Effect of Tool Pin Profile and Friction Stir Welding Speed on Tensile & Hardness Properties of Friction Stir Welded Joints of AA6082 & A319 Aluminium Alloy

V. Anand Kumar, N. Govind

Abstract - Fusion welding of aluminium alloys results in solidification cracking, porosity etc. which affects the properties of the weldment. FSW which is broadly used in welding of aluminium alloys. It overcomes the defects of fusion welding process in improving the properties of the joints. The current paper focus on studying the tensile properties of the disparate FSW of aluminium alloys AA6082 and A319 .Three dissimilar tool profiles (square, hexagonal and cylindrical) with three welding speeds (25, 30, 35 mm/min) and three tool rotational speeds (800, 1000 and 1300 rpm) have been used in studying the joint properties of the weld. Higher tensile strength was obtained for the parameters of square tool profile, 30 mm/min and 1300 rpm.

Key words: Aluminium alloys, FSW, welding speed, rotational speed, tensile strength, hardness.

I. INTRODUCTION

Aluminium alloys are broadly worn in the automobiles, marine and aerospace wherever more strength to weight ratio is a concern. But the joining of aluminium alloys by fusion welding always poses a problem of solidification cracking, porosity, intermetallic components etc affects the joint properties of the weld by reducing its strength. Also while joining dissimilar materials, the problems like variation in thermal and mechanical properties have negative impact on the potency of the disparate joints. FSW procedure is a solid phase welding method and it posses more advantage over fusion welding due to lower processing temperature and grain refinement which results in the decrease of weld defects, less distortion and less solidification cracking due to brittleness. FSW does not involve any flux or external material and the process is called environmental friendly welding process or green energy process. Also FSW has the advantage over fusion welding with its ability to weld unlike materials like Al-Cu, Al-Mg, and Al-steel has placed its use a prominent one in the ship building, aircraft panels, train bodies,

automobile parts etc [2]. FSW method involves a non consumable revolving tool having a cylindrical carrier over which protrudes a pin of suitable profile.

The pin aides in the stirring of the material from the joint interface as it rotate. The rule of thumb is that the head diameter should be three times of the pin diameter. The shoulder aides in transferring the material from one end to the other side and hold the material by the downward axial force. The success of the dissimilar FSW depends upon vigilant conclusion with reference to material position, FSW tool positioning and FSW process parameters varying upon the material to be joined[3],[4]. The FSW welding process parameters are welding speed, axial load, tool rotational speed, and tool profiles. Regarding the positioning of the base metals especially in case of dissimilar FSW, two options were viable.i.e. placing which of the base metal in the advancing side (AS) or retreating side (RS). Advancing side is the side where the tool rotation coincides with the path the translation of the welding tool .Retreating side is the one where the tool rotation motion and translation motion counteracts each other [5]. Lee et.al has reported in their studies on friction stir wielding of AA6061 to A356 aluminium alloy create that the stir zone is subject by the metals sited in the retreating side [6]. In the present investigation, FSW between dissimilar aluminum alloys of AA6082 and A319 were conducted using three tool pin profiles, three welding speeds and three tool rotational speeds.

II. EXPERIMENTAL PROCEDURE

The base metal, A319 cast aluminium alloy was procured as ingot from the supplier and cut into required dimensions for welding as 100x50x6 mm plates using milling machine and power hacksaw tool. Another base metal AA6082-T6, wrought aluminium alloy was obtained as rolled plates. Three unlike tools varying pin profiles as round, hexagon and square made from high speed steel without draft were used for FSW process (see Fig .2)

Fig.1 Experimental Setup

Effect of Tool Pin Profile and Friction Stir Welding Speed on Tensile & Hardness Properties of Friction Stir Welded Joints of AA6082 & A319 Aluminium Alloy
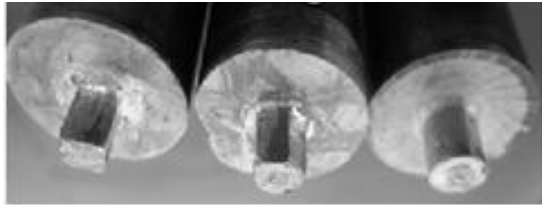

Figure.2 FSW tool pin profiles

TABLE I : COMPOSITION OF AA6063-T6 AND A319

Composition	Base Metals	
	AA6082	A319
Si	1.1	6
Cu	0.1	3.4
Mg	0.9	0.1
Mn	0.6	0.5
Ti	0.1	0.2
Zn	0.2	0.1
Fe	0.5	0.1
Al	Bal	Bal

Each tool shoulder diameter and pin diameter used is 18 mm and 3mm respectively. The tool pin length was maintained at 5.6 mm in length. The FSW tools were machined using CNC turning centre. To get the precise profile of the pin a wire cut EDM was used. Further the tool hardness is improved to 65 HRc by hardening process. FSW was conducted on an FSW machine supplied by R.V. Machine Tools, Coimbatore, India (see Fig. 1). It is a modified vertical end milling machine with a horizontal table which can move in the X and Y axes. It also has vertical guide ways for axial loading. The table has special provisions for mechanical fixture which holds the base material rigidly. The pin was to be found at the interface of the joint line. The process parameters chosen were given in table III. The experimental setup consists of FSW of the different materials which have been recognized using the progression parameters selected.A319 was kept at the advancing side whereas AA6082 was kept in the retreating side.FSW was conducted using three different welding speeds, three different rpm using three different tool profiles. A total of nine experiments were conducted. The joints when inspected where free for any exterior welding defects.

TABLE II : FSW PROCESS PARAMETERS

Process Parameters	Values
Tool Pin Profile	Round, Hexagon, Square
Welding Speed (mm/min)	25,30,35
Tool Rotation Speed (rpm)	800,1000,1300

TABLE.III : MECHANICAL PROPERTIES OF AA6082 AND A319 ALUMINIUM ALLOYS

MECHANICAL PROPERTIES	BASE METALS	
	AA6082	A319
UTS(MPA)	248	186
YS(MPA)	219	124
%ELONGATION	2.8	12
HARDNESS	90	85

The welded plates were then cut for tensile tests as per (ASTM E8-M04).From each specimen two tensile tests were primed for mechanical testing. Tensile test were done on the universal testing machine (Make FIE Bluestar, India; Model: UNITEK- 94100) where the specimen was weighed down at 100 KN/min. Vickers microhardness test was conducted at various locations of the FSW zones for all the nine specimens using Vickers microhardness tester of Model: MMT-X7 Matzusawa. A load of 0.5 kg was applied for 10s for the microhardness test.

Figure.3. FSW Tensile Specimens

III.RESULTS AND DISCUSSION

III.1Tensile Strength

The tensile results shows that the highest failures were originate to happening at the advancing side of A319 (see Fig. 3). Among the tool profiles square profile shows the highest tensile strength for all the other working functions (see Fig. 4). The tensile strength for round profile was calculated to be lowest. Hexagonal tool pin profile shows the moderate value of the tensile strength. The welding speed at 25 mm/min yields higher tensile results and the welding speed of 35mm/min yields the smallest. In case of tool rotational speed, 1300 rpm gives the maximum tensile strength. In case of unlike welding, when there is a variation in tensile and hardness properties, the malfunction of the tensile specimen will at all times take place at the lighter of the two metals.

The ultimate tensile strength of support metal A319 is of 180 MPa while AA6082-T6 was of 255 MPa. Also the presence of precast defects in A319 also acting a prominent role in disturbing the tensile strength of the specimen. Higher welding speed outcome in inadequate heat supply and faster cooling rate will affect the plastic flow rate of the material during stirring which results as kissing defect. But the lesser welding speed consequences in more heat supply per unit length distressing the perpendicular motion of the material [7]. On the contrary Ericsson and Sandstorm has reported that lower welding speed is further preferable than higher welding speed as the creation of the weld will be effective with proper metal flow [8]. Enhance in tool rotational speed fallout in pin hole with piping defect with the increase in turbulence of the plasticized material with high tool rotation speed [9]. Lower tool rotational speeds results in tunnel deficiency due to inadequate heat production during friction and thus insufficient metal transfer. Therefore for the present problem the progression array which satisfy the welding circumstances of the wrought (AA6082-T6) and cast (A319) aluminium alloys be preferred.
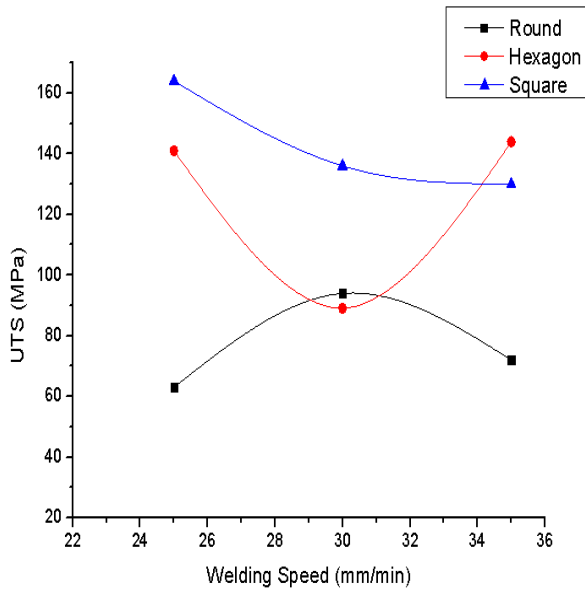
Figure.5. Effect of welding speed on tool pin profiles

The result of tool pin profile in determining the tensile strength can be seen from the high difference between round pin profile and square pin profile. The joint effectiveness for the weldment is of 92 % of tensile strength of A319 alloy and 72% of the tensile strength of AA6082 - T6 alloy.

III.2 Microhardness Results

Microhardness values were measured the length of the mid-thickness of the welded joint (see Fig. 6).The rigidity distribution of the SZ is found to be superior than that of the base metals. In the absences of the external defects, the tensile properties always follow the lowest hardness distribution. The fracture zones are identified in Table IV.Failure has in most place on the minimum hardness zone at the advancing side of A319 side. Fracture locations can be seen to be distributed at the Weld zone, TMAZ and HAZ of A319 side [10]. Ren et al. has measured the hardness across the thickness for the AA6061 alloy and correlated that fracture path with the lowest hardness distribution [11].

TABLE.IV: LHZ DISTRIBUTION OF WELD SPECIMENS

Microhardness Distribution From Weld Center 0 (mm)

| S.no	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
1	140	142	140	136	101	88	99	68	70	77	**40**	53	51	47	43	47	49	58	52	46	51
2	89	88	90	80	69	87	72	90	137	91	96	65	60	54	50	**45**	56	51	51	50	62
3	118	77	91	99	88	87	86	100	95	102	104	139	104	56	**45**	69	47	57	51	49	48
4	157	137	109	83	115	129	92	96	82	96	77	83	99	**47**	48	54	51	51	50	57	53
5	104	118	119	119	123	117	119	123	111	155	161	143	147	102	89	**54**	69	58	58	54	51
6	93	100	142	105	103	134	129	129	135	134	143	131	**55**	59	79	62	52	79	56	53	56
7	68	66	60	58	62	66	54	56	62	66	57	**49**	51	62	61	67	61	61	58	57	59
8	128	141	125	134	132	150	139	140	150	154	128	124	111	102	108	**66**	69	71	71	67	67
9	75	78	75	78	77	77	71	73	72	72	71	69	**64**	71	72	74	67	69	69	67	68
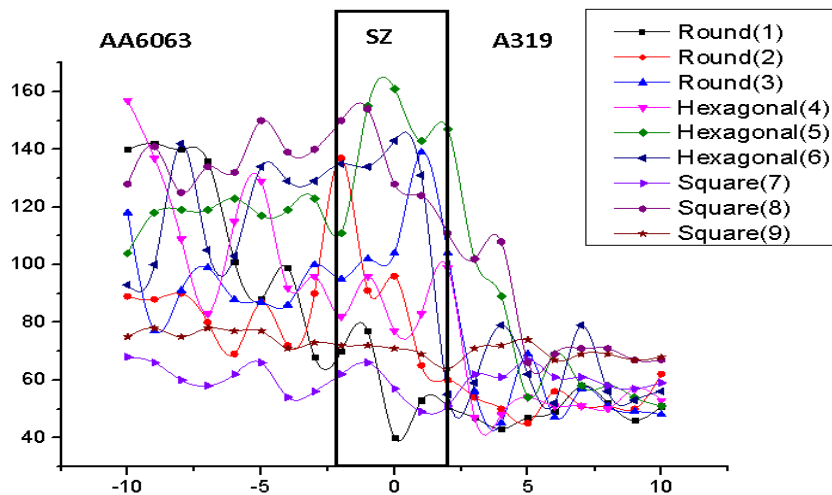
Fig.6.LHZ Distribution for Various Tool Pin Profiles

In the current study the hardness distribution has been taken for all the specimens by measuring the Vickers Microhardness beside the cross section of the FSW joint for every 0.5mm interval. The fracture locations were found to be reliable with the lower hardness sharing profile. All the specimens failed at the advancing side.

IV. CONCLUSIONS

In the current investigation the combined properties of the unalike fsw on cast aluminium alloy A319 to wrought aluminium alloyAA6082 were calculated by changing the working parameters of tool rotational speed, tool pin profile, and welding speed. Of the three dissimilar pin profiles, square tool pin profile shows highest tensile strength of 168 MPa at the welding speed of 25mm/min and at the tool rotational speed of 1300 rpm. Microhardness distribution profile revealed that the fracture points of the joints were in coherent with the lowest hardness values. All the specimens futile at the advancing side of the A319 wherever a lower hardness value was measured.

Retrieval Number: L25401081219/2019©BEIESP
DOI:10.35940/ijitee.L2540.1081219
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

2705

REFERENCES

1. R. Palanivel & P . Koshy Mathews ," The tensile behavior of friction-stir welded dissimilar aluminum alloys", Materials and Technology, Vol. , 2011, pp. 623–626.
2. Muna K.Abbass and Hassan H. Abd ," A Comparison Study of Mechanical Properties between Friction StirWelding and TIG Welded Joints of Aluminum Alloy (Al 6061-T6)" , Eng. &Tech. Journal, vol. Part (A), no.14, 2013, pp.2701 -2715 , University of Technology/ Baghdad.
3. G. Sundar raju and K. Sivakumar," Effect of Process Parameters on Friction Stir Welding of Dissimilar AA1100 and AA6082 alloys", Journal of Advanced Engineering Research, vol. 4, Issue 1, 2017, pp.36-41.
4. N. T. Kumbhar & K. Bhanumurthy ,"Friction Stir Welding of Al 5052 with Al 6061 Alloys ", Hindawi Publishing Corporation, Journal of Metallurgy , vol. , 2012, pp. 1-7.
5. R. Nandan, T. DebRoy and H. K. D. H. Bhadeshia, Recent advances in friction stir welding-Process, *weldment structure and properties, Progress Mater Sci.*, 53 (2008) 980–1023.
6. Lee W B, Yeon Y M and Jung S B,The Joint Properties of Dissimilar Formed Al Alloys by Friction Stir Welding According to The Fixed Location of the Materials,Scripta Materialia, 49 (2003) 423.
7. M. Ghosh, K. Kumar, S. V. Kailas and A. K. Ray, Optimization of friction stir welding parameters for dissimilar aluminum alloys, *Mater. and Design*, 31 (2010) 3033–3037.
8. Ericsson.M, Sandstrom.R, Influence of Welding Speed on the Fatigue of Friction stir Welds, and Comparison with MIG and TIG,*International Journal of Fatigue*,25 2003:pp1399-1409.
9. B. T. Gibson, D. H. Lammlein, T. J. Prater, W. R. Longhurst, C. D. Cox, M. C. Ballun, K. J. Dharmaraj, G. E. Cook and A. M. Strauss, Friction stir welding: Process, automation, and control, *J. Manuf. Process*, 16 (2014) 56–73.
10. Y.S.Sato and Kokawa,Distribution of Tensile Property and Microstructure in Friction Stir Weld of 6063 Aluminum, *Metal Mater Trans.A*, 2001, 32, 3023.
11. L. Giraud, H. Robe, C. Claudin, C. Desrayaud, P. Bocher and E. Feulvarch, Investigation into the dissimilar friction stir welding of AA7020-T651 and AA6060-T6, *J. Mater Process Technol.*, 235 (2016) 220–230.

AUTHORS PROFILE

V.Anand Kumar completed his graduation in KLCE college of engineering and Masters fromAU in Machine Design, Pursuing Ph.D in ANU, He Is a member in various renowed societies like ASME, CMSI, ISTE, IAENG.

Dr.N.Govind completed his graduation from ANU and masters from AU , Presently he is working as Associate professor in RVR &JC college of engineering