University of Thi_Qar Journal for Engineering Sciences
http://www.doi.org/10.31663/tqujes.11.2.382(2021)
Vol 11.2(April 2021)

ISSN :2664- 5572 (online)
ISSN:2664-5564 (print)
Available at http://jeng.utq.edu.iq
utjeng@ utq.edu.iq

Optimization of MIG welding parameters

Noor Hameed Majeed [†], Hazim Esmaeel Radhi [‡] and Hadier J. Abid [†]
[†]First author's Mechanical Engineering, College of Engineering, Thi-Qar University, Iraq
[‡]Second author's Mechanical Engineering, College of Engineering, Thi-Qar University, Iraq
[†]Third author's Mechanical Engineering, College of Engineering, Thi-Qar University, Iraq

Abstract

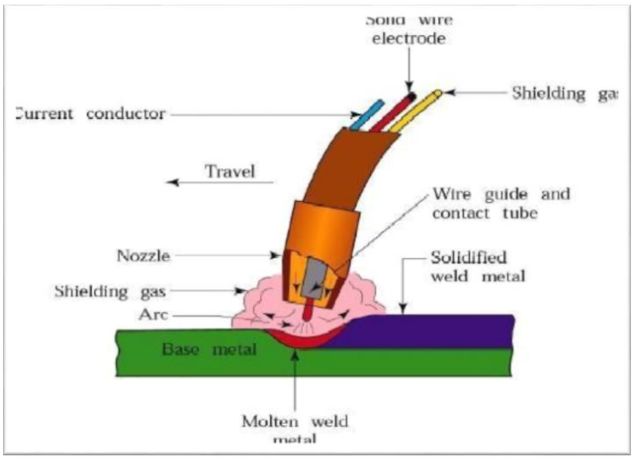
Welding is a technique used for joining metal parts usually during the application of heat. There are many types of welding, including an electric arc welding this means that welding is a process in which the electric arc forms a metal work piece and an electrode, which leads to this work to heat the metals and cause them to melt, and connect them with an inert metallic gas (MIG). This study clarifies the conclusion of welding parameters such as travel speed, current and wire feeding speed to medium carbon steel through Welding. Get the greatest parameters as it gives nature to alteration of the strength and the quality of product and its impact on tensile strength, and hardness at studies the conduct of AISI 1040 steel by using the Taguchi method in this experimental procedure and analysis of variance in Minitab software and Optimization method (OptiY program / Evolutionary Algorithms). It was found that the increase in current leads to an increase in the amount of tensile strength(TS) and hardness of the material. Also, decreasing the welding speed during the welding process leads to an increase in the tensile strength and hardness of the welding area**.** While, the effect of the input welding wire feed values on the welding region, specifications are largely dependent on the welding current and welding speed values chosen.

Keywords: MIG welding, Taguchi method, Evolutionary Algorithms, TS, AISI 1040.

1. Introduction

MIG welding process is much easier and faster to learn business according to the basic parameters of heat generation by electric arc. The heat is used to melt a expendable electrode and base plate metal and then solidify together and create a strong joint [1]. MIG welding is used comprehensively in a wide range of manufacturing due to its suitability and advantages for welding both ferrous and non-ferrous materials. An example of some MIG welding preferences. The sedimentation rate is higher, it always provides filler material; It is faster compared to electric arc welding, and produces clean weld and better quality for AISI 1040 steel plate.

Figure 1: Working principles of MIG welding [1].



In addition to its wide applications such as can be used to wide range of ferrous and non-ferrous materials like low alloy steels and carbon, magnesium, stainless steels, nickel, aluminum and their alloys etc. MIG can be used in a wide variety of industries such as refrigeration, automotive, aircraft, shipbuilding, and pressure vessel manufacturing, it can also be used for welding tool steels and cast steels. [2]. Automatic MIG welding machine is used. The input parameters are travel speed, current and wire feed speed. The output parameters are tensile strength and hardness. Used Taguchi method in this experimental procedure and Optimization method (OptiY program / Evolutionary Algorithms). Demonstration of the effect of welding coefficients on Heat-Affected zone (HAZ), the effect of heat input and grain growth. The role of grain size on the hardness and durability of AISI 1040 steel has also been studied, and it has been observed that the welding areas are greatly affected by the amount of electric current and the welding speed used in the welding process.

The effects of the input parameters (travel speed, current and wire feed speed) on prepared welding samples were clarified, as samples with good specifications for tensile and hardness test values were obtained.

2. Design of Experiments

DOE is a technique of important and exploit all possible combinations in an experiment linking multiple factors and to classify the best combination. Where, different factors and their stages are determined. **(**DOE) is also valuable to combine the issues at appropriate levels, each

with the respective acceptable range, to produce the best results and yet exhibit minimum variation around the optimum results. This project, (DOE) considers double factor interaction effects. DOE using Taguchi technology to meet the needs of projects to solve product/process design problems economically. Engineers, researchers, and scientists can reduce the time required to carry out such experimental investigations more broadly by learning and applying this technique. Therefore, the objective of accurately designed experiment is to get a
satisfactory job rendering through the product outputs by understanding any usual of variables in any process that impact performance more broadly and then it is done determining the best levels for these variables. There are several advantages of design of experiments are as follows:

1. Substantial decision variables which switch and improve the performance of the product or the procedure can be identified.
2. Can be found ideal setting for parameters.
3. Qualitative guess of parameters can be made.
4. Experimental mistake can be estimated.
5. A conclusion can be made about the parameters and their effect on the properties of the process.

Thus Design of experiment (DOE) is a technique to identify the important features in a process [1].

2.1 Taguchi method

Taguchi method of product quality control is an engineering method concerned with the role of research and development (R&D) and product design and development to reduce the occurrence of failures and defects in manufactured goods [3]. Taguchi method for analyzing the effect of each welding process parameter (arc gap, flow rate, welding current and speed) on welding clustering geometry (front and back height, front and back width). Their research on improved weld bath geometry included determination of the parameter range of the MIG welding process. When Taguchi technique is applied to planning, a significant improvement in productivity is observed during research and development as a result of using Taguchi method so that production is high quality, low cost and very fast. The Taguchi approach can be used by the DOE to significantly reduce the time required for experimental investigations. The first phase of this research has been adopted by the researchers, using orthogonal Taguchi matrices to perform experiments to find the contributions of each factor and to optimize parameter settings. Analysis using the Taguchi L9 design (3 ** 3) which represents:

1- L9 9 RUNS
2 - 3 3 levels
3- 3 3 factors

3.Material Selection

Machines was using in the present work is Medium carbon steel has wide applications and is important has wide applications and is important because of its easy operation, flexibility and moderate strength and resistance to good wear, therefore, it has used for large pieces, forgings and automotive components.

Table1: AISI chemical composition of 1040 carbon steel in wt. % [4].

Sample	Content
C %	0.370-0.440
Mn%	0.60-0.90
P%	≤0.04
S %	≤0.050
Fe	98.6-99

4. Experimental Set Up

In order to achieve the goal of this experimental work the welding samples were prepared to start the required tests. This is done by one rectangular AISI 1040 plate with dimensions (500x300x5) mm. This stage begins with dividing the surface of sheet into (100x 50) mm straight stripes and then cutting the stripes as shown in figure2 by cutting machine represents.

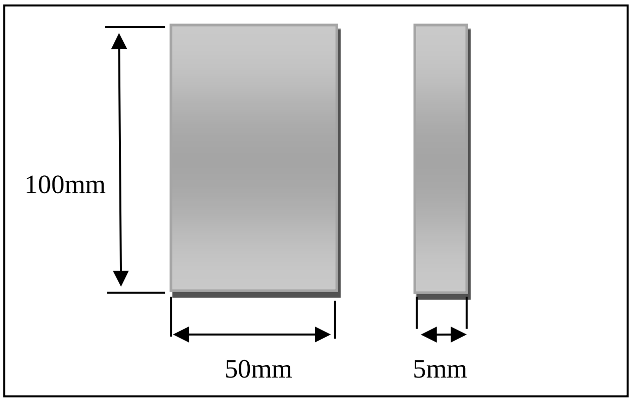


Figure 2: Weld pieces' dimensions Conclusions.

Then grinding weld pieces' edge by file to enhance contact between the welding surfaces with a root angle 45. represents removing any gaps and abrasiveness by file. These steps indicate the second stage of plate's preparation. Cleaning of contact surfaces between tool and work pieces. Fine sand papers or brushes were used to improve mixing action at joint area and good surface level. After these the work pieces put on the granite block and then spirit level or level indicator used to check leveling. The samples are tacked after preparation of edges to prevent any misalignment during the welding. Groove between samples is cleaned properly with wire brush and acetone to remove any dirt and oxide layer. Welding in each experiment is done according to conditions mentioned in design of experiment. Using Taguchi design the values of the optimum welding parameters (as shows in table2). Using automatic MIG welding machine and welding is done in one pass one root pass. After completing the welding of the panels, they are cut into the required samples with dimensions of 50 x 6 x 5 mm and prepared for the required tests.

Table 2: Selected welding parameters and their level.

Welding parameters	Level 1	Level 2	Level 3
Current(Amp)	90	110	140
Travel Speed (mm/sec)	3	4	5
Wire Feed Rate(m/min)	3	4	5

Table3: Taguchi design L9 (3*3) for input value parameter setting.

Run	Current (I)	Wire Feed (WFS)	Welding Speed(S)
1	90	3	3
2	90	4	4
3	90	5	5
4	110	3	4
5	110	4	5
6	110	5	3
7	140	3	5
8	140	4	3
9	140	5	4

Figure 3: Samples.

5. RESULT AND DISCUSSION

5.1 Tensile Measurement

Tensile strength is a measurement of the force obligatory to pull something such as rope, wire, or a structural beam to the point where it breaks. The tensile strength of a material is the upper limit of tensile stress that it can take before failure, for example breaking [5].

Figure 4: Tensile test specimens.

Table 4: Summarized the tensile test results.

Exp. No	Welding Speed (S)	Wire Feed (WFS)	Current (I)	Average Force (N)	Tensile strength (TS)
1	3	3	90	7312.61	243.75
2	4	4	90	13173.64	439.12
3	5	5	90	14475.31	482.51
4	4	3	110	7395.31	246.51
5	5	4	110	12119.54	403.98
6	3	5	110	12513.25	417.108
7	5	3	140	18540.31	618.01
8	3	4	140	18002.77	600.09
9	4	5	140	10225.89	340.89

It was found that the maximum value of the tensile strength at the speed of welding 3 (mm/sec), wire feed 4 (m/min) and the current of welding140(Amp), while the minimum value it was at the speed of welding 4 (mm/sec), wire feed 3 (m/min) and the current 110(Amp).

As a slight increase in the welding current leads to an increase in tensile strength. It was noted that decreasing the welding speed during sample welding produces a sample with a relatively high tensile strength, while noting other input welding parameters. The increase in TS ascribed to appropriate heat generated in the Welding area.

Grain softening and correct distribution of intermetallic particles are playing major role in the strengthening by increase each TS and hardens of weld joint. The position of fracture was in the HAZ and has cup-con type with fibrous surface.

An equation was obtained by regression using the Minitab program. For practical values taken from the table (4).

Tensile = -182 + (65.6 * S) + (22.0 *Feed) + (2.30* Current) …………(4.1)

The optimization program (OptiY software) was used to obtain the maximum tensile value of the samples. Insert the agreed parameters from Taguchi theory, and obtain an equation for tensile strength using the Minitab program. Then the results are analyzed and drawn using the OptiY program and the Matlab program. The resulting value was very close to the value extracted by the tensile device.

While, the agreed welding parameters were entered with a reference to 5000 attempts for the program to be more accurate.

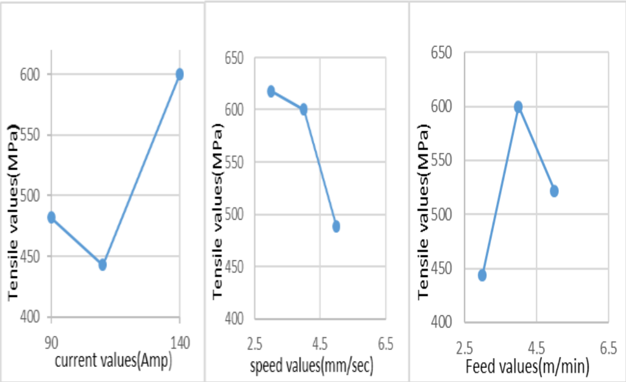


Figure 5: Main effect plot for means.

Table5: The max. ultimate tensile strength values obtained by The optimization (OptiY program/Evolutionary Algorithms).

Exp. No	Welding parameter values	Max. ultimate tensile strength (UTS)
1	Welding Speed 3.3(mm/sec)	615
2	Wire Feed 5 (m/min)	558.6
3	Current 139.8 (Amp)	599

It was observed that there is a slight difference between the practical and theoretical values of the tensile test, and this may be due to the working conditions during welding and the testing required in relation to the practical values.

5.2 Micro-hardness Test Results

Micro-hardness testing is (a method of determining a material's hardness or resistance to penetration when test samples are very small or thin, or when small regions in a composite sample or plating are to be measured) [6]. The precision hardness test definition of Vickers hardness (HV)by using the Vickers device and that is done was performed by indenting the diamond pyramid below a specific test load on the surface of the test sample. Then measure the indents of the indentation left on the surface after removing the load and test by means of the measuring microscope that is provided with the device. The test was performed on the samples to be examined Where, distribution of Micro-hardness along a straight line to the sample is located about (3mm) from upper surface of butt weld piece. The distance between one and another test point was (1mm) and for accurate reading the test was conducted three times at each point and then averages the results. As the Micro-hardness test with these points was performed on the weld samples according to the parameters entered during the weld of the samples, the Vickers device was used for this test because it is more accurate and easy than other hard devices. The table 6 shows the maximum micro-hardness values obtained in the test.

Table 6: The experimental micro hardness at different welding parameters.

Exp. No	Welding Speed(S)	Wire Feed (F)	Current (I)	MAX. Micro-hardness (HV)
1	3	3	90	200
2	4	4	90	209.19
3	5	5	90	197.64
4	4	3	110	196
5	5	4	110	201.85
6	3	5	110	205.52
7	5	3	140	195.608
8	3	4	140	209.87
9	4	5	140	207.0981

The maximum value of the micro-hardness calculated in the test was obtained at welding speed 3(mm/sec), wire feed 4 (m/min) and current 140 (Amp), while its minimum value was at welding speed 5 (mm/sec), wire feed 3 (m/min) and current 140 (Amp) shown in figure (13) and figure(14).

From profile of hardness a gradual increasing can be seen in the Vickers micro-hardness toward the center of weld. This happens because of the grain structure which consists of very fine grains produced due to higher heat. Fine grains mean more grains boundaries. It is known that one of the strengthening mechanisms is grain boundaries also this boundaries act as an obstacle for dislocation moving. Fine grains lead to high dislocations density and then increase the strength of this region.

The maximum value of the hardness obtained after inserting an instruction (5000) trying to obtain very accurate values. As previously, the results of the tensile strength test are analyzed.

An equation was obtained by regression using the Minitab program. For practical values taken from the table (6).

Hardness = 201.4 + (0.96 *S) + (3.11* Feed)- (0.1376* Current) ………. (4.2)

Where the parameters agreed upon were entered from Taguchi theory, and an equation of hardness was obtained using the Minitab program. Then the results are analyzed and drawn using the OptiY program and the Matlab program.

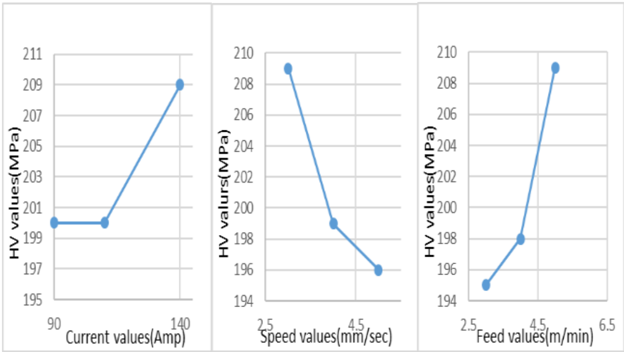
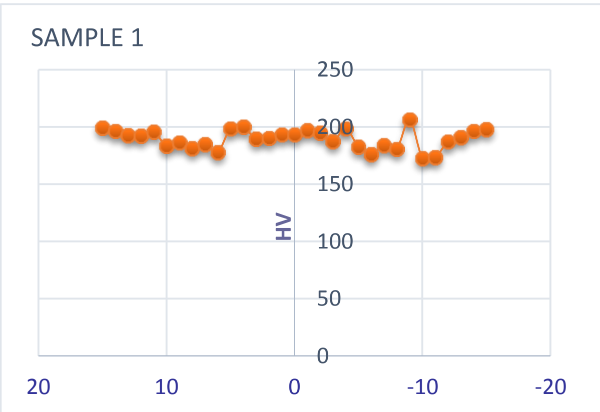


Figure 6: Main effect plot for means

The optimization was used (OptiY / Evolutionary Algorithms) the effect of the input parameters (travel speed, current and wire feed speed) on the results of the welding area hardness values. The maximum hardness value for each input parameter is obtained as shown in the table below.

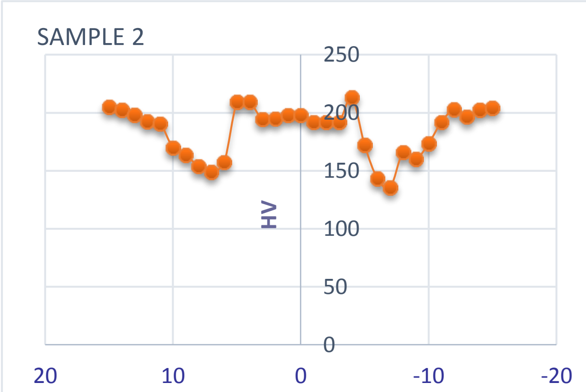
Table 7: The max. micro-hardness values obtained by The optimization (OptiY program/Evolutionary Algorithms).

Exp. No	Welding parameter values	Max. micro- hardness
1	Welding Speed 3.3(mm/min)	615
2	Wire Feed 5 (mm/sec)	558.6
3	Current 139.8 (Amp)	599



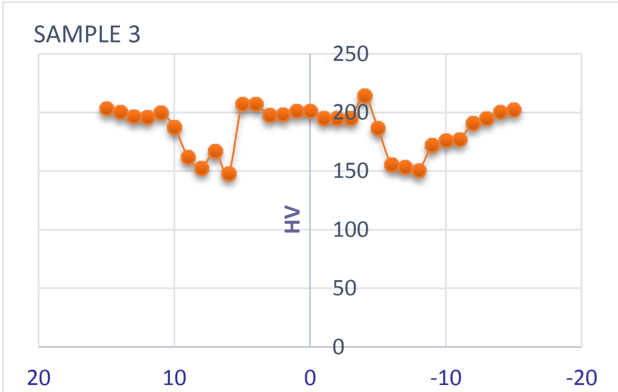
Distance from weld center in (mm).

Figure 7: Shows the variation of micro-hardness at welding speed 3(mm/sec), wire feed 3(m/min) and current 90(Amp).



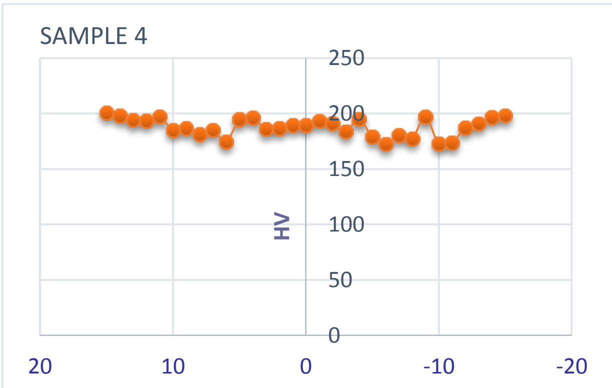
Distance from weld center in (mm).

Figure 8: Shows the variation of micro-hardness at welding speed 4(mm/sec), wire feed 4(m/min) and current 90(Amp).



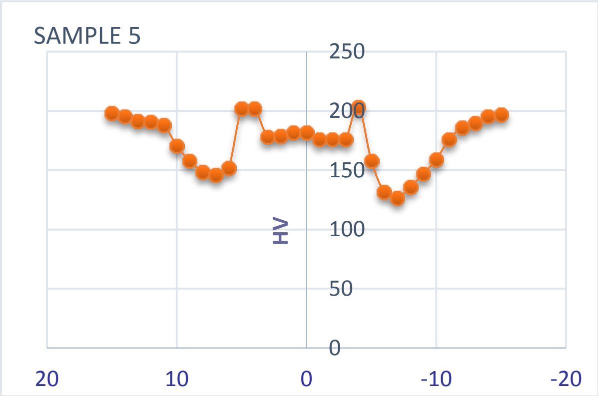
Distance from weld center in (mm).

Figure 9: Shows the variation of micro-hardness at welding speed 5(mm/sec), wire feed 5(m/min) and current 90(Amp).

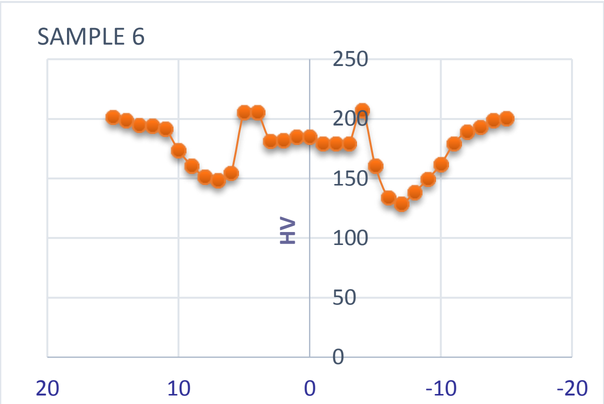


Distance from weld center in (mm).

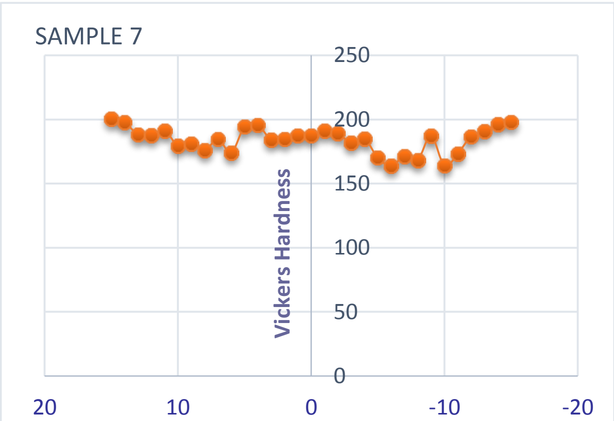
Figure 10: Shows the variation of micro-hardness at welding speed 4(mm/sec), wire feed 3(m/min) and current 110(Amp).



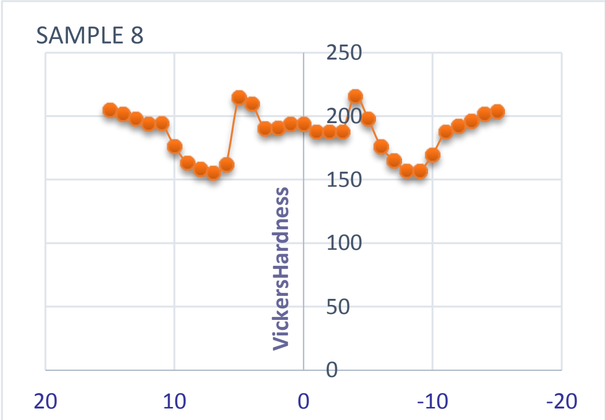
Distance from weld center in (mm).
Figure 11: Shows the variation of micro-hardness at welding speed 5(mm/sec), wire feed 4(m/min) and current 110(Amp).



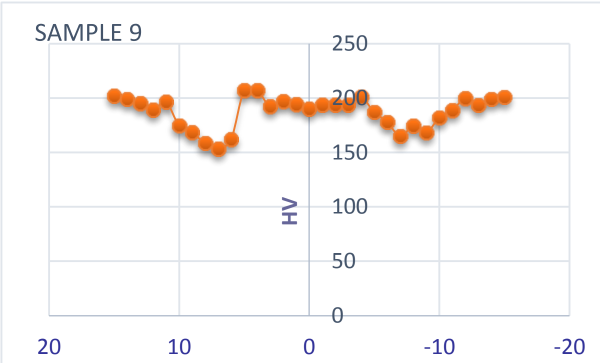
Distance from weld center in (mm).
Figure 12: Shows the variation of micro-hardness at welding speed 3(mm/sec), wire feed 5(m/min) and current 110(Amp).



Distance from weld center in (mm).
Figure 13: Shows the variation of micro-hardness at welding speed 5(mm/sec) wire feed 3(m/min) and current 140(Amp).



Distance from weld center in (mm)
Figure 14: Shows the variation of micro-hardness at welding speed 3(mm/sec), wire feed 4(m/min) and current 140(Amp).



Distance from weld center in (mm).
Figure 15: Shows the variation of micro-hardness at welding speed 4(mm/sec), wire feed 5(m/min) and current 140(Amp).

6.Conclusions

The Tagushi theory, the optimization (OptiY program/Evolutionary Algorithms) and Minitab program are used to obtain optimal welding parameters with the variance was analyzed and the following were concluded:
1- Welding regions are greatly affected by the amount of electrical current used in the welding process. where it was found that the increase in current leads to an increase in the amount of tensile strength of the material. The increase in TS is due to the appropriate heat generated and the appropriate wire feeding.
2- Heat-Affected zone (HAZ) region there is a growth process for the crystalline granules more than others, thus the percentage of crystalline boundaries decreases, which leads to the generation of relatively little hardness. Also, the melting area is the area most affected by the inputs, where the amount of hardness changes to increase more than the base rate in some cases when increasing The welding current goes down in other cases.
3- Effect hardness and tensile strength in the welding area are greatly influenced by the welding speed used during

welding. Where the increase in welding speed leads to a relatively high specification of that region.
4-The effect of the input welding wire feed values on the welding region, specifications are largely dependent on the welding current and welding speed values chosen.

References

[1] Satyaduttsinh P. Chavda, Jayesh V.Desai, and Tushar M.Patel, (2014), "A Review on Optimization of MIG Welding Parameters using Taguchi’s DOE Method", International Journal of Engineering and Management Research, Vol.4, Issue 1.
[2] Rohit Chopra, (2015), " Optimization of Process Parameters During Multipass Metal Inert Gas Welding of SS 304 Stainless Steel", Master of Engineering in Production Engineering, Mechanical Engineering Department Thapar University, Patiala.
[3]https://www.investopedia.com/terms/t/taguchi-methodof-qualitycontrol.asp, [Accessed August 2, 2019].
[4] I. Uslu, H. Comert and M. Ipek, (2007), " A comparison of borides formed on AISI 1040 and AISI P20 steels", Materials Science and Engineering Volume28, Issue 6.
[5]https://www.instron.us/our-company/library/test-types/tensile-test, [Accessed 22,2020].
[6]https://www.corrosionpedia.com/definition/621/hardness-test-material-science, [Accessed 3,2020].