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Effect of MIG Welding Parameters on the Mechanical Properties of AISI 304 Austenitic Stainless Steels

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Abstract

The present research investigates joints welding of 304L austenitic stainless steel using metal inert gas (MIG) welding method. The research explores the effect of process parameters (arc voltage, wire feed rate, and electrode wire diameter) on the mechanical properties of stainless steel. The above variables are varied respectively with 18.5, 19, 19.5 V, 116, 127, 137 mm/s, and 0.8, 1, 1.2 mm, with E308L as a filler electrode. The design matrix of the experiments was determined using the design of experiment (DOE) program Minitab 17 based on the levels of input elements used. The Taguchi orthogonal matrix methodology (Taguchi) technique was used to develop some empirical analysis for the maximum tensile strength and proper surface hardness as a function of the welding parameters mentioned above. The $(ANOV)$ analysis was used to statistically verify the model's adequacy. The results show that the wire feed rate had the greatest effect on the tensile strength of the welded joints when choosing the medium level of arc voltage (19 V), while the arc voltage had a substantial influence on the micro-hardness of all welded joints. The weld-joint zone is given a higher micro-hardness value compared to the base metal zone.

Keywords: *American Standard Test Method, Gas Metal Arc Welding, Metal Inert GasUltimate Tensile Strength, Vickers Hardness.*

1. Introduction

Many engineering materials used in different applications exhibit different mechanical stress in a chemical corrosion environment. Such applications require different metals depending on the required tasks and functions of the device's components. Sometimes, the process of saving raw materials is required, and the economic factor, is the key for the specific choice. However, Austenitic-Stainless Steels (ASS) is used in the food-industry, construction, chemical, petrochemical, and power-engineering applications usually use (ASS) Steels, because of its passive-protective layer that is created from its chromium content which leads to its enhancement in temperature-creep and corrosive-chemical environments [1]. Primarily, arc-welding has long been seen to be a feasible method of combining ferrous materials. However, metal-inert gas welding (MIG) is a type of gas-metal arc-welding $(GMAW)$ that uses inert gases as shielding gases. It has been considered as a solution to the consumable time in the industrial fields and certain issues such as a wide range of materials with various thicknesses, and provides a high-quality weld with the lowest welding-slag, making it preferred in the manufacturing sectors [2].

The study of this paper was on the effects of the MIG welding process on the nine of 304L Austenitic-stainless steel's mechanical and microstructure properties, when changing the shielding-gas and welding-current. Changing the quantity of hydrogen, by three levels, causes deferent shielding-gas condition-effects. Three different levels of welding-current were used in this study. The results of this paper show that the greatest tensile- strength is realized when the current fixed at $240\,A$) welding and argon (Ar) percentage is 1.% and H_2 percentage is 5% . The base-metal (BM) was found to have a higher hardness value than the heat-affected zone (HAZ). Salah S. Abed-Alkareem [4] discusses in his study the effects of the MAG welding process parameters on the AISI 1010 low carbon steel's mechanical strength. The chosen control parameters were welding voltage, wire feed speed, and welding speed with two levels. ANOVA techniques were used to predict the optimal process parameters; the results showed that the weld joint's efficiency was about 73% of the base metal's. Abid Al-Sahib N.K. Adnan N. Abood and Amer A. Tuama [5] report in their study the effects of MIG/MAG welding process parameters on the AISI DIN15Mo3 steel hardness, microstructure, and mechanical properties using the electrode ER80S-G as a filler metal with a spot joint configuration with three levels of plate thickness, welding current, and welding speed. The Co2 and Argon shielding gases were being used in this process. The results showed that the weld joints that were conducted with the Co2 shielding gas recorded a higher value of microhardness in the weld zone compared to the heat-affected zone. Furusawa and K. Yasuda [6] clarified the setting, procedures for weld bead, and penetration, implemented into Gas-metal Arc-welding (GMAW). By changing the thickness of the 304 stainless steel from 2 to 9mm, a reference voltage (Et) was chosen (due to the absence of short circuit at or above this voltage within this process) E 308 of 1.2 mm is used as electrode filler metal. An Ar + 3 percent O_2mixture was chosen as a shielding-gas for the MIG welding. The results of this paper showed considerable increase in penetration using welding-voltage of $(Et + 2\text{ V})$. A continuous acceptable bead was created when the welding was carried out at a welding-voltage of $(Et - 2\text{ V})$. L. S. Kumar, S. M. Verma, and B. Suryanrayana [7] investigated the impacts of TIG and MIG on austenitic SS. In two procedures, several properties such as the material-strength, hardness, ductility, grain-structure, modulus of elasticity, breaking point of the tensile strength, and high-temperature zone (HAZ) are observed and evaluated, and a conclusion is reached at the end of the analysis process. A sample of stainless steel 304 with dimensions of $150 \times 50 \times 3$(mm was obtained, and both welding processes were carried out. It was discovered that TIG is superior to MIG based on the findings of the study. The ultimate tensile strength, ultimate load, and percent of elongation are the quality-characteristics parameters to consider. A metallurgical investigation revealed the presence of porosity and intergranular corrosion, as well as other characteristics. V. Chauhan and R. S. Jadaun [8] studied the effects of the MIG welding control process parameters on $SS\,304$ and low-carbon steel dissimilar work-piece materials. Three factors, welding-current, welding-voltage, and welding-speed, were taken into consideration in the study, with the values of each parameter changing from low to high. To determine the effect of various factors, the Taguchi technique was employed. When it comes to ultimate tensile strength, the reaserchers discovered that the voltage and welding speed were both important factors to consider. I. M. Omiogbemi and D. S. Yawas [9] used the metal inert gas method to study the effect of input process parameters on tensile-strength, hardness, and impact-toughness of 3mm thick 304 stainless-steel that was exposed to 0.5M of hydrochloric acid at ambient temperature. The experiments were conducted using different tools such as a scanning electron microscopy (SEM) and the rockwell hardness test. The obtained results show that the process at 40 (cm/min) speed and a 110 Amp current, lead to an increase in the tensile-strength, and the hardness of a weldment is a function of the grain size of the weldment as well as the structural integrity of the welded-joints. S. A. Rizvi and W. Ali [10] studied the optimization of diferent GMAW welding process parameters on the mechanical-properties and weldability. It was decided that different welding factors, such as the welding-current, wire-feed speed, and gas-flow rate, would influence the weldability of SS304H by using the statistical approach, which was implemented. The tensile-strength, toughness, microhardness, and mode of fracture of SS304H were all measured to establish its weldability. The welding-voltage had the greatest impact, whereas the gas-flow rate had the smallest impact on the ultimate-tensile strength of the welded-joints. It is observed that the third-level of welding-voltage, the second-level of gas-flow rate, and the third-level of wire-feed speed give normal values of hardness Er. Saurabh and V. S. Aher [11]. The process parameters and their selection were important to achieve the required outcomes. However, the present work considered different optimization techniques. The outcomes of the welding process are measured in terms of strength, penetration, reinforcement, height, and hardness. In this work the results showed that the increase in welding-voltage from 18 to 22 V causes the strength value to increase from 358 (MPa) to 395.75 (MPa), and then at 24 V, the strength is maximum as 455.25 (MPa). The higher the voltage, the higher the strength A. Furqan and M. Amarnadha [12] Experiments based on the Taguchi-approach have been utilized to investigate the impact of MIG-welding parameters such as welding-current, welding-voltage, and welding-speed on the ultimate-tensile strength (UTS) of $AISI$ 1050 Mild-steel material during the welding procedure. Analyzing the welding properties of a material and optimizing the welding settings involves the use of an Orthogonal-array, Signal to noise (S/N) ratio, and ($ANOVA$) analysis techniques. The result is obtained in the form of a contribution from each parameter, and it is via this process that the best parameters for maximum tensile strength are discovered. According to the findings of this study, welding current and welding speed are the two most important characteristics that determine the Tensile-strength of welded-joint steel. The mechanical properties of weld joint had been studied by researchers however tensile strength from an austenitic stainless steel joint which used MIG welding was not enough. This study aimed to explore the effects of welding voltage, electrode wire diameter, and electrode feed rate of MIG welding on the tensile strength, and hardness of (304L) Austenitic-Stainless steel.The purpose of the research was to find only the optimal factors that are of benefit to welders for the purpose of working with them to find the best mechanical properties and a high quality weld joint.

2. Experimental Procedure

2.1. Selection of Workpiece-Material

The most common form of stainless-steel is austenitic stainless steel due to its high nickel content effect. Austenitic stainless steel is the most corrosion-resistant stainless steel with very good mechanical properties. Because stainless steel is classified into several types, including austenitic, ferritic, and martensitic, the choice comes on austenitic stainless steel 304L because this is the most expensive one, it has a wide variety of applications, and its ease of availability on the market. Table 1 shows the chemical composition of 304L stainless steel that was (Company for Inspection and Engineering Rehabilitation) (SIER) compared with standard value and compared with the standard according to the ASTM A240 standard [13].

Table 1,
Chemical contents of (304L) workpiece used in this work.

Composition	C%	“””Mn%”	P%	S%	Si%	Cr%	Ni%	N%
Nominal	0.08 max	2.00 max	0.045 max	0.030 max	0.75 max	18.00-20.00 max	8.00-10.05 max	0.10 max
Experimental	0.04	0.932	0.0175	0.0005	-	18.85	8.66	-

In this work, a sheet of 304L stainless steel alloy with thickness of (4 mm) as welding specimens was employed. A cold press machine was used to cut the sheets to the desired dimensions of (200×100) mm as welding specimens, and the two sheet’s edges were prepared with a squire butt joint with a single welding pass as shown in figure 1. using a consumable electrode, ER308L austenitic stainless steel was used, and it conforms to certification AWS A5.9/ASME SFA A5.9. Table 2 show the chemical composition of the electrode filler metal.

Table 2,
chemical contents of E308L filler metal used for this work.

Composition	C%	Cr	N	Mo	Mn	Si	P	S	N	Cu	Fe
E308L	0.03	19.5-22	9-11	0.75	1-2.5	0.3-0.65	0.03	0.03	0.75	0.75	Base

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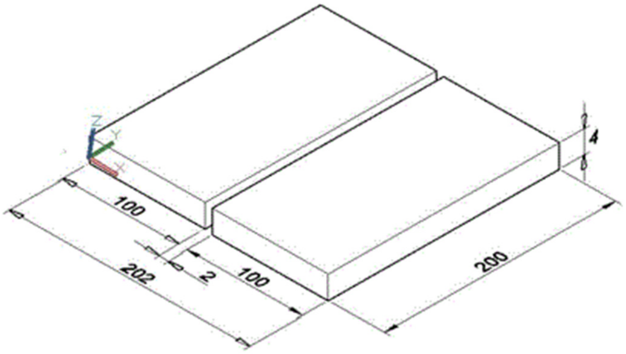


Fig. 1. Butt joint design for two sheetsall dimensions in mm.

2.2 Experimental Work

During the welding process, to ensure that the two sheets are carefully welded, the process was achieved by tightening and clamping the two sheets square butt design on the welding board configurations. the welding process was done manually by a skilled technician welder in the general company for engineering inspection and qualification. The welding machine used in this work was the type Lincoln Electric inverter as present in (SIER) state company, as shown in the figure 2. The wire systems are included with an automatic feeder in this welding machine. The welding machine provides a DC voltage ranging from 10 to 40volts and a welding current of 40 to 600 Amperes. The transistor in this circuit is used as an electronic switch to pass the current on and off at a very high speed, in order to adjust the strength and voltage of the welding current without fixed levels of adjustment. Thus, it provides the possibility of adjusting the welding parameters by a remote control and reduces the risk of a sudden rise or fall in the network voltage [14].

Fig. 2. Lincoln electric machine used in this work.

2.2.1 Ultimate Tensile- StrengthTests (UTS)

The tensile tests were performed in the SIER state company. A universal testing machine called “United” was obtained in the State Company for Inspection and Engineering Rehabilitation (SIER) and was used in this work. The tensile test was performed at 0.1 KN preload, 20 mm/min crosshead speed, and the specimen were loaded at a rate of 1.5 KN/min.The specimens were taken from the cross-sectional direction of base-metal, in a perpendicular orientation to the welded line. The transverse tensile tests were performed on subsiding sheet specimens at room temperature with dimensions that were presented according to the ASTM: E8/8M standards [15], as shown in figure 3.The location of fracture for all nine specimen is almost at the midsection of the specimens.

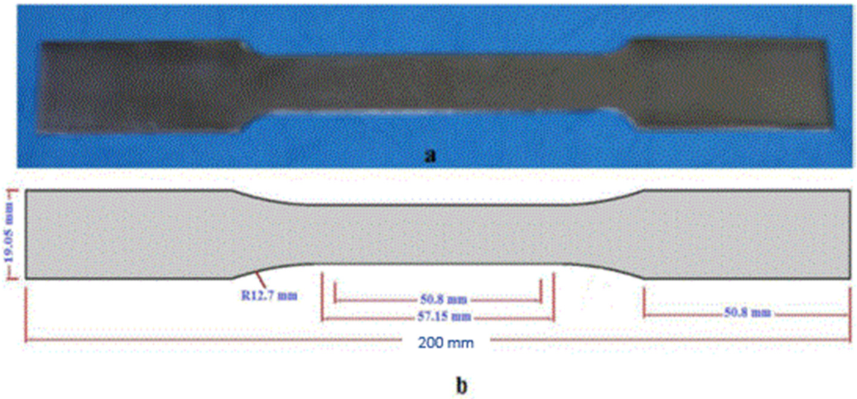


Fig. 3. ASTM: E8/8M Standard dimensions for tensile test specimens: (a) real& (b) schematic of the tensile test specimens.

2.2.2The Vickers hardness tests (VH)

Two directions were taken to achieve the measurement microhardness. The first direction was in the transverse direction with (2 mm) perpendicular to the base-plate surface, and the longitudinal direction that is parallel to the base-metal surface was the second direction taken to achieve the measurements for both zones, the weld-zone (W.Z), and the base-metal zone(BM.Z), by using the Vickers's micro hardness testing device. The reading of measurements were initially started at the weld-zone (WZ), heat affected zone (HAZ), and finally at the base-metal zone (BM) on both sides of the weld line with a distance interval of about 2 mm between one reading and the other as explained in figure 4. Table 4 shows the recorded reading and its average of two readings for both zones for the nine specimens of this work.

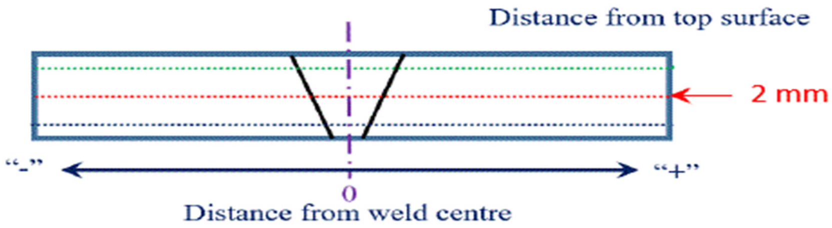


Fig. 4. Directions of measuring microhardness for the welded joint.

2.3 The Design of Experimental (DOE)

Before achieving the welding process, several stages (choosing the proper parameters that are involve in the experiment, obtaining the Features of the community under study,making the decision for the required amount of data which belongs to features of the experiment, and choosing the number of levels for each parameter) are necessary to reduce the errors while archiving the experiments and satisfying the optimum process parameters at the same time. The aim was to predict the simple difference between the parameters and their levels. Taguchi's design of experiment (DOE) tool with a set of descriptive statistics can be an effective method for this purpose. The method involves the selection the L_9 (OA) orthogonal array which employs to conduct the experiments. In the present work, the process parameters (welding-voltage (V), the electrode-wire diameter (WD), and the electrode-feed rate(F)) have been chosen with three levels for each parameter. Taguchi's descriptive statistics mean, signal-to-noise (S/N) ratios, and the formula (Smaller the better, Nominal is the best,and Larger the better) for the (s/n) can be organized according to the problem aspects and response criterias, and can be employed to satisfy the optimal value and their levels of the given process parameters. Table 3 explains the impact of the setting factors (welding voltage, electrode wire diameters, and electrode feed rate) on the tensile-strength and coss-sectional hardness behavior by using the Taguchi Orthogonal-Array that was designed and implement by using the Minitab17 program [16], [17].

Table 3,
Input parameters and their levels by using DOE for this work.

Exp. No.	V (v)	WD (mm)	F (mm/s)
1	18.5	0.8	116
2	18.5	1	127
3	18.5	1.2	137
4	19	0.8	127
5	19	1	137
6	19	1.2	116
7	19.5	0.8	137
8	19.5	1	116
9	19.5	1.2	127

3. Results and discussions

Analysis of variance is an analysis tool used in statistics that splits an observed aggregated variability found inside a data set into two parts: systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use the ANOVA test to determine the influence that thr independent variables have on the dependent variables in a regression study.

Finding the parameters that affect the ultimate-tensile-strength (UTS), Vickers-hardness (VH), and the quality of all specimens are the goal of these experiments. The orthogonal array is the base of these experiments with the goal of relating the best levels of the welding voltage, wire diameter, and wire feed rate. The work includes conducting the experiments as per the orthogonal array to obtain the various combination results.

3.1 Ultimate-tensile test(UTS)

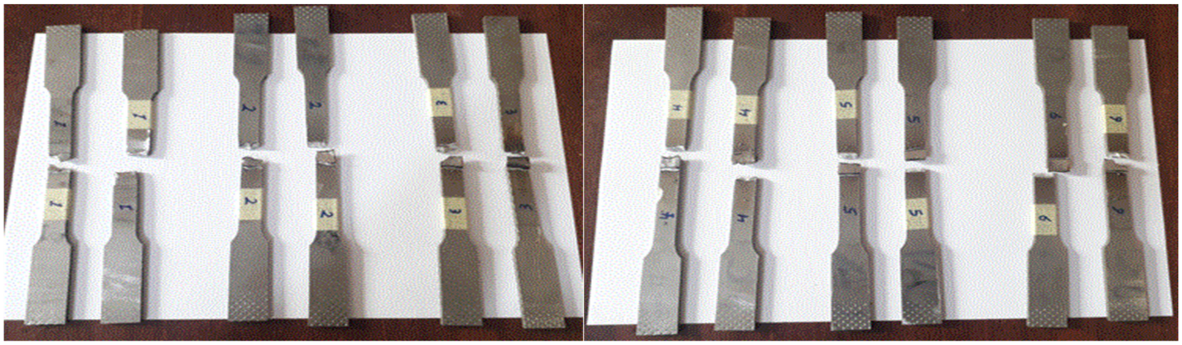
A visual inspection was performed after each experiment, and the suitable area of the weld surfaces was selected for preparation of the tensile test specimens after each experiment. To evaluate the results of tensile test for each welding joint, an average of two specimens were taken in a perpendicular orientation to the welded line. Table 4 shows the average and weld-joint efficiency for nine experiments with its joints efficiency achieved in this work. Joint efficiency is the ratio of the strength of the joint compared to the strength of the base metal. This ratio is called joint efficiency or joint quality factor. An efficient joint is one that is just as strong as the base metal. The weld joint efficiency computed by using the equation below [18].

Weld joint efficiency (WJE) (%) = $\frac{\text{UTS of the joint}}{\text{UTS of Base metal}} \times 100$

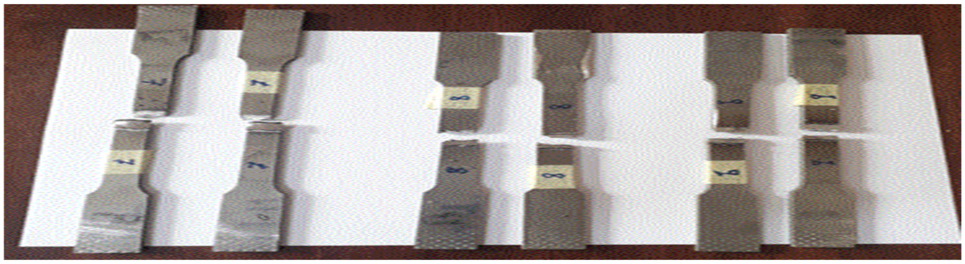
Table 4,
Results of average for nine experimental UTS tests of this work

Exp. No.	Experimental-Reputation 1	2	Averg.UTS (MPa).	Weld-Jointefficiency (%)
1	395.39	534.63	466.1	74
2	610	671.81	640.905	102
3	659.19	642.18	650.685	103.9
4	651.11	636.51	643.81	102.8
5	645.2	680.41	662.805	105.8
6	619.79	682.67	651.23	104
7	654.07	663.42	658.745	105.1
8	527.07	426	476.535	78.5
9	559.7	569.11	564.405	90

As can be seen in table 5, the ultimate-tensile strength reaches its maximum and minimum values of (652.71MPa) and (466.1MPa) respectively. At first, the low welding voltage causes the minimum value of tensile strength, then increasing the welding-voltage to the medium level leads to the increase of the tensile strength, until a threshold value is reached. Thereafter, the high level of the welding voltage starts decreasing the tensile sample after testing, as shown in figure 5. Tables 5, 6, and 7, show the statistical analysis results for the tensile responses which were obtained by the Taguchi method.



a) specimens (1 – 3) low voltage level **b) specimens (4 – 6) med. voltage level**



c) specimens (7 – 9) high voltage level

Fig. 5. tensile test specimens with three levels of arc voltage.

From the visual inspection, the low results of the tensile test are due to the lack of penetration for samples 1 to3 and fast cooling at the voltage level for samples 7 to 9, this is in agreement with the reference [19]. Tables 5, 6, and 7, show the statistical analysis results for tensiles, the responses were obtained by the Taguchi method.

Table 5,
Results of Statistical Analysis of Experiments by Taguchi technique for UTS

Run. No.	V (v)	WD (mm)	F (mm/s)	UTS (MPa)	SNRA1	MEAN1
1	18.5	0.8	116	466.1	53.6530	481.560
2	18.5	1	127	640.905	56.1359	640.905
3	18.5	1.2	137	650.685	56.2674	650.685
4	19	0.8	127	643.81	56.1752	643.810
5	19	1	137	662.805	56.4277	662.805
6	19	1.2	116	651.23	56.2747	651.230
7	19.5	0.8	137	658.745	56.3743	658.745
8	19.5	1	116	476.535	53.5619	476.535
9	19.5	1.2	127	564.405	55.0318	564.405

Table 6,
Response Table for s/n of UTS.

Level	V (v)	WD (mm)	F (mm/s)
1	55.35	55.40	54.50
2	56.29	55.38	55.78
3	54.99	55.86	56.36
Delta	1.30	0.48	1.86
Rank	2	3	1

Table 7,
Response table for a meanof UTS

Level	V (v)	WD (mm)	F (mm/s)
1	591.0	594.4	536.4
2	652.6	593.4	616.4
3	566.6	622.1	657.4
Delta	86.1	28.7	121.0
Rank	2	3	1

The ranks indicate that wire feed rate has the biggest influence on both the S/N ratio and the mean in our experimental analysis. For S/N, the arc voltage has the next greatest influence, followed by electrode wire diameter. From table 6 and table 7, the value of the S/N ratio and mean for all parameters is compatible by taking the large number so that we do not need to make a prediction. The main effect plot for the S/N ratio and the mean S/N ratio is shown the relationship between them in figures 5 and 6.

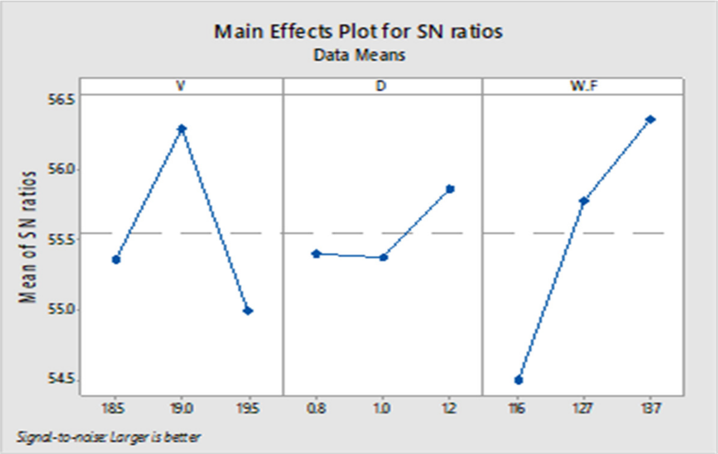


Fig. 6. Main effect plot of S/N ratio for UTS.

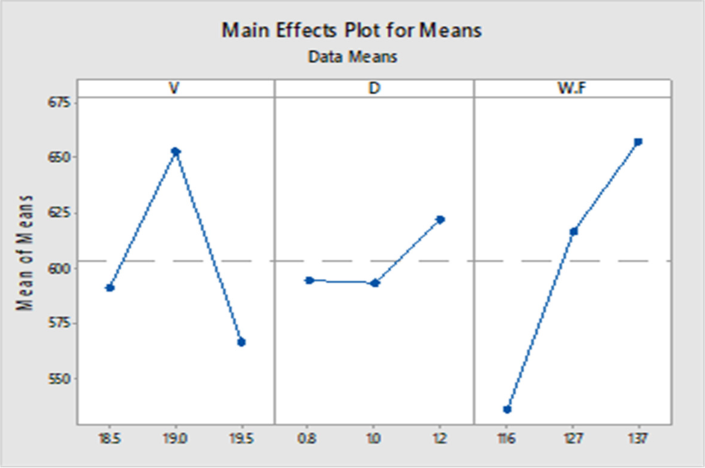


Fig. 7. Main effect plot of the mean for UTS.

The optimum value of parameters that based on the highest number of S/N ratio and welding voltage $V_{(2)}(19\ v)$, electrode wire diameter of $WD_{(3)}(1.2mm)$, and electrode feed rate $F_{(3)}(137\frac{mm}{s})$. The optimum level

$(V_{(2)}, WD_{(3)}, F_{(3)})$ for the optimum reach of Tensile-strength. , however, this experimental result, and there parameter's levels do not found in the nine experiments obtained in table 3. Taguchi orthogonal array only represent nine experiments from all the possibilities of experiment [3^3 = 9 experiments].

3.2 Vickers-Hardness(VH)Test

Figure 8 depicts the results that the microhardness profile tests achieved by using the Vickers hardness test method for AISI 304L stainless steels. The measurements were at the center of the cross-section area for both the welded zones (WZ), and base-metal zone (BM). Both no. 1 and 2 were shown were shown to have higher hardness values than other specimens, this is due to use a lower welding voltage level which causes the lower heat input to reduce the cooling rate and this turns to decrease in the microhardness in the weld joints [18]. In general, the hardness values of the weld-zones are higher in the center of the fusion zone than the base-metal zone, and tend to decrease with a little shift along the specimens' length. This might be due to the existence of electrode components and a difference in voltage [20].

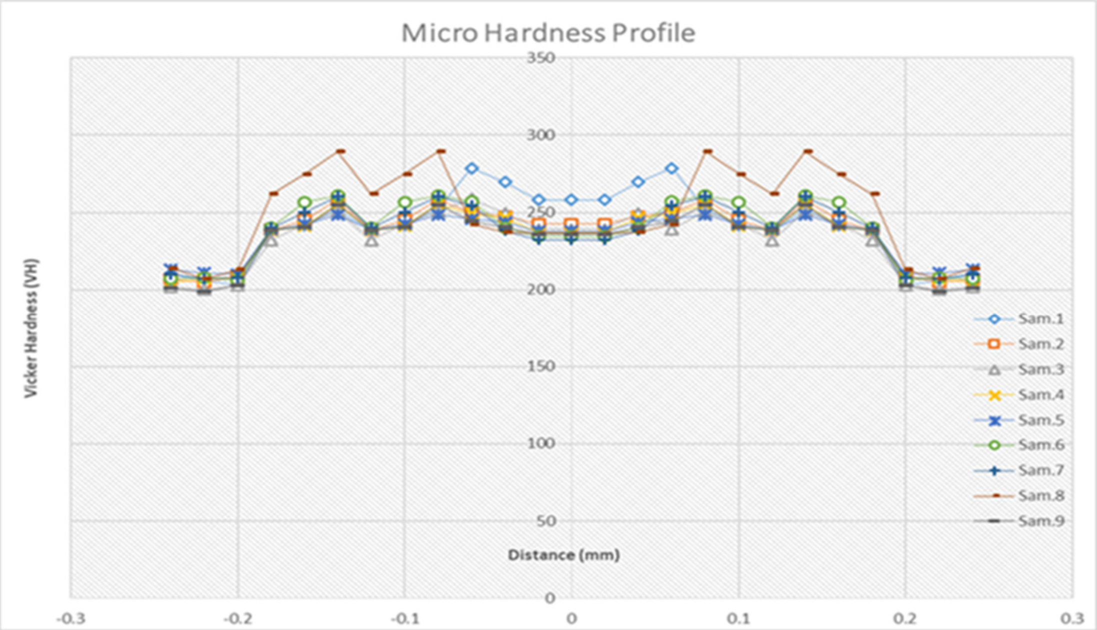


Fig. 8. The Results of the Vickers's Micro-hardness profile for nine specimens.

Tables 8, 9, and 10, show the statistical analysis results for cross-sectional hardness, the responses were obtained by the Taguchi method.

Table 8,
The Statistical Analysis Results for Hardness, Responses Obtained by the Taguchi method.

Run. No.	V (v)	W.D (mm)	F (mm/s)	VH	SNRA1	MEAN1
1	18.5	0.8	116	268.860	48.5905	268.860
2	18.5	1	127	246.700	47.8434	246.700
3	18.5	1.2	137	249.100	47.9275	249.100
4	19	0.8	127	244.868	47.7786	244.868
5	19	1	137	242.366	47.6894	242.366
6	19	1.2	116	240.233	47.6127	240.233
7	19.5	0.8	137	237.360	47.5082	237.360
8	19.5	1	116	238.800	47.5607	238.800
9	19.5	1.2	127	240.100	47.6078	240.100

Table 9,
Response for Signal to Noise Ratios for VH Larger is the Best

Level	V (v)	WD (mm)	F (mm/s)

1	48.12	47.96	47.92
2	47.69	47.70	47.74
3	47.56	47.72	47.71
Delta	0.56	0.26	0.21
Rank	1	2	3

Table 10,
Response ofMeans for VH Tests

Level	V (v)	WD (mm)	F (mm/s)
1	254.9	250.4	249.3
2	242.5	242.6	243.9
3	238.8	243.1	242.9
Delta	16.1	7.7	6.4
Rank	1	2	3

The test was performed for microhardness of the specimens weld zone. The ranks indicate that arc-voltage has the biggest influence on both the S/N ratio and the mean in our experimental analysis. For S/N, the electrode wire-diameter has the next greatest influence, followed by electrodefeed-rate. From tables 9 and 10 the value of the S/N ratio and mean for all parameters is compatible by taking the large number so that we do not need to make a prediction. The main effect plot for mean and S/N ratio is illustrated in Figure 8 and Figure 9, respectively.

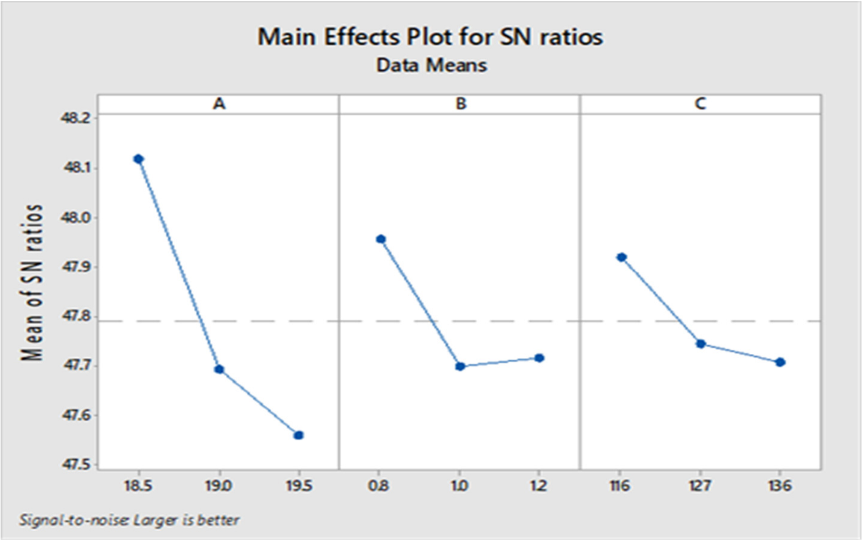


Fig. 9. Effect of a plot for S/N ratios for microhardness test.

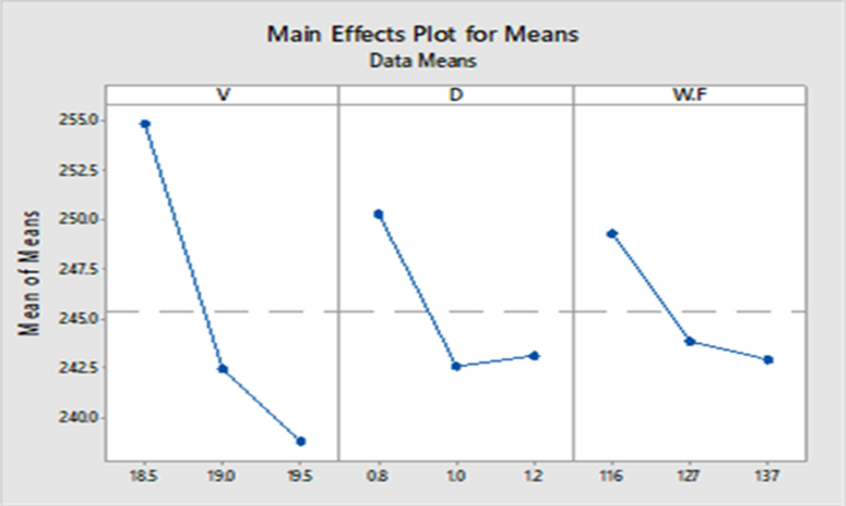


Fig. 10. The mean for the microhardness test.

The optimum value of parameters that based on the highest number of S/N ratio with a welding voltage ($V_{(1)}$) of 18.5 v, an electrode wire diameter ($WD_{(1)}$) of 0.8mm, and an electrode feed rate ($F_{(1)}$) of 116 $\frac{mm}{s}$. The optimum level for the ($V_{(1)}$, $WD_{(1)}$, $F_{(1)}$) process parameters was selected according to the standard (large is better) value of S/N ratio to have a maximum reaction that affected the optimum reach of hardness. However, this experiment's results and their parameter's levels are not found in the nine experiments obtained in table 3. Taguchi orthogonal array only represents nine experiments from all the possibilities of the experiment.

3.3. Analysis of Variance ($ANOVA$)

The analysis of variance ($ANOVA$) is statistical process used for determining the P% (percentage of contribution) for each parameterand their significance level. The MINITAB-17 program was used to anticipate the ideal value for this situation [21].

3.3.1 Analysis of Variance ($ANOVA$)for the Tensile-Strength(UTS) test

The ANOVA test was conducted using welding-voltage, wire diameter, and wire feed rate to show the effects of these parameters on the ultimate tensile-strength (UTS). Table 11 shows the results of the $ANOVA$) analysis for the UTS tests.

Table 11,
ANOVA analyses for UTS

Source	DF	Seq-SS	Adj-SS	Adj-MS	F-value	P-value	Contribution%
V	2	11795	11795	5897.6	1.12	0.472	25.30%
W.D	2	1576	1576	787.9	0.15	0.870	3.38%
W.F.R	2	22707	22707	11353.5	2.15	0.317	48.71%
Error	2	10538	10538	5268.9			22.61%
Total	8	46616					100.00%

Where:

P = the confidences interval

F = Fisher test

$SS = = \sum_{i}^{n}(y_i - y)^2$...(1)

Where, y_i is the observed S/N ratio value of the response, n is the number of observations or experiment numbers and y is the mean of S/N ratio.

$MS = \frac{SS}{DF}$ ..(2)

MS means the mean sum of squares due to the source.

SS Sum of squared deviation due to the source .

DF = means "the degrees of freedom in the source."

It can be noticed that the large parameter effect on UTS is the Wire. Feed. Rate with 48.71% percentage, followed by Arc voltage with 25.30% percentage, and followed by the Wire diameter with 3.38% percentage. which means that these parameters have a large effect on tensile strength compared to the other parameters.

3.3.2 Analysis of Variance($ANOVA$) for the Microhardness(VH) test

The results of statistical processing for the analysis of variance (ANOVA) for hardness test (shown in table 12) are used for determining the P% for each control parameter. It can be noticed that the largest parameter effect on hardness test is the arc voltage circuit with (57.94%) percentage followed by wire diameter with (15.21%) percentage followed by wire feed rate with (9.56%).

Table 12,
The average of each response

Source	DF	Seq-SS	Adj-SS	Adj MS	F-value	P- value	Contribution%
V	2	427.94	427.94	213.97	3.36	0.229	57.94%
W. D	2	112.30	112.30	56.15	0.88	0.532	15.21%
W.F.R	2	70.54	70.54	35.27	0.55	0.644	9.56%
Error	2	127.45	127.45	63.72	63.72		17.26%
Total	8	738.22					100.00%

It can be noticed that the large parameter effect on cross-sectional-hardness is the welding voltage with followed by the wire diameter and followed the wire feed rate. In the table above is the analysis of the ANOVA for the tensile test, the last column in the table shows the contribution (the effect of each factor on the final tensile test and according to the percentages mentioned in the same column (contribution)). It is clear that the effect of voltage is large (57.9%), followed by the effect of WD by (15.21%), and finally WFD by 9.56% .

4. Conclusions

1. The Tensile-strength, and microhardness of different welded joints are significantly affected by input process parameters. However, a good resultof these mechanical properties can be satisfied by choosing the required process parameter of the given welding process.
2. Wire feed rate has the majority influence on “tensile strength”, accounting for (48.71%) of the total, followed by Arc voltage (25.3%) and wire diameter (3.38%).
3. Welding-Voltage has the greatest influence on the “microhardness”, accounting for (57.94%) of welding voltage, followed by wire diameter (15.21%), and wire feed-rate of 9.56% respectively.
4. The confirmation test for the improved welding parameters ensures that the higher final tensile stress factor value is taken better so that the weld joint is strong enough to resist joint fracture, and a lower value is taken for the finer hardness factor, which is better to prevent brittleness as to not break the weld joint.

Scope for Future Work and Recommendations

1. Study the effects of process parameters on MIG butt joint for the metals with high melting temperature such as iron, steel, and titanium.
2. Optimization of process parameters for the MIG butt joint to improve the mechanical behavior of 304L stainless steel alloy by using new methods to analyze the results and choosing other process parameters such as (welding speed, current, gas flow rate, plate thickness, etc.).
3. Investigate optimization of process parameters for MIG joint of dissimilar alloys.
4. 4Study the effect of weld joint geometry dimensions on thermal for MIG process for different stainless steel alloys using the technical advancing devices for measuring and analyzing the temperatures during the welding process.
5. Investigate the influence of the strength fusion region heating mechanism and inspection the internal defects formation for MIG process by ultrasonic testing of welded parts.
6. In this present work-study, we used single-pass welding, so we recommend using multi-pass to enhance the mechanical properties in the welding zone.
7. In this work recommends using more advanced inspections for the Mechanical properties in the welding zone.

List of Abbreviations

GMAW	Gas Metal Arc Welding
MIG	Metal Inert Gas
ASS	Austenitic Stainless Steel
AWS	American Welding Society
E308L	American welding standard code for filler metal
WZ	Weld Zone
HAZ	Heat Effected Zone
BM	Base Metal
ASTM	American Society for Testing of Materials
DOE	Design of Experimental
OA	Orthogonal Array
ANOVA	Analysis of variance
S/N	Signal to noise ratio
UTS	Ultimate tensile strength
HV	Vickers microhardness test
MSN	Mean squared deviation
DF	Degrees of freedom
n	Number of trials
Av.	Average
WJE	Weld joint efficiency
F	Fisher test
P	The confidences interval
L9	The nine experiments that design by OA Taguchi

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تأثير متغيراتلحام MIGعلى الخواص الميكانيكية للفولاذ المقاوم للصدأ نوعAISI 304

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الخلاصة

يتضمن هدا البحث دراسة انتاج وصلات لحام من الفولاد المقاوم للصدا نوع (٣٠٤L) باستخدام طريقة اللحام بالغاز الخامل للمعادن (MIG) لتوضيح تأثير المتعيرات العملية التيتتضمن جهد القوس ومعدل تغذية السلك و كذلك قطر السلكوبثلاثة مستويات (٥.١٨, ١٩, ٥.١٩) فولت، (١١٦, ١٢٧, ١٣٧) ملم/ ثانيهو (٠,٨ , ١, ١,٢) ملم ، وسلك اللحام المستخدم نوع(ER٣٠٨) كمعدن حشو,على الخواص الميكانيكية للفولاذ المقاوم للصدأ. تم تحديد مصفوفة ا تصميم البرنامج الحاسوبي تاكوشي وفق مستويات عوامل الادخال، أستخدمت منهجية المصفوفةالمتعامدة في البرنامج واستخدم تحليل التباين (ANOVA) للحصول على النتائج لأجهاد الشد النهائي والصلادة الدقيقة للملحومات كدالة لمتغيرات اللحام المذكورة اعلاه . اظهرت النتائج ان معدل تغذية السلك كان له الدور الاكبر تأثيرا"على اجهاد الشد عند اختيار المستوى المتمثل بجهد القوس (١٩ فولت) . بينما كان لجهد القوس ثأثيرا" كبيرا" على الصلادة الدقيقة لجميع عمليات اللحام ومن جراء الفحوصات المختبرية توضح القيم ان منطقة اللحام قيمة صلادتها اعلى مقارنة بمنطقة المعدن الاساس.
