Effect of the welding speed on the friction stir weld of dissimilar Al 6061 to AZ31 Mg by using copper backing bar material.

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Abstract

The friction stir weld ability of fine grained high strength Al 6061 alloy and AZ31 Mg alloy with the plate thickness of 4mm was investigated. Defect free weld obtained with the combination of rotation speed of 545 RPM and lower welding speed 20 mm/min when Mg was put on the advancing side, tool offset 2 mm toward to Mg side and special consideration is that use the copper backing bar material. Metallographic studies showed that grain size in the stir zone is much finer than those base metals. Complex flow pattern was formed which has due to uneven distribution of micro hardness in the stir zone. In this study basic shows that tensile strength of the joint was mainly affected by the thickness of IMCs layer , tensile strength decreased with the increasing the thickness of IMCs layer.

Key words: Friction stir welding, Backing bar, Hardness, tensile strength

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1.Introduction

Due to unique properties including high strength, good formability and low density dissimilar metal welding of Al and Mg alloy can offers better possibilities of flexible design and have wide application in automotive, aircraft and shipping industries due to improved fuel economy and reducing environmental pollutions. Fusion welding is not applicable to produce sound hybrid joint of Al-Mg alloy due to formation of massive brittle intermetallic compounds (IMCs) and micro defects (cracks and voids) in the weld. With friction stir welding (solid state welding process) due to relatively low processing temperature and distribution of IMCs is dispersed under combined action of high strain rate and severe plastic deformation during welding high quality joint of Al-Mg alloys can be obtained.

Among the solid-state joining processes, friction stir (FS) welding is new solid-state joining technique which was investigated by The Welding Institute (TWI) in 1991 and it has joining of dissimilar materials due to the lower processing temperature over conventional fusion welding.

For Al/Mg dissimilar FSW, VAHID FIROUZDOR et al [4] investigated the Mg on the advancing side with tool offset toward Mg can provide a better chance for Mg to penetrate dipper in to the stir zone and increase the joint efficiency. Alireza MASOUDIN et al [6] investigated intercalated microstructure was formed and it is due to the uneven micro hardness distribution in the stir zone. SATO et al [11] investigated the dissimilar welding of Al 1050 alloy and AZ31 Mg alloy generated IMCs $Al_{12}Mg_{17}$ to the uneven micro hardness profiles. The present study investigated to understanding mechanical and microstructure properties of FSW between Al 6061 alloy and AZ mg alloy.

2. Experimental Procedure

Sample (4x50x100 mm) of extruded 061Al and AZ31 Mg were used during friction stir welding and chemical composition of Al 6061 and AZ31 Mg alloy are shown in Table 1 and Table 2, respectively.

Before, the welding stainless steel brush scrub to the plate to remove the surface oxide and the plates were cleaned with acetone.

The FSW tool was made from H-13 tool steel and the tool dimension was shown in Table 3. FS welding parameters in the present study are given table 4. It will be noted that the tool pin offset was shifted on Mg alloy side in the present study.

Table 1 Chemical composition of Al 6061

%	Si	Mn	Fe	Ca	Cu	Ni	Ti	Al	Zn	Mg
	0.0080	0.3210	0.0030	0.000	0.0010	0.0020	0.0100	2.5100	.07200	96.4200

Table 2 Chemical composition of AZ31 Mg

%	Cu	Si	Mn	Mg	Ti	Cr	Fe	Zn	Al
	0.1940	0.4920	0.0570	1.0900	0.0210	02200	0.1900	0.2100	97.4900

Table 3 Dimensions of FS welding tool

Shoulder Profile	Concave
Shoulder Diameter	18 mm
Pin Profile	Taper
Pin Diameter	Upper Diameter 7 mm Lower Diameter 6 mm

Pin length	3.8 mm

Table 4 FS welding Conditions

Tool Rotating Speed	545 RPM
Welding Speed	20-50 mm/min
Offset	0 to 2 mm toward Mg side
Angle of tilt	2^0
Backing bar material	Copper

The dimension of the specimen for tensile test is given in Fig 1. The tensile test was carried out room temperature with cross head speed of 0.2 mm/min.

Microstructure analysis was performed on the cross section perpendicular to the welding direction. A solution of 2 ml HF, 3 ml HCL, 5 mm HNO_3, 190 ml distilled water was used as the etchant of the specimen microstructure of weld was observed by optical microscope.

Micro hardness measurements were performed with micro hardness tester using 300 g load and dwelling time 10 s.

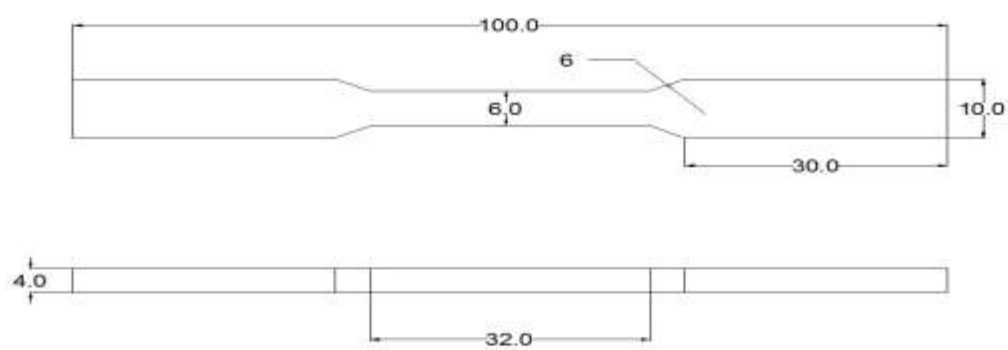


Fig 1 Dimensions of test piece for tensile test.

3. Experimental Result and Discussion

3.1 Friction stir welding of Al 6061 alloy to AZ31 Mg alloy

In the welding condition probe is inserted into the 2 mm off center to mg side with 50 mm/min welding speed has two kinds of defect can be observed from surface one is the surface tearing and another defect is groove like defect at the rotating speed 545 RPM. This defect is due to the short of heat input and consequently the insufficient plastic deformation of materials during Fs welding. A joint without any defect has been obtained at the welding speed of 31.5 mm/min and 20 mm/min and high tensile strength can be observed at low welding speed Fig 2. (Parameter cannot be optimize it's only to understand the effect of the welding speed on it).

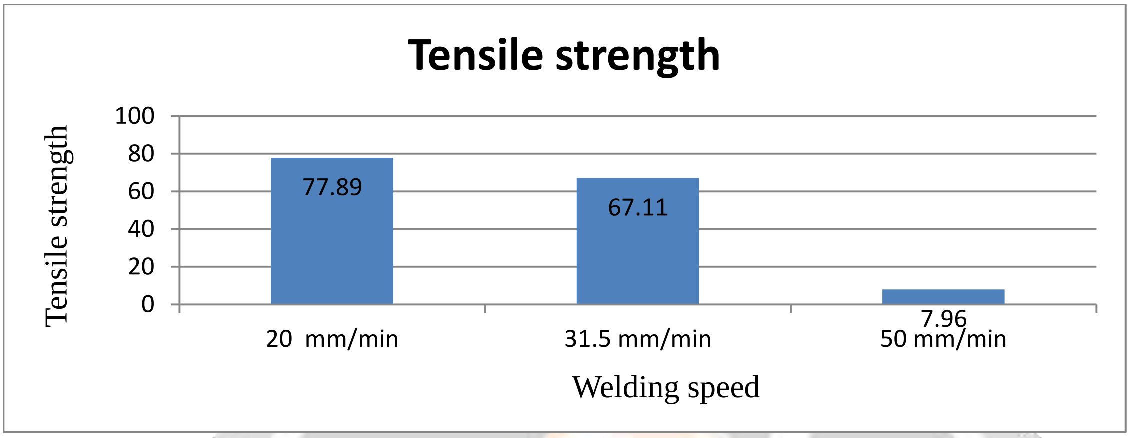


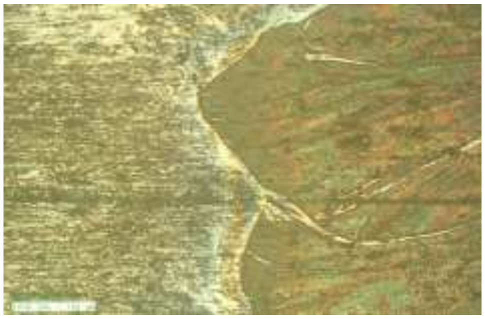
Fig 2 Effect of welding speed on tensile strength

When the welding speed is kept constant at 31.5 mm/min and the tool rotating speed 545 RPM to changing the various offset position and we saw small cavity has partially been observed when the offset position is 1 mm to Mg side. When the offset 0 mm means at the centerline defect become larger and groove type of defect can observe.

3.2 Microstructure of dissimilar weld zones

Microstructure was obtained with rotational speed 545 RPM and travel speed 31.5 mm/min and 20 mm/min with 2 mm offset to Mg side and Mg puts in the advancing side.

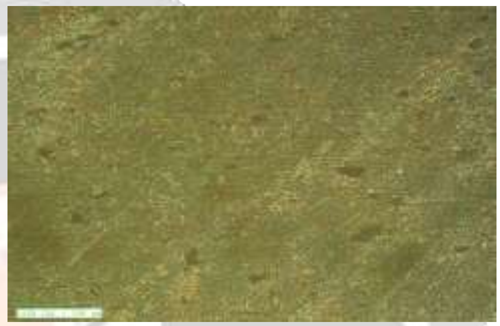
Many light-etching stripes are visible in the stir zone. The microstructure in the stir zone shows layer of AZ31 Mg are carried into the stir zone and very thin layer of intermetallic compound is visible at the interface between AZ31 Mg and 6061 Al. Fig 3 shows the transverse optical micrograph of the weld made 545 RPM , 2 mm offset to Mg side and Mg on the advancing side. The copper backing bar has high heat removal rate due to high thermal conductivities, higher welding speed 50 mm/min has shown higher thickness of intermetallic compound as compared to the lower speed 31.5 or 20 mm/min at the lower welding speed 20mm/min it can penetrate very deeply into stir zone and interlock with 6061 Al because of plasticized flow more difficult to achieve during the welding to the low heat input at the higher welding speed. It suggest a low heat input perhaps too low plasticize Mg and the material flow discontinuous. This observation is show that lower deformability of Mg than Al because of the Mg has hexagonal close-packed structure so the Mg has less slip planes available for deformation than Al which has fcc structure.



a)

b)

c)



d)

e)

f)

Fig 3 Microstructure photos a) nugget zone at 20 mm/min, b) Nugget zone of 31.5 mm/min, c) HAZ of Al side in 20 mm/min, d) HAZ of Mg side in 20 mm/min e) Parent metal of Al, f) Parent metal of Mg.(all photos capture 200X).

3.3 Micro hardness testing results

Fig 4 shows Vickers micro hardness distribution along the cross-section of the plate at 545 RPM of rotational speed and 20 mm/min welding speed with copper backing bar material. The maximum hardness 181 HV was measured in the stir zone and uneven hardness distribution was shown in the stir zone.

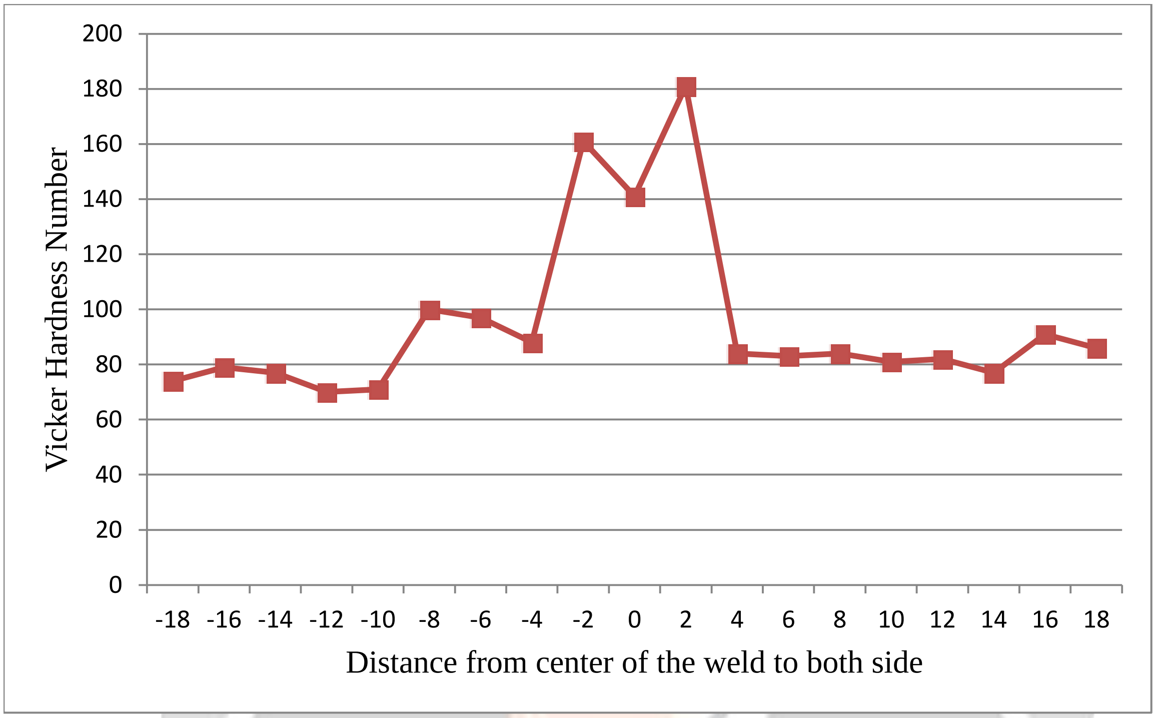


Fig 4 Micro-hardness variations at different rotational speeds

3.4 Tensile testing

The tensile properties of the base material and the welded specimen are listed in Table 5. The welded specimen failed at the TMAZ on the advancing side (magnesium side).

Table 5 Tensile properties of base metals and welded specimen

Specimen	Ultimate tensile strength (MPa)
6061 Al	320.25
AZ31 Mg	192.662
Al-Al similar weld	214.69
Mg-Mg similar weld	86.16
Al-Mg weld	77.89

Conclusions

- Copper backing bar material has defect-free weld between 6061Al and AZ31 Mg alloy was obtained using friction stir welding with a rotation speed 545 RPM and travel speed 20 mm/min.

- Tensile strength of the welded specimen was about 40% of the AZ31 mg alloy and it was near about the similar Mg-Mg weld joint strength.
- Micro hardness profile has uneven distribution and it has maximum value of the micro hardness value on the stir zone. The fracture located at TMAZ on the advancing side (magnesium side) which has highest hardness value.

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