# The effect of parameter on mechanical properties for tailor-welded blanks produced of AA7075 and AA6063 aluminium alloy by friction stir welding

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## Abstract

This research was study the welding joint variable of Tailor-welded blanks (TWBs) by Friction stir welding process (FSW) of AA7075 and AA6063 aluminium alloy. The investigation is welding speed at 120 mm/min, 250-1000 rpm/min of rotation speeds and angle of spindle 0-4 degree on the ultimate tensile strength, microstructure and hardness of welded. Experimental results found that the angle of spindle 2 degree and 250 rpm/min of rotation speeds has maximum tensile strength at 184 MPa and observe angle of spindle increase trends of tensile strength decrease. The weld zone was fine grain and stir zone microstructure not found crack in the weld. Hardness testing was found rotation speeds at 1,000 rpm/min average height hardness at 118 HV, the second is 500 and 250 rpm/min respective.

***Keywords:*** *Tailor-welded blanks, Friction stir welding, Mechanical properties*

## 1. Introduction

Tailor-welded blanks (TWBs) are welding to different strength, materials and/or thicknesses together [1]. Used an automotive and aircraft industry for weight reduction of parts to save energy and be environmentally friendly, as well as to reduce the cost of industrial component [1-5]. TWBs can weld the both laser arc welding process and the gas tungsten arc welding process, but are currently popular using the Friction stir welding process (FSW). Which is a solid state welding process that can welding a wide variety of materials without restrictions, such as similar or dissimilar welding joint. The advantages of FSW welding are distortion the weld and reduce the formation of metallic compounds in the case of dissimilar welding joint [6]. Therefore, TWBs with the FSW welding process have developed rapidly in the automotive parts industry by welding two different thickness materials with welding FSW before forming such as floor pan, door inner panel, roof reinforcement, and front rail structure [7].

In friction stir welding, a rotating tool, consisting of a smaller diameter pin-shaped probe and a larger diameter shoulder, is traversed under pressure along the interface between the two sheets being joined. The frictional heat generated by the rotating tool produces a thermally softened region at the interface and the adjoining area. The softened material is forced to flow in a rotary motion on the surface as well as in the interior by the rotating tool. As the material flowing around the tool coalesces, a butt weld is formed. The weld is formed without melting the material, as such any problems associated with melt solidification from fusion welded joints are greatly minimized and/or eliminated [7]. The early research on aluminum tailor-welded blanks for automotive applications concentrated on the weld line behavior, such as weld cracking and weld-line shift, during stamping. Since tailor-welded blanks are increasingly used in structural components, their mechanical properties must also be characterized [7]. According to recent research, the study of welding variables for dissimilar material types with different thicknesses has limited dissemination information. In which the majority of experiments are done for welding materials, thickness, and welding angles [8-10].

Accordingly, this research aims to study the FSW welding process to compare welding parameters. In this experiment, the study angle of spindle, tool rotation rate and the traverse speed of tool that effect on the shear strength. In the TWBs process between the AA6063 and AA7075 aluminum alloy by the FSW welding process to be the guideline for further research.

## 2. The principles of friction stir welding (FSW) [11]

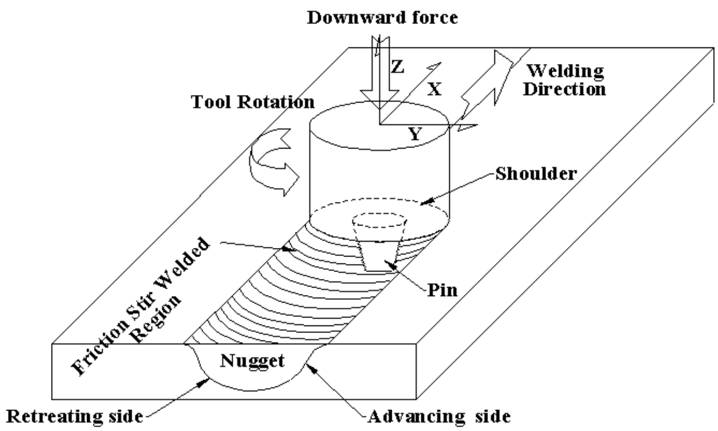
The basic concept of FSW is remarkably simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint **Figure 1(a)**. The tool serves two primary functions: (a) heating of workpiece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the workpiece and plastic deformation of workpiece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front the pin to the back of the pin. As a result of this process a joint is produced in 'solid state'. Because of various geometrical features of the tool, the material movement around the pin can be quite complex [12]. During FSW process, the material undergoes intense plastic deformation at elevated temperature,resulting in generation of fine and equiaxed recrystallized grains [11]. The fine microstructure in friction stir welds produces good mechanical properties.

Tool geometry is the most influential aspect of process development. The tool geometry plays a critical role in material flow and in turn governs the traverse rate at which FSW can be conducted. An FSW tool consists of a shoulder and a pin as shown schematically in **Figure 1(b)**. As mentioned earlier, the tool has two primary functions: (a) localized heating, and (b) material flow. In the initial stage of tool plunge, the heating results primarily from the friction between pin and workpiece. Some additional heating results from deformation of material. The tool is plunged till the shoulder touches the workpiece. The friction between the shoulder and workpiece results in the biggest component of heating. From the heating aspect, the relative size of pin and shoulder is important, and the other design features are not critical. The shoulder also provides confinement for the heated volume of material. The second function of the tool is to 'stir' and 'move' the material. The uniformity of microstructure and properties as well as process loads are governed by the tool design. Generally a concave shoulder and threaded cylindrical pins are used [11].

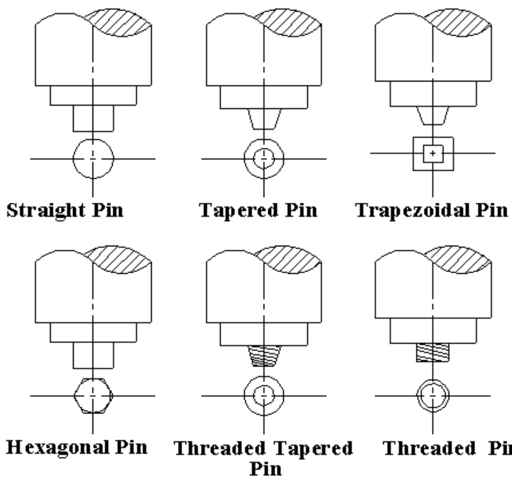
# 3. Material and experimental procedure

## *3.1 Materials*

The base materials used in this work are two aluminium alloys currently used in the industry : AA7075 and AA6063. The nominal chemical composition and mechanical properties of these alloys is shown in **Table 1**. Which the aluminum alloys, 7075 series alloys form the preferred material group in aircraft and space industries and in military sector due to its high strength. Likewise, AA6063 material which is used for construction automotive and low-temperature liquid gas equipment. The both is microstructure AA7075 and AA6063 show in **Figure 2**. In this study, AA7075 Aluminum alloy plate of 6.3 mm thickness with AA6063 plate of 3 mm thickness and was use. The plate was sliced into 150 mm length x 75 mm width by using Hydraulic Cutting Machine. The sliced plates were workpiece, to remove surface contaminants and then were cleaned with acetone to get rid of the oxide layers from the surface. The test was followed by the welding zone fracture test, and the welding zone strength measurement to evaluate the weldability.

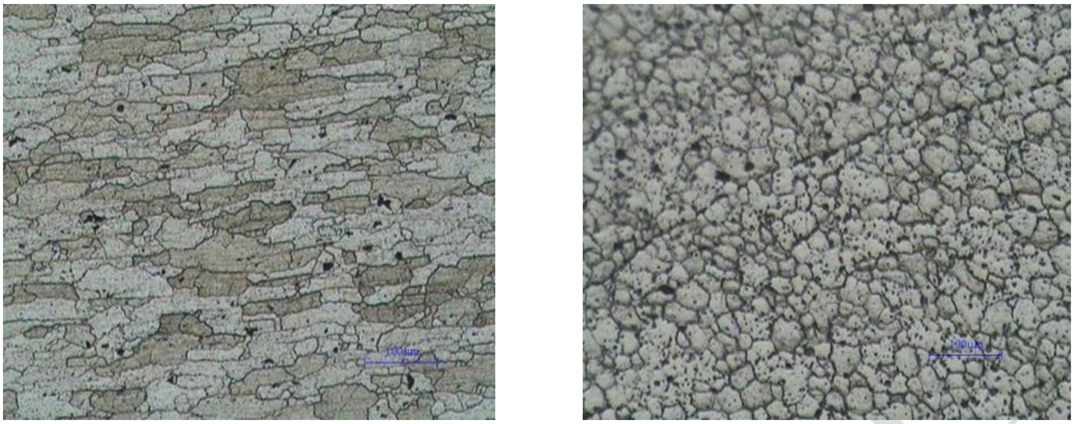



(a)




(b)

**Figure 1 The friction stir welding occured in (a) friction stir welding process. (b) Schematic drawing of the FSW tool geometries [11]**



(a) (b)

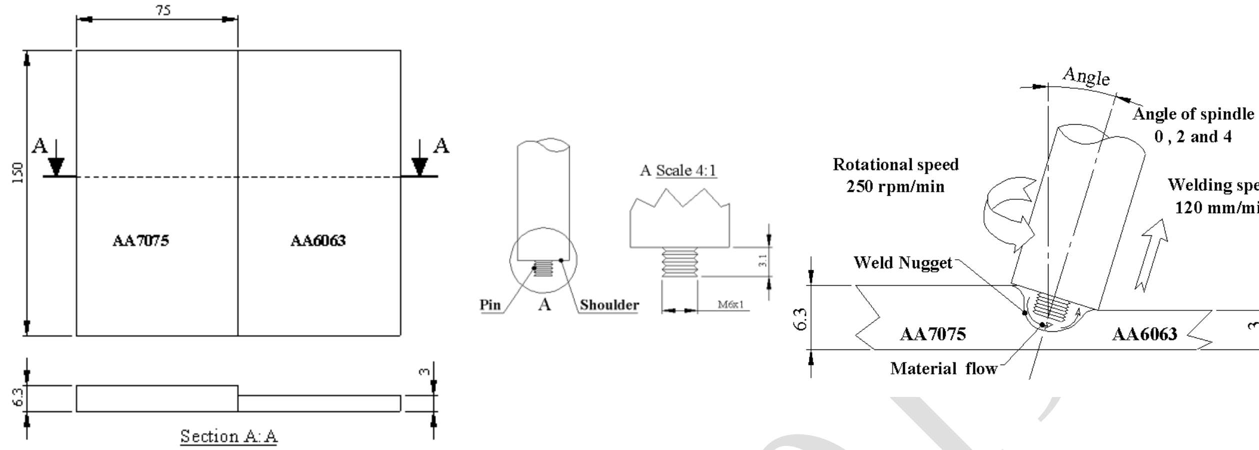
**Figure 2 The microstructure of base material in the experimental. (a) AA6063 aluminium alloy (b) AA7075 aluminium alloy**

**Table 1** Mechanical properties and chemical composition of the AA7075/AA6063 aluminium alloy.

| Material | Element | | | | | | | | | Mechanical Properties | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Al | $F_u$ (MPa) | % *El* | *HV* |
| AA7075 | 0.40 | 0.50 | 1.20 | 0.30 | 2.10 | 0.18 | 5.10 | 0.20 | Bal. | 152 | 17 | 96.9 |
| AA6063 | 0.35 | 0.25 | 0.10 | 0.10 | 0.45 | 0.05 | 0.05 | 0.05 | Bal. | 72.52 | 7.5 | 34.5 |

### *3.2 Experiment procedure*

FSW butt welding joint TWBs of AA7075 and AA6063 aluminum alloy. Determined AA7075 that is thickness than advancing side and AA6063 on the retreating side as shown in **Figure 3(a) Figure 3 (b)**. The tool consists of a thread pin and shoulder, Serves to heat caused by friction between the tool and workpiece. Adjusting the speed and steps for FSW uses a universal milling machine trademark TOS series FNGJ32. The FSW parameters consist of a rotational speed of 250, 500 and 1,000 rpm/min at the welding speed 120 mm/min. of tool and the angle of spindle to the Z axis at 0, 2 and 4 degrees, variables in the study as shown in **Figure 3 (c).** Welding tools are made from JIS: SKD11 tool steel, the geometry is shown in Figure 3 (b). Holding time before welding for 15 seconds. Tensile strength test according to ASTM E8M-04 [13] and weld hardness to be pressed through the welding process according to ASTM E92-17 [14]. Investigation the microstructure of the weld , sanding, polishing, and etching with 2 ml of HCL solution, $HNO_3$ 6 ml, 2 ml of HF and 92 ml $H_2O$, therefrom investigate with a optical microscope.

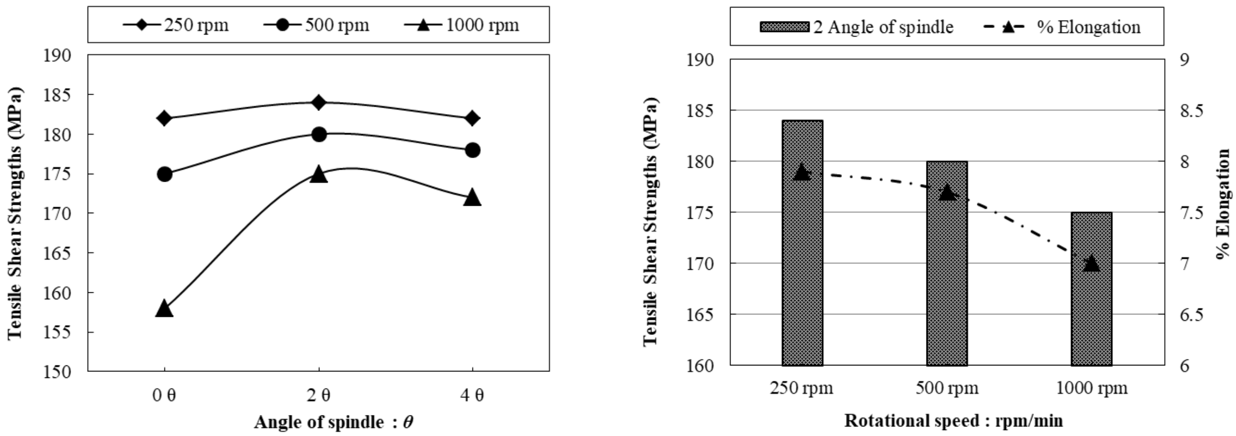



(a) (b) (c)

**Figure 3 Characteristics of TWBs aluminum alloy sheet by FSW joints.** (a) **Workpiece position** (b) **Tool geometry** (c) **Welding process**

## 4. Results and Discussion

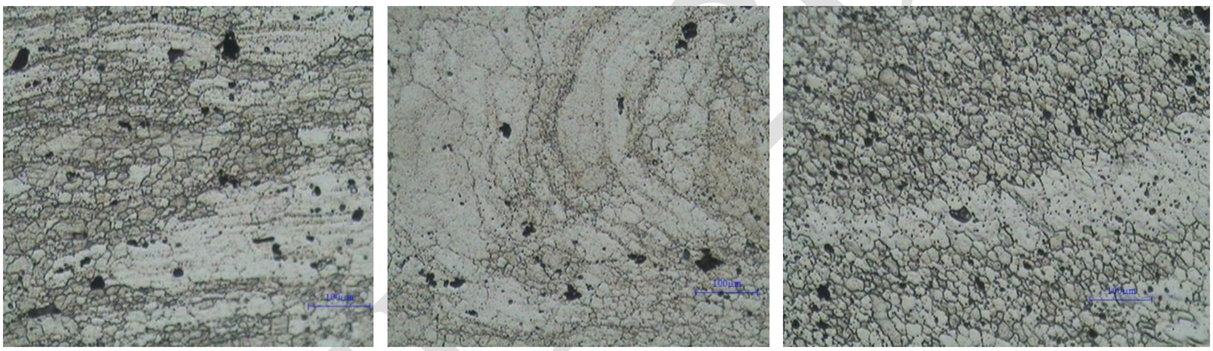
From **Figure 4** shows the relationship between the Angle of spindle at 0-4 degrees and the rotation speed at 250-1,000 rpm/min which affects tensile strengths as shown in **Figure 4 (a).** It was found that the maximum tensile strengths were 184 MPa at the rotation speed of 250 rpm/min. It was also found that when the Angle of spindle increased, the tendency of tensile strengths decreased. Therefrom, comparing the rotational speed that affects on tensile shear strengths and elongation, it is found that the maximum tensile strengths at 250 rpm/min are second to 500 and 1,000 rpm/min respective, which corresponds to the elongation characteristics of the weld shown in **Figure 4 (b)**.




(a) (b)

**Figure 4 Tensile Shear Strengths** (a) **Comparison of rotational speed and angle of spindle**
(b) **Compare Strengths with Elongation of weld**

Observe nugget zone the microstructure was mixed by both aluminium in weld zone show in **Figure 5**. But welded zone characterize of microstructure was different due to rotational speeds unlike. **Figure 5(a)** rotation speed at 250 rpm/min microstructure is fine and equiaxed grain of AA6063 mixed with plastic deformed areas. But when increasing the rotation speed to 500 rpm/min, the amount of internal plastic deformed increases as shown in Figure 5 (b). when the rotaion speed was increased to 1000 rpm / min, the weld is found the AA7075 high due to the hight rotation speed, the welding heat is higher, As a result, the advancing side into the lead AA7075 weld increases. Which corresponds to the welding hardness test results. When the rotation speed increases, the tendency of the welding hardness value is shown in **Figure 6**.



(a) (b) (c)

**Figure 5 Characteristics of microstructure TWBs aluminum alloy sheet by FSW.** (a) **250 rpm/min** (b) 500 **rpm/min** (c) **1,000 rpm/min**

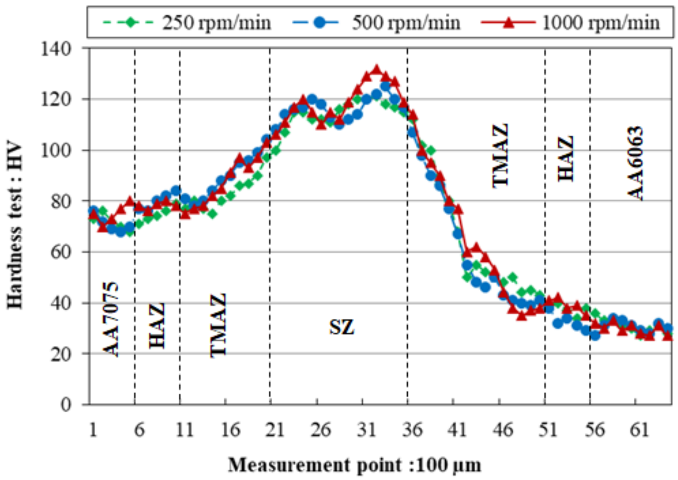



**Figure 6 Hardness profile across the weld joint along.**

## 5. Conclusion

Tailor-welded blanks (TWBs) by Friction stir welding process (FSW) of AA7075 and AA6063 aluminium alloy with a variety of different process parameters. At a constant welding speed of 120 mm/min on the effects of rotation speed and Angle of spindle on microstructures, microhardness distributions and tensile properties of the joints were investigated. Based on the above results and discussion, the following conclusions can be drawn accordingly.

- The influence of variables on the tensile strength of the weld is 2 degrees angle of spindle. By the rotation speed at 250 rpm/min has maximum tensile strength at 184 MPa and fracture AA6063 side.
- Hardness testing was found rotation speeds at 1,000 rpm/min average height hardness at 118 HV, the second is 500 and 250 rpm/min respective.
- The experimental observe angle of spindle and rotation speed increase trends of tensile strength decrease. Likewise when the rotation speed increases the tendency of the welding hardness value.

## Acknowledgement

Research is complete Received support from many people and related organizations such as Industrial Technology Engineering, Faculty of Industrial and Technology, Rajamangala University of Technology Rattanakosin, Wang Klai Kangwon Campus, for the information in writing this research until completion.

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