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Short Communication

Influence of temperature on the pitting corrosion behavior of AISI 316L in chloride–CO_2 (sat.) solutions

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A R T I C L E I N F O

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A B S T R A C T

The paper discusses the pitting corrosion behavior of AISI (American iron and steel institute) 316L stainless steel in aerated chloride solutions (0.1–2 M NaCl) at 25, 50 and 80 °C using potentiodynamic polarization technique. A comparison is made with CO_2-saturated chloride solutions. The results have revealed that pitting potential decreased in a logarithmic relationship with the chloride concentration, and decreased linearly with temperature. The influence of CO_2 on the chloride pitting of AISI 316L stainless steel is quite complex and found to be dependent on chloride concentration and test temperature. At 25 °C the presence of CO_2 appears to have insignificant effect on E_p irrespective of chloride concentration. As the temperature is raised to 50 or 80 °C the additions of CO_2 has caused marked negative shifts in pitting potential. The detrimental effect of CO_2 increases with NaCl concentration and temperature. The results indicate that pitting potential ($E_{p)}$ is influenced by a synergy between chloride, CO_2 and temperature, and that this synergy depends on the chloride concentration and test temperature.

1. Introduction

AISI 316L stainless steels combine good mechanical properties, weldability and corrosion resistance to corrosive environments. These characteristics are attributed primarily to relatively high level of chromium, lower carbon content ($\leqslant$0.03%) and the addition of molybdenum (2–3%). Chromium in this alloy promotes the formation of a protective surface oxide, molybdenum enhances the pitting corrosion resistance and the low carbon hampers the formation of chromium carbides during cycle exposure to high temperature. For the fact that it has good mechanical properties and outstanding resistance to corrosion, the AISI 316L austenitic stainless steel is widely used in chemical, petrochemical industries and multi-stage flash (MSF) desalination plants [1–5].

Although AISI 316L stainless steel alloys show extremely good general corrosion resistance, it is nevertheless prone to localized corrosion. Pitting attack, in particular, is the most critical and widespread form of corrosion failure in desalination plants and petrochemical allied branches [5,6].

The rate of pitting attack on AISI 316L stainless steel alloys in chloride solutions can be sharply raised with the change of the corrosion conditions such as solution chemistry or test temperature [7,8]. In general, increasing chloride concentration and temperature, and decreasing pH have been found to decrease the critical pitting potential of AISI 316L stainless steel [7]. Combined temperature and the presence of dissolved carbon dioxide (CO_2) are reported to have an important effect on the chloride pitting corrosion behavior and mechanism, leading to increased attack with temperature [8].

Numerous research papers have been published concerning the effect of chloride–CO_2 on steel, 13 chromium- martensitic stainless steels or duplex stainless steel alloys [9–16]. However, information about the response of AISI 316L in a medium containing chloride and dissolved CO_2 species at different temperatures is rather scarce [8]. Thus, the objective of the present work is to contribute to the study of the influence of dissolved CO_2 (sat.) and/or temperature on the chloride pitting corrosion behavior of AISI 316L widely used in used in oil & gas industry and multi-stage flash (MSF) desalination plants. The main source of CO_2 in desalination plant is bicarbonates present in seawater. The CO_2 is usually released in high temperature stages along with other dissolved gas, mainly oxygen and nitrogen. Despite the removal of CO_2 directly by vent system or even by passing through decarbonator before further degassing in the de-aerators, some CO_2 will still be present in the plant causing corrosion to steel alloy structures and condenser tubes [17]. In oil/gas system, however, water, chlorides and acidic gases such as carbon dioxide coproduced with the hydrocarbons constitute the corrosive environment.

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2. Experimental details

Austenitic stainless steel AISI 316L was used in this study. The average chemical composition of the alloy as determined by electron diffraction spectroscopy (EDX) is given as; C 0.03, Mn 2.0, Si 0.4, P 0.045, Cr 17.3, Mo 2.59, Ni 10.7, N 0.10, Fe bal. The test samples were connected (spot-weld) to an electrical connection (nichrome wire) and embedded in epoxy resin with an exposed working area of about 2 cm^2. The working surfaces were subsequently wet abraded with decreasing grit size to 1000 silicon carbide (SiC) paper and rinsed with distilled water.

The corrosive environments consisted of aqueous NaCl solution of varying concentration (0.1–2 M) and air saturated or saturated with 1 atm CO_2. The CO_2 was bubbled through the test solution for 3 h prior to any experimental test. The pH of the chloride–carbon dioxide (Cl^-–CO_2) solutions was monitored before and after the polarization test and no significant differences were observed. In general the final pH value of the air saturated and Cl^-–CO_2 solutions (measured at 25 °C) was 6.90 and 3.33, respectively. The working experimental temperatures were kept constant during the whole tests at 25, 50 and 80 °C. The test temperature was controlled using a hot plate type heater.

The pitting corrosion behavior of the AISI 316L alloy was monitored by polarization technique in a conventional three electrode cell (saturated calomel electrode (SCE), platinum auxiliary electrode and the 316L working electrode) of 500 ml capacity. A potentiostat (type Wenking MP 95) and sweep generator (type Wenking MVS 87) controlled by a personal computer were used. The anodic potentiodynamic sweeps were applied from −400 mV (SCE) to the pitting potential with scan rate of 1 mV/s after 30 min immersion in the chloride solution at rest potential. In Cl^-–CO_2 solutions the scan was started from −600 mV (SCE). Duplicate polarization runs were carried out for each condition to ensure reproducibility of the pitting potential data. Pitting was recognized by an abrupt and sustained increased in the output current. The potential corresponding to this current rise is taken as the pitting potential. After completion of the anodic polarization run, the specimens were observed in scanning electron microscopy (SEM) to examine the pitting attack.

3. Results and discussion

Figs. 1 and 2 depict potentiodynamic polarization curves of AISI 316 stainless steel in different chloride concentrations (0.1–2 M NaCl) and temperature (25, 50 and 80 °C) with and without CO_2 (sat.) presence. All tests exhibit characteristic of passivation–pitting corrosion behavior on the anodic sweep.

The results of the polarization studies are collected in Tables 1 and 2, which comprises the corrosion potential (E_{corr}) and critical pitting potential (E_p) values. In general, the data reveals a decrease in E_{corr} and E_p with increasing chloride concentration, presence of CO_2, or raising temperature.

As shown in Table 1 the presence of dissolved CO_2 significantly decreases E_{corr}, indicating that CO_2 plays an indisputably central role in the stability of the metal surfaces in chloride environments. The shift of E_{corr} towards more active values in Cl^-–CO_2 solutions indicates the enrichment of alloy's corrosion susceptibility compared to its behavior in plain chloride solutions. The effect of CO_2 on the corrosion potential in chloride solutions is consistent with the results reported for super-martensitic and duplex stainless steel alloys [16,18]. Anselmo et al. [16] have reported that the changes in corrosion potential of stainless steel alloys in the presence of CO_2 is related to changing in film composition of passive film. The destabilizing effect of CO_2 on the passive film has been explained by the dehydroxylation of the outer part of

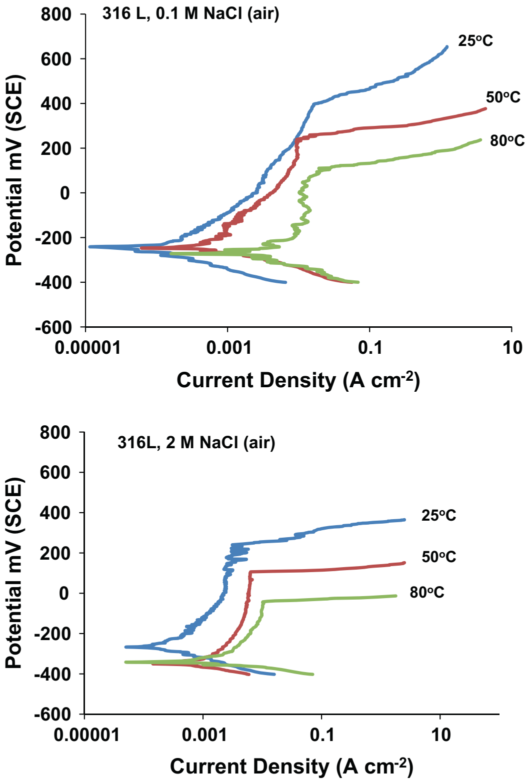

Fig. 1. Potentiodynamic polarization curves for AISI 316L stainless steel in aerated NaCl solutions.

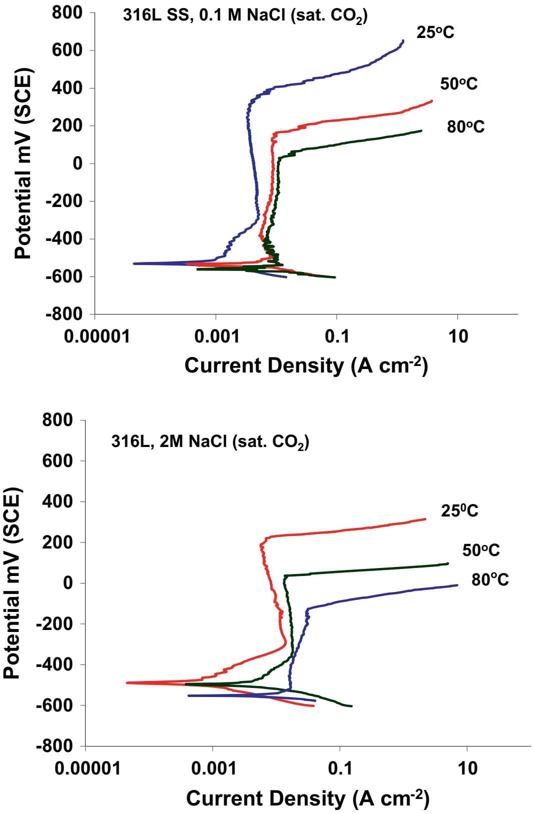

Fig. 2. Potentiodynamic polarization curves for AISI 316L stainless steel in CO_2-saturated NaCl solutions.