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OPTIMIZATION AND CHARACTERIZATION OF FRICTION STIR WELDING ON ALUMINIUM ALLOY 1050-H14

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ABSTRACT

In this study, the optimization and characterization study of friction stir welding to aluminum 1050-H14 has been investigated. Through optical microscopy joint test took placed including micro hardness measurements, and mechanical testing The effects of the tool rotational speed (i.e., 1270 and1650 rev/min) and the welding speed on were obtained at a rotational speed of1600 rev/min with a welding speed of 235 mm/min.In FSW, a cylindrical-shouldered tool, with a profiled threaded or unthreaded probe (nib or pin) is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together.

Keywords: *Friction stir welding - FSW, welding force, pin, shoulder, tensile tests.*

1. LITERATURE SURVEY

The heat caused by the friction results in an intense local heating that does not melt the plates to be joined, but plasticizes the material around Tool(1). The shoulder of the tool provides additional Frictional heat to the work pieces as well as preventing the plasticized material from being expelled from the weld. The joint efficiency values obtained are summarized in base plate and welded plates produced at both rotational speeds employed in this study, i.e., 1250and 1600 rev/min., the best combination of mechanical properties for a rotational speed1250 rev/min was obtained from the joint produced with a traverse speed of125 mm/min. The strength and ductility performances for this joint were 105 and84%, respectively. The specimens extracted from the joints produced at the rotational speed of 1250material (BM), except for the specimens produced with a traverse speed of 150 mm/min that failed in the weld zone (WZ).Moreover, the joint produced at the rotation rate of 1250 rev/min with a weld speed lower traverse speeds at this rotation(2)

Kwon (1998) has investigated on dissimilar friction stir welding between magnesium and aluminum alloy plate with thicknesses of 2 mm was performed. The tool for welding was rotated at speeds ranging from 800 to 1600 rpm under a constant traverse speed of 300 mm/min. For tool rotation speeds of 1000, 1200, and 1400 rpm, defect-free welds were successfully obtained and the surface morphology of the welds became smoother as the tool rotation speed was increased. The relatively simple bonded interface was clearly evident and had a zigzag pattern(3). A mixed microstructure of magnesium and aluminum alloys was formed near the bonded interface. The maximum tensile strength of about 132 MPa was obtained at the tool rotation speed of 1000 rpm. However, there were not noteworthy changes in the tensile strength as a function of the tool rotation speed. The elongation was 2% or less, regardless of the tool rotation speed(4). Zhang Da-tong (1995), investigated about the dissimilar FSW between 5052 aluminium alloy and AZ31B magnesium alloy in this sound weld could be produced through FSW with a rotation speed of 600rpm and welding speed of 40mm/min and microstructure of the base metal was replaced by equiaxed and fine grains in stir zone, at the top

of stir zone alloys were simply bonded(3). While onion ring structure which consists of aluminium and magnesium bands was formed at the bottom of the stir zone. Micro hardness has uneven distributions and the maximum value of micro hardness in the stir zone was twice higher than the base materials. The fracture position located at a distance of 2.5mm from the joint clearing leaning to the aluminum side.(5)

Component Elements Properties	**Metric**
Aluminum, Al	>= 99.50 %
Copper, Cu	<= 0.05 %
Iron, Fe	<= 0.40 %
Magnesium, Mg	<= 0.05 %
Manganese, Mn	<= 0.05 %
Other, each	<= 0.03 %
Silicon, Si	<= 0.25 %
Titanium, Ti	<= 0.03 %
Vanadium, V	<= 0.05 %

2. STEPS OF PROCESS

Table 1: Chemical component element properties aluminum 1050-H14

Thermal Properties	**Metric**	**English**
Heat of Fusion	390 J/g	168 BTU/lb
	21.8 µm/m-°C	12.1 µin/in-°F
CTE(linear)	23.6 µm/m-°C	13.1 µin/in-°F
	@Temperature 20.0 - 100 °C	@Temperature 68.0 - 212 °F
	24.5 µm/m-°C	13.6 µin/in-°F
	@Temperature 20.0 - 200 °C	@Temperature 68.0 - 392 °F
	25.5 µm/m-°C	14.2 µin/in-°F
	@Temperature 20.0 - 300 °C	@Temperature 68.0 - 572 °F
Specific Heat Capacity	0.900 J/g-°C	0.215 BTU/lb-°F
Thermal Conductivity	227 W/m-K	1580 BTU-in/hr-ft²-°F
Melting Point	646 - 657 °C	1190 - 1210 °F
Solidus	646 °C	1190 °F
Liquidus	657 °C	1210 °F
Titanium, Ti	<= 0.03 %	<= 0.03 %
Vanadium, V	<= 0.05 %	<= 0.05 %

Table 2: Thermal properties aluminum 1050-H14

Mechanical Properties	Metric	English
Hardness, Brinell	30	30
Tensile Strength, Ultimate	110 MPa	16000 psi
Tensile Strength, Yield	103 MPa	14900 psi
Elongation at Break	10%	10%
	@Thickness 1.60 mm	@Thickness 0.0630 in
Modulus of Elasticity	69.0 GPa	10000 ksi
Poissons Ratio	0.33	0.33
Shear Modulus	26.0 GPa	3770 ksi
Shear Strength	69.0 MPa	10000 psi

Table 3: Mechanical Properties aluminum 1050-H14

3. MATERIALS AND EXPERIMENTAL PROCEDURE

For the friction stir welding process, a vertical milling machine of great power was used. The process is conducted in laboratory conditions, similar to the production. Material used in the experiment includes the sheet aluminum 1050-H14, whose chemical composition is given in Table 1. And mechanical properties of basic material in Table 3. The size of workpiece is 100 X 100 mm, and it was obtained by cutting boards of sheet with the thickness of 7 mm. Tool shoulder diameter in a central point of the plan is D=27.5 mm, while the pin diameter d=6.75 mm. Tilt angle of the pin is $\alpha=2.87^0$.(7)

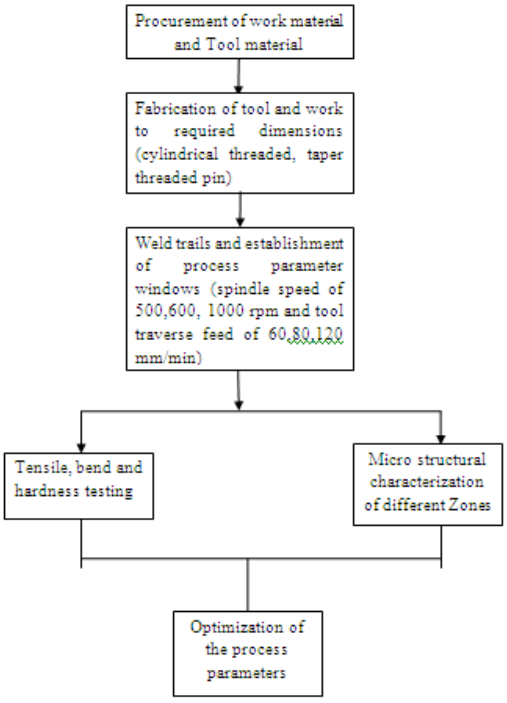
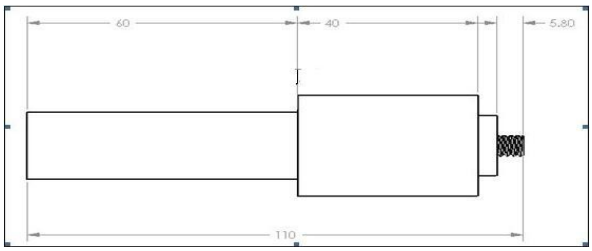


Fig.1 Methodology of FSW using aluminum 1050-H14

4.TOOLS USED IN FSW

A tool of a shoulder length of 30mm and pin diameter of 6mm was made of hardened high speed steel M2 was used for welding process. The tool is of cylindrical threaded pin of length 5.8mm. (Figure 2)



All dimensions are in mm

Figure 2- Tool with Cylindrical Threaded Pin

5. TOOL DESIGN AND FABRICATION

The tool was designed and fabricated by varying the profile of the tool pin namely Tapered threaded, Tapered cylindrical and Cylindrical threaded.



Figure 3-cylindrical threaded



Figure 4-tapered threaded



Figure 5-tapered cylindrical

6. THERMAL TREATMENTS

The following procedure is done on the HSS M2 steel to increase the hardness and tool life during the welding process.Preheat 1093K/1118K (820/845 ^{0}C), equalize, Second preheating stage at 1283K/1313K (1010/1040 ^{0}C) recommended for vacuum or atmosphere hardening .Austenisation 1283K/1448K (1010/1175^{0}C), 30/45 minutes at temperature. Standard recommendation to achieve RC60-62 QUENCH: Salt, oil or atmosphere quench to 813K/ 868K (540-595 ^{0}C)(5), equalize, then air cool to below 323K (50 ^{0}C) or hand war. stress relieving for Annealed Material is heated to 865K/1010K (595/740 ^{0}C), hold two hours, cool in still air and for hardened material is heated to 295K (15 ^{0}C) below original tempering temperature, hold two hours, cool in still air.(8)

7. RESULTS AND DICUSSION

Friction stir welding is carried out through conventional milling machine with auto control which is suitable than other machines. The rotary and traverse of the tool motion is very

important during welding on milling machine. The first trial were made on AZ31B magnesium alloy plates of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 720 RPM, feed rate of 50mm/min is done. The welding was done on one end of the plates , then plates were made upside down and same procedure was followed. This is known as double pass method. There was a formation of worm holes in between the plates.



Figure 6-shoulder penetration

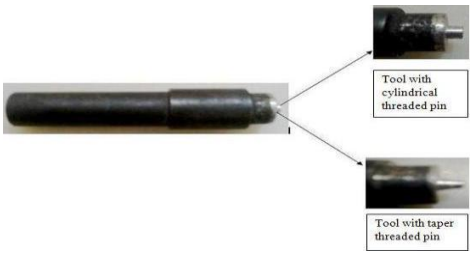


Figure 7-Tools Used in Welding Process

The tools used in this process were tool with cylindrical threaded pin and the tool with taper threaded pin having a pin diameter of 5.8mm, the tool with cylindrical threaded pin was used in double pass method and the tool taper threaded pin was used for remaining weld-ment.

The second trial was made on aluminum 1050-H14 plates of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 1100 RPM, feed rate of 22mm/min is done. The welding has not done due to tool broken

The third trial was made on aluminum 1050-H14 of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 1200 RPM, feed rate of 21mm/min is done. The welding has not done due to tool broken

The fourth trial was made on aluminum 1050-H14 of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 1250 RPM, feed rate of 25mm/min is done. The welding has not done due to tool broken

The fivth trial was made on aluminum 1050-H14 of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 1300 RPM, feed rate of 24mm/min is done. The welding has not done due to tool broken

The sixth trial was made on aluminum 1050-H14 of size 100x 200x 6 mm, the plates were properly fixed on milling machine bed with fixtures. The tool was fixed in the spindle of the machine and machining was done at a spindle speed of 1250 RPM, feed rate of 23mm/min is done. The welding has not done due to tool .



Figure 8- TMT Zone 50X

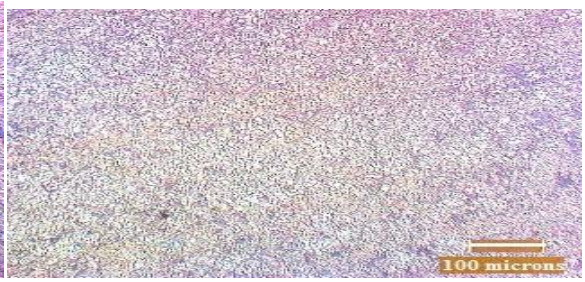
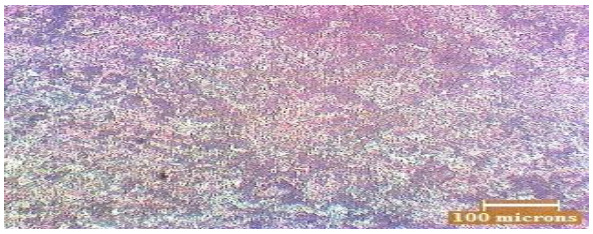


Figure9- TMT Zone 100X



Fig 7-Nugget Zone 100X Figure -TMT zone Retreading side 100X



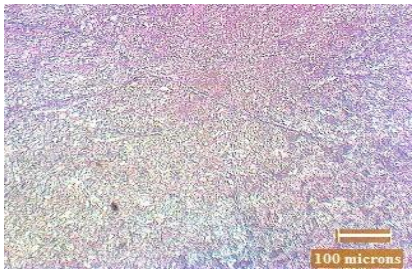


Fig10- Parent metal Retreading side 100X

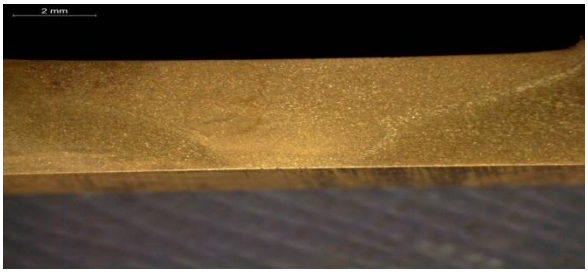


Fig 11- Macro structure

7. MICRO HARDNESS OF THE WELDED REGION

The micro hardness test was conducted on the welded plates. The test was conducted at every 3mm from the centre of the welded plates. The results were tabulated .The test was conducted with a load of 300grms, with a diamond indenter, at a time delay of 10 sec. the hardness values of heat affected zone (HAZ), thermo mechanically affected zone (TMAZ), and the welded nugget is lower than the base material, but the hardness of the HAZ and at the TMAZ was less when compared to the nugget zone.

Micro Hardness survey-Hardness measured along the horizontal direction of the specimen-

Distance from the edge	At rhe edge	2	4	6	8	10	12	14	16	18	20	22	24
Hardness in H.V. @ 0.5 Kg load.	129.4	128	126	125	126	129	137	138	138	137	137	138	133.9

Table-4 Hardness measured along the vertical direction of the specimen

A correlation matrix formed considering distance from the edge and Vickers hardness.

	128.1-125.1	128.1-125.6	128.1-128.5	128.1-133.9	128.1-137	128.1-137.2	128.1-137.6	128.1-137.9	128.1-138.3	2
128.1-125.1	**1**	-0.149	-0.100	-0.100	-0.149	-0.100	-0.100	-0.100	-0.100	-0.400
128.1-125.6	-0.149	**1**	-0.149	-0.149	-0.222	-0.149	-0.149	-0.149	-0.149	-0.596
128.1-128.5	-0.100	-0.149	**1**	-0.100	-0.149	-0.100	-0.100	-0.100	-0.100	-0.200
128.1-133.9	-0.100	-0.149	-0.100	**1**	-0.149	-0.100	-0.100	-0.100	-0.100	0.500
128.1-137	-0.149	-0.222	-0.149	-0.149	**1**	-0.149	-0.149	-0.149	-0.149	0.373
128.1-137.2	-0.100	-0.149	-0.100	-0.100	-0.149	**1**	-0.100	-0.100	-0.100	-0.100
128.1-137.6	-0.100	-0.149	-0.100	-0.100	-0.149	-0.100	**1**	-0.100	-0.100	0.000
128.1-137.9	-0.100	-0.149	-0.100	-0.100	-0.149	-0.100	-0.100	**1**	-0.100	0.400
128.1-138.3	-0.100	-0.149	-0.100	-0.100	-0.149	-0.100	-0.100	-0.100	**1**	0.100
2	-0.400	-0.596	-0.200	0.500	0.373	-0.100	0.000	0.400	0.100	**1**

Table 5- correlation matrix exist between distance from the edge and Vickers hardness

Source	DF
Model	8
Error	2
Corrected Total	10

Table 6-Variance analysis: Computed against model Y=Mean(Y)

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
2	11	0	11	4.000	24.000	14.000	6.633

Table 7- Summary statistics (Quantitative data):

One-sample T-test / Two-tailed test:

95% confidence interval on the difference between the means:
] 128.199, 146.351 [

Difference	137.275
t (Observed value)	48.133
|t| (Critical value)	3.182
DF	3
p-value (Two-tailed)	< 0.0001
alpha	0.05

Test interpretation:
H0: The difference between the means is equal to 0.
Ha: The difference between the means is different from 0.
As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.
The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

Disjunctive table:

	136.5-134.3	136.5-131.3	136.5-144.3
Obs1	1	0	0
Obs2	0	1	0
Obs3	0	0	1
Obs4	0	0	0

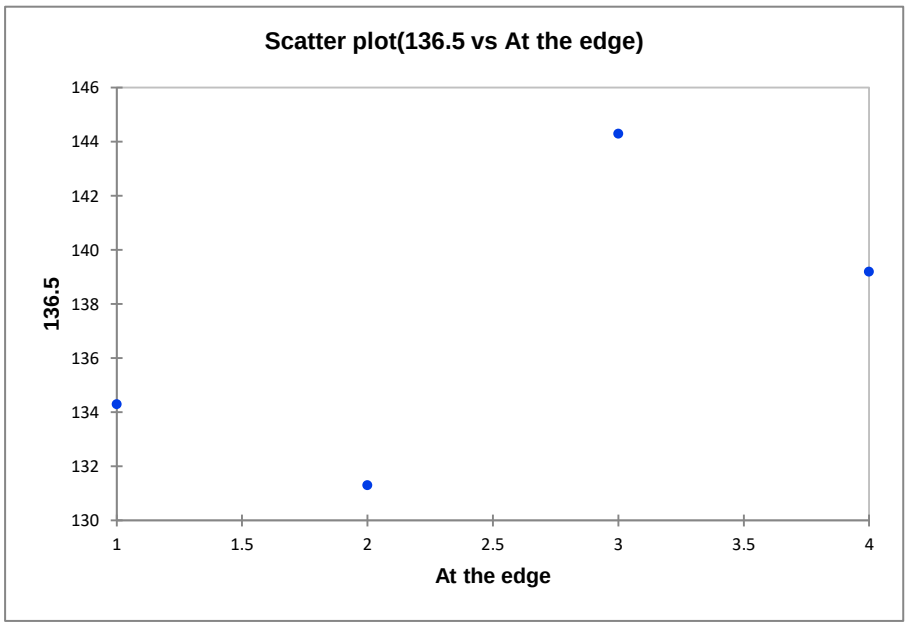


Figure 12-Scatter plot (optimized value 136.5 vs At the edge)

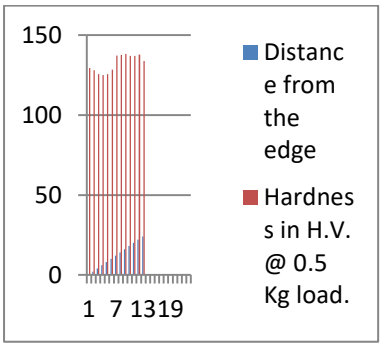


Fig-13 Micro hardness in the welded region

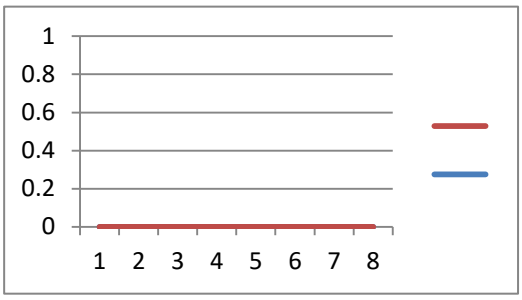


Fig-14Vickers hardness measured in horizontal direction

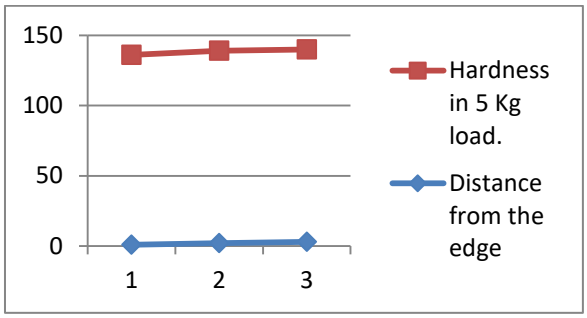


Fig-15 Vickers hardness measure along vertical direction

8. CONCLUSION

The tool material was selected for M2 because AL material was high strength. The tool pin profile was designed for consider plate thickness.The tool pin profile was made cylindrical, threaded cylindrical.The fabricated tool was hardened and tempered nearly 60 HRC.A perfect weld could be produced in brass by FSW process with the tool rotation speed of 1200 RPM- 1300 RPM, there is no defect in weld nugget region.As speed of the tool increases then the weld obtained is defect free and the mechanical properties achieved were nearer to parent material when compared with the weld done at lower speed.

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