

Parameter Optimisation Of Tig Welding Process For Dissimilar Welding Of Al6061-Al2014 Aluminium Alloys

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Abstract - Dissimilar welding of aluminium alloys is increasingly needed in aerospace, automotive, and construction industries to combine the benefits of different alloys, like corrosion resistance, strength, and weight reduction. This study investigates the dissimilar welding of Al6061 and Al2014 aluminium alloys using Tungsten Inert Gas (TIG) welding. The study provides insights into the weldability of dissimilar aluminium alloys and identifies significant factors influencing the TIG welding process.

The experiments were designed using L8 Orthogonal Array (OA) to optimize the welding process parameters: current, gas flow rate, and filler rods. Output parameters considered are Ultimate Tensile Strength (UTS) and Yield Strength. Signal-to-Noise (S/N) ratio and Analysis of Variance (ANOVA) were employed to analyze the effects of these parameters on weld quality. The results indicate the optimal combination of parameters. From the results, it is found that the optimal parameters for YS are Current 70 Amp, Gas flow rate 5l/min, Filler rod 5053 and for UTS, they are 70 Amp, 15l/min and 5053. Current is identified as the most significant factor from the analysis.

Keywords - Dissimilar Welding, Aluminium Alloys, TIG Welding, Taguchi Method

I. INTRODUCTION

Recent trends in the automotive manufacturing worlds have been transitioning from conventional materials to light metal such as aluminum alloy. Aluminum alloys is largely used in various parts of the industry due to their essentially high strength to weight ratio, high thermal conductivity, low density and high corrosion resistance. The joining of dissimilar metal becomes an enormous demand in the industry in order to create a product that can improve the quality in terms of strength and ductility but light in weight. This also include vehicles manufacturing, where there are numerous parts that employ the combination of different metal to reduce fuel expenditure and manage the pollution by using material that have light weight and good corrosion resistance such as aluminium alloys

In the fusion welding of aluminium alloys, some problem may occur during the welding process where the welds may fail in the soft and over aged heat affected zone. The difficulties to join dissimilar aluminum alloys are mainly related to the presence of a tenacious oxide layer. The occurrence of this film weakens grain boundary cohesion and consequently the weld becomes susceptible to inter-granular cracking as a result of shrinkage stresses experienced during weld-pool solidification. Besides that, different thermal conductivity and different composition in alloying elements are one of the major reasons these materials are difficult to join. Tungsten inert gas (TIG) arc welding, friction stir welding (FSW), Variable polarity plasma arc (VPPA) welding, and vacuum electron beam welding (VEBW) are the most popular methods currently used in the industrial field; however, each method has its own advantages and limitations. Among the various processes of dissimilar welding TIG welding is comparatively an cost-effective process and does not require costly equipment and environment. Many researchers recently studied the dissimilar welding of different aluminium alloys using TIG welding process. Vijay et al.[1] studied the effect of parameters of TIG welding such as current, gas flow rate and root gap on dissimilar aluminum alloys Al2024 and Al6063. Goriparthi et al. [2] studied the joining feasibility of dissimilar aluminum alloys AA5083-O and AA7075-T651 by TIG. Yelamasetti et al.[3] (2024) aimed to optimize the TIG welding parameters to join dissimilar metals of AA5083 and AA7075 using the Taguchi technique. Adin [4] (2025) in his paper examined the effects of groove angles on the joint strength of TIG welded dissimilar AA2024 and AA7075 aluminum alloys. Karthick et al [5] (2025) aimed to enhance the mechanical characteristics of AA5083-H11 and AA5052-H32 dissimilar aluminum alloy welds by adjusting tungsten inert as (TIG) welding parameters such as current, gas flow rate, and filler rod diameter. In the research works, the combination of 6XXX (Al-Mg-Si alloy) and 2XXX (Al-Cu alloys) are scanty. 6XXX series alloys have high strength-to-weight ratio and good corrosion resistance. They are predominantly used in automotive parts, marine structures and consumer products like

furniture. 2XXX aluminium alloys are high strength alloys primarily used in aerospace, defense and high stress structural applications. The major drawback of 2XXX alloys is their limited corrosion resistance. In this backdrop, the dissimilar TIG welding of 6061-2014 combination has been attempted in this work. This dissimilar aluminium weld combination is often used in aerospace and automotive applications particularly structural components like frames or brackets where strength, corrosion resistance and weight reduction are crucial. The Taguchi method is used to study the influence of input parameters.

II. MATERIALS AND METHODS

A. Materials

The two dissimilar aluminium alloys selected are Al6061 and Al2014. Al6061 is a heat treatable 6xxx-series aluminium alloy containing silicon and magnesium as its primary alloying elements. It is known for its excellent corrosion resistance, good formability and weldability. Al2014 is a high strength, 2xxx series copper based aluminium alloy. It provides high tensile strength and good fatigue resistance but it has poor corrosion resistance. Both the materials are widely used in structural, aerospace and automotive applications.

TABLE I. CHEMICAL COMPOSITION OF AL6061 AND AL2014

Materials	Elements in %								
	Al	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn
Al6061	95.4	0.9	0.6	0.7	0.15	0.30	0.25	0.15	0.15
Al2014	92.4	0.6	0.8	0.7	3.9	0.1	0.25	0.15	0.9

B. Method

The main objective of the work is to study the influence of TIG welding parameters on the mechanical properties of dissimilar 6061-2014 welded joints using Taguchi method. It is revealed that current and gas flow rate are considered as input parameters [6] in many works. It is important to choose a proper filler rod to join the dissimilar metals. As the influence of filler rod [7] is also dominant in deciding the mechanical properties it is also considered as another input parameter. Hence the three input parameters which influence the weldment quality such as Welding current(A), Gas flow rate (l/min) and types of filler rods are chosen. As the plates are aluminium, higher current leads to higher heat input and penetration. With few sample pieces tested, the current is fixed between 40 Amp and 70 Amp. The two commercially available filler rods ER4043 and ER5356 which are common in aluminium welding are used. ER4043 is a 5% silicon-aluminium filler rod and ER5356 is a 5% magnesium aluminium filler rod used for TIG welding of aluminium alloys. As the factor levels are different, mixed level design of orthogonal array L8 has been selected for conducting the experiments. The ultimate tensile strength and yield strength are considered as output responses.

TABLE II. PARAMETERS AND THEIR LEVELS

Parameter	Level 1	Level 2	Level 3	Level 4
Current (Amp)	40	50	60	70
Gas Flow Rate (l/min)	5	10		
Filler Rod Type	ER5356	ER4043		

TABLE III. ORTHOGONAL ARRAY

Exp.No	Current amp	Gas flow rate l/min	Filler Type
1	40	5	ER5356
2	40	15	ER4043
3	50	5	ER5356
4	50	15	ER4043
5	60	5	ER4043
6	60	15	ER5356
7	70	5	ER4043
8	70	15	ER5356

The Aotai ATIG 315 PAC is a high-performance, industrial-grade 3-phase (AC 380V) digital inverter AC/DC Pulse TIG welding machine, offering a 315A output at 60% duty cycle is used in the experiments. The Al6061 and Al2014 plates used are 150X50X3 mm size. The plates were edge prepared for V groove with a bevel angle of 45°. After edge preparation of all the samples the experiments were conducted as per the orthogonal array, setting the parameters at various levels. The welded samples are shown in Figure 1.



Fig. 1. Weld samples

The tensile specimens were prepared as per ASTM E8 standard and the prepared specimens are shown in Figure 2. The tensile tests were conducted in UTES40, a 400kN capacity hydraulic Universal Testing Machine.



Fig. 2 Tensile Test Specimens

TABLE IV. INPUT PARAMETERS AND RESPONSES

Exp .No	Curren t Amp	Gas flow rate l/min	Filler Type	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
1	40	5	ER5356	82.31	137.31
2	40	15	ER4043	53.28	120.03
3	50	5	ER5356	59.62	145.23
4	50	15	ER4043	78.30	139.50
5	60	5	ER4043	103.30	153.88
6	60	15	ER5356	124.97	155.42
7	70	5	ER4043	124.97	144.45
8	70	15	ER5356	145.50	175.46

III. RESULTS AND DISCUSSION

A. S/N ratio

The data were analysed in Minitab 16 statistical software. The signal to noise (S/N) ratio was analysed and larger is better was selected. The equation for larger is better is $S/N = -10 \cdot \log(\Sigma(1/Y^2)/n)$ where Y = responses for the given factor level combination and n = number of responses in the factor level combination. The S/N ratio plot for Yield Strength (YS) and Ultimate Tensile Strength (UTS)) are shown in Fig. 3 and Fig 4 for the input parameters current, gas flow rate and filler rod.

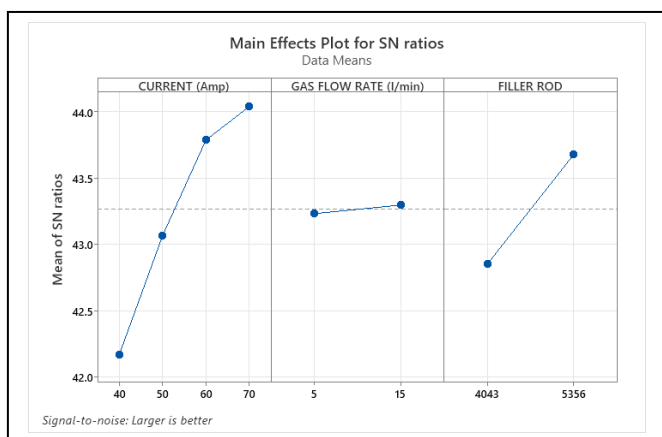


Fig 3. S/N Ratio Plot for Yield Strength

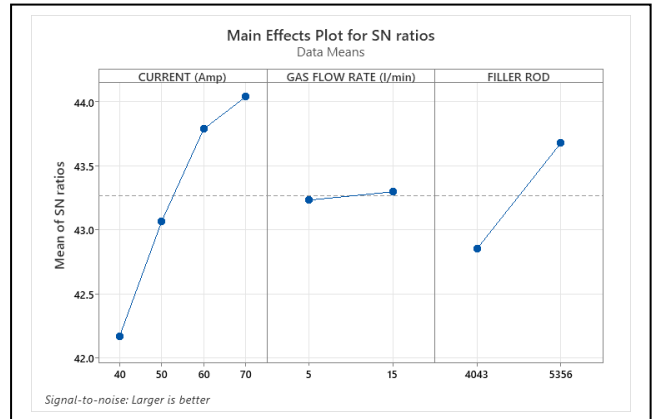


Fig 4. S/N Ratio Plot for Ultimate Tensile Strength

From the Fig 3 and Fig4 , it is understood that the increase in weld current increases the strength of the weld joints both YS and UTS. The increase in weld current increases the heat input, which improves penetration, ensuring a deeper, stronger bond. The gas flow rate does not play a significant role in the weld strength. It is also found that, welding using filler ER5356 yielded higher UTS compared to filler ER4043. Besides lower melting point and better flowability due to silicon presence in 4043, it may form brittle compounds when working with magnesium based alloy (6061) that lead to lower strength values .The higher magnesium content in 5356 filler alloy is compatible with 6061 base metal which also contains magnesium. This creates a better metallurgical match and stronger welds. It is also found that the optimal parameters for YS and UTS are A4B1C2 (Current 70 Amp, Gas flow rate 5l/min , Filler rod 5053) and A4B2C2 (Current 70 Amp, Gas flow rate 15l/min , Filler rod 5053) respectively.

The ranking of parameters are calculated based on delta value (higher value – lower value) of S/N ratio . The tables 5 and 6 depict the ranking of parameters for YS and UTS respectively.

TABLE V. S/N RATIO AND RANKING OF PARAMETERS FOR YIELD STRENGTH

LEVEL	CURRENT (Amp)	GAS FLOW RATE (l/min)	FILLER ROD
1	34.37	39.01	37.63
2	36.69	38.38	39.75
3	41.11	-	-
4	42.60	-	-
Delta	8.22	0.63	2.12
Rank	1	3	2

TABLE VI. S/N RATIO AND RANKING OF PARAMETERS FOR ULTIMATE TENSILE STRENGTH

LEVEL	CURRENT (Amp)	GAS FLOW RATE (l/min)	FILLER ROD
1	34.37	39.01	37.63
2	36.69	38.38	39.75
3	41.11	-	-

4	42.60	-	-
Delta	8.22	0.63	2.12
Rank	1	3	2

In both the cases, the current has a higher influence and ranked 1. The filler rod is next significant factor with a rank of 2 and the gas flow rate is the least significant with a rank of 3.

B. Analysis Of Variance (ANOVA)

Analysis of Variance (ANOVA) in Taguchi analysis determines which parameters significantly affect performance, quantifying their percentage of contribution to overall quality. It validates S/N ratio findings and identifies control factors that have a significant effect on the mean response. ANOVA for yield strength and ultimate tensile strength are given in Table 6 and 7 respectively. The analysis of variance is obtained from Minitab software.

TABLE VII. ANOVA FOR YIELD STRENGTH

Source	DF	Adj SS	Adj MS	F-Values	Percentage Contribution %
Current (Amp)	3	8089.42	2696.47	4.70	81.6
Gas Flow Rate (l/min)	1	17.46	17.46	0.03	0.17
Filler Rod	1	658.61	658.61	1.15	6.64
Error	2	1146.93	573.46	-	-
Total	7	9912.41	-	-	-

TABLE VIII. ANOVA FOR ULTIMATE TENSILE STRENGTH

Source	DF	Adj SS	Adj MS	F-Values	Percentage Contribution %
Current (Amp)	3	1126.49	375.498	3.38	61.25
Gas Flow Rate (l/min)	1	0.80	0.803	0.01	0.04
Filler Rod	1	489.56	489.563	4.41	26.6
Error	2	222.24	111.120	-	-
Total	7	1839.10	-	-	-

From the tables 6 and 7 , the major contribution for YS and UTS comes from current and the percentage is 81.6% and 61.25% respectively. The percentage contribution of filler rod has 6.64% for YS and 26.6% for UTS. Gas flow rate has a very negligible contribution in both YS and UTS.

IV. CONCLUSION

The dissimilar welding of aluminium alloys 6061 and 2014 has been conducted using TIG welding process. The influence of input parameters current , gas flow rate and filler rod on responses yield strength and ultimate tensile strength are analysed using Taguchi method. Experiments are conducted based on L8 orthogonal array and S/N ratio analysis and ANOVA are carried out . From the results, it is found that the optimal parameters for YS are Current 70 Amp, Gas flow rate 5l/min , Filler rod 5053 and for UTS, they are 70 Amp, 15l/min and 5053. For YS and UTS, the most significant factor is current as per S/N ratio analysis and the percentage of contribution is 81.6% and 61.25% respectively. The next significant factor is filler rod with a percentage contribution of 6.64% for YS and 26.6% for UTS. Gas flow rate neither influences YS nor UTS.

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