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ELECTRICAL BEHAVIOUR OF ALUMINIUM AND COPPER BIMETALLIC JOINT USING FRICTION STIR SPOT WELDING

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ABSTRACT

Solid state welding processes are superior to fusion welding in the sense that they are free from temperature effects and some welding defects. Bimetallic joints are mainly preferred to reduce cost and ease of manufacturing. FSSW process finds its extensive applications in many industrial sectors where self weight is considered as a predominant factor such as automotive, airplanes etc. In this investigation, aluminum alloy (AA6061) and copper alloy bimetallic joint is tested for its electrical resistivity and mechanical strength.

Keywords: *Friction Stir Spot Welding, Al-Cu bimetallic joints and Electrical resistivity*

1. Introduction

Although many metal joining processes are available in the industry, it is difficult to join dissimilar metals because of the defects and challenges available. However, light weight metal like aluminium has got many bundles to be welded with other metal. Starting from traditional riveting to spot welding (resistance, laser) posses many defects such as welding distortion, poor quality of weld, porosity at the weld interface, tool damage etc. Friction stir spot welding is an efficient method to make bimetallic joint for its advantages such as high strength, good bonding and excellent mechanical behavior. A rotating non consumable tool is in contact with the metal piece and high forging force is applied on the metallic lap interface.

2. Literature review

The effect of electrical properties of Cu-Al friction welded joint was investigated by Won-Bae-Lee et al [2&3] and concluded as the resistivity increases with the increases in thickness of bimetallic compound layers from 45μΩcm to 85μΩcm (21 to 107μm thickness). The influence of annealing was also to be pointed in this investigation. Weld nugget pull out failure was observed as the major cause of failure in the AA2024 Al alloy as investigated by Karthikeyan and Balasubramanian [6]. In an investigation by Yan et al. [7] there was plastic ring region, TMAZ, HAZ. In the paper titled characterization of dissimilar joints in laser welding by T.A. Mai et al. [1] reported that free porosity defects were difficult to be eliminated.

Peng-liu et al. [4&5] concluded that in weld joints of Cu (T2) and Al alloy (5A06), high quality weld joint could be obtained when tool rotational speed was 950 rpm and tensile strength was 296 Mpa. In the study of intermetallic compounds at Al to Cu electrical interfaces (IEEE), contact resistance varied directly with thickness of the intermetallic. The morphology of the intermetallic phase changes with different current intensities (400-1000 A). A comparison between annealing interface and electrical current flow was made and influence of current was found greater.

3. Experimental Details

3.1 Mechanical Joint fabrication

Lap joints with the length of 90mm and width of 25mmof the AA6061 Al alloy (1.6 mm thick) and pure copper sheet of (1.6mm thick). Before welding, the specimens should be cut with shear off machine and surface grounded to remove unwanted layers of oxides and formed scales. The properties of base alloys is follows Cu (90.73% Cu, 9.15%Zn,0.01%Ti, 0.02% k) and Al (0.25% Zn, 0.15&Ti, 0.7%Fe, 0.15%Cu, 0.33% mm, 0.53% Si, 0.69% Mg, 95.8%Al).

A special tool with HSS was used. The dimension of tool is major diameter 15mm, minor diameter 8mm, pin diameter 3mm, pitch 0.8mm where pitch metric left hand thread. HURCO UM*42 with 12000 rpm, 18KwCNC, FSW machine was used to make the joint.

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Process parameters selected were:

i. Tool rotational speed
ii. Plunge rate
iii. Dwell time

Trails were made to achieve good process conditions. Material properties such as Yield strength, Tensile strength, percentage elongation, hardness and density values were tabulated in Table 1.

Table 1 Mechanical properties of dissimilar metals

Alloy	0.2%Yield Strength (MPa)	Tensile Strength (MPa)	Elongation in 50mm gauge length (%)	Hardness at 0.5 kg (Hv)	Density of metal (Kg/m ^3)
Copper	220	268	28	297	8960
AA6061	276	310	12	107	2700

The different parameters such as Tool rotational speed in RPM, Dwell time in seconds, and plunge rate in mm/min were tabulated in Table 2.

Table 2 Process parameters for welding

Trial no	Tool rotational Speed	Dwell time	Plunge rate	Photo
	RPM	Sec	mm/min	
1	1600	10	3	
2	1800	15	5	
3	2000	20	7	

The FSSW lap welded specimens for different trials were shown in the photograph In Fig.1.

3.2 Electrical Testing

For different tool rotation speeds, plunge and dwell time, totally twenty-seven specimens were testes for resistivity and conductivity with different polarities. Table 3 shows the test results.

Fig. 1 Photograph of the welded Joints

Table 3 Electrical resistance of joint

Sample no	Speed	Plunge rate	Dwell time	Resistivity (10^3ω)		Average	Conductivity (10^2)
	Rpm	mm/min	Sec	Polarity 1	Polarity 2	Ω	S/m
1	1600	3	10	11	18	14.5	6.89
2	1600	5	10	13	18	15.5	6.45
3	1600	7	10	12	19	15.5	6.45
4	1600	3	15	15	30	22.5	4.4
5	1600	5	15	14	22	18	5.55
6	1600	7	15	14	48	31	3.22
7	1600	3	20	16	16	16	6.25
8	1600	5	20	12	12	12	8.33
9	1600	7	20	13	13	13	7.69
10	1800	3	10	11	44	27.5	3.63
11	1800	5	10	12	33	22.5	4.4
12	1800	7	10	13	13	13	7.69
13	1800	3	15	11	36	23.5	4.25
14	1800	5	15	15	22	18.5	5.4
15	1800	7	15	11	32	21.5	4.65
16	1800	3	20	18	33	25.5	3.92
17	1800	5	20	12	15	13.5	7.4
18	1800	7	20	11	25	18	5.55
19	2000	3	10	12	23	17.5	5.71
20	2000	5	10	18	40	29	3.48
21	2000	7	10	12	12	12	8.33
22	2000	3	15	20	35	27.5	3.63
23	2000	5	15	11	30	20.5	4.87
24	2000	7	15	11	27	19	5.26
25	2000	3	20	12	18	15	6.66
26	2000	5	20	17	27	22	4.54
27	2000	7	20	19	39	29	3.44

For different speeds, the variation in conductivity with respect to dwell time as a parameter**,** a graph was plotted and shown in Fig.2.

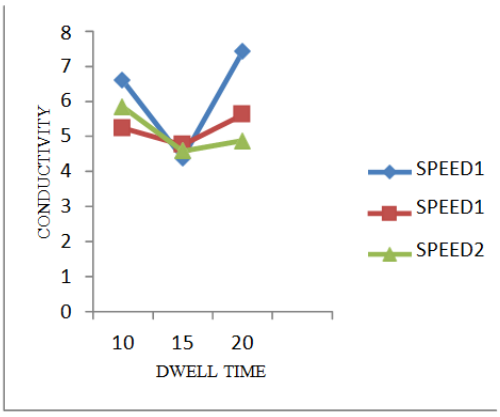

Fig. 2 Dwell time vs conductivity

For different speeds, the variation in conductivity with respect to plunge rate as a parameter, a graph was plotted and shown in Fig.3.

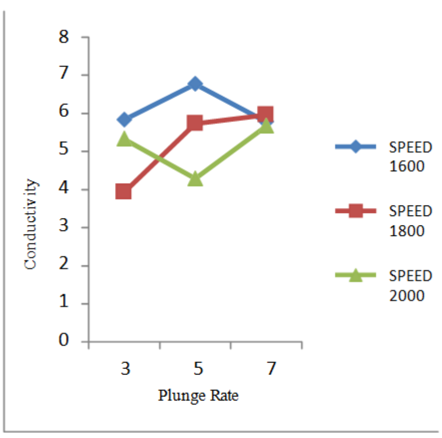

Fig. 3 Plunge rate vs. conductivity

4. Analysis

The following images were the results of the Joint Interface at different process parameters taken by Scanning Electron Microscope.

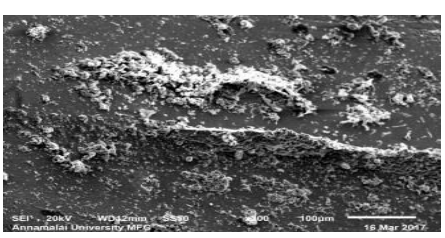

Fig.3.1.SEM Image I

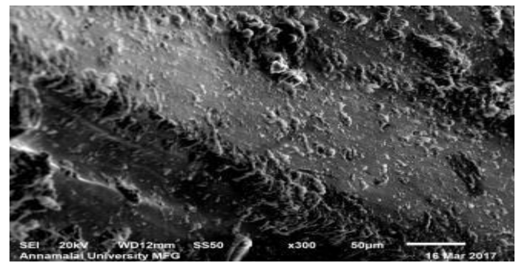

Fig.3.2.SEM Image II

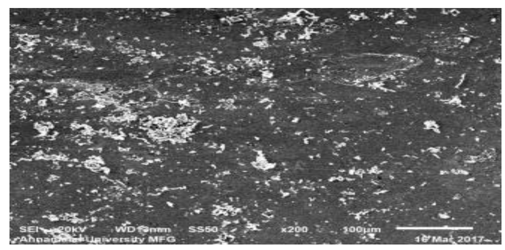

Fig.3.3.SEM Image III

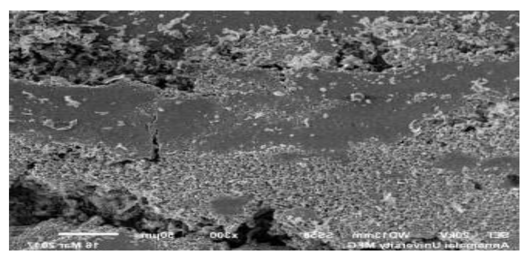

Fig.3.4.SEM Image IV

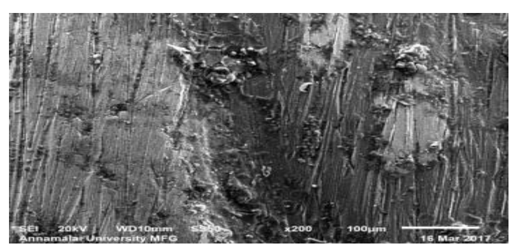

Fig.3.5.SEM Image V

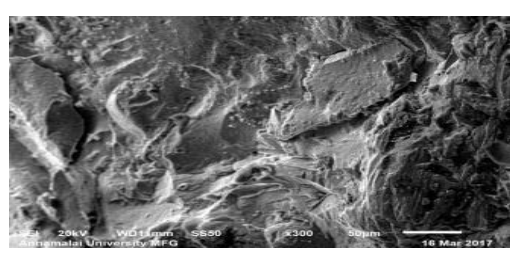

Fig.3.6.SEM Image VI

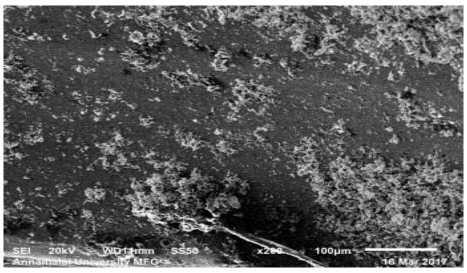

Fig.3.7.SEM Image VII

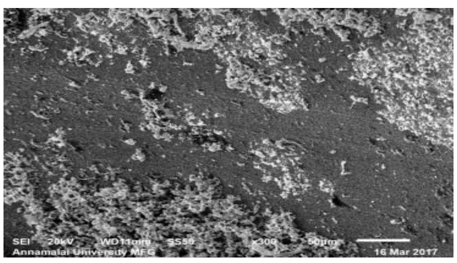

Fig.3.8.SEM Image VIII

In Fig 3.1., the SEM image magnified in the scale 100 nanometer, shows the bonding and particle distribution of Al and Cu. Fig.3.2., shows the tool patterns magnified by 50nm and it is seen that there is micro chip formation. In Fig.3.8, there is distribution of aluminium as spots of particles on the copper metal. In Fig 3.4, 3.5 & 3.6, the micrograph shows the failure region at the joint interface. Fig 3.7 & 3.8 clearly shows that dispersion of aluminium on the copper due to penetration of pin tool.

Fig. 2 and Fig. 3 Graph shows that both at 1600 rpm and 1800 speed, the conductivity is maximum (8.33).

5. Results

- **i.** For 1600 rpm speed and the plunge rate of 5mm/min the resistivity of the Joint is 6.77Ω
- **ii.** For 1600 rpm speed and the dwell time of 20 sec the resistivity is 7.42Ω
- **iii.** For 1800 rpm speed and the plunge rate of 7mm/min the conductivity is 5.96Ω
- **iv.** For 1800 rpm speed and the dwell time of 20 sec the resistivity is 7.42Ω
- **v.** For 2000 rpm speed and the plunge rate of 7mm/min the resistivity is 5.67Ω
- **vi.** For 2000 rpm speed and the dwell time of 20 sec the resistivity is5.84Ω

6. Conclusion

It is evident that that there is no significant change in resistivity of Cu-Al Joint at various process parameters. The resistivity varies in the range of 5 to 8 ohms. Since the change in electrical conductivity is not significant, the Copper and Aluminium Joint can be recommended for Electrical circuits where light weight applications are preferred. Also, this is very economical too. Hence it is highly recommended for Electrical connections and earth cabling of Air buses and moving objects to reduce self weight by replacing copper with aluminium.

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