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TEMPERATURE PROFILE AND FRACTURE LOCATION OF FRICTION STIR WELDED AA6063-T6 PIPE BUTT JOINT

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ABSTRACT

Friction stir welding (FSW) is a new promising solid state joining process which utilizes frictional heat to soften and joint (stirred) both metals together. This process is mainly invented to cater for a difficult-to-weld material such as aluminium but nowadays can be used to joint magnesium, copper, titanium, and steel. The only limitation is the tool materials rather than the material itself. The objective of this present study is to analyse the relationship between the temperature distributions on advancing and retreating side against the fracture location of the friction stir welded AA6063-T6 pipe butt joint. Several K-type thermocouples will be located at certain locations along the weld line of the pipe in order to take the real time measurement. The tensile test will be conducted to determine the maximum loading and fracture location for each friction stir welded (FSWed) sample. It was found that the advancing side gave higher temperature than retreating but fracture occurred either on advancing or retreating side of the specimens.

Keywords: friction stir welding, temperature, fracture location, aluminium, pipe, butt joint.

INTRODUCTION

Friction stir welding specially fits materials that are difficult to be welded with fusion welding process such as aluminium, magnesium, copper and titanium. Since being invented in 1991, FSW is widely used in many industrial activities such as marine, aerospace, rail, automotive and other process variants. FSW differs from fusion welding process as it utilizes frictional heat to soften and stir (joint) the materials together [1-2].

The source of frictional heat (external) depends on welding parameters (i.e transverse speed, rotational speed and downforce), type of alloy and tool design. The contact between tool's shoulder and material's surface will cause frictional heat and viscous dissipation in materials close to the pin tool which causes the heat generated to be increased further. The stirring process and heat input will cause the several regions to form known as Stirred Zone (SZ), Thermo-mechanically Affected Zone (TMAZ), Heat Affected Zone (HAZ) and Base Metal (BM). These zone boundaries are shown in Figure-1.

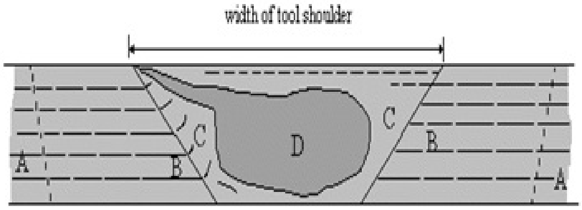


Figure-1. Zone boundaries on friction stir welded cross section (D- Stirred Zone, C- Thermo-mechanically affected zone, B – Heat affected zone, A – Base metal)

Many studies are conducted on the properties of friction stir welded aluminium flat panels instead of pipe. Mostly results showed free weld defects and fracture occurred either on the advancing or retreating side of the Heat Affected Zone due to a large amount of plastic deformation [1-9]. This present study will analyse the relationship between the temperature distributions against the fracture location of the friction stir welded AA6063-T6 pipe butt joint.

EXPERIMENTAL PROCEDURES

The 89mm outside diameter AA6063-T6 pipe with the wall thickness of 5mm were used as specimen materials. These pipes were butt joined by friction stir welding process utilizing a customised orbital clamping unit which attached to the CNC Bridgeport 2216 Milling Machine. This experimental setup can be referred to Figure-2.

Figure-2. Friction stir welded pipe butt joint experimental setup.

A surface hardened H13 high carbon steel tool has been utilised in this experiment setting. The diameter of shoulder and pin were 20mm and 5mm each respectively. The length of pin is about 3.8mm. The tool was offset about 6mm forward of centreline of the pipe. This setup is shown in Figure-3.

Figure-3. 6mm offset forward centreline of the pipe.

The 4 unit of K-type thermocouple was located at similar distance on both advancing and retreating side of the friction stir welded samples whereby 2 of them were located close to tool's shoulder. The arrangement of the thermocouples is shown in Figure-4.

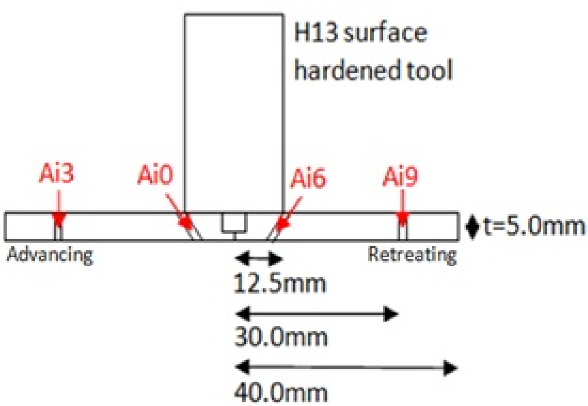


Figure-4. Cross sectional view and K-type thermocouples positioning.

Several selected welding parameters are listed in Table-1 with the increment of rotational speed and transverse speed respectively. The 4mm plunge depth and 30 s dwell time were used in this current setting [4,5].

Table-1. Friction stir welding parameters.

FSW Id No.	Rotational speed (rpm)	Transverse speed (mm/s)
FSW #1	900	1.2
FSW #2	1200	1.2
FSW #3	1500	1.2
FSW #4	1500	1.8
FSW #5	1500	2.4

The inspection of the friction stir welded specimens were assessed based on AWS D17.3, a specification for friction stir welding of aluminium alloys for aerospace application [10]. Three tensile specimens were prepared for each welding parameters according to ASTM E8 / E8M, a standard test method for tension testing of metallic materials [11].

RESULTS AND DISCUSSION

a) Temperature profile

Based on the results extracted via NI Signal Express, the temperature profile for all friction stir welded pipe specimen is shown in Figure-5 – Figure-9. Severe plastic deformation occurs on the advancing side caused by the temperature increase more on this side.

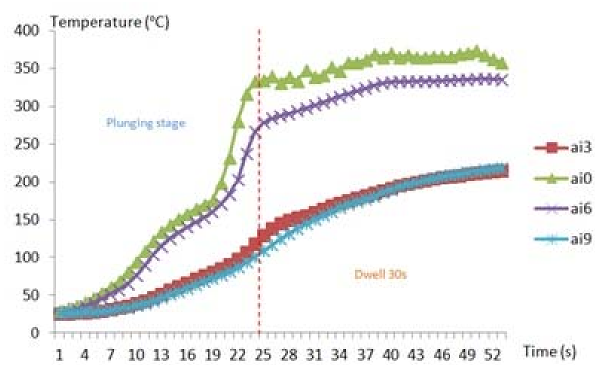


Figure-5. Temperature curve at rotational speed of 900 rpm.

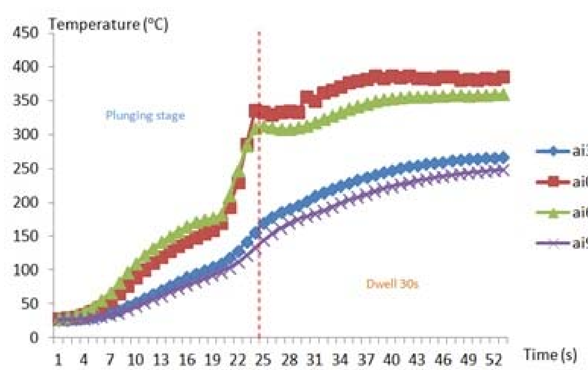


Figure-6. Temperature curve at rotational speed of 1100 rpm.

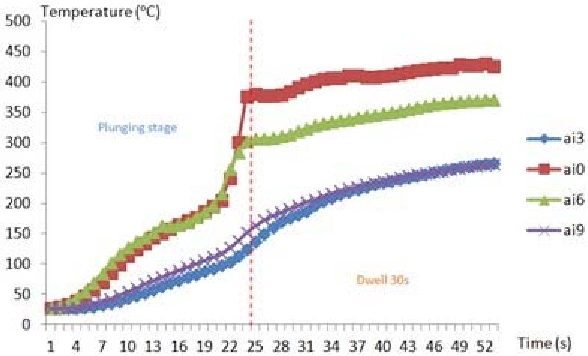


Figure-7. Temperature curve at rotational speed of 1300 rpm.

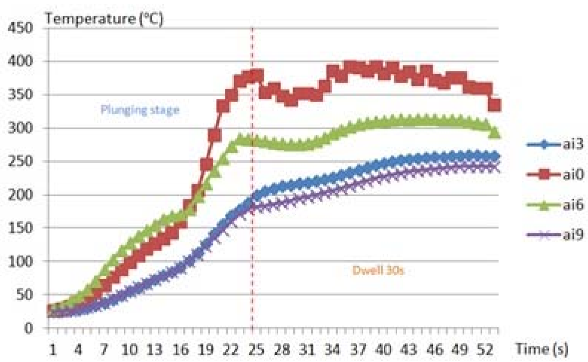


Figure-8. Temperature curve at rotational speed of 1500 rpm.

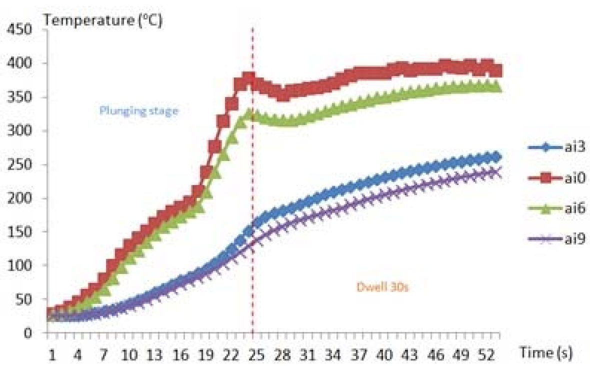


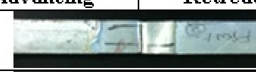
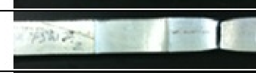
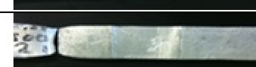
Figure-9. Temperature curve at rotational speed of 1700 rpm.

The temperature profile on advancing side gave higher temperature reading compared to the retreating side for all welding parameters. These findings are similar to those found by Saad *et al* [12]. The materials flow is more on the advancing side as the tool travels and pipe rotates against each other. The wider contact between shoulder and outer surface of pipe is due to offset condition during the friction stir welded of pipe sections causing more materials flow to be pushed forward on the advancing side compared to when it was brought inside on the retreating side.

b) Fracture locations

Table-2 shows the fracture location for each FSWed specimen. As detected on FSW #1, there was no defect but it fractured on the weld centerline due to mismatch of welding parameter which did not supply sufficient heat for joining to occur perfectly. Meanwhile, the FSW #2, FSW #3 and FSW #4 samples gave better joint strength as it fractured on the base metal either on advancing or retreating side. It is a bit different from the previous study which found that the fracture location was on the retreating side and this is applicable for certain grades of aluminum [3,13]. For FSW #5 specimen, it is clearly observed that by using the optical microscope, the micro crack did affect the strength of the joint as it fractured on the weld centerline.

Table-2. Fracture location on FSWed specimens.

FSW Id No.	Advancing	Retreating
FSW #1		
FSW #2		
FSW #3		
FSW #4		
FSW #5		

CONCLUSIONS

Based on the temperature curves gathered from this experiment, several conclusions can be drawn as follows;

- The advancing side gave higher temperature profiles than the retreating side.
- The defect free joints fractured outside the stirred zone, can be both either on advancing or retreating side unless micro cracks did exist in the weld joints.

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