A Review of Electrochemical Corrosion on Stainless Steel 316

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Abstract: *Electrochemical corrosion behaviour on stainless steel 316 has been studied with various solutions and its corroded samples along with the microstructural studies and prevention. The electrochemical corrosion occurs due to the transformation of electrons at the metal surface to depolarizer. In the existing approaches, the test methods of the electrochemical corrosion are performed to investigate its behaviour on stainless steel 316. The result shows that small and porous pits were observed when using some acidic solutions (eg: HCl, H_2SO_4, $FeCl_3$). Localized pitting effect on grain boundries of the corroded sample was analyzed by using an optical microscope and SEM. In PWR (Pressurized Water Reactor) environment, the potentiodynamic polarization test was performed to evaluate the electrochemical behaviour on stainless steel 316. Some results showed that the corrosion rate of stainless steel 316 can be avoided with the help of powder coating methods. Various powder composition such as acrylic, polyester, epoxy, nylon, and urethane can be used to prevent electrochemical corrosion. In this survey, the electrochemical corrosion behaviour on stainless steel 316 was studied and thus, a conclusion is drawn to prevent this electrochemical corrosion by using various powder coating methods.*

Keywords: *electrochemical corrosion, stainless steel 316, microstructure studies*

1. INTRODUCTION

Corrosion is the degradation of materials properties by electrochemical reaction with the environments. There will be a huge problem due to the loss of material by corrosion process. The common problem for the corrosion is rusting of the metal in atmospheric conditions. The rusting is formed due to the presence of hydrated ferric oxide on the surface. From the types of corrosion, we mention the wet corrosion or electrochemical corrosion which occurs when the metal is in contact with a conducting liquid and the two dissimilar metals or alloys are submerged to a limited extend in a conducting solution.

This corrosion occurs in separate cathode and anode region between the current flows through the conducting solution. From the electrochemical theory, corrosion of the material occurs due to the presence of atmospheric conditions. In the anode and cathode areas, a large number of galvanic cells are formed. In the anode, oxidation takes place and electrons are released and relocate towards the cathode region. The presence of the oxygen undergoes depletion at the cathodic region in the presence of moisture forming hydroxyl ions.

316 Stainless steel is used for various applications with high corrosion resistance, excellence in electrical and thermal conductivity and mechanical workability. Among all the materials AISI 316 stainless steel is a good source of material (petrochemical), water desalination, drilling marine ships, pharmaceuticals etc. 304 stainless steel and 316 stainless steel are used to handle highly dilute acid at low temperature.

The high corrosion resistance of 316 stainless steel arises from the formation of a passive layer on its surface [1]. The passive film is a part of the chromium oxy-hydroxide layer, iron and water containing-compounds which is formed at the metal interface and formed by chromium oxide [2]. The pitting corrosion which causes a failure in stainless steels, forms due to the presence of chloride ions. The main source of aggressive chloride ions is the hydrochloric acid (along with the seawater) [3-5].

The pitting corrosion occurs at steels in chloride media. Sulphuric acid is highly corrosive on stainless steel too. The stainless-steel corrosion processes in the various kinetics complexes involved have been investigated less in concentrated acid solution. Hence, it is essential and practical to study the influence of acidity, chloride and sulphide ions. The presence of ions causes inhibitors to avoid the destruction of the material surface with the aggressive solution.

In this investigation, a new development of pitting susceptibility on 316 stainless steel corrosion behaviour results in either hydrochloride or sulphuric acid solution. This process observes the inhibitors of stainless-steel corrosion utilizing non-toxic inhibitors.

2. EXPERIMENTAL STUDIES

The electrochemical corrosion behaviour on 316 stainless steel was investigated in the bases of sulphuric acid and deaerated hydrochloric acid by using the open circuit potential, chronoamperometric and voltammetric techniques. The corrosion is enhanced in stainless steel samples which has a huge HCl concentration, with a potential range between protection and pitting. The chloride ions improve stainless-steel corrosion through passive layer [6]. The pits growth is been differentiated by a constant potential procedure by Engell and Stollica [7].

In this process, the development on the electrochemical process is used for the following coating of 316 stainless steel on various application. In this work, the parameters are optimized for the use of electro-polishing and the temperature, duration of the electrolysis and the acid dipping are also accurately measured and discussed.

In this evolution, the surface topology was observed by atomic force microscopy, scanning electron microscope and profilometry. Hence the improvement occurred in terms of surface morphology on stainless steel 316 [8].

Electrochemical corrosion behaviour was investigated on 316 stainless steel and AISI 1010 carbon steel has been experimented with the NaCl solution at 3 wt.%. Hence the result shows that inhibitor concentration (25 ppm to 1000 ppm), enhances the polarization resistance on both plates of steel; the highest efficiency of corrosion inhibitors was gained by using imidazole at concentration 50 ppm on both plates of steel. The 316 stainless steel has an efficiency of 96% as compared to AISI 1010 carbon steel which has an efficiency of 73% [9]. This process explains the corrosion polarization behaviour of 316 stainless steel in acid chlorides and strong acids. The corrosion resistance on 316 stainless steel was performed in different concentrations at ambient temperature (intermediate and concentrated) of sulphuric acid (H_2SO_4) and phosphoric acid (H_3PO_4). Similar tests were also performed besides 2% (20g/l) of sodium chloride to specified acid concentration to form acid chlorides. For investigating the corrosion behaviour, the potentiostatic polarization method was used. The electrochemical corrosion characteristic reaction exhibits in both passive and active with 2% NaCl concentration led to an increase in the active corrosion reaction. Hence, the magnitude of corrosion could be considered as low and overall corrosion resistance performance of this alloy is excellent [10].

This process explains that the electrochemical noise was generated during pitting and general corrosion of austenitic 316 stainless steel in the acid chloride environment. It was observed as spontaneous fluctuation. This results in existing known pitting or general corrosion of stainless steel. By increasing and decreasing the frequency, noise amplitude occurs, which indicates the flicker noise. The 316 stainless steel surface is examined through the scanning electron microscope to check whether there is any occurrence of pitting and severe general corrosions [11]. The electrochemical behaviour of 316 stainless steel was studied to observe the effect of thiophene derivatives in acidic solutions which contains chloride ions. Both corrosion rate and pit growth were inhibited of the sulfur-containing compound in the corroded medium. The result shows that different thiophene derivatives were used to investigate the electrochemical behaviour of the 316 stainless steel. It was concluded that the inhibitors are of mixed type and the change of cathodic and anodic Tafel slopes was compared. In 0.5 M H2SO4 the 97% of inhibition efficiency was achieved on 316 stainless steel [12].

The electrochemical corrosion behaviour was analyzed on 316 stainless steel, it shows the effect of chemical vapor deposition and growth on carbon nanotubes and nanofibers. The 316 stainless steel plates were investigated on pristine, coated with carbon nanotube layer and carbon nanofiber layer. The Carbon nanotubes and carbon nanofibers were directly grown on stainless steel in chemical vapors deposition using ethylene as a carbon source. This layer is used to protect the stainless steel in porous nature; real corrosion damage is lower on 316 stainless steel at CVD atmosphere. It is also preventing the local damage of coating from high risk [13]. The electrochemical corrosion behaviour of 316 stainless steel has been investigated by using the acetic acid and dilute hydrochloric acid at 25˚C of oxygen gas. The electrochemical impedance spectroscopy and polarization curves illustrate the 316 stainless steel corrosion potential. From the various solutions, the electrochemical corrosion acts on low and high concentrations to perform current peak at below pitting potential of NaF solutions [14].

The characteristics of electrochemical corrosion of 316 stainless steel are simulated anode environment for proton exchange membrane fuel cell (PEMFC) with the dilute hydrochloric acid solution. To investigate the electrochemical measurement techniques, acid solution at 80˚C of unmixed hydrogen gas is used. The electrochemical impedance spectroscopy (EIS) and the polarization curve from the cathodic reaction on 316 stainless steel deteriorate the corrosion resistance. The EIS reveal the porous corrosion layer on stainless steel in the test solution. The 316 stainless steel exhibits in sulfate ion-containing dilute hydrochloric acid solution at similar corrosion behaviour [15].

The corrosion behaviour on 316 stainless steel with TiN coating was observed in proton exchange membrane fuel cell environment (PEMFC) with 0.01 M HCl + 0.01 M Na_2SO_4

solution with oxygen and hydrogen gases. TiN coating has better corrosion potential in simulated cathode anode environment. The result shows that TiN coating on 316 stainless steel has elevated corrosion resistance and electric conductivity by improving coating quality to examine long-term stability [16].

The 316 stainless steel with weld metals have better corrosion resistance compared to base metal. It has an inhomogeneous and dendritic microstructure with micro segregation of major elements (e.g. Cr, Mo, and Ni) in minor element (e.g. S and P) interface boundaries.

From this study, uniform and microstructure corrosion behaviour of 316 stainless steel varies Cr, Mo concentration with different ferrite content.

Hence in the microstructural studies, this material in the oxidizing medium has been proposed [17].

The Electrochemical corrosion on 316 stainless steel with polyaniline-graphene oxide (PANI-GO) composite was prepared by pulse current co-deposition method. Graphene oxide and aniline have occurred in the deposition process and compact coating on stainless steel was formed on the surface.

The corrosion inhibition efficiency and protection efficiency of the PANI-GO composite coating reached 98.4% and 99.3%. In addition, the deposition parameters had an obvious effect on the corrosion resistance of PANI-GO composite coatings due to changes of their porosity and wettability [18].

Electrochemical noise measurement on 316 stainless steel with TiN coated was monitored by corrosion-wear measurement. The corrosion-wear mechanism was executed in TiN coating with 316 stainless steel with sliding against corundum in 0.5 M H_2SO_4. The result shows that the electrochemical noise can identify the potential and current variation during the corrosion-wear measurement.

Corrosion wear mechanism of TiN coating depends on the material properties. This process reflects the properties of the coating in potential and current variations. And thus, the corrosion wear monitoring on 316 stainless steel with TiN coated material was enhanced on corrosion resistance [19].

Electrochemical studies on 316 stainless steel with peroxide solution was analyzed in this paper and the pollution control results in replacing the bleaching chemical (chlorine as peroxide).

The electrochemical test was conducted on 316 stainless steel comparing other quality stainless steels 304L, 316L, 2205, 6% Mo and mild steel in peroxide solutions (pH 10).

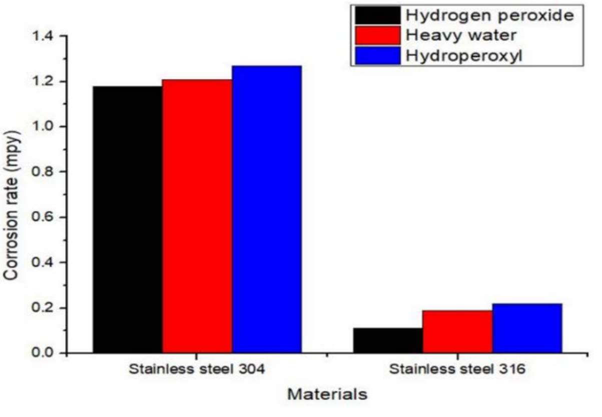

Fig. 1 – Corrosion comparison of stainless steel 304 vs 316

The materials are tested in the following process which contains all the corrosion factors that attack the welding area.

The experimental studies have been done on suitable material for handling the corrosion attack and the mechanical properties were also been analyzed [20]. It was determined that the 316 stainless steel has been improved in its corrosion resistance compared to the following materials in Figure 1.

3. CONCLUSIONS

316 Stainless steel has excellence in corrosion resistance as compared to other austenitic stainless steels. In this study, the addition of molybdenum content is of 3% in order to increase the corrosion resistance of the 316 stainless steel. Additional coating, micro and nanocomposites are used to enhance the corrosion outcomes. Our study shows that, in all corrosion applications, 316 stainless steel can be used with additives as a suitable material, with improved strength and durability.

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