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YUS 270, Super-austenitic Stainless Steel, for Piping and Tubing Applications

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Abstract

The paper gives the properties of YUS 270, super austenitic stainless steel containing 6% Mo, for piping and tubing applications. The steel has excellent corrosion resistance in chloride rich environment such as seawater and HCl and also in sulfuric acid environment. The maximum allowable tensile strength values for the steel have been prepared for power boiler use. Therefore, YUS 270 pipes and tubes are promising materials for desalination plants, food processing plants that deal with high salt concentration materials and heat exchangers in coal-fired power plants and incineration plants.

1. Introduction

The Nippon Steel group has commercialized 20Cr-18Ni-6Mo-0.2N super-austenitic stainless steel (trade name YUS 270) as a highly corrosion-resistant steel material in the form of a sheet, pipe, tube, bar, wire and so on[1-3]. The steel has been successfully applied to a wide variety of fields. Examples are: a desalination plant, a condenser of a thermal power plant and linings of marine constructions such as bridges, where the steel is in direct contact with seawater[4]; the roofs of buildings or monuments in coastal regions, where they are exposed to airborne salt[5]; food plant facilities that process materials having a high salt content[6]; and the inner lining of smoke stacks of a thermal power plant, where sulfuric acid forms[7].

This paper presents the characteristics of YUS 270, in relation especially with its use for piping and tubing.

2. Characteristics of YUS 270 Steel Pipe and Tube

2.1 Manufacturing methods and product size ranges

Nippon Steel makes two kinds of YUS 270 pipe and tube products available: hot-extruded seamless and welded ones, the latter being produced by forming a cut sheet or a strip coil of the steel into a tubular shape and welding the seam using a gas tungsten arc (GTA) welding. The size ranges of the products are shown in **Table 1**.

Table 1 Available size range for YUS 270 pipes and tubes

Manufacturing process		Outside diameter (mm)	Wall thickness (mm)
Seamless		10.5-139.8	1.2 minimum
Welded	Continuous roll forming	10.5-114.3	1.2-4.0
	Press forming	114.3-1,524.0	2.0-32.0

2.2 Chemical composition

The chemical composition of YUS 270 is characterized in that its content of Mo is as high as 6%, and the contents of Cr and N are higher than that of conventional stainless steel. **Table 2** shows the specified ranges and examples of YUS 270 pipes. The chemical composition of YUS 270 pipes and tubes are also designed so as to fall within the specified ranges of a similar standardized steel, UNS S31254 (AVESTA 254 SMO[8]).

2.3 Corrosion resistance

2.3.1 Resistance to pitting corrosion

Various stainless steels are compared in **Fig. 1** in terms of pitting corrosion resistance, based on the results of ferric chloride tests and standardizing the results using an index composed of the contents of

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Table 2 Specification and examples of chemical composition for YUS 270 pipes and tubes (mass%)

			C	Si	Mn	Ni	Cr	Mo	Cu	N
YUS 270	Specification		0.020 max.	0.80 max.	1.00 max.	17.00-19.50	19.00-21.00	5.50-6.50	0.50-1.00	0.16-0.24
	Example	Seamless	0.014	0.51	0.44	17.79	19.99	6.16	0.63	0.215
		Welded	0.013	0.46	0.52	17.69	19.90	6.08	0.65	0.203
UNS S31254 specification			0.020 max.	0.80 max.	1.00 max.	17.00-18.50	19.50-20.50	6.0-6.5	0.50-1.00	0.18-0.22

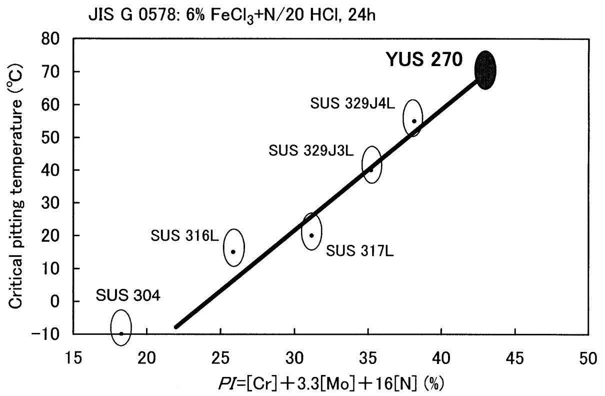


Fig. 1 Critical temperature for pitting in 6%$FeCl_3$ + N/20 HCl versus composition for austenitic and duplex stainless steels

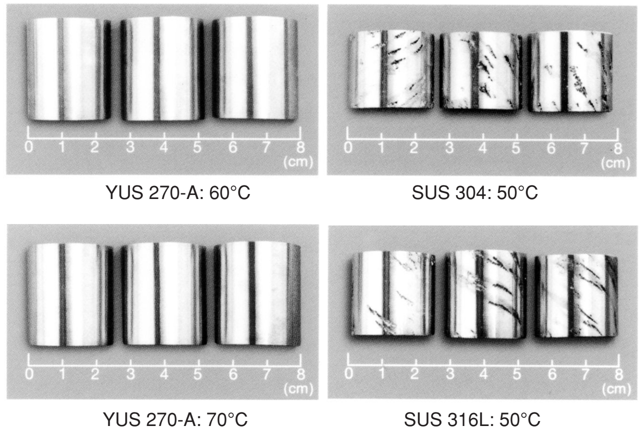


Photo 1 Appearance of specimens after ferric chloride tests

alloying elements[3]. The critical temperature of pitting corrosion becomes higher as the contents of Cr, Mo and N increase, and as seen in the figure, the critical pitting corrosion temperature of YUS 270 is higher than that of conventional stainless steels such as JIS SUS 316L and duplex SUS 329J4L.

The ferric chloride test results of seamless and GTA-welded pipes of YUS 270[2] are compared with those of other steels in **Fig. 2**, and the appearances of the specimens after the tests[2] are shown in **Photo 1**. It is seen here that the pitting corrosion resistance of a GTA-welded pipe of YUS 270 is superior to that of SUS 304 and SUS 316L, although a little inferior compared with that of a seamless pipe of YUS 270.

2.3.2 Resistance to crevice corrosion

Fig. 3 shows the results of crevice corrosion tests in a ferric chloride solution[3]. Addition of Cr, Mo, and N is effective also for enhancing crevice corrosion resistance; and the critical temperature of crevice corrosion of YUS 270 is higher than that of other stainless steels.

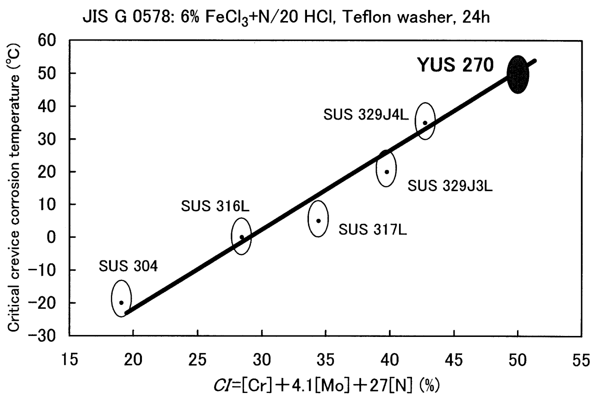
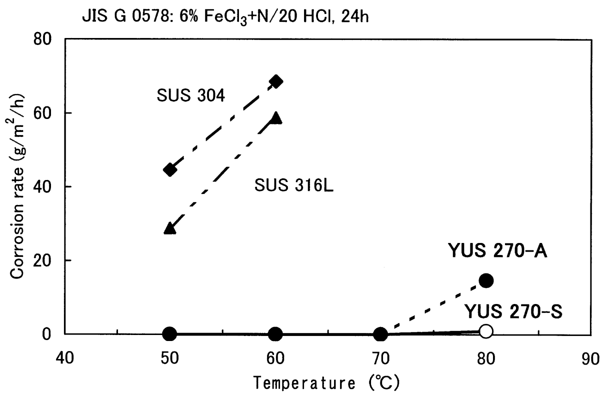


Fig. 3 Critical temperature for crevice corrosion in 6%$FeCl_3$ + N/20 HCl versus composition for austenitic and duplex stainless steels



(YUS 270-S: seamless, YUS 270-A: welded)

Fig. 2 Ferric chloride test results for tubes

2.3.3 Resistance to stress corrosion cracking

Fig. 4 shows the results of stress corrosion cracking tests in a boiling 42%-solution of $MgCl_2$ (143°C)[3]. Under the load stress condition where duplex SUS 329J4L, which is considered highly resistant to stress corrosion cracking, failed in 25 h, YUS 270 did not fail after elapsing 500 h or more, which is evidence of its excellent resistance to stress corrosion cracking.

2.3.4 Resistance to general corrosion

Fig. 5 shows the rates of general corrosion of various stainless steels in a hydrochloric acid solution[3], and **Fig. 6** the same in a sul-

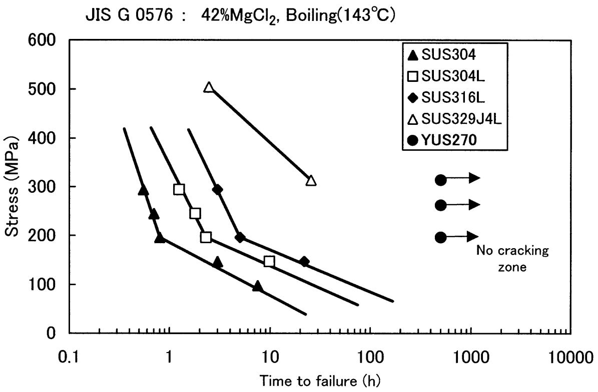


Fig. 4 Stress-corrosion cracking test results

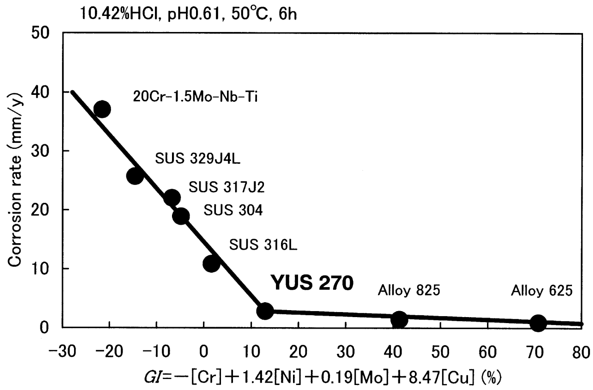


Fig. 5 Corrosion rate in 10.42%HCl versus composition for Ni-Cr-Mo-Fe alloys

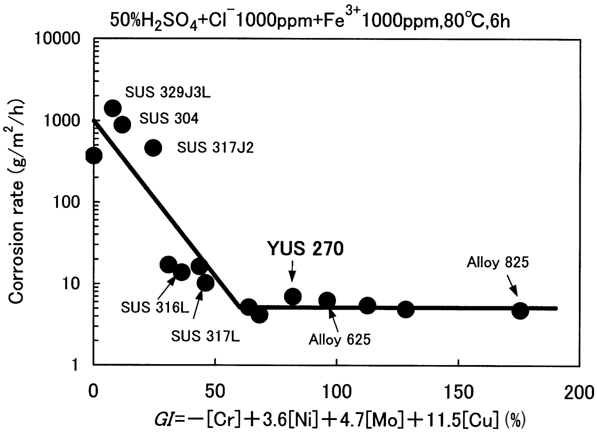


Fig. 6 Corrosion rate in 50%H_2SO_4 + Cl^- + Fe^{3+} versus composition for Ni-Cr-Mo-Fe alloys

furic acid solution containing Cl^- and Fe^{3+} that simulates the environment inside a smoke stack of a thermal power plant in a cold condition[9]. In either of the corrosion conditions, whereas the addition of Ni, Mo and Cu is effective for enhancing general corrosion resistance, the addition of Cr is detrimental. YUS 270 has high contents of Ni, Mo and Cu, and as a result, its general corrosion resistance is substantially as good as that of a Ni-based alloy. Under the above conditions, the corrosion resistance of duplex SUS 329J4L is inferior to that of SUS 304.

2.4 Mechanical properties

Table 3 shows the mechanical properties of YUS 270 pipes and tubes according to the specification and examples of measured values, and **Fig. 7** its tensile properties at elevated temperatures. YUS 270 is characterized by high tensile strength due to its high N content. The toughness of a YUS 270 pipe is sufficiently high in a heat-affected zone and weld metal as well as in the base metal.

The corrosion environment of a heat exchanger tubes used for plants such as a coal-fired thermal power plant and a waste incineration plant has become increasingly severe lately, and as a consequence, better corrosion resistance is ever more required in such applications. For the design of pressure parts the maximum allowable

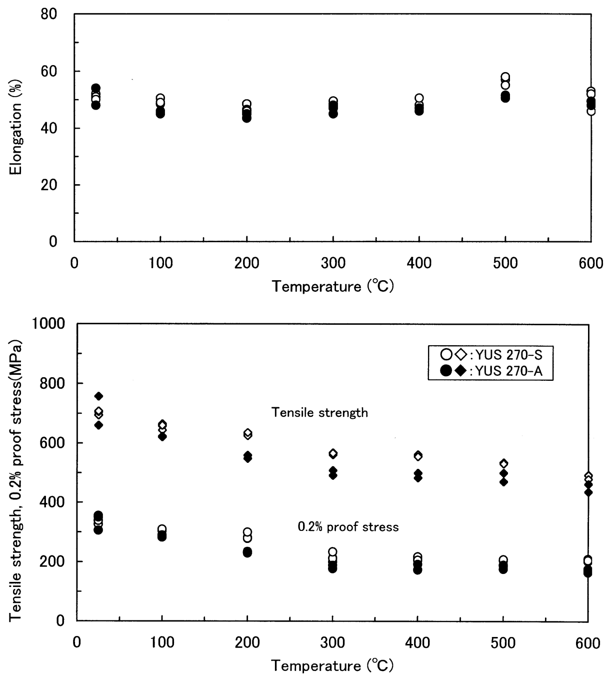


Fig. 7 Tensile properties at elevated temperatures for YUS 270 pipes and tubes

Table 3 Specification and examples of mechanical properties for YUS 270 welded pipes and tubes

		Tensile properties at room temperature			Hardness HV(9.8N)		Impact value at 0°C(J/cm²)		
		0.2% proof stress (MPa)	Tensile strength (MPa)	Elongation (%)	Base metal	Welded portion	Base metal	Heat affected zone	Weld metal
Specification		300 min.	650 min.	35 min.	-	-	-	-	-
Example	21.7 mmϕ × 1.5 mm thickness	348	712	61	185	184	-	-	-
	114.3 mmϕ × 3 mm thickness*	550	832	43	212	197	147	151	39

*: The pipe was welded with type 625 filler wire and stretched by 1% for straightening.

Table 4 Maximum allowable stress values for YUS 270 pipes and tubes

Temperature (°C)	0	40	75	100	125	150	175	200	225	250	275	300	325	350	375
Maximum allowable stress (N/mm^2)	157	157	157	156	153	149	146	143	141	139	137	135	134	134	132

Note: Conversion from ASME SA-249 S31254 (ASME Boiler & Pressure Vessel Code Section II Part D (1998 Edition))

stress values for ASME SA-249 S31254 can be applied to YUS 270 pipes and tubes, since YUS 270 is equivalent to S31254. **Table 4** shows the values of maximum allowable stress values converted from ksi and degrees Fahrenheit into N/mm^2 and degrees Celsius. It was confirmed in fiscal year of 2002 by the Ministry of Economy, Trade and Industry, that S31254 conformed to the Japanese technical standards for materials for thermal power plant equipment. Therefore, YUS 270 can be also applied to the pressure parts for the thermal power plants.

2.5 Workability

For welding YUS 270, the use of a filler wire of a high-Mo type Ni-based alloy equal or superior to 625 series (22Cr-9Mo-3.5Nb-Ni bal.) is recommendable. This is because there occur low-Mo portions in a weld metal as a result of segregation and unless the Mo content of the weld metal is equal to or higher than that of a base metal, the corrosion resistance of the weld metal inevitably deteriorates at the low-Mo portions. Like other austenitic stainless steels, no pre-heating or post-heat treatment is required for welding.

Since YUS 270 is an austenitic stainless steel, its workability is good, either hot or cold. However, it should be noted that since the Mo content of YUS 270 is high, a σ phase is likely to form during hot working, possibly resulting in poor corrosion resistance, and for this reason, it is desirable to apply solution heat treatment at high temperature (1,150°C or higher) after hot working.

2.6 Joints and accessories

Pipe joints such as tees, elbows and reducers are often required for actual piping work. Various kinds of joints of YUS 270 have been made available recently to meet the requirement[2)]. Since YUS 270 is available also in the form of a sheet, bar and so forth as described above, an entire plant facility can be fabricated using only YUS 270 steel; by so doing, the corrosion resulting from potential difference, which is likely to occur when pipes, sheets and other components of different metal materials are combined in a plant facility, can be avoided. **Photo 2** shows pipes and flanges, both made of YUS 270, used for a food processing plant.

Photo 2 YUS 270 pipe with flange for a food processing plant

3. Closing

YUS 270 pipes and tubes have been presented herein. Various piping accessories made of the steel such as pipe joints have been made available in addition to straight pipes to facilitate actual use of the product. Thus YUS 270 is expected to expand its use from desalination plants, for which the steel pipe has been used conventionally, to a wider variety of equipment such as food processing plants and heat exchangers of boilers.

References

1) Nippon Steel Corporation catalogue Cat. No. SS107
2) Nippon Steel Corporation catalogue Cat. No. PC308
3) Nippon Steel Corporation catalogue Cat. No. PC310
4) Sato, H. et al.: Shinnittetsu Giho. (377), 34(2002)
5) Nakata, U.: Seminar on Corrosion-resistant Metal Construction Materials, 1996
6) Suetsugu, K. et al.: Shinnittetsu Giho. (377), 31(2002)
7) Inoue, Y. et al.: Recent Progress in Welding Technology from the Viewpoint of Use of Stainless Steels. 2002, p.17
8) AVESTA 254 SMO. Alloy Digest. (May), 9(1984)
9) Matsuhashi, R. et al.: Proc. of 36th Japan Corrosion Conference. 1989, p.359