EPD Congress 2016
Edited by: Antoine Allanore, Laura Bartlett, Cong Wang, Lifeng Zhang, and Jonghyun Lee
TMS (The Minerals, Metals & Materials Society), 2016

EVALUATION OF JOINT PERFORMANCE ON HIGH NITROGEN STAINLESS STEEL WHICH IS EXPECTED TO HAVE HIGHER ALLERGY RESISTANCE

Kouichi Nakano[1]

[1]Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology, Hibikino 2-4, Wakamatsu-ku, Kitakyushu-shi, Fukuoka, 808-0196, Japan

Keywords: High Nitrogen Stainless Steel, Austenitic stainless steel, Rare Metal, Resource Saving, Nickel, Anti Metallic Allergy, Stud Welding, Vickers hardness

Abstract

Austenitic stainless steel, which includes nickel for stabilizing austenitic structure, is used for various purposes, for example, for structural material, corrosion-resistant material, biomaterial etc. Nickel is set as one of the rare metals and economizing on nickel as the natural resources is required. On the other hand, nickel is one of the metals that cause metallic allergy frequently. Therefore, high nitrogen stainless steel, where nitrogen stabilizes austenitic structure instead of nickel, has been developed in Japan and some of the foreign countries for the above reason. When high nitrogen stainless steel is fused and bonded, dissolved nitrogen is released to the atmospheric area, and some of the material properties will change. In this study, we bonded high nitrogen stainless steel by stud welding process, which is able to bond at short time, and we evaluate joint performance. We have got some interesting results from the other tests and examinations.

Introduction

Nickel stabilizes austenitic structure and austenitic stainless steel added nickel is used for various purposes, for example, for structural material, corrosion-resistant material, and biomaterial etc. Nickel is one of the rare metals. Economizing of nickel is required as the natural resources. On the other hand, nickel is one of the metals that cause metallic allergy frequently. Therefore, high nitrogen stainless steel, where nitrogen stabilizes austenitic structure instead of nickel, has been developed by solid-state absorption or pressure type electroslag remelting methods in Japan and some of the foreign countries for the above reason. But in case high nitrogen stainless steel is fused and bonded, dissolved nitrogen is released to the atmospheric area, and some of the material properties will change.

In this study, we bonded high nitrogen stainless steel by stud welding process, which is able to bond at short time, and we evaluated joint performance by tensile test, bending test, macro examination according to ASME Sec. IX. The measurement of vertical stability between stud and base plate, micro examination, Vickers hardness test, and Electron Probe Micro Analysis (EPMA) were also carried out.

Materials used and experimental methods

Materials used

SUS304N2 was used as stud material ($\Phi 9 \times L100$ mm), and a tip ($\Phi 0.9 \times L0.9$ mm) was prepared on the head of stud. Nitrogen content of SUS304N2 is 0.20wt%. SUS304N2-X was used as base plate (w30 × L30 × t9.0 mm). Nitrogen content of SUS304N2-X is 0.22wt%. Chemical composition of SUS304N2 and SUS304N2-X are listed in the Table I and II respectively.

Table Ⅰ Chemical composition of SUS304N2

		Chemical Composition (wt %)								
		C	Si	Mn	P	S	Ni	Cr	N	Nb
Standard requirements	Max.	0.08	1.00	2.50	0.045	0.030	10.50	20.00	0.30	0.15
	Min.						7.50	18.00	0.15	
Measured value		0.04	0.66	1.70	0.030	<0.001	8.22	18.34	0.20	0.08

Table Ⅱ Chemical composition of SUS304N2-X

		Chemical Composition (wt %)								
		C	Si	Mn	P	S	Ni	Cr	N	Nb
Standard requirements	Max.	0.08	1.00	2.50	0.045	0.030	10.50	20.00	0.30	0.15
	Min.						7.50	18.00	0.15	
Measured value		0.06	0.72	1.85	0.028	0.001	7.69	18.54	0.22	0.10

<u>Stud welding condition</u>

Welding conditions like primary welding voltage (E_0 = 100V), fixing strength (F = 63.7N), electric capacitor (C = 0.117F), and welding time (t = 0.003s) are set constantly. Secondly voltage (welding voltage) was set 130V, 140V, 150V, 160V, 170V and 180V. Materials were cleaned with acetone before welding. Spatter preventing solution was applied for the base plate surface. Spatter preventing solution is mixture of water and surfactant.

<u>The measurement of vertical stability between stud and base plate</u>

The measurement of vertical stability between stud and base plate was based on the welded surface of base plate, and the measurement error was within an angle of 0.1 degree. The measured value was plotted on the circular graph and investigated.

<u>Tensile test</u>

Tensile test was carried out for every five specimens, which were welded at each welding voltage, according to ASME Sec.IX QW-192.1.1. Afterward, every specimen was evaluated weather the value of tensile strength was higher than the least tensile strength of 210MPa or not according to the requirement of ASME Sec.IX QW-192.1.3.

<u>Bending test</u>

Every five specimens, which were welded at each welding voltage, have been bent at 15 degree according to ASME Sec. IX QW-192.1.1. And then, each specimen has been evaluated whether it had cracks or not after returning 15 degree according to the requirement of ASME Sec. IX QW-192.1.1.

<u>Macro and micro examination</u>

Macro examination observing at 10-fold magnification was carried out according to ASME Sec. IX QW-192.1.4. Afterwards, each specimen has been evaluated whether it has cracks or not.
Micro examination observing at 400-fold magnification was carried out for base plate, heat affected zone (HAZ), bond zone, and weld metal of each specimen.

Vickers hardness test

Vickers hardness test was carried out at 0.2 mm intervals from the bond interface to the both outer sides up to 2.0mm in length. Test force of 1.961N and holding time of 5 seconds were set constantly.

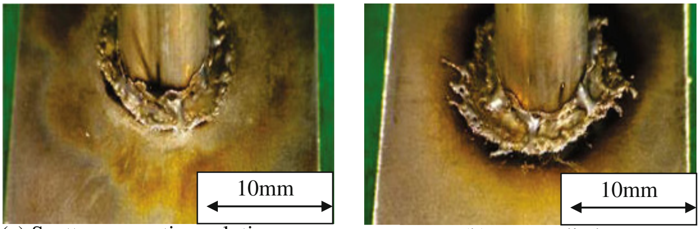
EPMA

EPMA was carried out for each cross section of the specimen in an axial direction of the stud weld. Analyzed chemical elements were Ni, Cr, N, C, and O.

Experimental Results and Discussion

Appearance of weld

Figure 1 shows the appearance of stud weld when the spatter preventing solution was applied on the base plate surface (a) and not applied (b). In case the spatter preventing solution was applied, the appearance of the stud weld became good as the ferrule was used on the joint. Melted metal didn't fly away and covered weld, therefore we thought stability of the weld increased in this case.



(a) Spatter preventing solution was applied (b) Not applied

Figure 1. Appearance of the stud welds

Tensile test

Figure 2 shows the relation between welding voltage and tensile strength. All specimens fractured at weld, but satisfied the least tensile strength of 210MPa, which is required by ASME Sec. IX QW-192.1.3.

Figure 3 shows the relation between breaking elongation and tensile strength. Breaking elongation becomes longer according to the increase of tensile strength. Positive correlation between breaking elongation and tensile strength is confirmed.

Figure 4 shows the evaluation model on stud welded joint strength based on droplet behaviour of molten metal. In case of parallel model, tensile strength will increase according to the droplet number of molten metal. On the other hand, in case of serial model, breaking elongation will increase according to the droplet number by this model.

The slope of the positive correlation between breaking elongation and tensile strength changed according to the welding voltage actually. So we think that the mixture ratio of the parallel and serial sequence will change according to the welding voltage.

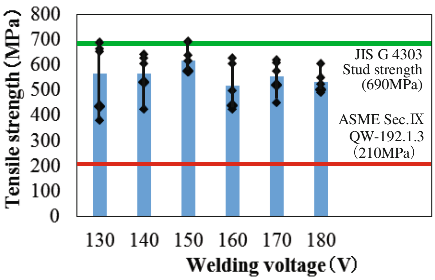


Figure 2. Relation between welding voltage and tensile strength

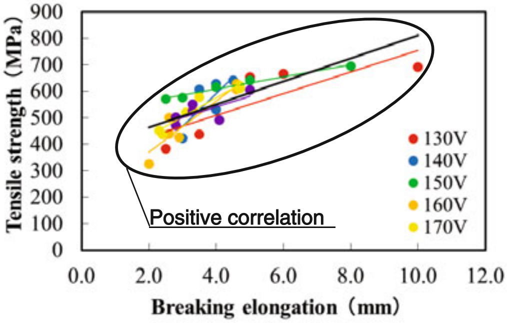


Figure 3. Relation between breaking elongation and tensile strength

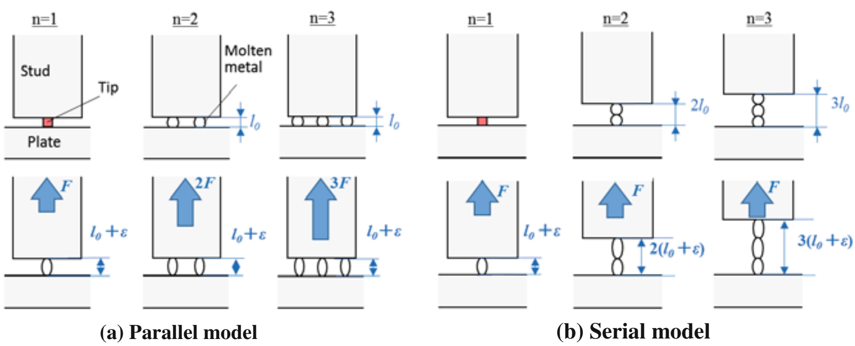


Figure 4. Evaluation model on stud welded joint strength based on droplet behaviour of molten metal (n: number of droplet, F: tensile strength, l_0: original length of droplet, ε : elongation of droplet)

Bending test

All specimens fractured at welds during bending test, and none of the specimen satisfied the requirement of ASME Sec. IX QW-192.1.2 in case welding voltage was 130V and 170V. One specimen satisfied the requirement in case welding voltage was 140V and 160V. Two specimens satisfied the requirement in case welding voltage was 150V and 180V. There is no positive correlation between bending performance and welding voltage. Figure 5 shows the vertical distribution of studs. The maximum value of tilt angle is almost 0.9 degree. So these results have a very little influence on bending performance.

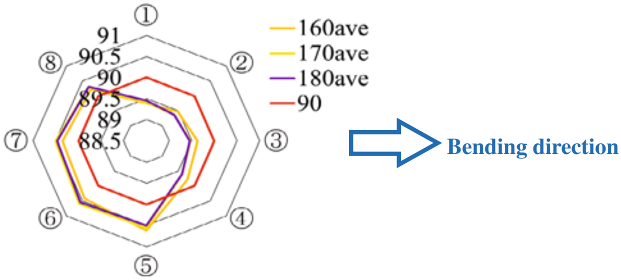


Figure 5. Vertical distribution of studs

Macro and Micro examination

Figure 6 shows the macrograph of cross section of the specimen (160-180V). Some of the lack of fusion area has been observed at the bond interface. Figure 7 shows microstructure at bond interface (140V). We observed dendrite growth toward the welding current direction from the bond interface.

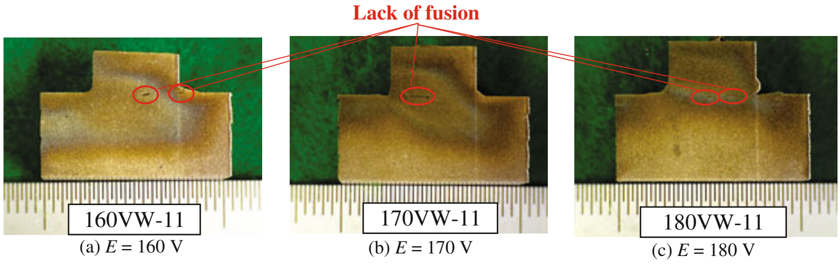


Figure 6. Macrograph of cross section of specimen (160-180V)

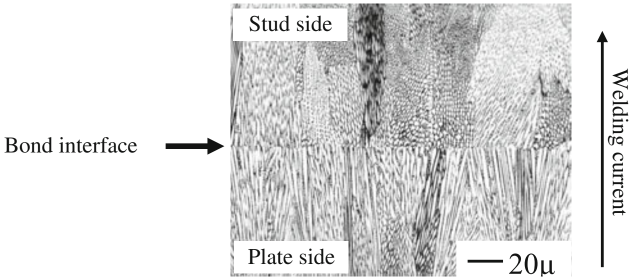
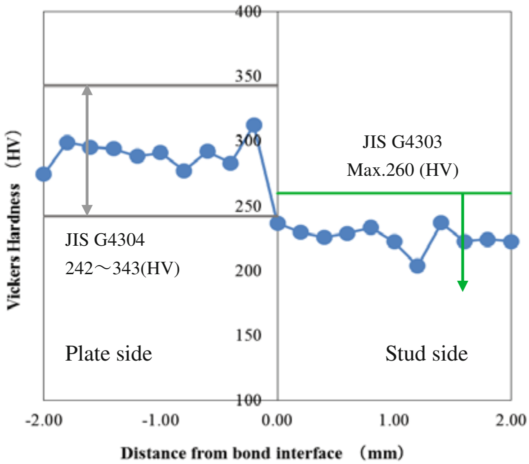
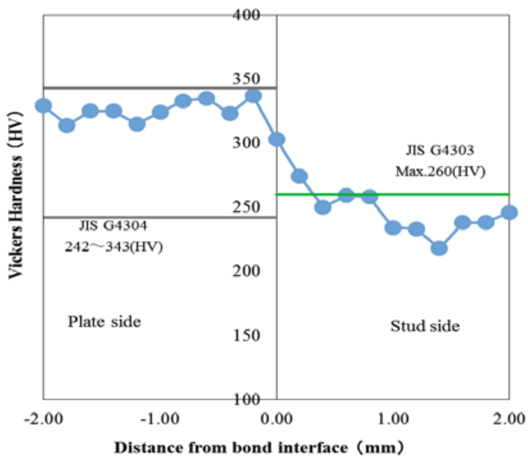


Figure 7. Microstructure at bond interface (140V)

<u>Vickers hardness test</u>
Each specimen which welded at 130~180V has satisfied the JIS G 4304 (base plate) and the JIS G 4303 (stud material) requirement, and indicates almost same hardness before welding. So we think that each specimen has same toughness before welding. Figure 8 shows Vickers hardness distribution from bond interface.



(a) E = 130V

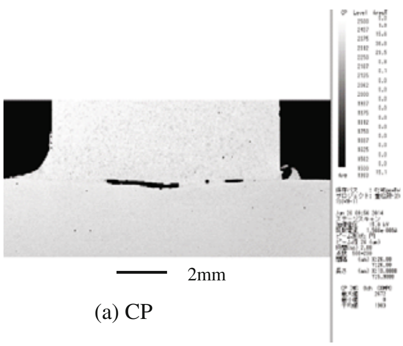


(b) E = 180V

Figure 8. Vickers hardness distribution from bond interface

<u>EPMA</u>

EPMA was carried out at the cross section of specimens. Nitrogen content of the weld metal indicated high enough level. We think that the joint performance will increase if there are no defects in the weldments. The difference of nickel contents between stud and base plate are observed clearly. Figure 9 shows the results of EPMA on the cross section of the specimen in case that the welding voltage is 150V.



(a) CP

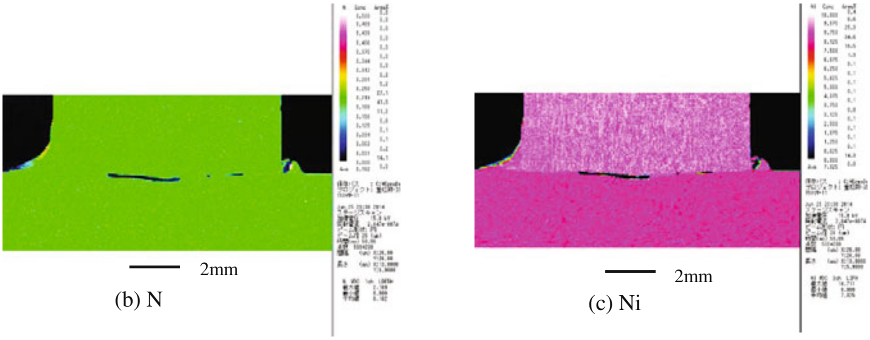


Figure 9. Results of EPMA on the cross section of the specimen (E=150V)

Conclusions

In this study, we bonded high nitrogen stainless steel by stud welding process, which is able to bond at short time, and we evaluated joint performance by tensile test, bending test, macro examination according to ASME Sec. Ⅸ. The measurement of vertical stability between stud and base plate, micro examination, Vickers hardness test, and Electron Probe Micro Analysis (EPMA) also carried out. The conclusions obtained in this study are shown as followed.

(1) Weld metal didn’t fly away and covered weld, therefore the stability of the weld increased in case of spatter preventing solution was applied.

(2) All specimens satisfied the least tensile strength of 210MPa, which is the requirement of ASME Sec. IX QW-192.1.3. Positive correlation between breaking elongation and tensile strength is confirmed. The slope of the positive correlation between breaking elongation and tensile strength changed according to the welding voltage actually. So we think that the mixture ratio of the parallel and serial sequence will change according to the welding voltage.

(3) There is no positive correlation between bending performance and welding voltage.

(4) Some of the lack of fusion area has been observed at the bond interface. Dendrite growth toward the welding current direction from the bond interface was also observed.

(5) Each specimen has held same toughness before welding.

(6) Nitrogen content of the weld metal indicated high enough level.

References

[1] Kouichi Nakano et al., Evaluation of hardness and corrosion resistance on high nitrogen stainless steel weldments, Proceedings of Japan Welding Society, Kyushu-chapter, No.7, (2010), 41-44 (in Japanese)