

## CORROSION BEHAVIOUR OF STEEL NITRONIC 60 IN RELATION TO STEEL 316L

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### ABSTRACT

*Austenitic stainless steels (ASS) have very good resistance to general corrosion but they are highly susceptible to localized corrosion such as crevice and pitting corrosion and SCC (Stress Corrosion Cracking). Nitronic 60 and AISI 316L are ASS with very good corrosion properties but AISI 316L steel is more famous than steel Nitronic 60. In this paper are presented results of investigation of corrosion properties for both steels. Two tests were conducted: investigation of general corrosion and pitting corrosion. Testing of corrosion were conducted in the corrosion cell according to Standard ASTM G5, on instrument potentiostat/galvanostat, Princeton Applied Research, model 263A-2, with the software PowerCORR® (Standard, ASTM G5-94) in 0.9% NaCl solution at room temperature ( $20 \pm 1$  °C). The results of corrosion tests show that steel AISI 316L is more resistant to a general corrosion than Nitronic 60 but it is more exposed to pitting corrosion.*

**Keywords:** austenitic stainless steel, AISI 316L, Nitronic 60, general corrosion, pitting corrosion, microstructure

### 1. INTRODUCTION

ASS-s are non-magnetic high alloyed steels with chromium and nickel and low content of carbon. These materials are widely used in automotive, petroleum, chemical, construction and other applications due to their excellent properties such as a corrosion resistance, good mechanical properties, attractive layout of the final product, long service life etc. The family of ASS-s have a wide variety of grades precisely designed for a specific application. The optimum choice of the grades would depend on service needs and this would require a clear understanding of the metallurgical parameters (alloy chemistry, sensitization, grain boundary segregation, presence of second phases, cold work, precipitation etc.) which control the microstructure and thus the mechanical properties, formability and corrosion resistance [1]. Nitronic 60 and AISI 316L belong to the family of the ASS. Nitronic 60 is a commercial name for silicon and manganese alloyed ASS. The addition of silicon and manganese inhibit wear, galling and fretting. The role of manganese in this steel is not only to decrease a content of nickel (the price of nickel is variable [2]) but also to increase the solubility for nitrogen, which is used for structure control, strengthening and improving corrosion resistance. Steel AISI 316L is one of the most used stainless steel which contain 2 to 3 % molybdenum. Molybdenum enhances corrosion resistance but it is a potent ferritizer. To prevent formation of delta ferrite, the nickel content has to be increased [3]. AISI 316L has lower carbon content than type 316. The lower carbon content minimizes deleterious carbide precipitation and 316L is used when welding is required in order to ensure maximum corrosion resistance [4]. The corrosion resistance of Nitronic 60 is between steel types of 304 and 316. General corrosion resistance of Nitronic 60 is not a quite as good as type 316 but it has better chloride pitting corrosion, stress corrosion cracking resistance and crevice corrosion resistance in laboratory conditions. Nitronic 60 has a better uniform corrosion resistance than steel 304 and excellent high temperature oxidation resistance. Thanks to good mechanical and corrosion properties Nitronic 60 found application for automotive valves, fastener galling, pins, marine shafts and pin and hanger expansion joints for bridges [5,6].

## 2. EXPERIMENTAL WORK

The aim of the research presented in this paper is testing the corrosion properties of steel Nitronic 60 and compare it with corrosion properties of commonly used steel AISI 316. Chemical composition of used steels is given in Table 1.

Table 1. Chemical composition of tested steels

Chemical composition, wt/%									
Steel	C	Si	Mn	Cr	Ni	Mo	P	S	N
Nitronic 60	0.05	3.9	9.0	16.0	8.7	-	0,007	0.006	0.179
AISI 316L	≤0.03	≤ 1.0	≤ 2.0	16.5-18.5	10.5-15.0	2.5-3.0	max.0.045	≤ 0.015	≤0.11

Two tests of corrosion resistance were conducted: investigation of general corrosion and pitting corrosion. Tafel extrapolation method was used for investigation of general corrosion of steels. Tafel extrapolation method implies scanning of working electrode potential on the order of  $\pm 250$  mV in relation to its Open Circuit Potential ( $E_{OCP}$ ), at the speed of  $0.2 \text{ mVs}^{-1}$ . Method of cyclic polarisation was used for investigation of pitting corrosion. The method of cyclic polarization includes scanning of the potential to a vertex potential and reverses at the current threshold after crossing the vertex potential. Scan rate was  $0.5 \text{ mV/s}$ . Investigations of corrosion were conducted in the corrosion cell according to Standard ASTM G5, on instrument potentiostat/galvanostat, *Princeton Applied Research*, model 263A-2, with the software PowerCORR® (Standard, ASTM G5-94). Investigation was performed in 0,9% NaCl solutions. Tests were performed at room temperature,  $20 \pm 1$  °C. The metallographic examination of samples tested on pitting corrosion was performed on the stereo microscope Leica with a maximum magnification of x60 and Olympus optical microscope with maximum magnification x1000. The samples were previously prepared (grinding and polishing) and etched in the Kalling's solution.

## 3. Results and Discussion

### 3.1. Testing of corrosion resistance

The results of general corrosion tests of investigated stainless steels are given in Figure 1 and Table 2. Figure 1 and Table 2. show the values of open circuit potential ( $E_{OCP}$ ) and corrosion current density ( $i_{cor.}$ ), of stainless steels samples treated in 0,9% NaCl solutions.

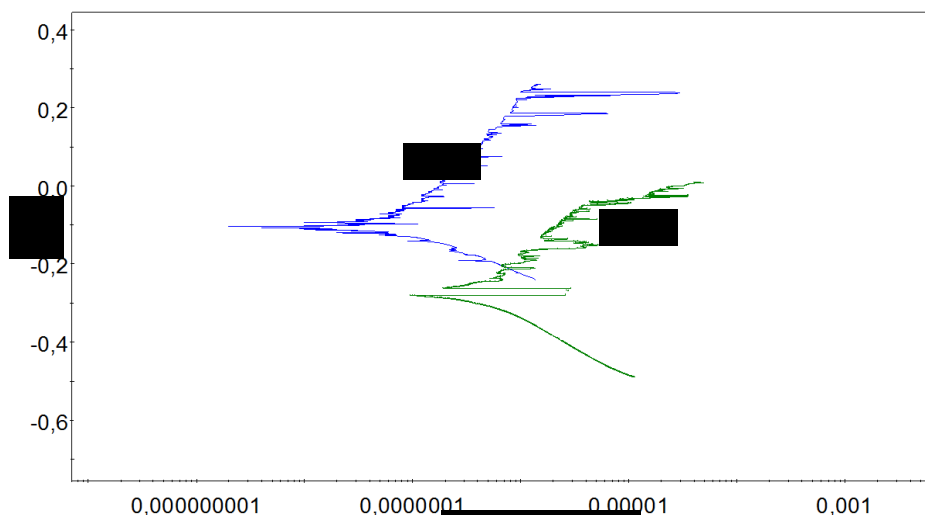


Figure 1. Tafel curves of samples tested in 0.9% NaCl solution (1 – sample of 316L and 2 – sample of Nitronic 60)

Table 2. The values of open circuit potential and corrosion current density

Designation samples	$E_{ocp}(mV)$	Corrosion current density, $i_{cor.} (\mu Acm^{-2})$
1	-103.48	$8.303 \cdot 10^{-2}$
2	-274.286	$5.45 \cdot 10^{-1}$

The results shown in Table 2 and Figure 1, show that steel 316L (sample 1) lead to a significant moving a open circuit potential ( $E_{OCP}$ ) to positive values as compared to the  $E_{OCP}$  of steel Nitronic 60 (sample 2). The results in Table 2 show that steel 316L has lower corrosion current density in comparison with steel Nitronic 60. According to both parameters ( $E_{OCP}$  and  $i_{cor}$ ), the steel 316L showed better corrosion stability. Pitting corrosion of stainless steels is manifested by the rapid growth of current at achieving specific values of anode potential, pitting potential ( $E_{pitt}$ ). Pitting potential is the potential at which pitting starts and that a phenomenon is noticed when the current of the polarization curve suddenly starts to rise. Surface of hysteresis loop is generally measure of the intensity of pitting corrosion. Larger surface loop means higher intensity of pitting corrosion [7]. The results of pitting corrosion tests of investigated ASS samples are given in Figure 2.

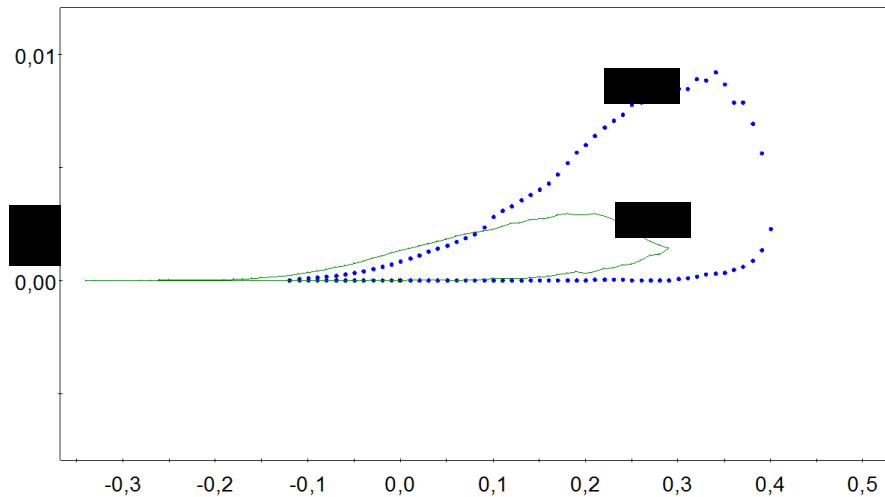


Figure 2. Cyclic polarization curves of samples tested in 0,9% NaCl solution (1 – sample of 316L and 2 – sample of Nitronic 60)

The results in Figure 2 show that both types of tested steels are exposed to the pitting corrosion but steel Nitronic 60 shows a significantly lower value of pitting potential (approx. 0,0805 V, Figure 2) than steel 316L with value of pitting potential about 0.370 V. This means that in real conditions the pitting corrosion would have occurred earlier on the steel Nitronic 60 than on the 316L type. On the other hand, the surface of the sample hysteresis of the sample 316L is much larger than the surface of the hysteresis of the loop of the sample Nitronic 60 steel. This means that the intensity of pitting corrosion for the 316L stainless steel sample is greater than for the Nitronic 60 (of course if pitting corrosion starts).

### 3.2. Analysis of microstructure

Analysis of microstructure of samples tested on pitting corrosion show presence of the pits on the sample surface. Concentration of pits is higher on the surface of 316L sample than Nitronic 60 sample, Figure 3. and 4. Microstructure of both samples is austenitic with presence of delta ferrite, Figure 3.b and Figure 4.b. However, presence of the delta ferrite is higher for steel 316L than for steel Nitronic 60. The delta ferrite content was determined using magnetic induction method by Feritscope MP 30E-S probe EGAB 1.3 Fe [8]. Percent of delta ferrite for steel Nitronic 60 was 0.14% and for steel 316L was 3.4%.

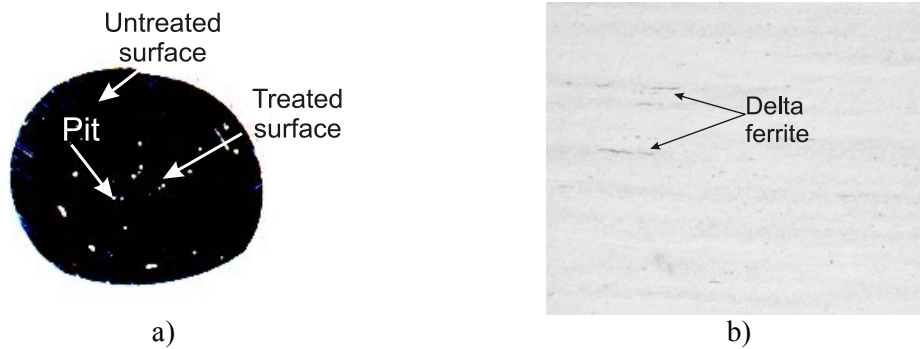


Figure 3. Microstructure of steel Nitronic 60: a) magnification x6.3 and b) magnification x100

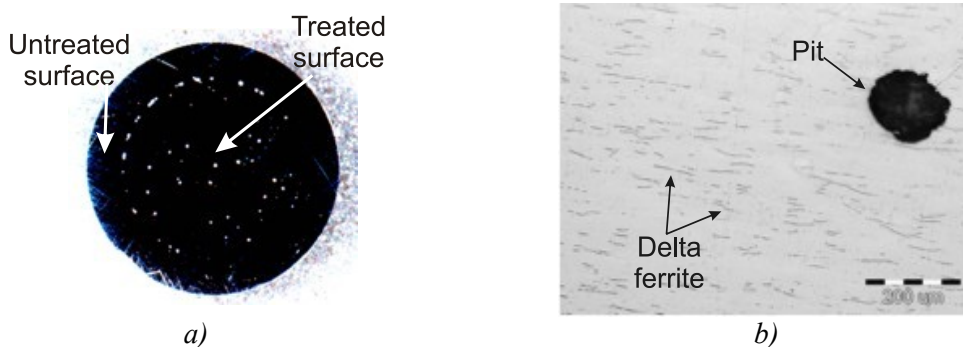


Figure 4. Microstructure of steel 316L: a) magnification x6.3 and b) magnification x100

#### 4. CONCLUSIONS

This paper presents the results of the corrosion tests of steels Nitronic 60 and AISI 316L. AISI 316L is one of the most used austenitic stainless steel thanks to good mechanical and corrosion properties. Nitronic 60 is austenitic alloy which was originally designed for using at high temperature (to 980 °C) but this grade is also known for its wear and galling resistance while its room temperature yield strength is nearly twice that of types 304 and 316. Investigation of general corrosion and pitting corrosion was performed in 0.9 %NaCl solution by instrument potentiostat/galvanostat, *Princeton Applied Research*, model 263A-2. Analysis of result showed that steel 316L has better general corrosion but difference is not so high i.e. steel Nitronic 60 showed also a good resistance to general corrosion. Testing on pitting corrosion showed that in the real conditions the pitting corrosion would have occurred earlier on the steel Nitronic 60 than on the 316L but the intensity of pitting corrosion for the 316L stainless steel sample is greater than for the Nitronic 60 (of course if pitting corrosion starts). Analysis of microstructure showed presence of the delta ferrite for both steels but content for type 316L is higher and it could have an influence on higher intensity of pitting corrosion.

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