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Friction stir welding on Al-Mg Alloy plates by using Vertical Milling Machine

Dr. K. LalitNarayan[1], S.Daniel Ephraim Babu [2]
[1] *Professor,Department of Mechanical Engineering,Sir C.R.Reddy College of Engineering,India*
[2] *Asst.Professor,Department of Mechanical Engineering,Sir C.R.Reddy College of Engineering,India*

ABSTRACT
Friction stir welding has been carried out on Al-Mg plates using Vertical milling Machine. Welding has been conducted with variable tool rotation speeds of 500,710 and 1000rpm. Experiments have been designed to weld Al-Mg alloy with varying percentage of Mg i.e.2.5% and 5%. Pure Al plates were also welded under similar conditions for comparison purpose. The welded specimens are tested for hardness using Rockwell hardness testing machine. Hardness values at the base metal and the weld nugget were studied. Comparative studies are to make to know the effect of Mg in Al and variable speeds on hardness in base metal and weld nugget. The welded specimens were also tested for tensile strength using Universal testing machine. Result shave shown that remarkable increment in hardness has been observed in weld bead area as compared to Base metal with variation of Mg content in Aluminum i.e. 2.5%Mg in Al, 5% Mg in Al and also remarkable increment in hardness has been observed in weld bead area as compared to Base metal with variation tool rotation speed i.e.500, 710, 1000 rpm. Higher speed i.e. 1000 rpm has significant effect on tensile strength compared to lower speed i.e.500rpm.

Keywords: *Aluminium, Friction stir welding, Hardness test, Magnesium, Tensile strength, Vertical milling machine.*

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I. INTRODUCTION

Modern welding technology started just before the end of the 19th century with the development of methods for generating high temperature localized zones. Welding generally requires a heat source to produce a high temperature zone to melt the material; there are different methods and standards adopted to melt the material, though it is possible to weld two metal pieces without much increase in temperature. There are different methods and standards adopted for increase in temperature and there is still a continuous search for new and improved methods of welding. Production of components of Aluminium is not very complex; joining of these materials can sometimes cause serious problems. Lack of structural transformations in solid state and excellent thermal & electrical conductivity cause problems in fusion and resistance welding of Aluminium alloys, that lead to the development of Friction Stir Welding, a solid state joining technique in which the joined material is plasticized by heat generated by friction between the surface of the plates and the contact surface of a special tool, composed of two main parts: shoulder and pin. Shoulder is responsible for the generation of heat and for containing the plasticized material in the weld zone, while pin mixes the material of the components to be welded, thus creating a joint. This allows for producing defect-free welds characterized by good mechanical and corrosion properties. This paper summarizes the results of an experimental campaign in which the Aluminium-Magnesium alloy was Friction Stir Welded, using various combinations of process parameters (speeds). Mechanical properties of the test welds were assessed by means of hardness test and tensile test.

Friction Stir welding, in late 1991 a novel and potentially world beating welding method was conceived. The process was duly named friction stir welding (FSW), and TWI filed for world-wide patent protection in December of that year. Consistent with the more conventional methods of friction welding, which have been practiced since the early 1950s, the weld is made in the solid phase that is no melting. Since its invention, the process has received world-wide attention and today many companies around the world are using the technology in production, particularly for joining aluminium alloys.

Fred delany ,Stephan W Kalle, Mike J Russell[1] Friction Stir Welding of Al ships stated. Friction Stir Welding is a remarkable new welding method that has rapidly grown into an important industrial process since its invention, by TWI, in 1991. Welding procedure specification or component approval have been issued by many classification societies including ABS, BV, DNV, Lloyds and RINA.

M Norrism, W M Thomas, J Martin, D J Staines[2] "Friction Stir Welding – process variants And recent industrial development", stated Friction Stir Welding is now a widely used and accepted process for welding of a range of mainly aluminium parts for production applications. The basic process is well understood and has proved robust and reliable in operation and the incentive exit to extend its use to more challenging applications and alternative materials. D G Staines, W M Thomas, S W Kallee and P J Oakley [3]Friction Stir technology-recent developments in process variants and applications: This paper provides example of the growing use of friction stir technology. Further developments of the technology are likely to increase the types of applications that can significantly modify the velocity gradient between the probe center and the shoulder diameter. These trails confirm that use of slower shoulder rotational speed lowers the HAZ temperature during the welding operation. This effectively reduces thermal softening in the HAZ region.

J.Adamowski et al[4] stated in Friction stir welding (FSW) of aluminium received 18.10.2006; accepted in revised form 15.11.2006, JAMME :Mechanical properties of FSW welded aluminium alloy changes with changing of process parameters. Tensile strength of FSW welds is directly proportional to the welding speed. Hardness drop was observed in the weld region that softening was most evident in the heat affected zone on the advancing side of the welds that corresponded to the failure location in tensile tests. An initial stage of a tunnel defects was found at the intersection of weld nugget and thermo-mechanically affected zone.

J Stephen Leon ,Bharathiraja.G, Jayakumar.Vet al [5] Joining of aluminium alloys is always a challenging task due to its easily oxidising property in its molten stage. In this review article, significance of friction stir welding comparing with other solid state metal joining process is addressed. Recent developments and application of this relatively new metal joining process in various industries are also discussed.

Pratik H Shah , Vishvesh J Badheka [6] The process finds its major application for joining hard-to-weld metals, especially the precipitation hardenable aluminium alloys and is widely adopted by industries for the welding of such aluminium alloys.

Virendra Pratap Singh , Surendra Kumar Patel , Alok Ranjan , Basil Kuriachen[7]The friction stir welding (FSW) of aluminium-magnesium of various grade has incited substantial scientific and industrial importance since it has a potency to transform the product with a good quality joint. The fabrication of such alloys is a challenging task through conventional fusion welding due to its various metallurgical concerns.

II. EXPERIMENTAL PROCEDURE

Work has been initiated on Al-Mg alloy using friction stir welding. In this process Al, Al-Mg alloy work pieces are welded using friction stir welding technique. Instead of friction stir welding machine vertical milling machine was used. Two Al plates of dimensions 100 x 50 x 4 m each were clamped on the work table of the vertical milling machine. Care has been taken in such a way that there is no noticeable gap between them as shown in fig .The work pieces are fixed on bed of milling machine with help of fixture. The tool is fixed in spindle as shown in fig. The tool rotation speed was set to 500 rpm. After the tool probe entirely is inside the two work pieces, the tool is traversed along the plates to get the required weld as shown in fig. Similarly welding is done on Al+2.5%Mg Alloy and Al+5%Mg plates keeping the tool rotation speed 500rpm.Then the above procedure is repeated for 710 rpm,1000 rpm on Al plates and Al+2.5% Mg, Al+5%Mg respectively. 3 pairs of ALUMINIUM,3pairs of Al+2.5%Mg,3 pairs of Al+5%Mg, totally 9 pairs of pieces which were joined by using FSW technique were obtained.

Fig 2.1 shows the fixing of work pieces on the bed of milling machine by using fixture

Fig 2.2 shows the fixing of tool in the spindle and the probe inserted into the work piece

2.1 TESTING

(a) Hardness

The obtained welded pieces are tested for hardness. Rockwell hardness testing machine is used for conducting the hardness test. The welded specimen is placed on the testing machine. The steel ball indenter of 1/16″ dia is forced into the test material under a preliminary minor load of 10kgf. A major load of 100kg is then applied which results in permanent increase in depth of penetration. This depth of penetration is used to calculate the Rockwell hardness number. The hardness test is first performed on base metal of the welded plates.

Test is performed at six different distances from the axis of weld. Hardness test is the performed at weld nugget (WN) at six different locations. Similar procedure is adopted for all the specimens i.e. Al, Al+2.5% Mg,Al+5%Mg at 500,710 & 1000 rpm tool rotations.

Fig 2.3 shows the hardness at the base metal region

Fig 2.4 shows the hardness at the weld nugget

(b) TENSILE STRENGTH

The welded pieces are tested for tensile strength. Universal testing machine is used for conducting the tensile test. The welded specimen is placed on the testing machine. Load is applied on the work piece and elongation and tensile strength were observed.

Fig 2.5 shows the Universal Testing Machine

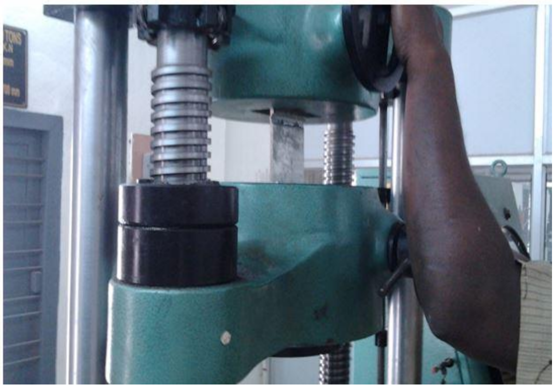


Fig 2.6 shows the shows the elongation test on UTM

III. RESULTS AND DISCUSSIONS

Hardness readings of the welded pieces at the base metal, and weld nugget were taken. The summary of hardness values were tabulated in the table 1

Table 1: Hardness values at various speeds for Aluminium

Welded plates	Speed Rpm	Hardness number	
		BM	WN
ALUMINIUM	500	14	28
		16	21
		17	28.5
		15	32
		14	30.5
	710	16	24.5
		15	30
		14	38.5
		13.5	39
		15	44
	1000	17.5	32.5
		16	28
		15	26
		14	33.5
		13	30

Table 2: Hardness values at various speeds for Aluminium+2.5%Mg

Welded plates	Speed Rpm	Hardness number	
		BM	WN
ALUMINIUM + 2.5% Mg	500	15	33
		18	32.5
		15.5	30.5
		20.5	41
		16.5	38
	710	20.5	48
		23	58
		23	47
		25.5	69
		21.5	40.5
	1000	34.5	53
		21.5	57
		26	59
		30	59.5
		32	65

Table 3 Hardness values various speeds for Aluminium+5%Mg speeds

Welded plates	Speed Rpm	Hardness number	
		BM	WN
ALUMINIUM+5 %Mg	500	13	38
		22	23
		18	25
		24	28
		16	32
	710	33	78.5
		42.5	71.5
		36	70.5
		38	78
		34.5	70
	1000	74	87
		77	99
		74.5	80
		76	61
		76	83

Table 4 Tensile Strength values for Aluminium, Aluminium+2.5%Mg, Aluminium+5%Mg at various

Welded plate	Speed Rpm	Load(KN)
ALUMINIUM	500	3.25
	710	3.25
	1000	5
ALUMINIUM+2.5 %Mg	500	1.62
	710	5.41
	1000	5.5
ALUMINIUM+5% Mg	500	0.25
	710	0.25
	1000	4.5

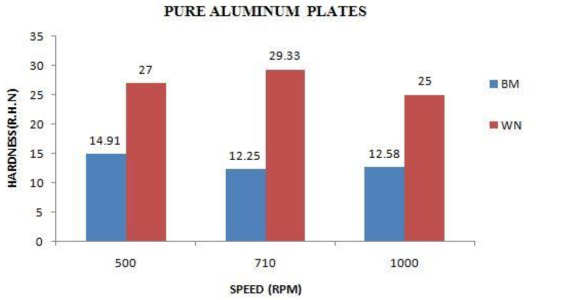


Fig 3.1 shows the effect of hardness for various speed

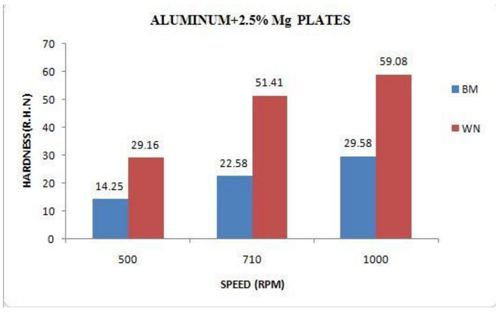


Fig 3.2 shows the effect of hardness for varies speeds

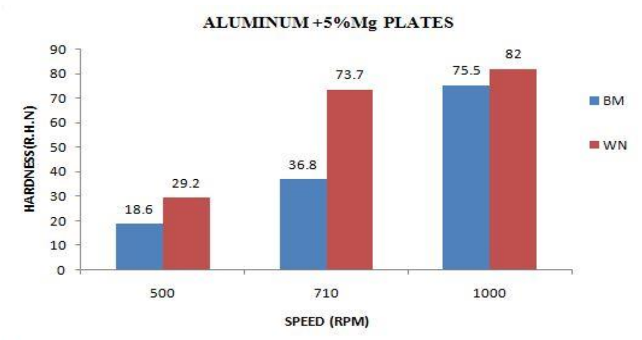


Fig 3.3 shows the effect of hardness for various speeds

For various speeds, the hardness at the weld nugget was found to be more than the base metal in Fig 3.1.For an alloy composition of Al+2.5%Mg by varying the speed, the hardness at the weld nugget was found to be more than the base metal as shown in Fig 3.2.For an alloy composition of Al+5% Mg by varying the speed the hardness at the weld nugget was found to be more than the base metal as shown in the Fig 3.3

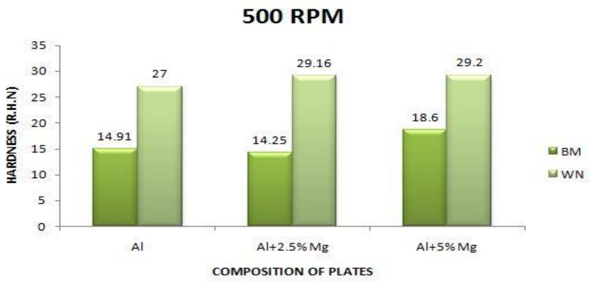


Fig 3.4 Shows the effect of hardness for various compositions

Fig 3.5 Shows the effect of hardness for various compositions

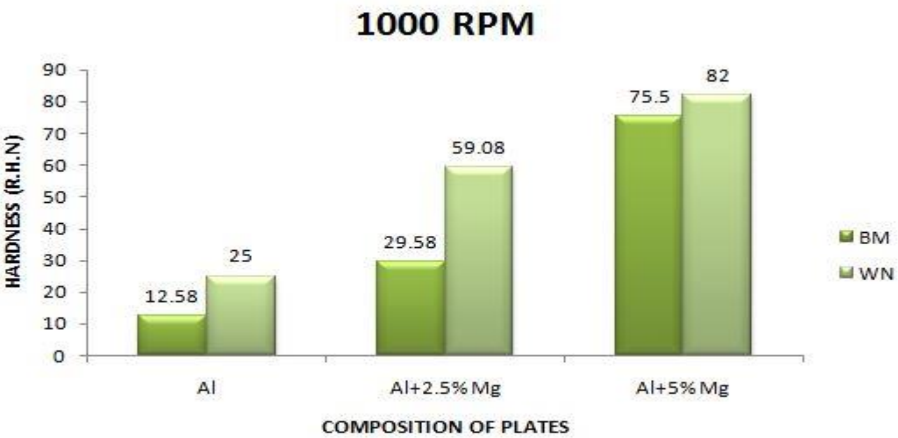


Fig 3.6 Shows the effect of hardness for various compositions

For various composition at 500 rpm the comparison graph is plotted to show that at the weld nugget is more than the base metal in the fig 3.4. For various compositions at 710 rpm a comparison graph is plotted to show that the hardness at the weld nugget is more than the base metal in the fig 3.5.For various compositions at 1000 rpm a comparison graph is plotted to show that hardness at the weld nugget is more than the base metal in the fig 3.6.

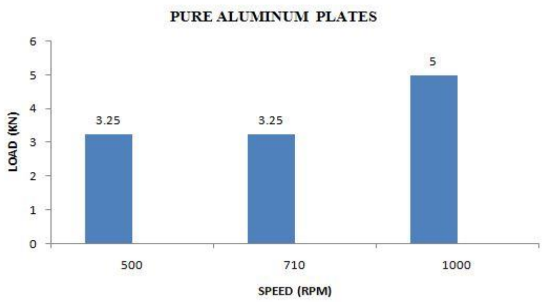


Fig 3.7 shows the variation of tensile strength for various speeds

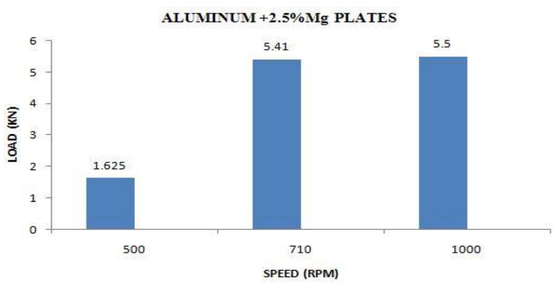


Fig 3.8 shows the variation of tensile strength for various speeds

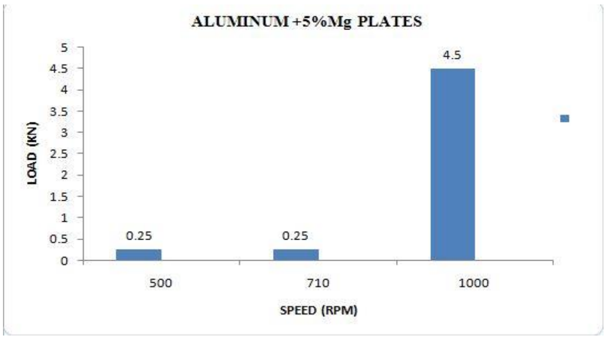
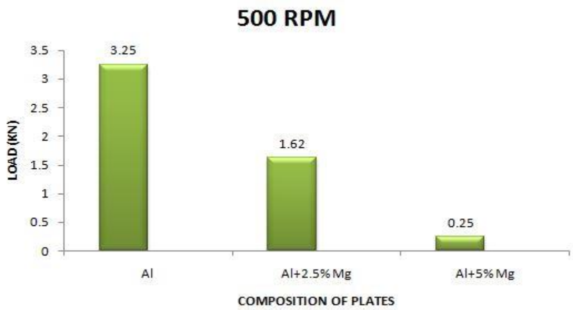


Fig 3.9 shows the variation of tensile strength for various speeds

For various speeds, the tensile strength doesn't change with respect to speed up to 710rpm, whereas the tensile strength increases at 1000 rpm in the Fig 3.7.For an alloy composition Al+2.5%Mg by varying the speed, the tensile strength increases in the Fig 3.8.For an alloy composition Al+5%Mg by varying the speed, the tensile strength doesn't change with respect to speed up to 710rpm, whereas the tensile strength increases at 1000 rpm in the Fig 3.9



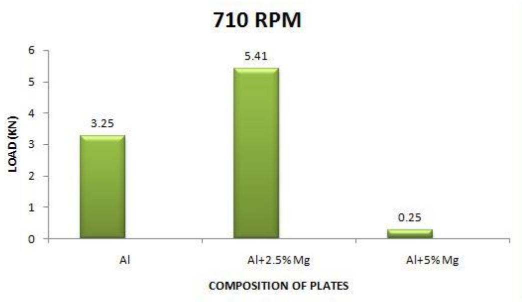


Fig 3.10 shows the variation of tensile strength various compositions

Fig 3.11 shows the variation of tensile strength for for various compositions

Fig 3.12 shows the variation of tensile strength for various compositions

For various composition at 500 rpm the comparison graph is drawn, it shows that, the tensile strength goes on decreasing with the increase of Mg content in Al in the Fig 3.10.For various composition at 710 rpm the comparison graph is drawn, it shows that, the tensile strength goes on increasing with the increase of Mg content in Al up to 2.5 %Mg in Al, it suddenly decrease with increase in Mg content in Al in Fig 3.l1.For various composition at 1000 rpm the comparison graph is drawn, it shows that, the tensile strength goes on increasing with the increase of Mg content in Al up to 2.5 %Mg in Al, it slightly decrease with increase in Mg content in Al in Fig 3.l2.

IV. CONCLUSIONS

Friction Stir Welding has been successfully performed using vertical milling machine. Remarkable increment in hardness has been observed in weld bead area as compared to base metal with variation of Mg content in Aluminium i.e. 2.5%Mg in Al,5% Mg in Al.Remarkable increment in hardness has been observed in weld bead area as compared to base metal with variation tool rotation speed i.e.500,710,1000 rpm.Higher speed i.e. 1000 rpm has significant effect on tensile strength compared to lower speed i.e.500rpm.At 500 rpm speed the tensile strength decreases with increase of Mg content in Al. At 710 & 1000 rpm the tensile strength increases with increase of Mg content in Al up to 2.5% Mg, but decrease for 5%Mg in Aluminium.

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