



A Study on Crevice Corrosion on Stainless Steel: Detecting Methods

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Abstract

Analysis of crevice corrosion on stainless steel and detecting its working method or modelling techniques is a part of the Na-hypochlorite solution. Corrosion considering burning products declared by heat burners. This study is an external potential application of 0 mV to +400 mV. This is a process for 316 stainless steel and 304 stainless steels. This research study will help to understand the methodology of the crevice corrosion process, how it works, what the method or techniques are following, and the result of the process corrosion.

Introduction

Aqueous corrosion involves a laborious process called the local attack. When exposed to an environment with too many chloride ions, stainless steel is vulnerable to localized corrosion. Pitting corrosion and crevice corrosion are the two main types of corrosion that damage stainless steel structures (SS), and they prevent the use of SS in certain conditions. Brown created the term "occluded cell corrosion," which denotes the simultaneous presence of both active anodes and passive cathodes. Thus, this type of corrosion affects alloys and metals that have a tendency to become passive. The bulk solution's constituents are distinct from those of the corroding solution inside the cavities. Because of the limited convection within the hollow, the oxygen level is reduced. Oxygen is also used in the reduction reaction at the cathode. Compared to the bulk solution, the cavity has a larger concentration of the corrosion products. This is explained by the fact that because of the sluggish rate of diffusion, less corrosion-related products are eliminated. Even after the oxygen reduction process has ended, the metal disintegration has not stopped. As a result, the passage of the chloride ions into the crevice causes the crevice solution to become positively charged and neutralize. The neutralizing process causes the pH of the crevice to decrease. When the critical value is reached, the crevice solution irreversibly ruptures the passive coating, starting the fast crevice corrosion. As a result, corrosion is increasing significantly. It soon became clear that knowledge of the cavity's reaction process would help explain the mechanisms underlying pitting corrosion and crevice corrosion.

By creating artificial pits and fissures, direct (in situ) analysis and semi-direct approaches (solution extraction and analysis) are used to analyze the electrochemical process inside the cavities. Microelectrodes were used to calm down the system's agitation. However, because

localized corrosion is challenging to control in a lab setting, it is challenging to analyze the experimental results. In order to analyze these processes, mathematical models have been introduced.

This study's main objective was to investigate the nature of SS crevice corrosion in hypochlorite solution and compare it to that corrosion in NaCl solution. For the purpose of evaluating various characteristics, an assembly of fake fissures was made (pH, potential, and chloride concentration). Microelectrodes were positioned at the top of the crevice and used to measure these variables at various points throughout the crevice. As determined by the roughness of SS, the crevice gap (0 - 10 m) in this study is smaller than the crevice gap (more than 50 m) reported in other studies.

The corrosion process stands on several types of stainless-steel structures such as crevice corrosion and pitting corrosion. When corrosion of stainless steel depends on oxide layer presence on its surface this process considers crevice corrosion on stainless steel. The main focus of the study is to understand the electrochemical process of a crevice, its functioning system, the result of this corrosion, the nature of the crevice corrosion as well as understanding the hypothetical solution.

SS and crevice corrosion

SS is a very important method for crevice corrosion on stainless steel. This process can work only in the presence of chloride ions. Stainless steel corrosion is an alloy of different elements such as iron, chromium, nickel, and some others [1]. Stainless steel is a green material it is a recyclable alloy. Oxygen deficiency is the first implement of crevice corrosion. Inside the crevice, the proton and the chloride ion boost the margin of the process. According to theory, the potential difference is not a crucial part of the crevice attack. Due to crevice corrosion, the oxygen films get thickened, to develop the potential difference between cathode and anode only important is potential leads. The crevice corrosion process depends on the various procedure or functions, such as an oxidizing agent presence of oxygen, creating a coordinating cell between the crevice and outer service, decreasing pH for the buffering cavity, oxygen layer lowering, solution pH lowering, and increasing chloride within the crevice or extra [2]. Crevice corrosion is a special variant of pitting corrosion. The crevices are filled with hydrogen. This chemical technology process builds or forms various materials. In crevice corrosion, SS is a very crucial element. When the surface the density of the surface became 0 contact point in materials crevice corrosion started from that time. Chloride ions are working like an alteration in the potential of pitting. This theory is based on fluctuating currents.

Methods of detection of crevice corrosion

This area of discussion will help to understand what the implementing methods are for crevice corrosion, how it works, or its components. Crevice corrosion working through some experimental methods is like - duplicate artificial pits or crevices, analysis of the extracted solution, and solution analysis freezing followed [3]. All methods are related to 0 at the closest contact point. Apart from all these some other components also work for this method. Plastic cover plates and metal plates were designed by an artificial crevice. The new variation of the

artificial crevice is part of an experimental study. All the designs are set by the mass transport within the crevice corrosion. The study of corrosion is a solution of several samples as chloride ions, potential, and current flow.

Crevice corrosion on stainless steel

This study is a descriptive discussion about the responsibility of crevice corrosion on stainless steel. The role of crevice potential is large, it works like a potential drop within a crevice or in another potential between a crevice and the outer area of the surface [4]. This is an active region. Corrosion is influenced by a decreased potential. Potential fails to affect the potential metal. The corrosion crevice followed a manner. A small crevice can increase a big potential drop in a firm solution. The potential of corrosion in the presence of chloride ions. The potential difference in the outer surface and crevice is a process related to oxygen [5]. An artificial crevice is related by a gap crevice to the surface. Proper application of cathode potential is responsible for the rate of corrosion.

Crevice corrosion modelling

The mechanisms for the localised crevice corrosion have been studied using different mathematical models, and the theories proposed by these mathematical models are later experimentally verified. The proposed basic mathematical model was separated as follows: time required for the depletion of oxygen was analysed in the first stage; graphs are plotted (pH versus time, and pH versus composition) in the second stage; the time required for starting the crevice corrosion and destroying the passivity in the third stage (Oldfield and Sutton 1978). The theoretical model proposed for pitting and crevice corrosion was quantitatively and qualitatively verified experimentally (Sharland and Tasker 1988). This model simulated the required parameters for starting crevice corrosion and was authenticated experimentally. The chemical reaction and the mass transport for pitting and crevice corrosion were mathematically modelled for forecasting the density of the current, potential, and composition of the electrolyte as a function of the distance, within the occluded cell (Walton 1990). The measured data complied with the predicted value of the position versus potential within the crevice. The simulation of the SS and Ni alloys subjected to crevice corrosion was carried out using different mathematical models through multiple assumptions (M. Watson and Postlethwaite 1990). The concentration of the metals, chloride, and pH (against time and distances from the mouth of the crevice) was simulated and forecasted. The simulated results indicated that the pH, deep within the crevice in 316 SS, reduced from 6 to 1.5 within 100 hours.

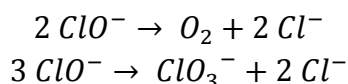
The most significant parameters for initiating and analysing the crevice corrosion are its depth and crevice gap. The influence of crevice corrosion by crevice gap profile was numerically simulated which revealed the significance of crevice gap profile in the mathematical analysis (M. K. Watson and Postlethwaite 1991). The points where the crevice corrosion starts are randomly located within the crevice. The presence of sub-crevices within the crevices hamper the mathematical analysis. A mathematical model was proposed for studying the starting of the crevice corrosion on 304 SS in NaCl solution, where the role of inclusion was incorporated (Alkire and Lott 1989).

Corrosion of SS in hypochlorite solution

The growth of microbes and fouling of seawater systems in the injection system for recovering the secondary oil and heat exchangers is hindered in presence of hypochlorites. Additionally, hypochlorites are used for disinfecting swimming pools and industries dealing with viscose fibres. The SS used in these applications is continuously exposed to hypochlorite solutions. The hypochlorite is a source of chloride ions as well as an oxidising agent, and both these factors are essential for the initiation of corrosion. The resistance to corrosion of steels in hypochlorite solutions ($1 - 10 \text{ g/dm}^3$ of Cl) was investigated by chemical exposure tests and electrochemical polarisation tests. (Kubiki) The SS of all examined varieties exhibited passivation continuously, followed by an abrupt enhancement in the density of current at high potentials, with the evolution of oxygen. An enhancement in the density of current is related to the reaction in which the pH and electrode potential are interdependent, as shown in equation



The potential generated due to the evolution of oxygen leads to a sudden enhancement in the current density at the anode. Two steel plates were connected using PTFE nuts and bolts for the immersion tests to examine the reactions. A drastic decrease in the concentration of chlorine in hypochlorite, enrichment of chloride ion concentration, and increase in the amount of chlorine in chlorate was observed after the formation of the corrosion products. The reactions are shown in equations



The corrosion products are hydrolysed within the crevice, and the acidity of the crevice is increased. Thus, the decomposition of Na-hypochlorite solution was boosted to form chloride ions, resulting in an autocatalytic process of crevice corrosion in SS. The resistance of SS corrosion to sterilised water in presence of hypochlorites demonstrated that pitting corrosion was prompted by chloride ions. Alternately, the rate of crevice corrosion was boosted by hydrogen ions and chlorate ions (M. Nakata, R. Takahasi 1991). Another study reported the corrosion of SS by Na-hypochlorite in seawater. It was found that corrosion was not initiated below the chlorine concentration level of 0.2 ppm, while the SS corroded within 5 weeks at 100 ppm as the reduction of oxygen was limited due to diffusion (Gundersen et al. 1991). Therefore, SS is easily corroded in presence of hypochlorite solution.

Model of crevice corrosion

Crevice corrosion is a study of analysis of various types of mathematical proposals, models, and calculations. All theories or mathematical proposals are experimentally identified. Basic mathematical modules are following some aspects such as depletion of oxygen, pH composition, and pH versus time or some another. The model of crevice corrosion and pitting corrosion is also verified experimentally [6]. SS and Ni alloys are responsible to use multiple mathematical models; simulated results are identifying 316 crevices or another.

The hypothetical solution to SS corrosion

For recovering the secondary oil and heat in the presence of hypochlorite this system is working. This is an application that can expose hypochlorite solutions smoothly. The SS process follows continually high potentiality, oxygen evolution, electrode potential, or extra. Corrosion product is in a crevice, acidity of the crevice [7]. This process is a solution to the hypochlorite cycle. Corrosion application is an attack on the external potential, cathode, and anode polarization. Corrosion is the presence of a solution and this solution or process is conducted by NaCl.

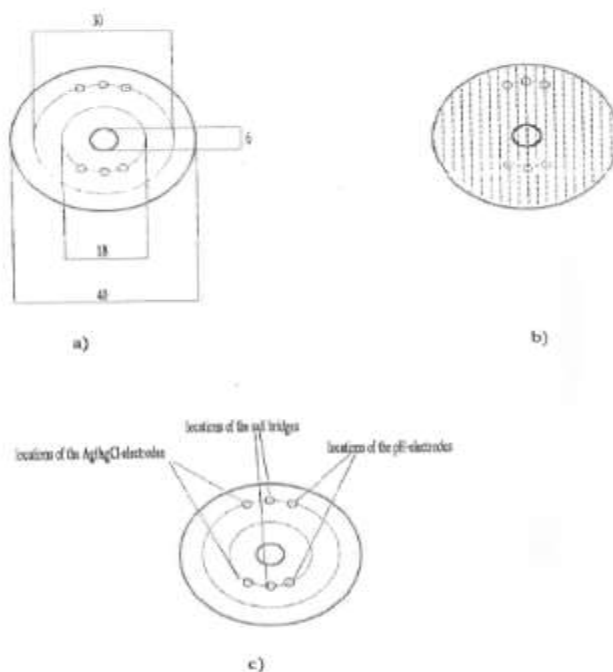
Antimony/antimony oxide electrode

This is a process of reaction that is providing a solution through equation activity between both solids. In this process of oxide electrode, antimony and antimony oxide are working alike single elements. In any area of solution, the electrode is functioning like hydrogen activity. This potential works by like containing several wires, and a heated glass tube, making a gap between glass and metal [8]. The relation between glass and tube for melting Sb. For the electrode, glass tubing is made 3 cm in length with fully covered resin. Electrode solutions are identified by the different buffer solutions. For example, glass tubing for electrodes was tested through different buffer solutions.

Electrode holder

This is a specific metal that has two circular parts, metal fixed for artificial service or process. In the two circular divisions of Perspex in the top, metal was fixed on the Perspex from the crevice. This particular process or device is a circular piece of Perspex with a diameter of a maximum of 40 mm which is from a sheet of Perspex [9]. A circle of Perspex is situated on top of the layer every time.

Figure 1



Test solutions

A test solution is a process used for chemical experiments. This solution is a mixture of NaCl and water which is processed in a volumetric flask. In this process, the reaction is shown as per the equation. In another way, vigorous shaking process in a glass bottle and reaction colour turns colour yellow [10]. One another solution is a starch solution and Na-thiosulphate solution under this procedure. Here indicator is used for the cooling method of the solution.

Experimental set-up (figure 2)

In this figure solution method is clearly mentioned. Figure 9 test solutions is showing how salt bridges are filled with freshly prepared salt solutions by adding 60 mg of agar in here. This solution is allowing cooling after sealing the ends into PE tubing. In external containers, external electrodes are also placed.

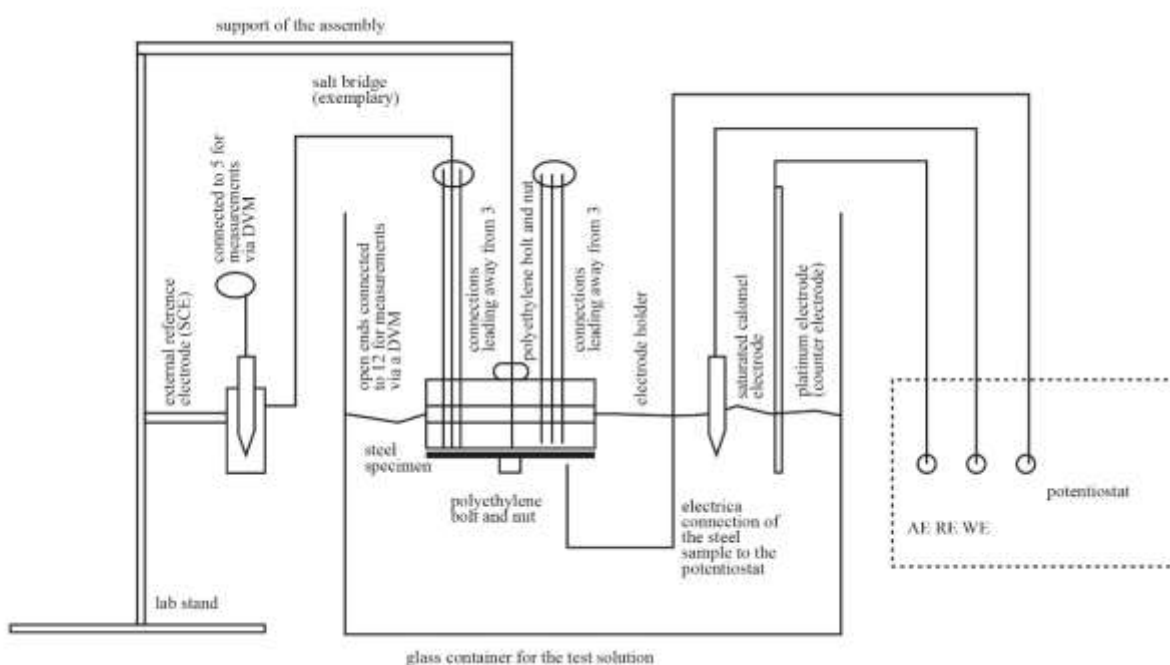


Figure (2) experimental set-up

Methods of measurement

Methods of measurement are an important part of chemical solutions [11]. In the test solution, a steady-state potential is attained in the crevice assembly before using the application in an external potential. In this process, the internal surface of the crevice was recorded and the steel sample was subjected to an anodic potential. In a voltmeter, crevices were measured by connecting the reference of the electrode. Ag – AgCl electrode or pH electrode was recorded by adding to the electrode through the same voltmeter [12]. The whole process of the experiment takes 24 hours.

Analysis of the polarisation effect

The polarisation is the important process of the solution method. In this polarisation experiment using a test cell of I, L was used here. In polarisation, the Pt electrode is used as the auxiliary

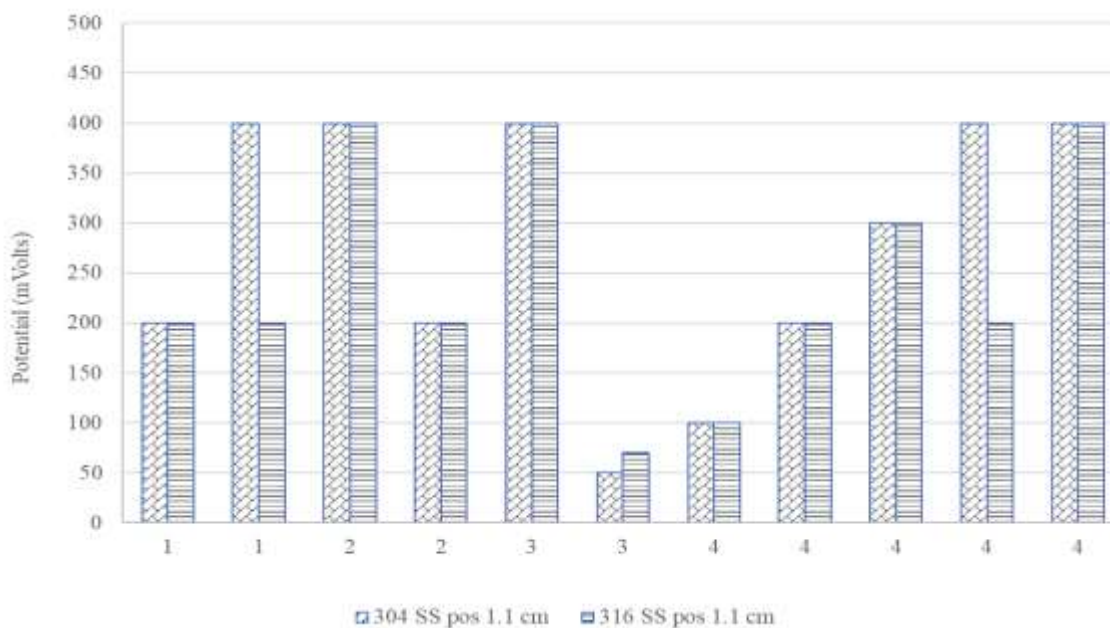
electrode [13]. Before the experiment, the solution was purged through nitrogen. For measuring potential always use a digital voltmeter.

Results

Visual observation of artificial crevices

Artificial crevice observation is an important term in this study. Analysis of this topic gives a clear view of the process of the crevice, its significance of it, and the work function of artificial crevice [14]. Here hypochlorite is considered as ‘chlorine’ while NaCl is referred to as ‘chloride’. In this study of visual observation of artificial crevices, experimental results are described as invisible corrosion, slightly visible corrosion, severe visible corrosion, localized corrosion as well as pitting corrosion [15]. The process of corrosion attacks 8 instances invisibly. When an application of corrosion is applied for high external potentials the attack of corrosion is called severe corrosion. For promoting the process of corrosion always external potential have to be higher than 200 V. It is an effective process for promoting corrosion. The main observation of this particular topic is no corrosion was implemented for 304 SS in 400 ppm chloride or a mixture of 40 ppm chlorine or 400 ppm chloride under the external process of potential 200V [16]. In pitting corrosion of the place of crevice mouth processing a mixture of 400 ppm chloride and 40 chlorine ppm. This experimental observation of the artificial crevice is described in the below figure.

Figure 3



	304 SS pos 1.1 cm	316 SS pos 1.1 cm
Mean	277.27	242.73
Standard Error	40.09	35.27
Median	300.00	200.00

Mode	400.00	200.00
Standard Deviation	132.97	116.97
Sample Variance	17681.82	13681.82
Kurtosis	-1.30	-1.06
Skewness	-0.49	0.26
Range	350.00	330.00
Minimum	50.00	70.00
Maximum	400.00	400.00
Sum	3050.00	2670.00
Count	11.00	11.00
Confidence Level(95.0%)	89.33	78.58

Influence of the different factors on measurement

Location

Measurement is a crucial part of any kind of chemical process. This paper described elaborately the measurement of several components. This part of the area covers a discussion related to different factors on measurement and what is the influence of measurement in the part of crevice corrosion. In the mouth of the crevice chloride and pH were measured at 0.5 cm and 1.1 cm. This total process happens in absence of localized attacks [17]. From the mouth of the crevice, the products of corrosion accumulate every time. One experimental fast is ohmic drop is hired along with the constricted gap of the crevice. The geometry of the crevice was difficult to reproduce in the creviced surface for both if it is crevice corrosion and pitting corrosion [18]. Basis of the position of measurement huge differences was observed in the experiment.

Potential

Potential is an element that analysis through various experiments. A drop of potential is a crucial part of a process or experiment [19]. Potential is actually influenced by the quality and quantity of steel with applied external potential, conditions of pitting, and various types of test solutions. Potential is the element that can regulate the value of potential drop such as a higher applied potential can increase the potential drop value in an experimental process. The below figure clearly mentioned how a drop in potential is important for a solution.

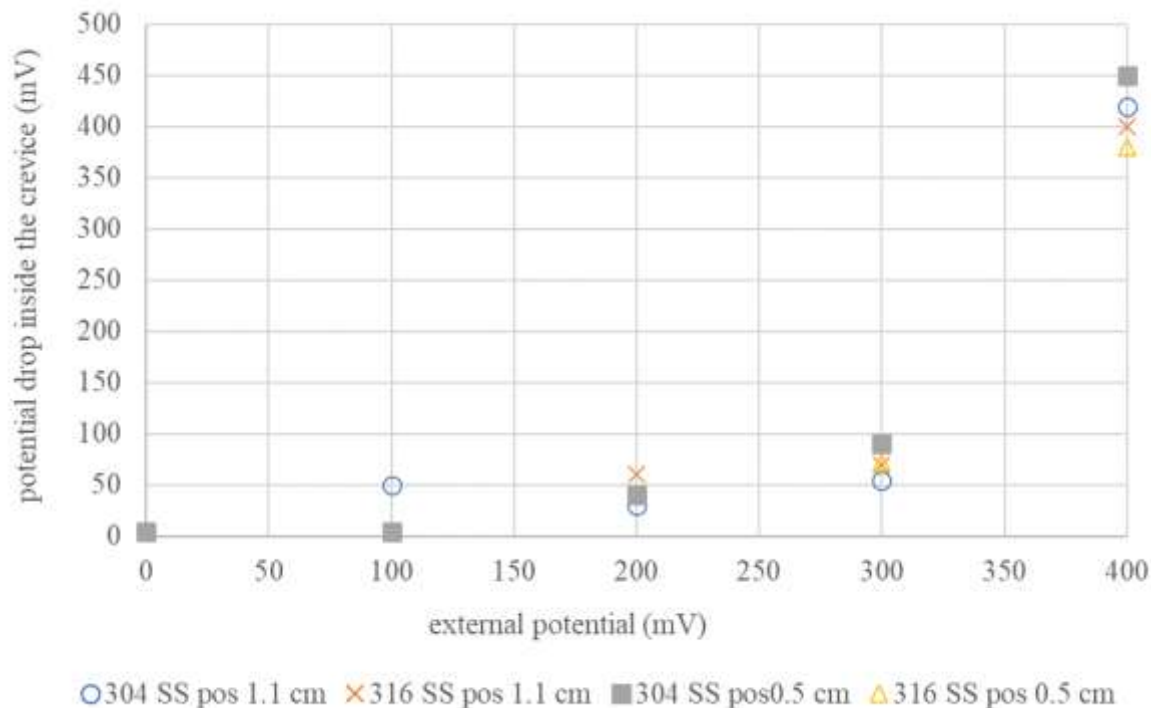


Figure (4) SS304 and SS316 with pos 0.5 cm and 1.1 cm

From that entire figure is clear information about the importance of potential drop. In a crevice, the formation of pits is the largest potential drop. In a mixture of 40 ppm, chlorine and 400ppm chloride are an external potential for 304 SS. In under of applied potential of +200 mV for the process of both steel samples in all various test solutions increasing crevice potential initially for 60 min – 400 minutes. In the process of potential, the rate of the potential drop was faster at the primary stage of the process or experiment and later stage of the experiment it becomes slow. This analysis study shows all information related to potential drops in a process of experiment.

pH

pH is an integral component of any type of experimental solution [20]. From 15 mV to 5 mV at a pH value of 0.1 - 0.3 is the lower potential of the artificial formation. Internal resistance drop between the elements of the salt bridge and electrode surface [21]. Observation of an experiment says as an oxidizing agent shifted potentials to the value of positive. Inside a crevice, the formation of pits and applied potential is strongly affected.

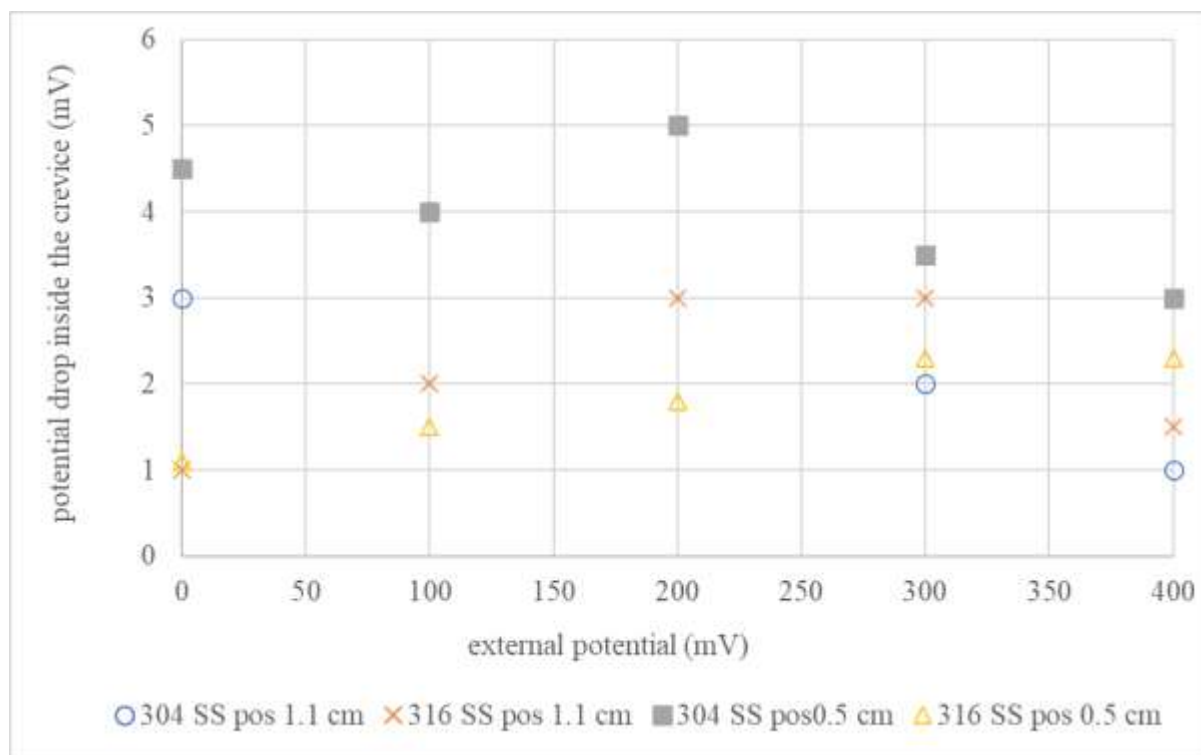


Figure 5 potential drop inside the crevice (mVolts) for both SS304 and SS316 with pos 1.1 cm and 0.5 cm

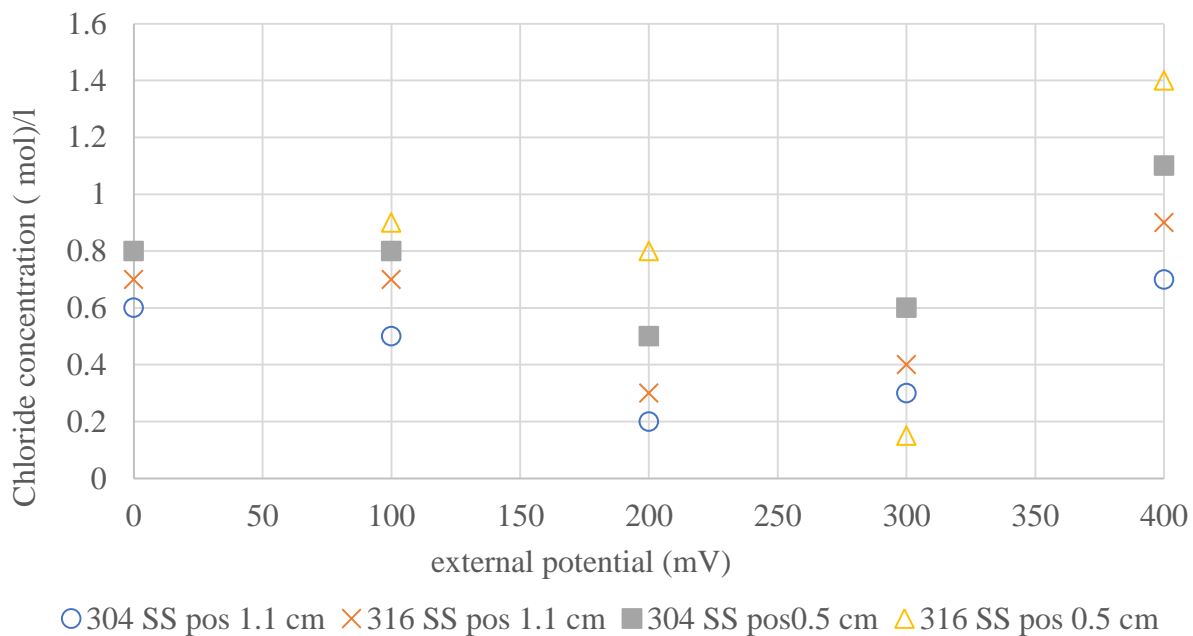


Figure 6 chloride concentration (mol/liter) and crevice in different pos in both SS304 and SS316

Chloride concentrations

Chlorine solution of 0.001 mol/L with a concentration of chloride in the range of 0.01 – 0.013 mol/L. This is an experiment with a steel sample. Steel sample is a reason for the polarisation of potential drop and steel sample within the range of 5 – 15 mV. The formation of any single pit within a crevice needs only the presence of a small second cavity [22]. In some cases, increasing the concentration of chloride to 2 mol/L. the maximum concentration of the chloride can dictate a bulk solution for any process of experiment.

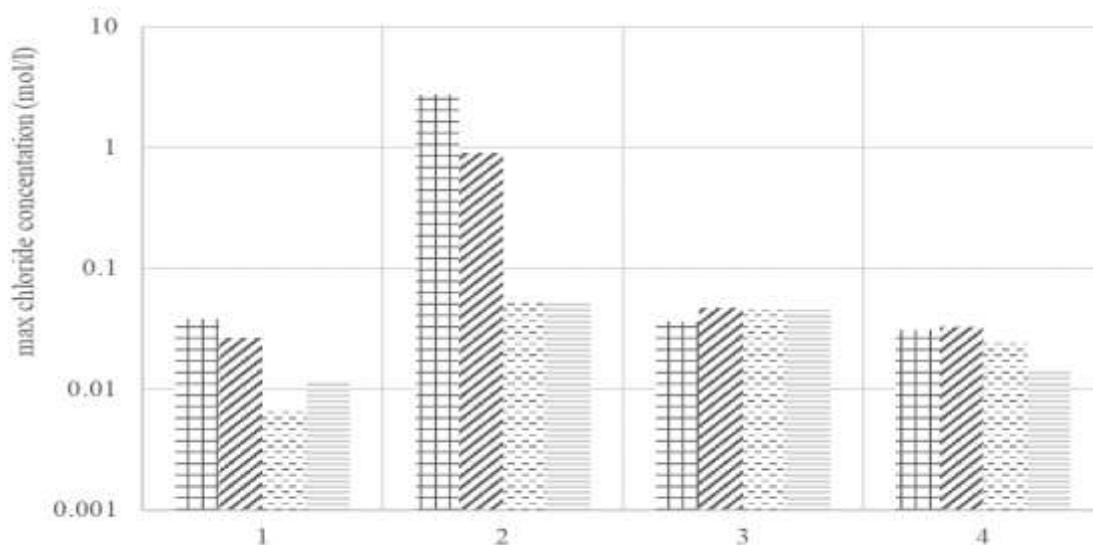


Figure 7 Max chloride concentration (mol/l) for different solutions

Polarisation

Polarisation is a process of experimenting with all solutions. This process continues through corrosion potential absence of oxygen and after that presence of oxygen [23]. For free corrosion potential, a positive value of chlorine is exhibited in all types of solutions. In free corrosion potential, oxygen-free conditions have a negative value in the NaCl. If the cathode is enhanced in any hypochlorite experimental solution in the current destiny in free corrosion potential. From chlorine solutions on 316 SS at a higher negative potential destroyed chloride solution [24]. From passive firm to breakdown positive value was more active on 304 SS in absence of oxygen. A mixture of 40 ppm, chlorine, and 400 ppm chloride solution shows a similar polarization curve. In an experiment on NaClO and NaCl anodic current was first attained. In the under of oxygen and nitrogen, the passive firm was destroyed at around 400 mV [25]. If increased density in the passive current manner in the absence of oxygen, then the solution mixture factor came to 5.

Discussion

Mechanism of crevice corrosion

An artificial crevice gives a result of corrosion mechanism of any process result became pH, potential or extra. The mechanism of crevice corrosion is a very crucial method in any chemical

experiment. Crevice corrosion is a reproducible experimental process that controls various components of the chemical process [26]. This process indicates several changes in the whole procedure. This solution is generally affected by the presence of sub crevice. Any kind of uncertainty in solution profile shows an error in the result.

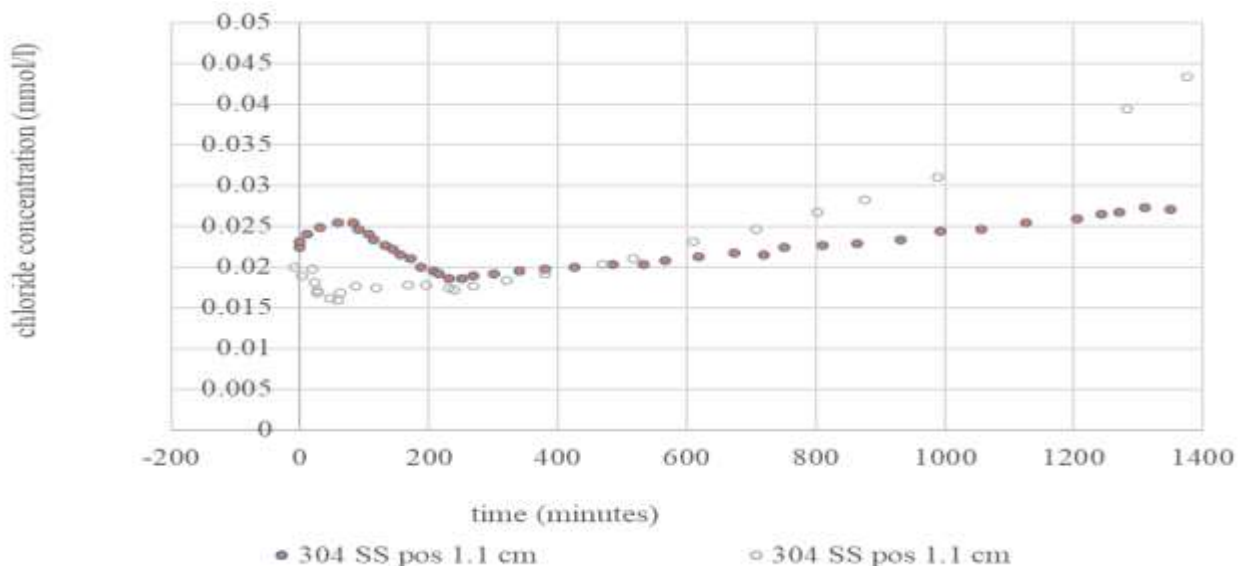
Visual observation

It is a kind of process of crevice solution. Visual observation is very impotent to detect forming or process function. This procedure actually observes corrosion products, pits along with crevice corrosion. This process works actually when one artificial crevice fails to create or play any other corrosion, at that time visual observation process really works to continue the process. Inside an artificial crevice, pits are processed in the presence of oxygen. This visual observation is very important to present the process of solution or crevice corrosion. The crevice corrosion method is a process that actually depends on various chemical factors [27]. This is a mixture of chloride ions. Due to the experiment, this process is supported by the fact to vanished AgCl. In a crevice corrosion process, the critical condition of chloride and potential difference play a crucial role. Due to pitting or crevice corrosion area of dissolution is still unclear. Inside a crevice, a huge number of corrosion products are found [28]. On another side, a per experiment inside a deep pit found zero corrosion. According to an earlier report, 304 SS was more useful corrosion as compared to 316 SS. In the process, molybdenum presents as a response element for any experimental program. This analysis study shows the value of chemical experiments, the responsibility of visual observation, values of critical analysis, or the value of crevice solution.

Analysis of potential

The potential analysis is also an important part of the experimental study. The potential method helps to know about the process of any kind of experimental observation, components of the process, and the result of a process, or another. Potential drop can measure in many ways like electrode through crevice gap in the flow of current, electrolyte rate in the bulk solution and crevice, dimension, and height of the crevice. The potential of +200 mV by thick oxide diminished passive current. The flow between the counter electrode and the metal in the crevice solution remains constant.

Figure 8



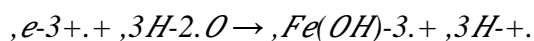
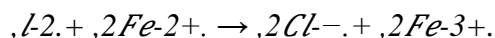
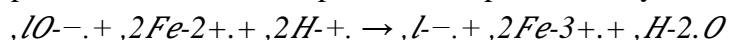
All those above figures show how potential solutions are working. How this function is important for any kind of chemical experimental process. Corrosion is a position where corrosion current is controlled by a cathode in a process. Under an application of 400 ppm as an external potential crevice, the potential was decreased very fast but oxygen and chlorine are decreased by hypochlorite solutions.

Chloride concentration

Chloride concentration analysis is a crucial part of crevice corrosion. In this process when electrode potentials were moved to the negative side than the concentration of chloride was very high. In a crevice, Ag/AgCl electrodes are affected by corrosion [29]. Opposite of Ag/AgCl electrodes forming a minor second crevice inside the main crevice. Observing the study provides a clear study of crevice corrosion, chloride concentration, the process of formation, and elements of this chemical experimental procedure, or another. In this process chloride concentration does not depend on any type of solution, this concentration is not influenced by bulk solution as well. Relation of elements in any process of solution is observed in a crevice of corrosion.

Different test solutions in crevice corrosion

In a solution of crevice different types of processes are available. In a chemical experiment test solution is a crucial part. Through the hypochlorite solutions process continues of formation of pits in the crevice. This procedure explains clearly in the below figure.



The above picture provides a clear knowledge about various points of crevice corrosion, its type of different solutions, the Variety of higher and lower potential drops, the density of the passive current, and the Variety of hypochlorite solutions, or extra. Under any normal atmosphere, all

testing formulas and results are the same. In any crevice, chlorate is a cathode reaction enhancing the level of pH.

Conclusion

Analysis of this study is a clarification of knowledge about crevice corrosion on stainless steel, analysis of its working method, the process of technology, and types of different aspects or elements about corrosion of crevice. There is still room for improvement in terms of reducing errors and improving the reproducibility of the outcomes. By enhancing the electrode holder surface and grinding process accuracy, the crevice gap profile can be altered. Using a sensitive torque wrench, screw the metal sample to the electrode holder. The pressure difference between the two surfaces should be reduced even more. The reactivity of the microelectrodes should be improved, but the surfaces of the Ag-AgCl electrodes utilized for analysis should not be polished. For changing the crevice spacing in the sample, different grits should be used. Additional tests can be carried out to see if the passive film is destroyed when the external voltage is reduced and the exposure time is increased. From this whole study conclusions such as

1. Analysis of pH and concentration of chloride
2. In a solution of hypochlorite, results are described in this study as compared to NaCl
3. A crevice solution analysis shows the formation of pits.

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