70(10A): 254-259; 2022. DOI: 10.18311/jmmf/2022/32760

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

Optimization of Gas Metal Arc Welding Process Parameters on Structural Steel Plates by Taguchi Method

Praveen Math[1] and B.S. Praveen Kumar[2]

[1]*Assistant Professor, School of Mechanical Engineering, REVA University, Bangalore, Research Scholar, Dept of Mechanical Engg, Govt Engg college, Ramanagar.*
[2]*Associate Professor, Govt. Enng. College, K.R. Pete*

Abstract

Steel welding is one of the most contentious academic topics nowadays. Shielded metal gas welding techniques' impact on the welding of AISI1040 steel have been qualitatively investigated (MIG and TIG). The experimental layout must be developed using the Taguchi approach. Arc voltage, arc current, welding speed, nozzle to work distance, and gas pressure have all been found to have an effect on weld quality. The backing plate's thickness as well as the plate's thickness both matter. A trial design based on an orthogonal array is used to create weldments. To determine how successfully the weldments were welded, a set of tests are performed on them. ANOVA is used to assess the suitability of the data. The computed result is used as a contribution from each parameter to obtain the optimum values for fault minimization. Weldments are examined using an angle beam test, and the outcomes are assessed using ultrasound testing (UT). The presence of faults in the tested specimens, such as LOP, LOF, Blowholes, and Cracks

Keywords : *Gas Metal Arc Welding (GMAW), Weld Dilution, Regression Analysis*

1.0 Introduction

Hot cracking may happen if the amount of ferrite in the weld is not under control. The issue is resolved when a deposition electrode is employed because a little quantity of ferrite is deposited in the weld metal. Although practically any metal can be joined using TIG (gas tungsten arc welding), it is frequently employed for nonferrous metals. Applications for carbon steel are limited by the availability of cheaper steel welding techniques like gas metal arc welding (MIG) and shielded metal arc welding (SMAW) (SMAW). Welds made with this method may be ductile, robust, and corrosion-resistant. AISI1040 steel with the following chemical composition was utilised in this project: C 0.370.44; Mn 0.60-0.90; P 0.40 (max); S 0.50. (max). This material is used to create axles, shafts, lightly stressed gears, and other parts for agricultural, earthmoving, and material handling equipment. The key determinants of weld quality, which are closely correlated with the kind of welding and process conditions, are the mechanical characteristics of the weld metal and the heat affected zone (HAZ). Bead geometry variables like heat affected zone, bead width, bead height, penetration, and area of penetration are greatly influenced by welding process parameters like welding speed, welding current, shielding gas flow rate, voltage, arc travel speed, contact tip - work distance, type of shielding gas, and so on. These parameters also have a significant impact on mechanical properties like tensile strength and hardness.

This technique uses ultrasonic testing to assess weld faults without actually hurting the welds. Ultrasonic flaw identification has long been the preferred non-destructive testing method in welding applications. Because of its safety, accuracy, and simplicity, ultrasonic inspection has become the most sophisticated inspection technique. The significance of online weld pool monitoring for flaws such as lack of fusion (LOF), porosity, undercutting, and inclusion – which are formed in proper TIG and MIG settings – is emphasised even though Stares [1] concentrated on mild steel and stainless steel for this study. Jung [2] describes how to pick the process parameters to get the optimal weld pool shape in stainless steel. Tarng [3] uses Taguchi method; weldability of ferrous metals, which is inversely correlated to steel hardenability, determines the chance of martensite formation during welding. Ferrous metals, including AISI1040, are prone to deformation because of their high coefficient of thermal expansion. Some of these alloys are prone to fracture and have poor corrosion resistance. To predict the ideal setting for each welding process parameter, techniques for detecting TIG welding process parameters are investigated on mild steels. For the purpose of optimising the bead geometry of pulsed TIG welding on 304L stainless steel, Giridharan [4] created and tested mathematical models. The Taguchi technique, which served as the basis for our study, was thoroughly outlined by Ross [5]. There is a dearth of study on AISI 1040 steel utilising the Taguchi methodology and defect detection using ultrasound testing, according to the literature. Many researchers have worked on stainless steel using different gas shielded arc welding processes.

2.0 Experimentation

The base of the research consists of 2mm and 4mm thick AISI 1040 steel plates bonded together by DCSP, TIG, and MIG welding methods. The samples have dimensions of 100 mm ´ 55 mm ´ 2 mm and 100 mm ´ 55 mm ´ 4 mm, respectively. Welding speed, nozzle to work distance, gas pressure, plate thickness, and backing plate thickness are process parameters for the experiment. Optimal parameter ranges are chosen from well-known welding publications [7, 8], and values in between the ranges are chosen, i.e., two values are required.

For testing, a L8 orthogonal array was used. The total of seven variables requires two experiments for a perfect analysis. On the other hand, carrying out such a vast number of tests is unfeasible, time-consuming, and expensive. The evaluation of TIG welding requires a total of 16 trials because the research is conducted using a L8 orthogonal array, which calls for a set of 16 tests. 16 MIG welding assessment exams were also completed. In the experiment described, TIG welding of AISI 1040 requires two levels of process variable selection, and welding of the coupons is carried out by choosing these limitations using typical data found in the literature (Table 1).

Table 1: Welding Parameters

Thickness	02 mm	04 mm
Groove pattern	sq	v
Electrodesize	03 mm	03 mm
Size of Filler rod	01.3 mm	03.4 mm
Nozzledimension	09.1 mm	09.1 mm
flow rate of Gas	08l/min	011 l/min
Shielded gas-type	Ar	Ar
Currentrange	056 A	075 A
No of passes	1.0001	1.0=111

Responses are acquired by employing the NDT method (ultrasound testing). The test is administered using the test items. A notched plate made of the same material is used to construct the Distance Amplitude Curve after the device has been calibrated, with the DAC drawn at echo levels of 80%, 40%, and finally 20%. If the echo crosses the curve, a problem exists that needs to be looked into. To acquire echo and find a flaw, the angle probe needs to be positioned so that the crystal faces the weld zone. On both the RHS and LHS sides of the weld, the probe is pushed in a zigzag motion from the weld centre line to the heat-impacted zone (HAZ). The beam path (BP/SP), surface distance (SD), and depth (D) are all determined. The impacts of factors are known in the form of contribution, as indicated in Tables 2 and 3, and ANOVA is used to assess the sufficiency of the data pertaining to the defect (s).

The distribution of lack of penetration (LOP) and underfill for various L7 orthogonal array configurations is depicted in Figures 1 and 2.

The image shows a typical ultrasonic scan of 5mm AISI1040 steel plate coupons that have been TIG welded. TIG welding employs echo signalling at a distance of 32mm from the edge of the work piece.

Figures 1 and 2 show the distribution of lack of penetration (LOP) and underfill in L7 orthogonal arrays under different conditions.

3.0 Results and Discussions

There are two steps at which the experimentation and coupon welding are completed. The standard data from the literature was used to choose these boundaries (Table 4).

Tables 5 and 6 show the LOP and underfill results, and MIG welded coupons go through the same ANOVA procedure as TIG welded coupons.

The distributions of the lake of penetration (LOP) and underfill for various L7 orthogonal array settings are shown in Figures 4 and 5.

Table 2: Lack of penetration in welding-ANNOVA approach

Ranges	SOS (SSxi)	D.O.F (n-1)	Mean of SSxi = SSxi/D.O.F	Fisher ratio F=M.SSxi/M.SSE	Contribution (%)
x1	105.5	1.	105.7	21.0421	-
x2	45.37	1.	45.29	9.1419	0.2449
x3	2673.04	1.	2673.14	535.1123	-
x4	7.5626	1.	7.5625	1.5121	-
x5	1785.08	1.	1785.12	357.0123	9.61
x6	13398.016	1.	13398.11	2679.6145	71.99
x7	473.02	1.	473.03	94.6123	2.51
/SSE = 37.6015		8.0	SSE/8.0=5		Total = 84.42
iSST = 18527.77					Others = 16.58

Table 3: ANNOVA approach Under fill in TIG

Para- meters	SOS (SS_{xi})	(n-1)	Mean of SSxi = SSxi/D.O.F	Fisher Ratio F=M*(SSxi)/SSE	Contribution (%)
x1	60.36	1.	60.36	134.5026	-
x2	187.33	1.	187.36	426.6275	45.50
x3	39.81	1.	39.73	88.3176	-
x4	16.37	1.	16.37	44.0421	-
x5	11.09	1.	11.08	24.4643	2.51
x6	97.03	1.	97.03	213.0719	22.79
x7	0.064	1.	0.068	0.1419	0.017
SSE = 3.51		8.	SSE/8 = 0.484		Total = 70.920
SST = 419.4375					Other = 29.11

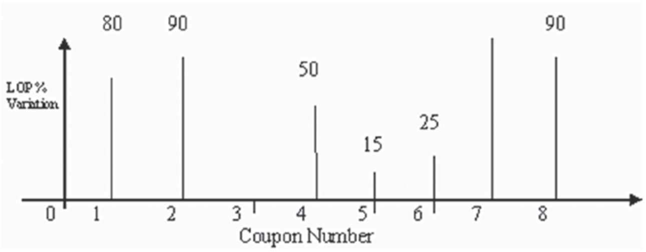

Figure 1: LOPvalues Distribution

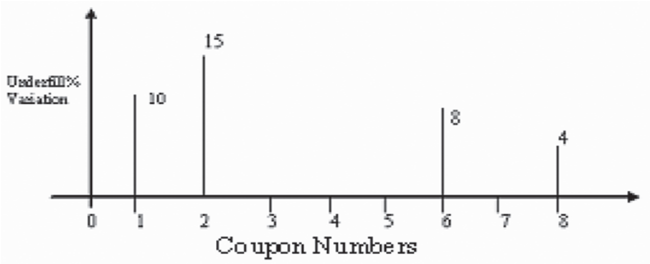

Figure 2: Distribution under fill for various conditions

Figure 3: A typical TIG welded coupon with porosity and overlap

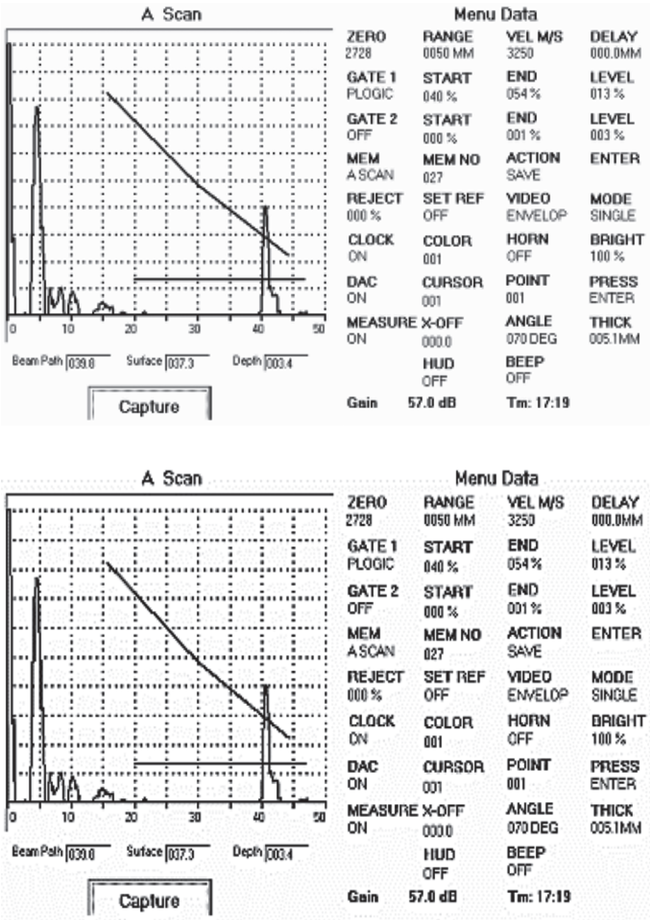

Figure 4: TIG welding has a lack of penetration at 41mm from the work piece's edge

Table 4: Parameters selection

Work piece thickness	2.mm	4.mm
Type of Groove	Square	V-type
dimension of Electrode	0.97mm	0.97mm
Voltage value	024 V	027 V
flow rate of gas	9.0l/min	10.0 l/min
Shielded gases type	CO2	CO2
Current range	121 A	145 A
Number of Passes	01	01
Feed rate	020 i.p.m	014 i.p.m
Distance between Nozleand work piecedistance	014	019

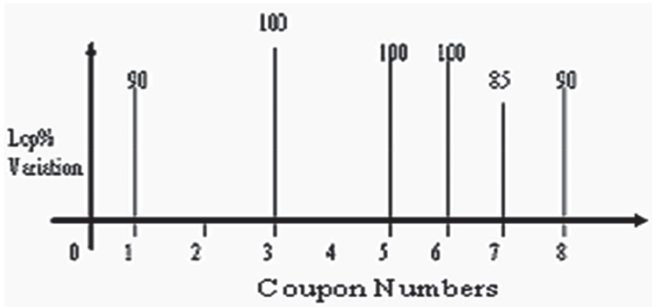

Figure 5: The lack of penetration is distributed in MIG welding

Table 5: Lack ofpenetration

Values	SOS (SSxi)	D.O.F.	Mean value of SSxi M.SSxi = SSxi/D.O.F.	Fisher ratio F = M. (SSxi)/M.SSE	Contribution (%)
X1	45.56	1.	45.56	22.0891	0.13
X2	8601	1.	8601.99	4170.4	32.39
X3	68.01	1.	68.14	32.77	0.27
X4	1.51	1.	1.499	0.75799	0.003
X5	9168.02	1.	9168.0599	4444.4753	34.56
X6	264.05	1.	264.0597	128.0123	0.89
X7	8326.57	1.	8326.61	4036.5386	31.47
S.S.E. = 16.5885		8.2	SSE/8 = 2.186		Total = 99.899
SST = 26493					Other = 0.09

Table 6: Under fill – ANOVA approach

Process Para- meters	S.O.S.	D.O.F.	Mean range of SSxi M.SSxi = SSxi/ D.O.F	Fisher Ratio F = M. SSxi/M.SSE	Contribution (%)
X1	11.73	1.	11.73	316.5991	21.33
X2	5.4049	1.	5.4099	145.9001	9.49
X3	2.8084	1.	2.8087	75.7246	4.89
X4	2.8076	1.	2.8043	75.7246	4.76
X5	5.4033	1.	5.4011	145.9001	9.71
X6	11.81	1.	11.67	316.5991	20.45
X7	16.6097	1.	16.6099	448.1943	29.51
SSE = 0.23899		8.	SSE/8 = 0.093742		Total = 99.97
SST = 56.7971					Others = 0.23

Figure 6: Weldzone porosity and underfill

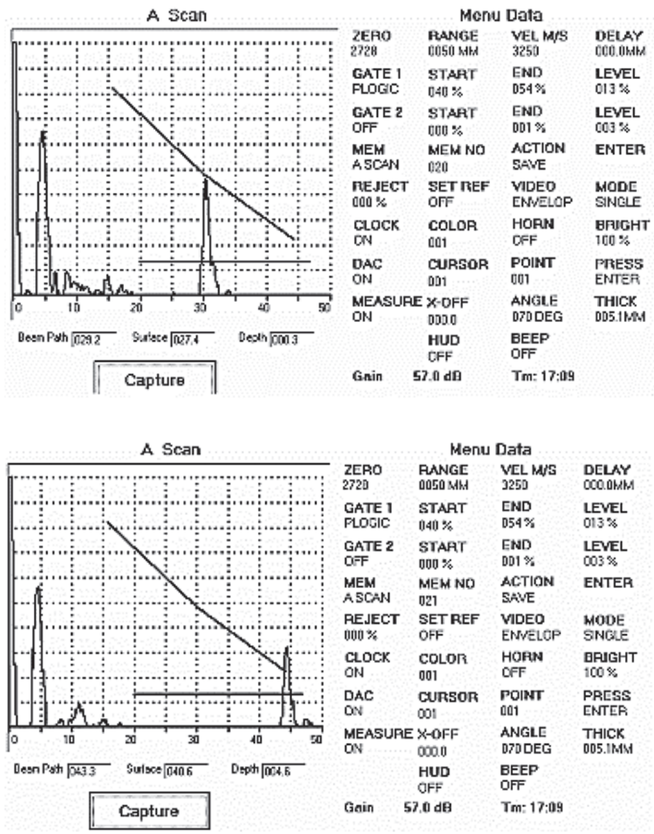

Figure 7: In MIG welding, an echo at 45 mm from the edge of the work piece indicates insufficient penetration

Figure 7 depicts an example of an ultrasonic scan of MIG-welded coupons on 5mm AISI1040 steel plate. Echo signalling happens 30 mm from the edge of the work piece when MIG welding.

4.0 Test Results Analysis

High welding speed led to underfill that might be as large as 8mm2 in TIG welding, but low current trials increased the percentage of variance of LOP in TIG and MIG welding. Additionally, MIG welding studies with a near nozzle tip distance revealed a lack of penetration overlap relative to blow holes and porosity can be detected in MIG welding at moderate speeds and low current levels; however, under fill is not always visible at high current levels. Because of its excellent weldability, AISI 1040 can be used successfully in both TIG and MIG welding techniques; however, in TIG welding, operator competency has been shown to be more important than process variables.

A gas flow rate of 9-10 l/min can achieve perfect shielding; in TIG welding, plate thickness has a large influence on lack of penetration, and current has a 45 per cent influence on under fill. Gas pressure can account for up to 35% of the lack of penetration in MIG welding, while current accounts for 31% of the LOP.

6.0 Conclusion

For MIG welding 3mm and 5mm plate, the suggested current values are 150A and 180A, respectively, to avoid LOP. The current TIG values for 3mm and 5mm plates are 65A and 80A, respectively. The MIG weld speed should be less than 0.45 m/min for 3mm plate and less than 0.35 m/min for 5mm plate, respectively.For 3mm plates, the nozzle tip distance should be around 10mm, and for 5mm plates, it should be around 12mm. The Taguchi technique has been shown to be reliable for designing experiments for quality assessment. You can cut the cost of your research by selecting the right orthogonal array for your studies.

References

[1] I.J. Stares, C. Duffil, J.A. Ogilvy, C.B. Scruby. 1990. On-line weld pool monitoring and defect detection using ultrasonics. *NDT International.* 23(4): 195-200.

[2] S.C. Juang, Y.S. Tarng. 2002. Process parameter selection for optimizing the weld pool geometry in the Tungsten inert gas welding of stainless steel. *Journal of Materials Processing Technology.* 122(5): 33-37.

[3] Y.S. Tarng and W.H. Yang. 1998. Optimization of the weld bead geometry in TIG process parameters for the welding of AISI 304L stainless steel sheets. *The International Journal of Advanced Manufacturing Technology*. 14: 549-554.

[4] P.K. Giridharan and N. Murugan. 2009. Optimization of Pulsed TIG process parameters for the welding of AISI 304L stainless steel sheets. *The International Journal of Advanced Manufacturing Technology.* 40: 478-489.

[5] Chih-Chun Hsieh; Dong-Yih Lin; Ming-CheChen; WeiteWu, Microstructure, Recrystallization, and Mechanical Property Evolutions in the Heat-Affected and Fusion Zones of *the Dissimilar Stainless Steels. Materials transactions* 2007, vol 48, 2898-2892.

[6] SrinivasaRao P.; Gupta O.P.; Murty S.S.N.; Koteswara Rao A.B., Effect of process parameters and mathematical model for the prediction of bead geometry in pulsed GMA welding. *International Journal of Advanced Manufacturing Technology*, 2009, vol 36, 1-10.

[7] Palani P.K.; Murugan N.; Selection of parameters of pulsed current gas metal arc welding. *Journal of Materials Processing Technology,* 2006,vol 172,1-10.

[8] Arunkumar N.; Duraisamy P.; Veeramanikandan S., Evaluation Of Mechanical Properties Of Dissimilar Metal Tube Welded Joints Using Inert Gas Welding. *International Journal of Engineering Research and Applications* 2012, vol2, 1709-1717.

[9] J.P. Ganjigatti, D.K. Pratihar. 2008. A Modelingof the MIG welding process using Statistical Approach. *The International Journal of Advanced Manufacturing Technology*. 35: 1166-1190.

[9] Harshal K. Chavan, Gunwant D. Shelakeand Dr. M.S.Kadam, "Finite Element Model To Predict Residual Stresses in MIG Welding", *International Journal of Mechanical Engineering & Technology* (IJMET), Volume 3, Issue 3, 2012, pp.350-361, ISSN Print: 0976–6340, ISSN Online: 0976–6359.

[10] Harshal K. Chavan, Gunwant D. Shelake and Dr. M.S. Kadam, "Impact of Voltage on Austentic Stainless Steel for the Process of TIG and MIG Welding", *International Journal of Mechanical Engineering & Technology* (IJMET), Volume 1, Issue1, 2010, pp.60-75, ISSN Print: 0976–6340, ISSN Online: 0976–6359.

[11] I.J. Stares, C. Duffil, J.A. Ogilvy, C.B. Scruby. 1990. On-line weld pool monitoring and defect detection using ultrasonics. *NDT International*. 23(4): 195-200.

[12] S.C. Juang, Y.S. Tarng. 2002. Process parameter selection for optimizing the weld pool geometry in the Tungsten inert gas welding of stainless steel. *Journal of Materials Processing Technology*. 122(5): 33-37.

[13] Y.S. Tarng and W.H. Yang. 1998. Optimization of the weld bead geometry in TIG process parameters for the welding of AISI 304L stainless steel sheets. *The International Journal of Advanced Manufacturing Technology.* 14: 549-554.

[14] P.K. Giridharan and N. Murugan. 2009. Optimization of Pulsed TIG process parameters for the welding ofAISI 304L stainless steel sheets. *The International Journal of Advanced Manufacturing Technology*. 40: 478-489.

[15] A. Kumar, S Sundarrajan. 2008. Effect of welding parameters on mechanical properties and optimization of pulsed TIG welding of Al-Mg-Si alloy. The *International Journal of Advanced Manufacturing Technology.*

[16] J.P. Ganjigatti, D.K. Pratihar. 2008. A Modelingof the MIG welding process using Statistical Approach. The *International Journal of Advanced Manufacturing Technology.* 35: 1166-1190.