CORROSION BEHAVIOR OF PLASMA SURFACE OXIDIZED INCONEL 718 SUPER ALLOY

Özgü Bayrak[1], Yenal Vangölü[1*], Ali Fatih Yetim[2], Ayhan Çelik[1]
[1] Ataturk University, Erzurum, Turkey
[2] Erzurum Technical University, Erzurum, Turkey

[*] corresponding author: yvangolu@atauni.edu.tr

Abstract

Inconel 718 is a sample of nickel-iron based austenitic FCC structured super alloys. This alloy is commonly used at high temperature working conditions such as gas turbine engines, discs, turbine blades, nuclear reactors etc. Even though Inconel alloy exhibits high oxidation and corrosion resistance, these properties can be enhanced by using plasma oxidation, which is one of the most practiced surface treatments. In this study, Inconel 718 alloy was plasma oxidized at 500°C, 600°C and 700°C for 1 and 4 hours. Structural properties were analyzed by means of XRD and it was observed that several oxide phases were formed on the surface. Corrosion properties were determined with polarization technique in acidic environment.

Keywords: Inconel 718, Super alloy, Plasma oxidation, Corrosion, Oxide layer

1. Introduction

Inconel 718 is one of the most widely used nickel-iron based super-alloy, which is strengthened by an austenitic FCC, due to its superior mechanical properties such as tensile strength, creep resistance, low-cycle fatigue strength, good formability and weldability [1-5]. Inconel 718 constitutes 45% of the wrought nickel-based super-alloys. As it was developed for the main construction material of gas turbine engines, nowadays it is beneficially used in aerospace, aviation, petroleum and energy fields[6, 7]. For aerospace and aviation applications, this alloy is used in the areas such as aircraft turbines, gas turbine blade, combustion chamber, etc. where it is exposed to fuel components. Kerosene or commonly known as Jet engine fuel is a combustible liquid hydrocarbon which contains approximately 0.3% of sulfur. Aggressive atmospheres that contain sulfur can be harmful for the subjected materials and cause irrecoverable damages. Besides all properties, Inconel 718 has affinity for oxidizing. Inconel 718 forms a stable thick and passivizing oxide layer under high temperatures, which protects the surface from further attack and especially from corrosion.

In this study, Inconel 718 alloy was plasma oxidized at different temperatures and times to achieve different coating thicknesses. The corrosion behavior of the oxidized alloys was studied in 1 wt.% H_2SO_4 solution at room temperature. Potentiodynamic tests were carried out and the curves were drawn against the saturated calomel electrode (SCE). Structural properties were analyzed by means of XRD and it was observed that several oxide phases were formed on the surface.

2. Experimental Procedure

Inconel 718 plates with dimensions of 10x15x1 were used in plasma oxidizing process. The chemical composition of Inconel 718 is shown in Table 1. The samples were grinded by 220-1200 mesh emery papers, and then polished with alumina powder with 1 μm grain size. The specimens were plasma oxidized at 500, 600 and 700°C for 1 and 4 hours.

Table 1. The chemical composition of Inconel 718 (% wt.)

	Ni	Fe	Cr	Nb	Mo	Ti	Al	C	Co	Si
Inconel 718	Bal.	19.45	18.30	5.30	3.00	1.04	0.58	0.03	0.07	0.09

The specimens were cleaned with alcohol and placed into the plasma chamber. The plasma-oxidizing chamber was evacuated to $2.5x10^{-2}$ mbar (2.5 Pa) with a vacuum pump. Prior to oxidizing process the specimens were cleaned with hydrogen sputtering for 30 min under a voltage of 500 V. Then, the inner pressure of the chamber was fixed to 5 mbar ($5x10^2$ Pa) by introducing 100% O_2 with a needle valve. Electrical discharge was started immediately after the power was turned on and the specimens were heated to the desired temperatures by increasing the applied voltage.

Gamry Series G 750 Potentiotat/Galvanostat testing device was used in order to determine the corrosion resistance of the specimens. Potentiodynamic tests were carried out in a three-electrode cell system. Graphite, saturated calomel and the specimen itself were used as the counter, reference and the working electrodes respectively. Potentiodynamic scans were carried out at a scan rate of 1 mVs^{-1} between -1 V to +2 V. An acidic solution, 1 wt.% H_2SO_4 was used as the test electrolyte.

3. Results and Discussions

XRD patterns of both untreated and oxidized Inconel 718 were given in Figure 1. Inconel 718 specimen, which was indicated as letter "a" in the graphics, was discussed as a single phased structure formed of main structure elements. There were no significant changes observed in the structure after the plasma oxidation process carried out at 500°C for 1 and 4 hours. However at 600°C and 700°C, the complex oxides of the alloying elements, which were existed in the structure of Inconel 718, such as Cr_2NiO_4 (ICDD #03-065-3105) or $NiFe_2O_4$ (ICDD #01-089-4927) were observed and Cr_2O_3 (ICDD #01-070-3766) in particular. It can be seen that the structures were more extensive at high temperatures for the same periods of time but the magnitudes became lower as the time increased.

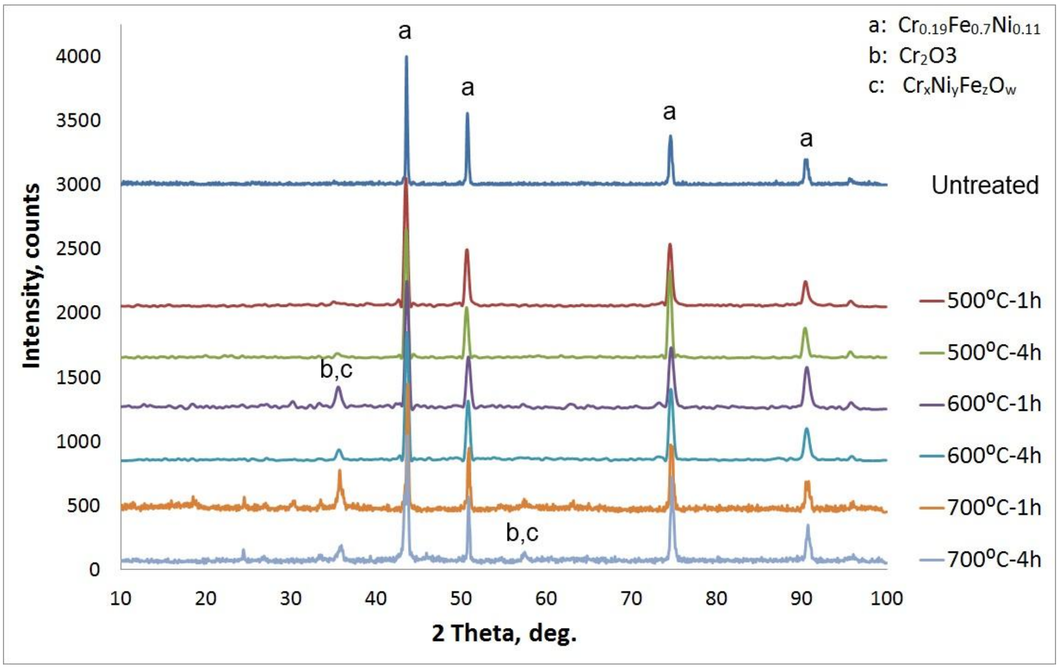

Figure 1. The XRD patterns of untreated and oxidized Inconel 718

The potentiodynamic scan curves of specimens oxidized for 1h and untreated Inconel 718 were given in Figure 2. According to the figure it can easily be seen from the curves of the specimens treated at 500°C and 600°C that the specimens showed a passivation behavior which can be described with decreased and remained stable or near stable current at the anodic area. After a certain potential, passivation was ended, current was increased rapidly and the corrosion was accelerated. In other words, trans-passive region was reached. There were no passivation observed in the specimens treated at 700°C and untreated ones. It was observed that the passing current was almost equal in the specimens treated at 500°C and untreated ones where it was quite low for the specimens treated at 600°C and 700°C.

The potentiodynamic scan curves of specimens oxidized for 4h and untreated Inconel 718 were given in Figure 3. In terms of the overall system and the current passing through the system, it can be said that both specimens showed a similar corrosion and passivation behavior except for the untreated ones. Trans-passive region was also reached on all the treated specimens at approximately the same potential value.

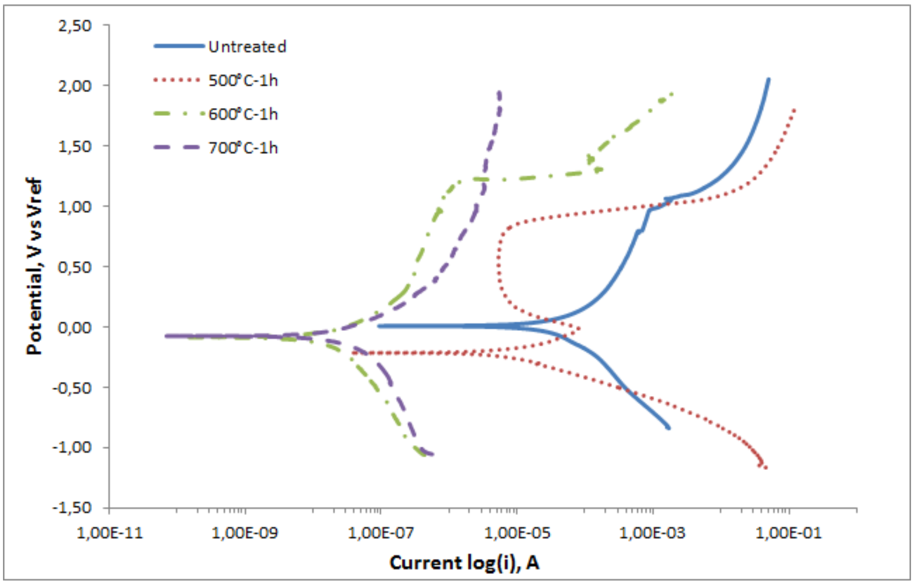

Figure 2. The potentiodynamic scan curves of specimens oxidized for 1h

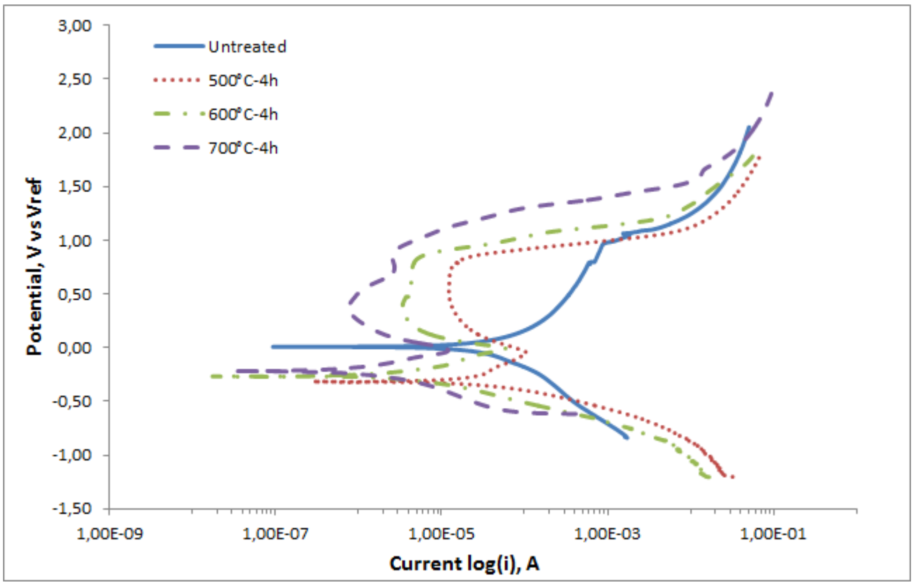

Figure 3. The potentiodynamic scan curves of specimens oxidized for 4h

Icorr, Ecorr and corrosion rate values of all conditions were given in Table 2.

Table 2. Icorr, Ecorr and corrosion rate values of treated and untreated Inconel 718

	Ecorr (mV)	**Icorr (nA)**	**Corrosion Rate (mmpy)**
Untreated	8,5	3870	897,8e-3
500°C-1h	-214	3620	28,5e-3
500°C-4h	-316	2920	17,4e-3
600°C-1h	-86	41	243,9e-6
600°C-4h	-267	689	4,1e-3
700°C-1h	-75	81	482,0e-6
700°C-4h	-218	1310	7,8e-3

4. Conclusions

Following conclusions can be drawn according to the results;
Complex oxide coatings, particularly Cr_2O_3 were formed on the surface of Inconel 718 after plasma oxidation process. The oxidation process made a positive effect on the corrosion behavior of Inconel 718 in general. According to either the phase density or the corrosion behavior, the best results were achieved from the specimens treated at 600°C and 700°C at 1 hour.

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