasing its concentration, but may decrease at higher temperature. The increase of nonaggressive ion concentration will increase the breakdown potential towards the pitting corrosion. Further study on kinetic parameter such as study of Langmuir adsorption isotherm need to be consider to indicate the presence of inhibitor decrease the activation energies and this outcomes will improve the breakdown potential towards the positive direction such as targeted pitting corrosion. The corrosion studies of SS316L stainless steel have been carried out at room temperature using four types of chemical that are NaCl,  $\text{KNO}_3$ ,  $\text{LiNO}_3$  and  $\text{NaNO}_3$ . The results obtained lead to the conclusion that NaCl is an effective corrosion promoter of SS316L in eutectic salt solution. Future work on the influences of the others salt components towards the corrosion is suggested to be done in order to develop the understanding on their relationship towards corrosion behavior on SS316L.

## Acknowledgements

This work was carried out with the financial support of Ministry of Education Malaysia under Research Acculturation Grants Scheme (RAGS), 600-RMI/RAGS 5/3(71/2012). The author would like to acknowledge staff and members of Research Management Institute, (RMI) UiTM and Faculty of Chemical Engineering, UiTM Shah Alam for their continuous support.

## References

- Bradshaw, R. W., & Siegel, N. P. (2008). Molten Nitrate Salt Development for Thermal Energy Storage in Parabolic Trough Solar Power Systems, 1–7.
- Cabeza, L. F., & Mehling, H. (2003). Review On Thermal Energy Storage With Phase Change : Materials, Heat Transfer Analysis And Applications (Vol. 23, pp. 251–283).
- Ebner, M. A., Sharpe, P., & Sharpe, P. (2010). Engineering Database of Liquid Salt Thermophysical and Thermochemical Properties Engineering Database of Liquid Salt Thermophysical, (March).
- Ebner, M.A & Sharp, P, (2010). *Engineering Data Base Of Liquid Salt Thermophysical And Thermochemical Properties*.
- Fontana, M.G. and Green, N.D, (1967). *Corrosion Engineering*. New York, McGraw-Hill. 51
- Jongnotte, B.J, (2007). *Stainless steel in architectural construction, beautiful but delicate*.
- Ma, F. (2012). Corrosive Effects of Chlorides on Metals, 178.
- Raade, J. W., Padowitz, D., & Vaughn, J. (2011) Low Melting Point Molten Salt Heat Transfer Fluid With Reduced Cost, *I(510)*
- Taltavull, C., Shi, Z., Torres, B., Rams, J., & Atrens, a. (2014). Influence of the chloride ion concentration on the corrosion of high-purity Mg, ZE41 and AZ91 in buffered Hank's solution. *Journal of materials science. Materials in medicine*, 25(2), 329–45.
- Temur, K. Ş., & Yildiz, S. (2006). Effect of Various NaCl Concentration on Corrosion of Steel in Concrete Produced by Addition of Styrofoam, *19(3)*, 163–172.
- Yang, C., Guo, W., Zhang, H., Qiu, R., Hou, J., & Fu, Y. (2013). Study on the Corrosion Behavior of 7A52 Al Alloy Welded Joint by Electrochemical Method, *8*, 9308–9316.