

STUDY OF PROCESS PARAMETERS IN FRICTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS

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Abstract

Friction stir welding was performed for four different tool rotation speeds namely 600, 800, 1000 and 1200. Defects were analyzed using radiography. It was found that defect concentration was maximum for the 600 RPM tool rotation. It was a little lesser for the 800 RPM parameter and even lesser for the 1000 RPM speed rotation. Minimum defects were observed for the highest tool rotation speed, namely 1200 RPM. An analysis of defects is given in this paper. Tensile Test values and bend test values were also reported.

Keywords: Friction stir welding, Aluminium based alloys, Lazy S, Weld trial, Radiography

1. Introduction

A method of solid phase welding, which permits a wide range of parts and geometries to be welded and called Friction Stir Welding (FSW), was invented by W. Thomas and his colleagues at The Welding Institute (TWI), UK, in 1991. Friction stir welding has a wide application potential in ship building, aerospace, automobile and other manufacturing industries. The process proves predominance for welding non-heat treatable or powder metallurgy aluminum alloys, to which the fusion welding cannot be applied. Thus fundamental studies both on the weld mechanism and on the relation between microstructure with mechanical properties and process parameters have recently been started. A great advantage is, in particular the possibility of joining dissimilar materials, which are not, or only with great difficulties weldable by classic fusion welding techniques. One of the possible applications is for example the welding of high performance materials, such as particle reinforced aluminium alloy, to larger structures made from a lower performance, but less expensive alloy. Friction stir welding is a relatively simple process as shown in Figure. A specially shaped tool, made from material that have a hard and wear resistant relative to the material being welded, is rotated and plunged into the abutting edges of the aluminium parts to be joined. After entry of the tool probe to almost the thickness of the material and to allow the tool shoulder to just penetrate into the

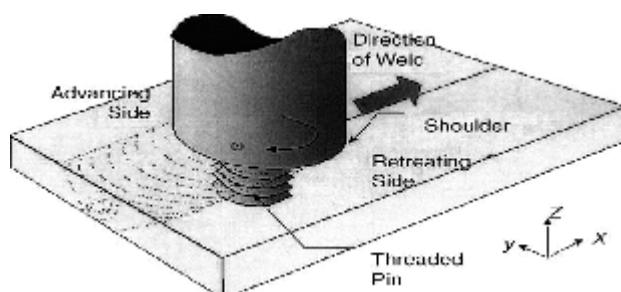


Figure 1: Schematic Drawing Of Friction Stir Welding

aluminium plate, the rotating tool is transitioned along the joint line. The rotating tool develops frictional heating of the material, causing it to plasticize and flow from the front of the tool to the back where it cools and consolidates to produce a high integrity weld, in the solid phase.

2. Defect analysis in friction stir welding

With lower welding speed 40 mm/min, the weld is perfect and no obvious defects produced. The materials were stirred and combined sufficiently and the weld was completely filled. There are flow lines near the weld root, see Fig. 1(a). When the welding speed increase, the welding line at the bottom is clear and there is clear flow lines generated from bottom extending to the up part of the weld. But no pores generated with welding speed increase to 120 mm/min, No pores produced when welding speed increase to 150 mm/min, as shown in Pore was produced when the welding speed was 200 mm/min [1].

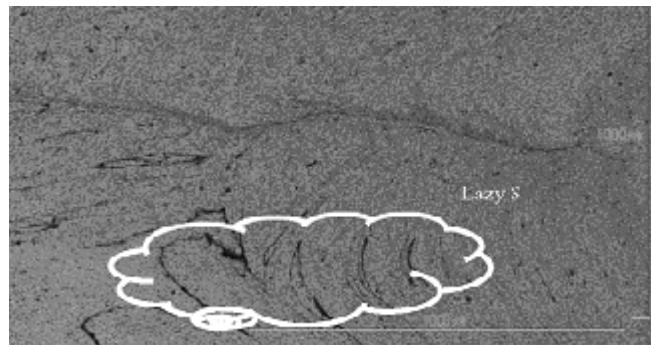


Figure 2: Schematic Drawing Of Friction Stir Welding

The appearance of “lazy S” is shown in Fig.2. A series of regularly black spaced curved lines, occur in the nugget zone. The appearance of lazy S in the nugget zone is known that the black “lazy S” lines probably was originated from the oxide.[2]. The following Figures show various defects seen in 5456 Aluminium alloy friction stir welds. Groove, void, onion ring and channel defect can be seen in the Fig.3 below.

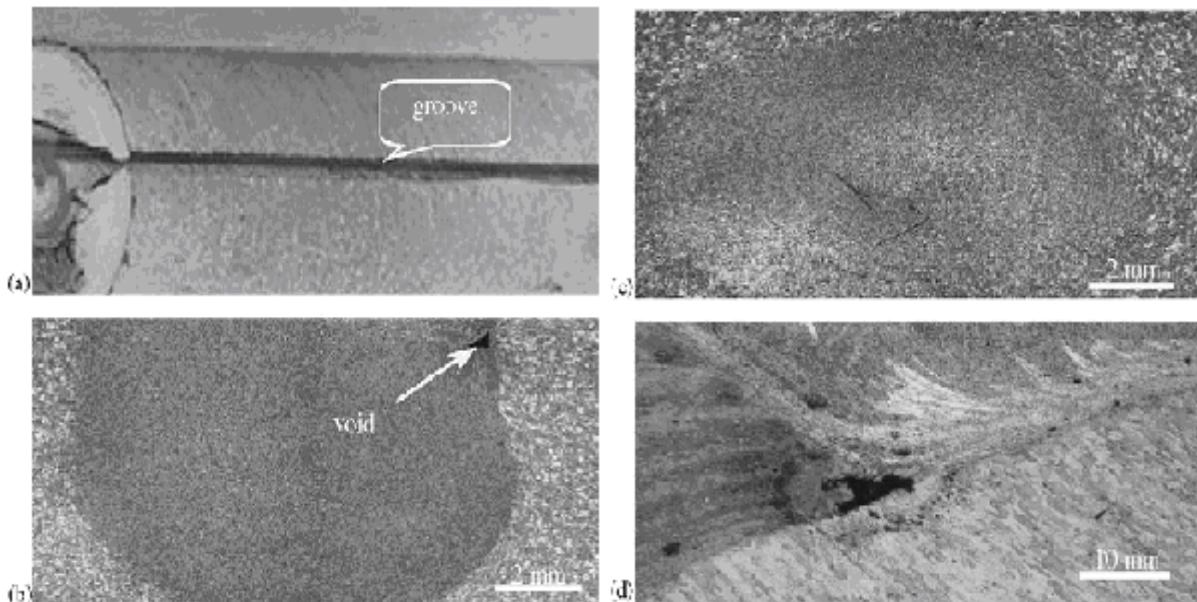


Figure 3: Schematic Drawing Of Friction Stir Welding

2.1 Welding parameters

In this study, downward force and welding speed are kept constant, only the tool rotation speed is varied. The welding parameters are given in Table1.

Table 1: Welding Parameters

Downward force (Tones)	1.5
Welding speed (mm/min)	62.5
Tool rotation speed (RPM)	600,800,1000,1200

2.2 Tool Parameters

Straight cylindrical tool was used as shown in Figure. The tool is made up of M2 high speed steel and which was tempered and hardened to 50 HRC. The tool material composition is given in Table 2.

Table 2: Tool Parameters

Material	C	Cr	W	Mo	V	Fe
M2	0.85	4.0	6.0	5.0	2.0	remaining



Figure 4: Schematic Drawing Of Friction Stir Welding

2.3 Weld trials

Four sets of welding trials were made at the base material AA7075, only by varying the tool rotation speed and keeping downward force and welding speed constant, the values of the parameters are given in Table 3.

Table 3: Weld Trials

Specimen Code No.	S600	S800	S1000	S1200
Tool rotation speed (RPM)	600	800	1000	1200
Welding Speed (mm/min)	62.5	62.5	62.5	62.5
Downward Force (Tones)	1.5	1.5	1.5	1.5

3. Experimental tests

3.1 Radiography Test

X-Ray radiographic inspection was carried out on the welded plates using Radiographic unit operated at 125 kV, 5 mA and duration of 1.5 min. To determine the quality of the weldment for pores and discontinuities at weld nugget.

3.2 Tensile test

Tensile tests were performed to determine the tensile properties of the weld material such as tensile strength and percentage of elongation. One specimen of each was tested at S600 and S800 condition as shown in Figure and the results of specimens were measured and reported. The tensile tests specimens were cut as per the ASTM E 1251 size on the 5 mm thick plate. Tensile tests were conducted at Computer Controlled AUTO Make Universal Testing Machine.

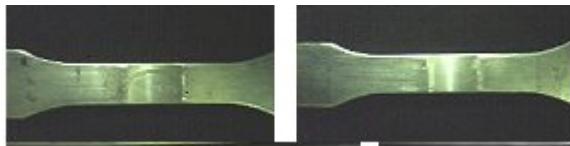


Figure 5: Schematic Drawing Of Friction Stir Welding

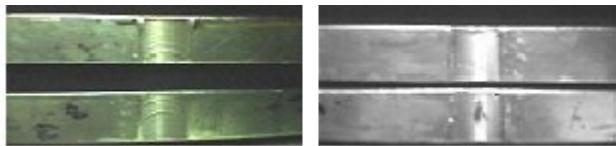


Figure 6: Schematic Drawing Of Friction Stir Welding

3.3 Bend Test

Bend tests were performed on both face and root side of the welds. Face and root bend tests are used as an important tool to understand about the ductility and toughness of friction stir welds. One specimen of each was tested at S600 and S800 condition as shown in Figure and the results of specimens were measured and reported. The specimens were cut as per the ASTM B 557 size on the 5 mm thick plate. Mandrel base has radius of 4-times of thickness of plate and 180 degrees of bend angle. Bend tests were performed at Computer Controlled AUTO Make Universal Testing Machine.

4.0 Results and discussion

4.1 Quality of weld-visual inspection

S600 and S800 welds are shown in Figure. The tool rotation speed in S600 is 600 RPM and tool rotation speed in S800 is 800 RPM. The weldments indicated no visible defects. The weld surface is even and uniform.

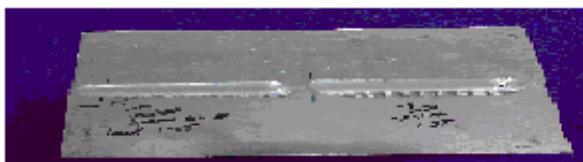


Figure 7: Schematic Drawing Of Friction Stir Welding



Figure 8: Schematic Drawing Of Friction Stir Welding

S1000 and S1200 welds are shown in Figure. The tool rotation speed in S1000 is 1000 RPM and tool rotation speed in S1200 is 1200 RPM. Similar to S600 and S800 welds, there are no visible defects in the S1000 and S1200 welds. Weld surface indicated a smooth surface finish produced at 1000 and 1200 RPM. This confirms that as the tool rotation speed increases smooth surface is produced at the weldment. The Figure shown above is a photograph of the weld at 100 rpm. It is seen that a bead-on welding was made on the base plate at 1200 RPM tool rotation speed. The weld surface is found to be defect less and smooth as shown in Figure?

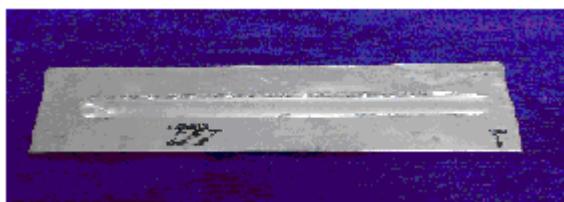


Figure 9: Schematic Drawing Of Friction Stir Welding

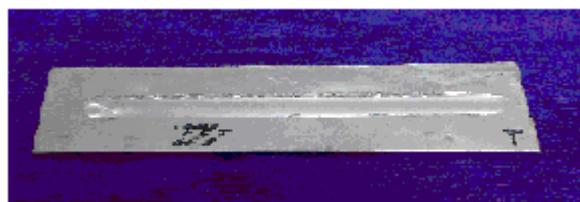


Figure 10: Schematic Drawing Of Friction Stir Welding

4.2 Radiography inspection

X-Ray radiographic inspection was carried out using Radiographic unit and the radiographs indicated a good quality weld without any pores and discontinuities at weldment. This confirms the presence of no defects at weld nugget irrespective to tool rotation speed.

4.3 Tensile properties

Tensile properties such as tensile strength and percentage of elongation have been evaluated for welded plates and compared with base metal. For S600 and S800 one specimen was tested and the results of the specimens are presented as the outcome of this study. The tested specimens are shown in Figure and results are given in Table 4.

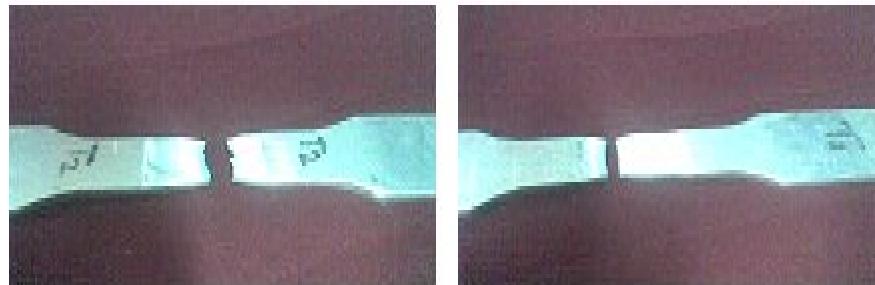


Figure 11: Schematic Drawing Of Friction Stir Welding

Table 4: Tested specimen results

S. No	Specimen Code	Breaking load N	Tensile strength MPa	Elongation %	Fracture position
1	S600	8850	101	21	Weld nugget
2	S800	9250	106	25.2	Weld nugget
3	Base Metal (ASM Hand Book,2000,vol.9)	--	110	42	--

4.4 Bend test results

Both face bend and root bend tests were performed on the welded specimens S600 and S800 and the photographs of tested specimens are shown in Figure. Most of the welds presented good ductility, allowing for very high bend angles and no cracks were observed. Such ductility is a well known characteristic of the AA7075. In case of weld samples that broke during the bend tests, the reason behind it is an incorrect mixing of the material and insufficient downward force. Bend tests results are given in Table 5.



Figure 12: Schematic Drawing Of Friction Stir Welding

Table 5: Bend Tested specimen results

SI. NO.	Specimen Code	Root bend	Face bend
1	S600	No cracks observed	No cracks observed
2	S800	Cracks observed after 90 degree bend	No cracks observed

5. Conclusion

From the FSW study on AA 7075 alloy weld plates it was found that

1. Quality welds could be produced with the tool rotation speeds of 600-1200 RPM. No defect occurs in weld nugget region irrespective to tool rotation speed.
2. The welded specimens passed both root and face bend test allowing for very high bend angles and no cracks were observed in weld nugget.

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