

COMPARISON OF UNIFORM CORROSION RATE OF AUSTENITIC AND DUPLEX STAINLESS STEELS

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ABSTRACT

This paper presents the results of uniform corrosion of austenitic and duplex stainless steels. Investigated uniform corrosion was performed in a solution of 1% HCl at 30 °C. Investigations were conducted in the corrosion cell according to ASTM G5 on instrument potentiostat/galvanostat PAR 263A-2 with the software PowerCORR®. Corrosion was investigated with method of Tafel extrapolation technique. The results show that the rate of uniform corrosion of duplex stainless steel of the applied electrolyte is less than the three used austenitic steels.

Keywords: austenitic stainless steels, duplex stainless steels, uniform corrosion, Tafel extrapolation technique.

1. INTRODUCTION

Stainless steels are iron-base alloys containing at least 10.5% Cr. With increasing chromium content and the presence or absence of some ten to fifteen other elements, stainless steels can provide an extraordinary range of corrosion resistance. Stainless steels are categorized in five distinct families according to their crystal structure and strengthening precipitates. Families of stainless steels are: ferritic stainless steels, austenitic stainless steels, martensitic stainless steels, duplex stainless steels and precipitation-hardening stainless steels. Each family exhibits its own general characteristics in terms of mechanical properties and corrosion resistance [1].

2. AUSTENITIC AND DUPLEX STAINLESS STEELS

2.1. Austenitic Stainless Steels

The detrimental effects of carbon and nitrogen in ferrite can be overcome by changing the crystal structure to austenite, a face-centered cubic crystal structure. This change is accomplished by adding austenite stabilizers, most commonly nickel but also manganese and nitrogen. Austenite is characterized as nonmagnetic, and it is usually relatively low in yield strength with high ductility, rapid work-hardening rates, and excellent toughness. These desirable mechanical properties, combined with ease of fabrication, have made the austenitic grades, especially AISI type 304, the most common of the stainless grades [2]. Processing difficulties tend to limit increases in chromium content; therefore, improved corrosion resistance is usually obtained by adding molybdenum. The use of nitrogen as an intentional alloy addition stabilizes the austenite phase, particularly with regard to the precipitation of intermetallic compounds. With the nitrogen addition, it is possible to produce austenitic grades with up to 6% Mo for improved corrosion resistance in chloride environments. The common austenitic grades, AISI types 304 and 316, are especially susceptible to chloride [2].

2.2. Duplex stainless steels

Duplex stainless steels can be thought of as chromium-molybdenum ferritic stainless steels to which sufficient austenite stabilizers have been added to produce steels in which a balance of ferrite and austenite is present at room temperature [3]. Such grades can have the high chromium and molybdenum responsible for the excellent corrosion resistance of ferritic stainless steels as well as the favorable mechanical properties of austenitic stainless steels. In fact, the duplex grades with about equal amounts of ferrite and austenite have excellent toughness and their strength exceeds either phase present singly. First generation duplex grades, such as AISI type 329, achieved this phase balance primarily by nickel additions [2]. These early duplex grades have superior properties in the annealed condition, but segregation of chromium and molybdenum between the two phases as re-formed after welding often significantly reduced corrosion resistance. The addition of nitrogen to the second generation of duplex grades restores the phase balance more rapidly and minimizes chromium and molybdenum segregation without annealing. The newer duplex grades combine high strength, good toughness, high corrosion resistance, good resistance to chlorides, and good production economy in the heavier product forms [2].

3. EXPERIMENTAL PART

Investigations were conducted in the corrosion cell according to ASTM G5, on instrument potentiostat/galvanostat PAR 263A-2, with the software PowerCORR®. Corrosion was investigated with method of Tafel extrapolation technique [4, 5]. Corrosion test was performed with stainless steels ASTM 304L, ASTM 316L, ASTM 321 and ASTM 2205 (S31803), the chemical compositions given in Table 1.

Table 1. Chemical compositions of tested stainless steels

Designation ASTM	C	Si	Mn	P _{max}	S	N	Cr	Mo	Ni	Others
304L	≤ 0,03	≤ 1,00	≤ 2,00	0,045	≤ 0,015	≤ 0,11	18 -20	-	10-12	-
316L	≤ 0,03	≤ 1,00	≤ 2,00	0,045	≤ 0,015	≤ 0,11	16,5-18,5	2-2,5	10-13	-
321	≤ 0,08	≤ 1,00	≤ 2,00	0,045	≤ 0,015	≤ 0,11	17-19	-	9-12	Ti: 5xC
2205	≤ 0,03	≤ 1,00	≤ 2,00	0,035	≤ 0,015	0,1-0,22	21-23	2,5-3,5	4,5-6,5	-

Investigated uniform corrosion selected stainless steels was performed in a solution of 1% HCl at 30 °C. Cells prior to testing the speed of corrosion is thermostated 1 hour at 30 °C. Deairation content of electrolytes within the cells was performed with argon, 30 minutes, as required by ASTM standard G5-94.

4. RESULTS AND DISCUSSION

For testing uniform corrosion of selected stainless steels used is method of Tafel extrapolation technique. The method involves scanning potential of working electrode ± 250 mV with respect to open circuit potential at scan rate of 0,2 mVs⁻¹. Results of test uniform corrosion of selected stainless steels above method are given in Figure 1 and Table 2.

Table 2. Corrosion rate of selected stainless steels in the tested solution, 1% HCl

Designation ASTM	E(I=0), mV	Corrosion rate, mm/year
304L	-334,307	0,6954
316L	-393,619	0,4572
321	-384,961	0,3249
2205	-307,251	0,1528

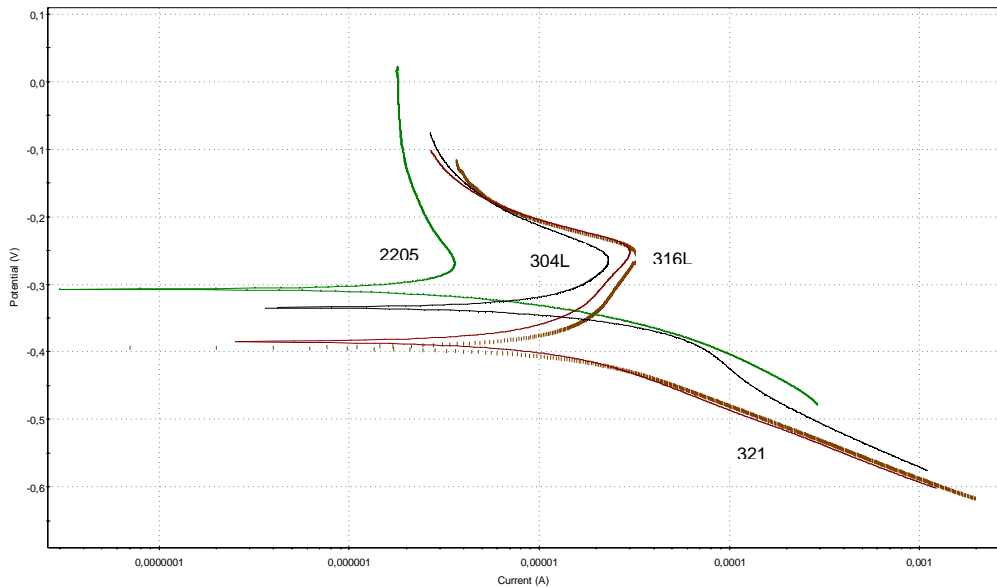


Figure 1. Potentiodynamic current-potential curves

Comparing the corrosion rate between the three austenitic stainless steels, Table 2; Figure 1, we see that it is the smallest of steel ASTM 321. This may be the addition of titanium to stainless steel ASTM 321, Table 1. The austenitic stainless steels can be sensitized to intergranular corrosion by welding or by longer-term thermal exposure. These thermal exposures lead to the precipitation of chromium carbides in grain boundaries and to the depletion of chromium adjacent to these carbides. Sensitization can be greatly delayed or prevented by the additions of carbide-stabilizing elements, titanium and niobium respectively.

Furthermore, the corrosion rate ASTM 316L stainless steel is less than the corrosion rate ASTM 304L stainless steel. The reason for this is the addition of molybdenum in the stainless steel ASTM 316L, Table 1. Molybdenum in combination with chromium is very effective in terms of stabilizing the passive film in the presence of chlorides. Molybdenum is especially effective in increasing resistance to the initiation of pitting and crevice corrosion.

Comparing the corrosion rate of austenitic stainless steels above with the corrosion rate of duplex stainless steel ASTM 2205, Table 2; Figure 1, we see that the corrosion rate of duplex stainless steel is less than the corrosion rate of all three used austenitic stainless steels. The reason is the high content of chromium and molybdenum in stainless steel ASTM 2205, Table 1, which provides high resistance duplex stainless steels to corrosion, particularly high resistance to chloride.

5. CONCLUSION

Addition of titanium and molybdenum, with chromium and nickel, leading to a reduction corrosion rate of austenitic and duplex stainless steels. Comparing the corrosion rate of austenitic stainless steels ASTM 321, ASTM 304L, ASTM 316L, with the corrosion rate of duplex stainless steel ASTM 2205, results show that the corrosion rate of duplex stainless steel is less than the corrosion rate of all three used austenitic stainless steels. The reason is the high content of chromium and molybdenum in stainless steel ASTM 2205, which provides high resistance duplex stainless steels to corrosion, particularly high resistance to chloride.

6. REFERENCES

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