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INFLUENCE OF THE COOLING RATE ON THE CORROSION RESISTANCE OF DUPLEX CAST STEEL

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The results of the influence of the cooling rate of the casting made of the acid-resistant ferritic - austenitic cast steel on the microstructure and corrosion resistance are presented in the paper. Samples cut out from the walls of the casting being cooled at the cooling rate of 3,2 - 0,5 ºC/s were used in the study. Different cooling rates create favorable conditions for the segregation processes lowering properties of castings. It was found, that differences in the polarization curves occur only in the more aggressive corrosive environment. The reason of such behaviour of cast steel is the segregation of elements dissolved in austenite and the difference in the volume fraction of ferrite and austenite in the walls of the different thickness.

Key words: electrochemical corrosion, casting, stainless steel, microstructures

INTRODUCTION

The characteristic feature of castings is their diversified thickness and complexity of shapes. In the case of castings made of acid resistant Cr-Ni cast steel, various cooling rates lead to the segregation of alloy components and differences in the precipitation processes rates within the temperature range: 300 - 1 000 ºC [1,2]. As the result of these processes phases of different structure and chemical composition (e.g. carbides, nitrides, σ, α') can nucleate in the casting walls [3-5]. Their occurrence in the microstructure worsens the corrosive resistance and passivation ability of castings made of Cr-Ni cast steel, especially in the environment containing Cl^- ions [6]. Performing the proper heat treatment of castings eliminates, in the majority of cases, a precipitation of those phases, however in the case of cast steel containing ferrite and austenite in its structure the volume fraction of those phases can vary in dependence of the hyper quenching temperature and casting wall thickness [7-9].

Operating conditions of castings require that the basic properties be retained in all thickness of its walls. This means that in thin-wall castings (e.g. rotors, steering gears), as well as in castings of a wall thickness of 50 - 70 mm (valve footings and housings, large industrial pumps), material structure should not reveal essential differences. Otherwise castings will not satisfy the requirements both at the surface and inside the casting wall.

Therefore an attempt to present the influence of cooling rates of the F-A cast steel castings on their corrosion resistance – in two different corrosive environments was undertaken in this paper.

MATERIALS AND METHODS

The influence of the cooling rate of the F-A cast steel casting containing 0,06 % C, 24,0 % Cr, 5,2 % Ni, 2,5 % Mo, 2,7 % Cu and 0,2 % Nb on its microstructure and corrosive resistance was investigated.

The casting of different wall thickness: 12, 24 and 45 mm was made under laboratory conditions. After pouring the mould with liquid metal the temperature change was recorded by means of thermoelements Pt-PtRh10, and on this basis the cooling rate of each wall was determined. Samples for metallographic and corrosive tests were cut off from the walls of a thickness 12 and 45 mm, cooling with rates of 3,2 - 3,4 ºC/s and 0,4-0,5 ºC /s – respectively.

Electrochemical measurements were performed for samples after the heat treatment (solution annealing) at 1 060 °C for 1 hour for each 25 mm. Samples polarization was performed with the application of the cyclic voltammetry in 3 % NaCl solution and 0,1M H_2SO_4. In both cases solutions were deaerated with argon. The polarisation curves were performed in a potential range from -1,5 to 1,0 V at the polarisation rate: 1 V/min. The chronopotentiostatic curve was performed for a potential of 0,5 V in 3 % NaCl solution. The reference electrode in 3 % NaCl solution was the calomel electrode, while in 0,1M H_2SO_4 the silver-silver chloride electrode.

The observations of the cast steel surface after the corrosion tests were carried out by the optical microscope Neophot 32 and the scanning electron microscope. The chemical composition analysis of ferrite, austenite and corrosion products was performed by means of the scanning microscope equipped with the EDX system of the IXRF Company for the X-ray microanalysis.

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DISCUSSION AND RESULTS

The microstructure of the investigated F-A cast steel consists of the ferritic matrix and austenite ‘islands’ (Figures 1 and 2) [8,10]. On the grounds of the investigations of the relative volume fraction of austenite in F-A cast steel cooling with a rate of 3,2 - 3,4 ºC/s and of 0,4 - 0,5 ºC/s, the difference of 1,6 % in the volume fraction was found. A lower cooling rate results in increasing the austenite volume fraction at the expense of ferrite. On the bases of the X-ray EDX microanalysis the differences in the chemical composition of the ferritic and austenitic phase, being the result of the alloying elements segregation, were found. The average content of the main elements not exceeding 1 %, excluding Si and Mn, are shown in Table 1. On the bases of the obtained results of the ferrite chemical composition the difference in the Ni content in walls of a thickness of 12 and 45 mm was found. In the case of austenite occurring in the wall of a thickness of 45 mm, an increased Cr and Mo content and a decreased Ni content was noticed as compared to austenite occurring in the wall of a thickness of 12 mm – Table 1.

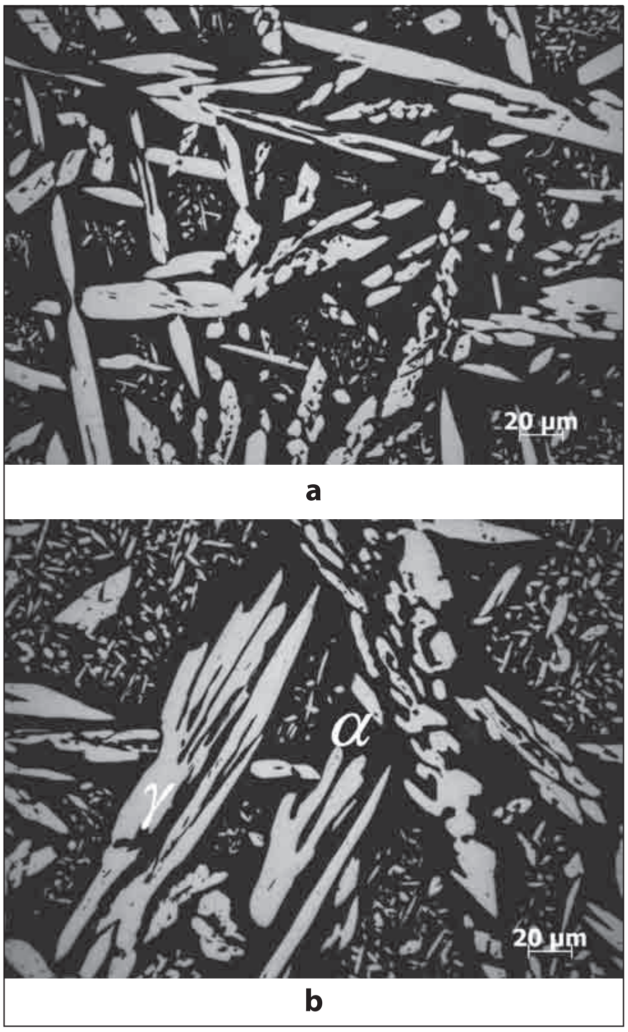

Figure 1 Microstructure of the investigated cast steel in the wall of a thickness: a) 12 mm, b) 45 mm; optical microscope, etchant - Beraha II

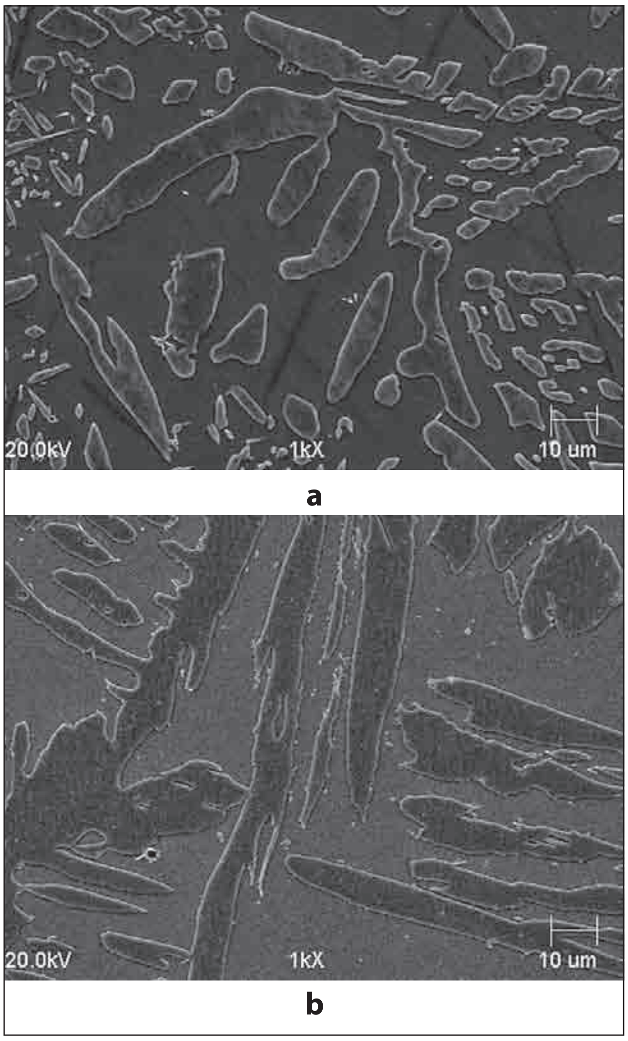

Figure 2 Microstructure of the investigated cast steel in the wall of a thickness: a) 12 mm, b) 45 mm; SEM

Table 1 **Chemical compositions of the ferrite and austenite in the investigated cast steel / mas.%**

Phase	Wall thickness / mm	Cr	Mo	Ni	Cu	Fe
		/ mas. %				
Ferrite	12	24,9	5,1	3,6	2,8	61,2
	45	25,1	4,7	4,3	2,9	61,0
Austenite	12	20,1	1,4	7,4	3,2	66,6
	45	21,7	2,1	6,5	2,7	66,9

Corrosion investigations

The performed corrosion investigations indicated very good corrosion resistance of the investigated cast steel in 0,1M H_2SO_4 solution as compared with 3 % NaCl solution (Figure 3a). The breakdown potential in 0,1M H_2SO_4 for the tested cooling rates was 1 V. The passive zone range was from –0,5 to 1,0 V (Figure 3b).

On the other hand, the difference in breakdown potentials for the tested cooling rates of castings in 3 % NaCl solution was noticed. The breakdown potential value for the casting cooling faster (wall: 12 mm) was app. –0,8 V, while for the casting cooling slower (wall: 45 mm) this potential shifted into positive values. Additional corrosion tests were performed at a constant

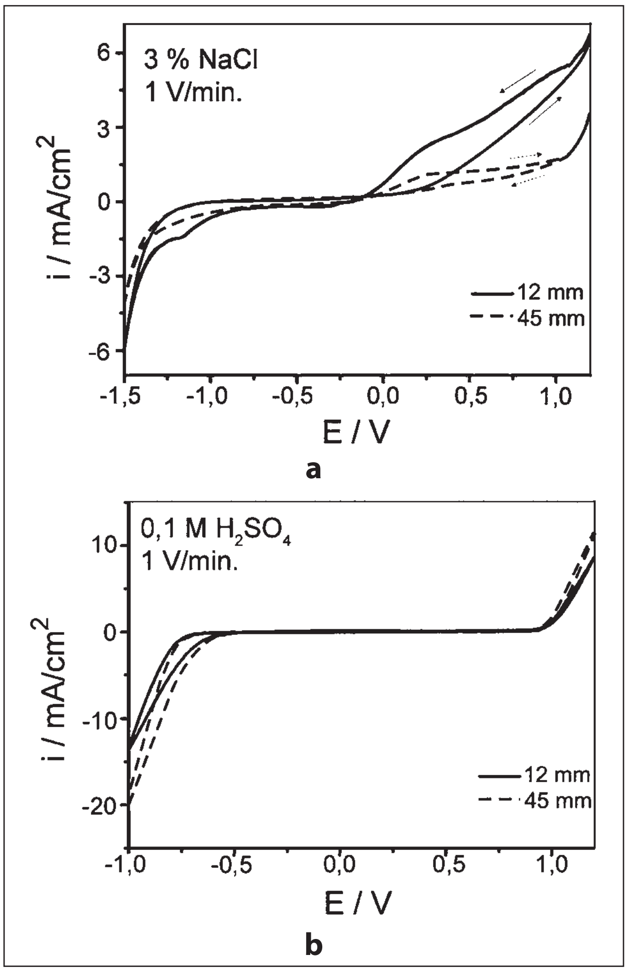

Figure 3 Influence of the casting cooling rate on the polarisation curves of F-A cast steel in 3 % NaCl solution -a) and 0,1M H_2SO_4 -b)

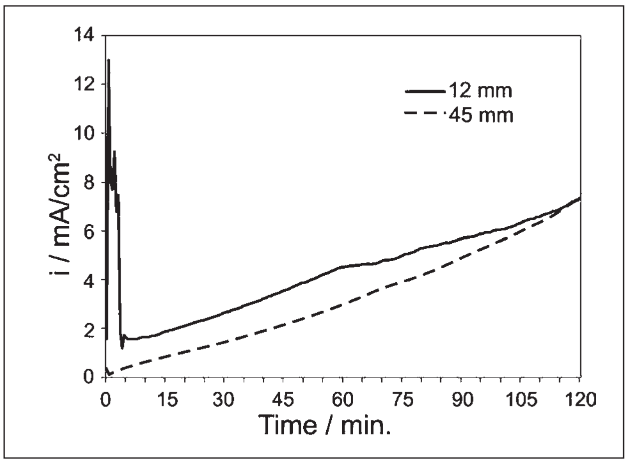

Figure 4 Chronopotentiostatic curves for the tested F-A cast steel at a potential of 0,5 V in 3 % NaCl solution

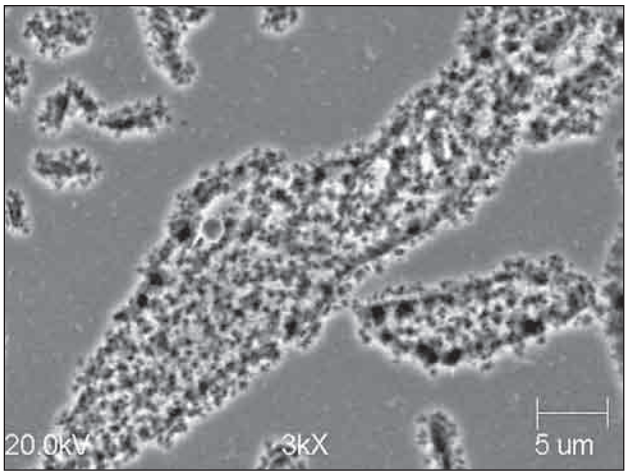

Figure 5 Surface of the investigated cast steel after corrosion tests in 3 % NaCl solution at a potential of 0,5 V

potential value, being 0,5 V, during 120 minutes (Figure 4). On the basis of the chronopotentiostatic curve, obtained for the sample cut off from the 12 mm thick wall, it was found that the corrosion process is the multistage one with a high velocity at the process beginning (up to ~5 minutes) and slowing down further on. Violent current oscillations recorded at the beginning of the curve, indicate an intensive sample etching accompanied by an intensive emissivity of hydrogen (the most probably) on the sample surface [11]. Further mild pathway of the chronopotentiostatic curve, at a constant potential of 0,5 V indicates pitting formation on the surface of tested materials. In turn, for the sample cut off from the 45 mm thick wall none increasing of the anodic reaction was found in the very first minutes of the measurement. At the final stage of the measurement the current density in both walls (12 and 45 mm thick) was similar.

Microstructural investigations performed after corrosion tests in 3 % NaCl solution indicated an intensive etching of austenite on the sample cut off from the 12 mm wall (Figure 5). The reason of such behaviour was the most probably a decreased Cr, Ni and Mo content in austenite (Table 1). Layers of corrosion products formed on the cast steel surface are heterogeneous and display corrosion damages in forms of clusters, dark spots, pores and pitting. The selective system of corrosive zones corresponds to the austenite arrangement. The SEM-EDX analysis of these zones indicated that they are strongly oxidised (20 - 34 % of oxygen) and enriched with Cr (17 - 19 %) and Fe (40 - 50 %).

The wall of the casting, which cooled more slowly (thickness of 45 mm), had only deep, fine spherical pitting without an intensive austenite etching as it was in the case of sample cut off from the 12 mm wall._

CONCLUSIONS

None essential influence of the cooling rate of the investigated F-A cast steel on the polarization curves pathway in 0,1M H_2SO_4 solution was seen. The breakdown potential in both cases was 1 V.

The investigated cast steel cooled with the cooling rate of 3,2 - 3,4 ºC/s (12 mm wall) retains its corrosion resistance - in 3 % NaCl solution - up to a value of –0,8 V, while the one cooled with the rate of 0,4 - 0,5 ºC/s (45 mm wall) up to a value of 0,01 V. The chronopotentiostatic curves recorded at a potential of 0,5 V during 120 minutes indicate the influence of the cooling rate in the initial period of curve pathways. For the cooling rate of 3,2 - 4,3 ºC/s the intensive corrosion processes were observed in the first minutes of investigations. The curves obtained at the final stage of investigations were similar for both samples.

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Note: The responsible translator for English language: "ANGOS" Translation Office, Krakow, Poland