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Influence Of Weld Parameters On Mechanical Properties Of Dissimilar Friction Stir Welded Al Alloy Flat Plates

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Abstract

Friction-stir welding (FSW) is a solid-state joining process and used to join light alloy metals having various industrial applications in aerospace, automotive and ship building, etc. FSW can be used successfully to weld most of Al alloys considering that superficial oxide generation is not deterrent for the process and no particular cleaning operations are needed before welding. In the present study dissimilar aluminium alloys AA 6262-T6 and AA 7075-T6 were Friction Stir welded by varying the process parameters Tool rotational speed, weld speed and axial force considering cylindrical tool pin profile. The mechanical properties (hardness and tensile strength) of the Dissimilar Friction Stir welded (DFSW) specimens were evaluated and compared with that of base materials.

Keywords: FSW, Dissimilar aluminium alloys, Mechanical properties.

1. Introduction

The remarkable up gradation of friction welding namely Friction Stir Welding (FSW) was invented in 1991 at The Welding Institute (TWI) [1]. The process starts by placing the plates to be welded in butt position and clamping them to a backing plate so that the plates do not fly away during the welding process. A rotating wear resistant tool is plunged at the interface of the plates to a predetermined depth and moves along the joint by applying vertical downward force to form the weld.[2].

Heat treatable wrought aluminium-magnesium-silicon alloy AA6262 is of medium strength and possess good welding characteristics over the high strength aluminium alloys while aluminium-zinc-magnesium alloy AA7075 [3] is of high strength and possess low welding characteristics. Both of these materials AA6262 and AA7075 are extensively employed in aircraft, automobiles and marine applications such as couplings, hinge pins, camera parts, screw machine products, [4,5,6].

When alloys are friction stir welded, phase transformations that occur during the cooling of the weld are of solid-state type. Due to the absence of parent metal melting, the FSW process is more advantageous over fusion welding. The material flow behavior is predominantly influenced by the FSW tool profiles, FSW tool dimensions and FSW process parameters namely tool rotational speed, weld speed and axial force [7-10].

In the present study, the dissimilar Aluminum alloys AA 6262-T6 and AA 7075-T6 of 6mm thick plates were joined through FSW with a square tool pin profile made of H13 tool steel considering tool rotational speed (1000rpm, 1200 rpm and 1400rpm), weld speed (0.4 mm/sec, 0.6 mm/sec and 0.8 mm/sec) and axial force (8kN, 9kN and 10kN) as the process parameters.

2. Experimentation Results

The considered the dissimilar Aluminum alloys AA 6262-T6 and AA 7075-T6 were butt welded using a H13 tool steel tool of cylindrical tool pin profile [11] with 18 mm shoulder diameter and 6mm pin diameter. AA 6262 was kept on the advancing side (AS) of the tool and AA 7075 was kept on retreating side (RS).

The Chemical compositions and mechanical properties at room temperature of the base metals (BMs) AA 6262 and AA 7075 are presented in Table 1 and Table 2 respectively. The initial joint configuration of the weld was obtained using a special fixture and mechanical clamps. The direction of welding was normal to the rolling direction. An indigenously designed and developed FSW machine

(15 HP; 3000 RPM; 25 kN) was used to fabricate the joints. The welding parameters considered and tool geometry are presented in Table 3.

Hardness testing was carried out using Vickers pyramid hardness testing machine (Leco make and LV 700) with a load of 5 kg. Hardness survey along the transverse direction of the weld was conducted with hardness measurements at regular intervals of 2 mm from the centerline of the weld on both sides of the weld.

The welded joints were sliced using power hacksaw and then machined to the required dimensions on EDM to prepare tensile specimens. American Society for Testing of Materials guidelines (ASTM E8) was followed for preparing the test specimens. Tensile test was carried out on 10 Tonne, computer controlled Universal Testing Machine. All the specimens are mechanically polished before tests to eliminate the surface irregularities [12,13]. The specimen finally fails after necking. The ultimate tensile strength was evaluated.

Table 1: Chemical Composition of AA6262-T6 and AA7075-T6

Material	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
AA6262	0.65	0.313	0.215	0.076	0.90	0.091	0.065	0.081	97.597
AA7075	0.104	0.254	1.56	0.063	2.32	5.95	0.191	0.055	84.496

Table 2: Mechanical properties of base metals

Base Metals	Tensile Strength (MPa)	Yield Strength (MPa)	%Elongation	Vicker's micro Hardness Hv)
AA6262-T6	346	319	22.8	108
AA7075-T6	589	471	20.8	195

Table 3: FSW Process Parameters and Tool Dimensions

Sl.No	Process parameters	Values
1	Tool rotational speed (rpm)	1000,1200,1400
2	Weld speed (mm/sec)	0.4,0.6,0.8
3	Axial force (kN)	8,9,10
4	D/d ratio of tool	3.0
5	Pin length(mm)	5.8
6	Tool shoulder diameter(mm)	18
7	Pin diameter (mm)	6

3. Results and Discussions

3.1. Effect of process parameters on hardness

Table 4 shows the Vickers micro hardness values in the stir zone (SZ) of all the dissimilar FSW specimens. The hardness profiles of the dissimilar friction stir welded specimens based on the lowest and highest SZ hardness is presented in Fig. 1. The highest and lowest SZ hardness are obtained with the welds fabricated with 1200 rpm, 0.6 mm/sec, 9kN and with 1000 rpm, 0.8 mm/sec and 8kN respectively.

Effect of Tool Rotational Speed

Fig 2. shows the bar charts depicting the effect of tool rotational speed on SZ hardness of friction stir welded specimens. It is observed that at constant1000 rpm tool rotational speed, the highest and lowest SZ hardness are obtained for 0.6 mm/sec, 9kN and 0.8 mm/sec 8kN (Fig 2(a)) on the other hand same trend is observed for constant 1200 rpm tool rotational speed(Fig 2(b)), and constant 1400 rpm tool rotational speeds(Fig 2(c)).

From the Fig 2, it is also evident that for a particular weld speed and axial force, as the tool rotational speed increases from 1000rpm to 1400 rpm, the SZ hardness has increased first and then decreased showing that the tool rotational speed has significant influence on hardness of the dissimilar friction stir welded joints. Of the total joints, the joint fabricated with 1200rpm tool rotational speed showed higher SZ hardness compared with the other joints.

Table: 4. Tensile properties of the friction stir welded specimens from tensile test

Tool Rotational Speed(rpm)	Weld Speed (mm/sec)	Axial Force (kN)	VHN	UTS (MPa)	YS (MPa)	%E (%)	Failure Position
1000	0.4	8	95.61	218.44	174.98	6.19	SZ
		9	99.50	221.29	179.31	9.32	HAZ of 6262
		10	98.37	219.63	176.09	7.83	SZ
	0.6	8	96.14	221.94	178.25	6.35	SZ
		9	99.05	229.44	187.01	9.65	HAZ of 6262
		10	98.97	223.37	182.48	8.58	SZ
	0.8	8	93.78	209.95	168.57	5.63	SZ
		9	96.81	215.83	178.49	7.91	SZ
		10	95.12	211.75	175.79	7.54	SZ
1200	0.4	8	108.60	225.75	184.57	7.57	SZ
		9	115.20	228.01	192.98	10.86	HAZ of 6262
		10	112.84	226.52	188.06	8.79	SZ
	0.6	8	110.40	229.86	192.03	8.24	SZ
		9	117.35	238.82	202.05	11.26	HAZ of 6262
		10	114.70	232.01	196.63	10.06	HAZ of 6262
	0.8	8	107.93	218.14	182.34	6.71	SZ
		9	114.57	224.55	190.27	9.05	HAZ of 6262
		10	111.07	221.95	187.77	8.48	SZ
1400	0.4	8	101.57	221.69	181.55	6.58	SZ
		9	111.90	225.86	189.20	9.81	HAZ of 6262
		10	109.40	223.40	180.86	7.95	SZ
	0.6	8	106.95	227.95	183.32	6.58	SZ
		9	113.72	236.36	193.01	9.93	HAZ of 6262
		10	111.18	229.51	186.92	8.69	SZ
	0.8	8	105.80	215.02	174.98	5.79	SZ
		9	110.80	221.36	182.42	8.08	SZ
		10	108.67	218.87	178.86	7.61	SZ

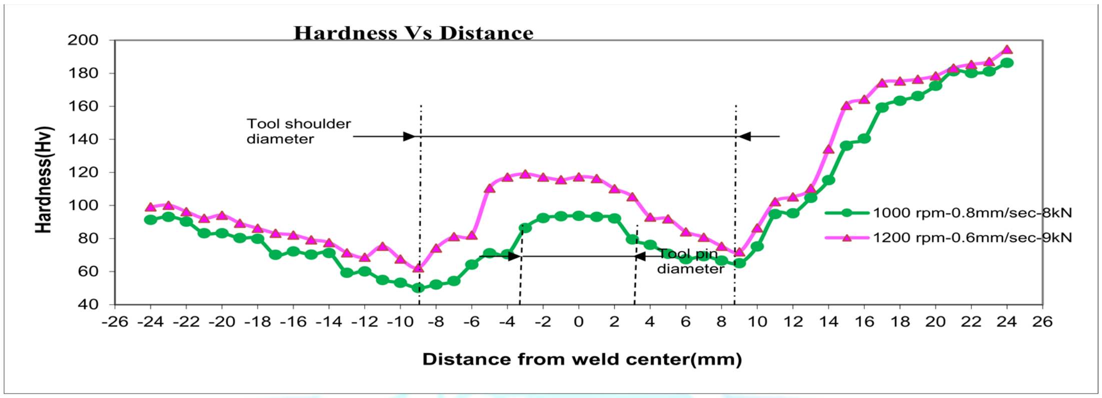
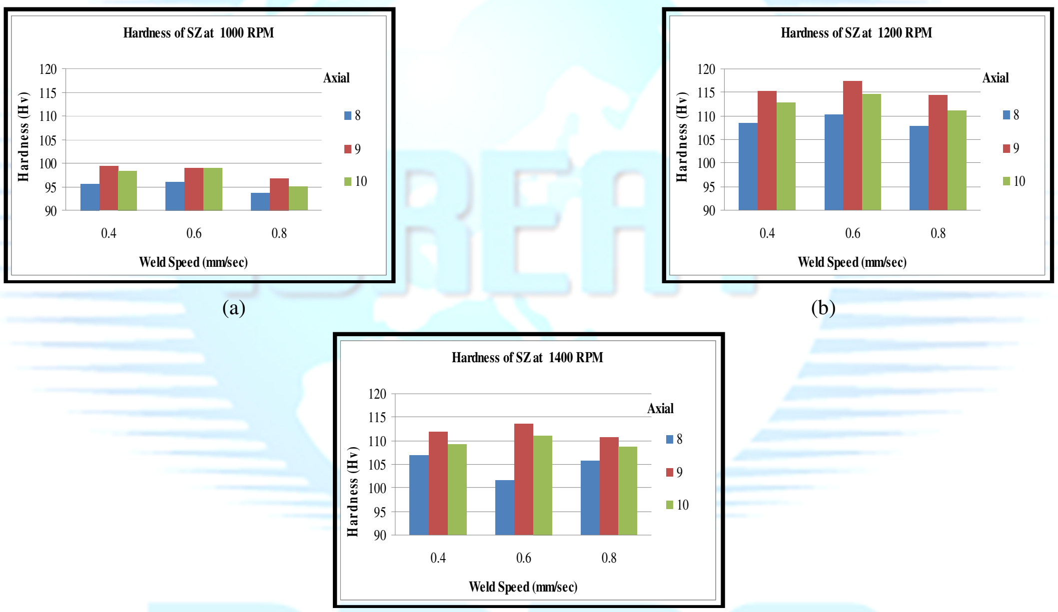


Fig. 1 Hardness profiles of FSWed specimens with process param-eters1200rpm, 0.6mm/sec, 9kN and 1000rpm, 0.8 mm/sec, 8kN.

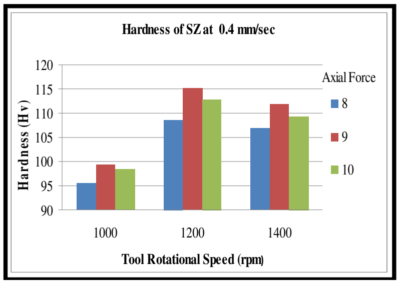


(c)

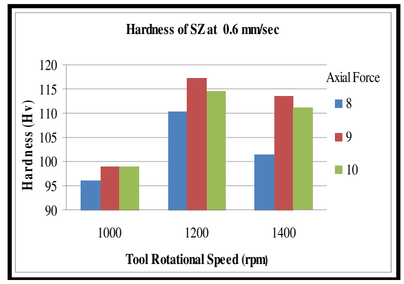
Fig. 2 Bar chart showing the SZ hardness values of the FSWed specimens for three tool rotational speeds (a) 1000rpm (b) 1200rpm (c) 1400rpm

Effect of Weld Speed

Fig. 3 shows the effect of weld speed on the SZ hardness of dissimilar friction stir welded specimens. It is also evident that for a particular tool rotational speed and axial force, as the weld speed increases from 0.4 mm/sec to 0.8 mm/sec, the SZ hardness has increased first and then decreased showing that the weld speed also influence the SZ hardness of the dissimilar friction stir welded joints. Of the total joints, the joints fabricated with a weld speed of 0.6mm/sec showed higher SZ hardness compared with the other joints.



(a)



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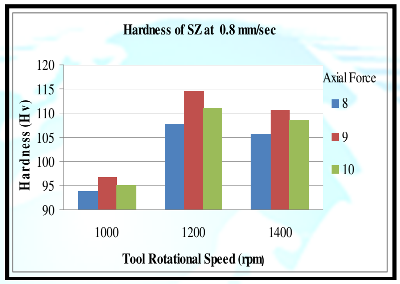


(c)

Fig. 3 Bar chart showing the SZ hardness values of the dissimilar friction stir welded specimens at weld speeds (a)0.4 mm/sec (b) 0.6 mm/sec (c) 0.8 mm/sec

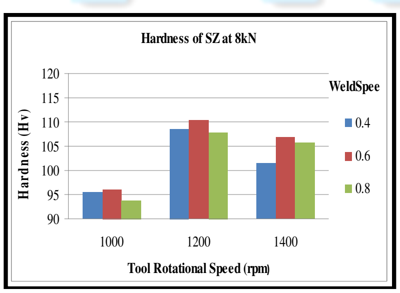
Effect of Axial Force

Fig. 4 shows the effect of axial force on the SZ hardness of dissimilar friction stir welded specimens. It is clear that for a particular tool rotational speed and weld speed, as the axial force increases from 8kN to 9kN, the SZ hardness has increased first and then decreased. Of the total joints, the joint fabricated with an axial force of 9kN showed higher SZ hardness compared with the other joints.

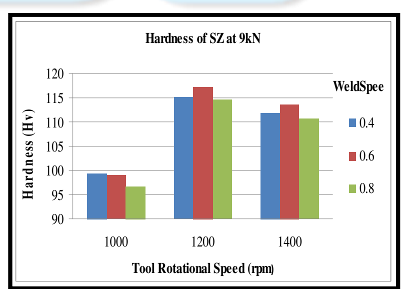
3.2. Effect on Tensile Properties

Effect of Tool Rotational Speed

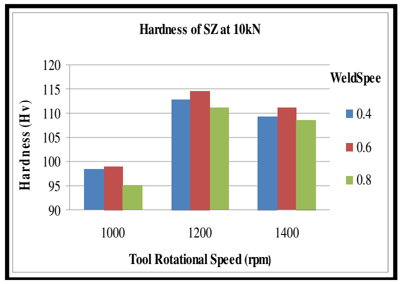
The Table 4 shows that the tool rotational speed has significant influence on tensile properties (UTS, YS and %E) of the dissimilar friction stir welded joints. At a particular weld speed and axial force, as the tool rotational speed increases, the tensile properties of the dissimilar friction stir welded joints has also increased first and then decreased. Of the total joints, the joint fabricated with a tool rotational speed of 1200 rpm showed higher tensile properties compared with other joints for which failure has occurred in heat affected region of AA6262. This tensile strength is higher than the tensile strength of AA 6262-T6 but less than that of AA 7075-T6. This may be due to the dissolution or coarsening of precipitates in SZ.



(a)



(b)



(c)

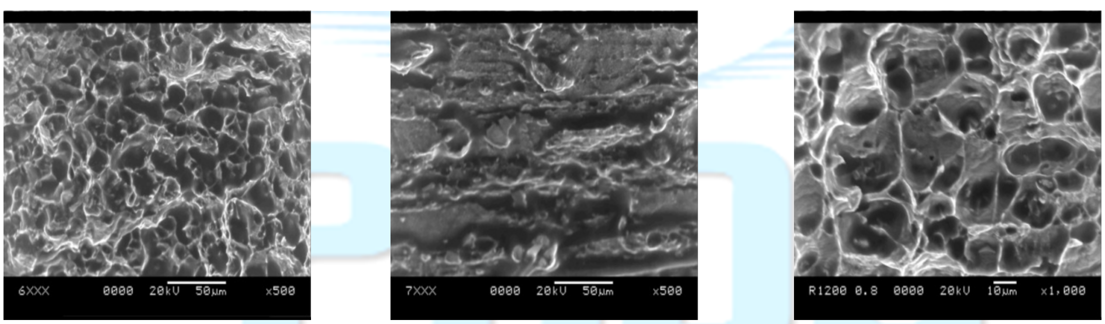
Fig. 4 Bar chart showing the SZ hardness values of the DFSWed specimens for axial forces (a)8 kN (b) 9 kN (c) 10 kN

At constant tool rotational speed and axial force, as the weld speed increases, the tensile properties of the joints also had increased first and then decreased. Of the total joints, the joint fabricated with a weld speed of 0.6mm/sec showed higher tensile properties compared with other joints which is higher than the tensile strength of AA 6262-T6 but less than that of AA 7075-T6. This may be due to the dissolution or coarsening of precipitates in SZ.

For a particular tool rotational speed and weld speed, as the axial force increases, the tensile strength of the joints also increased first and then decreased. Of the total joints, the joints fabricated with an axial force of 9kN showed higher tensile strength compared with other joints and this is less than that of AA 7075-T6 but higher than the tensile strength of AA 6262-T6 which may be due to the dissolution or coarsening of precipitates in SZ.

3.3. Effect of Process Parameters on Tensile Fracture

Fig. 5 shows Scanning Electron Microstructures of the tensile fractures of the base metals AA6262-T6, AA7075-T6 and the dissimilar friction stir welded specimens. Fig. 5(a) shows more dimples signifying more ductility where as in Fig. 5(b) appearance of flakes and less dimples are observed indicating less ductile nature and the Fig. 5(c) depicts the tensile fracture of dissimilar friction stir welded specimen showing more dimples which also portrays ductile nature.



(a) (b) (c)

Fig. 5 SEM pictures of the tensile fractures (a) AA6262-T6 (b) AA7075-T6 and (c) dissimilar friction stir welded specimen at 1200rpm, 0.6mm/sec and 9kN.

4. Conclusions

- The Friction stir welding used successfully to join dissimilar aluminium alloys (AA6262 and AA7075).
- The DFS welds fabricated with1200 rpm tool rotational speed, 0.6 mm/sec weld speed and 9 kN axial force process parameters has exhibited good weld and better mechanical properties compared to all the other process parametric conditions.
- The tensile failure of the specimen fabricated with 1200 rpm, 0.6 mm/sec and 9 kN parameters had depicted that it is also a ductile natured as that of base metal AA 6262.

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