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Manufacturing of Friction Stir Welding Tool and Characterisation of Welded Aluminium Alloy

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***Abstract:** Conventional process like arc welding and gas welding are not suitable for pure aluminium and copper and its alloys due to its low melting point, high thermal conductivity and presence of high impurities after welding. Here introducing an alternative method of welding for such materials known as friction stir welding by drilling machine. Here designed a tool shoulder which accurately fix into the machine. Then after a tool probe, which does the crucial job of friction welding. The tool probe and tool shoulder are manufactured based on the design and then assembled to make the tool and welding is completed. Conducted welding with three different speed and produces weld joint of different properties. Welded specimens taken for non-destructive and destructive testing to compare the mechanical strength, quality of and other mechanical properties of the weld produced.*

***Keywords:** Friction stir welding, tool shoulder, non-destructive and destructive testing*

I. INTRODUCTION

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminum alloys [1, 2]. When joining dissimilar metals such as Aluminum, Copper and Steel, friction welding is of great importance in engineering applications. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxed recrystallized grains [3]. Friction time, friction pressure, forging time, forging pressure and rotation speed are the principal welding variables in the friction welding method. In this paper, work has been done on friction welding Aluminum by changing tool traverse speed (n, mm/min) along the line of joint using a drilling machine, which is very much cost efficient, when compared to any other welding.

II. WELDING MACHINE

Selected the drilling machine for welding purpose since it is easy to apply vertical load by the same. The work piece clamped in position and the tool rotates to make a weld. This type of machine is used for very light works. The vertical column carries a swiveling table the height of which can be adjusted according to the work piece height. The table can also be swung to any desired position. At the top of the column there are two pulleys connected by a belt, one pulley is mounted on the motor shaft and other on the machine spindle. Vertical movement to the spindle is given by the feed handle by the operator.

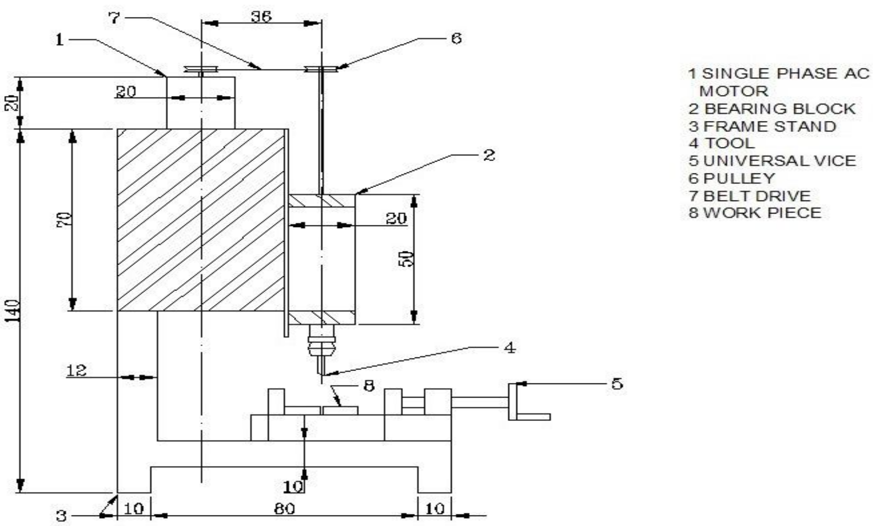

Figure 1 Friction stir welding on drilling machine

A. Tool And Holder Geometry And Design

Each of the friction tool parts has a different function. Therefore, the best tool design may consist of the shoulder and pin constructed with different materials. The work piece and tool materials, joint configuration and the user's own experiences and preferences are factors to consider when selecting the shoulder and pin designs. Very important factor of the tool design that the material flow has adequate direction and quantity during welding. Generally, the greater volume of material to stir better weld quality is obtained, but it has strong correlation with other technological parameters (rotational speed, welding speed).Horizontal material flow certainly occur during welding, but if some oxide occurs on the base material surface, the vertical material flow will be very significant and this is especially true at lap joint welding. If vertical flow doesn't occur during welding, the surface oxide will remains in the joint line and remains the creation of the join.

Total depth of the tool space in the spindle = 91 mm
Required holder length out of the spindle = 16 mm
Extra length required to lock the holder = 25 mm
Therefore Total length of the holder = 132 mm
Diameter at the bottom end of the spindle, D = 31 mm
Required Diameter at the top of spindle, d= 21 mm
Taper angle = tan inv{ [(D-d)/2] / depth}
= 3 degrees

The holder manufactured in lathe workshop according to the design.
1) First turned it to the greatest diameter in the design.
2) Then, done tapering according to the calculated taper angle.

Figure 2 Manufactured Holder

Mt = (Power*60)/2πN……………………………………N=800 RPM, Power= 1125 Watts
σb = (Fp* H)/ {(πR^4)/2}……………………………………………………..Bending Stress
τt = Mt * R/({ πR^4}/2)…………………………………………………Torsional Shear Stress
τmax = {[(σb/2)^2] + [τt^2]}^0.5…………………………………..Maximum Shear Stress

<u>NOTE:-</u> Temperature required in the process is 550 Deg Celsius (Melting point of He9 Aluminium is 600deg cel.) , Which will occur at 800 RPM.
τallowable = (τsteel@ 500 deg cel)/FOS………….....FOS=7 , τsteel@ 500 deg cel = 235 MPa
On equating,
R = 3.9 mm
So We took the Probe Diameter as 8mm.
Shoulder Diameter = 2.5(Probe Dia) = 20mm

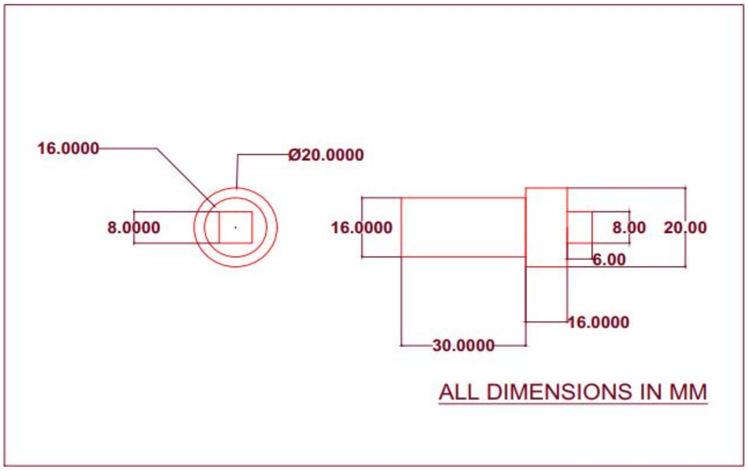

Figure 3 Tool Design

Figure 4 Manufactured Tool

B. Weld Characterization

1) *Visual Test:* The weld is initially characterized by visual observation. From the top of the joint, the size and uniformity of the weld spatter, lack of penetration, and concave, convex nature of weld bead crown. For all samples, weld was uniform without any spatter. In some samples size of flash has shown some variation. Clear onion rings are the indication of sound weld. Increase in linear speed of the tool decreased weld quality were noticed and optimized the speed accordingly

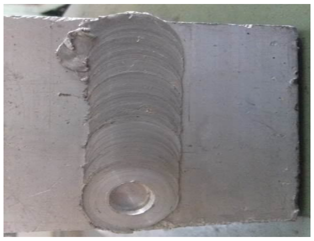

Figure 5 Weld specimen

2) *Liquid Penetrant Test:* All weld samples analysed through Liquid Penetrant Test and observed the sample using visible dye. The welding was found defect free in Liquid Penetrant testing.

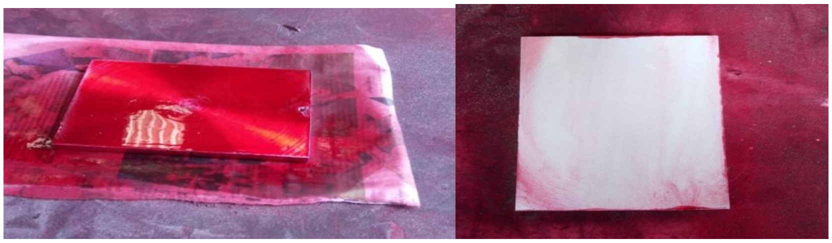

Figure 6 LPT Samples

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3) *Ultrasonic Testing:* In UT, very short ultrasonic pulse waves with center frequencies ranging from .1 to 15 MHz are transmitted into materials to detect internal flows.

Figure 7 Ultrasonic Inspection

4) *Brinell Hardness Test:* The Brinell hardness test method is used to determine the hardness of metals that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method. It uses 500 to 3000 kgf and a 10 mm diameter indenter so that the resulting indentation out of most surface and sub-surface inconsistencies. The resulting impression is measured with a specially designed Brinell microscope across at least 2 diameters at right angles to each other. Hardness values were measured and Fig showing the variation of the hardness of the specimen at different zone like weld zone, heat affected zone (HAZ) and parent material. The hardness value of the HAZ is greater than the weld zone and parent material, because of the grains in the HAZ is finer than the weld zone and parent material. But in the case of FSW, total energy is very low and welding velocity is very high because of this, HAZ will be negligible. Hardness at four different locations were tested; two on welded region, two on normal surface. Following are the brinnell hardness numbers obtained:-

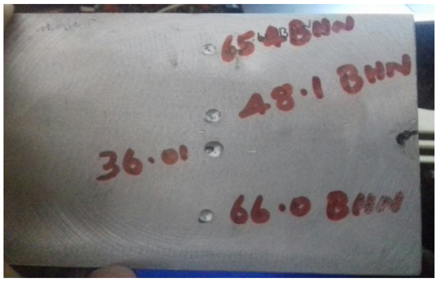

Figure 8 Brinell hardness

5) *Tensile Test:* Tensile test of samples were conducted. The min diameter for the test required was 12mm .Since tool was designed for 6mm plate, had to weld from both sides for this test. As a result manufactured the specimen according to the smallest standard size. Table showing the values of ultimate tensile strength, yield strength and percentage elongation in two different heat treated condition.

III.RESULTS

A. Ultrasonic Testing

RESULT:- Range: 0-20 mm, Probe: 10 mm diameter, 4 MHz , 71097, DAC : 1.2MM FBH

Linear indication noticed throughout Centre position (welded portion) of the job, 50 mm from the end at a specific depth of 6mm with respect to 1.2 FBH.

Metal Distance	% Height	Gain
5mm	100	56 dB
10mm	70	56 dB
15mm	40	56 dB

B. Brinell Hardness Test

Sample no.	Parent plate	Weld Bad	HAZ
1	65.4BHN,	36.01BHN	48.1BHN,
2	66.4BHN,	39.07BHN	45.4BHN,
3	65.8BHN,	37.01BHN	44.1BHN,

C. Tensile Test

No	UTS(N/mm2)	YS(N/mm2)	Elongation (%)
1	170	132	12.2
2	182	136	9.2
3	174	134	12.0
Avg	172	134	11.2

Tensile Strength of the Aluminum He9 alloy is 190 MPa.
For all samples, breakage obtained on parent material side. All failures looking ductile fracture also showing good response of welding.

IV. CONCLUSION

Successfully manufactured tool and completed friction stir welding using the drilling machine on aluminum alloy. Performed welding on 15 specimens and the tool never failed. Obtained satisfactory results in tensile tests, hardness tests, ultrasonic tests and liquid penetrant test. It was found that weld quality increased with increasing RPM and decreasing tool travel speed. Better weld quality at 800 RPM and 50 mm/min travel speed noted. The tool travel speed can be further increased by increasing the RPM. In tensile test, weld bead showed better results than the parent material. Most of the samples, breakage observed on parent material side (Ductile Fracture) and other tensile properties also showed good values.

V. ACKNOWLEDGMENT

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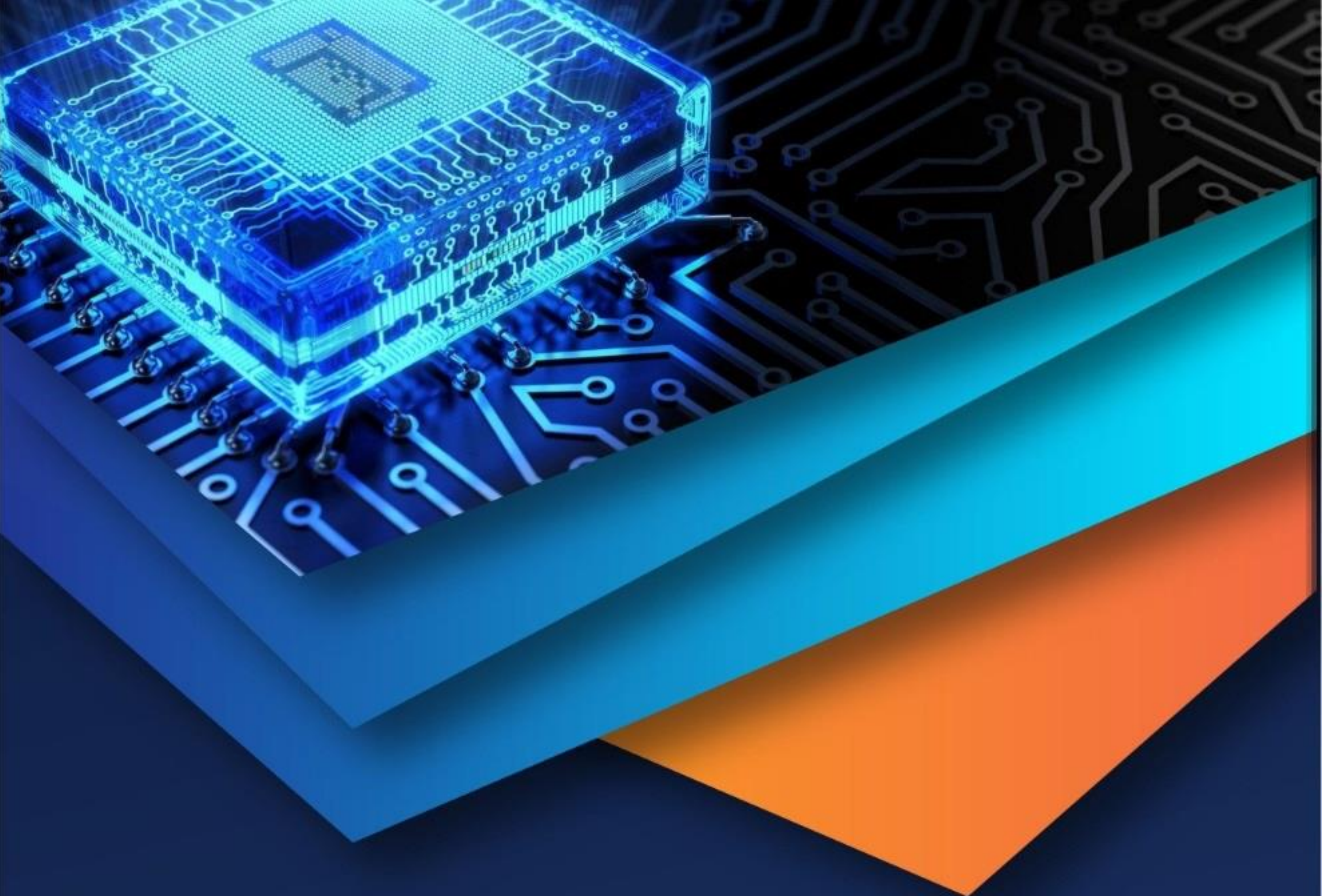

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