MULTI-OBJECTIVE OPTIMIZATION OF ACTIVATED TIG WELDING PROCESS PARAMETERS USING PROMETHEE

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Abstract
Activate TIG (Tungsten Inert Gas) welding is used to enhance the weld penetration with high degree of quality. In A-TIG welding fluxes are mixed with acetone and applied on the weld surface before welding. In this work, A-TIG welding process was used on mild steel of 10 mm thick plate . Experiments are performed to check the effect of various welding parameters on weld penetration and weld bead width during activated TIG welding. Taguchi method with L9 (9) orthogonal array is used for finding out the relationship between various responses (weld penetration and weld bead width) and welding parameters (welding speed, welding current and fluxes). For optimization Preference Ranking Organization method for Enrichment of Evaluations (PROMETHEE) method is adopted. In the present study A-TIG welding process parameters are Optimized by PROMETHEE.

Keywords:Activated Tungsten Inert Gas welding , Taguchi, Optimization, PROMETHEE Method.

I. Introduction

A-TIG technique makes it possible to intensify the conventional TIG practices for joining the thickness up to 10 mm in single pass, high penetration welds, with no edge preparation, instead of multipass procedures [1]. A-TIG welding process enhance the weld penetration which increases the weld production. Various fluxes like CaO, CrO3, Fe2O3,MnO2, TiO2, MoO3, and SiO2 are used for the A-TIG welding processes for different materials. In A-TIG, the temperature coefficient of surface tension on the molten pool changed from a negative to a positive value. The surface tension gradient introduces reversal Marangoni convection in the molten pool. In this condition, the fluid flow of the molten pool surface easily transfers from the weld pool edge to the centre [1]. Taguchi method is a powerful tool for designing high quality systems which has been used in this study.

In ATIG welding the flux is mixed with the acetone and converted into paste, provide good spreadability and convertibility. Smooth and clean surface were achieved before using oxide base flux. The high penetration depth and low bead width were achieved at different values of current. It was also found that there was reduction of the angular distortion using weld parameters [2].

In case of conventional TIG welding, angular distortion increases continuously with increase in current. It is clear that for any value of current maximum distortion in ATIG is quit lower than the all the value of TIG welding. So distortion is not the problem against increase in current density [4]. Jay J. Vora et al. [5] studied the effect of fluxes on Low Activation ferritic/Martensitic steel plate, full penetration was achieved due to reversed Marangoni effect. Paulo et al. [7] concluded that without activating flux is very less penetration is achieved with high bead width. High penetration is achieved by applying silicon dioxide as a flux . Wu Pan et al [8] noted that with higher welding speed penetration achieved decreases. Welding speed more than 200 mm/min arc fluctuates very much and this leads to lower penetration, bad quality weld. Kuang-Hung Tseng et al. [9] investigated that heat energy required for TIG penetration is reduces by applying thin layer of activated flux on the weld surface Tanaka,et al.[10] reported work on construction of arc on ss304,10mm plate by applying Tio_2 as a flux . Penetration depth increases sharply with increases the coating density of Tio_2 flux and remain constant when coating density greater than 1 mg/cm^2. Lahaet.al.[14] pointed the problem with diameter of electrode tip. In TIG welding people use electrode with tip having 2.4mm diameter. Same can be used in ATIG welding without any problem except silicon dioxide flux. In case of silicon dioxide flux current density is very high, so tip with 2.4mm diameter wears out rapidly as well as affects the weld quality. So it is better to go for 3.2 mm diameter. Tip with 3.2 mm diameter can sustain the high current value. So to be on safer side with all the fluxes electrode with 3.2 mm tip diameter is used.This shows that for desired penetration particular value of coating density is essential. PROMETHEE is proved to be the best method for ranking and selecting an alternative from finite range of data. The obtained responses are neither required to be normalized nor required to transform to a common dimensionless scale[11]. Various version of the PROMETHEE method has been developed such as PROMETHEE I, PROMETHEE II, PROMETHEE-GAIA, and PROMETHEE V. Among different version PROMETHEE II is most frequently used as it enables a decision maker to find a full-ranked vector of alternatives. Kazem et al. [12] apply PROMETHEE method for selection on best radial basic function which effectively solved 2-dimensional heat transfer equation based on Hermite interpolation.

In this study PROMETHEE II method is used for deciding best alternative from various available alternative of process parameter of A-TIG welding process. Ranking for various alternatives were obtained by net flow and this lead to selection of optimum process parameters.

II. Experimentation

For the experimentation 10 mm thick 150mm x 50 mm Mild steel plate is used as a base metal, whose chemical and mechanical compositions are listed in Table I and II. Activated flux of 40 micron particle size prepared in different combinations sets of SiO_2+CaO, SiO_2+TiO_2, MnO_2+Al2O_3. These powder mixed with methanol produce a paste, so it can be easily applied on the work piece surface. Different combination of flux are applied on to the surface of the joint to be welded. Methanol evaporates, leaving a layer of flux adhering to the surface of specimen having coating density of 5–6 mg/cm^2.

TABLE I MILD STEEL CHEMICAL COMPOSITION

Carbon	0.16-0.18 %
Silicon	0.40 % max
Manganese	0.70-0.90 %
Sulfur	0.040 % max
Phosphorus	0.040 % max

TABLE II MILD STEEL PROPERTY

Max stress	400-560 N/mm^2
Yield stress	300-440 N/mm^2
0.2% Proof stress	280-420 N/mm^2
Elongation	10-14 % min
Max stress	400-560 N/mm^2

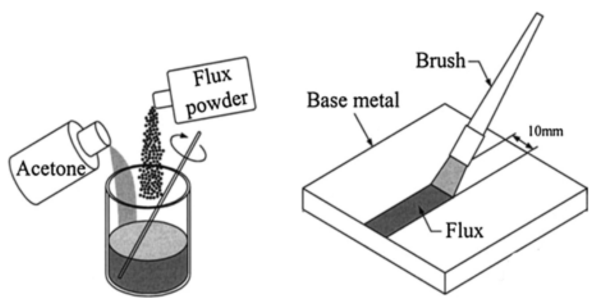

Figure1 Mixing and coating of Flux

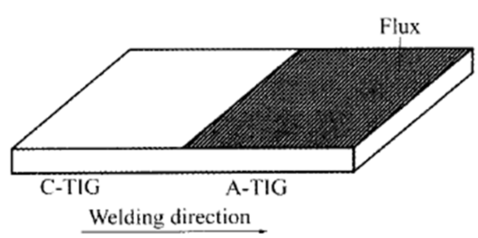

Figure 2 Activated TIG welding [13]

In the present study experiments are carried out based on various combination of welding speed, welding current and flux combination mentioned in table II. Experiments are planned by statistical method,Taguchi method for designing the parameters. Accordingly L9 matrix is selected having different combination of process parameter. Quality of welds analyzed through weld geometry. Table III show the combination of various process parameters based on which experiments were performed.

TABLE III WELDING PARAMETERS AND THEIR LEVELS

Parameter	Symbol	Level		
		1	*2*	*3*
Welding Speed(RPM)	V	150	180	210
Current (Ampere)	A	60	100	140
Flux	-	SiO_2+ CaO	SiO_2+Ti O_2	Al_2O_3+Mn O_2

TABLE VI L9 MATRIX AND EXPERIMENTAL RESULTS

STD	A: Current (ampere)	B: Speed (mm/min)	C: Flux	Penetration (mm)	Bead Width (mm)
1	60	150	1	2.16	5.1
2	60	180	2	3.16	7
3	60	210	3	2.1	4.8
4	100	150	2	2.8	7.2
5	100	180	3	1.9	5.8
6	100	210	1	2.5	6.4
7	140	150	3	2.3	5.5
8	140	180	1	3.1	6.4
9	140	210	2	2.36	5

Higher penetration depth is achieved in Activated TIG welding process due to reversal of meragoni convection [19]. Penetration and width of weld bead were measured using tool maker's microscope. Experimental results are shown in table III. These data were utilized for optimal parameter, combination required to achieve desired quality weld within the experimental domain.

III. Methodology of Promethee II

PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluations) has been used with success to solve many engineering problems [18]. The PROMETHEE II Multi-Criteria Decision Making method is composed of four steps as follows.

Step I

This step evaluate the each pair of possible decisions and for

each criterion, the value of the preference degree. Then the performance difference between each pair of alternative is calculated based on following formula

$$d_j(a, b) = g_j(a) - g_j(b) \quad (1)$$

Where gi(a) and gi(b) are performance of alternatives of a and b with respect to criterion j, and dj(a, b) denotes the difference between each performance. The preference functions used to compute these preference degrees are defined such as:

$$P_j(a,b)=F[d_j(a,b)] \quad (2)$$

Considering degree in normalized form $0 \le P_j(a, b) \le 1$

$P_j(a, b) = 0$ means no preference or indifference,

$P_j(a, b) \approx 0$ means weak preference

$P_j(a, b) \approx 1$ means strong preference, and

$P_j(a, b) = 1$ means strict preference

Step 2

This step consists in aggregating the preference degrees of all criteria for each pair of possible decisions. For each pair of possible decisions, required to compute a global preference index. Let C be the set of considered criteria and wj the weight associated to the criterion j. The global preference index for a pair of possible decision a and b is computed as follows:

$$\pi(a, b) = \sum_{j=1}^{k} P_j(a, b) w_j \quad (3)$$

Step 3

The third step, which is the first that concerns the ranking of the possible decisions, consists in computing the outranking flows. For each possible decision a, we compute the positive outranking flow $\varphi^{+}(a)$ and the negative outranking flow $\varphi^{-}(a)$ by the following equations.

$$\varphi^{+}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(a, x) \quad (4)$$

$$\varphi^{-}(a) = \frac{1}{n-1} \sum_{x \in A} \pi(x, a) \quad (5)$$

The larger the positive out ranking flow, better is the alternative. Similarly the negative out ranking shows the extent to which an alternative is dominated by all other alternatives. The smaller the negative out ranking flow, better is the alternative.

Step 4

The last step consists in using the outranking flows to set up a complete ranking between the possible decisions. The ranking is based on the net outranking flows. These are computed for each possible decision from the positive and negative outranking flows. The net outranking flow φ(a) of a possible decision a is computed as follows:

$$\varphi(a) = \varphi^{+}(a) - \varphi^{-}(a) \quad (6)$$

PROMETHEE II complete ranking is the defined: "a" is preferred over "b" when $\varphi(a) \geq \varphi(b)$,

"a" and "b" are indifferent when Ø(a)= Ø(b)

After comparing all alternatives, the alternative with highest Ø(a) can be considered as best alternative

IV. Result and Discussion

PROMETHEE method was used to obtain optimum combination of process parameter which will result in maximum penetration and minimum bead width. First step involves decision of the weightage of responses. Weightage selected for penetration and bead width are 0.6 and 0.4 respectively as per preference.

After selecting appropriate contribution, generate preference indices which consist of 9 alternatives with 3 criterions. Table VII to VIII shows the preference matrix for various criterions.

TABLE VII PREFERENCE INDICES FOR PENETRATION

Penetration	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	-	0	1	0	1	0	0	0	0
A2	1	-	1	1	1	1	1	1	1
A3	0	0	-	0	1	0	0	0	0
A4	1	0	1	-	1	1	1	0	1
A5	0	0	0	0	-	0	0	0	0
A6	1	0	0	0	1	-	1	0	1
A7	1	0	1	0	1	0	-	0	0
A8	1	0	1	1	1	1	1	-	1
A9	1	0	1	0	1	0	0	0	-

TABLE VIII PREFERENCE INDICES FOR BEAD WIDTH

Bead Width	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	-	1	0	1	1	1	1	1	0
A2	0	-	0	1	0	0	0	0	0
A3	1	1	-	1	1	1	1	1	1
A4	0	0	0	-	0	0	0	0	0
A5	0	1	0	1	-	1	0	1	0
A6	0	1	0	1	0	-	0	-	0
A7	0	1	0	1	1	1	-	1	0
A8	0	1	0	1	1	-	0	-	0
A9	1	1	0	1	1	1	1	1	-

Once the preference indices are generated, the matrix is multiplied with the corresponding weightages of the criterion. An aggregate preference index (π matrix) is prepared by matrix addition of the three criterion preference indices. Table IX shows the final aggregate matrix i.e. PI matrix.

TABLE-IX: FINAL AGGREGATE MATRIX: PI MATRIX

PI Matrix	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	-	0.4	0.6	0.4	1	0.4	0.4	0.4	0
A2	0.6	-	0.6	1	0.6	0.6	0.6	0.6	0.6
A3	0.4	0.4	-	0.4	1	0.4	0.4	0.4	0.4
A4	0.6	0	0.6	-	0.6	0.6	0.6	0	0.6
A5	0	0.4	0	0.4	-	0.4	0	0.4	0
A6	0.6	0.4	0	0.4	0.6	-	0.6	0	0.6
A7	0.6	0.4	0.6	0.4	1	0.4	-	0.4	0
A8	0.6	0.4	0.6	1	1	0.6	0.6	-	0.6
A9	1	0.4	0.6	0.4	1	0.4	0.4	0.4	-

After the PI matrix generated in flow and out flow was calculated based on above mention formula and base on those result net flow was calculated. Table X shows the result of inflow, out flow, net flow and corresponding ranking for various trials.

TABLE-X: CALCULATED IN FLOW, OUT FLOW AND NET FLOW AND CORRESPONDING RANKING

Trial	φ^+	φ^-	$\varphi(a)$	Rank
1	0.45	0.55	-0.1	7
2	0.65	0.35	0.3	2
3	0.475	0.45	0.025	4
4	0.45	0.55	-0.1	7
5	0.2	0.85	-0.65	6
6	0.4	0.475	-0.075	5
7	0.475	0.45	0.025	4
8	0.675	0.325	0.35	1
9	0.575	0.35	0.225	3

From table X, it can be seen that trail 8 has maximum net flow value thus welding parameter corresponding to trail 8 i.e. current 140 ampere , welding speed of 180 rpm flux combination SiO_2+CaO can be selected as best alternative which shows optimum value of penetration and bead width.

V. Conclusions

Activated flux is easy to apply and increased penetration capability in mild steel. Welding current and flux proportion are most effective parameters to increase the penetration. ATIG welding process parameters were optimized for mild steel joints to obtain desirable penetration and bead width .

PROMETHEE II method is used for deciding best alternative from various available alternative of process parameter of Activated TIG welding process. By employing the welding parameters, the PROMETHEE II calculation and the analysis are carried out using Excel spread sheets. Ranking for various alternatives were obtained by net flow and this lead to selection of suitable alternatives for process parameter. Ranking of alternatives provided that current 140 ampere , welding speed of 180 rpm , flux combination SiO2+CaO shows optimum value of penetration 3.1 mm and bead width of 6.4mm.

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