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Crevice Corrosion of Inconel and Hastelloy in a 60°C 3.5% Sodium Chloride Solution

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Abstract : The purpose of this paper is to examine crevice corrosion behavior of Inconel and Hastelloy in 3.5% sodium chloride solution at 60°C. This study investigates the important roles of chromium and molybdenum in crevice corrosion of these alloys. Results indicate that chromium and molybdenum plays a strong role in maintaining and stabilizing the passivity of Inconel and Hastelloy, respectively. No evidence of crevice corrosion was found in the Hastelloy specimen whereas it was observed in the Inconel alloy.

Keywords: *Crevice, corrosion, chloride, Hastelloy, Inconel.*

I. INTRODUCTION

Inconel and Hastelloy are widely used in a variety of applications where corrosive media are present. The amount of chromium (Cr) in Inconel and Hastelloy and the amount of molybdenum (Mo) in Hastelloy have a significant effect on their corrosion properties [1]. The current study was undertaken to determine the effect of the Cr and Mo content on crevice corrosion in these two alloys. The addition of Mo to Hastelloy changes the nature of the surface from one containing a more corrosive-prone nickel oxide to one with a more corrosive-resistant surface comprised largely of chromium oxide. The presence of chromium oxide reduces the crevice corrosion rate and increases the resistance to crevice corrosion.

Crevice phenomena are often created by contact between one material and another. The second material could be a component such as a connection such as a fastener made from the same material or from different material. In this study the second material is an elastic band which creates a crevice where deposits of mud and oxides and other solid particles that leave precipitates on the surface of the alloy test specimen. Corrosion in a crevice may be caused by exposure to the atmosphere or by retention of water; the other surface beyond the crevice are able to drain and dry. Crevice corrosion occurs by the same mechanism as pitting corrosion described earlier in since a crevice can be considered to be a pre-formed pit [2]. However, as with all types of corrosion, many factors influence the rate of attack, including the corrosive media, its concentration, and the alloying elements in the alloy.

Crevice corrosion is critical matter when considering material selection, especially where the environment is highly corrosive. A number of alloys such as the stainless steels, Inconel and Hastelloy have been successfully used in aggressive corrosive environments such as seawater or high temperature environments. Although, these alloys have excellent corrosion resistance in aggressive corrosive media, yet, there is some susceptibility to crevice and pitting corrosion, the degree of corrosion and degradation depending on the proportions of alloying elements and the concentration of the corrosive media. This paper briefly investigates crevice and pitting corrosion of Inconel and Hatelloy in 3.5 % sodium chloride solutions at 60°C for a period of 30 days.

II. EXPERIMENTAL PROCEDURE

The two alloys used in this study were Inconel and Hastelloy whose alloying elements are (Ni, Cr) and (Ni, Cr, and Mo) respectively, as indicated in data obtained from energy dispersive spectrometer EDS testing as shown in Figure 1. The two alloys were supplied as rod stock. Flat coupon samples with approximate dimensions of 0.5 inch in diameter and 0.25 inch width were cut from each alloy rod. It is noted that the dimension of the test specimens is not critical in this for the corrosion test described below. All specimens were tested under constant conditions and immersed all were immersed in the water bath corrosion testing device at 60°C±5°C for a period of 30 days. Final specimen preparation involved polishing with 600 grit papers followed by degreasing in a detergent solution and drying before immersion in the electrolyte bath.

Each specimen was held and tightens with an elastic band at the centre before immersion in a beaker containing a 3.5 % solution of sodium chloride. The beaker was then immersed in the water bath at 60°C ±5°C. The elastic band was also used to suspend the test specimen in the beaker.

A lid was placed over each beaker with just enough pressure to clamp the elastic hand used to suspend the specimen so that the elastic band was not cut. It was also important not to have a tight seal so as to eliminate any risk of an explosion due to the building of internal from to hydrogen generation. However, some level of containment is needed to prevent evaporation of the warm sodium chloride solution at 60°C.

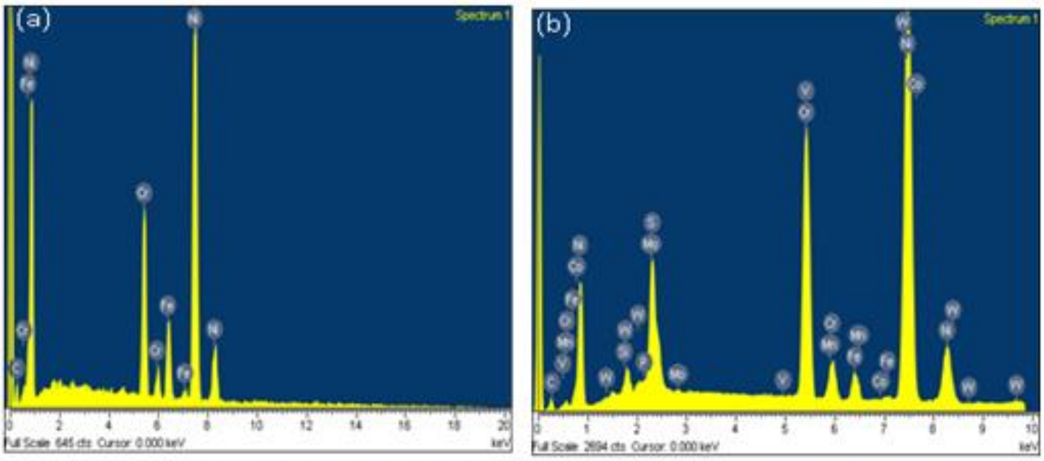

Figure 1 EDS charts showing alloy elements of both alloys (a) Inconel alloy and (b) Hastelloy.

III. RESULTS AND DISCUSSION

The influence of the proportion of alloying elements in each of these two alloys can only be demonstrated if crevice corrosion is initiated at or below 60°C. The degree of surface roughness, the materials and the tightening procedures used to form the crevice influence the test results as reported by several researchers [1].

Temperature plays an important role in crevice corrosion. With increasing temperature, the initiation of crevice corrosion and then its propagation in the crevice and mass transfer are accelerated

Nickel alloys are rarely used in corrosive environments as they readily lose their passivity and suffer crevice and pitting corrosion. Therefore it is essential to add alloying elements to pure nickel if they are to be used in corrosive environments.

After 30 days specimens were removed from beakers and the elastic bands carefully separated and removed from the specimens. With the naked eye it was seen that in the Inconel alloy a crevice formed beneath the elastic band and ran along the specimen and broadened and deepened with time such as in the case of Inconel alloy as shown in Figure 2 (a) where Hastelloy shows no crevice corrosion as shown in Figure 2 (b).

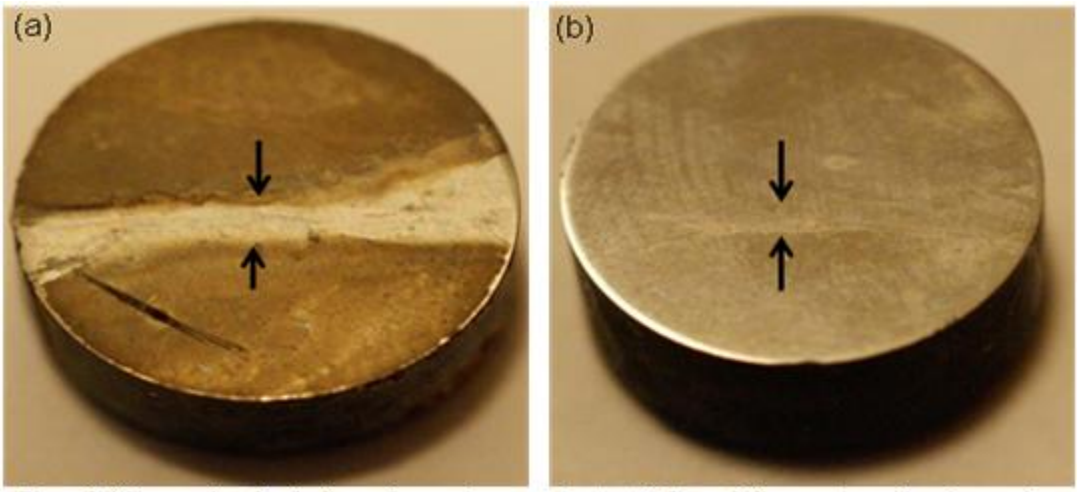

Figure 2: Micrographs of both alloys after crevice corrosion test (a) Inconel alloy specimen showing crevice corrosion and (b) Hastelloy specimen showing no evidence of crevice corrosion.

Microscopic observation using scanning electron microscopy (SEM) reveals a crevice corrosion zone in the Inconel specimen as shown in Figure 3. The difference between the part of the specimen surface unaffected by crevice corrosion and the part affected by crevice corrosion can be clearly seen in Figures 3 (a) and Figure 3 (b) respectively.

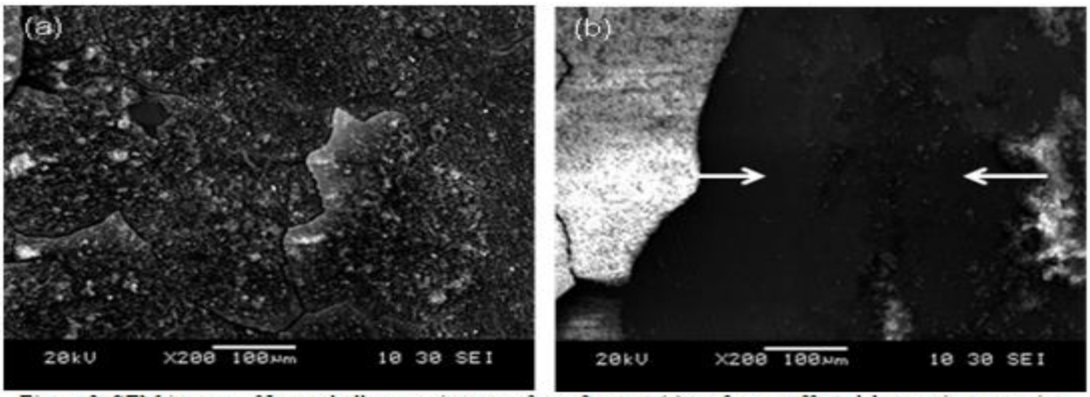

Figure 3: SEM images of Inconel alloy specimen surface after test (a) surface unaffected by crevice corrosion showing crystals of sodium chloride precipitate at the surface, and (b) crevice corrosion zone indicated by arrows.

Hastelloy, however show no indication of crevice corrosion on the specimens surface as can be seen in the SEM images where a part of the surface away from the creviced area is compared to the creviced as shown in Figure 4 (a) and Figure 4 (b), respectively. It is concluded that Hastelloy with Cr and Mo additions exhibits better crevice corrosion resistance than Inconel alloy.

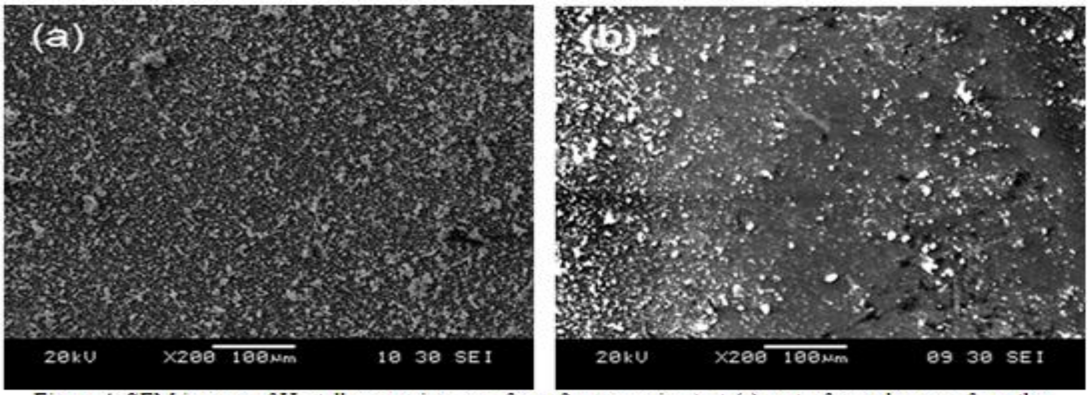

Figure 4: SEM images of Hastelloy specimen surface after corrosion test (a) part of sample away from the crevice area showing crystals of sodium chloride lying on the specimen surface, and (b) crevice zone with no indication of corrosion.

The crevice corrosion temperature for Inconel and Hastelloy is difficult to extrapolate from these results and become more complex corrosion process than it is in room temperature. However, these tests show that there is potential for crevice corrosion in Inconel alloys as can be seen from Figure 5.

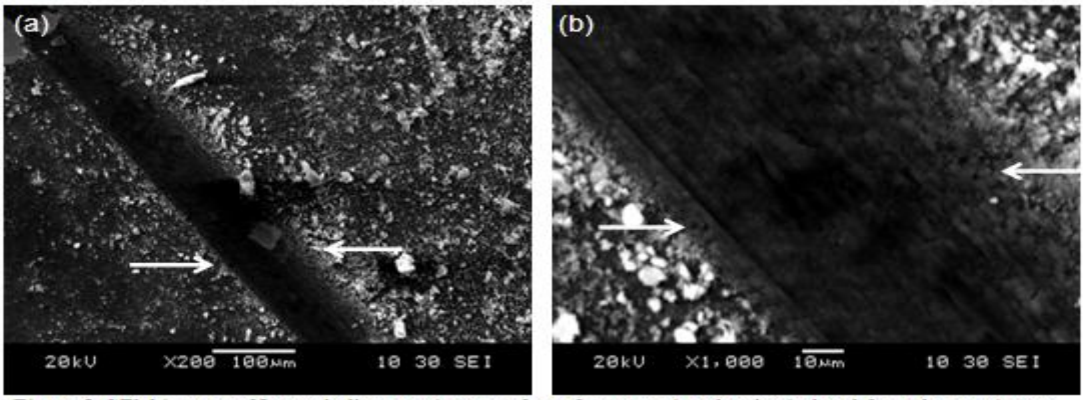

Figure 5: SEM images of Inconel alloy specimen surface after removing the elastic band from the specimens. Crevice corrosion is clearly indicated at (a) at low magnification and (b) at high magnification.

The main observations from this study are that Cr and Mo are responsible for passive behavior. The formation of a passive film on the surface generally occurred in both alloys tested in 3.5 % sodium chloride solutions. When molybdenum precipitates on the surface as an oxide (molybdate) within a pit it delays and prevents further pitting [2-4].

Figure 6 (a) and Figure 6 (b) show large pitting appearing on the surface of specimens of Inconel alloy as compared very small pits for Hastelloy, respectively.

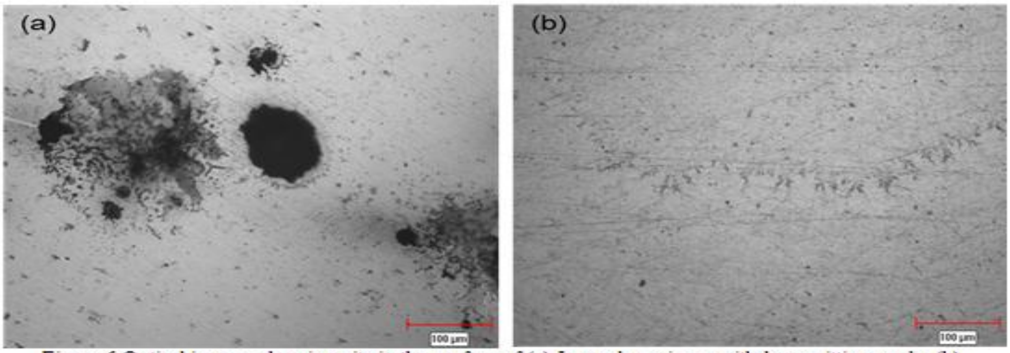

Figure 6 Optical images showing pits in the surface of (a) Inconel specimen with large pitting, and a (b) Hastelloy specimen with very small pitting

Nickel alloys possess excellent crevice corrosion resistance in sodium chloride solutions. The larger the proportion of alloying elements contents the greater their crevice corrosion resistance. Thus, increasing proportions of chromium and molybdenum lead to superior crevice corrosion resistance [1].

A study on alloy 625 in a sodium chloride solution at 15°C was reported by Olsen [6] while other studies observed crevice corrosion of alloy 625 in 15°C to an ambient temperature of 25°C in sodium chloride solution reported by [5,6]. Crevice temperature values ranging from 30°C to 50°C for alloy 625 have been obtained. Another study on crevice temperature tests of alloy 625 conducted in 4 % sodium chloride solution gave values from 25°C to 50°C as reported by [6,7].

Results from tests on alloy C22 show much higher values for crevice temperature of 55°C in a 4 % sodium chloride solution at 100°C. Alloy C22 should, therefore, be resistant to crevice corrosion in a 35°C sodium chloride solution [8,9]. Study reported crevice corrosion have initiated in alloy C22 at high chlorination levels in ambient temperature sodium chloride solutions. The crevice corrosion resistance of alloy C276 is similar to that for alloy C22 [8,9].

IV. CONCLUSIONS

Both Inconel and Hastelloy were tested to evaluate crevice corrosion in a 3.5 % sodium chloride solution at a temperature of 60°C±5°C for a period of 30 days. Observations indicated that Inconel alloy is susceptible to crevice and pitting corrosion whereas for the Hastelloy with addition of Mo and Cr there is no evidence of crevice and pitting corrosion. Results indicate that the proportions of Cr and Mo are responsible for passivation and stabilization of the surface oxide film and are especially marked in Hastelloy.

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