International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2015 Vol. 5 (2) April-June, pp.40-44/Rao and Naik

Research Article

EFFECT OF LIQUID NITROGEN ON FRICTION STIR WELDED JOINT OF MAGNESIUM ALLOY AZ31B

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ABSTRACT

An investigation has been carried out on Friction Stir Welded joint of AZ31 Rolled Magnesium alloy to study the effect of Cryogenic temperatures on Mechanical Properties at welded portion. Welded portion was brought to Cryogenic temperatures by pouring Liquid Nitrogen on Welded portion. It consists of comparison between Mechanical Properties of friction stir welded joint of AZ31 rolled Magnesium alloy which were subjected to with and without Cryogenic Temperatures. It was found that when the friction stir welded Portion Subjected to Cryogenic Temperatures the Mechanical properties such as Ultimate Tensile strength, Impact strengths, Hardness and Percentage of Elongation were varied when compared with Mechanical properties of welded joints which were welded at Normal Atmospheric Temperatures.

Keywords: *Friction Stir Welding, AZ31 Magnesium Alloy, Cryogenic Temperatures, Liquid Nitrogen and Mechanical Properties*

INTRODUCTION

Friction Stir Welding is a solid state welding process and has become an important industrial usage (Dawes, 1995). The main principle of FSW inserting a non-consumable rotating tool with a specially designed pin and shoulder into the butting edges of plates or sheets to be joined and traversed along the line of joint (Figure 1). The weld is produced by softening plastic deformation combined with forging action caused by tool rotation. A joint is produced in solid state in this process (Lee *et al.*, 1998; Munitz *et al.*, 2003). The material movement around the pin can be quite complex because of various geometrical features of the tool (Lockyer and Russell, 2001).

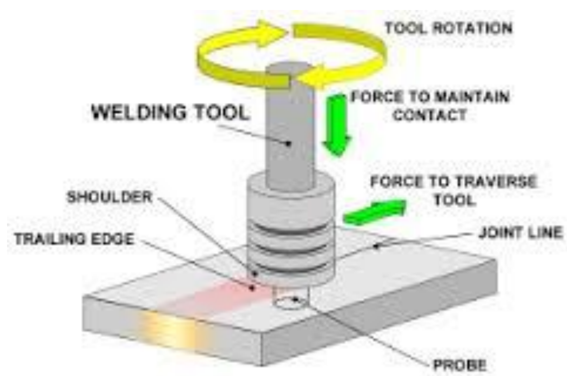

Figure 1: Friction Stir Welding Process

Cooling has some advantages in Friction Stir Welding process. Improvement to joint strength of Friction Stir Welded AA7075-T6 butt joints (Fratini *et al.*, 2010) and pure copper joints (Xue *et al.*, 2011) was achieved by rapid water cooling. Friction Stir Welding of AA2219-T62 aluminum alloy during water cooling was found to increase the strength and ductility of the samples under tensile testing (Xu *et al.*, 2012).
Magnesium is very soft material and has the density as small as 1.7g/cm^3, which is the lowest among all the structured metals or alloys (Callister, 2005) such an outstanding property, makes it highly important for manufacturing light weight structures. As it is soft it is necessary to add either alloy elements or

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reinforcements to make it stronger. Magnesium alloys are unique in having high specific strength and capability to absorb shock and vibration energy (Lee *et al.*, 1998). Rolled Mg alloy AZ31 containing 2.9% Al and 0.72% Zn, has been widely used in engine building industries and aircraft due its low density, high cast ability and good mechanical properties.

Table 1: Base material AZ31 Chemical Composition

Element	**Zn**	**Mn**	**Si**	**Fe**	**Cu**	**Ni**	**Mg**
Percentage	0.72	0.30	0.08	0.005	0.05	0.005	Reminder

MATERIALS AND METHODS

The Material of 4.33mm Thickness of Magnesium alloy AZ31 plates was used for butt joints. To get required dimensions of 100mm X100mm X 4.33mm plates were machined. The two plates were firmly clamped using holders for welding AZ31 Magnesium Alloy having the shoulder diameter of 20mm H13 tool was used. The tool had a pin height of 3mm, slightly shorter than the thickness of the plate.

The CNC milling machine made by Agni BMV 45 is capable to offer simultaneous forces controlled operation of three different axes with an adjustable tool. The CNC vertical milling machine is used to perform the welding process. The work pieces clamped to the fixture and the tool is placed in the tool holder by using collets of 20mm diameter. The initial welding has been done on the work pieces of Magnesium alloy AZ31 with four different runs at different rotational speeds such as 1200RPM, 1600 RPM and at different tool feed rate such as 24mm/min, 28mm/min. While welding liquid nitrogen was poured on welded portion to brought cryogenic temperatures i.e. -10^{0}C.

By pouring liquid Nitrogen on welded pieces pre-cooling was achieved. Cryogenic cooling has some advantages pertained to changes in Mechanical properties, Enhancement in life of the tool and surface finish. The area where it is to be cooled and reached to the target value of -10^{o}c till then liquid nitrogen is poured. This temperature drop would guarantee the Friction Stir Welding starting temperature would be around 0^{o}c by the time the process starts. The temperature of the setup during the pre-cooling phase was maintained by the thermocouples.

Welded Pieces were machined according to ASTM Standards to conduct Mechanical Tests such as Ultimate Tensile, Impact Strengths and Hardness.

Figure 2: Friction Stir Welded Pieces

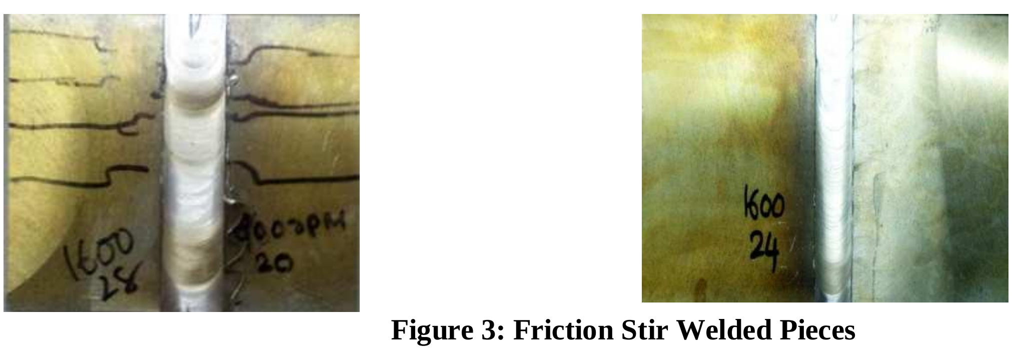

Figure 3: Friction Stir Welded Pieces

Figure 4: Pouring of Liquid Nitrogen on Welded Portion

Figure 5 (a): Mechanical Test Pieces For UTM

Figure 5 (b): Mechanical Test Pieces For UTM

RESULTS AND DISCUSSION

Table 2: Mechanical Properties of FSW joint at Normal Atmospheric Temperatures Around (35^0-40^0 C)

Runs	**Speed (RPM)**	**Feed (mm/min)**	**Tensile Strength (MPA)**	**Percentage of Elongation (%)**	**Bend Test** Failed at	**Hardness** HBW	**Impact strength J**
1	1600	28	76	0.42	90^o	57	3
2	1200	24	120	1.06	Do	57	4
3	1600	24	148	1.96	Do	95	4.5
4	1200	28	148	1.18	Do	63	4.5

Table 3: Mechanical Properties of FSW joint at Cryogenic Temperatures Around (-10^0 C)

Runs	Speed (RPM)	Feed (mm/min)	Tensile Strength (MPA)	Percentage of Elongation (%)	Bend Test Failed at	Hardness HBW	Impact strength J
1	1600	28	89	2.74	90^o	63	2
2	1200	24	12	2.52	Do	53	3
3	1600	24	86	2.84	Do	52	3
4	1200	28	47	3.26	Do	55	3

Table 4: Comparison Between Mechanical properties of FSW at Normal Atmospheric Temperatures Around (35^0-40^0 C) and Cryogenic Temperatures Around (-10^0 C)

Runs	Tensile Strength (MPA			Hardness HBW			Percentage of Elongation (%)			Impact strength		
	At Normal Temp. (X)	At Cryogenic Temp. (Y)	% Z= (X-Y)/X	(X)	(Y)	% Z	(X)	(Y)	% Z	(X)	(Y)	% Z
1	76	89	-17.11	57	63	-10.53	0.42	2.74	-2.32	3	2	33.33
2	120	12	90.00	57	53	7.02	1.06	2.52	-1.46	4	3	25.00
3	148	86	41.89	95	52	45.26	1.96	2.84	-0.88	4.5	3	33.33
4	148	47	68.24	63	55	12.70	1.18	3.26	-2.08	4.5	3	33.33

The Mechanical properties such as Ultimate tensile strength, hardness, percentage of elongation of friction stir welded joint of Magnesium alloy AZ31B at 1600 RPM Rotational speed and 28 mm/min feed were increased by 17.11, 10.53, 2.32 percentages respectively and impact strength was decreased by 33.33 percentage at cryogenic temperature si.e. -10^0 C than Normal Atmospheric Temperatures Around (35^0-40^0 C). At 1200 RPM Rotational speed and 24 mm/min feed. Ultimate tensile strength, hardness, impact strength were decreased by 90, 7.02, 25 percentage respectively percentage of elongation was increased by 1.46 percentage at cryogenic temperatures. At 1600 RPM Rotational speed and 24 mm/min feed. Ultimate tensile strength, hardness, impact strength were decreased by 41.89, 45.26, 33.33 percentage respectively percentage of elongation was increased by 0.88 percentage at cryogenic temperatures. At 1200 RPM Rotational speed and 28 mm/min feed. Ultimate tensile strength, hardness, impact strength were decreased by 68.24, 12.70, 33.33 percentage respectively percentage of elongation was increased by 2.08 percentage at cryogenic temperatures.

Conclusion

Mechanical properties of friction stir welded joint of Magnesium alloy AZ31B are changing at cryogenic temperatures. At cryogenic temperatures Mechanical properties at weld portion were decreased. So the components or objects which are subjected to cryogenic temperatures such as aerospace and automotives which are run at cold places will design by considering the Mechanical properties at cryogenic temperatures. Because Mechanical Properties were decreased at cryogenic temperatures. Always the design should be at lower values for safe design.

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