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To Predict the Tensile Strength of Dissimilar AA6101 and AA6082 by Underwater Friction Stirs Welding

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Abstract: This article presents prediction of ultimate tensile strength of joint between aluminium alloys AA6101 and AA6082 by using of underwater friction stirs welding (UWFSW). The considered process parameters are tool rotational speed, tool linear feed and tool shoulder diameter. The change of tool shoulder diameter and other parameters tensile strength varies. The ultimate tensile strength may increase or decrease with increase of tool rotation speed. Also, can decrease with increase of tool shoulder diameter and tool linear speed. Here, tensile strength of the welded alloy of the process, were measured and examined. It has been examined in this experiment that maximum tensile strength of joint is achieved 217 N/mm^2 by applying 18mm shoulder diameter with a rotational speed of 1000 rpm & welding speed of 30 mm/min. The tensile strength of welded specimens reached in the UWFSW joint is 75-80% of the parent metal tensile strength. Underwater friction stir welding is more efficient and decent welding technique compare to the other welding categories.

Keywords: Dissimilar material, H13 tool, Process parameter, tensile strength, Underwater friction stir welding.

I. INTRODUCTION

Friction stir welding was invented by The Welding Institute (TWI) in December 1991. TWI filed successfully for patents in Europe, the U.S., Japan, and Australia. TWI then established TWI Group-Sponsored Project 5651,"Development of the New Friction Stir Technique for Welding Aluminum," in 1992 to further study this technique [1]. Friction stir welding tool has a shoulder its distal end, and a non-consumable welding pin extending downwards centrally from the shoulder. As the rotating tool is brought into contact with the interface between plates, the rotating pin is forced into contact with the material of both plates. The rotation of the pin inserted into the work material and frictional rubbing of the shoulder with the upper surface of the material produces a large amount of frictional heating of both the welding tool and the plate interface [2].
Due to this heat material of the plates is softened in the area near the rotating pin and shoulder, causing commingling of material, which upon hardening, forms a weld. The tool is moved longitudinally along the interface between plates, thereby forming an elongate weld all along the interface between the plates. The welding tool's shoulder prevents softened material from the plates from escaping upwards, and forces the material into the weld joint. When the weld is completed the welding, tool is retracted. Friction stirs welding permits joining of two members in solid state without phase transformation which is characteristic of the fusion welding process which melts and solidifies the parent metal. This method is rapidly practice as an operation towards fabricate the lightweight products in area like aerospace, shipbuilding, marine, automotive, railway and electronics industries.

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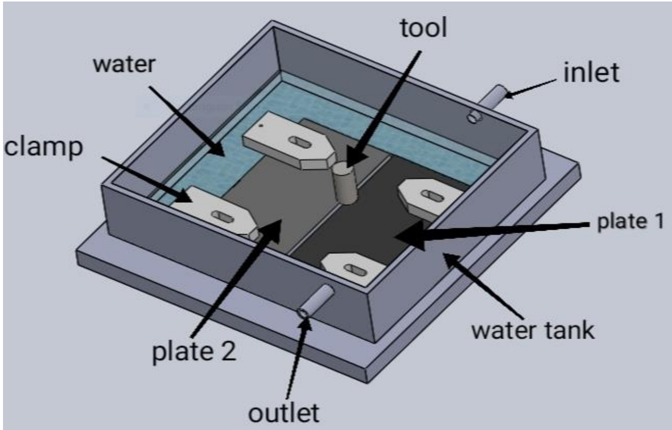

Figure 1 schematic diagram of underwater friction stirs welding (UWFSW)

II. LITERATURE REVIEW

1.1 Heena et.al. **[3]** They work on the Aluminium alloy 6061 and Magnesium alloy AZ31 plates of 6 mm thickness are welded in circular butt joint geometry by friction stir welding (FSW) process, using CNC vertical milling machine. Process parameters like welding speed and tool rotational speed play an important role to acquire a better weld joint for dissimilar metals/materials. In this research work, it is found that welded joint between dissimilar metals alloys Al 6061 & Mg AZ31 can be formed using friction stir welding by choosing suitable tool pin profile and welding parameters. It is suggested that friction stir welding of Aluminium alloy and Magnesium alloy with circular butt joint geometry would be useful in the future for automobile applications by getting the benefits from each material in a functional way.

1.2 Selamat et.al. [4] In this study, the friction stirs welding (FSW) known as the solid-state joining process was extensively used for joining similar and dissimilar 5 mm aluminium alloy plates. The butt-joint type of similar joints (AA5083-AA5083) and dissimilar joints (AA5083-AA6061) were carried out under the similar welding parameters; 1000 rpm (rotational speed) and 100 mm/min (welding speed). They found tensile strength of similar joint and dissimilar joint was 22% and 19% lower compared to the base metal of AA5083 and AA6061.

1.3 Sara et.al. [5] In this paper, the feasibility of butt friction stirs welding (FSW) of a metal matrix composite (MMC) with a very high SiC particle content to a monolithic aluminum alloy is tested in this work. It is demonstrated for the first time that sound FSW joints can be obtained between an AA6061 aluminum plate and a thick MMC plate consisting of AA6061 reinforced with 40 vol% SiC particles. The joints withstand tensile testing.

1.4 H.S. Patil & S.N. Soman [6] The effect of processing parameters on the mechanical and metallurgical properties of dissimilar joints of AA6082–AA6061 produced by friction stir welding was analyzed in this study. In all the experiments the rotating speed is fixed at 1600rpm. All the welds were produced perpendicularly to the rolling direction for both the alloys. Microhardness (HV) and tensile tests performed at room temperature were used to evaluate the mechanical properties of the joints.

1.5 S.S. Sabari et.al. [7] Under water friction stir welding (UWFSW) is a variant of FSW process which can maintain low heat input as well as constant heat input along the weld line. The heat conduction and dissipation during UWFSW controls the width of TMAZ and HAZ and also improves the joint properties. In this investigation, an attempt has been made to evaluate the mechanical properties and microstructural characteristics of AA2519-T87 aluminium alloy joints made by FSW and UWFSW processes.

III. EXPERIMENTAL SETUP AND PROCESS

Experimental setup was recognized using a vertical machining center machine (VMC machine). Not any additional setup is mandatory for friction stir welding excluding tool and fixture, so as to place part in correct location throughout welding as tool move forward, material is forced in flow from leading edge to trailing edge of tool & material flows around the tool, undergoes extreme level of plastic deformation. As tool passes, weld cools, there by joining the two plates together.

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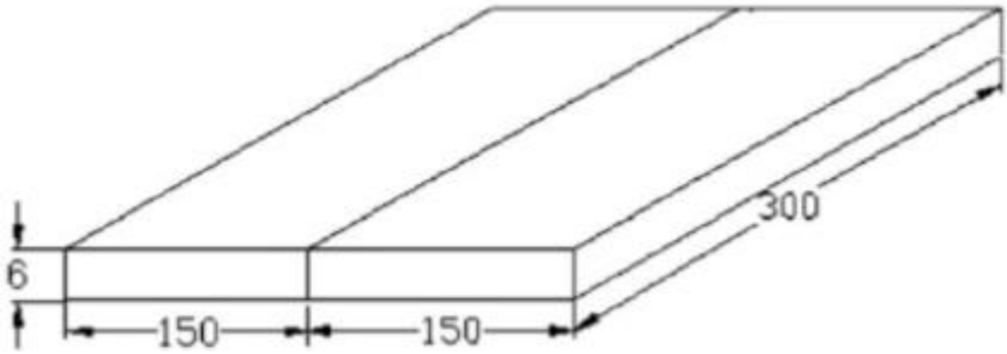

Figure 2 dimension of work piece

The set rolling plates of 6 mm width, AA6101 & AA6082 aluminium alloy, have been cut into the essential size (300mm X 150mm). Square butt joint shape generates, as shown in Figure has been arranged to fabricate UWFSW joints. The initial joint formation is obtained by locking the plates in position using mechanical clamps. The route of welding is regular to the rolling direction. Single pass welding technique has been followed to fabricate the joints. Non-consumable tool finished of Hot Work, Chromium steel is designed and developed to fabricate the joints. The chemical composition of AA6101 & 6082 is as below.

Table 1 Chemical Compositions of AA6101

Element	% Amount
Silicon (Si)	0.70 - 1.30
Magnesium (Mg)	0.60-1.20
Magnesium (Mg)	0.40 - 1.00
Iron (Fe)	0.0 - 0.50
Chromium (Cr)	0.0 - 0.25
Zinc (Zn)	0.0 - 0.20
Others (Total)	0.0 - 0.15
Titanium (Ti)	0.0 - 0.10
Copper (Cu)	0.0-0.10
Other (Each)	0.0-0.05
Aluminium (Al)	Balance

Table 2 Chemical Compositions of AA6082

Element	% Amount
Silicon (Si)	0.30-0.70
Magnesium (Mg)	0.50
Magnesium (Mg)	0.10
Iron (Fe)	0.03
Chromium (Cr)	0.03
Zinc (Zn)	0.35-0.8
Others (Total)	0.10
Titanium (Ti)	0.3
Copper (Cu)	-
Other (Each)	0.10
Aluminium (Al)	Balance

1.6 Process Parameter

Underwater Friction stir welding is a sequence of multifaceted physical events with characteristic problems and is controlled by a greater number of factors. A lesser set of factors would give a simpler model, a larger number give more predictive power. However, the greater the number of factors, the more tedious the experimentation and analysis.

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Table 3 Input process parameter of UWFSW

Sr. No.	Input parameter	Levels		
		Level 1	Level 2	Level 3
1	Shoulder dia. (mm)	16	18	20
2	Feed (mm/rev)	20	25	30
3	Rotational speed (rpm)	800	1000	1200

1.7 Tool material

Selection of the tool material as per review of research papers demonstration the usage of steel tools for plate materials such as Aluminium or Magnesium alloys and Aluminium matrix composites (AMCs) frequently welded by FSW. Steel tools have similarly used for the joining of dissimilar materials in both lap and butt joint shapes. The tool steel-H13 having chemical composition with supplementary carbon content was hardened after making the tool shapes for reducing tool wear throughout FSW process. [4] Using H13 tool for performing our trials which is widely used in real time. High carbon high chromium (HCHCr) tool steel has a remarkably high wear resistance among different tool steel grades. H13 is characterized by shock and abrasion resistance combined with red hardness. It has a chromium composition of 5% and has high toughness [8].

Applications of UWFSW H13 steel are a chromium-molybdenum hot-worked air hardening steel and are recognized for virtuous elevated-temperature strength, thermal fatigue resistance and wear resistance. The H-13 steel also facilitates a marginally wider range of principal alloying elements availing manufacturers the flexibility of providing mechanical properties for given heat treatments and application. It is widely used in real time applications of friction stir welding. H13 steel is a chromium. The chemical composition of H13 steel tool is as below.

Table 4 H13 tool Material properties

C	Si	Mn	Cr	Mo	V
0.39	1.10	0.4	5.2	1.4	1.95

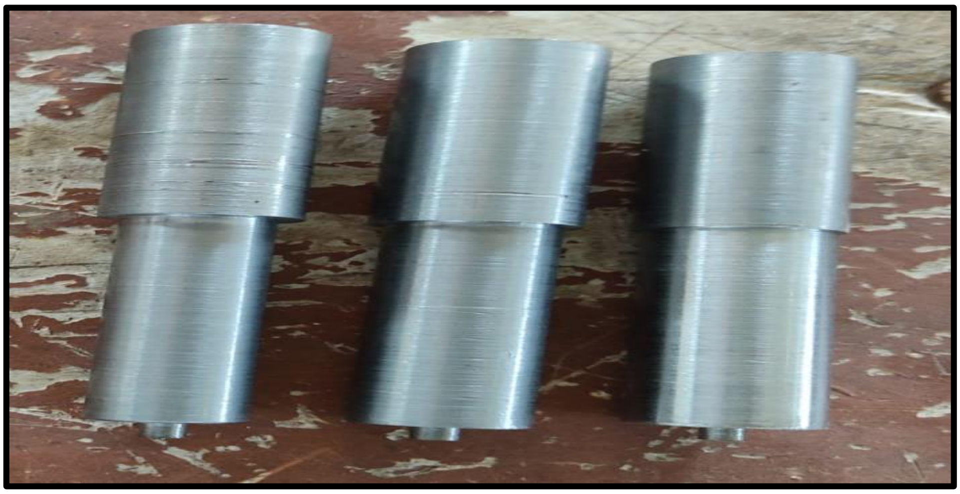

Figure 3 Different diameters of tool using in experiment

1.8 Tensile Test of welded plate

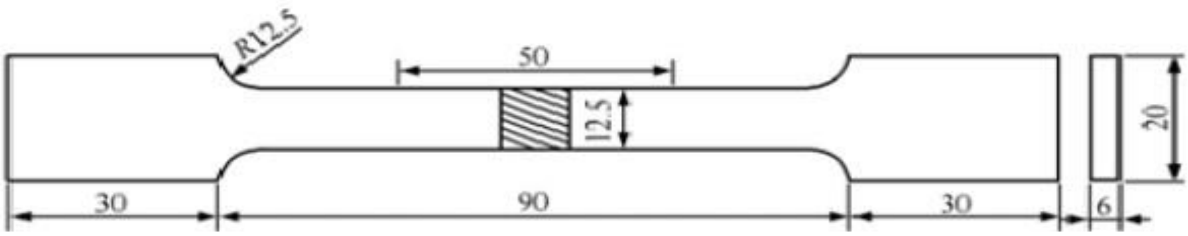

Figure 4 Specimen dimension for tensile strength

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From all the joints corresponding parameters three specimen are cut to measure the strength of the weld. The specimens are also cut on the milling machine. The all specimens are shown in above fig. Using the UTM (universal testing machine) of 60 Tone load capacity the load (in KN) that it can withstand at maximum elongation is measured and dividing it by the cross-sectional area of weld the tensile strength is measured.

III. RESULT AND DISCUSSION

1.9 Planning of experiments

For developing models based on experimental data, carefully planning of Experiment is essential. The factors considered for the experimentation and analysis of UWFSW between Aluminum alloy AA6101 and AA6082 are tool shoulder diameter, rotational speed and welding speed. It is significant to acquire accurate data with the minimum number of a well-designed experiment by Design of Expert. The Central Composite Design as below.

Table 5 Central Composite Design

Std. Order	Shoulder Dia. (mm)	Rotational Speed (RPM)	Welding Speed (mm/min)	Tensile Strength (N/mm^2)
1	16	800	20	180
2	16	800	40	182
3	16	1200	20	194
4	16	1200	40	186
5	16	1000	30	210
6	20	800	20	194
7	20	800	40	206
8	20	1200	20	190
9	20	1200	40	184
10	20	1000	30	192
11	18	800	30	180
12	18	1200	30	184
13	18	1000	20	198
14	18	1000	40	204
15	18	1000	30	216
16	18	1000	30	215
17	18	1000	30	217
18	18	1000	30	216

IV. CONCLUSIONS

In the sequences of investigational conditions in the existing study, the subsequent conclusions, which can be beneficial for underwater friction stirs welding of square butt weld joint between Aluminium alloy AA6101 and AA6082.

- This investigation shows that the underwater friction stir welding technique can be applied as a sort of approximately perfect shaping technology in material that is practically impossible to weld by other techniques
- It should be clear that, using the new production line, the base material consumption can be significantly reduced compared to the current production route.
- The tensile strength of welded samples stretched in the UWFSW joint is 75-80% of the parent metal tensile strength.
- Higher welding speed lead to in short exposure time in the weld area with inadequate heat due to underwater environment and poor plastic of the metal and causes about void like defect in the joint.

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• It has been examined that extreme tensile strength of joint is attained 217 N/mm2 with 18 mm shoulder diameter, rotational speed of 1000 rpm and welding speed of 30 mm/min.

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