

Corrosion Properties of UNS S83071, Super Duplex Stainless Steel with High Acid Corrosion Resistance

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ABSTRACT

Super and hyper duplex stainless steels (DSSs) are well-known materials in chemical industry. DSSs are characterized by excellent chloride stress corrosion resistance, very high mechanical strength, excellent resistance to pitting and crevice corrosion. The duplex structure also gives design advantages compared to austenitic stainless steels since the thermal expansion matches carbon steels.

However, DSSs are often optimized for chloride resistance, and therefore the performance in acid environments can be a limitation.

The recently developed UNS S83071 has been optimized for general corrosion resistance, which gives benefits where traditional super duplex grades suffer from high corrosion rates due to general corrosion. The composition is 30Cr-7Ni-3.5Mo-N, and the material is characterized by excellent acid corrosion resistance with the traditional benefits of DSSs, in combination with good structure stability and weldability.

This paper presents the results from general corrosion testing in acid environments and the results from standardized corrosion testing methods. The results show that UNS S83071 has excellent general corrosion resistance as well as excellent resistance to pitting and crevice corrosion, making it suitable to be used in demanding environments, such as acid production plants with or without seawater cooling.

Key words: Hydrochloric acid, Sulfuric acid, Stainless Steels, Crevice corrosion, Corrosion tests

INTRODUCTION

Austenitic-ferritic stainless steels, commonly known as duplex stainless steels (DSSs), are a group of materials typically consisting of equal amounts austenite and ferrite. DSSs are well-known materials in chemical industry and are often a cost-effective alternative as they combine high mechanical strength and fatigue resistance with good corrosion properties. Contributing to the cost-effectiveness is the low nickel content compared to austenitic stainless steels. Advantages with DSSs are high chloride stress corrosion cracking resistance (SCC), where austenitic steels with moderate nickel content are inherently more sensitive. In combinations with carbon steel it can be a benefit to use DSSs since carbon steel and DSSs have matching thermal expansion.

Among the applications where DDSs are selected are where common austenitic stainless steels face problems with chloride pitting or chloride stress corrosion cracking.

Duplex stainless steels were first developed in the 1930s. The first generation DSS had poor weldability since they did not have an optimized austenite and ferrite ratio. In most cases, the metallurgical process of the welding resulted in high ferrite content in the heat affected zone (HAZ) and weldments with unacceptable toughness and corrosion resistance. The materials were, therefore, mainly used as non-welded components.

A leap in the development of DSSs came in the 1970s and '80s with the addition of nitrogen. The nitrogen stabilizes the austenite and in combination with improved welding procedures solved the weldability problems, resulting in the good weldability of DSS we see today.

The commonly used 2205 type duplex is alloyed with chromium, molybdenum, and nitrogen for corrosion resistance. Other grades have since been developed with increased amounts of the alloying elements to further improve corrosion resistance and mechanical strength such as super duplex (UNS S32750), and hyper duplex (UNS S32707). Most of the duplex grades developed for increased corrosion resistance are so with the aim to have high chloride resistance, special attention has been placed on maximizing pitting resistance equivalent (PRE) and balancing the two phases with respect to PRE and chloride resistance. Although, they also have good general corrosion resistance in many environments, austenitic stainless steels are often preferred in acidic environments.

The recently developed super duplex stainless steel Sandvik SAF 3006[†] (UNS S83071) has been optimized for general corrosion resistance, which gives benefits where traditional super duplex grades suffer from high corrosion rates due to general corrosion. The composition of UNS S83071 is shown in Table 1.

Table 1

Chemical requirements for UNS S83071, the values are presented as weight% and are maximum values unless a range is indicated.

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	N
0.030	0.50	0.50-1.50	0.030	0.020	29.0-31.0	6.0-8.0	3.0-4.0	0.80	0.28-0.40

UNS S83071 is included in ASTM⁽¹⁾ A789 and A790, with pressure vessel approval per ASME⁽²⁾ Section VIII Code Case 2914.^{5, 6} The material has high mechanical strength, the requirements can be seen in Table 2.

[†] Trade name.

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⁽²⁾ American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990

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Table 2
Tensile and hardness requirements for UNS S83071.

	Yield strength		Tensile strength		Elongation	Hardness	
Temperature	R _{p0.2}		R _m		A	HBW	HRC
°C	MPa	ksi	MPa	ksi	%		
	min.	min.	min.	min.	min.	max.	max.
RT (20)	680	98	830	120	25	300	32

This paper presents new data from general corrosion testing in acid environments and the results from standardized corrosion testing methods. Corrosion data such as iso-corrosion diagrams are important tools for guidance during material selection and comparing materials.

EXPERIMENTAL PROCEDURE

Material

Seamless tubes with the dimension 31x2.5 mm produced from full-scale heats have been used for corrosion testing of UNS S83071. The heats were produced by melting in an Electric Arc Furnace (EAF) followed by Argon Oxygen Decarburization (AOD) refining. The chemical composition is given in Table 3. The tubes were produced by hot extrusion, cold pilgering, and final bright annealing with rapid quenching.

Table 3
Chemical compositions of UNS S83071, presented as weight%.

Heat	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	N
546696	≤0.02	0.25	1.02	0.017	0.0007	29.81	6.99	3.08	0.11	0.35
552724	≤0.02	0.20	0.91	0.018	<0.0005	30.36	6.95	3.06	0.10	0.35

General corrosion testing

General corrosion testing was performed in hydrochloric acid (concentrations up to 5 %) and sulfuric acid (concentrations up to 50 %) according to ISO⁽³⁾ 18069, with exception regarding activation.⁷ Specimens tested in hydrochloric acid were electrochemically activated for 20 seconds before periods 2 and 3 using a potentiostat with an applied potential of -700 mV. Specimens tested in sulfuric acid were activated by zinc activation in periods 2 and 3. The test was divided into three periods of 24 hours + 72 hours + 72 hours. The test specimens used were tube rings from heat no. 546696 and heat no. 552724 with the inner and outer surface in delivery condition and the cut edges wet ground with P120 grit paper. Two specimens per temperature and concentration were tested.

Intergranular corrosion testing

Intergranular corrosion testing has been performed according to ASTM A262 practice B (Streicher) in boiling 50 % ferric sulfate (Fe₂(SO₄)₃) + 50 % sulfuric acid (H₂SO₄) for a test period of 120 hours.⁸ The specimens were tube rings from heat 552724 with the inner and outer surface in delivery condition, and the cut edges wet ground with P120 grit paper.

Intergranular corrosion testing has been performed according to ASTM A262 practice C (HUEY) in boiling 65 % nitric acid (HNO₃) for a combination of five 48 hours test periods.⁸ After each test period, the mass

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