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Influence of the delta ferrite content on the corrosion behavior of austenitic stainless steel Nitronic 60

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Abstract: Nitronic 60 (UNS S21800) is a highly alloyed austenitic stainless steel with increased content of manganese and silicon. It has a good mechanical and corrosion properties at elevated temperatures and loads. Nitronic 60 has the austenitic microstructure at room temperature but depending on chemical composition the presence of other phase in austenite matrix is possible, i.e. delta ferrite. The aim of this study is better understanding of delta ferrite content influence on corrosion sensitivity of Nitronic 60. The corrosion sensitivity test was conducted in the corrosion cell using potentiostat/galvanostat according to Standard ASTM G5 (Princeton Applied Research, model 263A-2, with the PowerCORR® software), (Standard, ASTM G5-94). Investigation was performed in 0.9% NaCl solution. Taffel extrapolation method was used to test general corrosion. Method of cyclic polarization was used for investigation of pitting corrosion. Tests were performed at room temperature, 20±1°C.The corrosion tests results indicate that the intensity of both examined forms of corrosion, general and pitting corrosion, is increased with increasing delta ferrite content.

INTRODUCTION

Nitronic 60 is the commercial name for austenitic stainless steel, which according to the chemical composition belongs to AISI 200 class of steels. This high manganese steel is really material for all purpose owing to mechanical and corrosion properties especially at elevated temperatures (Lula, 1986). Generally, austenitic stainless steel (ASS) is widely used in all industries sectors (transport, food, chemical, building industry etc.) thanks to good mechanical properties (strength and toughness at elevated and room temperature) and corrosion resistance. The austenite type stainless steels have different chemical compositions and properties but the common characteristic is an austenite microstructure that is stable at room temperature. Depending on chemical composition it is possible to find presence of some other phase in austenite matrix called delta ferrite. The main alloy in gelements in austenitic stainless steels can be classified as alphagenic and gamagenic group of elements. The alphagenic elements (Cr, Si, Ti, Al, Mo, V, Nb and W) stabilize and support the formation of delta ferrite, until the gamagenic elements (Ni, Mn, C, N, and Cu) stabilize the austenitic phase (George and Shaikh, 2002; Gigović-Gekić et al., 2014). Delta ferrite has a body centered cubic structure and good stability at room temperature. In some cases, the delta ferrite phase is intentionally formed during manufacturing to improve hot workability or to prevent hot cracking in weld metal. On the other hand, the amount of delta ferrite in the weld metal should be considered very carefully because delta ferrite embrittles a weld metal and deteriorates corrosion properties (George and Shaikh, 2002). The effect of the delta ferrite content on the corrosion resistance of ASS can be explained with the following phenomena: the formation of Cr depleted zone, low concentrations of Cr and Mo in austenite phase and the segregation of sulfur or phosphorous along the δ/γ interface. The effects of delta ferrite content on the corrosion resistance of ASS were mutually contradictory and the mechanism was not clearly understood yet (Kim et al., 2007). There are

several techniques for testing of corrosion behavior of ASS in different media but the most used ones are the electrochemical technique of cyclic voltammetry and potentiodynamic measurements in chloride-containing media (Kim et al., 2007; Kocijan and Conradi, 2010; Osoba et al., 2016; Tavares et al. 2017).
For the purpose of testing the influence of the delta ferrite content on the corrosion properties of Nitronic 60, two forms of corrosion were tested (general and pitting corrosion). Both types of corrosion were tested in 0.9% aqueous solution of sodium chloride

EXPERIMENTAL

The aim of this research is to investigate an influence of the delta ferrite content on corrosion sensitivity of Nitronic 60. Following that idea, two types of corrosion were investigated (general and pitting corrosion). Two samples of Nitronic 60 were used for testing. Chemical composition of the samples and delta ferrite content are given in Table 1. The chemical composition of samples was within the limits prescribed by ASTM A276-96 standard, (Standard, ASTM A276-96).

Table 1. Chemical composition of the samples

Sample	Chemical composition (wt.%)						Delta ferrite content (%)
	C	Si	Mn	Cr	Ni	N	
V1692	0.04	4.4	7.4	18.0	8.1	0.18	10.25
V1696	0.05	3.5	7.9	16.9	8.6	0.12	1.4

The delta ferrite content was determined by Feritscope MP 30E-S probe EGAB 1.3 Fe using magnetic induction method (Gigović-Gekić et al., 2011), Table 1. Microstructures of initial state of the samples are presented in Figure 1. The metallographic examination was performed on Olympus optical microscope. The samples were previously prepared (grinding and polishing) and etched in the Kalling's solution.

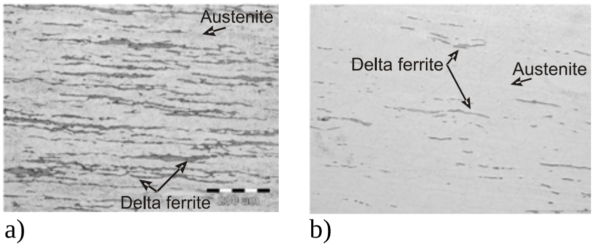


Figure 1. The sample microstructure: a) V1692 and b) V1696, x100

Tafel extrapolation method was used for investigation of general corrosion of the Nitronic 60 samples. Tafel extrapolation method implies scanning of working electrode potential on the order of ±250 mV in relation to its Open Circuit Potential (E_{OCP}), at the speed of 0.2 mVs^{-1}. Method of cyclic polarization 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 mV/s. Investigations of corrosion were conducted in the corrosion cell using potentiostat/galvanostat according to Standard ASTM G5, (Princeton Applied Research, model 263A-2, with the PowerCORR® software), (Standard, ASTM G5-94). Investigation was performed in 0.9% NaCl solutions. Tests were performed at room temperature, 20±1°C. The metallographic examination of the tested samples was performed on Olympus optical microscope with max. Magnification of 1000x and stereo microscope Leica with a maximum magnification of 60x.

RESULTS AND DISCUSSION

The results of general corrosion tests of the tested stainless steel (Nitronic 60) are presented in Figure 2 and Table 2.

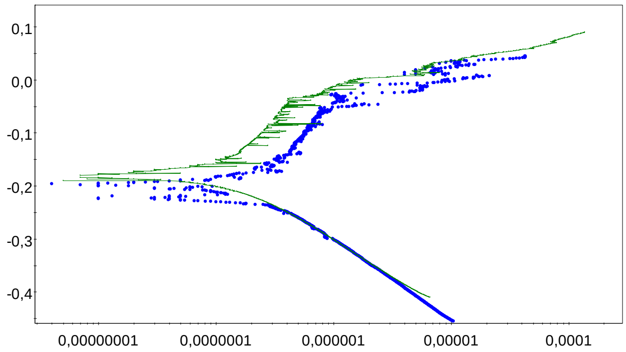


Figure 2. Tafel curves of the samples tested in 0.9% NaClsolution
1 – sample V1696,
2 – sample V1692

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

Designation samples	E_{ocp}(mV)	Corrosion current density, $i_{cor.}$ (μAcm^{-2})
1- V1696	-178,611	$1,037 \cdot 10^{-1}$
2- V1692	-203,57	$1,641 \cdot 10^{-1}$

The analysis of the results from the Table 2 and Figure 2 shows that sample having a lower delta ferrite content, sample 1, shows a significant moving of the open circuit potential (E_{OCP}) to positive values comparing to the E_{OCP} of the sample 2, (a sample with higher delta ferrite content).
The results present in Table 2 indicate that sample with lower delta ferrite content, sample 1, has lower corrosion current density as compared to the samples with higher delta ferrite content. According to both parameters (E_{OCP} and i_{cor}), sample with lower delta ferrite content has 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}), Figure 3. Pitting potential is the potential at which pitting starts and that phenomenon is noticed when the current of the polarization curve suddenly start to rise. Generally, measure of the intensity of pitting corrosion is the surface of the hysteresis loop, Figure 3. The larger surface of the hysteresis loop means a higher intensity of pitting corrosion (Bikić et al., 2014).

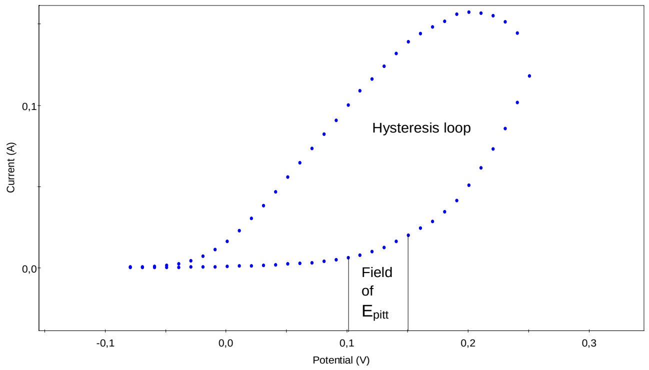


Figure 3. Cyclic polarization curve

The results of pitting corrosion tests of investigated samples are given in Figure 4.

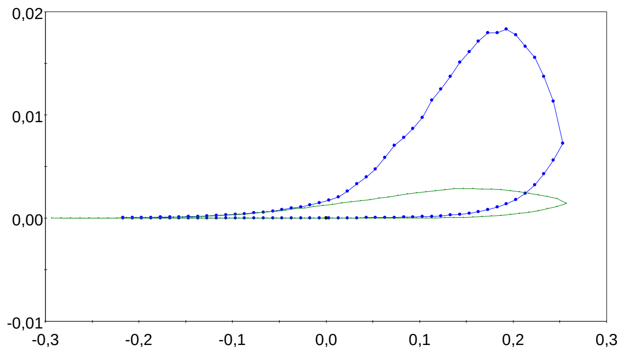
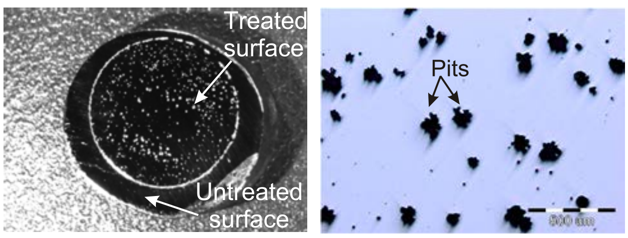


Figure 4. Cyclic polarization curves of the samples tested in 0.9% NaCl solution
1 – sample V1696
2 – sample V1692

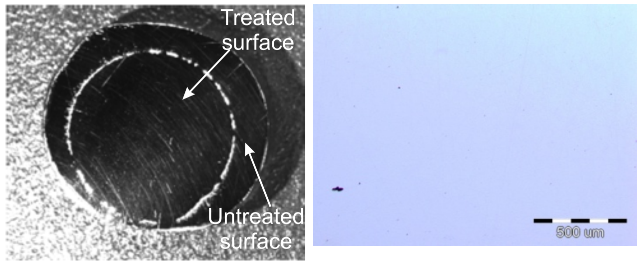
The results presented in Figure 4 show that sample with lower delta ferrite content, sample 1, has smaller surfaces of the hysteresis loop as compared to the sample with higher delta ferrite content which indicate that the tendency towards the pitting corrosion increases with increasing delta ferrite content.

Microstructure of the sample with higher delta ferrite content (V1692) shows presence of the pits on the sample surface, Figure 5. The presence of the pits on the surface of the sample with the lower delta ferrite content (V1696) were not noticed, Figure 6.



a) b)

Figure 5. Metallography of the sample (V1692) tested on pitting corrosion; a) magnification x6,3 and b) magnification x50



a) b)

Figure 6. Metallography of the sample (V1696) tested on pitting corrosion; a) magnification x6,3 and b) magnification x50

CONCLUSIONS

Nitronic 60 is a stainless steel with an austenitic microstructure. Depending on the content of the alloying elements, the presence of the secondary phase called the delta ferrite is possible. The sample with a higher percentage of Si and Cr shows a higher proportion of delta ferrite in the microstructure.

Stainless steel Nitronic 60 shows an increased tendency for both type of corrosion (general and pitting) with increasing content of the delta ferrite in 0.9% NaCl solution. The main reason for pitting corrosion is the difference in chromium content between the delta ferrite and austenite matrix. Delta ferrite has a higher content of chromium. The pitting attack was usually found at the delta ferrite/austenite interface.

REFERENCES

ASTM A276-96 (1996). Standard Specification for Stainless Steel Bars and Shapes.

ASTM G5 (1994). Standard Reference Test Method for Making Potentiostatic and Potenciodynamic Anodic Polarization Measurements.

Bikić F., Mujagić D. (2014). Investigation of possibility for reducing AISI 303 stainless steel pitting corrosion by microalloying with boron or zirconium, *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina*, 42, .41 -46.

George, G., Shaikh H. (2002). Introduction to Austenitic Stainless Steels. Khatak, H.S., Raj, B.(Ed.) Corrosion of Austenitic Stainless Steels Mechanism, Mitigation and Monitoring. (1-36). Narosa Publishing House.

Gigović-Gekić, A., Oruč, M., Avdušinović, H., Sunulahpašić, R. (2014). Regression analysis of the influence of a chemical composition on the mechanical properties of the steel Nitronic 60. *Materiali in Tehnologije*, .48(3), 433-437.

Gigović-Gekić, A., Oruč, M., Gojić, M. (2011). Determination of the content of delta ferriteinaustenitic stainless steel Nitronic60, in Proceedings of 15thInternational Research/Expert Conference "TMT 2011", 12-18 September 2011, Prague, Czech Republic, 157-160.

Kim, S.Y., Kwon, H.S., Kim, H. (2007). Effect of delta ferrite onCorrosion Resistance of Type 316 Stainless Steel in Acidic Chloride Solution by Micro-droplet

Cell, Solid State Phenomena Vols. 124-126, p.p.1533-1536 (doi:10.4028/www.scientific.net/SSP.124-126.1533) (03/03/2018)

Kocijan, A., Conradi, M. (2010). The corrosion behaviour of austenitic and duplex stainless steels in artificial body fluids. *Materials and technology*, 44(1)1, 21-24.

Lula R.A. (1986). Stainless Steel, ASM American Society for Metals.

Osoba, O., Elemuren, R.A., Ekpe, I.C. (2016). Influence of delta ferrite on corrosion susceptibility of AISI304 austenitic stainless steel. Cogent Engineering 3, (http://dx.doi.org/10.1080/23311916.2016.1150546) (08/11/2017)

Tavares, S.S.M., Feijo, G.F., Farneze, H.N., Sandim, M.J.R., Filho, I.R.S. (2017). Influence of Microstructure on the Corrosion Resistance of AISI 317L (UNS S31703). Materials Research, (doi: http://dx.doi.org/10.1590/1980-5373-MR-2016-1107)

Summary/Sažetak

Nitronic 60 (UNS S21800) je visoko legirani austenitni čelik sa povećanim sadržajem mangana i silicija. Ovaj čelik ima dobra mehanička i koroziona svojstva pri povišenim temperaturama i opterećenjima. Čelik ima austenitnu mikrostrukturu na sobnoj temperaturi ali zavisno od hemijskog sastava moguće je prisustvo i druge faze tj. deltaferita. Cilj ovog ispitivanja je bolje razumijevanje utjecaja sadržaja delta ferita na korozionu osjetljivost čelika Nitronic 60. Ispitivanje korozije je provedeno u korozionoj ćeliji prema standardu ASTM G5, na uređaju potenciostat/galvanostat Princeton Applied Research, model 263A-2, sasoftveromPowerCORR® (Standard, ASTM G5-94). Ispitivanje je provedeno u 0.9% vodenoj otopini NaCl. Tafel-ova ekstrapolaciona metoda koristila se za ispitivanje opšte korozije. Metoda ciklične polarizacije koristila se za ispitivanje pitting korozije. Ispitivanje je provedeno na sobnoj temperaturi 20±1°C. Rezultati ispitivanja korozije su pokazali da se intenzitet korozije povećava sa povećanjem sadržaja delta ferita u oba slučaja korozije, opšta I pitting korozija.