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Effect of TIG Welding Parameters on the Properties of 304L Automated Girth Welded Pipes Using Orbital Welding Machine

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Research Article

ABSTRACT

In this study, the effect of TIG welding parameters like pulse rate, pulse frequency, arc travel speed and wire feed rate on the properties of girth welding of SS 304L were experimentally examined. ER 308L filler wire was used for reinforcement of weld. The pipes were welded by using orbital welding machine. Samples were made by varying above mentioned parameters. Tensile, bend and hardness tests were performed to examine mechanical properties. It was examined that the sample welded at 90A pulse current was sounder having tensile strength of 605 MPa and hardness of base 160HB, HAZ 114HB, weld99 HB.

Keywords: Orbital TIG welding, Tensile test, Bend test

INTRODUCTION

Austenitic stainless steel is most widely used group of steels in the fabrication of industrial equipment because of its suitable properties of formability and weldability. Welding process is a very versatile process used for joining of metals. Therefore, it has been tried from a long time to optimize the various welding processes to achieve the higher quality welds so that the joints remain safe. Many Industries such as petrochemical, chemical and especially nuclear industry requires higher structural integrity which cannot even allow leakage from primary piping and vessels. Therefore, it is necessary to have joints that are leak proof and strong enough to ensure safe working of systems.

The Automatic Orbital Gas Tungsten Arc Welding (GTAW) is being used in a variety of industries in which maximum leak integrity, high performance, or ultra-cleanliness is of paramount importance [1]. Automated welding power supplies control many aspects of the welding process. The system controls various settings, such as travel speed, arc gap, current control, and gas flow, via electronic and mechanical means [2]. Therefore, the chances of weld defects are highly reduced and such a system enables welder to focus only on the progress of weld [3]. It only requires the start of the process and completes the weld automatically. The result is a more streamlined process that enhances productivity, weld consistency, and quality.

Gadewar et al. [4] investigated the effect of GTA welding process parameters like weld current, gas flow rate, thickness of work piece on the bead geometry of AISI 304L. It was found that the process parameters considered in the work affected the mechanical properties with great extent. Raveendra et al. [5] performed experimental work on pulsed and Non-pulsed TIG welding of stainless steel sheet (SS304). They conducted experiments on Weldment of 3mm thick sheet of SS304 with non-pulsed current and pulsed current at different frequencies of 3 Hz, 5 Hz and 10 Hz. Hardness test, tensile test and microstructure was analyzed to see the effect of above mentioned parameters on the characteristics of Weldment.

Ahmed Khalid Hussain et al. [6] studied the Influence of Welding Speed on the Tensile Strength of welded Joint in TIG Welding Process. It was found that penetration depth decreased with the increase of bevel height of single V butt joint

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and at lower welding speed tensile strength was high. The yield strength, tensile strength, hardness and impact energy values of 304L and 316L stainless steels welded by GTAW are higher than that of welded by GMAW.

EXPERIMENTAL WORK

Pipes of stainless steel SS304L material had been chosen to investigate the effect of gas tungsten arc welding parameters on the properties of weld material. Stainless steel of grade 304L is the most versatile of all steels and is widely used in the chemical industry and food processing industry because of its good strength and excellent corrosion resistance properties (**Table 1**).

Table 1. Composition of materials.

Material	C%	Si%	Mn%	P%	S%	Cr%	Ni%	N%
304L	0.027	1	2	0.045	0.03	18.2	10	0.1
308L	0.025	1	2	0.045	0.03	20	10.2	0.1

Orbimatic 300 CA orbital TIG welding machine was chosen for welding pipes with the variation of different parameters. The machine had a good control system that controlled the welding parameters and the welding process. Welding head model TP250 was used. The TIG welding parameters that affect the quality of weld joint i.e. pulse current, frequency of pulse current, Arc travel speed, and wire feed rate were selected for welding samples.

SS304L pipes of Ш2”, schedule 40 were selected for this study and thickness of each pipe was reduced to 2 mm by machining for weld joint. Samples were made by varying above mentioned parameters. Feed wire of 0.8 mm diameter was used because of the limitations of wire feed system installed in welding head TP250 used for welding. Tungsten electrode of 2.4 mm and argon as a shielding gas were used. Singles pass welding was done. The programmable machine was used in programming the parameters, circumference of weld joint was not divided into sectors as in typical orbital welding and parameters were kept constant throughout the circumference of joint.

Table 2. Parameters of samples.

Sample No.	Pulse current		Pulse frequency	Travel speed (mm/min)		HP wire feed (mm/min)
	Ip (A)	Ib (A)	(Hz)	HP speed	LP speed	
1	60	30	2.5	100	100	330
2	70	30	2.5	100	100	330
3	80	40	2.5	100	100	330
4	90	45	2.5	100	100	330
5	70	30	2	100	100	330
6	70	30	3.33	100	100	330
7	70	30	5	100	100	330
8	70	30	2.5	80	80	330
9	70	30	2.5	90	90	330
10	70	30	2.5	110	110	330
11	70	30	2.5	100	100	280
12	70	30	2.5	100	100	380
13	70	30	2.5	100	100	430

In total 13 samples were made and we had three samples for each variable plus one sample common in all four groups of samples. Parameters of samples were given in **Table 2**. After welding of samples, specimens of particular dimensions according to standards ASTM A370 were prepared [7]. Tensile specimens were prepared according to E8 standards [8] and bend test specimens were made according to E190 Standards [9]. One specimen for tensile test, two specimens for bend test and one strip for hardness test. All dimensions taken are in mm. Dimensions of bend test specimen are 200 Ч 19 Ч 2. Feed wire of 0.8 mm diameter was used because of the limitations of wire feed system installed in welding head TP250 used for welding. WAW 1000 computer control electro-hydraulic servo universal testing machine was used for the tensile test and bend tests. Three points guided bend test was performed using mandrel of 12 mm diameter. Both root and face bend tests were performed to examine the ductility and soundness of welded joints qualitatively.

Hardness was measured by using Equotip. It actually measures the Leeb value and then converts this measured value to the equivalent Rockwell (HRB, HRC) and Brinell hardness (HB). Leeb value is defined as thousand times the ratio of the rebound velocity to the impact velocity of indenter. Rebound velocity is dictated by the hardness of the material to be tested. Higher the hardness of material higher will be the rebound velocity and for softer materials we will have small rebound velocity of indenter.

RESULTS AND DISCUSSIONS

Results of Mechanical Testing

Tensile test was performed on all samples. The results of tensile test were compared and the effect of different parameters on the strength and ductility was examined. It was reported that ultimate tensile strength of SS 304L joined by TIG welding is 509 MPa, yield strength 312 MPa and elongation 40%. The values of tensile strength obtained in this study were much higher than the previous study but the elongation is much lower.

Table 3. Tensile test results of samples made pulse current variation.

High Pulse current (A)	σ_y (MPa)	σ_u (MPa)	e (%)
60	190	270	0.8
70	375	640	3.5
80	435	690	10
90	360	605	11

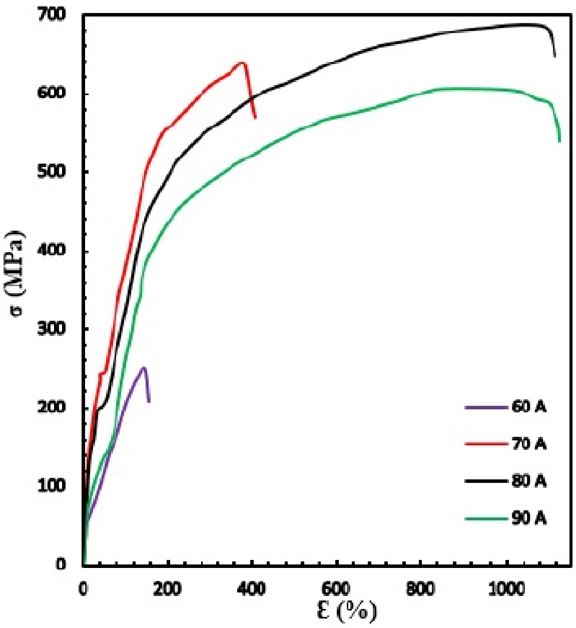

Figure 1. Tensile test results of samples made pulse current variation.

Results of the tensile test of the samples welded by pulse current variation were given in Table 3 and stress stain curves can be seen in Figure 1. Joint of fourth sample made at 90A proved to be stronger than base material as fracture occurred in HAZ. First three samples had lack of penetration because of which the joint was weaker and last sample had complete penetration. Tensile strength of sample made at 80A was highest but even then, the fracture occurred in weld. It showed that joint was weaker than the base material.

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Table 4. Tensile test results of samples made by variation of pulse frequency.

Frequency (A)	Yield strength (MPa)	Ultimate tensile strength (MPa)	% Elongation
2	295	500	10
2.5	375	640	3.5
3.33	325	545	18.7
5	170	310	1.18

Tensile test results and curves of samples welded at different frequencies were given in **Table 4** and **Figure 2** respectively. Tensile strength of sample welded at 2.5 Hz frequency was highest among all four samples. Sample welded at 5Hz frequency was the weakest. By comparing the% elongation, the sample made at 3.33Hz had more plastic behavior and had highest% elongation. It happened because by increasing frequency of pulse current, heat input per unit cycle of pulse current decreases which in turn decreases weld penetration.

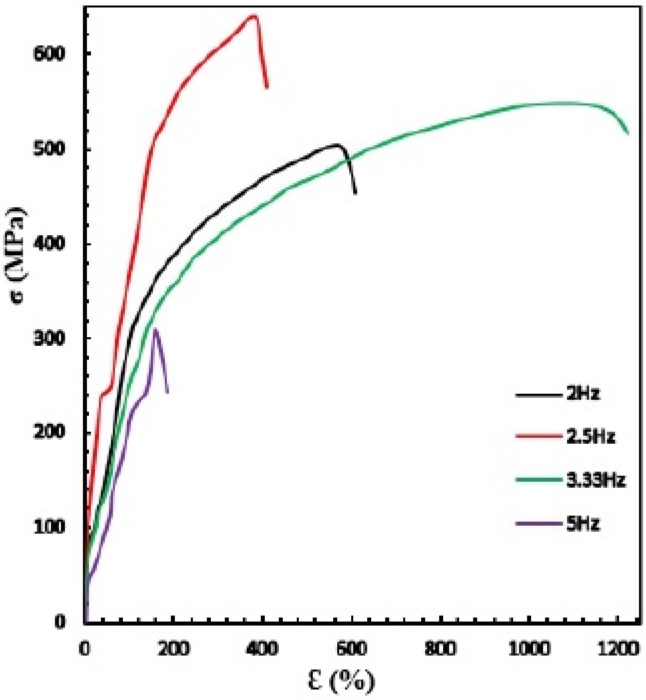

Figure 2. Tensile test curves of samples made by variation of pulse frequency.

Table 5. Tensile test results of samples made by variation of Arc travel speed.

Arc Travel Speed (mm/min)	Yield strength (MPa)	Ultimate tensile strength (MPa)	% Elongation
80	350	590	19.1
90	315	445	4.1
100	375	640	3.5
110	285	475	20

Tensile test results and curves of the samples welded at different arc travel speeds were given in **Table 5** and depicted in **Figure 3** respectively. Tensile strength of sample made at 100 mm/min was highest but its curve showed smaller plastic region. Sample made at 80 mm/min had good tensile strength and% elongation. Sample made at 110 mm/min had higher% elongation than all of the four samples but its strength was less and the behavior of sample 90 mm/min showed deviation from the expected behavior. Only one sample welded at 80 mm/min arc travel speed fractured at HAZ and other three samples fractured at weld joint.

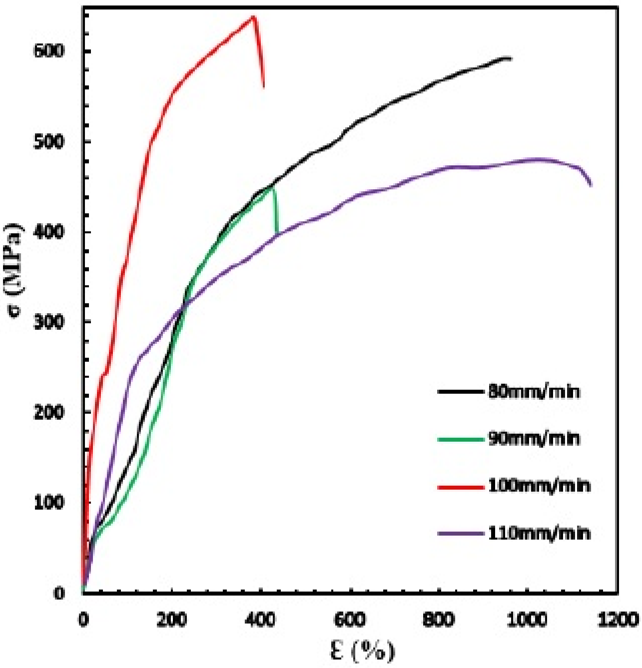

Figure 3. Tensile curves of samples made by variation of Arc travel speed.

Tensile test results and curves of samples welded at different wire feed rate were given in Table 6 and were represented in Figure 4 respectively. From the figure, it can be observed that at first by increasing wire feed from 280 to 330 mm/min, tensile strength had increased but by further increasing wire feed rate, the tensile strength of welded specimen started decreasing. It is due to the reason that increased wire feed rate requires high current to keep the penetration constant but if wire feed rate is increased without increasing current, the joint strength might increase up to a point where there is no considerable effect on penetration. With further increase in wire feed rate along with a decrease in penetration or improper fusion of wire, the strength of joint decreases.

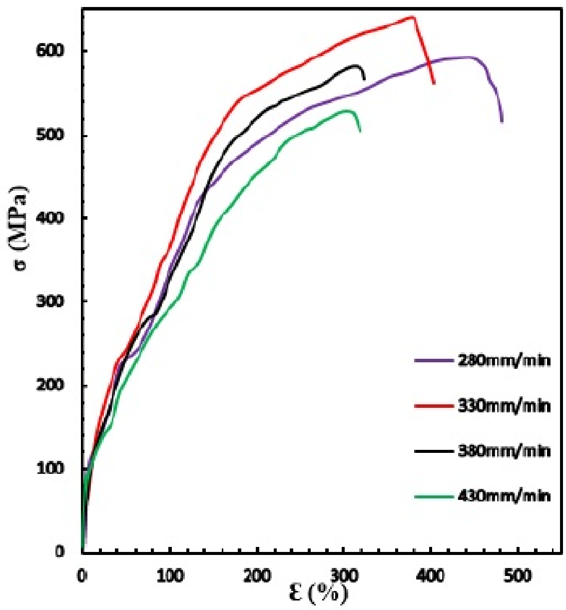

Figure 4. Tensile curves of samples made by variation of wire feed rate.

Table 6. Tensile test results of samples made by variation of wire feed rate.

Wire feed rate (mm/min)	Yield strength (MPa)	Ultimate tensile strength (MPa)	%Elongation
280	390	595	4.3

330	375	650	3.5
380	535	575	3.9
430	440	530	4

It was found that base metal had higher hardness values than HAZ and weld. Maximum value of hardness measured was 160 HB in base, 114 HB in HAZ and 99 HB in weld. Figure 5 showed that how the hardness of base metal, HAZ and weld varies with the variation of pulse current. At 70A the HB value of all the three zones has maximum value but the variation was very small. Hardness of weld was lowest and that of base metal was highest. Hardness results for frequency variation were depicted in Figure 6. Maximum hardness was measured in sample made at 2.5 Hz frequency.

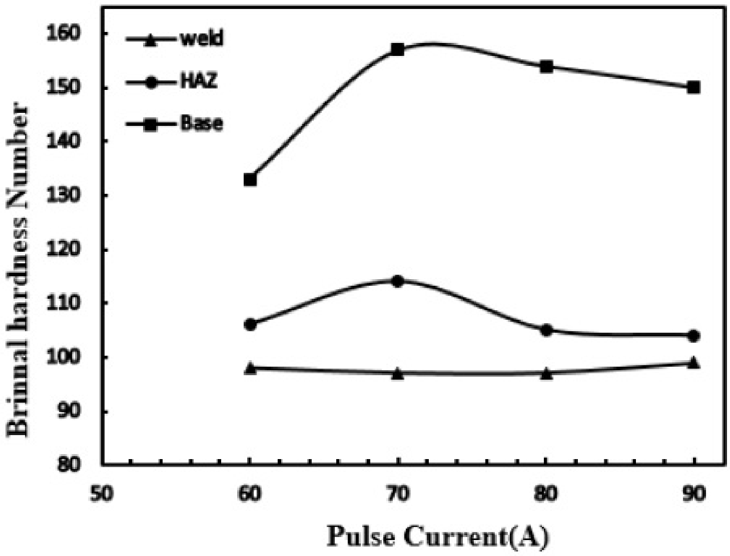

Figure 5. Effect of pulse current variation on variation of hardness.

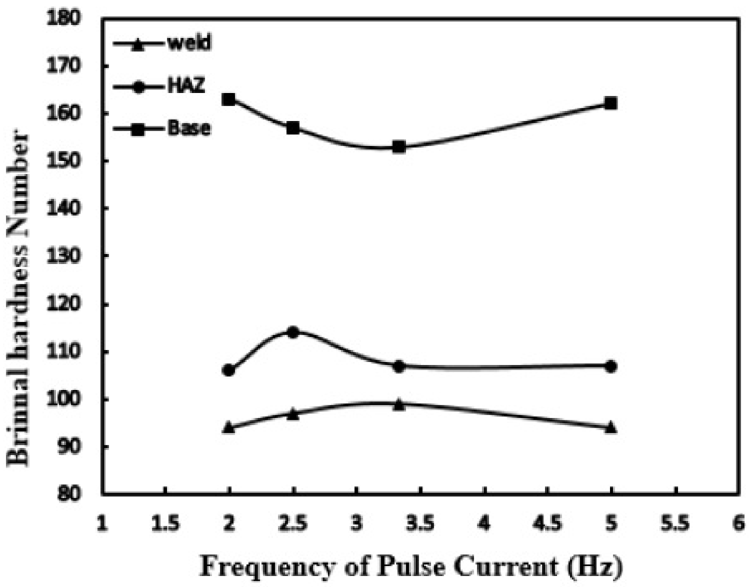

Figure 6. Graphical representation of effect of frequency on hardness.

Hardness results for arc travel speed variation were shown in Figure 7. Here in this case hardness of base metal is higher than that of HAZ and weld. At arc travel speed of 100mm/min all the three regions base metal, HAZ and weld have higher hardness values. Variation of hardness of welded area is least with the variation of arc travel speed.

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Figure 8 showed the trend how the hardness varies with the increasing deposition rate. In this case, the base metal had highest hardness values. It can be seen from the figure that hardness had linearly increased with the wire feed rate. Hardness of all the regions was smallest for the wire feed rate of 280 mm/min (Table 7).

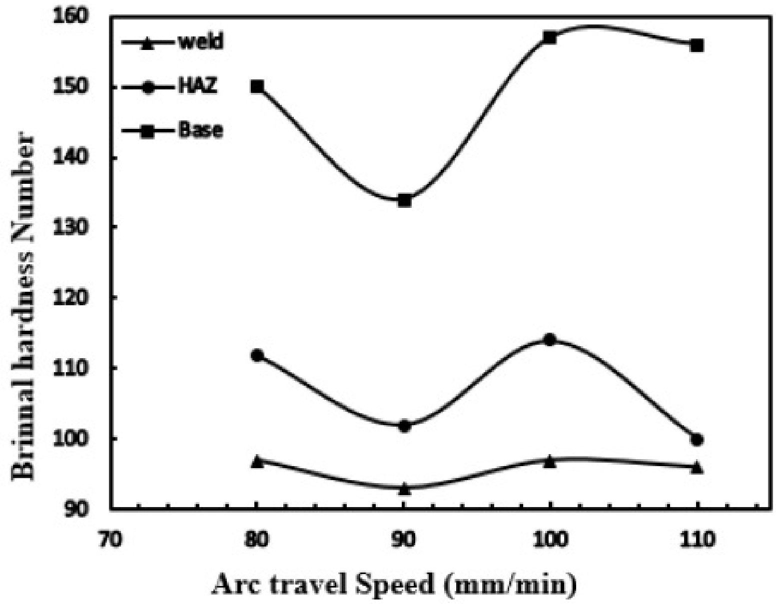

Figure 7. Graphical representation of effect of arc travel speed on variation of hardness.

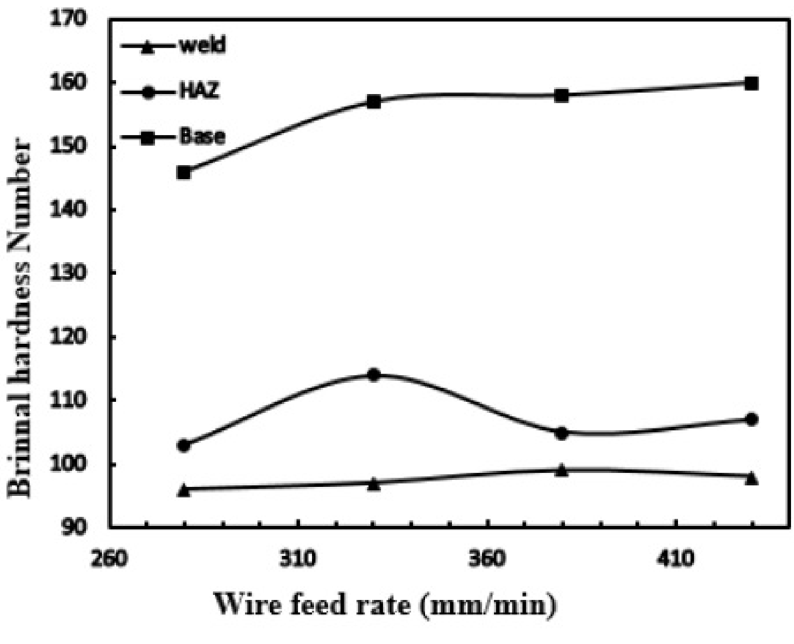

Figure 8. Graphical representation of effect of wire feed rate variation on hardness.

All of the samples that have failed in root bend test were cracked at weld. Sample made at 60A almost completely cracked. All of these cracks were due to lack of penetration.

Table 7. Results of bend test.

Variable	Face Bend test	Root Bend test
Pulse current 60 A	Pass	Failed
70 A	Pass	Failed

80A	pass	Failed
90 A	Pass	Passed
Pulse frequency 2 Hz	Pass	Passed
2.5 Hz	Pass	Failed
3.33 Hz	Pass	Failed
5 Hz	Pass	Failed
Arc travel speed 80 mm/min	Pass	Passed
90 mm/min	Pass	Passed
100 mm/min	Pass	Failed
110 mm/min	Pass	Failed
Wire feed rate 280 mm/min	Pass	Passed
330 mm/min	Pass	Failed
380 mm/min	Pass	Passed
430 mm/min	Pass	Failed

CONCLUSION

Tensile strength and soundness of joint has increased by increasing pulse current. Strength of joint is maximum for 2.5 Hz frequency. Strength and soundness of joint is maximum for arc travel speed of 80 mm/min but time taken for making a welded joint has increased. Increasing wire feed rate without increase in current decreases strength of joint. Various parameters variation has no significant effect on hardness.

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