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Solid state friction stir welding using square groove butt joint

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ABSTRACT

Purpose: of this paper is to high light the application of Friction Stir Welding (FSW) process using square butt joint.

Design/methodology/approach: The design adopted was tool spindle speed, tool plunge depth and transverse movement of the work piece.

Findings: The findings are encouraging. It is possible to increase the strength of the joint by 22.45% from the basic tensile strength. The optimum tensile stress obtained was at spindle speed of transverse speed of 700 RPM at transverse speed 325 mm/min taking into consideration the fracture of the materials. The optimum travel speed for the spindle speed 700 RPM is 325 mm/min, this is because the heat generation and the time for the material to joint was increased. But the 200 mm/min is not optimum for the spindle speed 700 rpm because, there is too much heat generation and the welded part become soft by the welding. When there is not enough heat generated, the stir between materials or part will not occur or not properly welded.

Research limitations/implications: The limitations in this research were proper fixture. Machine should have variable tool rotation instead of fixed machine spindle speed.

Practical implications: It is possible to weld by FSW process and not tested in any application.

Originality/value: The research on FSW The limitations in this research were proper fixture. Machine should have variable tool rotation instead of fixed machine spindle speed. is upcoming project and not much work done in this field. Using square shaped joint unique and no references so far using this square groove. Many of the research were by straight butt joint.

Keywords: Mechanical properties; Fatigue; Wear resistance; Friction Stir Welding; Solid state

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PROPERTIES

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1. Introduction

Friction Stir Welding (FSW) is a relatively new solid state joining process invented by The Welding Institute (TWI) in Cambridge, UK in 1991. During the welding, a special shaped FSW tool is rotated, plunged and then transverse along the joint to form weld. This FSW technique attempted in metal joining industries and is attracting more research attention especially metal flow pattern. Many researchers are attempting to find suitable reasons for material flow characteristics. In FSW process, there are two methods by which material is transported. The first is wiping of the material from the advancing side, and the second process is the material flow from the retreating side of the nib that fills in between the sloughed off pieces from the advancing side [1]. Compared to many conventional fusion welding methods, the FSW process has the advantages such as good mechanical properties, low residual stress and distortion, and reduced occurrence of defects [2-3]. Periyasamy et al [4]. reported that rotational speed has greater influence on tensile strength followed by axial force and welding transverse speed in welding Al / SiCp metal matrix composites. Reynolds classified FSW as an extrusion process, utilizing a 5454 –Hh32 tracer to study flow in butt welds of 2195-T8 and noted that the tool shoulder, the weld backing plate, and cold base metal outside the weld zone form a moving extrusion chamber [5]. Krishnan [6] classified FSW as an extrusion process as well, saying that for each rotation of the tool, a cylindrical section of material is extruded around the probe and a banded structure within the weld results. Krishnan asserted that these bands or onion rings, which can appears as concentric rings or semicircles depending on which cut plane they are viewed from, result from oxidation the surface of each semi-circle. The tool serves two primary functions: (a) heating the work piece and (b) movement of material to produce joint flow. The heating is accomplished by friction between the tool and the work material and plastic deformation of work material [7]. During welding, friction heating and deformation are produced by the rotating pin and shoulder [8]. The plasticized soft materials is transported from the front of the tool to the back that induces significant microstructure changes, including precipitate distribution, texture development and grain size [9,10]. There are four regions in welding process: (a) base metal (BM), (b) heated affected zone (HAZ), (c) thermo-mechanically affected zone (TMAZ) and (d) nugget zone (NZ). The micro-structural changes in various zones have great effect of the mechanical properties of the weld. FSW has shown not to cause severe distortion and residual stresses heat generated are low compared to the traditional welding. Weld defects like groove, cavity and kissing bond are easily formed under improper parameters or technological conditions [11-13]. The input variables include tool or spindle rotation, welding speed, plunge depth, tilt angle, sideways tilt angle, shoulder geometry, shoulder features (such as scrolls) probe geometry and probe features such as threads, flutes, and flats.

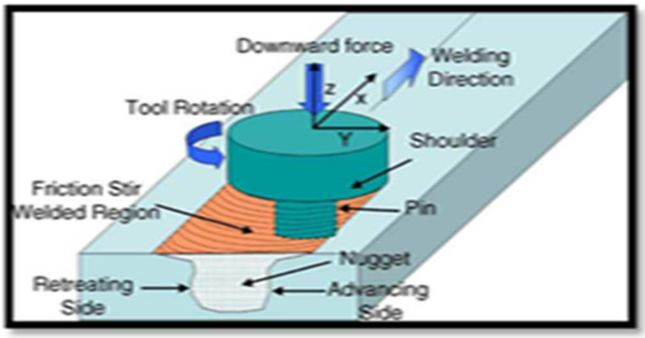


Fig.1. Working principle of FSW [14]

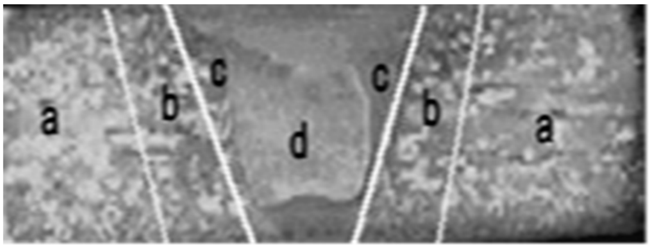
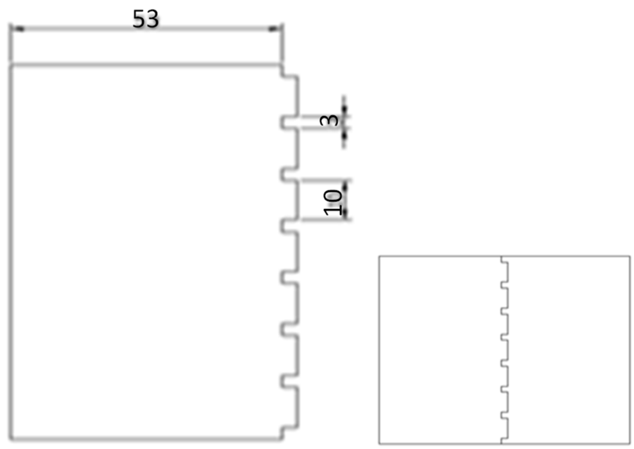


Fig. 2. Different zones of FSW: (a). Base metal, (b).Heat Affected Zone (HAZ), (c).Thermo – Mechanically Affected Zone, and (d). Nugget zone [15-16]



(a) (b)

Fig. 3. Square groove specimen (a) and (b) as welded

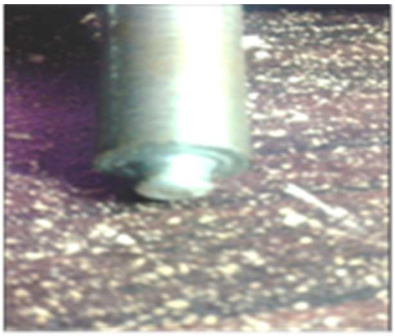


Fig. 4. FSW tool

Fig. 5. Welded test pieces

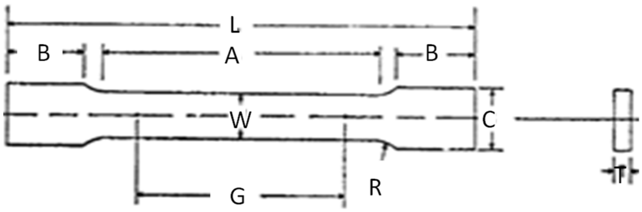


Fig. 6. Test specimen as per ASTM [17]

Table 1.
Alloying elements of aluminium

Fe	Cu	Si	Zn	Mn	Mg	Cr	Ti	Al
0.16	0.19	0.71	0.04	0.02	0.94	0.08	0.03	Remaining

Table 2.
Mechanical properties of 6061-T6 material

Ultimate Tensile Strength	Yield strength	Fatigue strength	Elongation	Brinell hardness
310 MPa	726 MPa	96.5 MPa	12 %	95

Table 3.
Operating parameters

Spindle rotation (RPM)	Transverse speed (mm/min)
700	200, 325, 500, 600, 725
1120	200, 325, 500, 600, 725

2. Experimental works

2.1. Operating procedures

Commercially available Aluminium alloy 6061-T6 having 100 mm in length, 75 mm in width and 1 mm thickness was used. All the plates were machined to dimensions mentioned above with square grooved as shown in the Figure 3. The square grooves were cut by wire cut machine to get minimum gap between grooves. FSW tool used is shown in the Figure 4. The operating parameters for the FSW are given in the Table 3. The tool was arranged to rotate in the clock wise direction and work piece was moved in the opposite direction which is called as advancing side. The macrostructure and, consequently, the mechanical properties of the Stirred Zone is mainly governed by the retreating side material, the dissimilar weld was produced with Aluminium positioned on the retreating side and aluminium alloy 6061-T6 on the advancing side. Only transverse specimen was produced and to be tested on the tensile test. The test specimens were machined from the central part of the joint according to ASTM E8M-01 [10] sub-size standard for sheet type material (gauge length 25 mm, width 6 mm, and overall length 100 mm). All samples were produced with minimal defects and conformed to specified dimensions with a tolerance of 0.1mm. The specimens were tested at room temperature using a 10 KN Servo pulsar Series Servo-hydraulic Testing Machines with front-opening hydraulic grips. The cross head speed is fixed at 30 mm/min. Table 4 shows the dimensions of the test specimen as per ASTM [17].

3. Results and discussion

3.1. Surface roughness

Surface roughness refers to the small, finely spaced deviations from the nominal surface that are determined by the materials characteristics and process that are selected or it is the measure of peaks and valley caused by machining process by using different tools on different materials. In machining, the increase in cutting speed at low feed rate and depth of cut produced smooth surface roughness. In machining as the cutting speed increased low surface roughness produced. In FSW also, low surface roughness are produced at high spindle rotation. In any machining surface roughness is an added value to machining performance and also the aesthetics sense of the products. The surface roughness in FSW process is similar to burnishing action between rotating and moving components. In turning process, low and smooth surface is possible with high rotation of the work material and low feed rate of the tool which will contribute to smooth roughness. FSW similarly produced high rotation of the tool and low transverse of the tool contributed low surface roughness. Figure 5 shows the FSW weldment used to measure the surface roughness.

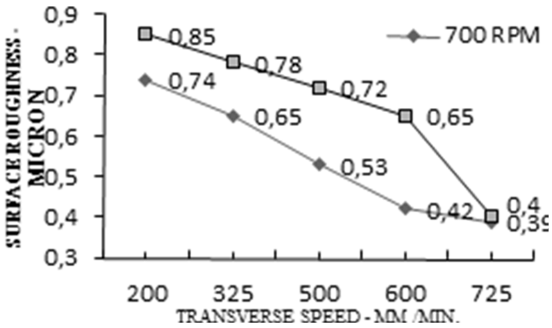


Fig. 7. Tranverse vs surface roughness at 700 and 1120 RPM

From the Figure 7 it is understood that at lower spindle rotation the surface roughness was lower and low transverse speed, the roughness is high. When compared with 700 RPM, the 1120 RPM maintains smooth surface at all transverse speed. Lowest value obtained at spindle rotation of 1120 RPM at transverse speed of 725 mm/min. This was due to high plastic deformation which causes the material to be smoothened.

3.2. Tensile strength

Figure 8 shows the tensile strength obtained for the operating parameters as given in the Table 4. Tensile strength of materials is an important property which is strength for the performance of weldment. At rotational speed of 700 RPM, at low transvers speed of 200 mm/min the tensile strength was low and increased as the transverse speed increased to 725 mm/min. The more the transverse speed, heat generated was high which makes the material flow easily and the strength was increased. However, it is reached the value of original tensile value of the material. It is not possible all the time to bond together rigidly and there is limitation. High temperature would result in softening the materials and strength values may decrease. Figure 9 shows the images obtained by SEM after performing the FSW process. Too hot the weld, process of welding there is so much heat generate. The generation of heat is proportional to the speed of moving tools and also the rotation of tools. The too high of processing temperature will result of the following friction stir welding: (i) the temperature approaching the solidus but where heat loss from the direct deformation zone is sufficiently retarded so as to result in unwanted thermal softening of the work piece, (ii) leading to degradation of the mechanical properties of the joint. Figure 9 (a), (b) and (c) shows the SEM images of the weldment. On certain weldment onion like surface obtained.

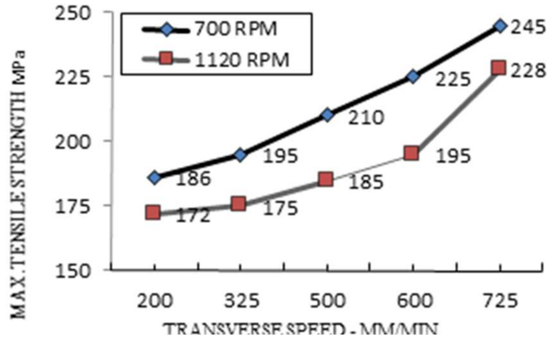


Fig. 8. Tensile result for 700 rpm and 200 mm/min

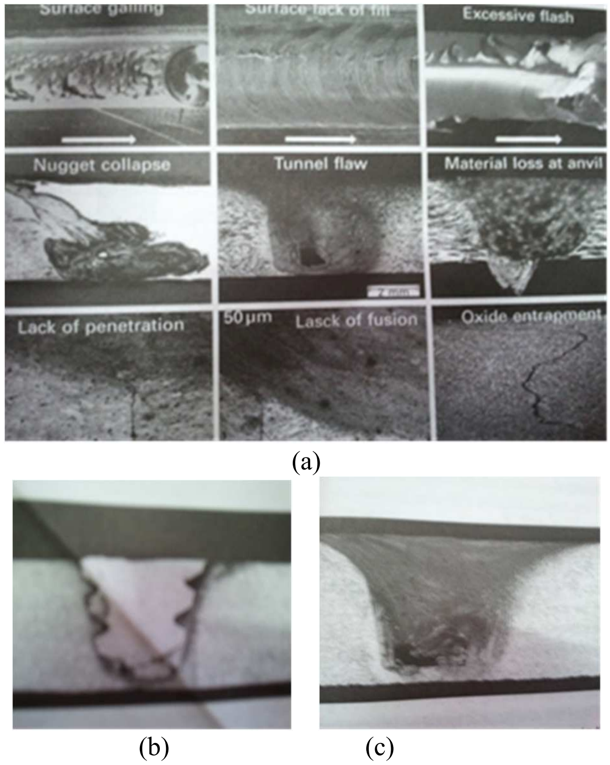


Fig. 9. Sectional view of the joints welded by different welding speed at 200 mm/min, 325 mm/min, 500 mm/min, 600 mm/min, 725 mm/min.

4. Conclusions

The square butt joint of material aluminium 6061-T6 was successfully joined using Friction Stir Welding by conventional milling machine. The following observations were obtained.

It was possible to increase the tensile strength of the joint by 22.54% compared to the normal joining joint. The optimum tensile stress obtained was at spindle speed of transverse speed of 700 RPM at transverse speed 325 mm/min taking into consideration the fracture of the materials.

The optimum travel speed for the spindle speed 700 RPM is 325 mm/min, this is because the heat generation and the time for the material to joint was increased. But the 200 mm/min is not optimum for the spindle speed 700 rpm because, there is too much heat generation and the welded part become soft by the welding. When there is not enough heat generated, the stir between materials or part will not occur or not properly welded.

The optimum travel speed for the spindle speed 1120 RPM is 200 mm/min, this is because the spindle speed is so fast and heat generation also increased rapidly. From the journal the high spindle speed will increase the blend of the materials and also the strength of the materials, but based on our finding the 700 RPM spindle speed possessed higher tensile strength than the spindle speed of 1120 RPM spindle speed. Therefore it is concluded that, based on our particular joining shape which is square butt join, the optimum spindle speed and travel speed of the tools is 700 rpm and 325 mm/min which give good strength.

Further research work

It was planned to extend the research further by using various tool pin diameters, title angle of the tool, dissimilar materials with varying thicknesses. Square groove joint can also use to test out the FSW. Apart from testing the UTS, fracture strength, fatigue life of the weldment can also be tested.

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Additional information

Selected issues related to this paper are planned to be presented at the 22nd Winter International Scientific Conference on Achievements in Mechanical and Materials Engineering Winter-AMME'2015 in the framework of the Bidisciplinary Occasional Scientific Session BOSS'2015 celebrating the 10th anniversary of the foundation of the Association of Computational Materials Science and Surface Engineering and the World Academy of Materials and Manufacturing Engineering and of the foundation of the Worldwide Journal of Achievements in Materials and Manufacturing Engineering.

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