Journal of Manufacturing Engineering, September, 2014, Vol. 9, Issue. 3, pp 163-166

EFFECT OF TOOL ROTATION SPEED ON TENSILE STRENGTH OF FRICTION STIR WELDED AA2024-T6 AND AA7075-T6 DISSIMILAR ALUMINUM JOINTS

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ABSTRACT

Solid state joining processes are ideally suited for joining dissimilar aluminum alloys since these processes does not involve the defects due to solidification. Among these processes friction stir welding was efficient for joining dissimilar joints. The joint efficiency greatly depends on the process parameters like tool rotational speed, welding speed, axial load and geometry of the tool. In this study the effect of tool rotational speed on tensile strength of AA2024-T6 and AA7075-T6 was discussed in detail. Five joints were made for different tool rotational speed. The other parameters included in this study are welding speed, axial load and the shoulder diameter to pin diameter ratio. Tensile properties of the joints have been evaluated. Macro and micro structural analysis was done by using optical microscopy. From this investigation it was found that at the tool rotational speed of 1200 RPM the joints exhibits the maximum tensile strength when compared to other joints.

Keywords*: Dissimilar aluminum alloy, Welding and Microstructure.*

1. Introduction

Friction stir welding (FSW) is an emerging solid state welding process invented at the Welding Institute, UK in 1991 [1]. FSW technique is widely used in aerospace and shipbuilding industries due to its advantages over other joining techniques. FSW uses a non consumable rotating tool to make a joint. The work piece are oriented and clamped in a specially designed fixture. The rotating tool was later plunged into the weld line and traversed. Fig.1 shows the butt joint made using FSW technique.

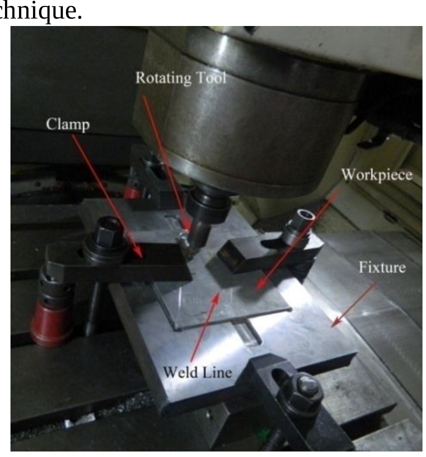

Fig.1 FSW Butt Joint

The simultaneous rotation and traverse movement of the tool and shoulder produces heat due to friction. Due to this the material from the advancing side moves towards the retreating side resulting in solid state joint between the work pieces. Several authors have reported the successful combination of the dissimilar aluminum alloy joints in recent years. Lee et al [2]reported an improvement in mechanical properties at the weld zone at different welding speed of friction stir welded aluminium alloys and fixed location of materials. Peel et al [3] studied the influence of welding speed on microstructure, mechanical properties and residual stresses in aluminium AA5083 friction stir welds. Bahemmat et al studied the characteristics of dissimilar friction stir welding of AA6061-T6 and AA7075-T6 and reported that the weaker alloy when placed in advancing side produces higher mechanical properties. Cavalier et al [4] discussed the fatigue properties of dissimilar 2024 – 7075 joint. They studied the microstructure and precipitate distribution at weld cross section and fracture surface. Kumar et al [5] studied the positional dependence of material flow in friction stir welding in dissimilar metal welding. They reported that the maximum tensile strength obtained was 423 MPa at a welding speed of 100 mm/min. Amancio et al [6] fabricated AA2024 – T351 and 6056 –T4

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dissimilar aluminum alloy and studied their effects on mechanical properties. Elongovan et al [7] discussed the influence of the tool pin profile and tool shoulder diameter on friction stir zone in AA6061 aluminum alloy. R.Palanivel et al [8] reported the effect of tool rotational speed and pin profile on the microstructure and tensile strength of dissimilar friction stir welding AA5083-H111 and AA6351-T6 aluminum alloys. The joint produced using tool rotational speed of 950 rpm and straight square pin profile yielded highest tensile strength of 273 MPa. Rajakumar et al [9] studied the effect of tool shoulder diameters on tensile strength of friction stir welded AA1100 Aluminium alloy joints and concluded that the joint with shoulder diameter of 15mm exhibits the higher tensile strength when compared to other joints.

2. Experimental Work

AA2024-T6 and AA7075-T6 Aluminum alloy sheets of size 150 x75 x 5mm were prepared for square butt joint by using power hacksaw and milling. The direction of welding was normal to the rolling direction of the base plates. AA2024-T6 was kept in the advancing side [8] and. The joint dimensions are shown in Fig 2. The chemical composition and the mechanical properties of the base materials are presented in Table 1 and Table 2. The parameters used in the study and their values are shown in the Table 3. Five different speeds were used to fabricate the joints.

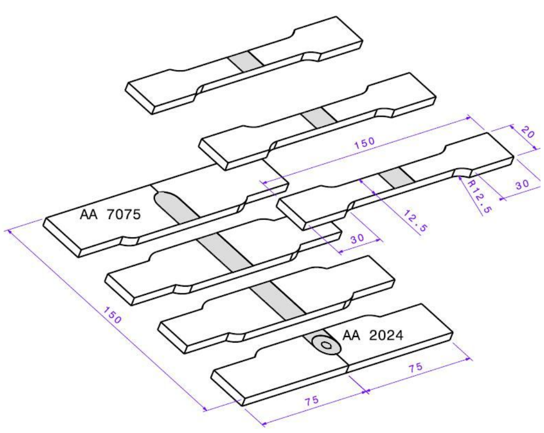

Fig.2 Joint and Tensile specimen dimensions

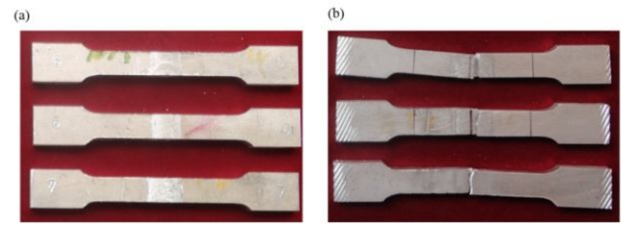

Fig.3 Sample tensile specimens (a) Before test

(b) After test

A computer numerical control FSW machine was used to produce the joints. The tensile specimen was prepared as per the ASTM E8M-09 guidelines [11] and the dimensions are shown in the Fig 2. A servo controlled universal testing machine was used to predict the tensile strength, From each joint three tensile specimen was prepared perpendicular to the welding direction and the average of the same was recorded. Fig.3 shows the tensile specimen before and after testing. For the metallographic examination the specimen was prepared to the required size from the joint which comprises the stir zone, thermo mechanically affected zone heat affected zone and the base metal. The specimen was finally polished using diamond compound and the samples were etched using 10% NaOH to show the general flow structure. Keller's reagent made of 5ml HNO3, 2ml HF, 3ml HCL, and 190ml H2O was used to reveal the microstructure of the weld. Macro and micro structural analysis was carried out using light optical microscope and the fractured surface of the tensile specimen was examined by a scanning electron microscope.

Table 1: Mechanical properties of AA2024-T6 and AA7075-T6

Base Material	UTS (MPa)	Yield Strength (MPa)	Percentage Elongation
AA2024-T6	410	382	20
AA7075-T6	485	410	12

Table 2: Chemical composition of AA2024-T6 and AA7075-T6

Aluminum Alloy	Si	Mg	Mn	Fe	Cu	Al
AA2024-T6	0.09	1.3	0.52	0.11	4.24	Bal
AA7075-T6	0.58	2.1	0.12	0.35	1.2	Bal

Table 3: Process Parameters

Parameters (Unit)	Range
Tool Rotational Speed (RPM)	800,1000,1200,1400,1600
Welding Speed (mm/min)	18
Axial load (kN)	8
Tool Shoulder to Pin Ratio	3

3. Discussion

3.1 Effect of tool rotational speed on tensile strength

From the experimental results it was found that the joint fabricated at the tool rotational speed of 1200 RPM exhibits the maximum tensile strength. Out of various factors that influence the tensile strength of the dissimilar joints it was found that tool rotational speed was the most significant process variable. At higher tool rotational speed the strain rate could raise thereby influencing the recrystallization process which in turn affects the FSW process [10]. At a higher rotational speed the temperature will be higher and slow cooling rate which affects the tensile strength. And moreover at very high tool rotational speed the joint experiences a high turbulence resulting in the excessive stirring of the material. Due to this the material flow to the top layer will be more. Due to this micro voids are created resulting in the reduced tensile strength. At a low tool rotational speed the temperatures within the nugget becomes less which produces the second phase particles. The low tool rotational speed results in inadequate heat generation their restricting the free flow of material from advancing to retreating side there will not be a proper mixing of material resulting in defects. This defects act as a crack initiation during the tensile test and lowering the tensile strength. Hence the tool rotational speed should be optimized to get the maximum tensile strength.

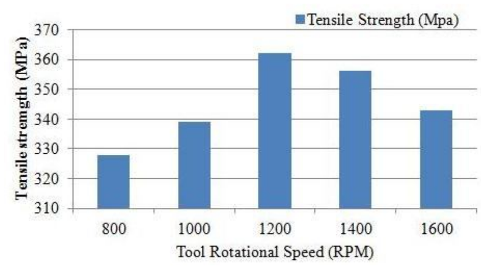

Fig.4 Effect of Tool rotational Speed on Tensile strength

Fig. 4 shows the tensile strength obtained at different tool rotational speed by keeping the other parameters constant. The following inferences were obtained from the Fig.4. (1)At higher tool rotational speed the heat input is more thereby reducing the coefficient of friction in the melt. Reduced tensile strength was seen and found to be 343 MPa. (2)At low tool rotational speed heat input was low which affects the plastic flow in FSP region. The tensile strength was lowest and found to be 328 MPa. (3)At the speed of 1200 RPM maximum tensile strength was found (362 MPa)

3.2 Structural characterization

The following inferences were obtained from the macroscopic, microscopic and fractography analysis made for the joint fabricated with the tool rotation speed 1200 RPM, welding speed of 18 mm/min, axial load of 8 kN and shoulder diameter to pin diameter ratio of 3. (1)Macroscopic analysis shows that the joint was produced at the speed of 1200 RPM was defect free. The dissimilar material mixing can be seen from the Fig 5a. (2)Micro structure at the stir zone was shown in the Fig 5b. Fine grain size was observed which aids in improving the tensile strength of the joint. (3)The fractography of the fractures specimen was characterized by fine dimples as shown in the Fig 5c.

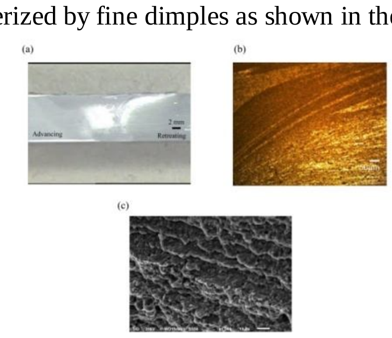

Fig.4 (a) Macro structure (b) microstructure at SZ

(c) Fractography at fractured surface.

4. Conclusions

In this investigation an attempt has been made to study the effect of tool rotational speed on the tensile strength of dissimilar AA2024-T6 and AA7075-T6 aluminum alloys. From this investigation the following conclusions were derived:

1. Of the five tool rotational speed used in this investigation, at the tool rotational speed of 1200 RPM the joint exhibits the maximum tensile strength.

2. Defect free, fine grain structure aids the maximum tensile strength to the joint

3. Tensile strength increases with the increase in tool rotational speed up to maximum and further increase in the tool rotational speed from 1200 RPM decreases the strength.

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