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# A Review on an Investigation on the Effect of Immersed Medium in Friction Stir Welding of Aluminium Alloys (AA 6061-T6)

KEYWORDS: Friction Stir Welding, Rotational Speed, Welding Medium, Axial Force, Mechanical Properties, Microstructure.

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**ABSTRACT** Friction stir welding is solid state welding technology used for welding of low melting point metals such as Al, Mg and its Alloys. FSW process can be controlled by different parameters like rotational speed, feed rate and welding medium. In this process, a cylindrical non-consumable tool, with a profiled probe (pin) rotating about its own axis is slowly plunged into the abutting edges of work pieces rigidly clamped to a backing plate. When the shoulder of the tool touches work piece surface, the tool is translated (with an axial force) along the length of the joint forming the joint in the solid state..In this research, submerged friction stir welding of aluminium alloy AA 6061-T6 is investigated. Aluminium 6061 alloy is commonly used for construction of aircraft structures. In experimental part, the effect of different welding parameters on thermal histories, tensile properties and micro structural properties are studied. Submerged friction stir welding consumes less energy. It provides improved mechanical properties. This paper gives review of basic concepts of friction stir welding.

## I.INTRODUCTION

Friction stir welding was invented and patented by a research team led by Wayne M. Thomas [Thomas et al., 1991] [Thomas et al., 1995] of the Welding Institute in England. FSW is defined by Thread gill of TWI as "a method for joining two or more work pieces where a tool, moving in a cyclic manner relative to the work pieces, enters the joint region, locally plasticizes it and moves along the interface thus causing a solid state joint between the work pieces" [Thread gill, 2007]. A schematic of the friction stir welding process is shown below in figure 1. It can be observed that that, due to the rotation of the tool, friction stir welding is an asymmetric process with respect to the joint line.

Friction stir welding is performed by a rotating non consumable tool which is plunged into the material to be welded. The tool is traversed along the joint line to create a solid phase weld. The material along the tool becomes softened and highly plasticized from the frictional heat generated during the process and is carried around the tool so that there is complete mixing of material from the two plates. The pin of the rotating tool hence provides the "stir" action in the material of the work piece. This result in a Heat Affected Zone (HAZ) with a better grain refinement required for a good weld joining.

A cylindrical, shouldered tool with different profiled probe (nib or pin) is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, until the shoulder of the tool forcibly contacts the upper surface of the material and the pin is a short distance from the back plate. The pieces are rigidly clamped onto a backing plate in a manner that prevents the abutting joint faces from being forced apart. The fixturing prevents the plates from spreading apart or lifting during welding. Frictional heat is generated between the tool shoulder and the work piece. This heat causes the latter to reach a visco-plastic state that allows traversing of the tool along the weld line. The plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged by the intimate contact of the tool shoulder and the pin profile. It leaves a solid phase bond between the two pieces.

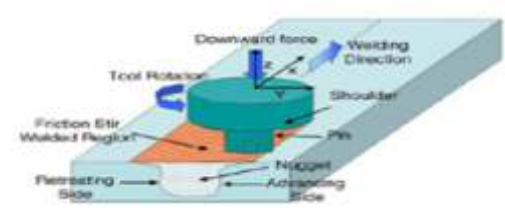


**Fig.1: Friction Stir Welding Process**

Fig. 2 shows the step by step process description of Friction Stir Welding

**Step 1:** Tool rotates at constant rpm about its axis as shown in step (a) of figure 1.

**Step 2:** Tool pin plunges into the abutting edges of the material to be joined due to the frictional heat between the tool pin and material. Tool shoulder contacts the material and plasticizes due to frictional heat between shoulder and material as shown in step (b) of figure 2.

**Step 3:** Welding is made on the material and tool withdrawn from the plate as shown in step (c) of figure 2.

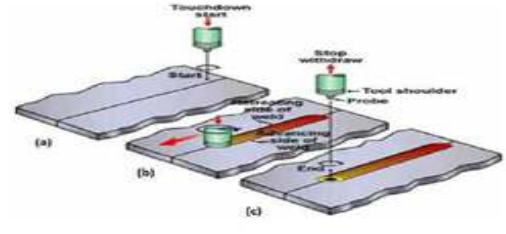


**Fig.2: Process Overview of FSW (TWI)**

## II. MICRO-STRUCTURAL FEATURES OF FRICTION STIR WELDS.

The first attempt at classifying microstructures was made by P L Thread gill (Bulletin, March 1997). This work was based solely on information available from aluminium alloys. A more comprehensive scheme has been developed by TWI, and has been discussed with a number of appropriate

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

people in industry and academia. This has also been accepted by the Friction Stir Welding Licensees Association.

The system divides the weld zone into distinct regions as follows. They are: (A) Unaffected parent material (B) Heat affected zone (HAZ) (C) Thermo mechanically affected zone (TMAZ) (D) Weld nugget (Part of thermo mechanically affected zone).

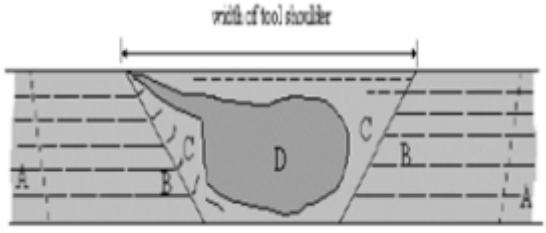


**Fig.3: Micro Structural Study of Plate (Copyright © 1997, TWI Ltd)**

The formation of above regions is affected by the material flow behavior under the action of rotating non-consumable tool.

**III. SUBMERGED FRICTION STIR WELDING**

Submerged Friction Stir Welding is a solid state welding process. It takes place at temperatures below the melting point of the material. In this method, a non-consumable rotating tool runs over the substrates under the submerged medium which results into the generation of heat due to friction. This leads to plastic deformation and softening of substrates near the tool area. Then, the substrates can be easily joined.

It also minimizes various welding defects like porosity, shrinkage, splatter, embrittlement, solidification, cracking etc. This process doesn't require shielding gas and filler material for welding which make this process cheaper. It consumes less energy and gives improved mechanical properties. It also provides well defined variation in grain size between different zones along the high quality weld joint produced.

In our study we are going to use AA 6061-T6.The chemical composition of AA 6061-T6 as follows.

| Composition | Amount (wt%) |
|---|---|
| Aluminium | Balance |
| Magnesium | 0.8-1.2 |
| Silicon | 0.4-0.8 |
| Iron | Max.0.7 |
| Copper | 0.15-0.40 |
| Zinc | Max.0.25 |
| Titanium | Max.0.15 |
| Manganese | Max.0.15 |
| Chromium | 0.04-0.35 |
| Others | 0.05 |

**Table.1: Chemical Composition of AA6061-T6.**

**IV.LITERATURE REVIEW**

Friction stir welding (FSW) is a new and promising welding process that can produce low cost and high quality joints of heat treatable aluminium alloys.

**Thomas et al (1991)** carried out the action of rubbing two objects together causing friction to provide heat. The principles of this method now form the basis of many traditional and novel friction welding, surfacing and processing techniques. The friction process is an efficient and controllable method of plasticizing a specific area of a material, and thus removing contaminants in preparation for welding, surfacing/cladding or extrusion. [1]

**R.S.Mishra et al (2005)** studied and understanding the development of fsw and fsp.Emphasis has been given to the (a) mechanisms responsible for the formation of welds and microstructural refinement, and (b) effects of FSW/FSP parameters on resultant microstructure and final mechanical properties. The study focusing on the aluminium alloys. [2]

**FU Zhi-Hong et al (2004)** were carried out friction stir welding of aluminium and titanium alloys etc.The processing of FSW, the microstructure in FSW alloys and factors affecting weld quality. They give conclusion that FSW is complex process and many factors affecting processing, main factors are tool's materials and configurations, rotating speed, welding speed, press force of tool on work pieces and kind of materials. [3]

**A Scialpi et al (2008)** studied micro friction stir welding of aluminium alloys 2024-6082. The alloys of 2024-T3 and 6082-T6 aluminium starting from 0.8 mm thick plates welded successfully. The conclusions are various zones in microstructure of dissimilar joints base metal, TAZ, TMAZ, Stirred zone for the 2024 and 6082 alloy. The mechanical properties of dissimilar joints are significantly improved in longitudinal direction. T he strength of 6082 alloy is higher. [4]

**Jingqing Zhang et al (2014)** studied underwater friction stir lap welding of aluminium alloy 6061-T6 to pure copper. The effect of external water on thermal history type thermocouple was utilized to measure the weld temperature. The XRD results shows that the interface of the welds mainly consist of the Al-Cu intermetallic compounds such as CuAl2 and Cu9Al4 together with some amounts of Al and Cu, and it is also found that the amount of the intermetallic in the underwater weld is obvious less than in the classical weld. The SEM images and the EDS line scan results also illustrate that the Al-Cu diffusion interlayer at the Al-Cu interface of the underwater weld was obviously thinner than that of the classical weld. [5]

**Z. Zhang et al (2014)** studied effect of friction stir welding parameters on the microstructure and mechanical properties of 5.6 mm thick 2219Al-T6. FSW joints could be obtained under lower rotation rates of 400–800 rpm and welding speeds of 100–800 mm/min; higher rotation rates of 1200–1600 rpm easily led to the tunnel and void defects.

The FSW thermal cycle resulted in low hardness zones (LHZs) on both retreating side (RS) and advancing side (AS). The LHZs may be located at the interface between the nugget zone (NZ) and the thermo-mechanically affected zone (TMAZ), at the TMAZ, or at the heat affected zone under the varied welding parameters. The tensile strength of FSW 2219Al-T6 joints increased when increasing the welding speed from 100 to 800 mm/min, and was weakly dependent on the rotation rates from 400 to 1200 rpm. The FSW 2219Al-T6 joints fractured along the LHZ on the RS. [6]

**Mohammad Ammar Mofid et al (2012)** studied friction stir

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

welding plates of AZ31 (Mg alloy) and AA 5083 H34 were joined in three different environment air, water and liquid nitrogen at 400 rpm and 50 mm/min.It is shown that in low temperature FSW, the flow stress is higher, plastic contribution increases, and so adiabatic heating, a result of high strain and high strain-rate deformation, drives the recrystallization process beside frictional heat. [7]

**Basil Darras et al (2013)** studied submerged friction stir processing of AZ31 Magnesium alloy. In this work, AZ31 Magnesium samples were friction stir processed while submerged in room-temperature and warm water. For comparison, FSP in air medium was also performed. The effects of submerging conditions on thermal fields, power consumption, resulting grain structure and tensile properties were discussed. The Formability AZ31 magnesium alloy can be enhanced. The increase in elongation% was achieved. [8]

**H.Farrokhi et al (2013)** studied friction stir welding of copper plates under different welding medium air and water. The rotation speed 1600 rev/min and traverse speeds of 50 and 100 mm/min.The finer microstructure achieved in underwater condition. The welded joints in underwater condition having higher tensile strength. [9]

**Rui-dong Fu et al (2011)** studied friction stir welding in cold and hot water, air condition carried out for 7050 aluminium alloys. The peak temperature during welding in air was up to 380.c and during hot and cold water about 300.c and 220.c. The distributions of micro hardness exhibited a typical ''W'' shape. The width of the low hardness zone varied with the weld ambient conditions. The minimum hardness zone was located at the heat affected zone (HAZ) of the weld joints. Better tensile properties were achieved for joint welded in hot water, and the strength ratio of the weld joint to the base metal was up to 92%. The tensile fracture position was located at the low hardness zone of the weld joints. The fracture surfaces exhibited a mixture of dimples and quasi-cleavage planes for the

joints welded in cold and hot water, and only dimples for the joint welded in air.[10]

**Conclusion**

A From the above literature survey we find that there are many research done on friction stir welding. But we found that there is very few researches done on submerged friction stir welding. Submerged friction stir welding is really an innovative and novel technique of welding. It improves mechanical properties and consumed less energy. In our research work AA 6061-T6 Alloys used.

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