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Multi objective Optimization of TIG welding AA6061 alloy using response surface methodology (RSM)

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Abstract - *This research paper discusses the experimental and numerical results of AA6061 TIG welding. The purpose of this research is to determine the best process parameters for GTAW of Argon, which is used as an inert gas in the aluminium alloy AA6061. The Taguchi method was used to optimize TIG welding process characteristics such as gas flow rate, welding current, and welding speed for connecting AA6061 plates. The Taguchi technique is used to obtain the Optimization parameters of Welding with tungsten inert gas on 6061 aluminium alloy. After examining the influence of various components with ANOVA and regression analysis, the Taguchi technique was used to find a desirable combination.*

Key Words: Hybrid laser-TIG welding Response surface methodology (RSM) Desirability approach, aluminium alloy AA6061, welding current, gas flow rate

1. INTRODUCTION

The general principle TIG (tungsten inert gas) welding, also known as GTA (gas tungsten arc) in the United States and WIG (Wolfram inert gas) in Germany, is a welding process used to produce high quality materials of various types Used for welding, specifically, stainless steel, titanium and aluminium.

1.2 Equipment

- AC / DC Power Source
- TIG Torch
- Work Return Welding Lead
- Shielding gas supply line, (normally from a cylinder)
- Foot Control Unit (common option)

Welding is the process of joining metals together, either with or without filler, to form coal's essence. Welding is a method of permanently joining materials. Shipbuilding, autos, and oil and gas are just a few of the industries that employ it. Arc welding is a process that involves creating an arc between the electrode and the workpiece, which warms and melts the metal. Electrodes can be consumable or non-consumable. Flux is used to protect weld metal from environmental gases. The procedure can be carried either automatically or by hand. In the shipbuilding business, arc welding, which was pioneered in the nineteenth century, became commercially vital during WWII. It's still utilised in the manufacturing of steel pipelines and automobiles today. [2] Figure 1.1 Metal arc welding with a consumable electrode shield. The most popular, dependable and cost-effective welding technology is shielded arc welding, often known as manual arc welding. The consumable electrode utilised in this application is compatible with flux-coated welded steel. An electric current is utilised to strike an arc when the electrode is scratched along the workpiece.

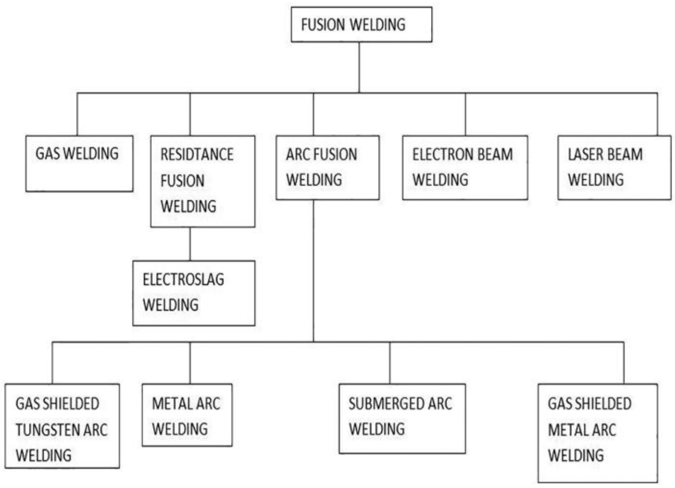


Figure 1.1 Classification of fusion welding processes.[46]

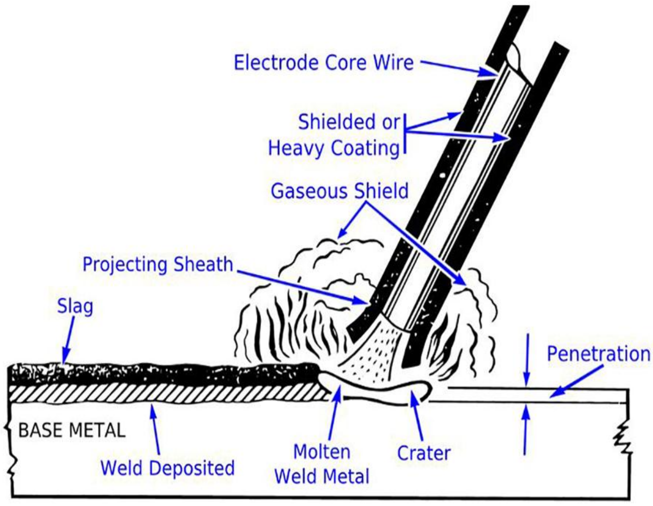


Figure 1.2 Shielded metal arc welding process [46]

Welding is a permanent joining process that uses heat, pressure, and filler materials to connect two or more materials, typically metals or thermoplastics. Tungsten inert gas welding is an electric arc welding method that uses non-consumable tungsten electrodes to create an arc between the electrode tip and the work piece. To prevent contamination of the weld with air, inert gases (argon, helium, etc.) are used.

A mixture of any two of the gases described above is often used. TIG welding is one of the most flexible welding methods available today, capable of connecting to almost any metal or metal alloy. This welding method is popular because of its inherent benefits, such as high-quality and better welds, less deformation, a smaller heat-affected zone, and the absence of slag or spatter. TIG welding is widely used in industrial industries such as automobiles, airplanes, nuclear power plants, food processing plants, precision manufacturing plants and maintenance and repair work. [45]

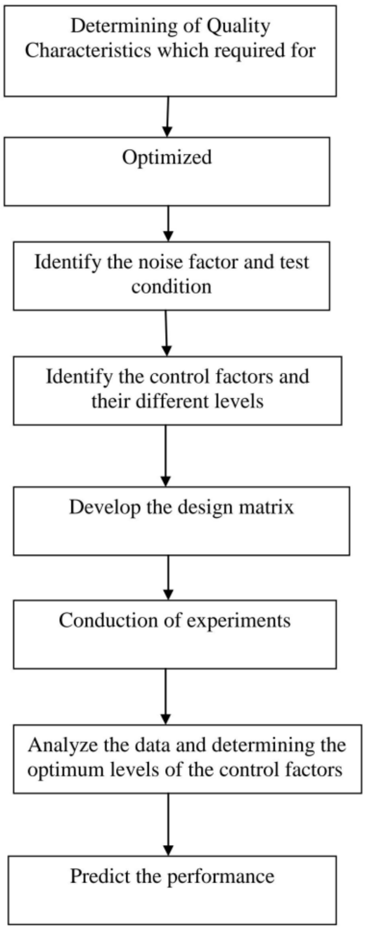


Figure3.2.1. Flow chart of Taguchi method [19]

Table 3.1 Tabulation oflevelsaccordingtoL16 orthogonal array

Welding Current	Gas Flow rate	Welding Speed	Impact Strength
170	8	47	1.514
170	10	50	1.942
170	12	54	2.114
170	14	58	2.085
180	8	50	1.714
180	10	47	2.142
180	12	58	1.714
180	14	54	1.971
190	8	54	1.657
190	10	58	2.142
190	12	47	2.000
190	14	50	2.000
200	8	58	2.142
200	10	54	1.885
200	12	50	2.028
200	14	47	1.942

Table 4.5 Experimental L16 layout for impact strength with calculated SN ratios

Welding Current	Gas Flow rate	Welding Speed	Impact Strength	SNRA1
170	8	47	1.514	3.60252
170	10	50	1.942	5.76498
170	12	54	2.114	6.50210
170	14	58	2.085	6.38212
180	8	50	1.714	4.68022
180	10	47	2.142	6.61639
180	12	58	1.714	4.68022
180	14	54	1.971	5.89373
190	8	54	1.657	4.38645
190	10	58	2.142	6.61639
190	12	47	2.000	6.02060
190	14	50	2.000	6.02060
200	8	58	2.142	6.61639
200	10	54	1.885	5.50623
200	12	50	2.028	6.14136
200	14	47	1.942	5.76498

2. RESPONSE SURFACE METHODOLOGY OF EXPERIMENT

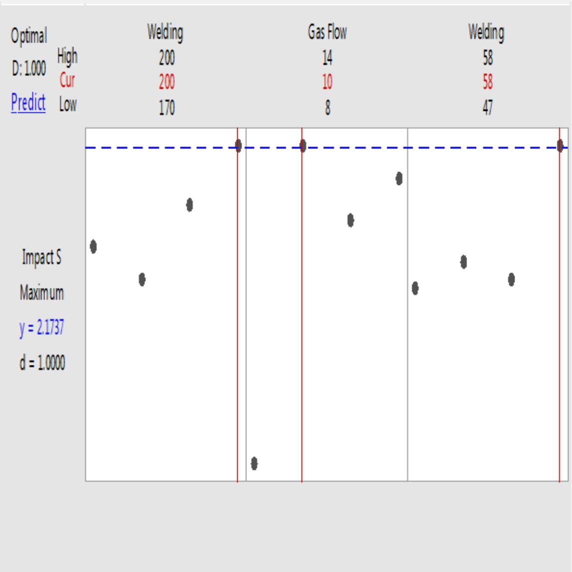


Fig. 5.1 Optimization results of impact strength by RSM

3. Confirmation test

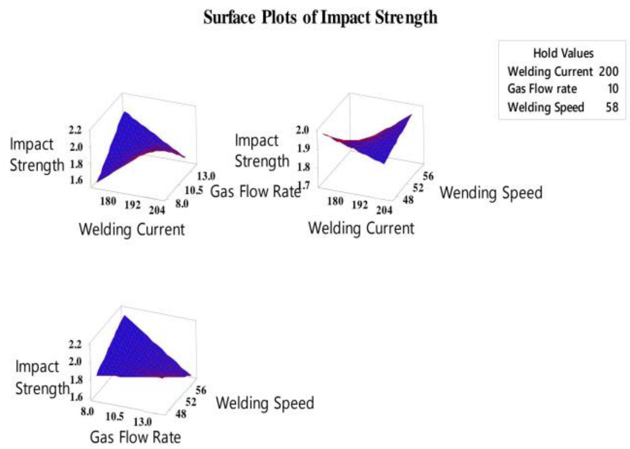
The optimization results obtained have been validated by performing confirmatory experiments. Table 6 represents the results of confirmatory tests

that are conducted in optimal conditions. It is seen from the table that the error in terms of percentage between the estimated and experimental results is very small and is less than 1%. This indicates that the optimized TIG welding process parameters higher NTS and UTS of 316L stainless steel can be obtained. Three fresh experiments are conducted for confirmation of models Eqs. (3) And (4), with achieved optimal values of cutting parameters. The average of measured values for surface roughness and kerf taper angle are tabulated in Table 6. The accuracy of the models isanalyzed on the basis percentage error. These errors are found to be 1.18 and 2.24% for surface roughness and kerf taper angle, respectively. It is possibly due to some vibrations during machining which affects the measurement techniques. Since the error is less than10%, it is evidently proved that there is a good agreement between experimental and predicted values [38].

Table 5.1Multi-objective optimization results

Optimal Control Parameters	Level	Optimal Level	Experimental	Predicted (RSM)	Error (%)
Welding Current (A)	A	A_4 B_2 C_4	2.251	2.1737	5.3
Gas flow rate (L/min)	B				
Welding Speed (mm/s)	C				

Fig. 5.2The effect of the process parameters on the Impact strength :(a) welding current and gas flow rate (b) Welding speed and welding current (c) gas flow rate r and welding speed.



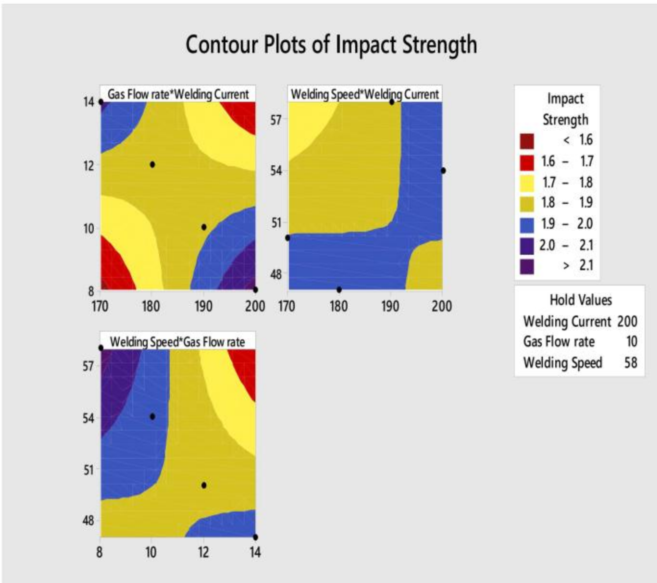


Fig. 5.3 Impact power contour plot (A) welding current and gas flow rate) (B) and welding speed and welding current (C) gas flow rate and welding speed

Figure 6-8 shows the limits of impact strength (A) against welding current (L / min), welding speed (mm / s) against gas flow rate (L / min), and welding speed (mm / s) (A) against the contour band welding current shown in (a). As shown in fig. 6, the impact strength is greater when the current is 190 A and the gas flow rate is 10 L/min. According to Fig.7, maximum impact strength is obtained at high welding speeds (54 mm/s) with a gas flow rate of 13 L/min.

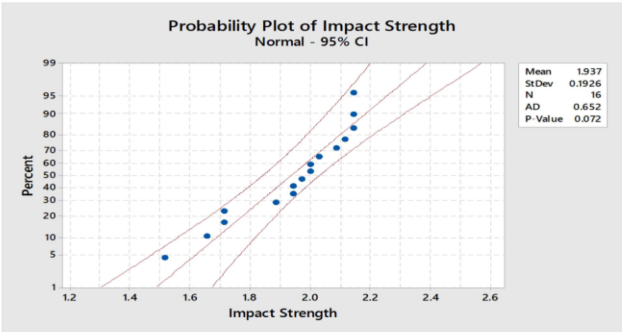


Figure5.4. Probability plot for impact strength

Where A is welding current in Amps, B is the gas flow rate in lit/min and C is welding speed in mm/sec.The residuals are normally distributed along the straight line in the normal probability plot for impact strength asshown in Fig.

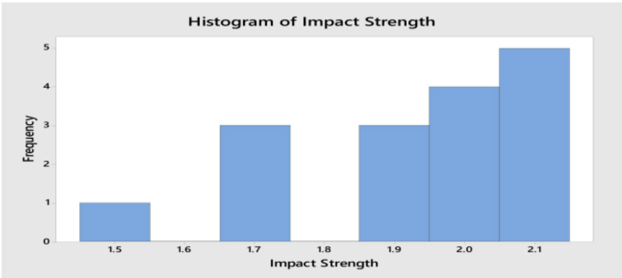


Figure 5.5 Histogram for impact strength

4.CONCLUSION AND FUTURE APPLICATIONS

1. Response surface methodology (RSM) has been found to be extremely useful in the current study's optimization process. In this case, the predicted value from the models is very close to the experimental value.

2. The most important welding parameter affecting ultimate tensile strength is gas flow rate, which is followed by welding current and welding speeds.

3. The most important factor influencing percentage elongation is welding current, with gas flow rate coming in second, followed by welding speed.

5. Impact strength ANOVA result (J). It is discovered that the most significant influence on impact strength is the Gas flow rate (L/min) (P=0.393) (32.62%), followed by Welding Speed (mm/s) (P=0.859) (6.90%) and the least significant influence is the Welding Current (A) (P=0.900) (5.22%). Welding current is an insignificant factor for impact strength in the current study.

6. According to the ANOVA analysis, gas flow rate is the most important factor influencing the impact strength of TIG welded AA6061 joints, followed by welding speed.

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