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***Journal of Scientific and Engineering Research*, 2017, 4(8):128-133**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Welding defects recorded on FSSW-welded sheets

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Abstract The main FSSW overlapped process parameters focused in this study: plunge rate (0.133, 0.366, and 0.45) mm/s, higher dwell time (5, 10 and 15) s and lower rotational speed (653, 1280 and 1700) tr/mn. Friction stir spot welding aluminum alloy sheet 2024-T3 with 1.6 mm thickness was the aim. In the present work, we will describe all defects that recorded on specimens welded with friction stir spot welding. Defects appear on three sides, bottom, middle plan and top specimens. Generally these defects accelerate the rupture of the welded joint when it is loaded onto it.

Keywords FSSW, Surface linear crack, Flaking, Swelling

1. Introduction

Friction Stir Spot Welding process (FSSW) was developed in 1991 and has been studied in much applications especially in aeronautic industry [1]. This welding process derives from Friction Stir Welding (FSW), and the main difference is the nugget which formed in circumference joint. Shoulder and pine were the principal entities in friction stir welding tool and the machine use must generate rotation and translation. The main roles of the FSSW tools are to heat the work piece, induce material flow and constrain the heated metal beneath the tool shoulder and probe friction with thework piece and by the severe plastic metal deformation. Stirring causes material flow around the probe [2].

In FSSW process, sheets form a lap-joint and the tool penetrates into sheets only in a point, making a punctual bond. The resulting weld has a characteristic hole in the middle of the joint; this hole is left by the probe after removal [3]. In the FSW process sheets are disposed in a butt joint configuration and immobilized to eliminate any displacement when welding process started and tool moves towards the joint direction. Therefore, FSSW process has three steps: plunging, stirring and retracting [4]. Mainly parameters studied are plunge rate, rotational speed, plunge depth, axial load and dwell time[5,6].Analyze of variance pick up correlations between mechanical properties and parameters to find better one to join 2024-T3 aluminum alloy sheets and to understand the influence of each parameters on welds. The mechanical properties measured in most works are restricted to tensile shear tests [5, 7, 8], cross-tension tests [9] and fatigue tests. Some authors have performed studies in AA 5000 and AA 6000 aluminum alloys series, determining fatigue lives, failure modes, micro structural analysis and failure prediction model [10-11]. Different tool geometries have been used, especially shoulder surface and probe form. Flat, concave, convex, flat with domes, flat with flutes etc... Everyone can be used in shoulder geometry. Cylindrical, conical, triangular, cylindrical threaded, conical threaded, cylindrical fluted etc.., and everyone can be used in probe geometry[12].

2. Experimental Welding method

2.1. Welding Assembly and thermal insulation

The welding assembly consists of holding the parts to be welded and ensuring a complete connection with the table of the machine. In order to produce the weld points of the FSSW type, the assembly must prevent the flow

of the material in the welding direction and block the rotation of the two welding plates around the axis of rotation of the tool.
In order to isolate the assembly of the two sheets and not to allow the heat to propagate to the machine parts, granite with a relatively low thermal conductivity was used below 2.8 W / m ° K.
In order to increase the amount of heat generated by the friction of the shoulder of the tool on the plates to be welded on the one hand and not to increase the thermal conductivity of the granite on the other hand [13].

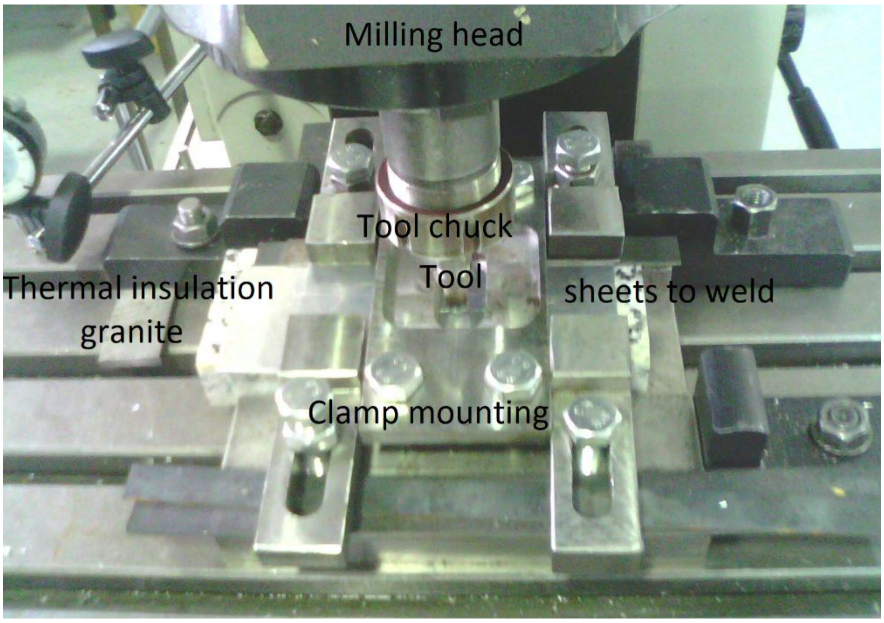
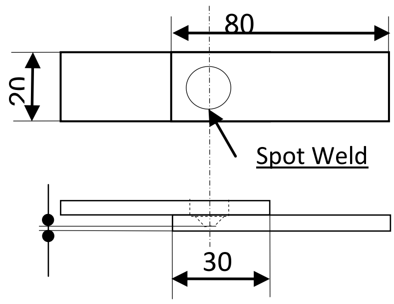


Figure 1: Welding and holding of welding specimens

2.2. Specimens and material

A.A 2024-T3 aluminum alloy sheet with 1.6 mm thickness was chosen for the presentstudy. The lap-shear specimens were made by using two 20 mm x 80 mm x 1.6 mm aluminum sheets with a 20 mm x 30 mm overlap area Fig.1. Weld point made in the overlap area middle with a spot friction by the concave tool. Two square doublers made of aluminum 2024-T3 sheets are located into end sheets and the machine jaws. A clearance of f=0.2 mm is left between the bottom surface of the assembly to be welded and the end of the pin so as not to completely perforate the latter.



2.3. Tool geometry

With fixed probe plunge and shoulder penetration depths 0.2 mm for all tests friction stir spot welding was realized in same position on overlap area.

Only the rotational speed N, the plunge rate V and the dwell time t were varied. The welding tool was constituted of high steel X160CDV12 treated at 62 HRC, with a conical pin and concave shoulder. The diameter of the shoulder, root and tip of the pin are respectively, 10, 4.2 and 3 mm. The pin length is 2.8 mm. And the concave face of the shoulder is angled at 10°.

2.4. Plan of experiments

In this experimental study, tool geometry and high alloy steel material were kept constant through all experiments. We purpose to screen the effects of three operating factors; tool rotational speed N, tool plunge rate V and dwell time t.

The experimental layout for three welding parameters with three levels is using a full factorial design with 27 runs Table.1.

Table 1

Levels	Rotational speed N(Rpm)	Plunge rate V (mm/s)	Dwell time t(s)
Low level	653	8	5
Center level	1280	22	10
High level	1700	27	15

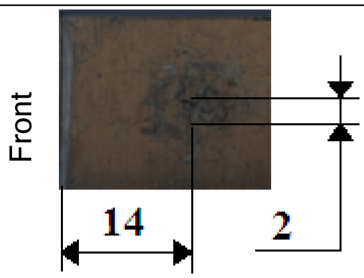
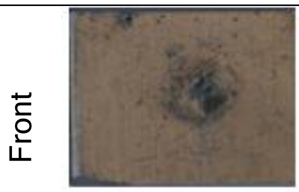
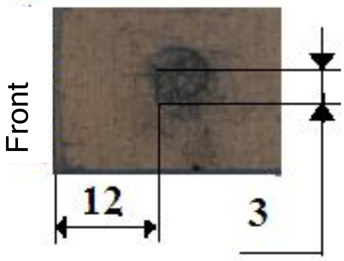
3. Welding defects

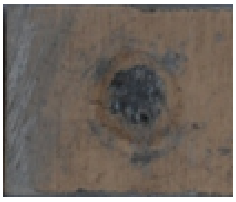
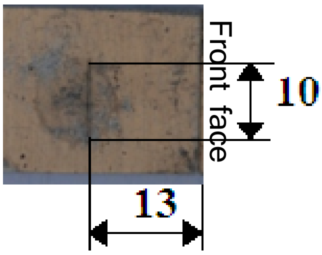
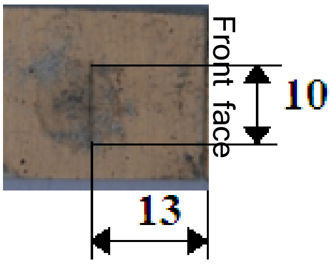
The examination of the welded samples revealed some defects in the weld points, on the underside of the bottom plate and at the welded joint.

3.1. Defects on underside of specimens:

All defects retained on specimens are summarized in Table .2.

Table 2: Examples of recorded defects

Test number	Conditions of realization	Defects recorded on SIPIs	Defect type and length
2	N= 653 rpm V= 8 mm/mn T= 10s		Surface linear crack of length 2mm
4	N= 653 rpm V= 22 mm/mn T= 5s		Flaking
5	N= 653 rpm V= 22 mm/mn T= 10s		Surface linear crack of length 3mm
7	N= 653 rpm V= 27 mm/mn T= 5s		Flaking

9	N= 653 tr/mn V= 27 mm/mn T= 15s		Swelling of the layer under the pawn
18	N= 1280 rpm V= 27 mm/mn T= 15s		Swelling of the layer under the pawn
19	N= 1700 rpm V= 8 mm/mn T= 5s		Surface linear crack length 10mm
20	N= 1700 rpm V= 8 mm/mn T= 10s		Surface linear crack of length 10mm

Using Table 2, it is noted that:

- It will be noted that the surface crack has a length equal to approximately the diameter of the shoulder of the tool when rotational speed is 1700 rpm for low plunge rate (8 mm / min).
- The lack of chipping is mainly due to the use of relatively high rotational speeds (1280 and 1700 rpm).
- The swelling of the surface under the peg is due to the use of a dive speed and high holding times (27 mm / min and 15 s).
- Without taking into account the dive speed, flaking is a result of the union of the rotation speed 653 rpm and the holding time 5 s.

3.2 Defects in the joint plan:

There are two types of defects noted at the joint plane. The lifting of the tip of the upper plate (figure 1) is the first type recorded during the welding of the first series. And the imprint shoulder tool left on the underside of the top plate is also a registered defect after break (Figure 2).

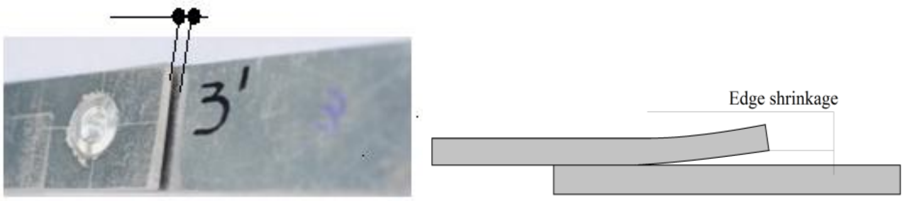


Figure 2. Lifting the top plate of specimen 3'

For some welded joints, there is an impression at the joint plane on the underside of the top plate. Indeed, the latter is due to the force of pressure of the shoulder on the two plates superimposed during the welding and which can cause a play "j". The impression is initiated by an induced twisting moment, during the tensile-shear test.

3.3. Defects in the upper surface of the specimen:

After rupture, the upper surface of the weld spot is identical for all specimens (Figure 3.a) except that the specimen represents a surface defect (Figure 3.b). It is clear that there is a layer in the form of a scale that has formed below the shoulder indicating that there is a lack of consolidation of the material.

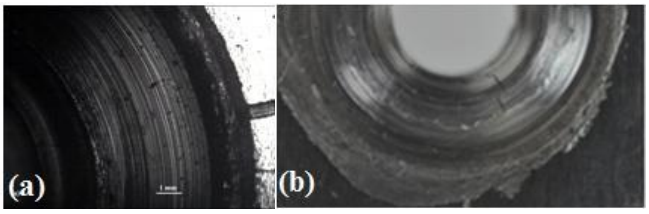


Figure 3: Peeling at the shoulder level of the face

4. Conclusions:

- It is clear that the machining assembly used causes several defects. The use of the granite below the welding assembly is essentially for insulation just to not let the heat spread and what remains to locate in the welding spot.
- Flaking and swelling requires the use of a rigid insulator on its upper surface.
- The holding and tightening is remarkably insufficient to obtain assemblies without defects.

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