# Process parameter optimization of friction stir welding to maximize the UTS of aluminium alloy 5083

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***Abstract:*** In the present investigation, the affect of four different process parameters i.e. tool rotation speed, transverse/welding speed, tool tilt angle and tool pin profiles on ultimate tensile strength of welding aluminium alloy 5083 by friction stir welding carried by Universal milling machine. The main aim of this study to find the optimum levels of process parameters to maximize the Ultimate tensile strength of the weld joint. L16 orthogonal array has come out as the possible solutions for designing the experiments. Hence, L16 orthogonal array is selected for the present investigation. The study revealed that the 1950 rpm of tool rotation speed, 35mm/min of welding speed, cylindrical threaded tool pin with tilt angle of 2 degree are the optimum levels of process parameters.

Key words: Friction stir welding, Aluminium alloy, Ultimate tensile strength

## I. INTRODUCTION

Friction stir welding was invented in 1991 in TWI US. Friction stir welding is a solid state welding method by which the metal plates joined with the help of a rotating tool consisting of a shank, a shoulder and a profiled pin. It is a solid state process, which means that the base material to be joined does not melt during joining and is used where the original properties of the metal must remain as constant as possible. The 5083 aluminum alloy contains magnesium, and a small amount of manganese and chromium have been used as working materials for this experiment. AA 5083 shows an excellent corrosion resistance and very good weldability. Because of such excellent properties it is used in shipbuilding, bridges, storage tanks, road and rail storage tanks, pressure vessels, pipes and pipes, tools and welding equipment for chemical equipment.

## II. LITERATURE REVIEW

Uzun et al. [1] has joined, aluminium alloy 6013-T4 with stainless steel X5CrNi18-10 by using FSW technique. The TRS was 800 RPM and WS was 80mm/min. Zhang and Zhang [2] joined two plates of Al 6061-T6 by using FSW. The tool consisting of the pin and the shoulder of radii were 5 and 22.7mm, resp. The two plates were of (100* 40 * 8) mm. Zhang et al. [3] joined the plate of AA 6061-T6 using FSW having tool of pin radius of 3mm and the shoulder radius of 7.5 mm. The welding plates were of 100*30*3 mm in length, width and thickness respectively. Kulekci et al. [4] made lap joints by FSW of AA 5754 plates of thickness 3 mm, length 200 mm and width 100 mm. In this study, three different instruments were selected with a shoulder diameter of 15 mm, a threaded pin height of 5 mm, a thread pin diameter of 3 mm, 4 mm and 5 mm, and an angle of inclination of 2 degrees. Sakthivel et al. [5] joined two plates of aluminium of dimensions (300*150*6) mm by using friction stir welding at a constant TRS of 1,000 rpm with different WS. The tool having a cylindrical threaded (1mm pitch 6mm) pin of length 5.75-mm with 15 mm shoulder dia. Sarsılmaz and Caydas [6] have studied how the stir geometry influences the mechanical properties of AA 1050 welded with AA 5083 friction welding. Borino et.al [7] studied the AA6082-T6 welded by FSW on a vertical milling machine. The tool used for this study was made of H13 steel and hardened at 1020° C and characterized by a hardness of 52 HRC; a cylindrical pin with a diameter 4 mm, height 2.9 mm and shoulder diameter 10 mm has been used

## III. EXPERIMENTAL SET-UP

The experiment was statistically planned using the powerful Taguchi Experimental Method (DOE). Before finalizing a particular orthogonal array for the purpose of designing an experiment, the number of parameters, the number of interactions and the level of interest must be established. In the present investigation, four different process parameters i.e. tool rotation speed, welding speed, tool tilt angle and tool pin profile has been selected as already discussed, and four different levels for all the selected process parameters were selected as shown in table 3.1[8].

A universal vertical milling machine used as the experimental machine in this study with a fixture used for clamping the workpiece. The vertical milling machine used for this research work is consisting of a 3Hp motor which is connected to the spindle. The belt pulley arrangement is used for varying the spindle speed with respect to motor speed and speed of spindle can vary in four steps from minimum 1200 rpm to maximum 4600 rpm. Two aluminum alloy 5083 plates measuring 120 mm × 60 mm × 6 mm were mounted on the fixture of the vertical milling machine, and the butt joint was fabricated by the friction stir welding process.

The tools for welding AA5083 by FSW were made of high carbon steel shown in figure 3.1. The consists of shank, shoulder and a pin. The shank diameter was made of 17 mm For holding the tool on milling machine, shoulder diameter, tool pin diameter and length of pin was of 18 mm, 6 mm and 5.5 mm respectively.

Figure 3.1 Pictorial views of FSW tools

Various experiments were performed to optimize response parameter i.e. ultimate tensile strength.

Table 3.1 Control variables and levels

| **S. No.** | **Parameters** | **Level 1** | **Level 2** | **Level 3** | **Level 4** |
|---|---|---|---|---|---|
| A | Tool rotation speed (RPM) | 1200 | 1950 | 3080 | 4600 |
| B | Welding speed (mm/min) | 20 | 25 | 30 | 35 |
| C | Tool tilt angle | 0 | 1 | 2 | 3 |
| D | Tool pin profile | Cylindrical | Cylindrical threaded | Trapezoidal | Square |

## IV. EXPERIMENTATION

The experimentation for this study is consisted of sixteen trial runs as shown in table 4.1. The experiments are done as per sequence of design of experiment given by L16 orthogonal array[9].

Table 4.1 Design of Experiment

| Experiment No. | Tool rotation speed (A) | Welding speed ( B) | Tool Tilt angle (C) | Tool Pin Profile (D) |
|---|---|---|---|---|
| 1 | 1200 | 20 | 0° | Cylindrical |
| 2 | 1200 | 25 | 1° | Cylindrical threaded |
| 3 | 1200 | 30 | 2° | Trapezoidal |
| 4 | 1200 | 35 | 3° | Square |
| 5 | 1950 | 20 | 1° | Trapezoidal |
| 6 | 1950 | 25 | 0° | Square |
| 7 | 1950 | 30 | 3° | Cylindrical |
| 8 | 1950 | 35 | 2° | Cylindrical threaded |
| 9 | 3080 | 20 | 2° | Square |
| 10 | 3080 | 25 | 3° | Trapezoidal |
| 11 | 3080 | 30 | 0° | Cylindrical threaded |
| 12 | 3080 | 35 | 1° | Cylindrical |
| 13 | 4600 | 20 | 3° | Cylindrical threaded |
| 14 | 4600 | 25 | 2° | Cylindrical |
| 15 | 4600 | 30 | 1° | Square |
| 16 | 4600 | 35 | 0° | Trapezoidal |

A tensile sample is then extracted from each weld. Sample sizes conform to American Society for Testing and Materials (ASTM) standards, as shown in Figure 4.1. Samples after the welded plates were extracted are shown in Figure 4.2. Table 4.2 shows the values of UTS against the input parameter setting for L16 orthogonal array.

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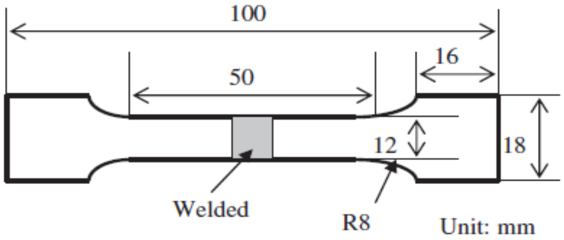


Figure 4.1 Specimen Size for the UTS and elongation

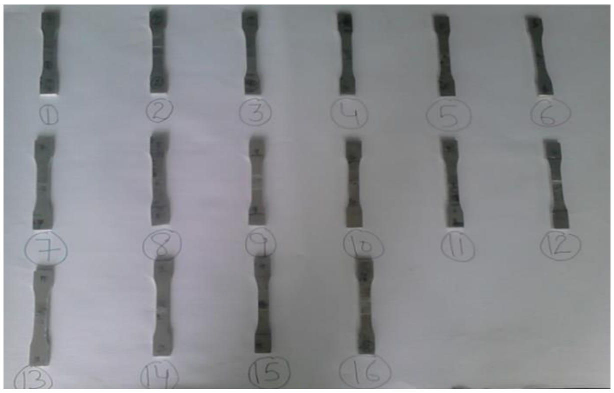

Figure 4.2 Specimen for the UTS

Table 4.2 Taguchi's L16 OA for Ultimate tensile strength

| **Experiment No.** | **Tool rotation speed (A)** | **Welding speed ( B)** | **Tool Tilt angle (C)** | **Tool Pin Profile (D)** | **UTS (MPa)** |
|---|---|---|---|---|---|
| 1 | 1200 | 20 | 0° | Cylindrical | 190.24 |
| 2 | 1200 | 25 | 1° | Cylindrical threaded | 192.85 |
| 3 | 1200 | 30 | 2° | Trapezoida | 201.86 |
| 4 | 1200 | 35 | 3° | Square | 197.08 |
| 5 | 1950 | 20 | 1° | Trapezoida | 185.21 |
| 6 | 1950 | 25 | 0° | Square | 188.66 |
| 7 | 1950 | 30 | 3° | Cylindrical | 200.86 |
| **8** | **1950** | **35** | **2°** | **Cylindrical threaded** | **206.56** |
| 9 | 3080 | 20 | 2° | Square | 187.64 |
| 10 | 3080 | 25 | 3° | Trapezoida | 189.74 |
| 11 | 3080 | 30 | 0° | Cylindrical threaded | 195.74 |
| 12 | 3080 | 35 | 1° | Cylindrical | 194.86 |
| 13 | 4600 | 20 | 3° | Cylindrical threaded | 190.60 |
| 14 | 4600 | 25 | 2° | Cylindrical | 189.90 |
| 15 | 4600 | 30 | 1° | Square | 182.45 |
| 16 | 4600 | 35 | 0° | Trapezoida | 190.26 |

## V. CONCLUSIONS

The following conclusions can reveals after this experimentation study**:**

1. The four parameters i.e. Tool rotation speed, welding speed, tool tilt angle and tool pin profile affects the weld quality of AA 5083 by friction stir welding.

2. The Ultimate tensile strength is maximum at tool rotation speed of 1950 rpm, welding speed of 35mm/min, tool tilt angle of 2 degree and cylindrical threaded tool pin profile.

3. Maximum value of UTS at optimum parameters is 206.56 MPa.

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