INVESTIGATING THE INFLUENCE OF WELD PENETRATION AREA TO PREVENT EXCESSIVE REINFORCEMENT AT A GAS TUNGSTEN ARC WELDING USING TAGUCHI MODEL

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ABSTRACT

Achieving a joining process with high weld quality not affected by weld defect such as excessive reinforcement, is the bed rock of welding activity. The purposes of this research is to use a performance measure target value for weld penetration area on performance measures as it affects excessive penetration prevention, using Gas Tungsten Arc Welding (GTAW) process. Taguchi robust design used in this research, is aimed at finding controllable process parameter settings such as welding current (I), welding voltage (v), welding speed (s) and shielding gas flow (SGF), for a minimal effect of noise. Controllable variables established in the ranking of 4, 3, 2, 1, were shielding gas flow rate (SGF) 17 lit/min, welding current (I) 155.3 amperes, welding speed (s) 96mm/min and welding voltage 17volts, using the larger is better criterion. The largest effect and least effects of weld penetration area with an optimal value of 26.42 mm² to prevent excessive penetration were welding current and welding speed respectively with optimal heat input ratio value of 21.5KJ/min.

KEYWORDS: Taguchi Methods, L9 (3⁴) Orthogonal Array, Weld Penetration Area, Heat Input Ratio, Excessive Reinforcement, Gas Tungsten Arc Welding

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INTRODUCTION

Weld defect presence in welded joint, compromises weld standard and quality, hence preventing its occurrence cannot be over emphasized in any welding process (Ali et al, 2009). Excessive reinforcement presence in welded joints is an economic waste (Arkbar et al, 2020). It occurs due to too wide gap in the root of a parent metal to be welded. The root face may either be too small in dimension and can create stress raisers in a welded joint (Nguyen et al, 1998). To eradicate excessive reinforcement defect in welds, a shielding gas torch that is moderate in size for the thickness of the mild steel plate to be used, should be considered (Ramachandra, 2016). Adequate welding current (as a too high welding current can cause excessive reinforcement) should be used (Osayi et al, 2015). There should also be adequate welding speed at the welding technique used (Walsh, 2017). Gas Tungsten Arc welding (GTAW) process is used in this research where the shortest possible arc length is maintained so as to achieve welds that are sound and the melting of the filler rod into the weld pool is done at a slow travel speed to avoid solidification that is too quick and also to prevent excessive reinforcement (Jeyaprakesh et al, 2015). For the purpose of the research, the groove angle is 60° for the filler metal deposited forming stringer weld bead to produce welds free from excessive reinforcement (Kishore et al, 2010). Four factors were determined and used, these factors were welding current, welding speed, welding voltage and shielding gas flow rate. The performance of the factors were predicted with individual factor contributions, relative factor interactions, analysis of variance (ANOVA) and

signal to noise analysis and the results were validated using the Taguchi robust design.

MATERIALS

The materials used in this research for conducting the experiment for the welding runs were: oxyacetylene cutting gas, mild steel plates and Gas Tungsten Arc welding machine.

Figure 1: Oxyacetylene Cutting Gas.

Figure 2: Butt Joint V-Groove.

Figure 3: Preparation of Root Gap Before Tacking.

Methods

In order to achieve the objectives of the research, the following methods were used;

1. Selection of input process parameter/ and their levels

2. Selection of the response parameters
3. Selecting a Design matrix
4. Predicting the performance characteristics/analysis of signal –to - noise ratio (SN ratio)
5. Analysis of variance (ANOVA)
6. Taguchi validation using analyzed Taguchi design options

Methods

Using the Gas Tungsten Arc Welding (GTAW) process, restraints were used to clamp the base metal of 10mm thickness mild steel plate in a flat position (1G) in order to prevent distortion during welding and movement of the base metal in the direction of the weld. Weld runs, which were nine (9) experimental runs, were carried out and used to analyze and evaluate input – output results of the investigation

Table 1: Input Process Parameters

Input Process Parameters	Notation	Levels	
		High	Low
Welding Current	I	180	100
Welding Voltage	V	20	14
Welding Speed	S	110	90
Shield Gas Flow	SGF	19	10

Table 2: Response Parameters

Response	Units	Ranges
Weld Penetration Area (WPA)	mm ²	20 – 27
Heat Input ratio (HIR)	KJ/min	20 – 26

Table 3: Weld Schedule

Weld Scheduled	Specification
Experimental Mins	Nine(9)
Weld type	Butt weld/V-groove
Welding technique	Gas Tungsten Arc Welding Process
Weld current	100 -180 amperes
Weld voltage	14 – 20volts
Welding speed	90 – 110
Shielding gas flow	10-19
Groove angle	60 ⁰
Shield gas	Argon Gas (100%)
Plate thickness of mild steel plate	10mm thickness

Table 4: Experimental Design Matrix

S/N	Welding current	Welding voltage	Welding speed	Shielding gas flow	Heat input KJ/min	Weld penetration (mm ²)	
1.	1	1	1	1	20.90	20.50	20.50
2.	1	2	2	2	20.95	20.75	20.75
3.	1	3	3	3	21.00	21.0	21.00
4.	2	1	2	3	21.05	21.25	21.25
5.	2	2	3	1	26.50	21.75	21.75
6.	2	3	1	2	26.45	26.40	26.30
7.	3	1	3	2	26.70	26.60	26.60

8	3	2	1	3	21.30	26.70	26.70
9	3	3	2	1	26.35	26.24	26.24

Predicting the performance characteristics using signal to noise ratio

$$SN_{\max} = -10 \log \left[\left[\frac{1}{N_i} \sum_{\mu=1}^{N_i} \frac{1}{y_{\mu}^2} \right] \right]$$

$$SN_i = 10 \log \frac{y_i^2}{S_i^2}$$

Where $\bar{y}$ = the mean value of performance characteristics

S_i = the variance

S_i^2 = the standard deviation

$$\bar{Y}_i = \frac{1}{N_i} \sum_{\mu=1}^{N_i} Y_{i\mu}$$

$$S_i^2 = \frac{1}{N_i - 1} \sum_{\mu=1}^{N_i} (Y_{i,\mu} - \bar{Y}_i)^2$$

i = experimental number

μ = trial number

N_i = Number of trials for experiment i

$SN_{\max}$ = maximized signal to noise ratio for larger is better criterion

Table 5: Taguchi Design for Weld Penetration Area

WELD PENETRATION AREA					
Input Process Parameters	Levels				
	1	2	3	Delta	Rank
Welding voltage	26.47	26.50	26.30	0.19	3
Welding current	26.35	26.23	26.68	0.45	1
Welding speed	26.65	26.31	26.30	0.34	2
Shielding gasflow	26.41	26.52	26.34	0.19	4
Rank					

Rank Rank

4 1 2 3 1 2 3 4

SGF I S V I S V SGF

Factors that affect the performance characteristics in ranking are;

- Rank 1 welding current (largest effect)
- Rank 2 welding speed
- Rank 3 welding voltage
- Rank 4 shielding gas flow (least effect)

It was observed that welding current had the largest effect on weld penetration area and shielding gas flow had the least effect on weld penetration area.

Table 6: ANOVA Table for Weld Penetration Area (mm²)

Source	Weld Penetration Area (mm ²)				
	DF	Adj SS	Adj MS	F-value	P-Value
	7	3.6145	0.5164	1.080	0.631
	1	0.0991	0.0991	0.728	0.210
	1	0.4646	0.4646	0.970	0.504
	1	0.5593	0.5593	1.170	0.475
	1	0.0349	0.0349	0.830	0.070
	1	0.1100	0.1100	0.715	0.230
	1	0.6001	0.6001	1.260	0.463
	1	0.0304	0.0304	0.843	0.060
	1	0.4767	0.4767	0.001	0.001
	8	4.0912	0.002	0.002	0.002

Figure 5: Main Effects Plot for SN Ratios (Weld Penetration).

DISCUSSIONS

From Table 7: showing Taguchi design for weld penetration area, the optimal value for weld penetration area was recorded as 26.4mm². Current ranking as rank 1, indicated that welding current had the highest effect on weld penetration area. When welding current is too high and excessive during GTAW process, excessive reinforcement will occur. Melting the filler rod into the weld pool using excessive welding current can lead to occurrence of reinforcement defect. Welding current applied to produce the weld penetration area of 26.42mm² was 155.3 amperes. So applying welding current of 155.3 amperes at a speed of 96mm/min, welding voltage of 17volts and shielding gas flow of 17lit/min prevented excessive reinforcement. A heat input ratio of 21.05 KJ/min applied during the experiment yielded a weld free from excessive reinforcement.

CONCLUSIONS

Optimized values of input process parameters obtained from current with a value of 155.3 amperes, voltage with a value of 17 volts, speed with a value of 96mm/min and shielding gas flow of 17lit/min should be used at a GTAW process on a 10min mild steel plate, prevented excessive reinforcement. Optimized values obtained from the two critical dimensions

used in this study namely: weld penetration area with a value of 26.42mm^2 (maximized) and heat input ratio value of 21.05KJ/min should be used at a GTAW process on a mild steel plate with a thickness of 10mm for in order to eliminate the presence of excessive reinforcement in welds produced.

- A defined heat input and weld penetration area that will eradicate excessive reinforcement in welds at a GTAW process using a 100% argon gas has been established.
- Optimal values of input process parameter as well as their responses have been established :Input process parameter Welding Current (I) = 155.3amperes, Welding Current (v) = 17 volts , Welding Speed (s) = 96mm/min, Welding Shielding Gas Flow rate (SGF) = 17lit/min. **Responses:** Heat input = 21.05KJ/min ,Weld penetration area = 26.42mm^2 ,Using these area optimal values, services life of welds will be extend by weld quality and excessive reinforcement is avoided.
- Excessive reinforcement defect can now be eradicated and a data bank to eradicate excessive reinforcement defect in a GTAW process has been established.

CONFLICT OF INTEREST

There is no conflict of Interest associated in this work.

REFERENCES

1. Osayi, A.O., Egbe, A. P and Lawal, S.A. (2015) Optimization of process parameters of manual Arc welding of mild steel using taguchi method, *American Journal of mechanical engineering* 3(1): 93 – 97
2. Kishore, K., Gopal, P.V. and Veladri, K (2010) Analysis of defects in gas shielded Arc welding of International Journal of Engineering and Applied Sciences 59(1):17-26
3. Kumar, M. Naveen, Sriram. Venkatesh, and M. MANZOOR Hussain. "Experimental investigation on influence of process parameters in selective laser sintering on roundness using taguchi medthod." *International Journal of Mechanical and Production Engineering Research and Development* 7.6 (2017): 45-52.
4. Jeyaprakash, N., Haile, A. and Arrunprasath, M (2015) The parameters and equipmentsusedin TIG welding: A review *International Journals of Engineering and Sciences* 4(2): 11-20
5. Walsh (2017) Influence of weld porosity on the integrity of marine structures
6. Ramachandran (2016) Investigation of metallurgical and mechanical properties of laser welded high strength low alloy steel.
7. Sivaraman, B. "Optimization of grinding parameters in austenitic stainless steel AISI 317L using taguchi method." *International Journal of Mechanical and Production Engineering Research and Development* 8.2 (2018): 1033-1038.
8. Nguyen,T.N and Wahah,M.A.,(1998) The effect of weld geometry and residual stress on the fatigue of welded joints under combined loading. *International journal of Material Process Technology* 77(1),201-208
9. Francis, Vishal, and Ashutosh Dubey. "Application of Taguchi and response surface methodologies for surface roughness in face milling operation." *International Journal of Mechanical and Production Engineering Research and Development* 3.2 (2013): 213-220.
10. Ali,A.,andSanuddin,A.,(2009) Characterization of ASTM A516 Grad70 fusion welded joints. *International journal of Reviews of mechanical Engineering* 3(5),531-542

11. Chu, NGOC-HUNG, and V. D. Nguyen. "The Multi-Response Optimization of Machining Parameters in the Ultrasonic Assisted Deep-Hole Drilling Using Grey-Based Taguchi Method." *Int. J. Mech. Prod. Eng. Res. Dev* 8 (2018): 417-426.
12. Akbar,J.,and Mohsen.R.,(2020) Stress intensity factor for welded butt joints with undercut and inclined lack of penetration defects considering the effects of joint shape *International journal of applied and computational mechanics*.6(4),878-898