IMPROVEMENT OF GAS TUNGSTEN ARC WELDABILITY FOR FERRITIC STAINLESS STEELS

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ABSTRACT

Ferritic stainless steels would be the most important alloys under the chloride environment. They are a cheaper alternative to austenitic stainless steels [1]. The present study is related to gas tungsten arc welding (GTAW) characteristics of Type 444 stainless steels. The heat of welding leads to grain coarsening in the HAZ and in the weld metal of ferritic stainless steels because they solidify directly from the liquid to the ferrite phase without any intermediate phase transformation. It is therefore recommended that these alloys be welded with a low heat input and at high welding speeds. Attempts to improve weldability were made by using of direct current straight polarity (DCSP) and pulsed current GTAW processes in this study. Measuring weld bead, grain size and Erichsen test were performed and the effects of heat input, pulse frequency on the weld metal and HAZ were studied. The main results were obtained as followings: decreasing heat input was effective to control the width of weld both in DCSP welding and in pulsed current welding; pulsed current welding was found to refine the grain size effectively and the finest grain size was found at the frequency of 150Hz in pulsed current welding; it was found that decreasing heat input also refine the HAZs effectively and the frequency had no different effect on HAZ at the same heat input; the ductility could be improved effectively in pulsed current welding.

KEYWORDS

GTAW, ferritic stainless steel, weld bead, grain size, Erichsen test.

1. Introduction

Type 444 ferritic stainless steel is a low carbon and low nitrogen ferritic stainless steels containing 18% chromium, 2% molybdemum, which is stabilized with additions of columbium and titanium for resistance to intergranular corrosion. One of its big advantage over austenite stainless steels, such as 304 and 316 alloys, is the practical immunity to chloride stress corrosion cracking (SCC) [4]. Type 444 is superior to conventional ferritic steels, and to austenitic Types 304 and 316 in specific high-chloride environments. Its columbium-stabilized alloy composition also provides good resistance to pitting and crevice corrosion [6]. Applications requiring superior corrosion resistance and resistance to chloride stress corrosion cracking are ideal for this alloy. Current uses include food process, brewery and wine-making equipment; hot-water tanks and heat-exchanger tubing and automotive components, forming in cold weather [5].

Type 444 can be fusion welded by all methods generally suitable for stainless steels. But, this particular alloy is generally considered to have poorer weldability than the most common alloy of the stainless class, Type 409. Welding heat input should be kept to a minimum to avoid excessive grain growth and loss of strength in the HAZ. The beneficial effects of pulsed current welding most often reported in the literature include claims that the total heat input to the weld is reduced, which results in the reduction of weld bead size, residual stresses, distortion, and porosity [2]. When welding, the welding heat input makes the grain size in weld metal very coarse as seen in Fig.2, Usually grain size is measured by optical metallography [3]. American Society for Testing and Materials (ASTM), measuring the width of indivisual grain(WIG) and Point Counting Method (PCM) were employed to measure the grain size in this study.

2. Experimental

2.1 Materials

The materials used in this investigation were plates (200×80×1.5mm) of Type 444 ferritic stainless steels; the chemical compositions are given in Table 1.

Table 1 **Chemical composition of Type 444 ferritic stainless steels**

Material	Element (wt%)									
Type 444	C	Si	Mn	P	S	Ni	Cr	Mo	N	NB
	0.01	0.24	0.167	0.034	0.017	0.143	18.39	1.877	0.01	0.4533

2.2 Welding

All plates were cleaned prior to welding for removing surface contaminants by alcohol. Autogeneous welds were then carried out down the center of the plate with Inverter type TIG welder under a variety of welding conditions, as seen in Table 2 and Table 4. During the whole experiments, tungsten electrode was ∅2.4mm, tip clearance was 2mm, shielding gas was Ar, and gas flow was 15L/min, base current was 25A in pulsed current welding.

2.3 Preparing the specimens

After welding, the welding plates were sectioned, grounded, and then mounted. Then, all the mountings were initially polished on a series of silicon carbide abrasive paper up to #2000 and then fine polishing was carried on using 0.3μm alpha alumina abrasive particles. After that, electrolytic etching technique was employed to reveal weld bead profile, grain size. All the specimens responded well to an electrolytic reagent using 10% oxalic acid in distilled water at 6V for times up to 1 min .

2.4 Measuring weld bead and grain size

After preparing the specimens, the weld bead profile revealed by taking use of optical projector magnified 20×. The weld depth (WD) and the weld width (WW) of weld bead were measured and calculated.

2.5 Erichsen test

For measuring the ductility, Erichsen test was conducted according to KS B 0812.

3 Results and discussions

3.1 weld bead

Table 2 Welding condition for measuring the weld bead

Welding Current	Specimen No.	Welding current (A)	Welding Voltage (V)	Welding speed (cpm)	Frequency (Hz)	Heat Input (J/cm)
DCSP	1	80	9	30	None	1440
	2	100	9	30		1800
	3	80	9	20		2160
	4	100	9	20		2700
PULSE	5	80	9	30	30	1440
	6	100	9	30	30	1800
	7	80	9	20	30	2160
	8	100	9	20	30	2700
	9	80	9	30	10	1440
	10	80	9	30	50	1440

Table 3 Weld bead characteristics for Type 444 stainless steels (mm)

Specimen	1		2		3		Average	
No	Width	Depth	Width	Depth	Width	Depth	Width	Depth
1	2.7395	0.5825	2.3140	0.4760	2.6355	0.5775	**2.5630**	**0.5453**
2	3.5310	0.7590	3.6270	0.8795	3.6990	0.8130	**3.6190**	**0.8172**
3	3.2465	0.6950	3.4135	0.7475	3.3320	0.7315	**3.3307**	**0.7247**
4	4.4325	1.1685	5.0005	1.0400	4.5050	1.0910	**4.6460**	**1.0995**
5	3.4575	0.5900	3.4425	0.5895	3.4305	0.5395	**3.4435**	**0.5730**
6	4.5510	0.9310	4.5275	0.9575	4.8310	0.9815	**4.6365**	**0.9567**
7	3.9890	0.7955	3.8110	0.7065	3.8520	0.6645	**3.8840**	**0.7222**
8	5.5715	1.2635	5.3010	1.1675	5.2790	1.0355	**5.3838**	**1.1555**
9	3.6095	0.4635	3.7940	0.6355	3.8740	0.6690	**3.7592**	**0.5893**
10	3.3965							

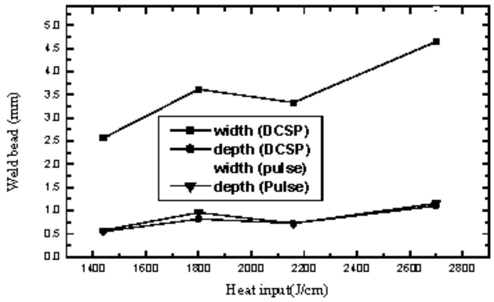

Fig. 1 Effects of heat input on weld bead

The welding conditions for measuring the weld bead were presented in Table 2, and the results were shown in Table 3. Specimen No.1 to No.4 were welded in DCSP welding with heat input from 1440J/cm to 2700J/cm. Specimen No.5 to No.10 were handled with the same heat input range in pulsed current welding. The effects of heat input on weld bead was presented in Fig.1, it was found that DCSP and pulsed current GTAW had no obvious different effect on the depth at the same heat input; for the width, pulsed current welding was found to increase width at the same heat input, and the width of weld bead was increased with the heat input increasing.

3.2 Grain size

The sample of microstructures of weld metal and HAZ were seen in Fig.2.

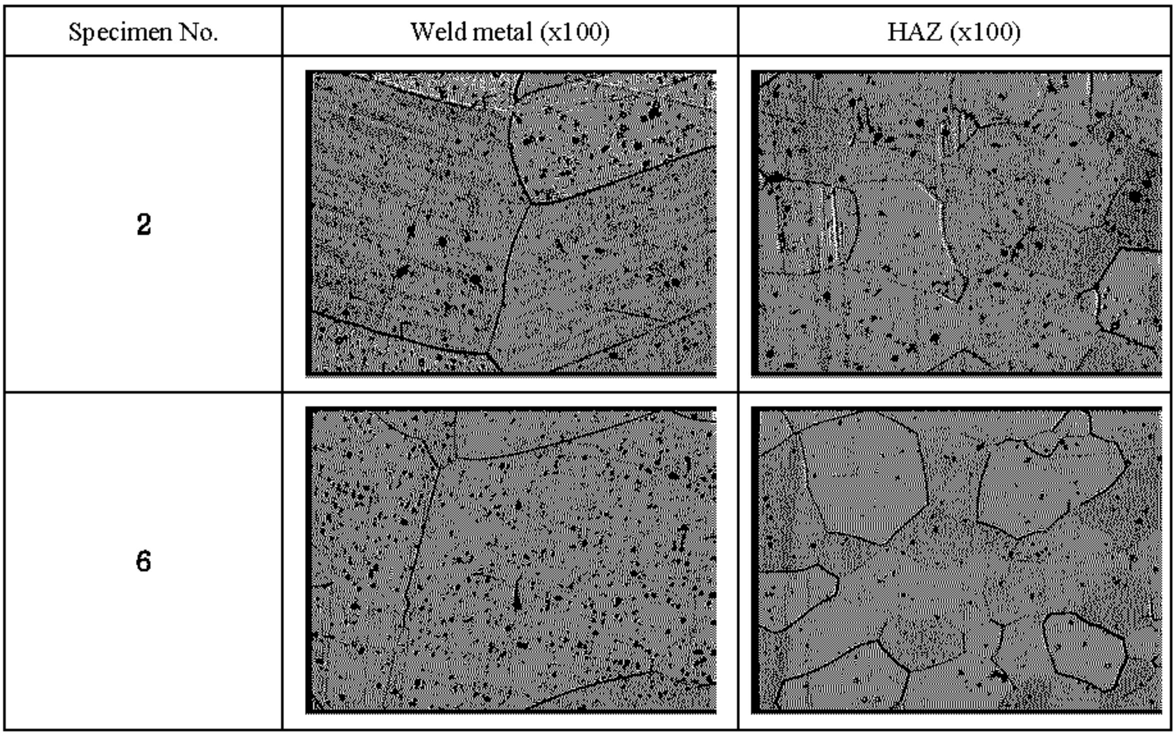

Fig.2 Microstructures of weld metal and HAZ (Specimen No.2 and No.6)

Table 4 The welding conditions and results of grain size by PCM and WIG

Specimen No.	Welding conditions		PCM (grains)	WIG (㎛)	
				Weld	HAZ
1	DCSP		5.8	321.4064	178.0622
2	120A, 50cpm PULSE	30 Hz	5.3	296.2855	193.9470
3		100 Hz	4.7	303.4327	193.9432
4		150 Hz	**6.6**	**276.0171**	189.8098
5		200 Hz	6.1	282.8281	183.8638
6	DCSP		7.4	330.2679	210.7401
7	80A, 30cpm PULSE	30 Hz	6.1	326.8364	224.0629
8		100 Hz	4.6	298.3162	258.8825
9		150 Hz	**9.0**	**275.3173**	236.3603
10		200 Hz	3.8	296.6359	227.0546

Table 4 showed the welding conditions and grain size results by PCM and WIG. It was observed that the appropriate corporation of welding currents and welding speeds were 120A, 50cpm (centimeter per minute) and 90A, 30cpm, which were chosen after many welding trials. From the results of these two methods, the finest grain size was found at the frequency of 150Hz. In respect with HAZ, it was found that all the HAZs in 120A,50cpm welding condition were finer than those in 90A,30cpm conditions having larger heat input, which suggested that decreasing heat input could control the HAZs effectively; it was found that the HAZs changed a little varying the frequency at the same heat input, that is, the frequency had little effect on the HAZs..

The effect of pulse frequency on grain size in weld metal by PCM was given in Fig.3, it was evident that the finest grain size was obtained at the frequency of 150Hz. Fig.4 show the relationships between frequency and grain size by WIG, it was seen that grain size in weld metal in pulsed current welding was finer than those in DCSP welding and the finest grain size was obtained at frequency of 150 Hz.

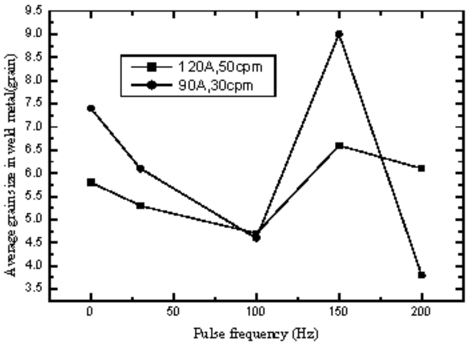

Fig. 3 Effects of pulse frequency on grain size in weld metal by PCM

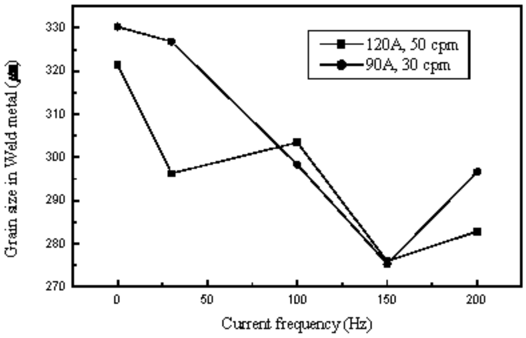

Fig.4 Effects of pulse frequency on grain size by WIG

3.3 Erichsen test

The effect of frequency on Erichsen value was given in Fig.5. The results of Fig.5 showed that the Erichsen values of pulsed current GTAW were higher than those of DCSP at the same heat input, that is, the pulsed current welding could obtain the better ductility than DCSP welding does. We also found that the ductility increased with increasing frequency between 100Hz and 200Hz. Sample of the profile and appearance of crack in Erichsen test was shown in Fig.6.

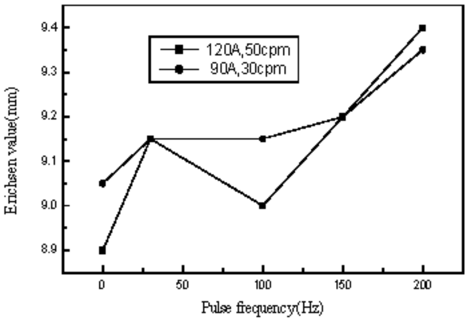

Fig. 5 Effects of pulse frequency on Erichsen valules

(a) Surface (b) Bottom

Fig.6 Profile and appearance of crack in Erichsen test

4. Conclusions

The most important results of this study could be summarized as follows:

1. The width of weld bead had been increased with increasing the heat input; DCSP and pulsed current GTAW had no obvious different effect on the depth at the same heat input; pulsed current welding could increase the width compared with DCSP welding at the same heat input.
2. Pulsed current welding was found to refine the grain size effectively by WIG; the finest grain size was found at 150Hz in pulsed current welding by PCM and WIG. For the HAZ, it was found that decreasing heat input could refine the HAZs effectively and the frequency had no different effect on the grain size in HAZ at the same heat input.
3. Erichsen test results of pulsed current GTAW were better than those of DCSP at the same heat input, that is, we could improve the ductility effectively with pulsed current welding. Moreover, the ductility could be increased with increasing the frequency between 100Hz and 200Hz.

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