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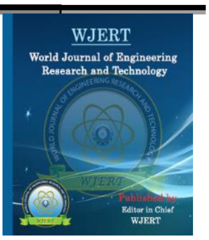

INFLUENCE OF WELDING PARAMETERS ON THE HARDNESS, IMPACT AND TENSILE STRENGTH OF ALUMINUM A6063T5 PIPE WELDED JOINT AT THE HEAT-AFFECTED ZONE

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ABSTRACT

This work investigated the hardness tensile, and impact strength of aluminum A6063T5 welded pipe joints at the heat-affected zone. The Taguchi method is employed to optimize the welding process parameters namely current travel speed. Hardness, Impact and tensile tests were conducted to assess the mechanical properties of the Heat Affected Zone (HAZ). The Taguchi method reveals the optimal combination of welding parameters of current 100amps, voltage 33volts and travel speed of 13inches/mm to give a Brinell hardness number of 74.80, impact strength of 0.0181 J/mm^2 and tensile strength of 154.20 MPa. This study provides insights into the mechanical properties namely hardness, impact and tensile strength of A6063T5 aluminum alloy welded joints pipe at the HAZ.

KEYWORDS: A6063 T5 Aluminum, welded joints, Hardness, Impact strength, tensile strength.

1.0 INTRODUCTION

Aluminum alloys have various applications ranging from automobile, marine structures, manufacturing industries to aerospace etc., due to their light-weight, high strength-to-weight ratio and corrosion resistance properties.[1,5] In most fabrication processes the most joining technique is welding. The welding process requires high skills and competencies to enable complex design welded parts to perform optimally in services. it is important that the welding of aluminum alloy joints be given consideration, due to its high thermal conductivity and natural tendency for oxidation, higher heat input which could lead to welding defects like warping and porosity.[6,13] Aluminium welding commonly employs Gas tungsten arc welding (GTAW) or TIG, Gas metal arc welding (GMAW) or MIG, and other methods like laser and resistance welding, each offering unique advantages for different applications and purposes. Successful aluminium welding necessitates selecting the right filler material, adjusting welding parameters, and using appropriate shielding gas to prevent contamination and achieve durable welds. Aluminium alloyed pipes are widely used in industries. This required parts to be joined through welding. However, during the welding process, the heat-affected zone (HAZ) experiences significant changes in microstructure and mechanical properties, which can affect the overall performance of the welded joint. Several studies and review work have been conducted to evaluate the performance of aluminum alloyed welded joints.[13] It is essential to note that the heat-affected zone's area is influenced by welding process parameters.[14] proposed a novel hybrid manufacturing process for strengthening the welded joint of AA5083-O and AA6061-T6 Aluminum alloy and observed that the tensile properties of the joints produced by the novel hybrid manufacturing process were higher than the base condition and that under in-situ cooling conditions, an increase in the WFS from 3000 mm/min to 5000 mm/min causes the weld reinforcement to become large, increasing the rolling reduction from 50 % to 64.4 %.[15] Li, et al. 2022 examined the temperature and residual stress distributions of stiffened aluminum plates made of AA 5083 during metal inert gas (MIG) welding and their results show that the constraint conditions employed in their study have little effect on the peak value and overall distribution of residual stress, despite the significant difference in distribution of residual stress that they observed near the constraint point.[16] investigated the stability of 6082-T6 aluminum alloy columns (AACs) under an axial compressive load and a bending moment at high temperatures, which they tested usijng 30 AACs eccentric compression in a high-temperature environment, and they found after the test, that all the AACs suffered bending and torsional instability and from their finite element model the reliability of their formula, at five different temperatures with two different cross sections showed that the formula for the stability bearing capacity of AACs under eccentric compression at high temperatures was safe and reliable.[17] conducted the effect of friction welding parameters on mechanical and metallurgical properties of aluminum alloy 5052–A36 steel joint and they observed that the joint strength increased with increasing upset pressure and friction time until it reached a critical value.

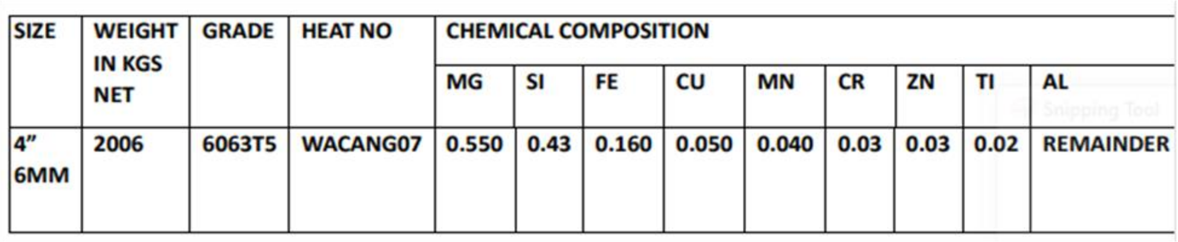
Because of the enormous application of A6063 T5 aluminum alloy. Its welded joint and weld integrity needs further consideration. From the literature considered thus far, the influence of welding parameters namely current, voltage and travel speed on the hardness, impact and tensile strength of A6063 T5 aluminum alloy welded pipe has not been thoroughly explored. Hence, this study seek to examine the influence of welding parameters namely current, voltage and travel speed on the hardness, impact and tensile strength of A6063 T5 aluminum alloy welded pipe using Taguchi optimization method.

2.0 METHODOLOGY

2.1 Material Used

T This study was carried out at the Petroleum Training Institute Effurun, Delta State, Nigeria. The materials used for the experiment are A6063 T5 aluminum alloy pipe with chemical composition shown in table1 and E4043 electrode.

Table 1: Chemical Composition of A6063T5 Aluminum Alloy Pipe.



SIZE	WEIGHT IN KGS NET	GRADE	HEAT NO	CHEMICAL COMPOSITION								
				MG	SI	FE	CU	MN	CR	ZN	TI	AL
4" 6MM	2006	6063T5	WACANG07	0.550	0.43	0.160	0.050	0.040	0.03	0.03	0.02	REMAINDER

2.2 Weld Joint Preparation and Set Up

The dimensions and geometry of the samples are determined based on the specific testing requirements, ensuring that the welded part and the HAZ is included in the samples. The base material was prepared and set up according to table 2.

Table 2: Welding Setup.

Process	Shielded metal arc welding
Material spec	A 6063 T5 Aluminum alloy
Pipe thickness	6mm
Joint design	Groove weld: V
Filler Material and specification	E4043
Number bead	Three
Electrical flame characteristics	AC
Position	PA = 5g
Direction of welding	Down head
Number of welder	One
Time lapse between passes	6minutes

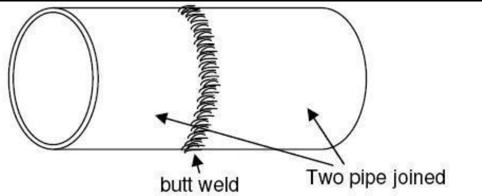
Initial and inter-pass cleaning	Wire brushing and grinding
Electrode flux class	Basic
Techniques	Weaving
Qualifications specification	ISO9606-1
Joint fit-up A = Groove angle 60 B = Root face 2 mm C = Root gap 2mm D = Material thickness 6mm	

Fig. 1: A6063 T5 aluminum alloy welded pipe.

2.3 Hardness, Impact and Tensile Test

2.3.1 Hardness Test

Brinell Hardness was used to determine the sample for the A6063 T5 aluminum alloy welded part at the HAZ. The Brinell scale involves the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test piece.[18,19] The value of the Brinell Hardness Number (BHN) is expressed as

$$BHN = \frac{2P}{\pi D\{D - \sqrt{(D^2 - d^2)}\}} \qquad (1)$$

Where, P= load applied (KN), D=diameter of indenter (mm) d= diameter of indentation (mm). The readings and recordings for the hardness test were computed accordingly.

2.3.2 Impact Test

The Charpy impact test is a standardized method used to measure the toughness or impact strength of a material. The Charpy impact testing dimension are 10 mm × 10 mm × 55 mm. A 2mm deep notch with an angle of 45° and a tip radius of 0.25mm is then machined into one face of the bar. The Impact strength could be determined as;

Impact Strength = (Energy absorbed by the specimen) / (Thickness of the specimen) (2)

The energy absorbed by the specimen is determined by measuring the difference in height of the pendulum before and after striking the specimen. The thickness of the specimen is measured at the point of impact. The unit is in Joules per millimeter (J/mm^2). Figure 2 shows the Impact test sample after failure.

Fig. 2: Sample after Impact test.

Fig 3: Sample after Tensile Test.

2.3.3 Tensile Test

For the tensile test, the sample was subjected to a tension test with the ends of the test piece fixed into grips connected to a straining device and a load-measuring device in the universal testing machine. The test involves straining a test piece by tensile force generally to fracture to determine tensile properties using the ASTM B557 standard. Figure 3 shows the tensile test sample after failure.

2.4 Design of Experiment (DOE)

The design of Experiment using Taguchi method was adopted with larger-the-better as expressed in equation 1

$$S/N = -10log \sum \frac{1/y^2}{n} \qquad (4)$$

The welding parameters are the input variables, which are Current(A), Voltage (V) and travel speed inches/min as shown in table 2, and the Response variables are Hardness, Impact and tensile strength. of was selected as expressed in equation 1. MINITAB statistical software with L9 orthogonal array was employed to evaluate the optimum response value for the three-welding parameters

Table 2: Welding Parameters and their Level.

Factors	**Symbol**	**Unit**	**Level 1**	**Level 2**	**Level 3**
Current	A	Amp	100	110	115
Voltage	V	Volt	30	33	37
Travel speed	S	Inches/min	9	11	13

3.0 RESULTS AND DISCUSSION

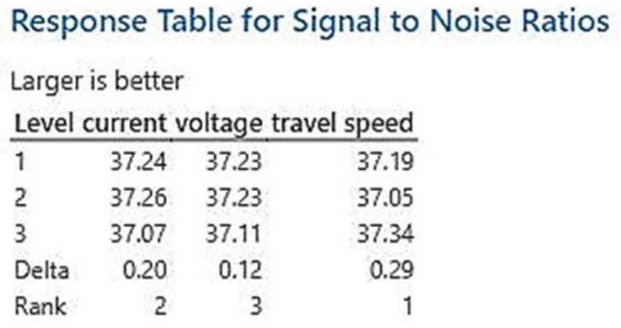
3.1 Optimum Parameter Selection from Signal to Noise Ratio for Hardness at HAZ for A6063 T5 Aluminum alloy welded Sample

Table 3 shows the Taguchi Experimental Design Matrix using Minitab for the Hardness optimum values. From table 4 and figure 4 the optimum hardness value of 74.80 requires a current of 110Amp, 33 Volts and 13 inches/min travel speed.

Table 3: Experiment Design Matrix Using Minitab.

S/N	Current (A)	Voltage (V)	Travel Speed (Inch/min)	Brinell Hardness at HAZ
1	100	30	9	73.4
2	100	33	11	73.3
3	100	37	13	71.7
4	110	30	11	70.5
5	110	33	13	74.8
6	110	37	9	73.7
7	115	30	13	74.3
8	115	33	9	70.0
9	115	37	11	69.8

Table 4: Response table for signal to Noise Ratio for Hardness for A6063 T5 Aluminum alloyed welded Sample.



Response Table for Signal to Noise Ratios

Larger is better

Level	current	voltage	travel speed
1	37.24	37.23	37.19
2	37.26	37.23	37.05
3	37.07	37.11	37.34
Delta	0.20	0.12	0.29
Rank	2	3	1

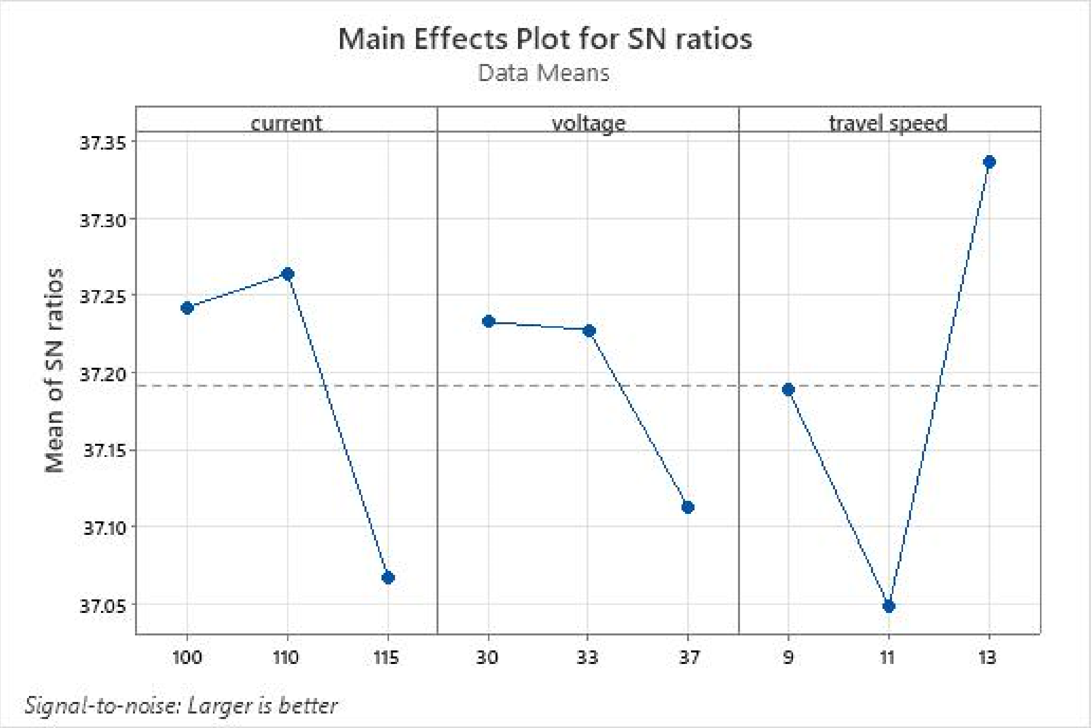


Fig. 4: Signal to Noise Ratio Hardness at HAZ.

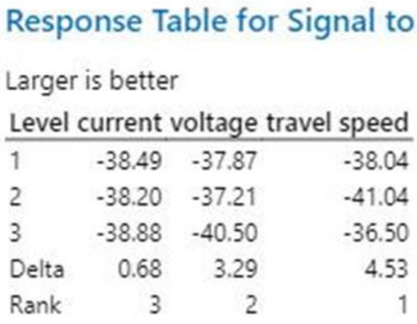
3.2 Optimum Parameter Selection from Signal to Noise Ratio for Impact Strength for A6063 T5 Aluminum alloy welded Sample

Table 5 shows the Taguchi Experimental Design Matrix using Minitab for the Impact strength optimum values. From table 6 and figure 5, the optimum impact strength value of 0.0181 J/mm^2 requires a current of 110Amp, 33 Volts and 13 inches/min travel speed.

Table 5: Experiment Design Matrix and Result Using Minitab.

S/N	Current (A)	Voltage (V)	Travel Speed (Inches/min)	Impact at HAZ (J/mm^2)
1	100	30	9	0.0136
2	100	33	11	0.0091
3	100	37	13	0.0136
4	110	30	11	0.0113
5	110	33	13	0.0181
6	110	37	9	0.0091
7	115	30	13	0.0136
8	115	33	9	0.0159
9	115	37	11	0.0068

Table 6: Response table for signal to Noise Ratio for Impact Strength for A6063 T5 Aluminum alloy welded Sample.



Response Table for Signal to Noise Ratios

Larger is better

Level	current	voltage	travel speed
1	-38.49	-37.87	-38.04
2	-38.20	-37.21	-41.04
3	-38.88	-40.50	-36.50
Delta	0.68	3.29	4.53
Rank	3	2	1

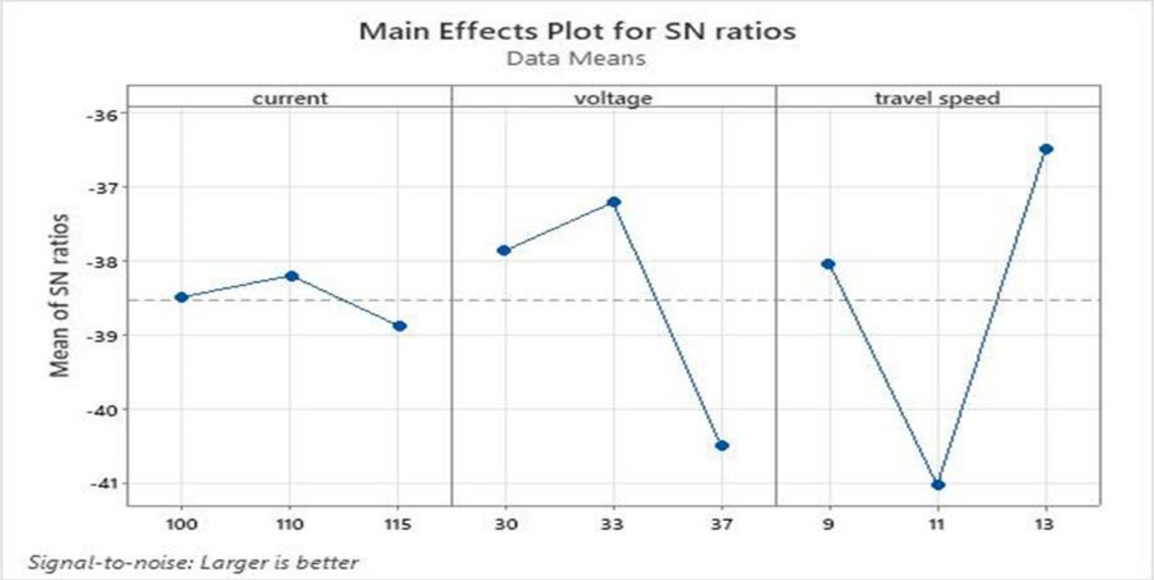


Fig. 5: Signal to Noise Ratio Impact Strength.

Optimum Parameter Selection from Signal to Noise Ratio for Ultimate Tensile Strength for A6063 T5 Aluminum alloy welded Sample

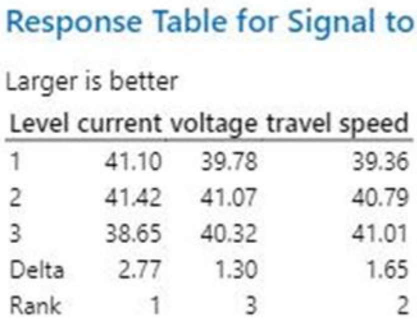
Table 7 shows the Taguchi Experimental Design Matrix using Minitab for the Impact strength optimum values. From table 8 and figure 6, the optimum tensile strength value of 153.20 MPa requires a current of 110Amp, 33 Volts and 13 inches/min travel speed.

Table 6: Experiment Design Matrix and Result Using Minitab.

S/N	Current (A)	Voltage (V)	Travel Speed (Inches/min)	UTS at HAZ (MPa)
1	100	30	9	89.37
2	100	33	11	153.20
3	100	37	13	106.69
4	110	30	11	101.38
5	110	33	13	130.22

6	110	37	9	123.74
7	115	30	13	102.13
8	115	33	9	72.57
9	115	37	11	84.66

Table 6: Response table for signal to Noise Ratio for Tensile Strength for A6063 T5 Aluminum alloy welded Sample.



Response Table for Signal to Noise Ratios

Larger is better

Level	current	voltage	travel speed
1	41.10	39.78	39.36
2	41.42	41.07	40.79
3	38.65	40.32	41.01
Delta	2.77	1.30	1.65
Rank	1	3	2

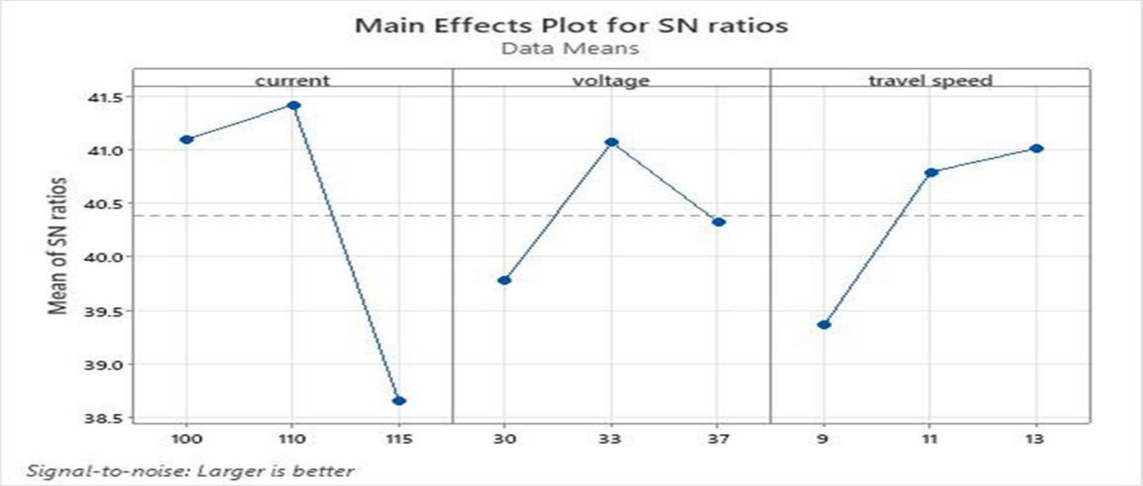


Fig. 6: Signal to Noise Ratio UTS.

CONCLUSION

In this study, the optimum value for the hardness, impact strength, and tensile strength for A6063 T5 Aluminum alloy welded pipe has been investigated and the following observation could be made

a) Optimum input variables of current=110A, voltage=33V and travel speed=13inches/min gave a maximum Brinell hardness value of 74.80

b) Optimum input variables of current=110A, voltage= 33V and travel speed=13inches/min gave a maximum impact strength value of 0.0181 J/mm^2

c) Optimum input variables of current=110A, voltage=33V and travel speed=13inches/min gave a maximum tensile strength value of 153.20 MPa.

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