New Welding Consumables for Austenitic Stainless Steel for Boiler Tube

1. Introduction

In terms of heat resistant steels used for boilers for thermal power generation, there are ferritic heat resistant steels and austenitic heat resistant steels. Since austenitic heat resistant steels afford superior high-temperature strength to ferritic heat resistant steels, they are widely used for superheaters and reheaters, which are pressure devices subject to very high temperatures.

However, when carbon is added to 18-8 austenitic heat resistant steel to enhance its high-temperature strength, the steel becomes more susceptible to intergranular corrosion. On the other hand, adding Mo or other alloying elements (other than carbon) for the same purpose makes the steel costlier. In order to resolve this problem, Nippon Steel has developed low-C-18Cr-9Ni-W-Nb-V heat-resistant steel XA704 (KA SUS 347J1TB) which has better intergranular corrosion resistance than conventional 18-8 austenitic heat resistant steels because of its lower carbon content and yet affords superior high-temperature strength to 18-8 thanks to the enhanced precipitation of CrNbV and enhanced solution of W and N[1]. **Fig. 1** compares allowable stress between XA704, the conventional austenitic heat resistant steel SUS 347HTB, and 20Cr-25Ni austenitic heat resistant steel NF709 which has far superior high-temperature strength to the conventional 18-8 austenitic heat resistant steel. XA704 allows for about 30 MPa more stress than SUS 347HTB, and at 625 and 650℃, XA704 offers comparable strength to NF709.

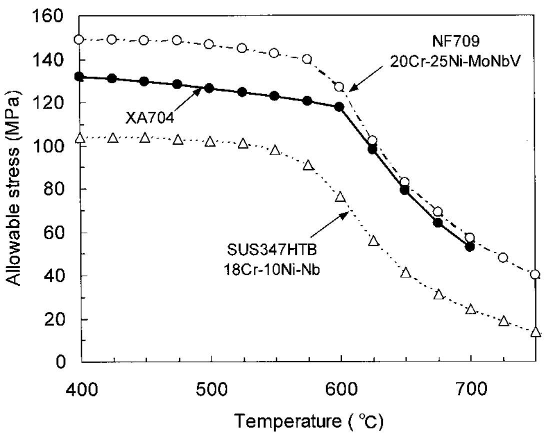


Fig. 1 Maximum allowable stress of austenitic heat resistant steel

However, since boilers for thermal power generation are welded structures, when it comes to using XA704 for those boilers, development of a suitable welding technology is indispensable. To weld austenitic heat resistant steel, a matching welding consumables or Ni-based welding consumables is used. AWS ERNiCrMo-3 (Inconel 625) is an example of a Ni-based welding consumables. Ni-based welding consumables can be applied to XA704. However, considering the need for composition adjustment and the cost involved, it is desirable to use a matching welding consumables for XA704. This paper describes a matching welding consumables developed for XA704.

2. Weld Metal Composition and Characteristics

When a ferrite phase is contained in the weld metal, it can change into a brittle phase, causing the weld metal toughness to deteriorate during service. Therefore, it is desirable that the weld metal structure should be fully austenite. On the other hand, a fully austenite weld metal is highly susceptible to hot cracking and is inferior in weldability. The newly developed matching welding consumables feature the optimum balance between the austenite-forming elements and the ferrite-forming elements. This material is fully austenite and free from hot cracking.

Table 1 shows examples of chemical compositions of deposited metals prepared using the matching welding consumables. The welding methods used are GTAW and SMAW. As in the case of the base metal, the required high-temperature strength of the deposited metals was ensured by adding W to the welding consumables. **Fig. 2** shows the microstructures of weld metals for tube joints prepared using the matching welding consumables. Both weld metals present a fully austenite structure.

Fig. 3 shows the results of a side-bending test of welded joints prepared using the matching welding consumables. A liquid penetrant

Table 1 Chemical compositions of base metal and deposited metals (mass%)

		C	Si	Mn	Ni	Cr	W	Cu	Nb	V	N
Base metal		0.03	0.27	1.69	9.85	18.5	2.13	-	0.37	0.30	0.23
GTAW	DM	0.04	0.29	1.21	13.2	18.3	2.58	-	0.39	0.3	0.14
SMAW	DM	0.05	0.42	1.45	15.0	18.3	3.12	2.01	0.36	0.3	0.12

DM: Deposited metal

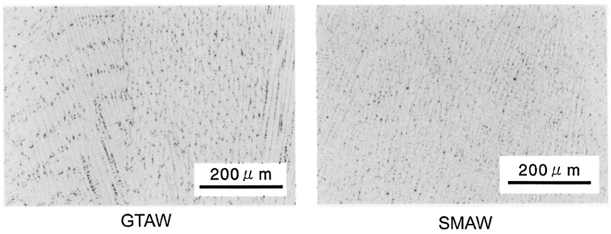


Fig. 2 Microstructures of weld metals

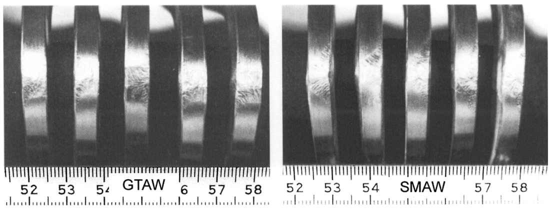


Fig. 3 Macro-appearance of weld joint after side bend test

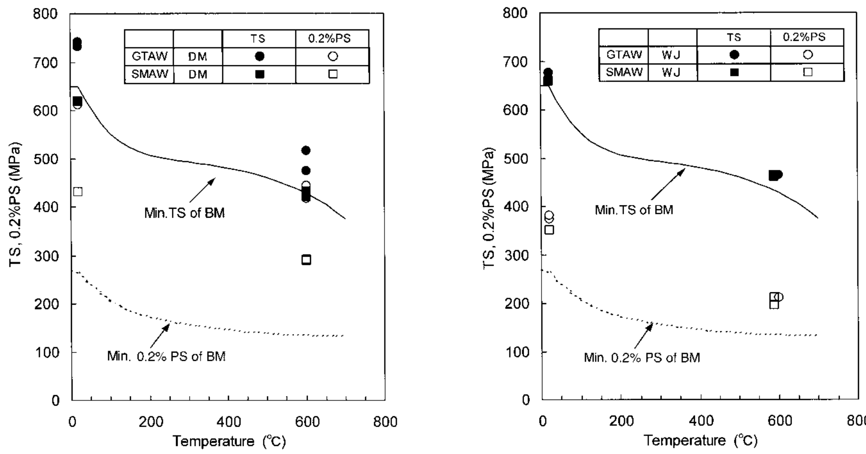
testing carried out after the bending test showed no cracks in any of the welded joints. Although the welded joints are all austenite, they are free from hot cracking.

Fig. 4 shows the tensile properties of deposited metals and welded joints. As shown in Fig. 4 (a), the tensile strength of the deposited metal is equal to or higher than that of the base metal. Because of this, in a tensile test of welded joints too, the tensile strength of the welded joints was equal to or higher than that of the base metal as shown in Fig. 4 (b). **Table 2** shows the toughness of the deposited metals. It can be seen that the deposited metals are appreciably tough.

Fig. 5 shows the creep rupture strengths of deposited metals and welded joints. In the figure, the solid lines indicate the average values

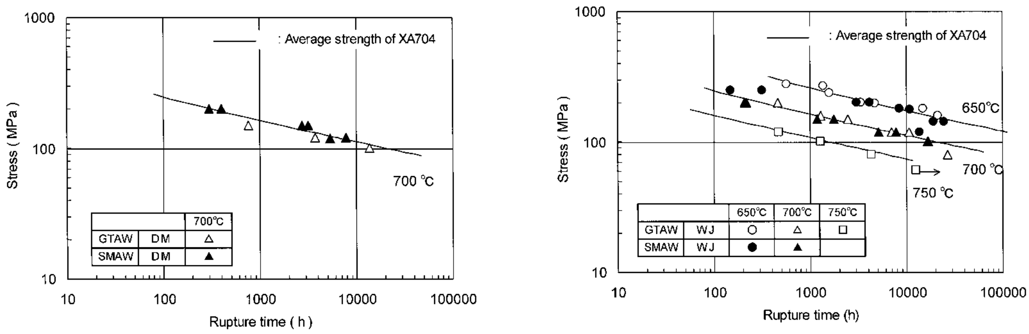
Table 2 Toughness of deposited metals

Welding method	Absorbed energy at 20℃ (J)	
GTAW	163, 167, 166	Ave. 165
SMAW	105, 122, 122	Ave. 116



(a) Deposited metal **(b) Weld joint**

Fig. 4 Tensile properties of deposited metals and weld joints



(a) Deposited metal **(b) Weld joint**

Fig. 5 Creep rupture strength of deposited metals and weld joints

for the base metal. Both GTAW and SMAW deposited metals show creep rupture strength comparable to that of the base metal. Therefore, the creep rupture strength of welded joints prepared from tubular joints obtained using the matching welding consumables is as high as that of the base metal.

3. Conclusion

Through optimization of the weld metal chemical composition, matching welding consumables were developed that are suitable for the newly developed austenitic heat resistant steel XA704. By using these welding consumables, it was possible to obtain sound welded joints with high-temperature strengths comparable to the base metal.

Reference

1) Ishizuka, T. et al.: Shinnittetsu Giho. (380), 91 (2004)

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