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Effect of Process Parameters on Friction Stir Welding of Dissimilar AA1100 and AA6082 alloys

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ABSTRACT

In this study, Microstructure and Mechanical characterization of friction stir welded dissimilar AA1100 and AA6082 Aluminium alloys joints are examined. Welding specimens with dimensions of 4 x 150 x 300 mm are joined in butt position. A tool made up of high alloy steel with a conical cylindrical tool tip profile was used. A shoulder diameter, probe diameter and pin length of 25 mm, 18 mm and 3.7 mm. Microstructure, hardness test, tensile test, was performed. Grain refinement was observed in all three layers across the nugget zone with smaller grains in AA1100 and AA6082 layers. All the obtained joints fractured in the Fusion zone on the AA1100 and AA6082 side during tensile testing, three different speeds parameters used are 1200, 1400 and 1600 rpm among these 1600 rpm provides good tensile strength. The maximum joint strength was attained when welding was conducted with premier welding speed. It was found that the hardness of the dissimilar joints attained intermittent hardness value of AA1100 and AA6082.

Keywords*:* Friction Stir Welding, Hardness, Speed, Tensile Strength.

1. INTRODUCTION

Friction stir welding (FSW) is a solid state welding process. FSW was invented in 1991 in The Welding Institute (TWI). Initially, the process was regarded as a "laboratory" curiosity, but it soon became clear that FSW offers numerous benefits in the fabrication of aluminum products, Compared to fusion welding process minimizing weld defects due to joining of metals in recrystallization temperature.

The principle of FSW is a cylindrical tool with profiles pin is rotated and plunged into the joint area between two pieces of sheet or material, Frictional heat between the wear resistant welding tool and the work piece causes to soften the material, The probe is slightly shorter the weld depth required. FSW is considered to be the most important development in metal joining due to its energy efficiency. It is provides twice the fatigue resistance of fusion welds, As compared to the conventional welding methods, FSW does not create hazards such as welding fumes, radiation, high voltage ,liquid metals thereby making the process environmentally friendly.

The joining does not involve any use of filler metal and therefore any aluminium alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding.

Fig.1 Photograph of the welding process and weld bead appearance

From Cavaliere et al. [17] it is found that the optimum parameter for dissimilar welding is found to be welded by using higher rotational speed and lower weld speed, and it is under the range of 1600rpm of rotational speed of tool spindle, for aluminium. And similarly position of higher strength material or lower strength material towards the advancing side plays an important role during the process of stirring. Cavaliere obtained good weld results when keeping lower strength material on the advancing side. Similarly Donatus et al. [18] also found and verified that lower strength material must be placed in the advancing side, so that intermixing of material flow takes place, and onion ring microstructure is resulted. Sarsilmaz et al. [20] considered the effect of tool shape and welding speed on the mechanical and fatigue behavior of dissimilar friction stir welded AA7075–AA6061 joints. They reported that the welds done using a treated cylindrical pin tool have the best properties. On further to this consideration, we welded 1xxx and 6xxx series alloys with this parameter selections.

In the present work, an attempt has been made to understand the process starts with clamping the plates to be welded to a backing plate so that the plates do not fly away during the welding process. A rotating wear resistant tool is plunged on the interface between the plates to a predetermined depth and moves forward in the interface between the plates to form the weld. The advantages of FSW technique is that it is environment friendly, energy efficient, there is no necessity for gas shielding for welding aluminium. Mechanical properties as proven by fatigue, tensile tests are excellent. There is no fume, no porosity, no spatter and low shrinkage of the metal. Joining dissimilar and previously unweldable metals can be attempted by this unique process.

Friction Stir Welding can be used to join aluminum sheets and plates without filler wire or shielding gas. Material thicknesses ranging from 0.5 to 65 mm can be welded from one side at full penetration, without porosity or internal voids. In terms of materials, the focus has traditionally been on non-ferrous alloys, but recent advances have challenged this assumption, enabling FSW to be applied to a broad range of materials.

In this paper we have identified the effects of different process parameters on friction stir welding of aluminium 1100 and aluminium 6082 which is mostly used in aircrafts, aluminium 6082 is used in wing ribs which are costly and more weight when compared to aluminium 1100. So aluminium 1100 can be welded with aluminium 6082 by friction stir welding process and be used

2. EXPERIMENTAL PROCEDURE

The Aluminium 1100 and aluminium 6082 were chosen as substrates for friction stir butt welding. The thickness of the materials is 6mm. Before welding both the materials are cleaned.

The tool selected for the welding is made of High Speed Steel. The design of the probe is cylindrical with threads. The diameter and the length of the probe is 6mm and 5.7mm respectively. The diameter of the shoulder is 18mm.

The chemical composition of the materials is shown in the Table 1.

The materials are clamped in the soft material AA1100 is on the advancing side. After clamping, the materials should be drilled to insert the probe. Then a load of 5kN is applied for the welding.

Table 1: Chemical Composition

Elements	Si	Fe	Cu	Mn	Mg	Cr	Al
AA1100	0.038	0.774	0.061	0.016	0.001	0.005	99.08
AA6082	0.762	0.459	0.068	0.751	0.802	0.026	97.10

Welding Parameters selection based on the previous work, and conducted in six samples with the following parameters mentioned in the Table 2.

Table 2 Welding Parameters

Sample no	Rotational Speed (rpm)	Travel Speed(mm)
1	1200	35
2	1200	50
3	1400	35
4	1400	50
5	1600	35
6	1600	50

The welded butt joints were cut for section view, of which the structures and compositions were examined by optical microscope. The mechanical properties of the joints were evaluated by tensile test and hardness test.

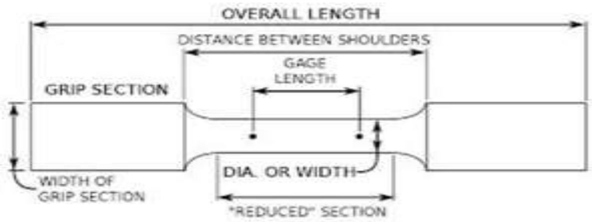
3. TESTING RESULTS AND DISCUSSION

The mechanical properties of the joints were evaluated by tensile and hardness test. These tests were conducted according to the ASTM standards.

3.1. Tensile Test

Transverse tensile strength properties are examined from the tensile specimen and found that the tensile strength, yield strength and percentage of elongation are found to be higher than the base material.

According to ASTM E8 standards, the tensile test specimens are cut to the dimensions as shown in the figure



Width of grip section = 10 mm

Width of reduced section =5 mm

Length of grip section = 30 mm

Length of reduced section =25 mm

Fig. 2 Tensile test specimen

The tensile testing is conducted using universal tensile testing machine and the obtained results are shown in the following Table 3.

Table 3 Tensile test results

Sample No.	Rotational Speed (rpm)	Travel Speed (mm)	Tensile Strength (N)
1	1200	35	2222
2	1200	50	2291
3	1400	35	2473
4	1400	50	2120
5	1600	35	2548
6	1600	50	2686

From the results it is found that sample 6 shows the best result, that is the sample welded with 1600 rpm and 50 mm/min.

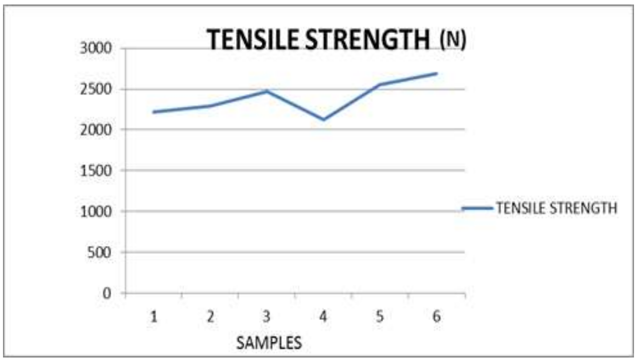


Fig. 3 Graph for the tensile test results

3.2. Hardness Test

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied.

Fig. 4 Brinell hardness test specimen

Brinell hardness test is conducted according to ASTM E 10 standards. The load applied is 250kgf and the diameter of the ball indenter is 5mm

From the results it is found that sample 5 shows the best results that is the sample welded with 1400 rpm and 35 mm/min.

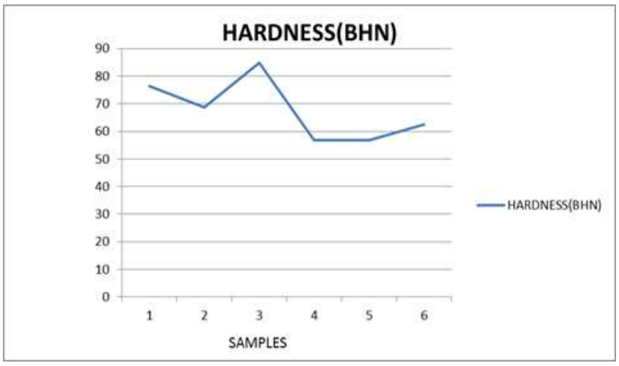


Fig. 5 Graph for the Brinell hardness test results

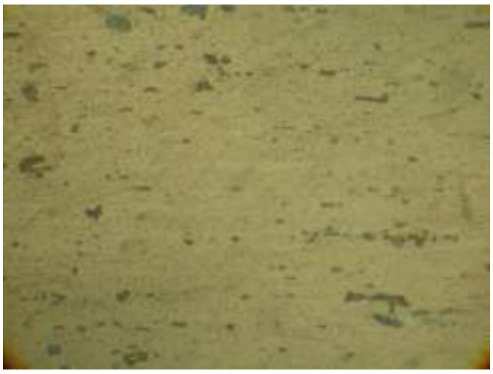
Table 4 Brinell hardness test results

Sample No	Rotational Speed (rpm)	Travel Speed (mm)	Brinell Hardness Number (BHN)
1	1200	35	76.3
2	1200	50	68.8
3	1400	35	84.9
4	1400	50	56.8
5	1600	35	56.8
6	1600	50	62.4

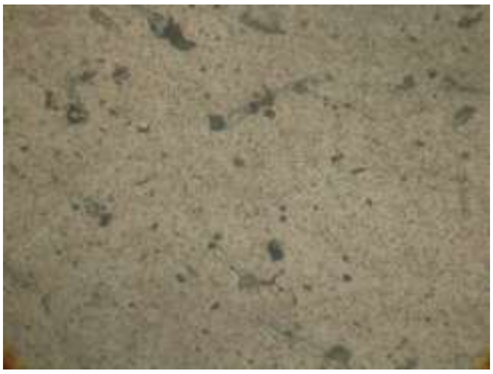
3.3. Microstructure Study

The microstructure of the welded zone is analyzed with the optical microscope.

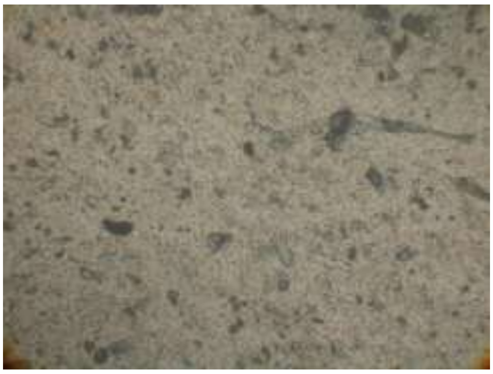
From the micro structure analysis it is found that grains are large and coarse in first sample that is the sample welded with 1200rpm and 35 mm/min travel speed. Among microstructure analysis of all the samples the specimen welded with rotational speeds 1400rpm and 1600rpm shows better mixing and uniform flow of the materials.



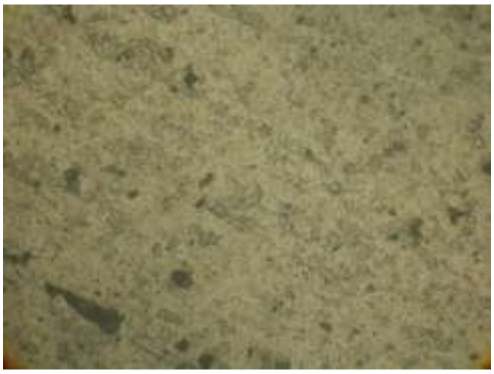
Welded Sample no-1



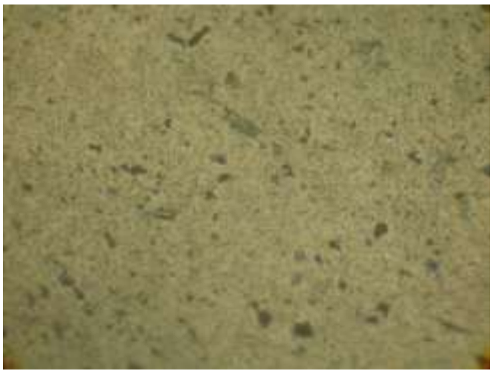
Welded Sample no-2



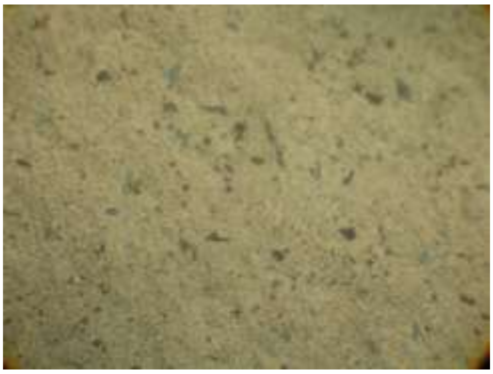
Welded Sample no-3



Welded Sample no-4



Welded Sample no-5



Welded Sample no-6

Fig .6 Microstructure of Weld Zones of Six Samples

4. CONCLUSION

A welding tool with a probe of circular shape with thread is designed for friction stir butt welding of AA1100 and AA6082. The microstructure of weld zone and mechanical properties of the joints were investigated. The following conclusions are drawn:

i) All the samples show the tensile strength and hardness values as the intermittent values of AA1100 and AA6082. Among all the samples, sample three that is the sample welded with 1400 rpm and travel speed of 35 mm/min has the best mechanical properties.
ii) Among microstructure analysis of all the samples the specimen welded with rotational speeds 1400rpm and 1600rpm shows better mixing and uniform flow of the materials.

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