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OPTIMIZATION OF WELD STRENGTH OF ALUMINIUM ALLOY BY APPLICATION OF ANALYTICAL HIERARCHY PROCESS

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Abstract

Here Analytical Hierarchical Process was used for optimization of weld strength of aluminium composite using Pulsed Current Tungsten Inert Gas Welding. The experiment was designed using Aluminium 6063. The research focuses on evaluating the importance of various welding parameters and their influence on the weld quality of aluminium alloys. The Analytical Hierarchy Process is utilized as a decision-making tool to prioritize and rank the significance of different welding parameters. The parameters considered for PCTIG welding were pick current, base current, pulse frequency and pulse on time. The optimum condition was at peak current 160A, base current of 60A, pulse on time 50%.

Keywords: *Welding, PCTIG, AHP, Optimization, Weld Strength.*

Introduction

Welding of aluminium alloy and aluminium composite materials using arc welding, such as PCTIG welding is inexpensive. The major challenge of PCTIG welding is the reduce weld strength. Constant current PCTIG welding on aluminium alloy causes reduced weld strength strength due to high heat input and low cooling rate of weld pool. There reduced strength results in coarse grain structure in weld zone and induces thermal stresses in heat affected zone. In PCTIG welding, current supplied to the weld zone is not constant in nature as opposed to normal PCTIG welding. In PCTIG the current oscillates its magnitude between base values and peak values. The peak value is higher than the base value which causes sufficient weld bead penetration and improves the weld bead contour. The base current on the other hand maintains a stable arc throughout the process. A suitable pulse frequency provides sample time to transfer excess heat from the weld and heat affected zone to the base metal, simultaneously reducing thermal stresses and the heat affected zone width. . Ugur Esme et. al. [1] This study investigated the multi-response optimization of tungsten inert gas welding (TIG) welding process for an optimal parametric combination to yield favourable bead geometry of welded joints using the Response Surface Methodology (RSM). J.J.Wang et.al. [2] An image sensing system for the TIG (tungsten inert-gas arc) welding process of aluminium alloy was established. The symmetry of the weld pool for aluminium alloy was studied when the welding current is large. Experiments show that using the image sensing to control the TIG weld width for aluminium alloy is an effective method. Pankaj C Patil et.al. [3] Aluminium alloys are alloys in which aluminium is the predominant metal. TIG welding technique is one of the precise and fastest processes used in aerospace industries, ship industries, automobile industries, nuclear industries and marine industries. Effect of welding parameters on the tensile strength and hardness of weld joint will analyse.

Table 1: Welding Parameters and Levels: -

PC parameters	Desirable limit	Higher than the desired limit	Lower than the desired limit
Peak current	140-160AWeld depth or weld penetration	Above 160A Excessive penetration and burn through	Below 140A Inadequate penetration
Base current	40-60A Stable welding arc	Above 60A Unstable arc and wandering	Below 40A Short arc length causing discontinuous weld
Pulse on time	40%-60% weld surface free from arc splatters	Above 60%weld bead appearance similar to CCTIG	Below 40%poor weld bead surface appearance
Pulse frequency	2-10Hz Improve weld bead appearance	Above 10Hz presence of arc splatters	Below 2 Hz weld bead appearances similar to the CCTIG

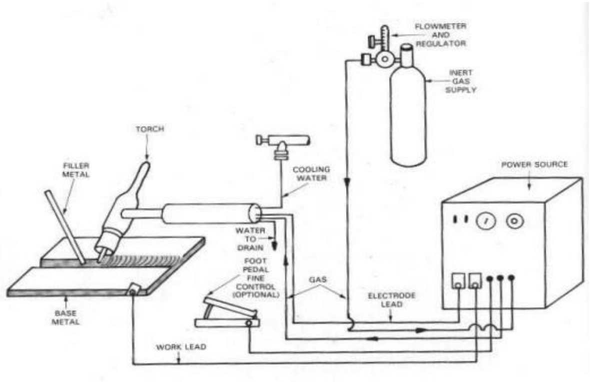

Fig-Schematic diagram of PCTIG Welding

Experimental setup

This section describes the experimental setup employed in the study, including the welding equipment, aluminium alloy specimens, and measurement instruments. Details regarding the selection and variation of welding parameters are provided, along with the rationale behind their choices. Safety protocols and precautions implemented during the experiments are also discussed.

The Analytical Hierarchy Process (AHP) is a very simple and widely used decision making tool. The AHP can solve many complex multi criteria decision-making problem hierarchically. This was applied to solve several manufacturing and production problems.

The AHP process involves identifying a decision problem and then decomposing this into a hierarchy of smaller and simpler sub-problems, each of which could then be analysed independently, without losing focus of the overall decision problem at hand. In the AHP, the hierarchy structure is first constructed. At the top level of the hierarchy, the goal or the objective of the decision is placed. Next the criteria, sub-criteria (if any) and decision alternatives come in the subsequent descending levels.

Experimental procedure

The TIG welding parameters, such as pulse on time, pulse frequency, peak current and base current exert influence on tensile strength. To determine the working limits of the TIG welding parameters on 10 mm plate of aluminium composite from trail runs, the results are tabulated in Table1.

Experimental runs were conducted using four factor and three levels. Taguchi L9 orthogonal array was used to design nine experiments. Various conditions are presented in Table 2.

Table 2: Experimental conditions for TIG welding: -

TIG welding condition	Peak current (A)	Base current (A)	Pulse on time (%)	Pulse frequency (Hz)
1	160	35	55	10
2	140	55	55	2
3	150	55	35	10
4	140	35	35	5
5	150	45	55	5
6	140	45	45	10
7	160	45	35	2
8	160	55	45	5
9	150	35	45	2

During welding the thermocouple was marked 10mm away from the weld centre ans 30mm from the welding starting place to acquire data for time -temperature profile. Data were obtained using data acquisition system. This system consists of Lab view software coupled with National Instrument NI cDAQ9174 kit which uses a temperature – acquiring module.

Next, alternative matrices are constructed corresponding to each of the criteria using the same basic process. Since, there are six criteria, six alternative matrices are constructed. While assigning the values to alternative matrices, the trial runs which have a greater influence on increasing the UTS are given higher value compare to others. For example, in the alternative matrix corresponding to base current, the numerical value of 140 is assigned compared to other values whose influence were less on UTS.

Tensile test results: -

The cases in which the difference in global weights is negligible, they have almost the same influence. For example, alternatives 5 and 3 have almost similar influence on the UTS of the specimen.

Table:- 3 Tensile test results:-

Results

The Criteria Matrix: -

TIG Welding parameters	Trail 1 (MPa)	Trail2 (MPa)	Mean (MPa)	Standard Deviation
1	96.05	84.20	90.10	5.53
2	101.22	97.33	100.20	1.5
3	95.47	84.24	88.72	5.2
4	128.20	118.43	122.80	4.9
5	99.54	92.60	96.17	3.1
6	110.65	97.40	104.5	6.9
7	120.93	103.20	112.50	8.9
8	142.50	127.47	135.50	7.0
9	114.27	101.33	108.35	5.5

To improve weld strength	Peak Current (A)	Base Current (A)	Pulse on time (%)	Pulse Frequency (Hz)	Peak Temperature	Cooling Rate	GM	Criteria Weight
Peak Current	1	1/4	5	2	1/3	1/5	0.717	0.0782
Base Current	5	1	7	5	2	1/2	2.213	0.2610
Pulse on time	1/6	1/7	1	1/2	1/6	1/7	0.211	0.0213
Pulse Frequency	1/3	1/5	2	1	1/5	1/5	0.398	0.0337
Peak Temperature	4	1/2	6	4	1	1/2	1.570	0.1733
Cooling Rate	6	2	8	6	3	1	3.225	0.2833

The global weights are obtained using the usual process prescribed in the AHP algorithm. It is evaluated by multiplying the local weight of each criterion with corresponding alternative weight and then adding them up

The Alternative matrix for peak current: -

Peak current	E1 (160)	E2 (140)	E3 (150)	E4 (140)	E5 (150)	E6 (140)	E7 (160)	E8 (160)	E9 (150)	GM	Alternative weight
E1 (160)	1	6	2	6	2	6	1	1	2	2.3570	0.2131
E2 (140)	1/5	1	1/2	1	1/2	1	1/5	1	1/3	0.3114	0.0214
E3 (150)	1/2	2	1	2	1	2	1/2	1/2	1	1	0.0705
E4 (140)	1/5	1	1/2	1	1/2	1	1/5	1/5	1/2	0.3123	0.0234
E5 (150)	1/2	2	1	2	1	2	1/2	1/2	1	1	0.0708
E6 (140)	1/5	1	1/2	1	1/2	1	1/5	1/5	1/2	0.3415	0.0212
E7 (160)	1	5	2	5	2	5	1	1	2	2.1341	0.2121
E8 (160)	1	5	2	5	2	5	1	1	2	2.2341	0.2023
E9 (150)	1/2	2	1	2	1	2	1/2	1/2	1	1	0.0605

The Alternative Matrix for Base Current: -

Base Current	E1 (40)	E2 (60)	E3 (60)	E4 (40)	E5 (50)	E6 (50)	E7 (50)	E8 (60)	E9 (40)	GM	Alternative weight
E1 (40)	1	1/6	1/6	1	1/3	1/3	1/3	1/6	1	0.2621	0.02012
E2 (60)	6	1	1	6	2	2	2	1	6	2.3214	0.2021
E3(60)	6	1	1	6	2	2	2	1	6	2.3315	0.2301
E4 (40)	1	1/6	1/6	1	1/3	1/3	1/3	1/6	1	0.2723	0.0212
E5(50)	5	1/2	1/2	3	1	1	1	1/2	3	1.0756	0.0705
E6(50)	3	1/2	1/2	3	1	1	1	1/2	3	1.1725	0.0705
E7(50)	3	1/2	1/2	3	1	1	1	1/2	3	1.1702	0.0702
E8 (60)	6	1	1	6	2	2	2	1	6	2.2245	0.2103
E9 (40)	1	1/6	1/6	1	1/3	1/3	1/3	1/6	1	0.2231	0.02123

The Alternative matrix for pulse on Time: -

Pulse on time (%)	E1 (60)	E2 (60)	E3 (40)	E4 (40)	E5 (60)	E6 (50)	E7 (40)	E8 (50)	E9 (50)	GM	Alternative weight
E1 (60)	1	1	4	4	1	2	4	2	2	2	0.1905
E2 (60)	1	1	4	4	1	2	4	2	2	2	0.1905
E3(40)	1/4	1/4	1	1	1/4	1/2	1	1/2	1/2	1/2	0.0476
E4(40)	1/4	1/4	1	1	1/4	1/2	1	1/2	1/2	1/2	0.0476
E5 (60)	1	1	4	4	1	2	4	2	2	2	0.1905
E6 (50)	1/2	1/2	2	2	1/2	1	2	1	1	1	0.0952
E7(40)	1/4	1/4	1	1	1/4	1/2	1	1/2	1/2	1/2	0.0476
E8 (50)	1/2	1/2	2	2	1/2	1	2	1	1	1	0.0952
E9 (50)	1/2	1/2	2	2	1/2	1	2	1	1	1	0.0952

The Alternative matrix for Pulse Frequency:

Pulse frequency (Hz)	E1 (10)	E2 (2)	E3 (10)	E4 (5)	E5 (5)	E6 (10)	E7 (2)	E8 (5)	E9 (2)	GM	Alternative weight
E1 (10)	1	7	1	4	4	1	7	4	7	3.0366	0.2350
E2 (2)	1/7	1	1/7	1/3	1/3	1/7	1	1/3	1	0.3625	0.0280
E3 (10)	1	7	1	4	4	1	7	4	7	3.0366	0.2350
E4 (5)	1/4	3	1/4	1	1	1/4	3	1	3	0.9086	0.0703
E5 (5)	1/4	3	1/4	1	1	1/4	3	1	3	0.9086	0.0703
E6 (10)	1	7	1	4	4	1	7	4	7	3.0366	0.2350
E7 (2)	1/7	1	1/7	1/3	1/3	1/7	1	1/3	1	0.3625	0.0280
E8 (5)	1/4	3	1/4	1	1	1/4	3	1	3	0.9086	0.0703
E9 (2)	1/7	1	1/7	1/3	1/3	1/7	1	1/3	1	0.3625	0.0280

The Alternative matrix for Cooling Rate: -

The Alternative matrix for Peak Temperature: -

Peak Temp.	E1	E2	E3	E4	E5	E6	E7	E8	E9	GM	Alternative weight
E1	1	1/3	1/5	2	1/3	1/3	1/4	1/6	2	0.4010	0.0223
E2	3	1	1/2	3	2	2	1	1/3	5	1.3210	0.1123
E3	5	2	1	4	3	3	2	1/2	5	2.9032	0.2103
E4	1/2	1/3	1/4	1	1/3	1/3	1/4	1/7	1/2	0.2123	0.0132
E5	3	1/2	1/3	3	1	1	1/2	1/3	3	0.8326	0.0563
E6	3	1/2	1/3	4	1	1	1/2	1/4	4	0.8324	0.0539
E7	4	1	1/2	5	2	2	1	1/3	5	1.625	0.1235
E8	7	3	2	8	4	4	3	1	7	3.8923	0.2935
E9	1/2	1/5	1/6	2	1/4	1/4	1/4	1/7	1	0.2003	0.0212

Cooling Rate	E1	E2	E3	E4	E5	E6	E7	E8	E9	GM	Alternative weight
E1	1	1/7	1/6	1/3	1/9	1/6	1/6	1/9	1/6	0.1973	0.0153
E2	7	1	3	5	1/2	3	3	1/3	3	1.9822	0.1542
E3	6	1/3	1	4	1/4	1	1	1/4	1	0.9259	0.0720
E4	3	1/5	1/4	1	1/7	1/4	1/5	1/8	1/5	0.3104	0.0241
E5	9	2	4	7	1	4	4	1	4	3.1693	0.2465
E6	6	1/3	1	4	1/4	1	1/2	1/5	1/2	0.7743	0.0602
E7	6	1/3	1	5	1/4	2	1	1/4	1	1.0251	0.0797
E8	9	3	4	8	1	5	4	1	4	3.4493	0.2682
E9	6	1/3	1	5	1/4	2	1	1/4	1	1.0251	0.0797

Observation

The observations derived from the data analysis are discussed in detail. The relative importance and influence of different welding parameters on the weld quality of aluminium alloys are presented and analysed. The findings from the Analytical Hierarchy Process are used to identify the critical parameters that significantly affect weld quality.

Discussion on the results Obtained, based on the assessment done in this work, the following outcomes were obtained.

Conclusion

The conclusion section summarizes the key findings of the research and their implications. The study highlights the significance of the Analytical Hierarchy Process in assessing the importance of welding parameters and its potential for optimizing welding processes in the context of aluminium alloy weldability. The limitations of the study are acknowledged, and suggestions for future research directions are provided.

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