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Investigation on Friction Stir Welding of Dissimilar Aluminium Alloys AA 6061 T6 & Magnesium Alloy AZ31 using Cetrium Powder

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Abstract: ***Friction Stir Welding (FSW) is the latest innovative and most complex process which is widely applied to the welding of lightweight alloys, such as aluminum and magnesium alloys. In this process which provides the frictional heating and plastic deformation realized at the interaction between a non-consumable welding tool that rotates on the contact surfaces of the work-pieces. The admixture pattern of the stir zone, weld microstructures and mechanical properties of the welds were investigated in the current work through friction stir welding of aluminum alloy 6061T6 and magnesium alloy AZ-31 using cetrium particles. The effects of friction stir welding process parameter such as tool rotational and traverse speeds were also examined.***

Keywords: Friction stir welding, frictional heating, Plastic deformation

1. Introduction

The friction stir welding (FSW) is a new welding technique in the domain of welding. It is a solid state welding process and invented by the welding institute (TWI) of Cambridge, England in 1991 [1].This process is simple, environment friendly, energy efficient and becomes major attraction for an automobile, aircraft, marine and aerospace industries due to the high strength of the FSW joints as near as base metal. It allows considerable weight savings in light weight construction compared to conventional joining technologies. In contrast to conventional joining process, there is no liquid state for the weld pool during FSW, the welding takes place in the solid phase below the melting point of the materials to be joined [2].

Magnesium is the lightest of the structural metals with a density two-thirds that of aluminum and one-quarter that of steel. The ability to join magnesium components effectively to other engineering materials would allow further design flexibility and increased application of this lightweight material. The welding conditions, such as material position, tool offset, rotation rate and traverse speed, significantly influenced the weld properties of Al–Mg dissimilar metal FSW joints. However, a comparison of the results showed that large scatter existed in the proper welding condition, and typically only one or two aspects in the welding conditions were considered [3].

Yan et al. (2004) showed that the highest joint strength was achieved by offsetting the tool position towards the Mg alloy, while placing the Al alloy on the advancing side. It was suggested that if the tool is offset towards the Al side; it will result in lower joint strength since the strength of the AZ31 is higher than that of Al 1060 alloy [4]. During joining of 2mm sheets, Kwon et al. (2005) found that Al 5052 to AZ31 can be welded, by using a tool with a 10 mm shoulder diameter, 4 mm pin diameter and 1.7 mm pin length. They found valley-like defects in the joints using welding parameters including a rotation speed of 800 r/min and travel speed of 300 mm/min, while no defects were observed when the tool rotation speed increased to between 1000 to 1400 r/min [5]. Khodir and Shibayanagi(2007) claimed that the Al alloy should be located on advancing side(AS) to achieve FSW of 2024-T3 Al alloy and AZ31 Mg alloy in receiving side(RS)[6].While Kostka et al. (2009) stated that the sound joint was obtained when Mg alloy was on AS in FSW of AA6064 Al alloy and AZ31 Mg alloy[7]. Firouzdor and Kou, (2010) reported strong influences of rotation rate and traverse speed on the joint strength of Al–Mg welds, with Mg on AS and tool offsetting to Mg, the processing window for rotation and traverse speeds was the widest[8].

Figure 1: Friction stirs welding Process

In this study, dissimilar FSW between AA6061 T6 and AZ31 alloy plates was performed. Then, the influence of the tool rotation speed on surface appearance, microstructure, and tensile properties of the friction-stir-welded plates were experimentally investigated.

2. Experimental Process

2.1 Materials Employed

AZ31 Mg alloy and Al6061 T6 alloy sheets of size 100 ×100 ×5 mm were prepared for the experiments. The chemical composition of the materials is given in the Table1:

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Table 1: Chemical composition of the materials

Alloy	Element % by weight							
	Mg	Al	Zn	Si	Mn	Cr	Fe	O
AZ31	90.2	8.7	0.95	0.0037	0.065	0.003	0.01	0.05
AA6061 T6	2.7	97.5	5.5	0.4	0.3	0.18	0.5	0.02

2.2 Friction Stir Welding Machine

A retrofitted universal milling machine with accessories and dynamometry to look as friction stir welding machine is employed in the current investigation. A 15mm shoulder diameter H13 tool steel with a taper pin is employed as the tool in the processes (Fig.2)

Figure 2: FSW Tool used in the present work

2.3 Process Parameters

In this process three parameters have been chosen to perform the welding. Table.2. shows the parameters and their values.

Table 2: Process Parameters

Parameters	Levels	
	Low	High
Speed (rpm)	900	1120
Feed (m/min)	60	80
Angle (°)	1.5	2

2.4 Powder Employed in the Present Investigation

The Cetrium powder was employed in order to produce surface composite layers and refine the microstructure of the weld joint. The powder type of reinforcements is the most commonly used particles in FSP of magnesium alloys. They range from carbides, borides, and oxides expand cetrium thermodynamically stable in molten Mg alloys and it has relatively good wettability with Mg in comparison to the other reinforcements. The specifications of the used for cetrium powder are shown in Table 3.

Table 3: Properties of Cetrium powder

Molecular Weight	10.811(gm/mol.)
Appearance	Powder
Melting Point	2079 °C
Boiling Point	2550 °C
Density	2.08 g/cm^3
Specific Heat	0.125 Cal/g/K
Thermal Conductivity	27.4 W/(m·K)
Vickers Hardness	50-58 MPa

2.5 Methodology of Joining

AZ31 being the hard metal was placed on the advancing side and AA6061 being the soft metal was placed on the retreating side and the weld was carried out using the required parameters. The cetrium powder is manually filled into the prebuilt groove in the plates and weld was formed with friction stir welding operation. The methodology for experimentation is given in the flow chart (Figure.3)

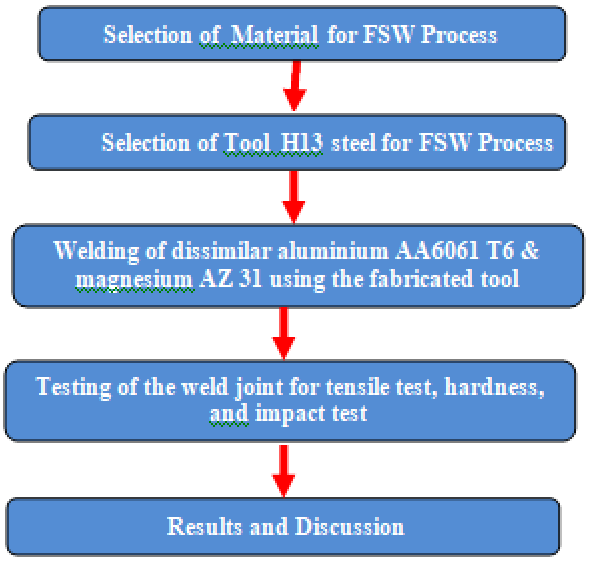


Figure 3: Methodology Flow chart

3. Results and Discussion

3.1 Tensile test

The welded joints are sliced in Figure.4 using power hacksaw and then machined to the required dimensions to prepare tensile specimens according to, American Society for Testing of Materials (ASTM E8M-04). Tensile test has been carried out on 100 KN, electro-mechanical controlled Universal Testing Machine (INSTRON) (Figure.5).

Figure 4: Image showing the sample of tensile test specimen

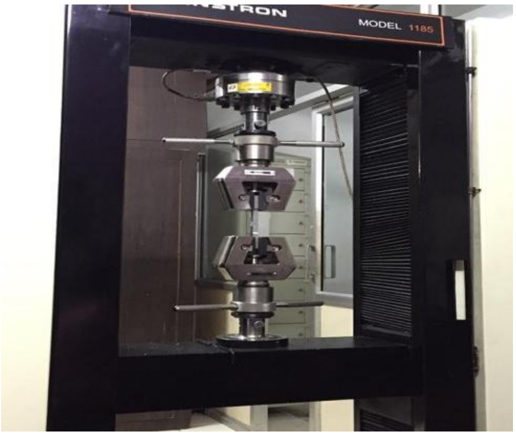


Figure 5: Specimen mounted over the universal testing machine (Instron)

Transverse tensile properties of FSW joints such as ultimate tensile strength, yield Strength and percentage of elongation have been evaluated as shown in Table.4. It can be inferred that the tool shoulder geometry, welding speed and rotational speed are having influence on tensile properties of the FSW joints.

Table 4: Mechanical properties of welded joints with boron

S.No	Tool speed (rpm)	Feed (mm/min)	Tool angle (degree)	Elongation %	Yield stress (N/mm^2)	Ultimate tensile stress (N/mm^2)	Ultimate load (KN)
1	900	60	2	3.22%	59.516	83.737	4.840
2	900	80	1.5	3.18%	59.46	83.40	4.65
3	1120	60	1.5	3.15%	54.26	81.45	4.25
4	1120	80	2	3%	54.18	82.12	4.15

3.2 Rockwell hardness test

The test was conducted on the Rockwell hardness testing machine with a load of 150kg and using a 1/16 inch ball indenter and the values were observed in HRC scale.

Figure 6: Hardness testing machine

The hardness of the specimen are compiled in Table.5.

Table 5: Hardness properties of welded joints with boron

S.No	Tool Speed (rpm)	Feed (mm/min)	Tool angle (degree)	Avg hardness (HRC)
1	900	60	2	57.87
2	900	80	1.5	62.5
3	1120	60	1.5	54.2
4	1120	80	2	61.25

3.3. Impact test

The Impact Test entails striking a notched impact specimen with a swinging weight attached to a swinging pendulum Figure.7. The specimen breaks at its notched cross-section upon impact, and the upward swing of the pendulum is used to determine the amount of energy absorbed (notch toughness) in the process. Energy absorption is directly related to the brittleness of the material.

Figure 7: Impact testing machine

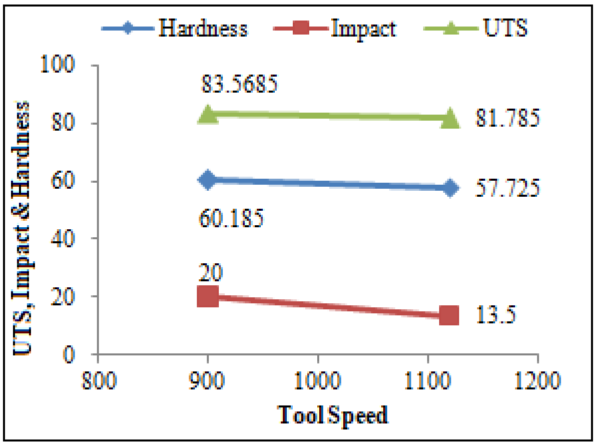
The impact toughness recorded is compiled in Table.6.

Table 6: Impact test results with boron powder

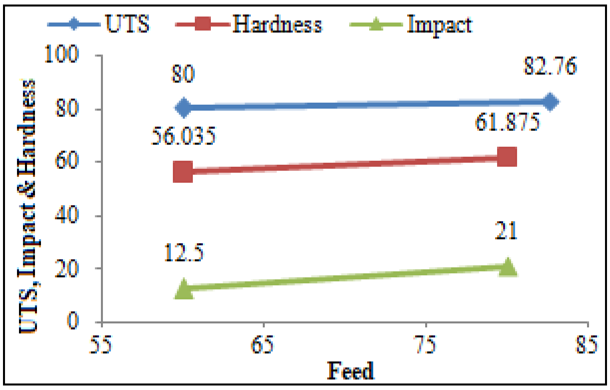
S. No	Tool Speed (rpm)	Feed (mm/min)	Tool angle (degree)	Impact Test (joules)
1	900	60	2	16
2	900	80	1.5	24
3	1120	60	1.5	9
4	1120	80	2	18

3.4 Discussion

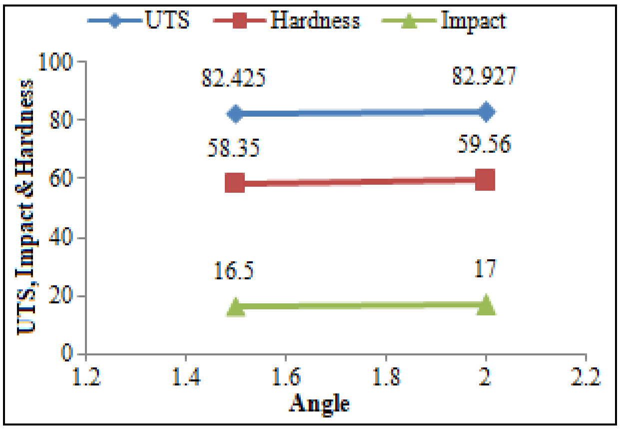
The hardness was best observed in the weld joint made with cetrium powder as cetrium is considered to be the hard material compared to aluminum, introducing it in the weld joint increased the hardness of the weldments. Graphs were plotted between Tool speed, Feed & angle of the tool vs Ultimate stress, Impact strength and Hardness.



Graph 1: Tool Speed vs Ultimate stress, Impact Strength & Hardness



Graph 2: Too Feed vs Ultimate stress, Impact Strength& Hardness



Graph 3: Tool Angle vs Ultimate stress, Impact Strength& Hardness

From the above graphs it has been observed that the ultimate stress, hardness and impact strength are reducing in case of tool speed where as the values are increasing in case of the change in feed and tool angle.

4. Conclusion

In this investigation an attempt has been made to study the effect of cetrium powder in the weld joint of dissimilar aluminum alloys AA6061 T6 and magnesium alloy AZ31. The tensile properties, hardness, impact properties and microstructure have been obtained, it is concluded that

- The tensile strength is higher in the joints made without boron powder.
- By using cetrium powder in the friction stir weld joints only the hardness has been improved and the other properties of the weld joint have reduced.
- The optimum parameters that were observed in the investigation are were at 900RPM, feed rate of 60 mm/min and tool angle 1.5- 2 degrees.
- The maximum tensile stress obtained is 83.737 KN and elongation% of 3.22%.

References

[1] W.M. Thomas, E.D. Nicholas, J.C. Needham, M.G. Murch, P. Templesmith, C.J. Dawes, G.B.Patent Application No.9125978.8 (December 1991).

[2] Hofmann Douglas C, Vecchio Kenneth S. “Thermal history analysis of friction stir processed and submerged friction stir processed aluminium”. Material Science Engineering, 2007, Pages 165–75.

[3] http://www.hitachi.com/rd/hrl/interview/monozukuri_platform-ks.html.

[4] Yan J, Xu Z, Li Z, Li L, Yang S. Microstructure characteristics and performance of dissimilar welds between magnesium alloy and aluminum formed by friction stirring. Scripta Materialia. 2005;53:585-9.

[5] Kwon, Y.J., Shigematsu, I., Saito, N., 2008. Dissimilar friction stir welding betweenmagnesium and aluminum alloys. Mater. Lett. 62, 3827–3829.

[6] Khodir, S.A., Shibayanagi, T., 2007. Dissimilar friction stir welded joints between2024-T3 aluminum alloy and AZ31 magnesium alloy. Mater. Trans. 48,2501–2505.

[7] Kostka, A., Coelho, R.S., Dos Santos, J., Pyzalla, A.R., 2009. Microstructure of friction stir welding of aluminium alloy to magnesium alloy. Scripta Mater. 60, 953–956.

[8] Firouzdor, V., Kou, S., 2010a. Al-to-Mg friction stir welding: effect of material position, travel speed, and rotation speed. Metall. Mater. Trans. A 41, 2914–2935.