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Sandwiched based Friction Stir Welding of Aluminum Alloy

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ABSTRACT

In this paper, the process of friction stir welding (FSW) has been used to create the multi-lap joint between the two sheets of the aluminum alloy: Al5052-H32 while a pure copper foil was placed in between. The tool material M2HSS is selected considering its heat tolerance capacity and high strength. Taguchi method's L_9 approach is used in this work. Ultimate shear strength test is done on all the samples. In case of AlA-Cu-AlA welds, it is observed that the optimum values of the ultimate tensile strength are obtained for the parameters such as tool rotation speed at 800 rpm, traverse speed at 5mm/min and the plunge depth being 0.2 mm. We know that, the AlA-AlA join the as greater value of the ultimate shear strength when compared to AlA-Cu-AlA joint. It is also observed that the clamping also plays an important role in friction stir welding.

Keywords: Friction Stir Welding, Thin Sheets, Multi-lap Joint, M2HSS tool, Dissimilar Material Welding, Solid State Welding Process efficiency.

1. INTRODUCTION

The FSW process is a kind of solid state welding process and hence, for the joint to be formed, the material need not reach its melting point [1-2]. Instead, the temperature just enough for plasticizing the material is required to be maintained while the force applied by the tool in downward direction with the simultaneous rotational movement of tool intermixing the base materials creates a joint [3,4]. The heat is generated by the frictional force between the rotating tool and the surface of the base material in contact with the tool.[5] With significantly lesser heat than the melting points of the base materials, lesser HAZ (heat affected zone) is created and hence there is a lesser effect on the original material properties[6].

The FSW was invented in 1991 at 'The Welding Institute (TWI)' when Wayne Thomas used a tool having a probe with the correct rotational speed and torque [7, 8]. The tool selected had hardness greater than that of any of the base materials [9]. FSW could be utilized for joining similar as well as dissimilar materials. However, only lap and butt arrangement of sheets is feasible while making a joint [10]. Several samples of the multi-lap joint consisting of two dissimilar materials had been evaluated for their shear strengths. The thickness of the sheets used was relatively lesser (i.e., 1 mm each forAl5052-H32and0.1 mm for pure copper) than the thickness of sheets that are usually joined with the FSW process [11,12,13].The scanning electron microscopy was performed on the friction stir welded AlA-Cu-AlA sample having the highest value of the ultimate shear strength by carbon-coating the sample. The copper cladded aluminium tubes which are excellent heat sinks can be fabricated using the process discussed in this paper, while keeping their weight to the minimum since no extra filler material is used in the discussed joining process [14].

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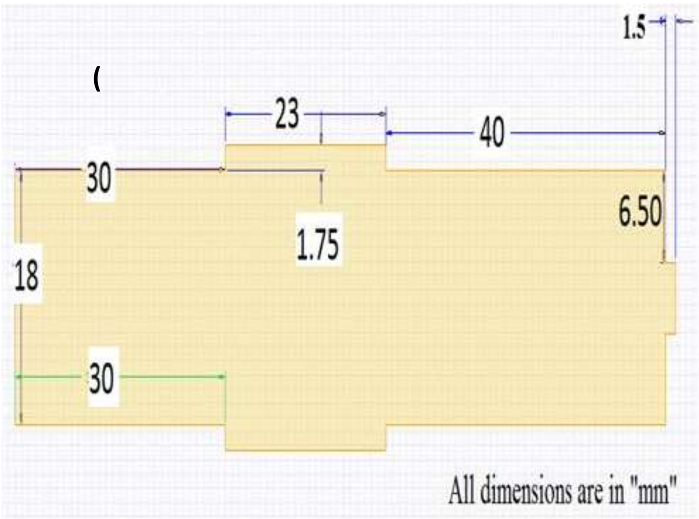
2. EXPERIMENTAL SET UP

There were two different base metals used: *Al-5052 H32* and *pure copper* for the sheets and foil to be joined using friction stir welding process. The thickness of each sheet of aluminium alloy was 1 mm while the thickness of the copper foil was 0.1 mm and hence, the total thickness soft hemulti lap joint was 2.1mm. The tool was made up of M2 (Molybdenum) H.S.S. (High Speed Steel). It also goes by the name 'tool steel' & is renowned material in tooling standards.

The tool material M2 HSS has much higher value of hardness, i.e., 60 HRC (Rockwell C Hardness) than that of Al-5052H32 that has a Brinell hardness of 60 and pure copper having a Rockwell Hardness (F-scale) of 54, even without the heat treatment. In order to keep the flexibility of the tool during its working while it is prone to shocks, it wasn't tempered. The chemical composition of the aluminium alloy used in the experimentation is specified in the following Table 1. The physical



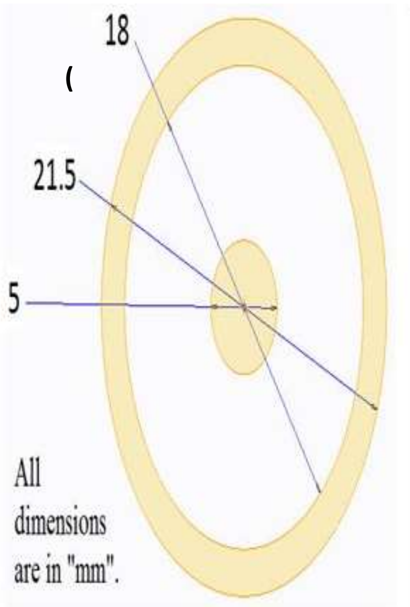


Figure1 (a) Side View of Tool; (b) Top View of Tool

Properties of the aluminium alloy, pure copper, and tool steel used in the experiment are mentioned in the following Table2.

Table1 Chemical Composition of Al5052-H32

Element	Mass
Mg	2.48%
Fe	0.3%
Cr	0.23%
Si	0.09%
Mn	0.03%
Cu	0.02%
Ti	0.02%
Al	Remaining (96.83%)

Table 2 Physical Properties of Al5052-H32, Pure Copper, and M2HSS

Material	Density	Melting Point
Al5052-H32	2.68g/cm3	607 °C-649 °C
Pure Copper	8.96g/cm3	1085 °C
M2 HSS	8.16g/cm3	1427 °C

Table3 Tool specifications

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Pin Parameters	Dimensions
Pin Height	1.5 mm
Pin Diameter	5mm
Shoulder Diameter	18 mm
Collet Size For Tool	18 mm
Total Length of the Tool	94.5 mm

The Vertical Milling Centre (VMC) was used for the friction stir welding of two sheets ofAl-5052H32 with a copper foiling the middle. Also a work table was mounted over the base of VMC for making the clamping of work-pieces easier. The design of experiment was established by referring Taguchi's L_9 approach and the parameters are listed in Table3:

Figure1 (a) Vertical Milling Centre; (b) Cast Iron Work Table

Table 3L-9 Orthogonal Array used in welding

Rotational Speed (RSM)	Traverse (mm/min)	Plunger Depth (mm)
700	5	0.1
700	10	0.2
700	15	0.3
800	5	0.2
800	10	0.3
800	15	0.1
900	5	0.3
900	10	0.1
900	15	0.2

Figure3 Welded joints at different parameters according to L-9 orthogonal array

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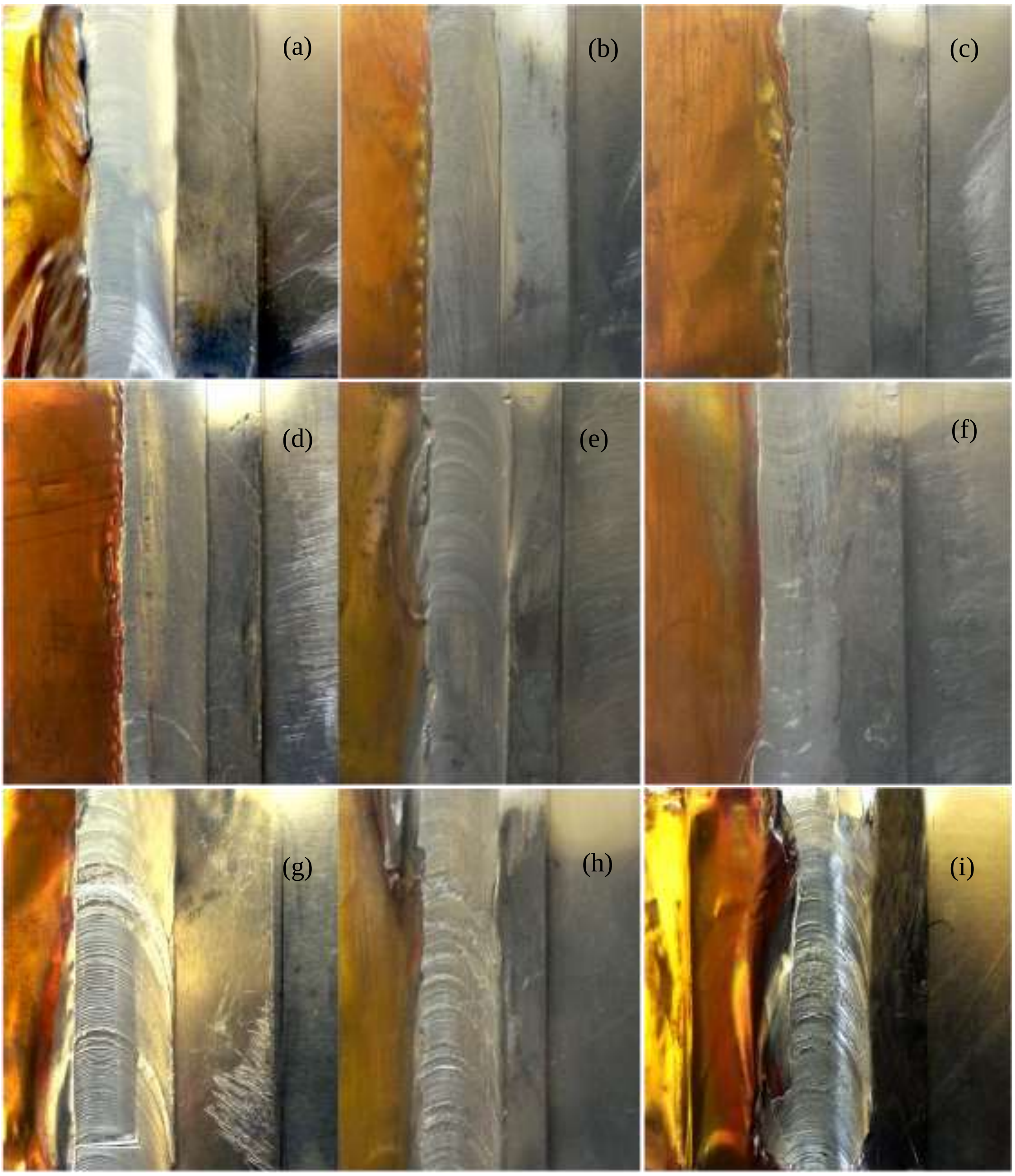

3. RESULTS AND DISCUSSIONS

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Fig. 3 shows the morphology of the welded specimens before shear test. The samples are free from defects and very smooth layer of welding was observed.

The values of 'Fracture Load' along with the visual appearance of joints after the friction stir welding of AlA-Cu-AlA for the parameters obtained by L9 orthogonal array are listed in the Table4.

Table 4 Fracture Loads for the F S Wed Samples

S. No.	Parameters	Sample For Shear Testing	Shear Fracture Load(N)
1	800 RPM; 5mm/mintraversespeed;0.2mmplungedepth		3177.459
2	800 RPM; 15 mm/mintraversespeed;0.1 plungedepth		2823.318
3	900 RPM; 10 mm/mintraversespeed; 0.1mmplungedepth		2819.394
4	800 RPM; 10 mm/mintraversespeed; 0.3mmplungedepth		2727.18
5	900 RPM; 15 mm/mintraversespeed; 0.2mmplungedepth		2442.69
6	700 RPM; 5 mm/mintraversespeed; 0.1mmplungedepth		2159.181
7	900 RPM; 5mm/mintraversespeed;0.3mmplungedepth		1799.154
8	700 RPM; 10 mm/mintraversespeed; 0.2mmplungedepth		1654.947
9	700 RPM; 15 mm/min traverse speed; .3 mm plunger depth		1617.669

The area of contact between the plates is same as the welded region in prepared sample for shear strength testing. Thus, Area = Diameter of tool shoulder * Width of sample = 0.018m * 0.04 m = 7.2 * 10^{-4} Also, ultimate shear strength (MPa) = maximum load of fracture (N) /contact area (m^2). Hence, the values for the ultimate shear strength are given in Table5.

Table5 Ultimate Shear Strength Values For The F S Wed Samples

S. No.	Parameters for AlA-Cu-AlA Joint (Tool Rotation Speed in RPM; Traverse Speed in mm/min; Plunger Depth in mm)	Maximum Shear Load (N)	Ultimate Shear Strength(MPa)
1	800;5;0.2	3177.459	4.413
2	800;15;0.1	2823.318	3.921
3	900;10;0.1	2819.394	3.915
4	800;10;0.3	2727.18	3.787
5	900;15;0.2	2442.69	3.392
6	700;5;0.1	2159.18	2.998
7	900;5;0.3	1799.154	2.498
8	700;10;0.2	1654.947	2.298
9	700;15;0.3	1617.669	2.246

The highest ultimate shear strength came out to be 4.413 MPa in the case of AlA-Cu-AlA joint with the parameters: 800 rpm, 5 mm/min traverse and 0.2mm plunge depth. For the same parameters, the ultimate shear strength came out to be even higher as in the case of AlA-AlA joint having the ultimate shear strengthas5.955 MPa. Moreover, the second highest value of the ultimate shear strength came out to be 3.921 MPa, in case of AlA-Cu-AlA joints at the parameters: 800 rpm, 15 mm/min traverse and 0.1 mm plunge depth. For the same parameters, the ultimate shear strength for the AlA-AlA joint came out to be 4.922 MPa.

The SEM (Scanning Electron Microscope) images obtained for the AlA-Cu-AlA sample welded at 800 rpm tool rotation speed, 5 mm/min tool traverse speed and with a plunge depth of 0.2 mm are given below:

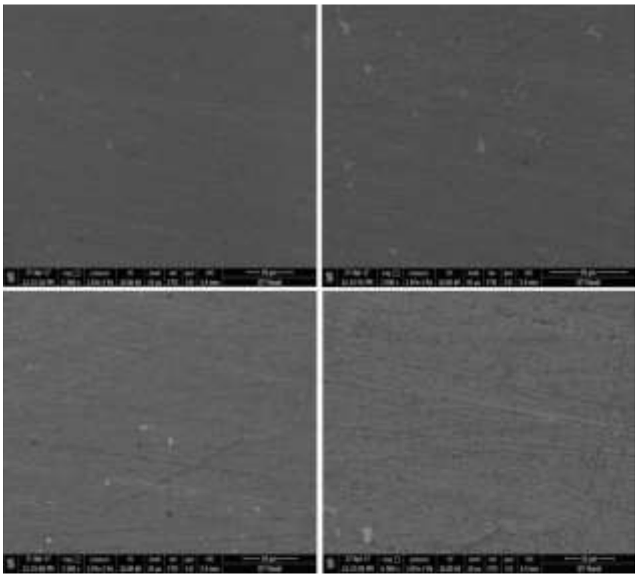
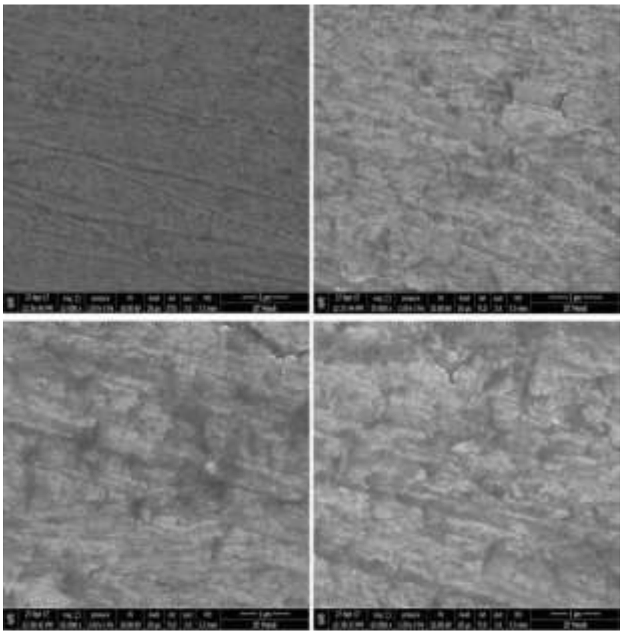


Figure4 Microstructure of Welded joints at different parameters according to L-9 orthogonal array



4. CONCLUSIONS

Following conclusions are drawn from the present investigation:

- The friction stir lap welded bond of AlA-AlA always has ultimate shear strength higher than the AlA-Cu-AlA F S Wed lap joint for the same parameters.
- For the thin sheets, clamping is vital because otherwise the sheets may bend under the heavy loads.
- All the factors: plunge depth, tool rotational speed and the traverse speed play a very significant role in the surface as well as the strength of the joint.
- In case of thin sheets of AL5052, lower values of tool rotational speed cause the material not to plastic properly and thus making a weak and irregular joint while the higher values of tool rotational speeds burnt he work-piece material and cause tunneling defects.

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