EVALUATION OF BENDING STRENGTH OF FRICTION STIR WELDED AA 6082 ALUMINUM ALLOY BUTT JOINTS

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ABSTRACT

Aluminum alloys have gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio and good corrosion resistance. Modern structural concepts demand reductions in both the weight as well as the cost of the production and fabrication of materials. Compared to the fusion welding processes that are routinely used for joining structural aluminum alloys. Friction stir welding (FSW) process is an emerging solid state joining process was invented in 1991 by TWI, in which the material does not melt and recast. The major advantage in FSW process is that the maximum temperature reached is less than 80% of the melting temperature ie the joint is performed in the solid state and excessive micro structural degradation of the weld zone is avoided. This process uses a non consumable tool to generate frictional heat in the abutting surfaces. The welding parameters such as tool rotational speed, welding speed, axial force, tool pin profile, plunge speed play a major role in deciding the weld strength. This paper focus on bending characteristics for friction stir welded AA6082 Aluminum Alloy in varying the process parameters such as rotational speed, welding speed and plunge speed. Taper cylindrical tool pin profile is used for this investigation in evaluating the bend strength of the FSW AA608 butt joints.

Keywords: Aluminum Alloy, Friction Stir Welding, Bending Strength, Pin Profile & Welding Parameters.

I. INTRODUCTION

Friction stir welding (FSW) is a recent addition to the welding process and it is a solid state joining technique [1], [2]. It was performed as Al and its alloys are now carried out as copper, magnesium and different material combinations. Different pin profiles have been used to weld aluminum alloys [3], [4] and it has been found that the tapered pin gave defect free welds when compared to other profiles. When FSW of steels is performed by straight pin profiles, pin failure takes place before the complete insertion, and moreover, the weld joint could not be formed due to rapid tool wear. The tapered pin has been reported to give better joint strength because of the easy penetration of the pin inside the steel plate with reduced pin failures [5], [6]. The amount of friction heat produced for a better weld depends mainly on the process parameters such as tool rotation speed (Rpm), weld speed (mm/min), plunge depth(mm), plunge speed (mm/min) , plunge force(kN) & tool tilt angle. The schematic diagram of Friction stirs Welding as shown in fig.1

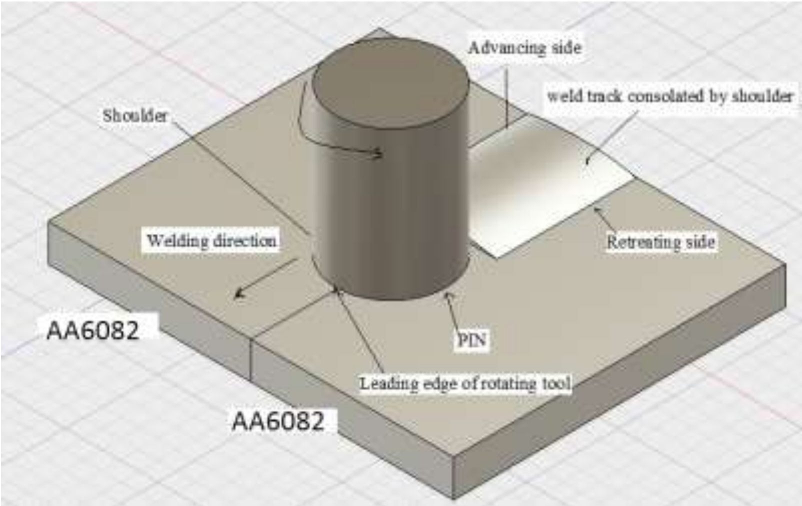

Fig.1. Schematic Diagram of Friction Stir Welding

II. SELECTION OF MATERIAL

Aluminum Alloy AA 6082: Aluminum alloy AA 6082 is a high strength alloy with excellent corrosion Resistance. This alloy is known as structural alloy. In plate form, AA 6082 is the alloy most commonly used for machining. The addition of large amount of manganese controls the grain structure which is turn results in a stronger alloy.

Table1:- Chemical Composition of Aluminum alloy AA 6082 (wt%)

Si	Fe	Cu	Mn	Mg	Ti	Zn	Cr	Others	Aluminum
1.240	0.415	0.041	0.567	1.124	0.006	0.047	0.042	0.054	Balance

Table2:- Mechanical Properties of Aluminum alloy AA 6082.

Base material	AA 6082
Density (X 1000 kg/m^3)	2.7
Elastic Modulus (Gpa)	70
Ultimate Tensile Strength (Mpa)	267.453
Yield Strength (MPa)	250
Hardness (VHN)10kgs	82.3
Percentage Elongation	17.56

III. TOOL MANUFACTURING

The FSW Tool is designed for this Research is tool pin profile of cylinder of D/d ratio 3. Out of various Tool materials like tool steel, High speed steel (HSS), high carbon chromium steel, carbon and carbon boron nitride, among which HSS steel is chosen as Tool material because of its high strength, high hot hardness, easy to process, easily available and low cost. The FSW tool is manufactured using CNC Turning centre and wire cut EDM (WEDM) machine. The tools are oil hardened to obtain a hardness of 52 HRC. The tool material properties as given in table (3). The hardening temperature of HSS-M_2 is 1240-1290^{0}C, the quenching medium is oil/air, the tempering temperature is 550-580^{0}C and Brinnel Rockwell hardness is 64-66

Table3: Tool Material Properties

C	Si	MN	Cr	Ni	W	Co	V	Mo
0.75-0.9	0.10-0.35	0.20-0.40	3.57-4.50	-	5.50-6.50	-	1.75-2.00	5.50-6.50

IV. EXPERIMENTAL WORK

The Three factors chosen are varied at two different levels low & high as shown in the table.4.

Table.4.Factors & their levels

	Levels	
Factors	**Low**	**High**
N (Rpm)	1800	2400
V(mm/min)	30	50
P(mm/min)	10	20

Table.5.Factors Arranged According to L8 Orthogonal Array

Experiment Exp.Number	Spindle Speed	Welding Speed	Plunge Speed
L1	1800	30	10
L2	1800	30	20
L3	1800	50	10
L4	1800	50	20
L5	2400	30	10
L6	2400	30	20
L7	2400	50	10

L8	2400	50	20

The friction stir welded joints of AA6082 aluminum alloys were produced at rapid CNC works, Hyderabad using CNC Vertical milling machine. The thickness of both plates were 5mm. The plates were in a butt joint configuration and the welding process was carried out normal to the rolling direction of the plates. The dimensions of the aluminum alloy plates are 150mm x 75mm at two rotational speeds 1800 Rpm & 2400 Rpm, two welding speeds 30mm/min & 50mm/min and two plunge speeds 10mm/min & 20mm/min and tilt angle as 0^0 as constant in this a taper cylindrical tool pin used was machined from HSS M2 tool steel and hardened to 52 HRC. Studies of bending strength of base alloy was carried out and the values are tabulated in table.5 & fig 2.The bend tested specimen size is 150mmx10mmx5mm for base alloys and for welded joints. 8 joints were welded with the above range of parameters to evaluate the bending characteristics. The tool pin profile photo copy, CNC vertical milling machine are presented in fig 3 and Bend testing machine is presented in fig 4.

Table 6. Bending Strength for Base Aluminum Alloy.

Material	**Angle of Bend (Deg)**	**Mandrel Dia (mm)**	**Remarks**	**Bending Strength (Mpa)**
AA6082	180	4T	No cracks or Fissures observed	35.852

Fig 2. Bend tested Base Alloy

Fig 3 a) Tool pin profile

Fig 3 B) CNC Vertical Milling Centres **Fig 4) Bend Testing M/C**

V. RESULTS & DISCUSSIONS

Bending Characteristics of the Welds:

In the FSW Process, three factors contribute to the formation of the joints. The first is the temperature difference in the welding region, which softens the Base Metal(BM) in the Stirred Zone(SZ). The second factor is the stirring of plastic materials in accumulating multi layer plasticized materials behind the tool, by the interaction of rotational & welding speeds & pin profile. The last element is forging of plasticized materials conducted by the tool shoulder. Any inappropriate adjustment of these factors results in defective joints. In this experiment the ratio of shoulder diameter to pin diameter was assumed to be constant and, the only parameter affecting the temperature rise in the welding zone was the welding speed and Rotational speed. Since the temperature increase at the welding speed of 50mm/min was not enough to soften the base material, the materials were not sufficiently plasticized to be stirred and forged easily for the pin profile resulting lesser bending strength. Defect was in the root for all the joints fabricated. This defect is known as the Tunnel hole defect. Though the appearance of the welded surface seems to be good, tunnel defects could be observed at the advancing side and the stirred zone of the weld. The plastized metal under the shoulder cannot flow sufficiently during the welding process due to insufficient heat generation. This problem can be alleviated by optimizing the process parameters, particularly by reducing the welding speed and increasing the rotational speed and the depth of the pin penetration in the BMs. At the welding speed of 30mm/min, rotational speed 2400rpm, with the Taper cylindrical tool the temperature did increase enough, so the BMs adequately soften to go higher bending strength. The hardness profile in these alloys is strongly affected by the precipitate distributions rather than the grain size. So precipitate dissolution and coarsening make the hardness of the SZ become less than the hardness of the BMs. Although the TMAZ undergoes plastic deformation, recrystallization usually does not occur in this zone owing to insufficient deformation strain. Heat Affected Zone (HAZ) experiences a thermal cycle but does not undergo any plastic deformation the predicted peak temperature is between 80 to 140 deg C. Typical bended specimens for face and Root bends are shown in fig. 6(a) & 6(b).

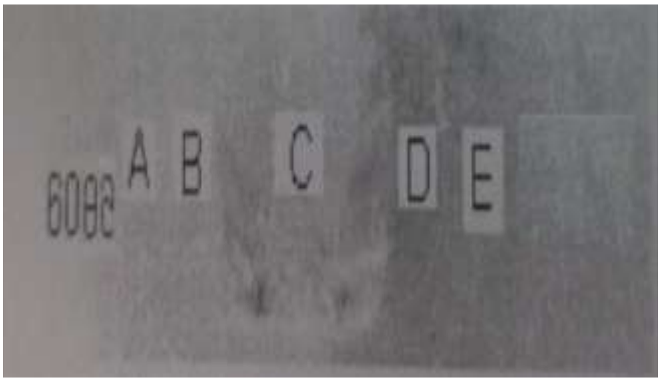

Fig. 5: The cross section of FSW weld (2400rpm,30mm/min); 'A' denotes HAZ at AS,'B' is the TMAZ at AS,'C' is the SZ, 'D' is the TMAZ at RS, 'E' is the HAZ at RS; showing tunnel defect.

Fig 6 a) Typical bended specimens of Face bend

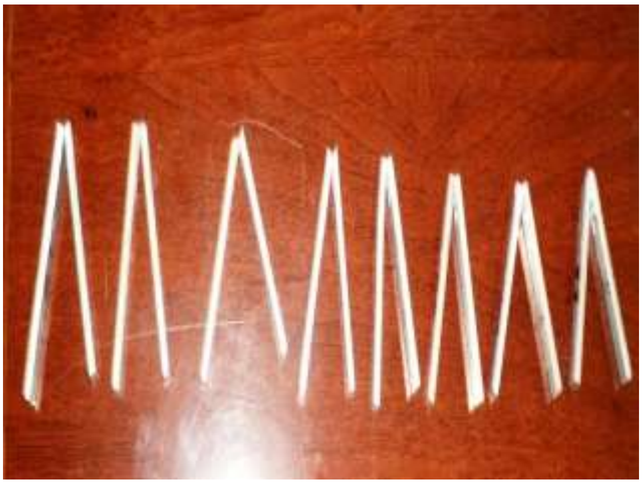

Fig 6 b) Typical bended specimens of Root bend

The experimental bending results for both face & Root bend for the 8 combinations of process parameters are listed in table.6.

Table.6: Bending Strength for Experimental Combinations

Joint Number	Face Bend/ Root Bend	Ultimate load In KN	Disp .at F max in mm	Max Disp.in mm	Bending Strength in N/mm^2	Remarks
L1	Face Bend	1.02	5.8	6.8	18.903	No openings observed
L1	ROOT BEND	0.72	1.4	4.7	13.117	BROKEN INTO TWO HALVES
L2	Face Bend	0.84	3.4	6.2	16.783	Broken In to two halves
L2	ROOT BEND	0.43	4.26	36.82	8.6	BROKEN INTO TWO HALVES
L3	Face Bend	0.6	0.2	4.2	11.945	Broken In to two halves
L3	ROOT BEND	0.17	1.74	23.2	3.4	BROKEN INTO TWO HALVES
L4	Face Bend	0.72	2	3.8	13.001	Broken In to two halves
L4	ROOT BEND	0.22	1.24	51.5	4.4	BROKEN INTO TWO HALVES
L5	Face Bend	1.5	22.7	35.2	29.3562	No openings observed
L5	ROOT BEND	0.04	1.2	2.4	0.8	BROKEN INTO TWO HALVES
L6	Face Bend	1.86	22.7	40.3	37.951	No openings observed
L6	ROOT BEND	0.49	3.93	55	9.8	BROKEN INTO TWO HALVES

L7	Face Bend	0.9	3.5	4.3	17.588	Broken In to two halves
L7	ROOT BEND	0.34	2.71	51.5	6.8	BROKEN INTO TWO HALVES
L8	Face Bend	0.6	0.1	7.2	11.4	Broken In to two halves
L8	ROOT BEND	0.28	2.88	56.5	5.6	BROKEN INTO TWO HALVES

\ At the welding speed of 30 mm/min, rotational speed 2400 Rpm, with the taper cylindrical tool the temp did increases enough, so the BMs adequately soften to go higher Bending strength. Since the temperature range also less than base alloys are not soften with stirring [7]. The materials are not thoroughly mixed during the welding process. If we go for lower welding speed in the range 30mm/min & higher rotational speed 2400 Rpm, we can get the high bending strength for taper cylindrical tool pin profile. The specimens are mostly failing at the HAZ of the advancing side of AA6082 which have the lowest hardness values.

VI. CONCLUSION

This research reveals that there are several defects in the joints fabricated at a welding speed of 50mm/min & rotational speed of 1600 Rpm. At the welding speed of 30mm/min, rotational speed 2400 Rpm, with the taper cylindrical tool the temperature did increase enough, so the base metal adequately soften to go higher bending strength.

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