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# Comparisonal Analysis on Effects of Processing Parameters on Microstructural and Mechanical Behaviour of Underwater Friction Stir Welding (UWFSW) Of Al6082

P. Prem Kumar[1], G.K.Thirumaran[2], R.VijayaRaghavan[3]
[1]Assistant Professor, St. Joseph Engineering College, Chennai, India
[2,3]UG students, St. Joseph Engineering College, Chennai, India

***Abstract*— Friction stir welding is a modern welding technique to join similar and dissimilar metals, extensively used in Mechanical and Manufacturing field, whereas Under Water Friction Stir Welding (UWFSW) is a latest research area. In FSW process, the frictional heat produced at the tool surface causes plastic dissipation and softening of the material which is extruded around the tool and consolidates to form a weld. In UWFSW the entire FSW process is carried out in a specially prepared setup where the work piece and tool are immersed in water. In UWFSW the width of the Thermo Mechanical Affected Zone (TMAZ) and Heat Affected Zone (HAZ) are controlled, thereby increases the Mechanical properties of the weld. Attempt has been made to conduct the FSW and UWFSW processes in Conventional Milling Machine. The improvement of Hardness and compression strength of the UWFS welded Aluminium joints are studied.**

***Keywords*— Heat Affected Zone (HAZ), Thermo mechanically Affected Zone (TMAZ), Under Water Friction Stir Welding (UWFSW)**

## I. INTRODUCTION

Friction Stir Welding is a solid state joining process which is utilised to weld various types of ceramics, polymers, Aluminium alloys(1). FSW finds its applications in various areas like mechanical, aerospace, railways, automobile industries. FSW is based on friction heating and local plastic flow in the joint region by stirring with a rotational tool pin. FSW used to create high quality, high strength butt or lap joints in a wide range of material thickness and length (2). The process is carried out by plunging a rotating tool and translating it along the desired weld line. The heat generated by the friction at the tool surface and plastic dissipation in the deforming region of the work pieces soften the material to the plasticised state which is then extruded around the tool and consolidates to form a weld . From various researches it is confirmed that FSW can produce sound joints in heat treatable Aluminium alloys. However, the thermal cycles exerted during FSW resulted in the reduction of mechanical properties of the joints due to coarsening and dissolution of strengthening precipitates in Thermo Mechanically Affected Zone (TMAZ) and Heat Affected Zone (HAZ). In FSW heat generated in stirred zone and the heat conducted TMAZ and HAZ causes the precipitates to be either solutionized or coarsened. The loss of precipitates during solutionising and coarsening reduces the joint properties and causes non-uniformity along the weld region (3). In order to overcome the heat dissipation problems created in surrounding regions of weld and to improve the strength of the weld joint, the heat should be dissipated readily using a cooling method . The water cooling method is more efficient than other cooling methods terms of uniform cooling and highly transfer coefficient (4). In Under Water Friction Stir Welding, the entire Friction Stir Welding (FSW) process is carried out under the surface of water (as shown in fig 1)

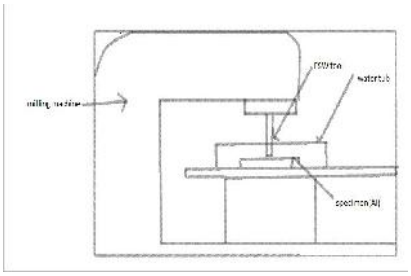

Fig 1 Simple layout of UWFSW

Rapid cooling of the welded joints improves the strength of the joints by restricting the coarsening and dissolution of strengthening precipitates(6). Under Water Friction Stir Welding reduces the common weld defects like hydrogen embrittlement oxidation, porosity. In our investigation of Under Water Friction Stir Welded Aluminium alloy (Al6082) we found the improvement in mechanical properties.

## EXPERIMENTAL SETUP AND WORK

The process of Friction Stir Welding and Underwater Friction Stir Welding are carried out by changing the tool and attachments in conventional CM milling machine (fig3,4). The welding machine has a table size of 100 by 700 mm . The 5.5KW 3 phase squirrel cage induction motor is used (5). The tool employed was 4mm long probe with 25 mm concave shoulder machined from HSS. The Al6082 Aluminium specimen of dimensions 120mm L X 50 mm W X 5 mm T

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were prepared. A tank was constructed in order to immerse the specimen under water.

Fig 2 3D Modelling shows tank setup in UWFSW

Fig 3 Attachment of FSW tool

Fig 4 shows the bed length and vice setup

The shaper vice is mounted into the tank for holding the work specimen .The experimental setup is shown in the fig 3 and the specifications of the tool are listed.
Fig 3 indicates the tool of FSW in the milling machine.
Fig 4 indicates vice setup , shaper vice is best used since it is easily adaptable to the specimens.

Fig 5 position of FSW tool while machining

The rotational speeds were selected based on the available setting of the conventional CM milling machine. In this experiment we have conducted FSW and UWFSW of Al6082 Aluminium alloys at 900 and 1200 rpm.

The Aluminium plates to be processed in Under Water Friction Stir Welding were butted and fixed to the vice which is directly bolted to the bed of the milling machine(2). The tank is filled with room temperature water. The water enters the tank through the inlet valve to the level above the tool shoulder. The rotating UWFSW tool pin is plunged into the interface at starting end of the material and halted until there is adequate friction energy to plasticize the material around the tool shoulder which is then extruded around the tool and consolidates to form the weld(7). During welding inlet and outlet valves are adjusted to control the water flow in such a way to maintain the temperature of the water below $60^0$C near to the welding location.

MATERIAL SELECTION

MATERIAL COMPOSITION

Typical chemical composition of Aluminium alloy Al 6082 in the table 2

| ELEMENTS | %PRESENT |
|---|---|
| Si | 0.7-1.3 |
| Fe | 0.0-0.5 |
| Cu | 0.0-0.1 |
| Mn | 0.4-1.0 |
| Mg | 0.6-1.2 |
| Zn | 0.0-0.2 |
| Ti | 0.0-0.1 |
| Cr | 0.0-0.25 |
| Al | Balance |

Table 2

PROPERTY

- Medium strength alloy
- Excellent corrosion resistance
- Good machinability
- Good weld ability.
- Cold workability

Fig 6 Aluminium Al6082 samples

Typical Mechanical properties of Al6082 are listed in table 3

| Property | Value |
|---|---|
| Density | 2.71g/cm$^3$ |
| Young's Modulus | 71GPa |
| Ultimate tensile strength | 140 - 330MPa |
| Yield strength | 90 – 280MPa |
| Thermal expansion | 23.1 x $10^{-6}K^{-1}$ |
| Melting point | 555$^o$C |
| Thermal conductivity | 180$Wm^{-1}K^{-1}$ |

Table 3

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Aluminium alloy Al6082 is a medium strength alloy with high corrosion resistance. Al6082 is known as structural alloy. The addition of large amount of Manganese controls the grain structure.

TOOL SELECTION

Tool material selected for carrying out FSW and UWFSW is HSS (High Speed Steel).

PROPERTIES

- High working hardness.
- High wear resistance.
- Compression strength.
- Resistance to abrasion

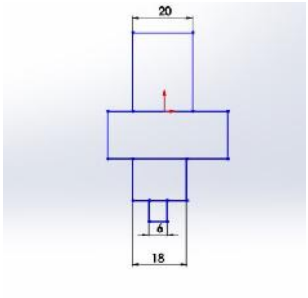


Fig 7 Normal pin UWFSW tool

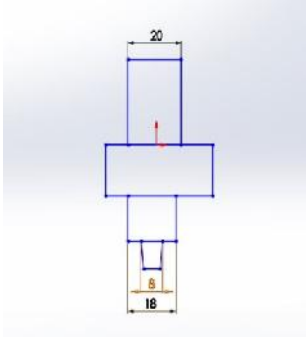


Fig 8 Tapered pin UWFSW tool

Welds produced with normal pin seems to have lateral flashes thus reduces the weld quality whereas welds produced with tapered pin does not have any flashes. Tapered pin profile gives a good surface finish and high weld strength.

PROCESSING PARAMETERS

Underwater Friction Stir Welding process is carried out with the help of some process parameters as show in the table 4

| Process Parameters | FSW | UWFSW |
|---|---|---|
| Tool rotational speed/rpm | 900,1200 | 900,1200 |
| Pin length/mm | 4 | 4 |
| Tool shoulder diameter mm | 25 | 25 |
| Pin diameter/mm | 5 | 5 |
| Pin profile | Tapered cylindrical | |

Table 4

RESULTS

HARDNESS

The Rockwell Hardness was measured along the welded region in the middle over the tool distance. The hardness value is shown in the table5

| Type | speed (rpm) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| FSW | 900 | 67 | 76 | 70 | 69 | 75 | 72 | 70 | 75 |
| UW FSW | 900 | 65 | 75 | 76 | 79 | 83 | 78 | 76 | 73 |
| FSW | 1200 | 68 | 69 | 75 | 79 | 80 | 69 | 70 | 70 |
| UW FSW | 1200 | 63 | 83 | 74 | 87 | 90 | 79 | 86 | 80 |

Table 5

A graph is plotted between Rockwell Hardness Number vs. distance across the weld. The advancing of the weld is on the right side of the plot . The weld starting region is on the left of the plot . When welding with a higher frictional input, the whole work piece was heated above the temperature of recrystallization, where the grain growth occurs . The graph is shown

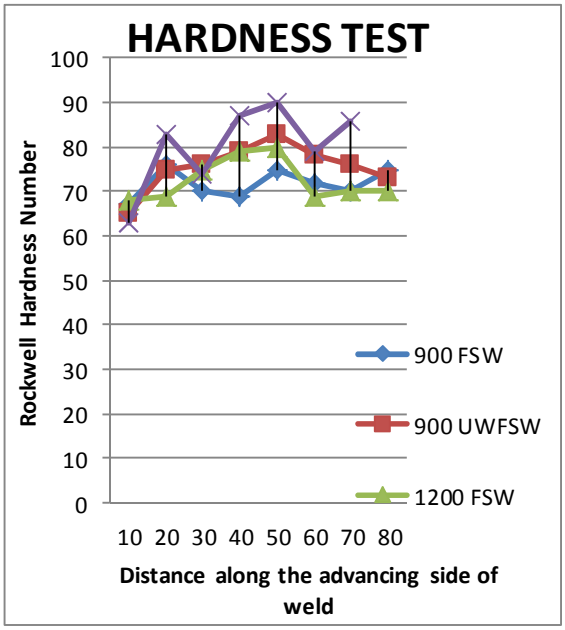

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Fig 9 Rockwell hardness Testing machine

From the graph, result inferred is that Underwater Friction Stir Welding Hardness value increases more along the advancing sides of the weld when compared with Friction Stir Welding.

COMPRESSION TEST

In a compression test a material experiences opposing forces that push inwards upon the specimen from both the sides. The test sample is generally placed in between two plates that distribute the applied load across the entire surface area of two opposite loads on the test samples and are compressed using Universal Testing Machine .The ultimate strength value is listed in table 6

| S.No. | Type | Rotational speeds(rpm) | Ultimate Strength(KN) |
|---|---|---|---|
| 1. | FSW | 900 | 72 |
| 2. | FSW | 1200 | 84 |
| 3. | UWFSW | 900 | 108 |
| 4. | UWFSW | 1200 | 120 |

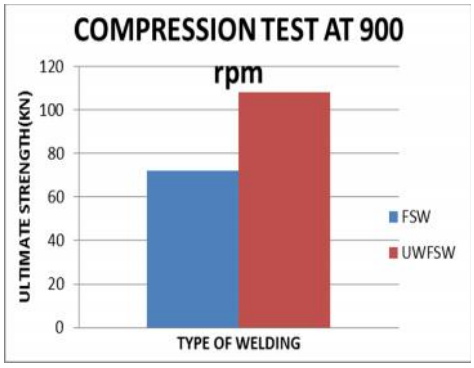
Table 6

The compression test shows that the compression property of Under Water Friction Stir Welded Aluminium alloy Al6082 is 40-50% increasing than the Friction Stir Welded Aluminium alloy Al 6082. Underwater Friction Stir Welded Aluminium Al6082 samples have high weld strength as it withstands high compressional loads.

A graph is plotted between ultimate strength and the rotational speeds of the tool.


Fig 10 Compression testing machine

Fig 11 Value after compression test



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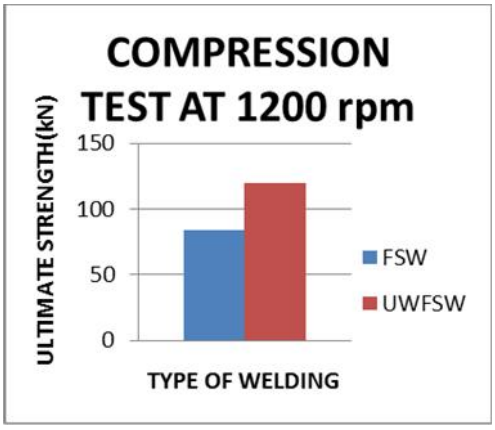


MICROSTRUCTURE

The Under Water Friction Stir Welded Aluminium alloy Al6082 is subjected to micrographic test .The microstructural images of the welded sample are listed below.

Fig a


Fig b

Fig a,c,e are the micrograph of FSW


Fig c

Fig d

Fig e

Fig f

Fig b,d,f are the micrograph of UWFSW

It can be seen that along the weld zone contains inter-metallic particles .The welded zone reveals fine crystallised grains along the advancing sides of the welded zone.

From the micrographic study of FSW and UWFSW welded joints it is found that the grain deposition is finer in Under Water Friction Stir Welding and less defects in comparison with Normal Friction Stir Welding.

## CONCLUSION

- The conventional milling machine could be successfully used to carry out Friction Stir Welding and Under Water Friction Stir Welding.
- Observations from hardness test indicates , the hardness along the advancing side of the weld zone in Under Water Friction Stir Welded sample is approximately 12 – 15 % higher than that of Friction Stir Welded sample.

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- Compression test results indicates that the ultimate strength in Under Water Friction Stir Welded smple is 1.5 times greater than that of Friction Stir Welded sample .


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