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Original Research Article

Evaluation of Welding Parameters on Tensile Strength and Hardness of AISI 1018 Low Carbon Steel Plate Welded Joints

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Abstract

This work explores the optimum tensile strength and hardness of AISI 1018 low carbon steel plate welded joint using an E7018 electrode. The effect of metal metal arc welding process parameters namely; welding current and welding travel speed on AISI 1018 low carbon steel samples. The optimum performance of weld joints has been assessed based on the ultimate tensile strength and hardness of welded joints considering the welding current and travel speed variation. Taguchi-based L4 orthogonal array has been considered for the design of the experiment. The welding parameters on Tensile strength and Hardness of AISI 1018 low carbon steel plate welded joints were evaluated. The results show that there was no significant effect in current variation from 80A to 100A on the Ultimate Tensile strength and hardness of AISI 1018 low carbon steel plate with an average UTS and hardness of 434MPa and 122, respectively. However, it seemed that the welding travel speed of 20 to 21 mm/s, slightly affected the ultimate tensile strength and the hardness.

Keywords: Welding Parameters, AISI 1018 low Carbon Steel, Taguchi method, Ultimate tensile strength, Hardness.

1.0 INTRODUCTION

Welding is the process of joining ferrous or non-ferrous metals with the use of heat and/or force, with or without filler metal. Traditional welding methods, primarily depend on the local melting and fusion of material, producing significant residual stresses in the weldment [1]. The integrity of weldment is critical to the optimum performance of the welded part in service. Low-carbon steel, also known as mild steel, is one of the most common types of steel used in engineering and construction Industries. AISI low-carbon steel provides material properties that are acceptable for many applications. All the conventional welding processes can instantly weld AISI 1018 mild/low carbon steel. Consequently, these have outstanding ductility and toughness. Typical applications include automobile body components, structural shapes (e.g., I-beams, channel and angle iron), and sheets used in pipelines and buildings. Researchers had made attempts to explore the performance and behaviour of steel weldment [2], examined the effects of various welding parameters of SMAW and TIG welding on the distortion of weld joints in different configurations and observed that TIG weld joints showed lower angular distortion while SMAW weld joints showed maximum angular distortion [3], compared the effect of SMAW, GMAW, and GTAW processes on the fatigue crack growth behaviour of AISI 409M FSS using filler metal AISI 2209 grade DSS and their results showed that GTAW weldments have higher fatigue strength than SMAW and GMAW weldments [4], studied the effect of welding speed on the fatigue strength of FSW welds and compared it with that of TIG and MIG welds and they concluded that the fatigue strength of FSW welds is greater than TIG and MIG welds of the same material [5], compared the SMAW and GTAW weldments of 17 Cr FSS in terms of microstructure and mechanical properties and observed that GTAW weldments having equiaxed grain structures possessed better tensile and yield strength than SMAW weldments [6], compared the GMAW, GTAW and FSW processes on the basis of the tensile strength of AA6061 aluminium alloy weldments and found that FSW weldments exhibited higher strength as compared to MIG and TIG weldments [7], compared the influence of SMAW, GMAW and GTAW process parameters on tensile properties, impact, hardness and microstructure of AISI 409M FSS weldments using AISI 308L ASS as filler metal and their experimental results showed that

GTAW weldments exhibited superior mechanical properties than SMAW and GMAW weldments [8], compared the TIG and SMAW processes based on microstructure and mechanical properties of weldments such as tensile property, toughness, and microhardness using AISI 304 SS as base material and electrode SS E308L as the electrode. The input process parameters used were welding current and arc voltage. Their results showed that joints made using the GTAW process have better tensile and impact properties [9], reviewed available work on different welding processes and optimization methods and they were able to compare different welding processes and optimization methods developed. Studies have shown that optimization of the welding process is important to the effective output of the welded joint. For example [10], optimized the SMAW process parameters from the sustainability perspective using a neural network model and fuzzy-based grey relational analysis and they concluded that voltage is the most important parameter followed by current and welding speed [11], studied the correlation between various parameters of SMAW and post-weld heat treatment on low carbon steel and found that on increasing the welding current, hardness and ultimate tensile strength (UTS) increase but there is a notable decrease in the impact strength [12], examined the mechanical properties of SMAW welded AISI 1020 low carbon steel joints using different electrodes and current values and found that the mechanical properties such as hardness and tensile strength decrease on increasing the heat input. Aman Gupta *et al*., [13], experimented on the effects of heat input on microstructure and corrosion behaviour of UNS S32750 super duplex stainless steel using scanning and optical electron microscopy in SMAW, they concluded that weld behaviour is affected marginally by heat input. Researchers have deployed different optimization techniques such as Taguchi-based orthogonal array, Genetic Algorithm, Factorial Composite Design, and RSM in the experimental assessment matrix and evaluation [12-22]. The success of this welding process hinges on various factors such as the material plate/type, choice of the electrode, and the welding technique. Selecting appropriate welding parameters in low-carbon steel plate welded joints is challenging. It has led to the weakness of welded structures, cracks in the joints, and various defects in the welded joints. This study focuses on Taguchi optimization of welding current and speed on AISI 1018 low carbon steel using manual Metal Arc Welding technique.

2.0 MATERIALS AND METHODS

2.1 Material Used

This study was carried out at the Petroleum Training Institute Effurun, Delta State, Nigeria. The materials used for the experiment are E7018 electrode, ASTM AISI 1018 low carbon steel grade purchased at Donasulu Steel Company in Warri, Delta State Nigeria, with the following chemical composition shown in table 1.

Table 1: Chemical Composition of AISI 1018

Element	Carbon	Manganese	Phosphorus	Sulphur	Iron
Weight %	0.15	0.60	0.042	0.045	98.7

2.2 Methods

The fabrication procedure, plate preparation, root gap, plate thickness, bevel type, bevel angle and type, and plate length, about tensile and hardness test specimens, were followed as specified by ASTM E8M. Specimens for testing were machined according to sizes and edge preparation was done properly to obtain good results after welding. The joint fit-up was done before welding was carried out. The root face is 2mm and the spacing of the root is 2mm with an angle of 60-degree bevel. Figures 1 and 2 show the joint fit-up and welded part of the plate.

Fig. 1: Joint fit-up of Sample AISI 1018 steel

Fig. 2: Weld joint of Sample AISI 1018 steel

After the welding procedure was completed, Eight (8) samples were obtained from the AISI low-carbon steel plate welded joints for investigation. The Eight samples were prepared into four (4) for tensile and four (4) samples for Brinell hardness tests, respectively.

2.3 Tensile Testing

A Universal Testing machine shown in Figure 3 was employed to carry out the tensile tests of the welded AISI 1018 low carbon until failure occurred and the ultimate tensile strength was determined. Figure 4 shows the samples after testing.

Figure 3: Specimen after tensile test

The Ultimate tensile strength UTS is computed from the relation;

$$UTS = \frac{P\ (MPa)}{A(mm)} \qquad (1)$$

Where; P= Maximum Load (MPa)
A = Area (mm²)

2.4 Hardness Test

The sample for the hardness test is prepared as shown in Figure 4. Brinell hardness test was carried out with a universal material testing machine of 10 tons. The machine was set up and calibrated to handle the indentation of the sample at the heat-affected zone. The hardness reading was recorded with a veiner caliper and the readings were calculated using the equation;

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

Where, P= load applied (KN)
D=diameter of indenter (mm)
d= diameter of indentation (mm)

Figure 4: Specimen for hardness test

2.5 Taguchi Method

Taguchi optimization method from Minitab software was used to optimize the performance of the welding parameters of AISI 1018 with Signal-to-Noise ratios for larger the better for the optimization of Static Problems under consideration using the expression;

The S/N =-10*log(-10 log [(Σ 1/Yi 2)/ n]

$$S/N = -10log \sum \frac{1/_{y^2}}{n} \qquad (3)$$

where Y= responses for the given factor level combination and n= number of responses in the factor level combination.

2.5.1 Experimental Parameter

The control factor and their levels namely current and travel speed as input parameters while ultimate tensile strength (UTS) and hardness as Response are shown in tables 2 and 3, respectively.

Table 2: Control Factors and their level for UTS

S/N	Welding Current (A)	Travel speed (mm/s)	UTS	SNRA 1
1	80	20		
2	80	21		
3	100	20		
4	100	21		

Table 3: Control Factors and their level for Hardness

	Welding Current (A)	Travel speed (mm/s)	Hardness	SNRA 2
1	80	20		
2	80	21		
3	100	20		
4	100	21		

3.0 RESULTS AND DISCUSSION

3.2 Tensile Strength Results

Ultimate Tensile Strength is a larger-the-better type quality characteristic. Therefore, higher values of Ultimate Tensile Strength are considered to be optimal.

From Figure 5, tables 4 and 5, there seems to be no effect on the current variation from 80A to 100A on the AISI 1018 UTS. However, variation is slightly observed in the travel speed on the UTS of the AISI 1018 low-carbon weldment.

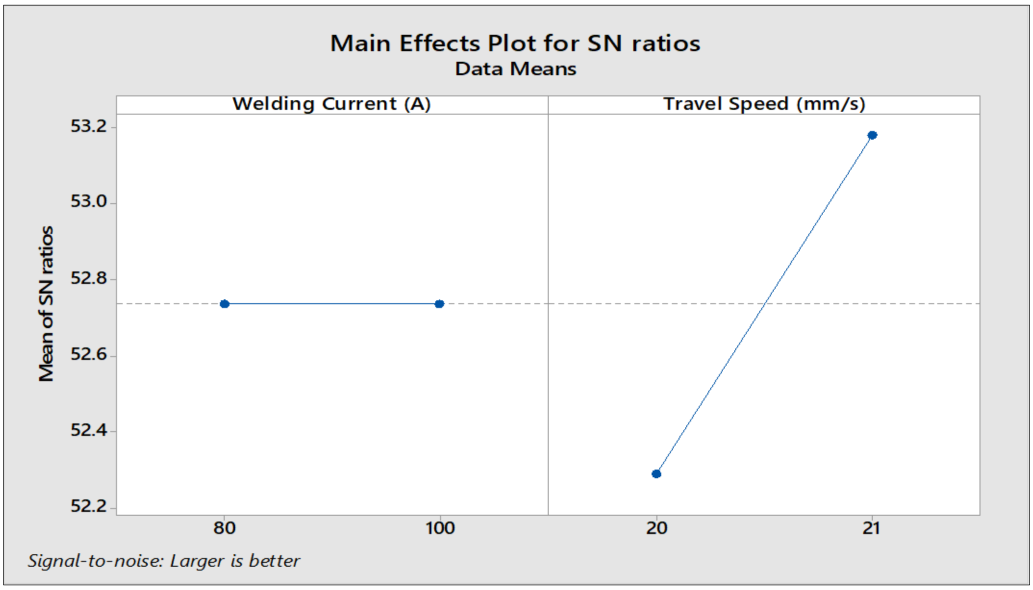

Fig. 5: Main effects plot for UTS of the weld

Table 4: Taguchi Result Analysis

S/N	Welding Current (A)	Travel speed (mm/s)	UTS	SNRA 1
1	80	20	411.7	52.2916
2	80	21	456.1	53.1812
3	100	20	411.7	52.2916
4	100	21	456.1	53.1812

Table 5: UTS (MPa) versus Welding Current (A), Travel Speed (mm/s)

Level	Welding Current (A)	Travel Speed
1	52.74	57.37
2	52.74	57.70
Delta	0.00	0.89
Rank	2	1

3.2 Hardness Results

Hardness is a larger-the-better type quality characteristic needed. So, the higher values of hardness are considered to be optimal. From Figure 6, tables 5 and 6, there is no variation of current from 80A to 100A on the hardness of the AISI 1018 low-carbon steel. However, variations exist slightly with the travel speed on the hardness of AISI 1018 low carbon weldment.

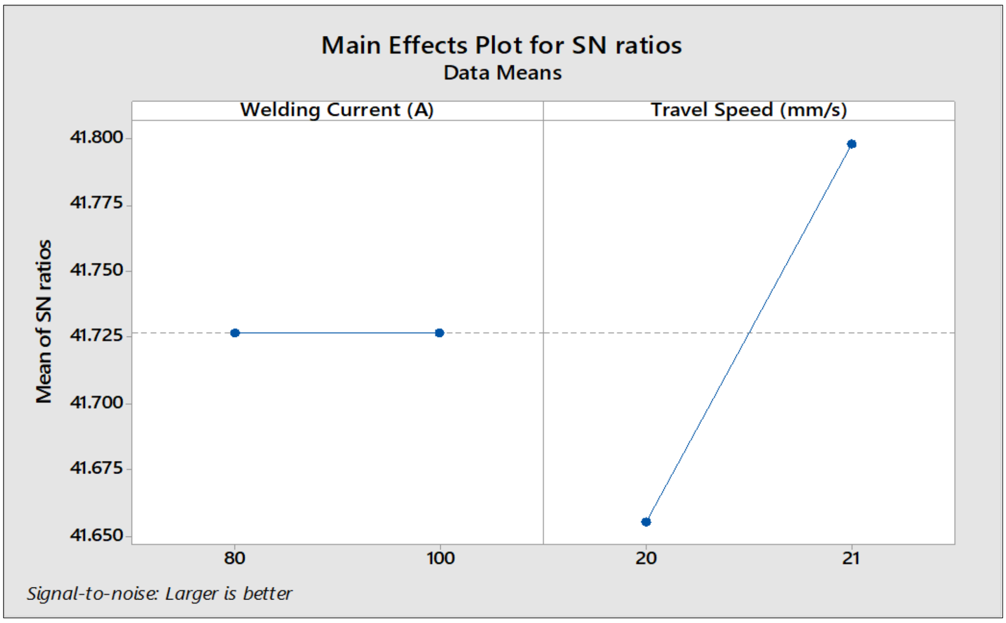

Fig. 6: Main effect plot for hardness of the weld

Table 5: Response Table for Signal-to-Noise Ratios Larger is better

	Current (A)	Travel speed (mm/s)	Hardness BHN (KN/mm²)	SNRA2
1	80	20	121	41.6557
2	80	21	123	41.7981
3	100	20	121	41.6557
4	100	21	123	41.7981

Table 6: Response Table for Signal-to-Noise Ratios -Larger is better for Hardness

Level	Current	Travel Speed
1	3.643	3.577
2	3.441	3.507
Delta	0.201	0.070
Rank	1	2

4.0 CONCLUSION

The Welding Parameters on Tensile strength and Hardness of AISI 1018 low carbon steel plate welded joints has been evaluated. It was observed that no significant effect in current variation from 80A to 100A on the Ultimate Tensile strength and hardness of AISI 1018 low carbon steel plate. However, it seemed that the welding travel speed of 20 to 21 mm/s, slightly affected the ultimate tensile strength and the hardness.

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