Advanced Manufacturing Technology by Under Water Friction Stir Welding Technique

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Abstract

Under water friction stir welding (UWFSW) is one of the modern and advanced manufacturing technologies of solid state joining and it is used for welding a wide range of materials. The energy-efficient technique used to the 6061 aluminum alloy joint and it has been demonstrated to be an effective method to improve the mechanical properties of joints. To illuminate the characteristics of underwater FSW, the microstructural evolution and its effect on mechanical performance of an underwater joint were investigated in the present paper. This work compared the parameters of normal friction stir welding (FSW) and UWFSW on the weld joint. In this investigating FSW used in underwater environment, for this operations research pin covered and shielded from contact water by hollow shaft spin (HSS), the HSS controlled the heat conduction of pin and disconnect with water, applying for the first time a novel underwater FSW technique developed in various industries. The metallographic exams indicate that weld nugget grain size has been decreased. The mechanical testing illustrated that hardness and tensile strength have been increased, on the other hand the percentage of elongation and impact energy have been diminished.

Keywords: Advanced Manufacturing, Under Water, Friction Stir Welding.

1. Introduction

Welding is the most widely used fabrication technique in the manufacturing industry. Friction stir welding (FSW) was invented by Thomas WM at TWI UK in 1991 to overcome the fusion welding problems [1].Under water friction stir welding is the latest technique which is widely acceptable in the industries like aerospace and shipbuilding for joining of different aluminum alloy series such as (6xxx, 7xxx, 8xxx) due to the light weight and high strength. It is very difficult to weld these alloys by using fusion method so, friction stir welding is introduced and it is widely taken into consideration for performing such welding process [2]. Four stages during friction stir welding (FSW) have been carried out: the plunging stage, the dwelling stage, the welding stage, and the escape or retracting stage of the tool. The FSW procedure is essentially carried out by plunging a spinning FSW mechanism unit through the interface of two rigidly clamped sheets before the shoulder meets the surface of the material being welded [3]. The travel of the unit progresses along the weld line allowing the material to displace from the advancing side to the retracting side. Meanwhile, the tool shoulder consolidates the material at the back of the pin, resulting in a stable state [4]. Compared to other conventional welding processes, FSW process uses a significant amount of energy. The absence of flux or cover gas makes the process environmentally safe [5].

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They are critical in heat generation, forging strain, the flow of material, welding appearance, and performance. As a result of increasing the dislocation density, the nugget area has high stiffness at higher speeds [6]. Furthermore, the axial forces also shift at varying rotational speeds. The softened area gets narrower as welding speed increases, and precipitate corrosion is weakened. The ultimate tensile strength (UTS) of the welded joint is boosted by lower heat generation and high volume fraction of precipitate as a result of greater travel speeds, grain boundary reinforcement [7]. Maximum penetration demands maximum plunge depth, otherwise it will lead to a decrease in loadbearing potential. The depth of penetration is seen to influence the consistency of the welds. There is a linear relationship between the shoulder force and torque and the penetration depth. FSW is recommended for maximum depth [8]. The mechanical and metallurgical characteristics are depending on the environments, the base material and the consumables in general. The working environment to which the joint is exposed is often critical. There is a chance of crack expanding as the joint is exposed to high-pressure and high-temperature fluids, which stops the device itself from operating [9]. FSW is a solid state welding process in which a rotating tool is forced along the joint line, heating the abutting components by friction, and producing a weld joint by large plastic deformation (stirring) of materials from the two components. Compared to classical fusion welding techniques FSW can overcome problems such as

weld porosity, use of filler metals, and cracking in the heat affected zones (HAZ) [10].
Friction Stir Welding- Process advantages such as: The process advantages result from the fact that the FSW process (as all friction welding of metals) takes place in the solid phase below the melting point of the materials to be jointed. The benefits therefore include the ability to joint materials which are difficult to fusion weld, for example 2000 and 7000 series aluminum alloys [11]. Friction stir welding can be use purpose-designed equipment or modified existing machine tool technology. The process is also suitable for automation and adaptable for robot use [12]. After this, the area of FSW research is broadening, and their excellent performance either in the joining of similar material or dissimilar material documented [13,14] and successfully used in various industries, including railway, automobile, defense, aerospace and renewable energy, as shown in Fig. 1 [15,16].

Fig. 1. Application of FSW in various industries [16].

2. Materials and Methods

Different process steps invitation:
1. Simulation underwater environment by glass
2. Designed special tools for FSW
3. Improved mechanical properties tools by heat treatment in order to used water environment
4. Cut weld sample for preparation of mechanical test by machining
5. Microstructure weld observed by optic microscope and scanning electron microscopy (SEM).

Fig. (2.a) illustrates an aluminum alloy joint welded in schematic and simulation of the UFSW. In this technology pin covered and shielded from contact water by hollow shaft spin (HSS) Fig. (2.b).
Materials tools have a characteristics specification include wear (abrasive) resistance, shock resistance thermal resistance, mechanical power condition made of low –alloyed carbon tool steel (H13) and heat treated as quenched and tempered. After machining pin tools is kept in 1050 ˚C temperature and austenite 1h duration then quenched hardening by oil.

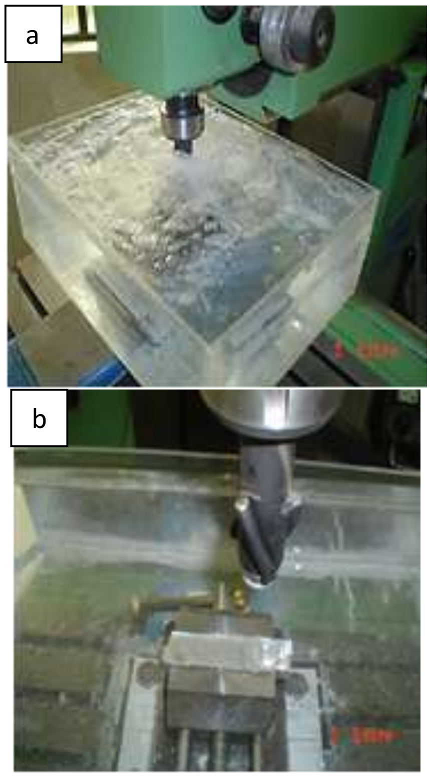

Fig. 2. (a) Simulation of the UWFSW (b) Isolated pin by hollow shaft.

Pin tools have a lot of various form but AISI-H13 tool steel dimensions as show in Fig. 3.

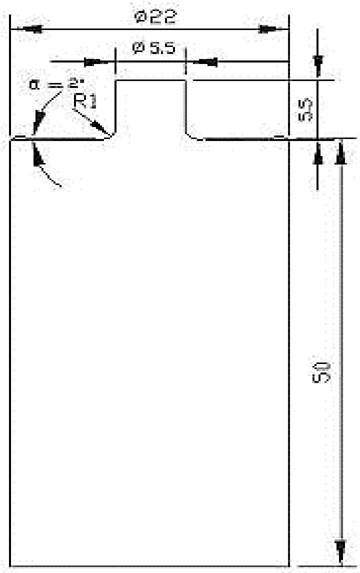

Fig. 3. AISI-H13 tool steel dimensions.

Temper heat treatment in 530 ˚C temperature and 20min duration and air quenched finally. In this technology pin designed hallow shaft surface is attached by special embossing form with 60˚ degree so controlled heat condition of pin and disconnect with water.

The novel technique acceptance given by the experimental setup on the AA6061, ten strip used with 150×50×6 mm dimensions in butt welding position fixed. Pitch welding (v/w) is adjustment on the CNC instrument. Chemical compositions AA6061 given in Table. 1.

Table. 1. Chemical Composition AA6061 % by Weight [1].

AL	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn
97.6	1.0	0.5	0.3	0.2	0.15	0.10	0.10	0.05

Friction stir welding (FSW) was done in two environments and two different as v/w, welding condition include normal FSW and under water FSW given in Table. 2.

Table. 2. Welding condition of different samples.

NO.	Welding Condition	Linear Velocity (V)	Angular Velocity (W)	Pitch Welding (V/W)
1	Normal FSW	100	150	1/15
2	Normal FSW	110	100	1/9
3	Under water FSW	100	150	1/15
4	Under water FSW	110	100	1/9

Mechanical test from weld is included hardness and tensile strength test was done on different samples. Tensile strength tests according to ASTM AWSB4 were carried out.

The hardness test was done with Brinell method with 2.5 mm indentor and the force of 62.5 kg. The optical metallographic test were done by Olympus DMI3000M with image analysis and scanning electron microscopy (SEM) test were done by VEGA\TESCAN-XMU. Mechanical, furthermore polishing and aching with 1CC hydrofluoric acid, 95CC and 4CC hydrofluoric acid and distilled water.

3. Results and Discussion

Fig. 4. shows the picture of different samples, it can be seen that the underwater sample do not have any cracks or defects and surface quality of underwater sample similar as other sample that welded in normal FSW. Table. 3. Given the mechanical test of different samples. It can be seen that by increasing the welding pitch, the hardness, yield and tensile strength of weld metal in normal FSW and underwater FSW condition increased. In addition the hardness, yield strength and tensile strength of weld metal in underwater FSW as higher than the normal FSW condition.

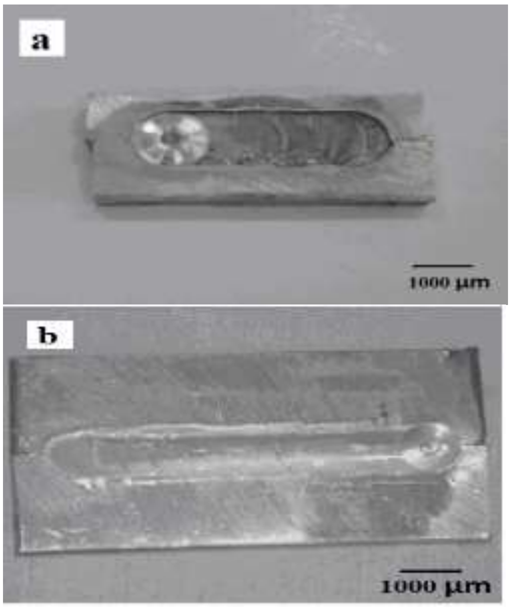

Fig. 4. Visual surface on friction stir welding AA 6061 (a) UFSW (b) FSW.

Table. 3. Mechanical Test Result FSW And UFSW.

NO.	Welding Condition	Pitch Welding w/v	Hardness (HV)	Strength (Mpa)	Tensile Strength (Mpa)
1	Normal FSW	15	88	130	212
2	Normal FSW	9	104	153	245
3	Under water FSW	15	111	170	272
4	Under water FSW	9	127	177	279

Fig. 5.A more comprehensive scheme has been developed by TWI, and has been discussed with a number of appropriate 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.

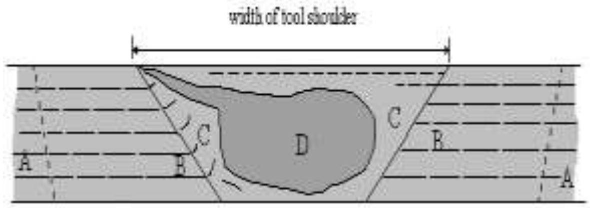

Fig. 5. The system divides the weld zone into distinct regions: A. Unaffected material B. Heat affected zone (HAZ) C. Thermo-mechanically affected zone (TMAZ) D. Weld nugget (Part of thermo-mechanically affected zone).

Fig. 6. The line scan analyses of Al-Mg-Si confirmed the elemental composition of the welds at the nugget zone.

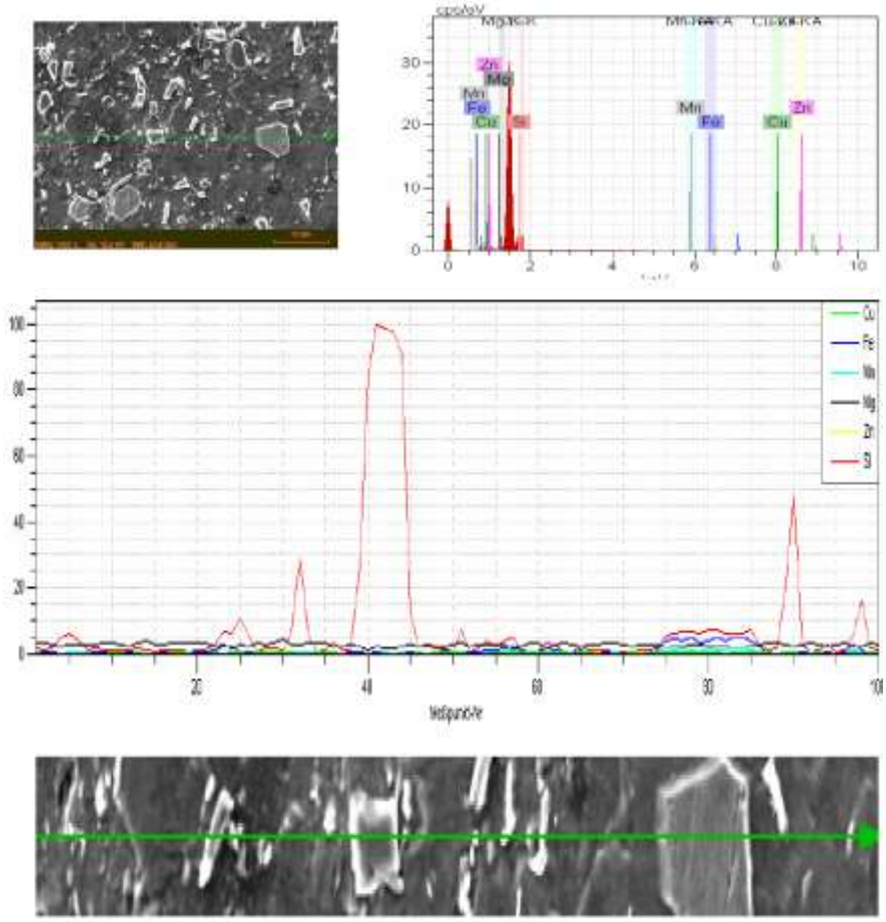

Fig. 6. The line scan analyses of AA 6061.

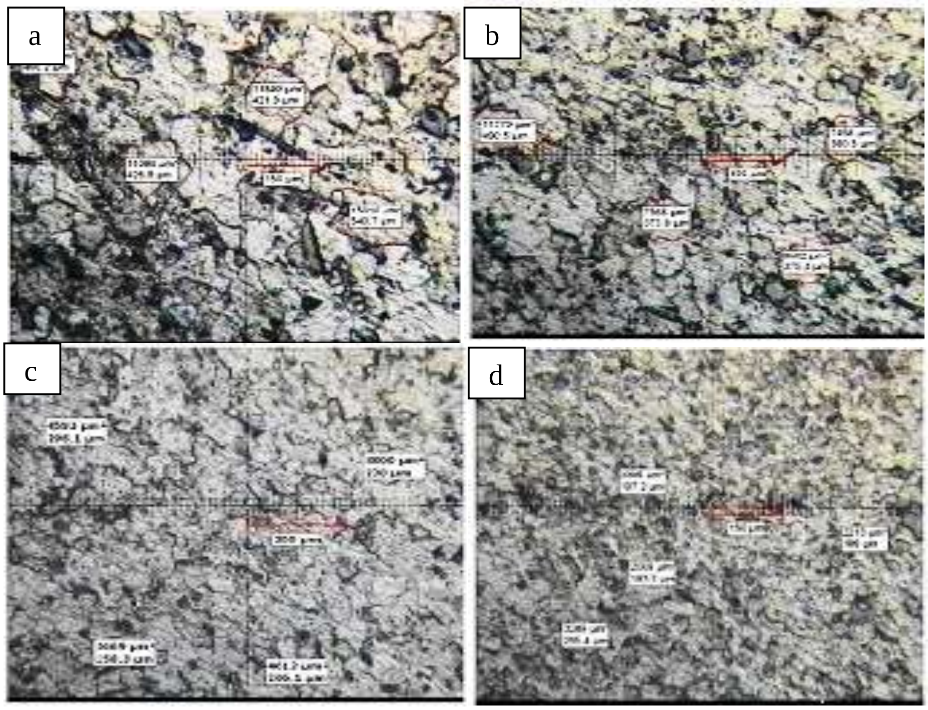

Fig. 7. Microstructure nugget weld by optic microscopy (a) FSW 15 Pitch welding, Grain size 142(b) FSW 9 Pitch welding, Grain size 120μ (c) UWFSW 15 Pitch welding, Grain size 84μ (d) UWFSW 9 Pitch welding, Grain size 61μ .

The first attempt at classifying microstructures was made by P L Threadgill (Bulletin, March 1997) [17]. This work was based solely on information available from aluminum alloys. However, it includes become evident from work on other materials that the behavior of aluminum alloys is not typical of most metallic materials, therefore the scheme cannot be broadened to encompass all materials.

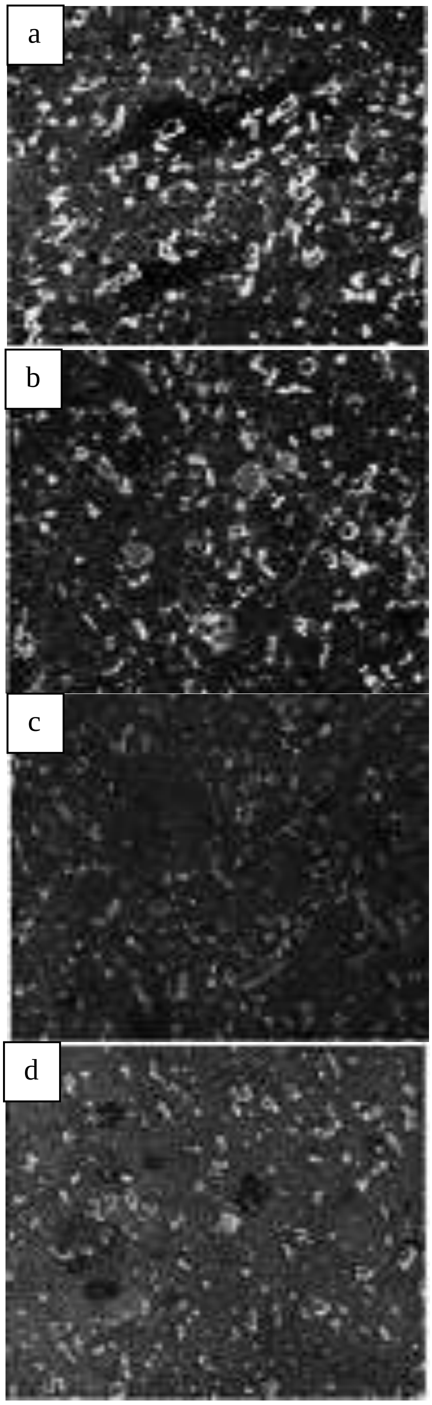

Fig. 8. Microstructure weld by scanning electron microscopy (SEM).(a) FSW 15 Pitch welding, Grain size 142μ (b) FSW 9 Pitch welding, Grain size 120μ, (c) UWFSW 15 Pitch welding, Grain size 84μ (d) UWFSW 9 Pitch welding, Grain size 61μ.

The microstructure weld metal by optic microscopy shown in Fig. 7. In dry condition with 1/15 and 1/9 pitch welding Grain size 142μ and 120μ Fig. (7.a, b) was gained when two microstructure nuggets compared in wet condition with 1/15 and 1/9 Pitch welding Grain size 84μ and 61μ Fig. (7.c, d) therefore grain size in wet condition is half of dry conventional as same case state. The microstructure of weld metal result illustrated that by scanning electron microscopy (SEM) approved. Fig.8. the UWFSW microstructure grain size has been decreased.

4. Conclusion

Advanced manufacturing technology by underwater friction stir welding technique used to 6061 aluminum alloy joint and the following conclusions can be drawn:

1. This clean energy process is without flux or filler material and heating the abutting components by friction.
2. This advanced manufacturing method is used various joint, especially non-congener joint material and composite is easy carried out.
3. Increasing heat input treatment so that minimum residual stress and minimum change mechanical properties compare other welding method.
4. The tensile strength of joints formed in UWFSW is higher than those of FSW.
5. The UWFSW microstructure grain size has been decreased so mechanical properties improved.
6. Tool traversing speed has played a predominant role in improving the mechanical properties of the joints produced by UWFSW.

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