BALKANTRIB'O5
5th INTERNATIONAL CONFERENCE ON TRIBOLOGY
JUNE.15-18. 2005
Kragujevac, Serbia and Montenegro

THE FRICTION BEHAVIOUR ON THE EXTERNAL SURFACE OF THE FRICTION STIR WELDING OF AA 6063-T6 TUBES

**E.Gerçekcioglu, **T.Eren, **K.Yıldızlı, **N.Kahraman, ***E.Salamcı*
** Assoc.Prof.Dr., Erciyes Univ., Dept.of Mech.Eng., Division of Const.and Prod., 38039-Kayseri/TURKEY*
*** Erciyes Univ., Dept.of Mech.Eng., Graduate students., 38039-Kayseri/TURKEY*
**** Assoc.Prof.Dr ., Zonguldak Karaelmas Univ., Technical Education Faculty, Karabük/TURKEY*

Abstract

The joining of similar Al 6063-T6 tubes was carried out using friction stir welding (FSW) technique under the varying rotational speed of stirrer and forward speed of tube. External worn surfaces of the Al 6063-T6 tubes have been investigated. The worn surface was characterised by optical microscope after welding. During the friction stir welding, the shoulder of stirrer is deformed out of he external surface of tubes. To weld the tubes the shoulder below of stirrer and out of the external surface of tubes must be kissed together.
The goal of this work is to investigate the friction behaviour on the worn surface of AA 6063-T6 tubes welded via friction stir welding method.

Keywords: *Friction stir welding, AA 6063-T6, Friction, solid state welding.*

1.INTRODUCTION

Friction stir welding (FSW) is a relatively new joining process that is presently attracting considerable interest. The FSW process was developed at TWI in 1991 [1]. FSW involves plunging a rotating shouldered pin tool into the faying surface of two plates and traversing the tool its length [2]. Welding, which is in solid state, is achieved by plastic flow frictionally heated material. The joining takes place through the movement of rotating shouldered tool with profiled pin plunged into the joint line between either two pieces of sheet, plate material or tubes. When the rotating pin tool moves along the weld line, the material is heated up by the friction produced between the shoulder of the stirrer and the workpiece to be weld. Frictional heat causes the material to soften without reaching the melting point.

Material around the rotating pin tool is often referred to as being frictionally heated, plastically altered, and extruded to the back of advancing pin where it consoilidates, forming the weld bead [3]. However, the friction-stir weld zone is always characterized by dynamic recrystallization which arises through either localized or large –scale shear instabilities forming narrow or extended adiabatic shear bands.

Extensive research has been accomplished on developing the friction stir welding process for aluminum alloys [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 2], aluminum- steels [15, 16] and steels [17]. And also, this method is one of the most popular welding technique for joining dissimilar materials. FSW has several advantages over the commonly used fusion welding methods, such as low energy input, short welding time, low distorsion and relatively low welding temperatures. Therefore, FSW has been developed for aerospace, automotive, marine and nuclear assemblies [15].

This paper will focus on the outer worn surface of AA 6063-T6 tubes after friction stir welding.

2. EXPERIMENTAL

In this study, AA 6063-T6 pipes have been used for welding materials. Two pipes which are the 5 mm thickness and the 50 mm length 6063-T6 aluminium alloy have been used as welding materials. The diameters of shoulder and pin are 20 mm and 5 mm, subsequently. The heights of shoulder and pin are 5 mm. For welding, the diameter and height of AA 6063-T6 are 110 mm and 50 mm, subsequently.

The stirrer pin was prepared by AISI 4140 steel. It has been heat treated to a Rockwell C hardness of 55. The pipes were friction stir welded using milling machine that some apparatus were adapted on its working table. Fig.1 and 2 show schematically Friction Stir Welding (FSW) apparatus and equipment.

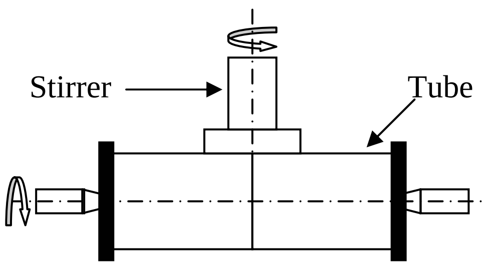


Fig.1: *Illustration of friction stir welding equipment.*

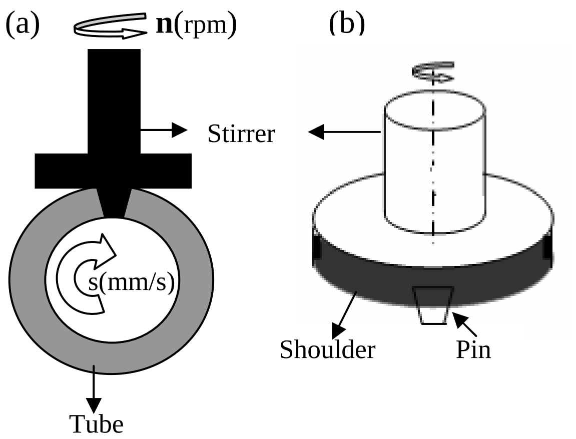


Fig.2: *Friction Stir Welding Apparatus. (a) Tube and (b) Stirrer tool.*

This stirrer rotation speeds (n) were 450, 510, 710, 900 and 2800 rpm. Rotational forward speed of pipes was kept constant at 2.87 mm/s. But, it has been observed the researches mainly at 450, 510 and 710 rpm.

Fig.3 Shows the steps of friction stir welding (FSW). As shown in Fig.4, the outer surface of the pipes welded is deformed by the pressing power of shoulder. Because shoulder bottom surface and outer surface of pipes must be kissed each other during the movement, ie, welding. In this case, shoulder bottom surface has deformed plastically on the surface of pipes.

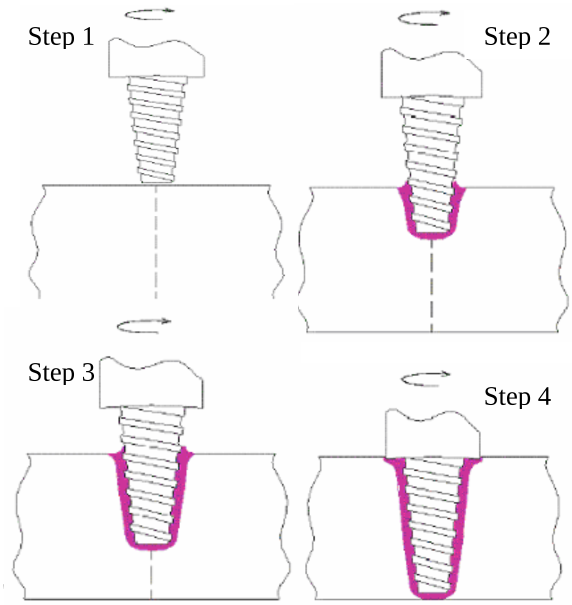


Fig.3: *The steps of Friction stir welding operations [18].*

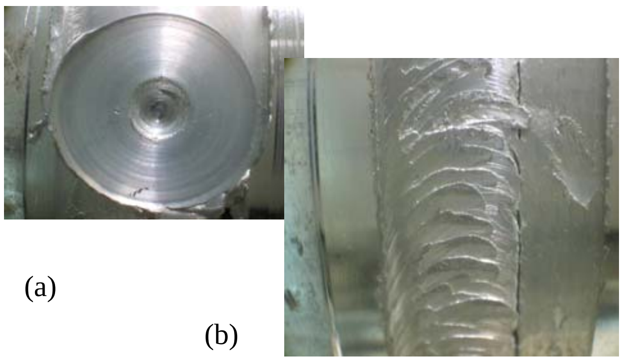


Fig.4: *Friction stir welding, n = 510 rpm and s = 2.87 mm/s. (a) Initial point of welding and (b) the welding surface near the initial point.*

3.RESULT AND DISCUSSION

During the welding, some plastic deformations on the pipes and pin have been occurred by friction. The deformation rate of both materials depends on some parameters, such as, material hardness, friction heat and rotational spees of stirrer, and rotational forward (feed) speeds of pipes.

In this study, the welding surface was only investigated for friction and wear. The investigation on the stirrer tool was present in the past [3].

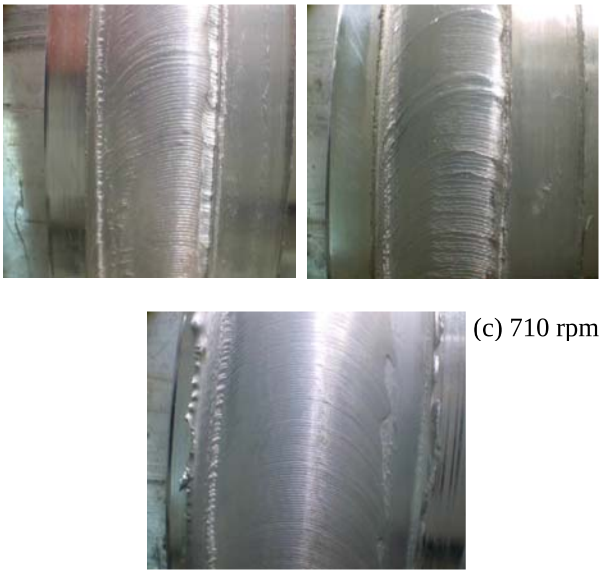
Present studies showed that the rotational feed speed for both materials has been effected friction and surface deformation. At high rotational feed speed of pipes and low rotational speed of stirrer, it was found rough surface quality. Before the rotational movement of tubes, the stirrer must be pushed downward into interface of pipes as shown in Fig.3 and then waited a short time to get enough frictional heat. As the stirrer rotates and moves forward around the bond line the pipe at the bond line begins to heat up, forcing it to flow around the rotating tip to consolidate on the pin stirrer's backside. This heat source is developed mainly due to the local friction and plastic deformation while keeping the pin stirrer's shoulder in intimate contact at all times with the pipes. The tubes must be securely fitted on the milling machine equipment as shown in Fig.1 in a manner that prevents them from moving and being forced apart at the abutting joint. FSW has the potential for welding materials because the processing temperature occurs well below the metal's melting point, thereby eliminating the solidification defects and undesirable chemical reactions. Otherwise, welding surface quality was obtained rough as shown in Fig.4 (b). On the other hand, initial starting point is the most important that pin must be come to the interface both pipes. Besides, the bond desired between the both tubes can not be taken place well. And also, some gaps and cracks can be occurred as shown in Fig.4 (b).

Some similar observation for rough surface was shown in Fig.5 because of high rotational feed speed of pipes. Other thing, the tube can not be absorbed enough frictional heat.

By studying the influence of rotational speed of stirrer at a constant feed speed of tubes, a trend was observed. According to the variation speeds, welding surface quality was changed as shown in Fig.6. During inreasing the stirrer speed at a constant pipe feed speed, surface roughness was decreased as shown in Fig.6 (a).

Fig.5: *Friction stir welding, at n = 710 rpm and s = 7.87 mm/s.*

(a) 450 rpm (b) 510 rpm



(c) 710 rpm

Fig.6: *The outer welding surface of tubes according to the varying speeds of stirrer at a constant rotational speed, 2.87 mm/s.*

Because the tubes are absorbed enough heat by friction of stirrer with the increase in the stirrer rotational speed. Finally, solid state welding is occurred. This case is shown in Fig.6. But, the accumulation along the welding side is taken place for extreme temperature. During the welding, the temperature of materials is reached over 500 ^{0}C. Shoulder's external side accumulates the materials along welding side while the pin welds both tubes.

4.CONCLUSIONS

In this study, the effective of rotational speed of stirrer on the outer surface of friction stir welding has been investigated. The stirrer was manufactured in a left-hand-threaded from AISI 4140 steel. To investigate the deformation on the welding surface, it was studied at different rotational speed- 450, 510 and 710 rpm-counter clockwise rotation speed in the FSW.

The results showed that plastic deformation of tubes is increased if stirrer's speed is increased. Therefore, welding surface quality is obtained well. Both speeds of stirrer and tubes must be chosen available. Otherwise, some distorsion on the tubes is taken place at extreme stirrer's speeds.

For this problem solution, some available apparatus can be adapted on the FSW equipment.

REFERENCES

[1] BY.T.J.Lienert and et al., "Friction stir welding studies on mild steel", Welding Journal, Jan.2003, pp.1-9.

[2] BY G.Oertelt and et al., "Effect of thermal cycling on frriction stir welds of 2195 aluminum alloy", Welding Research Supplement, pp.71-79.

[3] R.A.Prado and et al., "Tool wear in the friction-stir welding of aluminum alloy 6061+20%Al_2O_3: a preliminary study", Scripta Materialia, 45(2001), pp.75-80.

[4] M.M.Attallah and H.G.Salem, "Friction stir welding parameters: a tool for contrtolling abnormal grain growth during subsequent heat treatment", A 391(2005), pp.51-59.

[5] A.Squillace and et al., "A comparison between FSW and TIG welding techniques: modifications of microstructure and pitting corrosion resistancee in AA 2024-T3 but joints", J.Mat.Processing Tech., 152 (2004), pp.97-105.

[6] R.W.Fonda and et al., "Development of grain structure during friction stir welding", Scripta Materialia, 51(2004), pp.243-248.

[7] P.Staron and et al., "Residual stres in frictionstir-welded Al sheets", Physica B, 350 (2004), pp.e491-e493.

[8] M.Boz and A.Kurt, "The influencee of stirrer geometry on bonding and mechanical properties in friction stir welding process", Materials and Design, 25 (2004), pp.343-347.

[9] Y.S.Sato, et al., "Post-weld formability of friction stir welded Al alloy 5052", Mat.and Sci.Eng.A, A369 (2004), pp.138-143.

[10] Y.S.Sato, et al., " FIB-assisted TEM study of an oxide array in the root of a friction stir welded aluminium alloy", Scripta Materialia, 50(2004), pp.365-369

[11]A.C.Somasekharan and L.E.Murr, "Microstructures in friction-stir welded dissimilar magnesium alloys to 6061-T6 aluminum alloy", Materials Characterization 52(2004), pp.49-64.

[12] H.J.Liu and et al., "tensile properties and fracture locations of friction-stir welded joints of 2017-T351 aluminum alloy", J.of Materials Proc.Techn. 142 (2003), pp.692-696.

[13] P.Ulysse, "Three-dimensional mode-dling of the friction stir-welding process", Int.J.of Machine Tools and Manufacture 42 (2002), pp.1549-1557.

[14] BY J.Chao and et al., "Effect friction stir welding on dynamic properties of AA 2024-T3 and AA 7075-T7 351", Welding Research Supplement, August 2001, pp.196-200.

[15] H.Uzun and et al., "Friction stir welding of dissimilar Al 6013-T4 T0 X5CrNi18-10 stainless steel", Materials and design 26 (2005), pp.41-46.

[16] C.M.Chen and R.Kovacevic, "Joining Al 6061 alloy to AISI 1018 steel by combined effects of fusion and solid state welding", Int.J.of Machine Tools and Manufacture 44(2002), pp.1205-1214.

[17] X.K.Zhu and Y.J.Chao, "Numerical simulation of transient temperature and residual stresses in friction stir welding of 304l stainless steel", J.Materials Proc. Techn. 146 (2004), pp.263-272

[18] Israel Stol, Alcoa June 2004