DISIMILLAR LAP JOINT FRICTION STIR WELDING (FSW) USING VARIED LENGTH OF PIN

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The lap joint will be used on aluminum 6061 and 10 mm thick brass with the Friction Stir Welding method. The probe used is EMS 45 steel with variations in pin lengths of 11 mm, 11.5 mm and 12 mm. The results of this study are in length 11.5 mm with the highest Vickers hardness value of 104.26 VHn compared to 11 mm and 12 mm pin length is 98.93 VHn and 70.43 VHn. The results of shear stress are 67.32 MPa at 12 mm pin length, higher than the 11 mm and 11.5 mm pin lengths of 40.2 MPa and 42.14 MPa.

KEYWORDS

Friction Stir Welding, pin, probe, Lap.

1. INTRODUCTION

Friction Stir welding (FSW) is a solid phase welding joint technique widely used in the fabrication industry. Solid welded joints (FSW) will produce good quality on one-sided and two-sided joints. Invented and patented in 1991 by TWI, it was originally only used for aluminum alloy butt joints [Thomas 1991].

Friction Stir Welding is a solid metal welding method, which can be done by joining two different types of metal (Dissimilar) in a plastic condition and under pressure. The probe is a solid welding support to produce heat and make the material plastic. This connection occurs because the plastic material is continuously stirring along the joint line. The Friction Stir Welding (FSW) method was discovered and patented by The Welding Institute (TWI) by [Thomas 1991].

Friction Stir Welding (FSW) is a solid phase joining technique on fabrication industry. Good quality single sided and double sided butt, "T", and lap joints. Invented in 1991, and was originally used to produce butt joints of aluminum alloys [Thomas 1991].

The base materials for welding were AA6063 (Al–0.7%Mg–0.4%Si) aluminum alloy and AA5052 (Al–2.5%Mg) aluminum alloy. The thicknesses of the AA6063 plate and the AA5052 plate were 4 mm and 2 mm, respectively.The plates were friction stir welded vertical to their rolling directions. The so-called lap–butt joint of dissimilar to AA6063/AA5052 aluminum alloys consisting of three plates [Bo Li 2011].

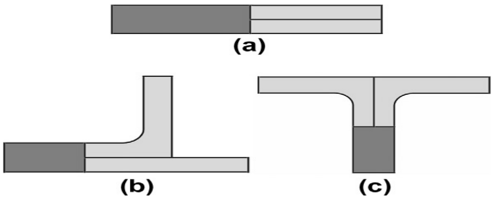

Figure 1. Sketches of the so-called lap–butt composite joint (a) and its applications on some engineering structures (b and c) [Bo Li 2011]

Different types of welding are carried out Sheets of AA5083 and commercially pure copper, 2.5 and 3 mm thick respectively, 150 mm long and 100 mm wide were selected for lap joint welding processes [Bisadi 2012].

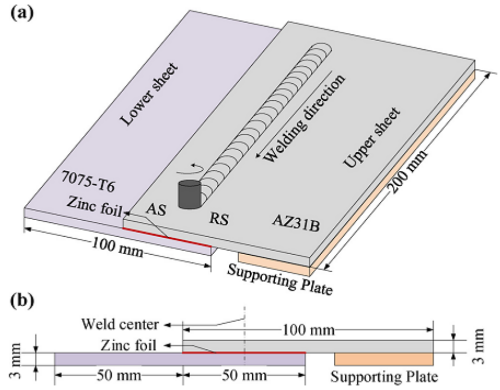

Figure 2. Schematics of Friction stir lap joint [Niua 2018]

connected with different types of materials between base materials were 6082-T6 aluminum alloy sheets with dimensions of 3mm×330mm×90mm and QSTE340TM steel sheet with dimensions of 2mm×330mm×90mm [Huang 2018].

Connected with welds of different types of materials between copper and aluminum with the FSW method, the microstructure and the strength of materials will be studied [Zadeh 2007].

Brass is a mixture of copper (Cu) and zinc (Zn). Copper is the main component of brass, usually classified as a copper alloy. Brass with a Zn content of 47.5% will form β crystals first at a temperature of 890°C, then there is a double phase (β + liquid) that is very small, and no segregation occurs. At temperatures reaching 880°C, the liquid will freeze completely to form homogeneous β crystals. This kind of brass is called brass β (beta) with hard and brittle mechanical properties [Ardleyand 1953].

In this paper, Aluminum 6061 and brass will be joined by lap friction stir welding (FSW) method, with the preparation of an aluminum 6061 plate on the top side, then a thermocouple is installed with a distance of 20 mm, there are 7 thermocouples and a brass bottom plate.

The pin length variation parameter is used to find the relationship, microhardness, microstructure and tensile force, then will determine the quality of the connection.

In this study, it is known that the connection of different types of materials and the melting temperature can be connected by friction stir welding. The success of this connection, is done by preparing the probe pin design. The microstructure, microhardness, and tensile strength of lap joints were evaluated and compared with those published in previous papers.

1.1 FRICTION STIR WELDING (FSW)

Heat is generated FSW (friction stir welding) by friction between the tool and the workpiece through via plastic deformation. The fraction of the plastic deformation energy is stored within the thermomechanically processed region in the form defect densities increment [Nandan 2008].

Friction stir welding (FSW) is a friction welding, requires no added ingredients. The heat generated from friction between probe and workpiece. Probe spin at a certain speed then placed on a connection that has gripped material. The friction of the two objects creates 0.8 Tm of workpiece heat [Tang 1998].

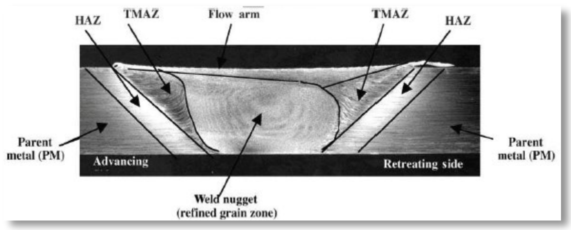

Figure 3. Heat zone pada friction stir welding [Mishra 2007]

Nugget is a plastic area where there is a lot of deformation, due to the friction heat of the probe and workpiece (FSW), then it will form a fine-grained microstructure, whereas TMAZ is the thermo mechanically affected zone between the base metal and the nugget. Beyond the TMAZ there is a heat affected zone (HAZ). This zone experiences a thermal cycle, but does not undergo any plastic deformation, so as a zone a temperature rise above 250 ^{0}C for a heat-treatable aluminum alloy [Mishra 2007].

Increased shear stress is caused by the increase in probe rotation and the penetration of the length of the pin that enters the plate sheet of the lap connection with the Fsw method [Cao 2010].

The stir zone has the highest stress and strain rate and high temperature, sothis combination causes this part to occur with dynamic recrystallization.The microstructure of the mixture is very dependent on the shape of the welding tool, the speed of rotation and translation, the pressure and characteristics of the material to be connected [Cui 2012].

In addition, this section is also part deformed part of the effect of heat thermomechanical (thermomechanical affcted zone) occurs coarsening precipitates amplifier but no dynamic recrystallization. During the heat welding process that occurs in the section of the heat affected zone (HAZ) only grows grains. The Journal stated that Friction stir welding (FSW) is a method that can connect different materials (dissimilar) with a shoulder which has a variety of rotating pins over the plate pieces to be joined. When the rotating probe moves forward along the weld line, it will generate heat from the friction between the plate and shoulder, the heat generated is lower than the liquid welding method [Malarvizhi 2012].

FSW is a current technique in joining aluminum without feederelectrode required. The heat is generated from the rotation of welding tool which results in deformation in the welding area. This joining process is called solid welding [Padgett 2003].

FSW can be applied in similar or dissimilar metals with more efficient result, whereas liquid welding may cause hot cracking, blow holes, and distortion [Kazi 2001] [McNelley 2008].

T1 is probe conical screw thread pin, produce wide and thin weld nuggets, T2 is cylindrical-conical thread pin large and wide weld nuggets are produced, T3 is stepped conical thread pin small and short weld nuggets are produced, while T4 is neutral flared-triflute pin a large weld nugget is produced and there is an air hole [Salari 2014]

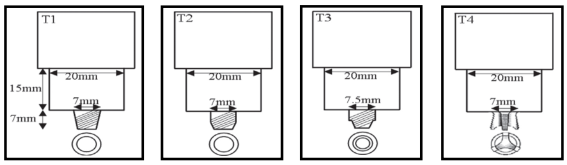

Figure 4. Geometry and technical details of the investigated tools [Salari 2014]

Carbonize Steel ST 37 and Aluminum 6061 can welded with solid welding, on pin long connection produced was strong and the inter-metallic compounds were thick [Setiawan 2016].

2.EXPERIMENTAL PROCEDURES

The aluminum 6061 and brass will be joined by means of a friction stir welding method. The dimensions of aluminum are 175 mm long, 95 mm wide, and 10 mm thick, while brass is 175 mm long, 95 mm wide and 6 mm thick. The probe used as a heat generator is made of medium carbon steel EMS 45 which has been hardened, and the variations are probe pin lengths of 11.0 mm, 11.5 mm and 12.0 mm. This research will examine the joint strength, hardness and microstructure.

Compositions	Mg	Si	Cu	Mn	Fe	Cr	Ti	Zn	Al
Contens	0.9	0.6	0.25	0.086	0.18	0.1	0.192	0.01	Bal

Table 1. Chemical composition of aluminum alloy 6061 (wt.%) top side plate friction stir welding

Compositions	Cu	Zn
Contens	0.85	0.15

Table 2. Chemical composition of brass (wt.%) bottom side plate friction stir welding

Compositions	Mn	C	Si	Fe
Contens	0.486	0.450	0.156	Bal

Table 3. Chemical composition of carbon steel EMS-45 (wt.%) material of probe

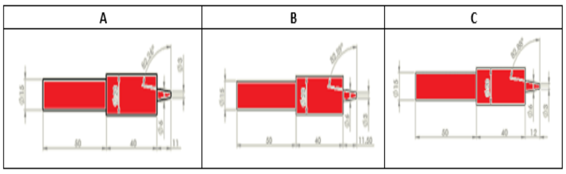

Figure 5. Variations in probe plan pin length, A) 11 mm pin length, B) 11.5 mm pin length, and C) 12 mm pin length

Figure 6. Pin probes Steel EMS 45

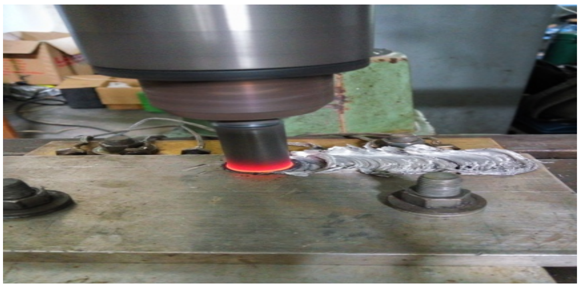

Figure 7. Dissimilar welding that will be tried

This process uses the engine speed of 2000 rpm and feedrate of 10 mm/min using the lap joint friction stir welding method. The temperature is measured using a thermocouple data logger, then processed with data acquisition and excel will obtain a temperature graph.then processed with a data logger, thermocouple placement as seen in the picture fig 8 and fig 9.

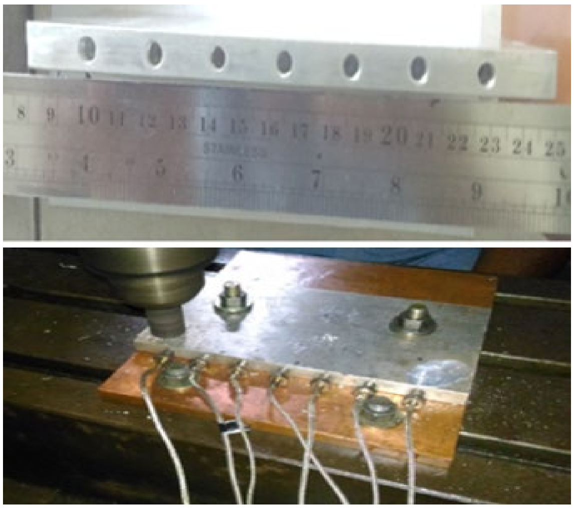

Figure 8. Positioning of 7 thermocouples at a distance of 20 mm

Figure 9. Data acquisition and for displaying graphs and fsw processes in a plastic state

3. RESULTS AND DISCUSSION

3.1. MACROSTRUCTURE

Visually, the material produced by the friction stir welding process with the length of the probe pin 11.0 mm, 11.5 mm and 12.0 mm (figure 5.) Is as follows :

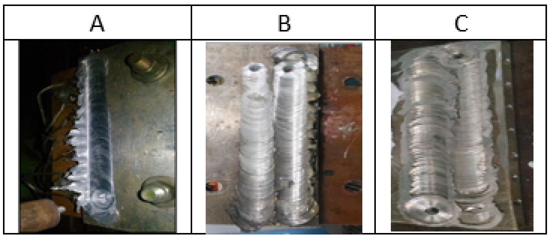

Figure 10. Visual FSW Welding Results (A) length of pin probe 11.0 mm, (B) length of pin probe 11.5 mm, (C) length of pin probe 12.0 mm

Macrostructure images are clear that at the 12 mm nugget pin length formed a lot on the advancing side and retreating side, then line defects occur along the weld path. This happens because a large compressive force will cause high heat energy and form a lot of plastic material too. For a pin length of 11.50 mm nuget which formed not much on the advancind and retreating side, then no defects occur. This is because the pressing force used to connect lower is not much plastic material formed.

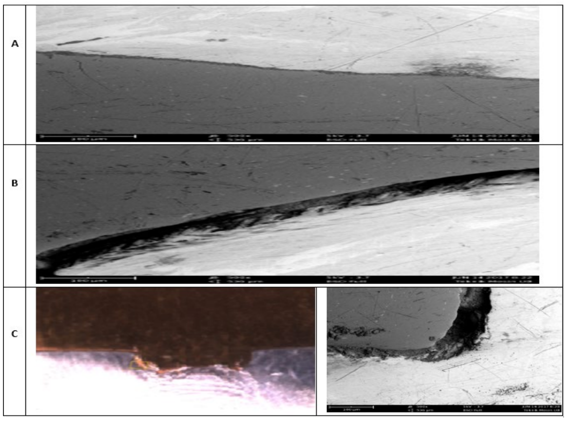

Figure 11. Macrostructure and SEM FSW Welding Results (A) length of pin probe 11.0 mm, (B) length of pin probe 11.5 mm, (C) length of pin probe 12.0 mm.

Results of welding of 12 mm long lap joint pins are often defective, due to scrap formed in the area of advancing and retreating, this will result in the strength of the connection that occurs.

3.2 TEMPERATURE MEASUREMENT

Temperature measurements using thermocouples are then processed using loggers and acquisition data, for each pin length of 11 mm, 11.5 mm and 12 mm.

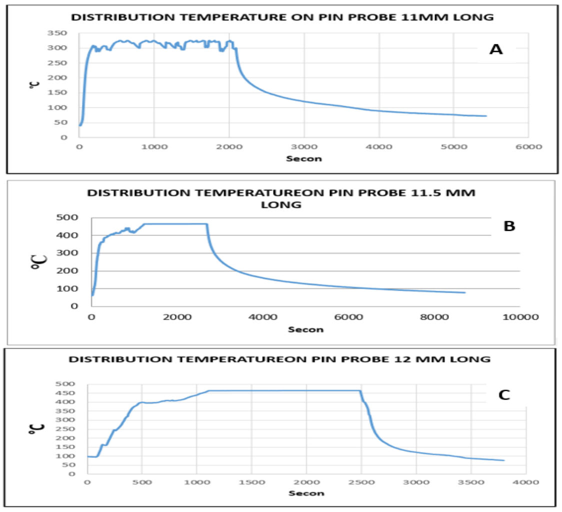

Figure 12. Welding Temperature Graph(A) length of pin probe 11,0 mm, (B) length of pin probe 11,5 mm, (C) length of pin probe 12,0 mm

Measurement of welding temperature a lap joint for 12 mm pin length is the highest, which is 470⁰C. This will produce perfect plastic material, then the strength of the joint is better. The 11 mm and 11.5 mm pin lengths produced temperatures between (330-410)⁰C lower than the temperature produced at 12 mm pin length. The graph shows the peak temperature of the 11 mm pin length is 325ºC, the 11.5 mm pin is 460ºC and the 12 mm pin length is 470ºC. The temperature can't rise anymore because a lot of heat is lost, due to the brass plate

3.3 MICROSTRUCTURE

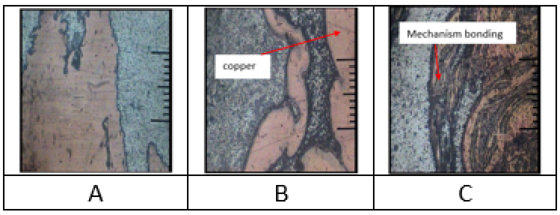

Figure 13. Microstructure of fsw with (A) length of pin probe 11.0 mm, (B) length of pin probe 11.5 mm, (C) length of pin probe 12.0 mm

Weld nuggets are areas that are affected by heat generated during welding, as well as deformed areas due to the process of mixing of pin probes. The weld nugget area occurs in grain refinement, which is an area that undergoes plastic deformation and heating during the FSW process resulting in recrystallization which produces fine grains in the stirring area. The length of the 11 mm pin is formed by many oxides trapped in the material, this is caused by the low compressive force of the probe during welding, resulting in low heat energy, and consequently imperfect plastic material formed.

The defects that occur at 11.5 mm pin length are mostly caused by scrap which is formed on the side of advancing and retreating. A good weld connection occurs at 12 mm pin length, this can happen because the heat energy produced is high, so that it will form plastic material then stir it perfectly.

3.4 MICROHARDNESS

Tests of hardness on the test specimens were carried out on the connection area (figure 9), with an indentation point of 20 points with 10 points towards the right of the connection center and 10 points towards the left from the center of the connection.

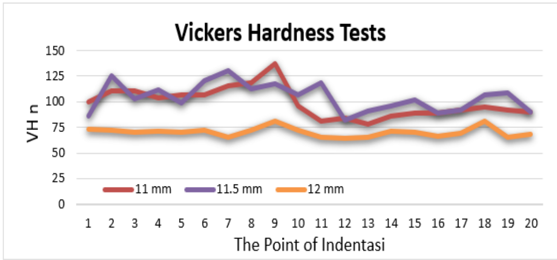

Figure 14. MicroHardness Vickers number tests

The micro Vickers hardness tests results show that the lowest hardness value is 75 VHn in welding using a 12 mm pin length. Heat energy is too large because of the length of the pin, so it will produce a 470⁰C temperature, and cause a lot of plastic material to form. This will cause a lot of scrap on the side of advancing and retreating, and defects will occur.

The micro Vickers hardness test values on 11mm and 11.5mm pins on average higher are 100 VHn.

Causing the heat energy that occurs is lower than the pin length of 12 mm, so that little scrap is formed and no defects occur.

3.5 SHEAR TESTS

This shear test is carried out four times for each pin length varied, then static loads are used.

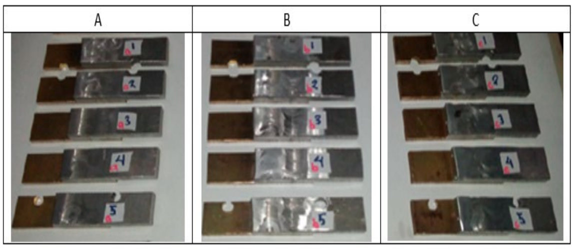

Figure 15. Specimens ready for shear tests A) 11 mm pin length, B) 11.5 mm pin length, and C) 12 mm pin length

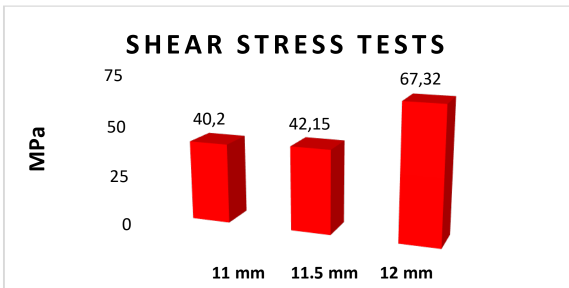

Figure 16. Shear Stress Tests

The average shear stress for 12 mm length is higher than the 11mm and 11.5 mm pin lengths of 65 MPa. This is due to more even distribution of plastic material and more incoming pressure. Even though defects occur on the surface because a lot of plastic material is formed. The pin lengths of 11 mm and 11.5 mm of low shear distribution of a small amount of plastic material, heat energy and a small amount of plastered material.

4. CONCLUSIONS

Welding of aluminum 6061 and brass material with the type of parallel lap joint connection using the friction stir welding method and with variations in the length of pin probe 11.0 mm, 11.5 mm and 12.0 mm that have been carried out, the following results are obtained :

The parallel lap joint welding process, dissimilar metal aluminum 6061, and 6 mm thick brass with friction stir welding method can be done. Formed scrap on the side of advancing and retreating. High heat energy will produce a high temperature of 470^{0}C which will produce low Vickers micro hardness of 75 VHn, but high shear stress of 65 Mpa at 12 mm pin length.

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