

Investigation on the localized corrosion performance of lean duplex stainless steels in urban wastewater treatment plants

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ABSTRACT

Stainless steels are successfully used in the range of water compositions encountered during wastewater treatment. Austenitic stainless steels are the most often used grades in water treatment applications. S30403 and S31603 are known to be suitable for municipal and industrial wastewater with respectively moderate and increased chloride contents. Considering the comprehension of economic cost, good corrosion resistance and higher mechanical properties, lean duplex stainless steels can be a good alternative to these commonly used austenitic grades but they are still too rarely chosen, probably due to a lack of case studies.

The present paper deals with the localized corrosion performance of lean duplex (S32101, S32202 and S32304) in solutions simulating pre-treatment unit waters, using electrochemical testing. The localized corrosion was compared with austenitic stainless steels (S30403 and S31603) and with more alloyed duplex grades (S82441 and S32205). Pitting corrosion methods were adapted from standard electrochemical test methods ASTM G150 ASTM G61 to assess critical pitting temperature (CPT) and pitting potential (PP) respectively. Environmental parameters (chloride content, pH and temperature) were selected to be representative of the different environments that can be encountered in urban wastewater treatment plants.

All the results permit to have an overview of corrosion properties according to the environmental parameters and to choose properly the best stainless steel grade for urban wastewater treatment units. This study allows also to have a clearer view of the behavior of duplex stainless steel grades versus austenitic grades in such environments. It confirms that lean duplex grades S32101 and S32202 can be used as alternatives to S30403 and S31603 respectively.

Key words: stainless steels, lean duplex, pitting potential, critical pitting temperature, urban wastewater treatment plant

INTRODUCTION

Wastewater coming from both municipal and industrial activities present corrosive properties toward metals and can in certain cases exceed the tolerances of the most often used stainless steels such as 304L and 316L, thus resulting in the need of superior alloys. The main factors influencing the corrosiveness of the fluids in wastewater treatment plants are high concentration of halides (more specifically chlorides), H_2S , low pH, temperature and their combined action. Corrosiveness of incoming fluids at a municipal wastewater treatment finds its roots in the municipal collection network. In most of the cases, the chloride concentration, around 50-200 mg/L in municipal wastewater streams, of this water doesn't present major issues for austenitic grade such as 304L. However, in certain conditions, chloride concentrations can reach 3 000 - 6 000 mg/L and in extreme cases 10 000 mg/L for seaside-located facilities or when de-icing salts are used during winter [1,2], requiring more corrosion resistant alloys.

Considering the comprehension of economic cost, good corrosion resistance and higher mechanical properties, lean duplex stainless steels can be a good alternative to these commonly used austenitic grades but they are still too rarely chosen, probably due to a lack of case studies. In view of defining the limit of use of selected lean duplex stainless steel grades to for urban wastewater treatment units, a European project was initiated, involving stainless steel manufacturers, end-users, corrosion and microbiological laboratories. Both laboratory screen tests and field exposure in urban wastewater treatment plants were performed [3].

The present study deals with the localized corrosion performance of lean duplex (S32101, S32202 and S32304) in solutions simulating pre-treatment unit waters, using electrochemical testing adapted from ASTM G150 and ASTM G61 pitting test methods. The results were compared with austenitic stainless steels (S30403 and S31603) and with more alloyed duplex grades (S82441 and S32205).

EXPERIMENTAL PROCEDURE

Materials used

The following lean duplex stainless steel (DSS) grades were supplied for the project: UNS S32101 (2101, EN 1.4162), UNS S32202 (2202, EN 1.4062), and UNS S32304 (2304, EN 1.4362), together with duplex stainless steels UNS S82441 (2404, EN 1.4662) and UNS S32205 (2205, EN 1.4462). Austenitic stainless steels UNS S30403 (304L, EN 1.4307) and UNS S31603 (316L, EN 1.4404) were used as reference materials. All are industrial cold rolled materials with a plate thickness of 3 mm. Table 1 gives the typical composition of the tested alloys and their pitting resistance equivalent number (PREN). The PREN formula is often used to estimate the localized corrosion resistance ranges of It is given by $PREN = \%Cr + 3.3(\%Mo) + 16(\%N)$. The PREN must be used with care since this number does not consider other very important parameters, such as the metallurgical state of the alloy, the nickel content, or the surface state.

Table 1.**Typical composition (wt%) of the selected grades and PREN (%C + 3.3%Mo + 16%N)**

Grades	2101	2202	2304	2404	2205	304 L	316 L
UNS	S32101	S32202	S32304	S82441	S32205	S30403	S31603
EN	1.4162	1.4062	1.4362	1.4662	1.4462	1.4307	1.4404
C	0.03	<0.03	<0.03	0.02	<0.03	0.020	0.017
Cr	21.5	22.9	23.8	24.0	22.8	18.0	17.0
Ni	1.5	2.6	4.3	3.6	5.5	8.0	10.0
Mo	0.3	0.2	0.5	1.6	3.0	0.16	2.0
N	0.22	0.21	0.18	0.27	0.17	0.07	0.03
Mn	5.0	1.3	1.8	3.0	1.8	1.2	1.8
Fe	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.
PREN	26	27	28	33	35	20	24

Samples preparation

Prior to electrochemical testing, specimens were polished under water with SiC paper to 1200 grit finish. Then, they were degreased in an ultra-sonic acetone/ethanol mixed bath, rinsed with distilled water, dried, and finally aged for at least 18h in ambient air to obtain a reproducible aging of the passive film.

Electrochemical tests

Pitting corrosion was evaluated using methods adapted from standard electrochemical test methods: ASTM G150 for evaluating critical pitting temperature (CPT) and ASTM G61 for assessing pitting potential (PP) [4,5]. Environmental parameters (chloride content, pH and temperature) were selected to be representative of different environments that can be encountered in wastewater units. The selected environments for pitting corrosion testing are presented in Table 2. Three laboratories were involved in the evaluation of the pitting corrosion testing. All materials were tested by all laboratories while the conditions have been divided between the laboratories.

Table 2.**Test matrix for pitting corrosion tests**

Chloride content (ppm)	pH	Critical pitting temperature	Pitting potential	
			@ 35°C	@ 50°C
500	6	X	/	X
1000	6	/	X	/
5 000	6	X	/	X
10 000	6	X	X	X
20 000	6	X	X	/
200	3	X	/	/
3 000	3	X	/	/

For all electrochemical tests, the specimens were exposed to the simulated wastewater solutions (Table 2) purged for at least 30 min. with inert gas to remove oxygen.

Critical pitting temperature testing in simulated wastewater.

After an initial temperature stabilization period, at about 0°C, the solution is heated at a rate of 1°C/min.