The Effect of Rotational Speed on Weld Strength of Friction Stir Welded Butt Joint

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Abstract: *The research work is carried out in order to achieve the following objectives which are to investigate the effect of different rotational speed on the weld quality of metal of aluminum alloy AA 5083 during FSW and to analyze the optimum rotational speed towards tensile property improvement. The rotational speed is important in producing the frictional heat to induce plasticized flow. The rotational speed determines tensile strength and quality weld surface. The result obtained for this research is based on tensile testing. The welding parameter involved such as welding speed (67mm/min), tilt angle (3^0), tool shoulder diameter (40mm), tool pin type (Threaded Cylindrical) and variable rotational speed of 490rpm, 653rpm, 910rpm, 1280rpm, and 1700rpm by using universal milling machine milko 37.*

Keywords: *friction stir welding process, rotational speed parameter, FSW, milling machine*

1. Introduction

Friction Stir Welding was invented by Wayne Thomas, TWI Ltd in 1991[1,6] in order to overcome many problems associated with traditional joining techniques. FSW is a green process manufacturing technique due to its energy efficiency and environmental friendliness which produces welds of high quality in difficult to weld materials such as aluminium [1,3]. For this friction stir welding process, milling machine was used with the tool chucked on it and rotated. The clamp, it is needed to prevent the specimen from spreading of lifting during process while the specimen is secured to a base clamp plate. By keeping the tool rotating and moving it along the seam to be joined, the softened material is literally stirred together forming a weld without melting [1].

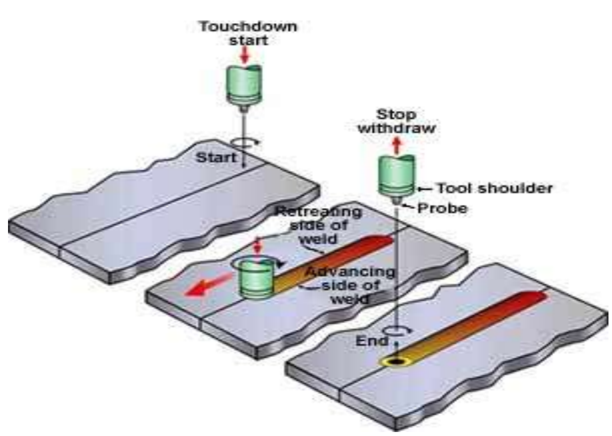

Fig. 1: Schematic of Friction Stir Welding.

The standard dimension of specimen has been acquired from papers reviewed. The dimension for specimen AA5083 is 356mm x 204mm x 5mm [2]. H13 tool is chosen due to its easy machinability material compared to other [3]. It can be used to operate at 600 to 1500 rpm which is within rotation speed of research scope [4]. This material is classified as hot worked tool steel with good tensile and wears resistance properties [5].

There are various types of shape of the shoulder such as convex, concave, and flat shoulder. Convex shoulder tools for thicker material were only realized with the addition of a scroll to the convex shape [6]. S. Hirasawa, H. Badarinarayan, K. Okamoto, T. Tomimura and T. Kawanami found that triangular pins with concave shoulders resulted in high strength spot welds [4]. The flat shoulder end surface is the simplest design, it's not effective for trapping the flowing metal material under the bottom shoulder, leading to the production of excessive material flaws . The concave shape was chosen as tool shoulder shape for restricting material extrusion from the sides of the shoulder [3]. Concave shoulders produce quality friction stir welds, and this design can be easily machined. Forward movement of the tool forces new material into the cavity of the shoulder and pushing the existing material into the flow of the pin [6].

Pin shape is the crucial role in material flow and regulates the welding speed of the FSW process. H. Fujii achieved defect free welds in softer alloys such as AA 1050 using a columnar tool pin without any thread. D. G. Hattingh observed that a trifluted tapered pin with a thread pitch produced defect free welds [4]. The shape that used is a round bottom straight circular threaded, a left hand threaded probe under clockwise rotation causes the material to be drawn down by the threads along the probe surface. The material may circulate multiple times around the tool before being deposited behind the tool [3]. Around end to the pin tool reduces the tool wear upon plunging and improves the quality of the weld root directly underneath the bottom of the pin. Machining a radius at the bottom of the threads will increase tool life by eliminating stress concentrations at the root of the threads [6].

This FSW process is possible to perform the closed butt joining of AA5083 plate by using a milling machine available at MIMET. FSW has many of its advantages over the conventional welding techniques some of which include very low distortion, no fumes, no porosity or spatter, no consumables, no special surface treatment and no shielding gas requirements. The different rpm produces different frictional heat and it will affect the strength of the joint. The welding parameters are the key art of friction stir welding process.

2. Experimental setup

Milko 37 is a universal milling machine that has been used to perform the Friction Stir Welding (FSW) of aluminum AA5083 in closed butt joint configurations. Specification of the machine is suitable in conducting the friction stir welding process experimentally. The variation in rotational and transverse speed is shown in Figure 2. Adjusting the speed can be made by turning the lever on the machine to set up the speed needed.

Fig. 2: MILKO 37 Universal milling machine

A base plate was specially designed, fabricated and bolted to the bed with the use of 16 mm bolt and nut. The base plate and customised clamping fixtures were fabricated at UniKL MIMET machinery workshop, Lumut, Perak. The experimental setup for the assembly of the base plate and the clamping fixtures are shown in Figure 3.

Fig. 3: Assembly of base plates, clamping fixtures and aluminum sheets

The tool employed was a 5mm long threaded pin with 15mm concave shoulder, machined from H13 tool steel and hardened to 52HRC. The schematic diagram of the FSW tool used in this research work is presented in Figure 4.

Fig. 4: FSW tool - Threaded pin and concave shoulder

The FSW of aluminum AA5083 were cut into 356 mm x 102 mm x 5 mm size sheets. The aluminum sheets to be friction stir welded were abutted and clamped on the base plate which was bolted directly to the bed of the milling machine. The surfaces of the sheets were cleaned with power brush before the welding procedure. Detailed chemical composition and mechanical properties for AA5083 are listed in the Table 1 and 2.

TABLE I: chemical composition

Element	% Present
Si	0.4
Fe	0.4
Cu	0.1
Mn	0.4-1.0
Mg	4.0-4.9
Zn	0.25
Ti	0.15
Cr	0.05-0.25
Al	Balance

TABLE II: mechanical properties

Temper	value
Proof Stress 0.2%	145MPa
Tensile Strength	300MPa
Shear Strength	175MPa
Elongation A5	23%
Hardness Vickers	75HV

The welding speeds and the rotational speeds were achieved using the control system and the panel. Table 3 below are the details of parameters for this experiment.

TABLE III: welding parameter

sample	Welding parameter		Remark
	Rotational speed (rpm)	Travel speed(mm/min)	
1	490	67	Vary in rotational speed but constant in travel speed
2	653	67	
3	910	67	
4	1280	67	
5	1700	67	

Other parameters such as the tool tilt angle, the plunge depth and dwell time were kept constant at 3º, 4.95 mm and 30 seconds respectively. The tensile samples were tested in accordance with ASTM E-8. An Instron tensile testing machine was used to conduct the tests and the macro testing was conducted according to ASTM E340-00e1[7].

3. Results and Discussion

3.1. Macro appearance

The surface and the root appearances of a typical friction stir processed sheet is presented in Table 4.

TABLE IV: weld surface finishing

Sample	Weld surface finishing	Remark
1		(490 rpm) Rough surface
2		(653 rpm) Rough surface
3		(910 rpm) Smooth surface
4		(1280 rpm) Rough surface with flash & defect
5		(1700 rpm) Rough surface with flash & defect

Visual inspection of the weld top surfaces indicates a good top surface appearance without defect and the deformation at the root indicate effective plunging of the tool during the welding process.

3.2 Tensile Test

The graph below is the graph that obtained from tensile test which is the strongest based on 5 parameters selected. 490 rpm rotational speed shows the higher tensile strength than other.

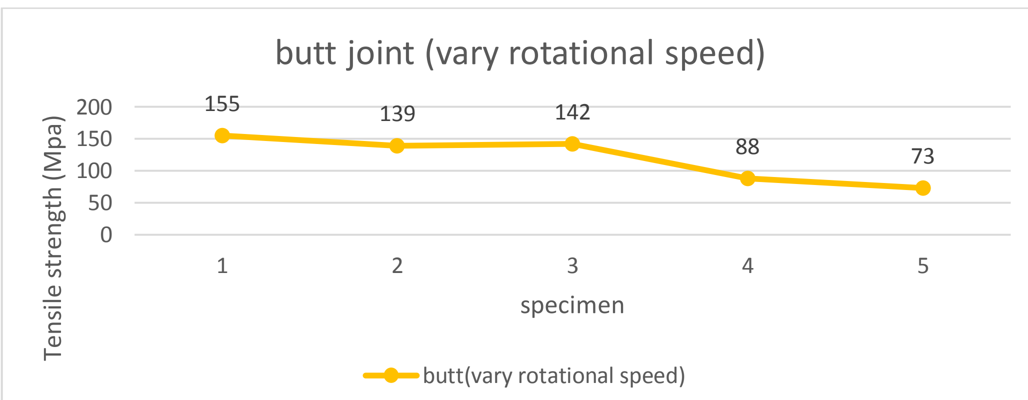

Fig. 6: tensile test graph

4. Conclusion

The modification of conventional milling machine MILKO 37 to make the butt joint process using friction stir welding technique was successful. FSW tools, base plate and the clamping system were fabricated and optimized in this research work. Friction stir welding produced satisfactory butt welds of AA5083 grade with a joint efficiency of around contributes 60% to 90% (based on alloy AA5083). Increasing the rotational speed for a constant travel speed creates a varying contact condition at the material interface. Several conclusions can be drawn such as follows:

1. Weld surface finishing for 910 RPM gives better result compared to others.
2. Even the weld surface finishing for 490 rpm is rough, tensile strength show it has better strength.

3. The rotational speed for 1280 rpm and higher produced more lateral flash on weld surface.

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