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Effect of Welding Parameters on Friction Stir Welded AL64430 and PURE COPPER

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ABSTRACT
Modern structural applications demands reduction in both the weight and as well as cost of the fabrication and production of materials. Aluminium alloys are the best choice for the reduction of weight, cost and replacing steels in many applications. Copper–aluminium joints are inevitable for certain applications due to unique performances such as higher electric conductivity, heat conductivity, corrosion resistance and mechanical properties. Friction welding is the most common method used due to material and energy saving. The joining of dissimilar materials by conventional fusion welding is difficult because of the poor weld ability arising from the different chemical, mechanical, and thermal properties of welded materials and the formation of hard and brittle inter metallic compounds. FSW is solid state welding process in which material is not melted during welding process so it overcomes many welding defects compared to conventional fusion welding process which is initially used for low melting materials. Present investigation is carried on two dissimilar AL 64430 & PURE COPPER metals of 6mm thickness using various parameters like tool pins, tool rotational speed and welding speed. Experiments are carried out, defects and strength of the joints are analysed through tensile test, hardness test, micro structure examination through scanning electron microscope (SEM) and EDS analysis is carried out to find the chemical composition of welded joints. Results are obtained and summarised.

KEY WORDS
Ultimate tensile strength, yield strength, hardness, welding quality, process parameters, diagrams, graphs, tests to measure welding quality

1. INTRODUCTION
Copper and aluminium are widely applied in engineering structure due to unique performances such as higher electric conductivity, heat conductivity, corrosion resistance and mechanical properties. However, the melting points of both materials have a significant difference (nearly 400 °C). This may lead to a large difference in microstructure and performance of Cu–Al joints if copper and aluminium would be joined. Moreover, the Al was easily oxidized at an elevated temperature, and some welding cracks existed easily in a joint of brazed or fusion welding Cu . Therefore, a high quality weld joint of Cu/Al was difficult to obtain by means of conventional welding methods. During fusion welding or pressure welding (brazing, diffusion bonding, etc), the Cu-Al intermetallic, which resulted in decreased mechanical properties of joints, is very difficult to be avoided in Cu/Al dissimilar materials joint. Dissimilar materials like Cu-Al have special properties such as good thermal and electrical conductivities. Therefore, it can be applied for applications such as bus-bars, connectors, foil conductors of transformers, windingsof capacitors and condensers, refrigeration and heat-exchangers tubes, etc. At present, many researchers are performing research on Cu-Al FSW. Most of the available articles of this system elucidate the effect of process parameters on properties of joint. Somepapers are also covering IMCs mechanisms and its influences on mechanical properties. It has been found that, very few articles areavailable in the area ofinfluence of tool design on formation of defects for dissimilar Cu-Al FSW system. The defects formation is major factor in dissimilar joints because of its differences in properties.

Defects such as cracks and voids generally occur due to fragments of Cu particles. Additionally, defects such as tunnel defects, kissing bond, oxide entrapment, pores and flash effect were reported in FSW technology due to imbalance in parameters. FSW tool plays a major role to obtain quality joint. It is mandatory to see the effect of tool design on formation of defects in dissimilar FSW system. Therefore, in the present study, the effects of polygonal tool pin profiles along with different cylindrical pin designs on formation of defects were investigated in dissimilar Cu-Al FSW. Copper and aluminium have been widely applied as engineering structure materials due to their good comprehensive properties such as excellent corrosion resistance, ductility, heat and electric conductivity. Recently, joining dissimilar materials such as aluminium and copper is of great interest in engineering applications because of their technical and beneficial advantages. Composite structure composed of aluminium and copperwill contribute to mass and cost reduction by decreasing the amount of precious metals usage. However, due to great difference in their physical and chemical properties, the dissimilar combination of copper and aluminium is generally more difficult. Various welding methods, including fusion welding, braze welding and pressure welding, have been applied to joining Al−Cu dissimilar materials but many problems occurred such as oxidation, cavities and cracks.

2. MATERIALS AND CHEMICAL COMPOSITION

Material used for friction stir welding was commercially available 99% copper. Copper is widely used in the electrical industry and refrigeration and air-conditions plants. The properties of copper are shown in table 1. These properties show its versatility among the engineering material. Aluminium 64430 is a wrought aluminium which is made of casting process it is an alloy of aluminium family. The chemical composition of Al 64430 is shown in table 2. Tool used for friction stir welding is made of ASTM A681 Grade – H42 having a pin of desired length which is to be inserted to the abutting edges of metal pieces. Description of tool material shown in table 3.

Table 1: Chemical composition of pure copper

Cu%	Pb%	Bi%	Total impurities
99.9	0.003	0.001	ZERO

Table 2: Chemical Composition of AL-64430

Cu%	Mg%	Si%	Fe%	Mn%	Zn%	Cr%	Ti%	AL%
0.001	0.909	0.949	0.145	0.628	0.004	0.002	0.017	97.345

Table 3: Chemical Composition of Tool

C%	Mn%	Si%	S%	P%	Cr%	V%	W%	Mo%
0.69	0.27	0.31	0.009	0.019	3.84	2.19	5.53	5.03

3. EXPRIMENTAL PROCEDURE

The plate size of Al64430 and pure CU having 75mm length 100mm width and 6mm thickness. The edges are smoothed using shaper machine and clamped to the bed of the welding machine. The welding has carried between the rotational speed of 800 to 1000 rpm with difference of 50rpm at feed rate of 10mm/min and 12mm/min. In this process 2 super high speed steel tools are used. Table 3.1 shows the measurements of both the tools. Figures of 2 tools and experimental set up were shown in fig 3.2 and 3.3. Totally 10 experiments are being carried out with different tool pin designs by changing rotation speed and welding speed. Table 3.2 shows the experiments carried out.

Tools used	Shoulder diameter	Pin diameter	Pin length	Threaded orientation
Straight circular threaded tool	18mm	6mm	5.7mm	Anti-clock wise direction
Taper circular threaded tool	18mm	5mm	5.7mm	Anti-clock wise direction

Table 3.1 shows the measurements of straight circular threaded tool and taper circular threaded tool

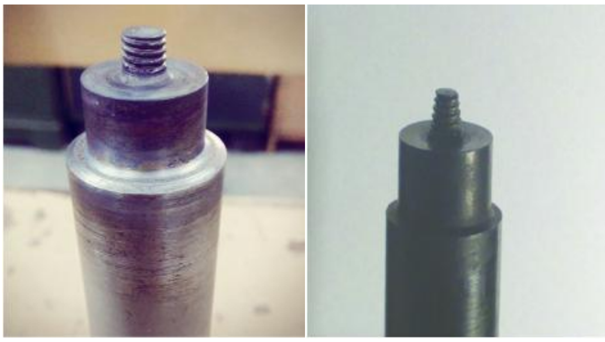

Fig 3.1 shows the straight circular threaded and taper circular threaded tools

TOOL USED	TOOL ROTATIONAL SPEED (rpm)	WELDING SPEED (mm/min)
TAPERED CIRCULAR THREADED	800	10
	850	12
	900	12
	950	12
	1000	12
STRAIGHT CIRCULAR THREADED	800	10
	850	12
	900	12
	950	12
	1000	12

Table 3.2 shows the list of total experiments conducted

Fig 3.2 Fig shows the experimental setup and welded joint

Tensile and hardness tests are conducted, and fractorography analysis is carried out on Scanning Electron Micro scope with various magnifications and EDS analysis is carried out to know the chemical composition of the welding joint.

4. RESULTS AND DICUSSIONS

Welds are obtained according to the experimental design. Among the different parameters only 2 welds are obtained defect free i.e. at 900rpm at welding speed of 12mm/min for each tool pin design and other joints are formed with defects like cracking, surface tunnelling and voids. These are formed due to the lack of heat input and improper stirring. During FSW process the materials are transported from advancing side to retreating side behind the rotating pin. Obtained defect free joints are cut into required dimensions of tensile specimen, hardness specimen and fractograpy specimen for testing and analysis. Fig 4.1 shows the extraction of specimen from the welded joint. Defects like voids, surface tunnelling and surface cracking was obtained due to insufficient supply of heat input and improper stirring of materials in this process parameters like tool pin design, welding speed and rotational speed plays an important role.

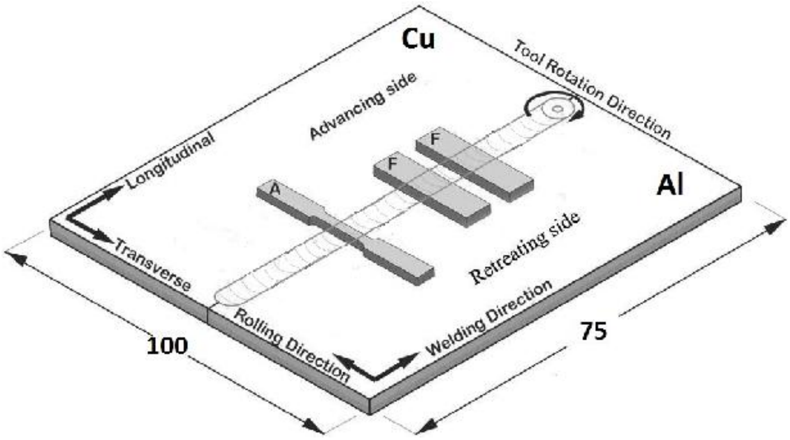

Fig 4.1 shows the extraction of specimen from the welded joint

A load vs displacement graph obtained for the taper circular threaded tool weld joint and ultimate tensile strength was 51.407 n/mm^2 and yield strength was 49.959 n/mm^2.A load vs displacement graph obtained for the straight circular threaded tool weld joint and ultimate tensile strength was 32.468 n/mm^2 and yield strength was 20.626 n/mm^2. Fig 4.2 shows the load vs displacement graphs of tensile test conducted for 2 different tool

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pin designs. Hardness test was carried on Rockwell harness test machine values are found to be 62.00 for taper circular tool weld joint and 65.33 for straight circular threaded tool joint. Three impressions are taken at 1mm distance for each sample. Fig 4.3 and 4.4 shows the hardness sample after conducting experiments.

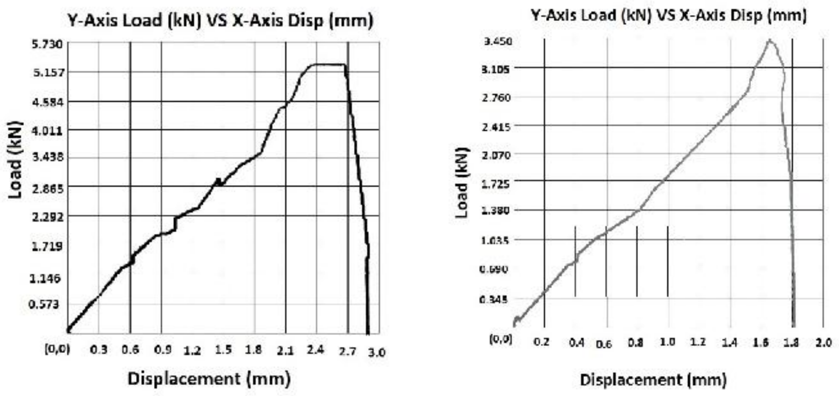

Fig 4.2 shows the Load vs Displacement graphs for 2 different tool pin designs

Sl.NO	Location	Observed values in HRB			
		IMP 1	IMP 2	IMP 3	AVG
1	sample piece 1	62	64	60	62.00

Fig 4.3 shows the hardness sample of taper circular threaded joint

Sl.NO	Location	Observed values in HRB			
		IMP 1	IMP 2	IMP 3	AVG
1	Sample piece 2	66	64	66	65.33

Fig 4.4 shows the hardness sample of straight circular threaded joint.

5 Fractorography:

Micro structure of welds were taken through scanning electron micro scope. At the centre the weld mix region of Al-Cu were found cracks and voids are found for the welding joint done with taper circular threaded tool. Metallic particles were found in the weld joint done with straight circular threaded tool. SEM images of each tool pin design are shown in fig 5.1

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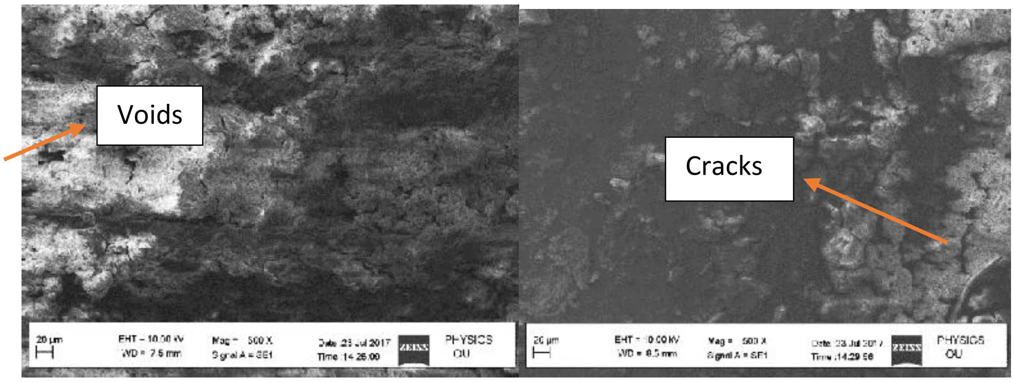

Fig 5.1 Shows the SEM images of trapper circular and Straight circular tool and their Defects

5.2 EDS ANALYSIS:

EDS analysis is one with 2 different weld joints. In order to know the chemical composition in the welding portion. We are getting different results for each joints. For the joint done with taper circular threaded tool the aluminium occupied more portion than the copper and some elements like sio_2, $Caco_3$ and are formed. For the joint done with straight circular threaded tool mixing of Al-Cu are formed at equal portions and elements like Sio_2, $Caco_3$ and Al_2o_3 are formed. Fig 5.2 and 5.3 shows the EDS analysis of taper circular threaded tool and straight circular threaded tool.

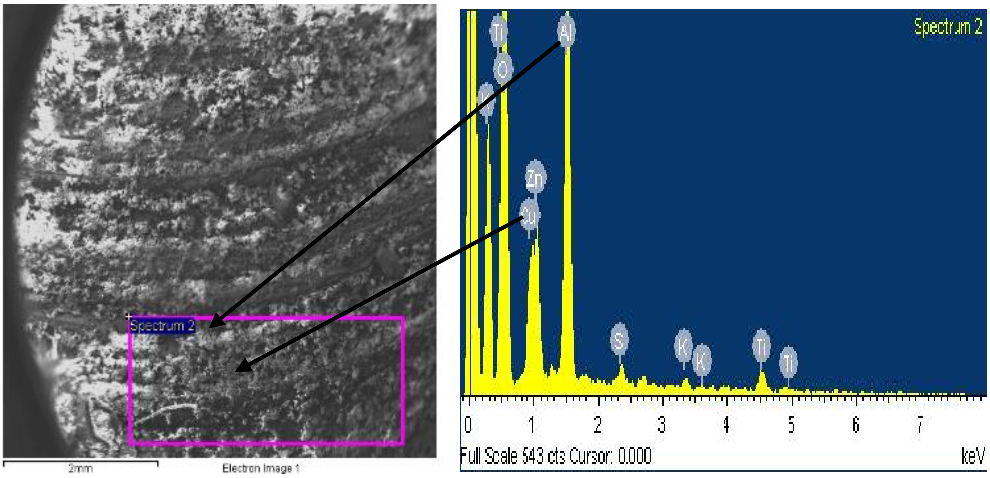

Fig 5.2 Shows the EDS analysis of Taper circular threaded tool

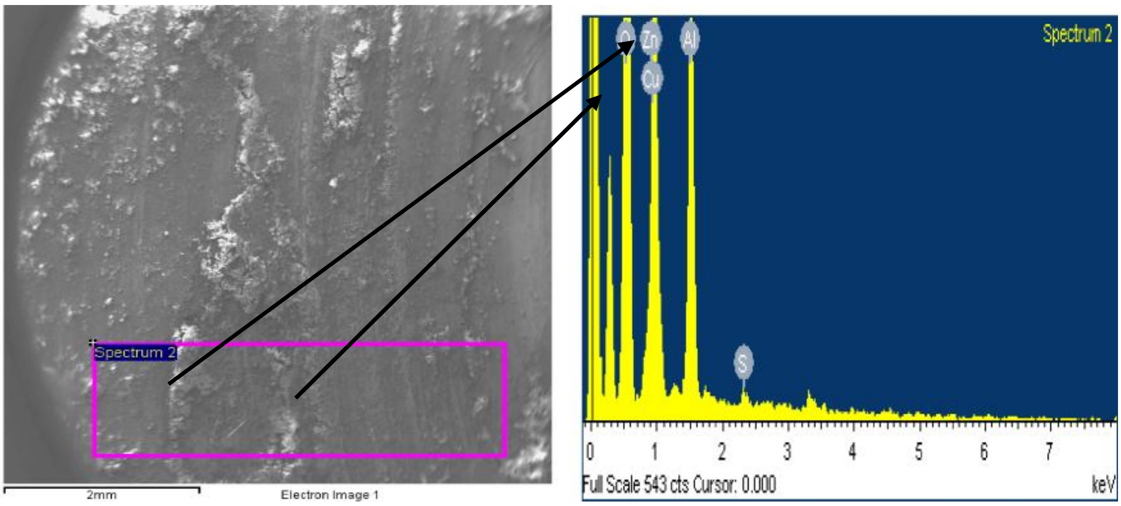

Fig 5.3 shows the EDS analysis for Straight Circular Threaded tool

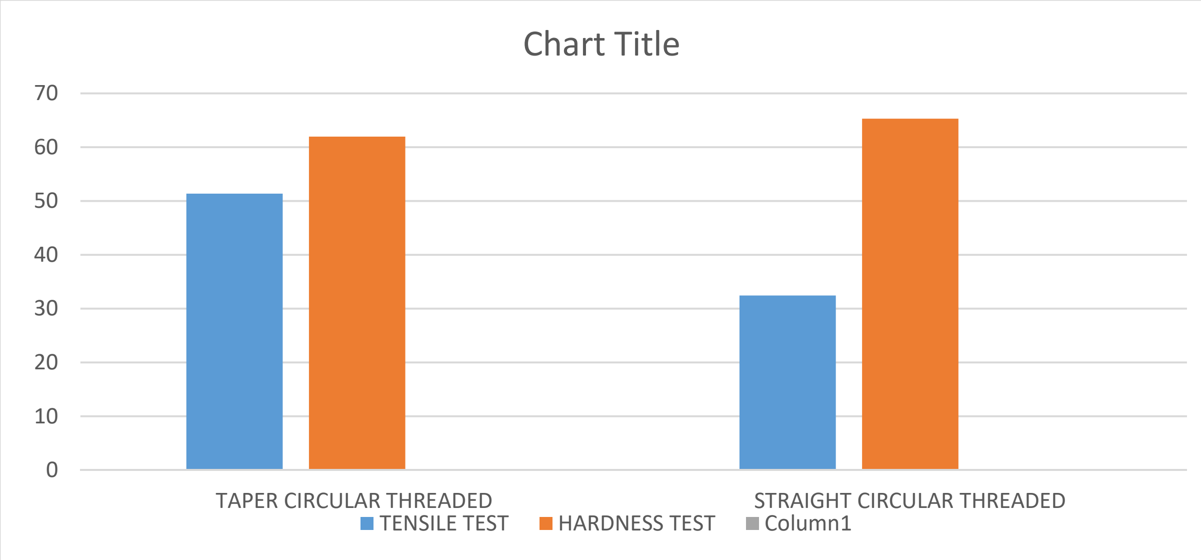

Fig 5.4 SHOWS THERESULTS COMPARISION BETWEEN TAPER CIRCULAR THREADED TOOL JOINT AND STRAIGHT CIRCULAR THREADED JOINT

6. CONCLUSION

1. Among the different parameters used for 2 different parameters used for 2 different tool pin design only 2 of them have formed with defect free for each tool at 800rpm at welding speed of 12mm/min.
2. Voids and cracks are observed in the SEM analysis for the joints made of Taper threaded circular tool.
3. Voids and cracks are formed due to the improper stirring of Al and Cu
4. Tensile test results are less for the joint made of straight circular threaded tool joint it due to welding parameters and tool pin design
5. From the EDS analysis it is observed that for the joint made of Taper threaded circular tool aluminium is occupied than copper due to this the tensile strength is more than the other joint
6. For the other joint made of Straight Cylindrical Threaded tool no defects are formed.
7. From the EDS analysis it is observed that for the joint made of Straight Cylindrical threaded circular tool both aluminium and copper are Stirred in the equal portion so that it has very less tensile strength.
8. Defects like cracks, surface tunnelling, voids are formed they occur due to less heat input and welding parameters.

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