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Effect of Traverse Force and Temperature variation during FSW

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ABSTRACT

Friction Stir Welding (FSW) is an effective technique to join similar/dissimilar materialsin solid state, i.e. aluminum to copper. FSW process parameters and welding strategy influence the temperature and different forces encountered during the joining. Temperature generationand traverse force are required to be controlled in order to achieve satisfactory joint quality. In this paper, the effect of temperature and traverse force during joining of Al-6101 and pure copper is studied by varying the rotational speed at three different levels keeping the other process parameters constant. The traverse force and temperature during joining are observed and related to the joint quality. From the present study, it is found that the heat ratio significantly affects the temperature and traverse force during the welding.

Keywords: Friction stir welding (FSW), Temperature, Traverse Force, Tool

I.INTRODUCTION

Copper (Cu) due to its higher electrical conductivity and strength is widely used in electrical industry. However, copper is a costly and dense material, so the components made by using Cu are heavier and costly. Aluminum (Al) alloys are lighter and cost-effective than Cu and some Al alloys are also electrically conductive so the partial replacement of Cu with such Al alloys can make the lighter and cost-effective electrically conductive components [1, 2]. Al-Cu aredifficult to join due to wide difference in their mechanical, thermal and electrical properties. Conventionally these are joined using fusion welding techniques but such processes results in various welding defects due to melting and solidification of the base materials [3, 4]. FSW being a solid state joining process is able to eliminate the inbuilt problemsof the fusion welding processes [5-7]. A cylindrical tool is a main element to perform the FSW which consist of two parts, i.e., shoulder and pin. During FSW the rotating tool is inserted inside the base materials and allowed to travel along the joint line. The tool movement inside the base material creates the required frictional heat for plastically deforming the base materials and the deformed materials gets coalesces at the back of the tool in solid state [8-10]. FSW processeliminates the various welding defects found during fusion welding such as porosity, cracks, slag inclusion etc. [11]. FSW is able to join similar and dissimilar materials, i.e., Al to Mg, Al to steel, and Al to Cu. FSW process parameter and strategy affects the jointquality such as tooldesign and geometry, tool offset, tilt angle, plunge force, base metal positioning, rotational and welding speed etc. [12-15]. The different forces and temperature during joining also get influenced by the FSW process parameters. Researchers have studied the variation of traverse force during FSW and have reported that the axial and traverse force increases with the increment in traverse speed [16]. It has been also reported that the traverse speed majorly influences the traverse force rather than axial force [17]. The dissimilar joining of different materials has been studied by many researchersbut limitedliterature is available on joining of electrical grade Al with Cu [18, 19].Also,the combinedvariation of force and temperaturestudiesin literature is lacking. To fill this gap, the present study has been conducted to join electrical grade Al to Cu and the variation of traverse force and temperature generation during FSW with different rotational speed is studied.

II. EXPERIMENTAL WORK

The base materials used during thestudy are Al-6101 and commercially pure Cu2.8 mm thickness, 195 mm length, and 37 mm width. The butt joining of the base materials are performed using H13 hot die steel tool material. H13 tool steel possesseshigh-temperature stability, high strength and wears resistance. The chemical composition, mechanical and thermal properties of the base and tool materials aregiven in Table 1**.**

Table 1. Chemical composition (wt%) of Al-6101, pure Cu, tool material and their mechanical and physical properties

Chemical Composition of Al-6101 alloy (wt%)								
B	Cr	Cu	Fe	Mg	Mn	Si	Zn	Al
0.05	0.009	0.038	0.260	0.68	0.029	0.404	0.054	Balance

Chemical Composition of pure Cu (wt %)									
Sn	Fe	P	Ni	Co	Ag	Zn	Pb	Others	Cu
0.04	0.001	0.043	0.24	0.001	0.018	0.012	0.003	<.001	99.65

Composition of H13 hot die steel tool (wt%)										
C	Mn	Si	Cr	Ni	Mo	V	Cu	P	S	Iron
0.32-0.45	0.20-0.50	0.80-1.20	4.75-5.50	0.3	1.10-1.75	0.80-1.20	0.25	0.03	0.03	Balance

Physical and Mechanical properties of base materials (BM)			
	Density (g/cm^3)	Thermal Conductivity (W/mK)	Melting Point (^{0}C)
Al-6101	2.7	218	588
Pure Cu	8.96	385	1083

A robust vertical milling machine is modified by attaching a specially developed tool adapter and work fixture for performing the FSW. The tool and workpiecesare securely heldon tool adapter and work fixture respectively for joining. FSW tool of shoulder diameter 16 mm, pin diameter 5 mm andpin length 2.5 mmwas used during joining. The base metal Al and Cu were placed and retreating side (RS) and advancing side (AS) respectively and a pin offset of 0.5 mm and a tilt angle of 2^0 was maintained. The combined effects of tool rotational (ω) and welding speeds (v) temperature generated during FSW are studied by the heat ratio (ω^2/v). Table 2 shows the levels of process parameters and heat ratio used during theexperiment. The combined effects of tool rotational (ω) and welding speeds (v) temperature generated during FSW are studied by the heat ratio (ω^2/v). The heat ratio is divided by 1000 to make the digit smaller.

Table 2: FSW parameters and their levels

Exp. No.	Shoulder Diameter	Pin Offset	Welding Speed	Rotational Speed	Heat Ratio
1	16	0.5	50	710	10.82
2	16	0.5	63	900	12.85
3	16	0.5	80	1120	15.68

The traverse force applied to the FSW tool during FSW was measured using a load cell and thetemperature was measured using a K-Type thermocouple. Six thermocoupleswas inserted into the base materials at AS and RS as shown in Fig.1.

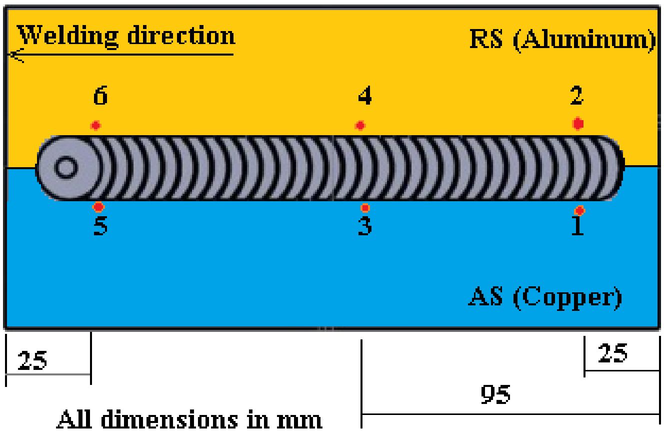


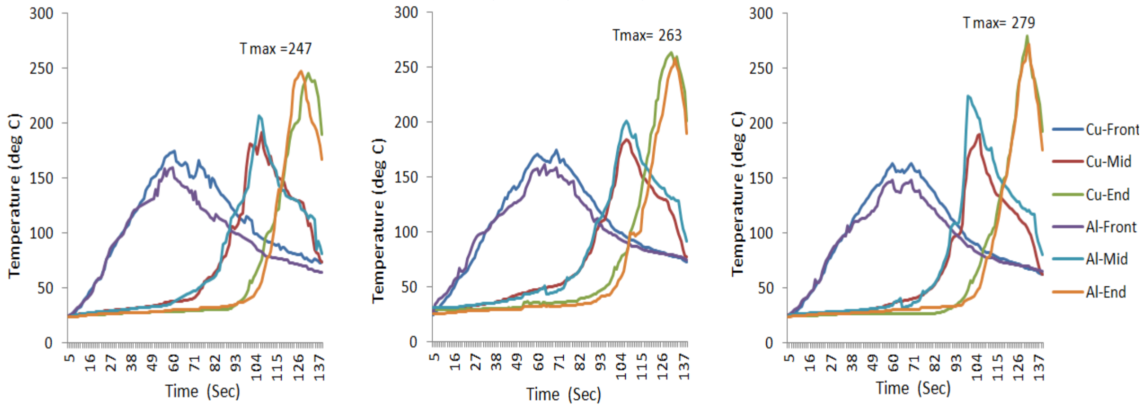
Figure 1. Positions of inserted Thermocouples

III.RESULTS AND DISCUSSION

The following sections describe the analysis ofthe temperature and force values observed during the joining process in different process parameters combinations.

3.1Temperature variation under the influence rotational and welding speed during FSW

Temperature variation profile and the maximum value of temperature during joining of all three specimens are shown in Fig.2.



(a) ω:710; *v:50* (b) ω:900; *v:63* (c)ω:1120; *v:80*

Tmax247 263 279

Figure 2: Temperature variation at during FSW

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Fig. 2 illustrates the variation of temperature during joining along the traverse direction. The temperature at each location of thermo-couple reaches to its peak value when the tool passes near from the thermocouple. After the travel of the tool from the thermocouple location, the rate of heat dissipation becomes larger than the frictional heat input thus the temperature starts to drop. The heat dissipation after the passing of the tool increases due to the increment in heat conduction distance of the tool and stir zone till the thermocouple. Also after passing of the tool from the thermocouple location the temperature gradient decreases thus the heat input also decreases and results in adecrement of the thermocouple temperature. Due to the high thermal conductivity of the base material Cu which was placed at advancing side shows the maximum temperature in all the thermo-couples during joining in all joints. On the advancing side material (Cu), the peak temperature values observed was at near the end of the joint as 247, 263, and 279 at the heat ratio of 10.82, 12.85, 15.68 respectively. The at the retreating side the temperature values was lesser due to the lower thermal conductivity of the base material Al-6101 (as shown in Table 1). From Fig. 2, it is clear that the higher heat ratio in the main factor for the increment of the peak temperature. The temperature is found to be maximum at highest rotational speed and traverse speed.This maximum temperature at this parameter combination can be anticipated as in this experiment maximum heat was developed leading to intense plastic deformation.

3.1 Traverse force variation under the influence rotational and welding speed

The variation in traverse force applied on the tool during FSW while tool travels in all the three experiments are depicted in Figure 3. The values depicted in the traverse profile are from the starting of the welding speed.As the joining starts the traverse force increases due to the force exerted by the FSW tool traverse speed.At starting of the traverse speed the process is slightly unstable (high peak and low values of traverse force) because of the variation in the traverse force and after some time the curve falls down (lower traverse force) and reaches the stable state. Any further movement of the tool causes a gradual rise in the traverse force mostly and the force again stabilizes after some distance at a respective value It is clear from the Fig.3., that the traverses force is dominantly affected by the traverse speed than rotational speed [20].

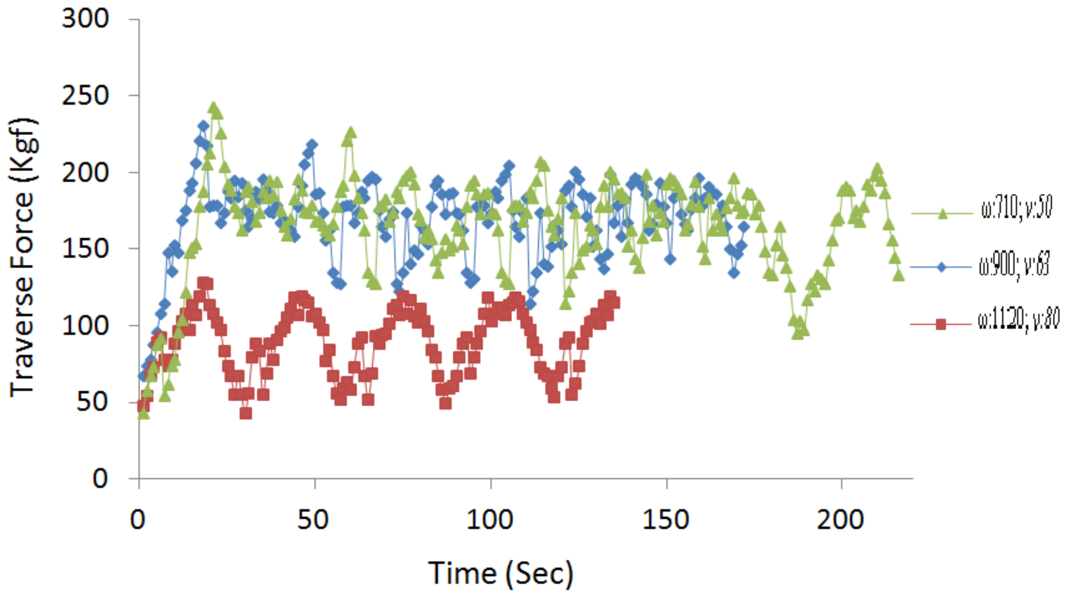

Figure 3: Traverse force variation during FSW

The traverse force depends on the flow strength/stress of the material which is linked with the temperature produced during the welding. Traverse force increases with a decrease in temperature due to increase in flow stress of the material and vice versa.From Fig. 3 it is evident that higher heat ratio creates the larger traverse force .The maximum traverse force was obtained at rotational speed of 700 rpm and welding speed of 50 mm/min during experiment due to lower value of heat ratioand less plastic deformation leading to reduction in temperature and enhancement in the flow stress of the material.

IV.CONCLUSIONS

It is observed from the present study that the FSW can efficiently join the dissimilar materialsthe dissimilar butt joining of as Al 6101 with pure Cu was successfully performed. TheFSW temperature and traverse force is correlated with the rotational and welding speed of the FSW tool. The followings are the results interpreted from the present study.

1. Temperature increase till the tool comes in thevicinity of the thermocouple and after reaching a peak it starts to decreases.
2. Higher heat ratio increases the temperature to maximum level during FSW.
3. The maximum peak temperature occurs in the advancing side Cu due to its higher thermal conductivity.
4. The traverse force is dominantly affected by the rotational and traverse speed.
5. The higher flow stress due to low heat ratio occurring at lower rotational and traverse speed increases the traverse force.

REFERENCES

[1] H. Singh, H.S. Arora, Friction stir welding - technology and future, in: Natl. Conf. Adv. Futur. Trends Mech. Mater. Eng., 2010: pp. 32–38.

[2] M. Sahin, Joining of aluminium and copper materials with friction welding.the International Journal of advanced Manufacturing technology, 49, 5 (2010) 527-534.

[3] M. Braunovic, N. Aleksandrow, Effect of Electrical Current On the Morphology and kinetics of Formation of Intermetallic Phases in Bimetallic Aluminium-Copper joints, in: Proc. Thirty-Ninth IEEE Holm Conf., IEEE, 1993: pp. 261–268.

[4] N. Sharma, A.N. Siddiquee, Z.A. Khan, Friction Stir Welding Defects in Aluminum to Copper Joining- An Overview, journal of manufacturing technology research, volume 9, issue 1-2, issn1943-8095

[5] J.P. Bergmann, F. Petzoldt, R. Schürer, S. Schneider, Solid-state welding of aluminum to copper — case studies, Weld. World. 57 (2013) 541–550. doi:10.1007/s40194-013-0049-z.

[6] H. Okamura, K. Aota, Joining of dissimilar materials with friction stir welding, Weld. Int. 18 (2004) 852–860. doi:10.1533/wint.2004.3344.

[7] T. K. Bhattacharya, H. Das, S. S. Jana, & T. K. Pal, Numerical and experimental investigation of thermal history, material flow and mechanical properties of friction stir welded aluminium alloy to DHP copper dissimilar joint. The International Journal of Advanced Manufacturing Technology, 88(1-4),2017, 847-861.

[8] R.S. Mishra, Z.Y. Ma, Friction stir welding and processing, Mater. Sci. Eng. R Reports. 50 (2005) 1–78. doi:10.1016/j.mser.2005.07.001.

[9] R. Nandan, T. Debroy, H.K.D.H. Bhadeshia, Recent advances in friction-stir welding – Process , weldment structure and properties, Prog. Mater. Sci. 53 (2008) 980–1023. doi:10.1016/j.pmatsci.2008.05.001.

[10] B.T. Gibson, D.H. Lammlein, T.J. Prater, W.R. Longhurst, C.D. Cox, M.C. Ballun, K.J. Dharmaraj, G.E. Cook, A.M. Strauss, Friction stir welding: Process, automation, and control, J. Manuf. Process. (2013) 1–18. doi:10.1016/j.jmapro.2013.04.002.

[11] K. Savolainen, J. Mononen, T. Saukkonen, H. Hänninen, A Preliminary Study on Friction Stir Welding of Dissimilar Metal Joints of Copper and Aluminum, in: 6th Int. Frict. Stir Weld. Symp., 2006: p. 79.

[12] T. Debroy, H.K.D.H. Bhadeshia, Friction stir welding of dissimilar alloys – a perspective, Sci. Technol. Weld. Join. 15 (2010) 266–270. doi:10.1179/174329310X12726496072400.

[13] N. Sharma, A.N. Siddiquee, Z.A. Khan, T. Mohsin, Material stirring during FSW of Al-Cu : Effect of pin profile, Mater. Manuf. Process. 33 (7), 786-694, 2017. doi:10.1080/10426914.2017.1388526.

[14] T. Saeid, A. Abdollah-zadeh, B. Sazgari, Weldability and mechanical properties of dissimilar aluminum – copper lap joints made by friction stir welding, J. Alloys Compd. 490 (2010) 652–655. doi:10.1016/j.jallcom.2009.10.127.

[15] K.P. Mehta, V.J.Badheka, Influence of tool design and process parameters on dissimilar friction stir welding of copper to AA6061-T651 joints. The International Journal of Advanced Manufacturing Technology, 80(9-12),2015, 2073-2082.

[16] Muthukumaran, S., and S. K. Mukherjee. "Multi-layered metal flow and formation of onion rings in friction stir welds." *The International Journal of Advanced Manufacturing Technology*38, no. 1-2 (2008): 68-73.

[17]Buchibabu, V., G. M. Reddy, and A. De. "Probing torque, traverse force and tool durability in friction stir welding of aluminum alloys." *Journal of Materials Processing Technology*241 (2017): 86-92.

[18] N. Sharma, Z.A. Khan, A.N. Siddiquee, Friction stir welding of aluminum to copper — An overview, Trans. Nonferrous Met. Soc. China. 27 (2017) 2113–2136. doi:10.1016/S1003-6326(17)60238-3.

[19] M.A. Wahid, A.N. Siddiquee, Z.A. Khan, M. Asjad, Friction Stir Welds of Al Alloy-Cu: An Investigation on Effect of Plunge Depth, Arch. Mech. Eng. 63 (2016) 619–634. doi:10.1515/meceng-2016-0035.

[20] Atharifar, Hosein, Dechao Lin, and Radovan Kovacevic. "Numerical and experimental investigations on the loads carried by the tool during friction stir welding." *Journal of Materials Engineering and Performance* 18, no. 4 (2009): 339-350..