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Research Article
A Preliminary Experimental Study of Underwater Friction Stir Welding AA5083 Plate Butt Joint

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Abstract

Underwater Friction Stir Welding (UFSW) is an advanced solid state welding technique that allows welding to be efficiently carried out underwater by utilising a non-consumable high rotating tool. The use of UFSW process will simplify the process of joining the two metals underwater. This present study will study the best welding parameters for producing good aluminium AA5083 plate butt joint bu UFSW process. Three experiments were conducted at several selected different welding parameters. It was found that the best joining occurred at 1700 rpm of rotational speed, 16 mm min^{-1} of travel speed, 50 sec of dwell time and 2° of tilt angle with underwater condition at 100°C water temperature.

Key words: Underwater friction stir welding, non-consumable high rotating tool, AA5083 plate, butt joint

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Friction Stir Welding (FSW) is an advanced technology which is extremely useful in all areas at present[1]. This advanced solid state joining process will not melt the metal but the high friction heat generated near the tools soften and join two metals together. This technique is preferred because of defects-free end product[2]. The Underwater Friction Stir Welding (UFSW) had been tested successfully by the welding institute (TWI), United Kingdom. The experimental setup as shown in Fig. 1 and 2. The same equipment could be used except the rotating tool and metal will be placed in a tank filled with water. The tool tilting angle and profile play an important role in obtaining a perfectly welded structure and smooth surface appearance without producing much lateral flash. The proper tilt angle should be more than 0° and less 3°

Fig. 1: Experimental setup of UFSW

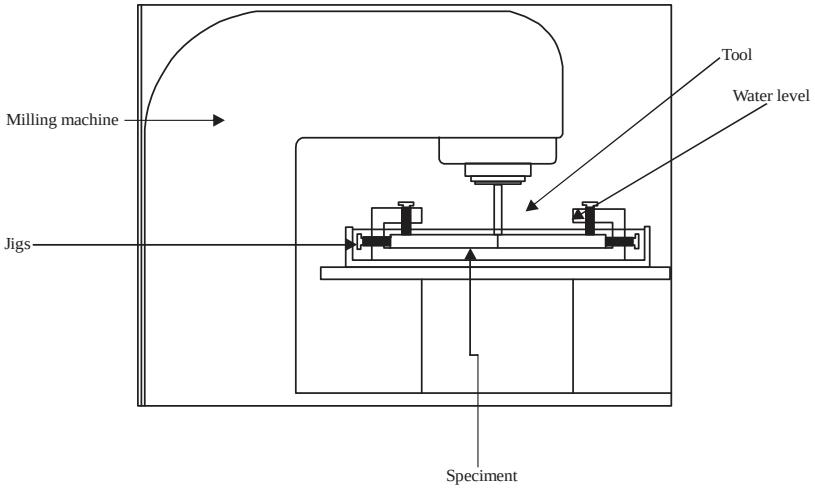


Fig. 2: Schematic diagram of UFSW

to supply suitable downward force to the material during the joining process[3]. In addition, the welding parameters such as travel speed and rotational speed are also used to play a very important role in an experiment in order to make sure the metals joined perfectly[4].

Aluminum 5083 is used as the specimen the experiment due to several reason. Aluminum 5083 is highly recommended to be used since it is one of the marine grade that suitable to be used in marine applications. It also very high resistant to attack by seawater or chemical environments while it also one of the metals type that has excellent resistance to general corrosion[5]. The chemical composition for aluminium alloy 5083 and its typical mechanical properties as shown in Table 1 and 2.

This study will discuss the suitable welding parameters to be used in order to get a good weld sample by the UFSW method (Table 3).

MATERIALS AND METHODS

Experimental setup: A Milko 37 universal milling machine was used to perform the Friction Stir Welding (FSW) experiment. The tool employed was a 5 mm long threaded pin with 15 mm concave shoulder, machined from H13 tool steel and hardened[6] to 52HRC. The UFSW tool profile used is as shown in Fig. 3.

A customized jig was specially designed, fabricated and bolted to the Milko36 conventional milling machine. A tank was constructed in order to immerse the specimen underwater (Fig. 4). The six AA5083 aluminum specimen were prepared according to the AWS D17.3 requirement[7]. The size of each specimen is 356 mm L×204 mm W×5 mm T. The aluminum sheets to be processed in the underwater friction stir were butted and clamped on the base plate which was bolted directly to the bed of the milling machine. The rotational speeds and travel speed were selected based on the available setting for Milko36 conventional milling machine. In this experiment the rotational speed is constant at 1700 rpm to give highest heat supply and sufficient heat in welding process while 16 mm min^{-1} travel speed is used in this experiment to give enough heat impact on the metals during the welding process. Table 1 shows the welding parameters used for this experiment setting. Other parameters such as the plunge depth need to be less than plate thickness and were kept constant at 4.95 mm during the experiment.

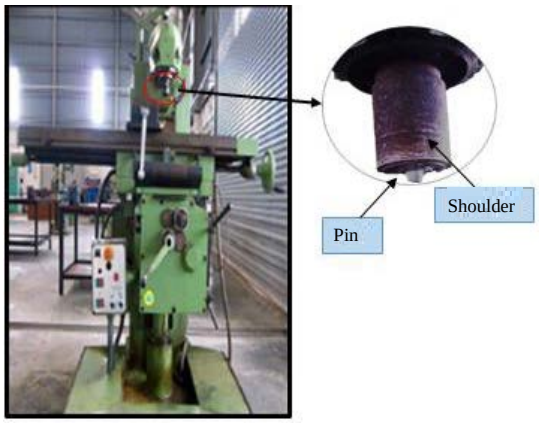


Fig. 3: Underwater Friction Stir Welding (UFSW) tool

Fig. 4: A complete jig and tank with the specimen

Table 1: Typical chemical composition for aluminum alloy 5083

Elements	Ti	Zn	Cr	Mg	Mn	Cu	Fe	Si
Present (%)	0.15	0.25	0.05-0.25	4.0-4.9	0.4-1.0	0.1	0.4	0.4

Table 2: Typical mechanical properties for aluminum alloy 5083

Temper	H32	0/H111
Proof stress 0.2% (MPa)	240	145
Tensile strength (MPa)	330	300
Shear strength (MPa)	185	175
Elongation A5 (%)	17	23
Hardness Vickers (HV)	95	75

Table 3: Welding parameters

	Welding parameters				
Sample ID	Rotational speed (rpm)	Travel speed (mm min^{-1})	Tilt angle (°)	Water temperature (°C)	Dwell time (sec)
UFSW#1	1700	16	3	100	30
UFSW#2	1700	16	2	100	40
UFSW#3	1700	16	2	100	50

RESULTS AND DISCUSSION

The surface appearances of the underwater friction stir welded samples are presented in Table 4. The sample of UFSW#1 shows rough surface with some lateral flashes formed and both metals are not properly joined. Its cross section shows the root has no penetration with wormholes detected. In order to stress out in the cross section of a welded plate, the advancing and retreating side is very vital to be recognized. The velocity rotational and tool's features plays important roles as it gives effect to the friction stir welding process become asymmetric and unequal. When the rotational and traversing velocity is preservative on the welded side, that can be known as advancing side. Thus, the retreating side is when the rotational and traversing velocity are destructive in welded side[8] (Fig. 5).

The water content in the tank will reduced the generated frictional heat cause insufficient heat to soften the materials and higher tilt angle give excess plowing effect cause a bit excess of metal removal. This phenomena similar finding by Tolephih *et al.*[9]. The material flow from advancing and retreating side or vice versa are retrcited due to less softening of adjoining metals.

Meanwhile, the sample of UFSW#2 show better surface appearance and joining of both metals together, thus indicating effective plunging and tilting angle of the tool during the underwater FSW process without the formation of lateral flash. The similar welding parameters were used as sample #1 but the tilting angle of rotating tool was reduced to 2°. With this new tilt angle setting, suitable plowing effect is achieved for better joining and surface condition. The water temperature was maintained at 100°C to maintain sufficient heat supplied to the material during the joining process. The tool direction was changed to follow the angle of tilt. The travel for each particular angle were drag backward and push forward, respectively. Less defects on the root was detected. The weld surface appearance for sample of

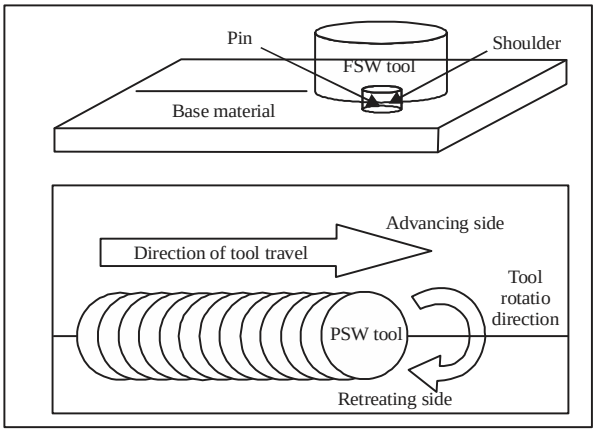
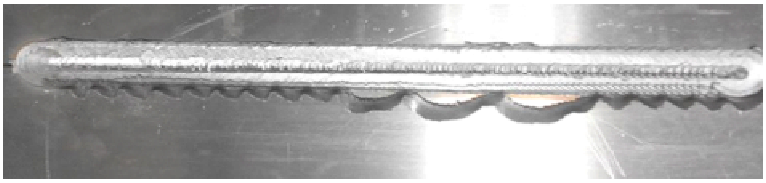
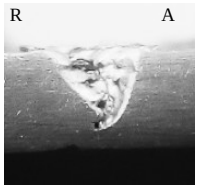
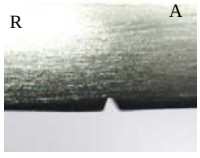
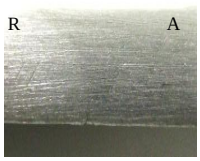


Fig. 5: Advancing and retreating side

Table 4: Underwater friction stir welded samples

Surface condition	Cross sectional
UFSW#1	
	
UFSW#2	
	
UFSW#3	
	

UFSW#3 is much better than before as the preheat took a longer time before the rotating tool started to travel along the adjoining sections. The weld root got better penetration than a few other previous samples. The surface condition and cross sectional view for each sample was shown in the Table 4.

CONCLUSION

The experimental results showed that a good underwater friction stir welded specimens could be produced with suitable welding parameters. Different welding parameters created varying surface conditions and joining quality. Suitable tilt angle, higher rotational speed and water temperature are required in order to obtain better joining of AA5083 plates by underwater friction stir welding process. The best welding parameters are the ones associated with sample UFSW#3 as they give better joining quality and surface condition.

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