INFLUENCE OF THE FILLER METAL IN WELDED POINTS OF DUPLEX STAINLESS STEELS

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Abstract

The aim of this work was to study the effect of welding with ER2209 filler metal and its effectiveness, to be used in “Butt” and “T” unions in a UR2202 stainless steel with a thickness of 8 mm, and in a 201LN2B stainless steel with a thickness of 5 mm, using the welding process of Gas Metal Arc Welding (GMAW), with a 97% Argon – 2.5 % CO_2 gas protection by means of a pulsed arc transfer. Hardness of this material shows a decreasing going from 21.2 to 30.8 Rockwell G in the “T” samples and from 27.1 to 37.2 Rockwell G for “Butt” samples, whereby the distortion caused by the welding process is minimal. In the same way, these welds showed micro structures with perlite and ferrite phases in welding cords. Mechanical properties due to hardness tests also were determined.

Keywords: Stainless steel, GMAW, “Butt” joint, “T” joint

Introduction

The growing interest in duplex stainless steels by industries, like metalworking, petrochemical or that devoted to energy generation, is due to their best mechanical and corrosion resistance properties, that show over other stainless and structural steels. The above mentioned properties are due to the presence of a relationship of austenite and ferrite phases of approximate 50/50 *(Lincoln Global Inc., 2000; Oxgasa, 2000; Koellhoffer, 2006)*. These properties can be altered by welding processes, because these can modify the phase proportion during or after welding process *(Kalpakian S. & Schmid S.R., 2008)*.

Duplex stainless steels show an excellent behavior against localized corrosion pitting, thanks to the high content of molybdenum in composition, which gives them a PREN between 30 and 50 *(Lowe R. & Jeffus L., 2008; ASTM A240/A240M-13a, 2004; ANSI/AWS, 2012)*. But this value can be modified during welding processes, overall in that processes where filler material in involved, due a possible modification in alloy elements content. So it requires a careful choice of the filling material in welding operations.

Welding arc (GMAW) is a process that can be used in a great variety of metals, being excellent in all thicknesses of welded points, likewise it can be applied in all position welding, which produces no slag and has low spatter. The principal disadvantages of process could be the portability, because it is not suitable for field work since this is sensible to drafts, the material to be welded or metal base must be completely clean of oxides, greases, etc., and the use in this process of gases, like carbon dioxide (CO_2), mixtures of argon and carbon dioxide ($ArCO_2$), mixtures of helium, argon and carbon dioxide ($HeArCO_2$), mixtures of helium – argon (HeAr). For this specific study case, a mixture of 97.5 % Ar – 2.5 % CO_2 has been used *(Lincoln Global Inc., 2000; Oxgasa, 2000; Koellhoffer, 2006; Kalpakian S. & Schmid S.R., 2008; Metals Handbook, 1948; Pardo A. et al., 2001).*

It is important to know if a filler material will resist in a welding point, so this study is devoted to find if filler material ER2209 really fits with requirements to be used in "Butt" and "T" joints for stainless steel plates of 5 and 8 mm of thickness. To evaluate this, proofs of hardness, tension strength, yield strength; among others, were carried out *(ASTM E8/E8M-13A. (2014); ASTM E238, 2012).*

Experimental Procedure

This work was done using two kind of samples, first one a "Butt" sample which was done in two plates of 201ln stainless steel (152.4 mm length, 101.6 mm width, 5 mm thickness and a groove angle of 60°), with the following chemical composition (Table 1). For the second sample in "T" shape, this was made with a UR2202 stainless steel (304.8 mm length, 101.6 mm width, and 8 mm thickness) which chemical composition is shown in Table 2, and a 202Ln stainless steel plate (304.8 mm length, 101.6 mm width and 5 mm thickness).

Table 1 Chemical composition of 201ln stainless steel.

% wt. Element	C	Mn	P	S	Si	Cr	Ni	N
Minimum	0.15	5.50	0.06	0.03	1.00	16.0	3.50	0.25
Maximum	---	7.50	---	---	---	18.0	5.50	---

Table 2 Chemical composition of UR2202 stainless steel

% wt. Element	**C**	**S**	**P**	**Si**	**Mn**	**Ni**	**Cr**	**Mo**	**Cu**
Minimum	0.015	---	---	0.30	0.80	8.00	21.5	2.50	---
Maximum	0.045	0.015	0.025	0.75	10.0	10.0	23.0	3.50	0.50

Samples were treated with a protection of 97.5 % Ar – 2.5 % CO_2 (gas mixture), by a transfer of pulsed arc. To obtain distortion in samples, was fundamental to take all their measurements before to be welded; then after welding process, samples were measured again using a height calibrator to detect distortion degree in the *z* axis, but for *x* and *y* axis some shims were used to obtain displacement of sample due to process. On the other hand, to get good results, welding process was carried out by a qualified welder which used as filler metal the AWS A5.9 ER2209, with pulsed arc in straight advance of 140 amperes, 24 volts, advance speed of 47.5 cm / min, wire speed of 965 cm / min for "T" sample. For "Butt" sample, the filler metal used was AWS A5.9 ER2209, with pulsed arc in straight advance of 97 and 163 amperes, 21.7 and 25.3 volts, advance speed of 20 cm / min, wire speed of 714 and 1257 cm / min, for background and view welds, respectively.

For the analysis, samples of 30 mm length, 30 mm width and 25 mm thickness were cut for "T" samples; while for "Butt" sample, pieces of 30 mm length, 30 mm width and 10 mm thickness were prepared. Then all samples were polished and chemically attacked using ferric chloride, hydrochloric acid and 100 ml of water, with an attack time of 3 minutes.

Hardness of samples was taken from inside to outside welding points to compare values, using an IKON hardness tester, while microstructure analysis was done using a JEOL JSM6300 Scanning Electron Microscope with a resolution of 300,000 magnifications and an EDS detector attached.

From these samples, some pieces were selected to metallographic analysis and others were prepared to stress test according ASTM E-8-81 standard *(2014).* In the same way, some samples were prepared to impact test under standard ASTM E-238 *(2012).* Such assay was done in the temperature range of -15 to 150 °C, to determinate how vary the adsorbed energy due to impact, according to temperature and transition temperature in different kind of welds.

Quantification of present phases in microstructure was carried out by points method, using a standard grid of 144 points on photographs taken at 100 x. Hardness assays were done in the Rockwell G scale, micro hardness of present phases was measured using a Vickers indenter and finally, the tensile test was carried out in a universal machine with a load of 5,000 kg.

Results and Discussion

By hardness measures done in the “Butt” joint, it was found that this decreases in minor amount in the weld zone. On the other hand, hardness achieved in the “T” joint was quite similar showing a decreasing in the weld zone, such as can be seen in table 3.

Table 3 Rockwell G hardness measured in welds of Stainless Steels

Notch	1	2	3	4	5	6	7
Hardness / “Butt” Joint	33.7	28.5	27.5	29.2	23.8	27.1	37.2
Hardness /“T” Joint	27.3	30.7	29.9	21.2	27.8	30.8	27.1

Distortion obtained during welding process in “Butt” samples gave an average measurement of 4.35 mm, as can be seen in table 4.

Table 4 Distortion due to welding process in the “Butt” joints

Plate A (before)		Plate B (after)			
Measure	**Value**	**Measure**	**Value**	**Difference**	**Plate 2**
1	5.45	1	14.05	8.60	4.30
2	5.68	2	14.37	8.69	4.345
3	5.80	3	14.48	8.68	4.34
4	5.69	4	14.41	8.72	4.36
5	5.44	5	14.24	8.80	4.40
				Average	4.349

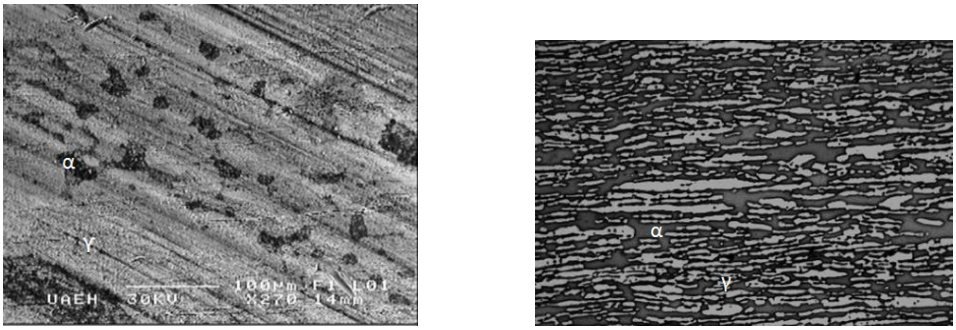
Meanwhile distortion obtained due welding process in “T” samples gave an average measurement of 1.80 mm, as can be seen in table 5.

On the other hand, figure 1 shows the original microstructure of stainless steels used (UR2202 and 201ln). In the same way, figure 2 shows perlite and ferrite phases obtained in the weld for joints type “Butt” and “T”; such microstructures were observed by Scanning Electron Microscopy. In figure 3 can be seen the microstructures of welds done by GMAW in the 2202 duplex stainless steel and in the 201ln stainless steel, using ER2209 as filler metal.

Table 5 Distortion due to welding process in the “T” joints

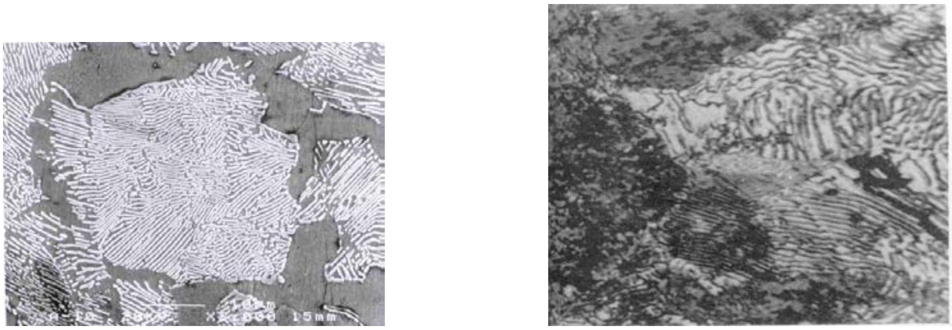
Plate A (before)		Plate B (after)			
Measure	**Value**	**Measure**	**Value**	**Difference**	**Plate 2**
1	8.23	1	11.86	3.63	1.815
2	2.37	2	11.76	9.39	4.695
3	8.44	3	11.60	3.16	1.580
4	8.35	4	11.41	3.06	1.530
5	8.33	5	11.25	2.92	1.460
6	8.31	6	11.05	2.74	1.370
7	8.31	7	10.93	2.62	1.310
8	8.24	8	10.77	2.53	1.265

9	8.16	9	10.62	2.46	1.230
				Average	1.806



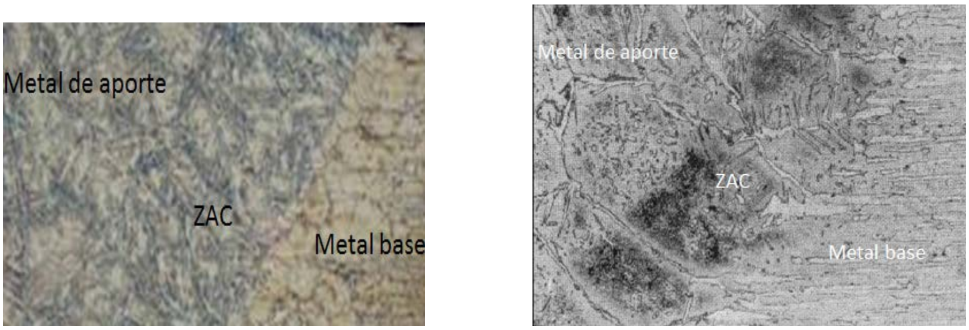
(A) (B)

Figure 1 Typical microstructures of; (A) UR2202 Stainless Steel, and (B) 201ln Stainless Steel



(A) (B)

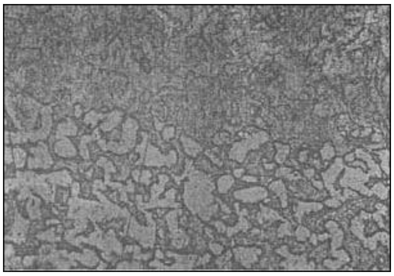
Figure 2 Perlite and ferrite microstructures of welds; (A) “Butt” type Joint, (B) “T” Type Joint.



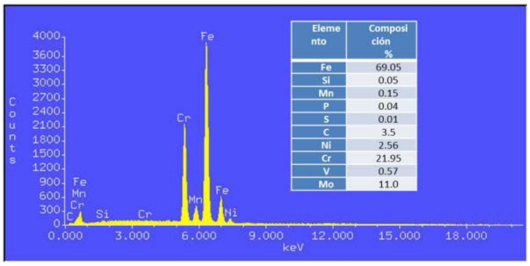
(A) (B)

Figure 3 Microstructures of welds done by GMAW using ER2209 as filler metal in; (A) Duplex Stainless Steel, (B) 201ln Stainless Steel.

In figure 4, it can be observed the microstructure and chemical composition of weld, showing as majority elements iron, chromium, and nickel; and as minors, thallium, silicon and carbon.



(A)



(B)

Figure 4 (A) Microstructure of weld ER2209, and (B) EDS spectrum of semi - quantitative chemical composition of such weld (SEM –EDS).

Effect of type of welding on Mechanical Properties

Both the properties of yield and tensile strength, show an increasing in "T" welding, which can be appreciated in table 6, where can be observed an increasing in tensile strength of 618 MPa for "Butt" joint and up to 647 MPa for "T" joint. For yield strength values, these increased in values of 520 MPa to 530 MPa, respectively. In the same way, an increasing in hardness of 217 and 231 Vickers degrees was noted for ferrite and perlite phases, having values of 618 to 401 for the "Butt" and "T" welds respectively. Such values are also shown in table 6.

Table 6 Metallographic analysis results and mechanical properties of welds

Kind of Joint	Ferrite (%)	Micro hardness Vickers ferrite	Perlite (%)	Micro hardness Vickers Perlite	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)
"BUTT"	76	217	15	394	520	618	13
"T"	76	231	9	401	530	647	11

In table 7, are shown the results of impact assay (Charpy test) for the two different kinds of studied welds.

Table 7 Results obtained in the Charpy test (In Joules).

Kind of Weld	-15 °C	-10 °C	0 °C	25 °C	50 °C	100 °C	120 °C	150 °C
"BUTT"	6.42	6.77	7.32	10.87	14.78	14.02	14.27	14.02
"T"	3.97	3.40	7.05	8.49	11.67	12.98	13.50	12.98

Changes in transition temperature are quite evident from one kind of weld to another, and the impact properties are affected by increasing transition temperature, noting that "Butt" weld presents better properties, basically at 25 °C.

Conclusion

Distortion produced by welding process is quite low obtaining hardness values between the range of 21.2 to 30.8 Rockwell G in "T" samples; and in the range of 27.1 to 37.2 Rockwell G in "Butt" samples. In the same way, it was observed in weld microstructure, the presence of ferrite and perlite, which are beneficial for this welding process.

Filler metal ER2202 used in the welding process (GMAW), is an efficient material for "Butt" and "T" welds, giving so reliability due its tenacity and resistance.

Welding in Stainless Steel is very difficult of controlling because the behavior of this material is not common, and experience of welder is also of importance to obtain good results during welding. So, for this kind of work, is recommendable the use of a robot, or a semi - automatic mechanism to get a minor variation in joints, for effective response and repeatability in results.

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