Study on TIG welding parameters for joining different kind of aluminium tube with a tube plate

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Abstract. Welding is a vital metal joining technique with a wide range of industrial uses. In this study, numerous process factors such as current, feed rate, and distance between tube and work piece, among others, were used to investigate in Tungsten Inert Gas (TIG) welding. We used Aluminum 6063 tube to Aluminum 6061 tube plate for this TIG welding. After the welding is finished, a radiographic test is performed to show any welding faults that might lead to defect-free welds. The most critical control factors that would result in better joint strength were identified to use a Taguchi L9 orthogonal matrix. Furthermore, the most relevant process parameter was determined using quantitative independent test (ANOVA). In addition, the mechanical tests were performed to determine the welding strength. The value of the best welded connection strength for tubes with holes welded at interference was found to be 318.716 MPa.

Keywords: aluminium alloy; TIG; ANOVA; compressive strength; Taguchi.

1. Introduction
Welding is a continuous connecting procedure that involves fusing metals, alloys, and polymers. To establish a weld a melted pool material that solidifies to provide a robust bond between the components, a filler material is occasionally utilized [1, 2]. The steelmaking modifications which take place all through welding, as well as adjustments in stiffness in the weldment led to fast crystallization, the dimensions of combustion caused by materials reacting with atmospheric oxygen, and the propensity for brittle fracture in the joint angle, all have an impact on a molecule’s hardenability [3, 4]. During welding, the parts to be joined are burned at the junction, and a stable union can be formed after unification. TIG welding is an electric welding technique which uses a semi spark plug to make welds. The weld region is shielded from the environment by an inert gas mixture.
(inert gas), and a raw material is commonly utilized [5, 6]. Through an arm or welding torch, electricity is delivered from the source of energy (rectifier) to a wire put into the work piece.

A steady welding fusion reactor creates an electrical conductor between both the tungsten electrode and the work piece [7, 8]. The consumable electrode and melting region shielded out against ambient air. A graphical chart illustrates the physics of TIG welding. The conductive capacity of such a sensor is determined by whether it has been attached towards the favorable or unfavorable terminus of a Dc voltage source. The battery packs ability which delivers a guidance and support power capacity while the angle is altered across many centimeters. As a reason, natural variations in angle have no effect on TIG welding in manual welding [9, 10, 11]. Once the emitter is close to the end to the work piece surface, having capability to restrict the power here to set point is indeed crucial; alternatively, an exceedingly demanding present would flow, causing damage to the anode [12, 13]. The constant current voltage of the power supply ranges from sixty to eighty amps.

According to the literature research, conventional arc welding presents a significant problem when welding different grade of aluminium alloys. Welding repeatability is again dependent on welding speed and other processing factors. An automated TIG welding system was built for in this study to execute welding of 50 mm aluminium 6061 plate to an aluminium 6063 tube. To achieve a high strength joint, the welding current and welding speed of the aluminium plate and tube were changed.

2. Experimental setup

Welding setup has been designed in-house for appropriate welding and management of welding parameters, particularly welding speed. Figure 1 depicts the automated welding setup and its primary components and parameters are included in Table 1.

![Experimental setup](image)

**Figure 1.** Experimental setup.

**Table 1.** Welding parameters.

| Parameters                        | Levels |
|----------------------------------|--------|
| Welding current (Amps)           | 80 100 120 |
| Travel speed (mm)                | 50 60 70  |
| Work piece to Tungsten electrode Distance (mm) | 2 4 6 |

Experimentation was carried out in two stages for this study. The aluminum tube and tube plate will be perpendicularly fitted. As a result, TIG welding is done at the tube's top and bottom, which is securely firm ed. Various process parameters, such as speed, voltage, and distance, must be used to weld the tube and tube plate. These are the L9 Orthogonal Array process parameters. Taguchi will then optimize it, and ANOVA will be used to determine the most influential process parameters [14, 15]. Microstructure studies and Hardness Values aid in the future performance of the joint. The work
piece material for this experiment was an aluminum 6061 alloy plate with a thickness of 6 mm. With the help of a band-saw, a 50 mm x 50 mm Al 6061 plate was cut with the dimensions of 50 mm x 50 mm, and the edge was ground to smooth the surface to be joined. After that, emery paper is used to clean the surfaces to eliminate any exterior material. The aluminum is positioned perpendicularly in the center of the plate. After sample preparation, aluminium plates and tube are clamped side by side at the working table using flexible clamps and welded to make a butt joint.

In the tests, TIG welding with Alternate Current (AC) was utilized since it focuses heat in the welding region. For this experiment, zirconiated tungsten electrodes with a diameter of 2.5 mm were used. The electrode's end was prepared by grinding the tip diameter down to 2/3rd of its original size and then striking an arc on a scrap piece of material [5, 7]. This forms a ball at the electrode's end. In general, an electrode that is too tiny for the welding current will produce an abnormally huge ball, whereas an electrode that is too large will produce no ball at all.

3. Results and discussion

An experiment was conducted when holes drilled in the aluminium tube. As a result, the filler material flows to the work piece's gap, forming a very strong connection. Because of the greater bonding that happens between the tube and the tube plate, TIG welding has highest compression better performance compared to other welding situations.

3.1. Radiography test

In a dark environment, the Radiography test (RT) produces gamma rays on this film to locate the fractures. Figure 2 shows a radiography image of a TIG welded weld with holes. It is apparent from the result that there must be no more faults.

![Figure 2. Radiography test sample.](image)

3.2. Compression test

Compression testing has been done with UTM, where a burden is progressively increased supplied till the object is ready to cracks. Specimen for compression testing with fractures each combination of process parameters was examined with 9 samples, and The Taguchi approach was used to choose the mean amount for refinement. Table 1 shows the components and levels of the L9 orthogonal array. The samples are welded using the L9 Orthogonal array, and the internal variables and output variables of the L9 orthogonal array are listed in Table 2 Most important factors to consider when describing the quality of TIG Welding Joints in this study.

In this work, the control parameters for greater joint strength were found using the Taguchi approach, and The ANOVA approach was used to determine the relative contribution of every variable [5]. For both cases, to find the optimal wear resistance, the regression analysis is used. The experiment for this study was carried out using the Taguchi L9 orthogonal array. Each experiment is carried out using a mix of several parameters that are categorized into three stages. TIG welding was
used to unite identical metals with and without projections, and Figure 2 illustrates the welded work piece after welding. Mechanical properties are evaluated utilising universal compaction instruments. Each piece would be compressed, and its joint strength is measured at its highest point of collapse or until it is shattered.

**Table 2.** L9 orthogonal array input variables and load conditions.

| Input Parameters | Output Constrains (TIG welding) |
|------------------|---------------------------------|
| Current (amps)   | Feed rate (mm/sec) | Distance b/w work piece to Electrode (mm) | Compressive strength (MPa) |
| 80               | 50                | 2                                     | 297.863                    |
| 80               | 60                | 4                                     | 299.343                    |
| 80               | 70                | 6                                     | 300.782                    |
| 100              | 50                | 4                                     | 305.646                    |
| 100              | 60                | 6                                     | 307.034                    |
| 100              | 70                | 2                                     | 311.267                    |
| 120              | 50                | 6                                     | 314.347                    |
| 120              | 60                | 2                                     | 318.716                    |
| 120              | 70                | 4                                     | 318.568                    |

3.3. **Response Table for Means**

At 110 V current 60 mm/s speed, 2 mm distance, 8 holes, 1.5 mm hole diameter, and 2.0 projection, the joint strength was at its peak. This is owing to the fact that when a tool revolves at a steady pace. It generates enough heat to melt the material and distort the work piece. The 2 mm projection aids in filler contact, and metal is melted and flowed via the tool's central axis to offer superior the welded work piece's integrity and resilience and it also contains 1.5 mm diameter 8 holes, implying increased joint strength and metal flow across the deleted area. Dislocation of atoms in metals arises as a result of this. Table 3 shows the response and the mean effect plots are given in Figure 3.

**Table 3.** Response table of means.

| Level | Current (amps) | Feed rate (mm/s) | Distance b/w tool & w/p (mm) |
|-------|----------------|------------------|-------------------------------|
| 1     | 299.3          | 306              | 309.8                         |
| 2     | 308            | 308.9            | 307.9                         |
| 3     | 317.7          | 310.2            | 307.4                         |
| DELTA | 18.4           | 4.3              | 2.4                           |
| RANK  | 1              | 2                | 3                             |

**Figure 3.** Main effects plot.
3.4. Analysis of Variance (ANOVA)

This statistical approach for assessing the percentage impact of each variable to study outcomes is ANOVA. The condition 1 tube was welded without holes in this investigation, and the parameters influencing joint strength were determined using the ANOVA. The MINITAB is suited to compute the percent contribute every variable to total joint strength. Findings of compression strength ANOVA are shown in Table 4.

The findings from the ANOVA show that the tube projection of the tool contributes the majority of the percentage contribution in this study were about 73 percent for joint strength and 55 percent in tensile strength and hardness. This is because the TIG created as a result of the tool on the plate's the majority of the top surface is attributed to the tool's protrusion. Like in this piece of work, there are no holes, allowing for excellent bonding between the atoms inside the metals. The interactive plot is given in Figure 4.

| Source            | D/F | Adj.SS  | Adj.MS  | % of contribution |
|-------------------|-----|---------|---------|-------------------|
| Speed (rpm)       | 2   | 506.84  | 253.432 | 92.7              |
| Projection (mm)   | 2   | 28.346  | 14.173  | 5.1               |
| Depth (mm)        | 2   | 9.595   | 4.797   | 1.7               |
| Error             | 2   | 1.657   | 0.829   | 0.5               |
| Total             | 8   | 546.462 | 273.234 | 100               |

![Table 4. ANOVA table.](image)

3.5. Optimal Joint Strength Regression Analysis

In this work, regression analysis and MINI TAB were used. The regression equation is created by using the Taguchi L9 orthogonal array to provide internal and external variables. This aid is determining the reason of one variable's effect on another. The two equations are derived from the values of three components as well as compressive strength. In this work, input characteristics like as projection, depth of cut, speed, and compressive strength are used to derive regression equations for tubes without holes. The regression equation for the case where there is no hole is illustrated in the equation below.

Compressive Strength = 252.60 + 0.4470 Current + 0.2127 Feed Rate - 0.474 Distance b/w tool & w/p

![Figure 4. Interaction plot.](image)
Using a regression equation based on the maximum value attained in the output parameter compression strength, the relevant values of input variables are used to compute the optimal joint strength of the work piece. For best results, Proportion of influence each and every operating parameter was calculated using MINITAB software. For tube with condition, the tube projection has the greatest impact on joint strength. In comparison to other work pieces, this one has higher compression strength. An empirical distribution function is a distribution function that is related with a sample's empirical measure in statistics. This cumulative distribution function is a step function with each of the n data points jumping up by 1/n. The empirical CDF chart of input and output constraint is displayed in Figure 5.

4. Conclusion
The TIG welding procedure was employed to join an aluminium 6063 tube to an aluminium 6061 tube plate in this research study, which is a ground-breaking technology with a wide range of applications. The maximum joint strength was identified as 318.716 MPa for a piece of craftsmanship having holes in its inner borders, and the process parameters are optimized. At 120 amps current, 60 mm/s speed, and 2 mm distance, the joint strength was found to be at its peak. Due of the lack of holes in the work pieces, it has become possible. ANOVA was used to identify out the proportion of each process's contribution variables, where the current has contributed the most (92.7%), tube projection 5%, and distance 2%. Mechanical tests revealed that the tube and tube plate were well-bonded, that aluminium was present as an intermetallic compound between the tube and tube plate.

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