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Performance Evaluation of Friction Stir Welding of Dissimilar Materials

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Abstract.*The friction Stir Welding is a process concerning plastic deformation of the materials to be joined.This process does not involve the melting of the materials to be joined. This thing makes thisprocess suitable for joining the different materials having different mechanical and chemicalproperties and different material structure.In contemporary work FrictionStir Welding of AA6101 Aluminium and pure Copper plates of 5mm thickness in butt joint configuration is done.Friction stir welding is done at 700 rpm and at 11mm/min tool traverse speed with cylindrical H13 material tool.For this vertical machining center is used. Joint shows onion ring structure in stir zone. Cavity like defect are seen atthe surface of joint.*

Keywords-Friction Stir Welding, Plastic Deformation,Aluminium, Copper, Tensile Strength

I. INTRODUCTION

Solid-state welding is the process wherein combination isproduced at temperatures below the melting point of thebase metal without the use of any filler metal. Examples ofsolid-state welding procedures consist of friction welding, FrictionStir Welding (FSW), ultrasonic welding, resistance welding,explosive welding and diffusion welding. There are fewerdefects in solid-state welding due to the fact the metals do not attaintheir melting temperatures for the duration of the welding method.However, the base metals being joined retain their uniqueproperties and the Heat Affected Zone (HAZ) is small whilstin comparison with the fusion welding techniques [1]. Friction StirWelding is a variation of friction welding that produces a weldbetween or greater workpieces by the heating and plasticmaterial displacement due to a rapidly rotating tool thattraverses the weld joint [2]. The schematic diagram of theprocedure is presented in Fig 1. [3] In FSW, the interrelationship among the system parameters is complex; thetwo maximum critical welding parameters being the toolrotational speed in a clockwise or anti-clockwise direction,and the device traverse pace alongside the joint line [4]. Therotation of the device results within the stirring and mixing ofthe fabric across the rotating pin at some point of the welding procedurewhich in turn have an effect on the evolving residences of the weld. Assuch, information the connection between the procedureparameters and the ensuing homes of the welds is vital.

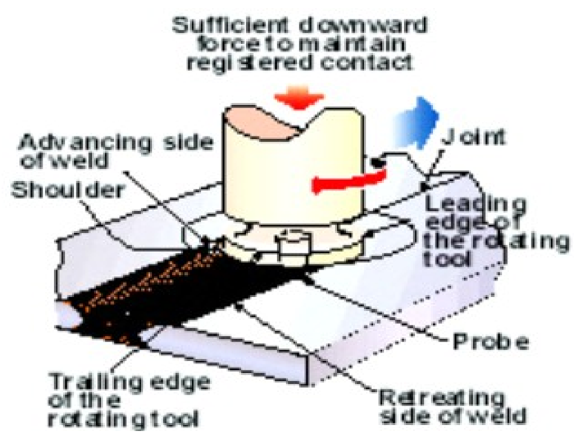

Fig. 1: Schematic diagram of friction stir welding process [3]

Research studies on process-property relationship [4-7]reported that the input process parameters are found to exertsignificant effect on the resulting joint integrities. Inattempting to further understand the process-propertyrelationship in FSW, statistical analyses of the weld data havebeen conducted on similar joints of aluminium alloys.Rajamanickam and Balusamy [8] conducted statisticalanalysis on the weld data obtained in FSW of 2014 aluminiumalloy and concluded that the weld speed has the higheststatistical influence on the mechanical properties of the weldsproduced. Also, Benyounis and Olabi [9] conducted aliterature survey on optimization of different weldingprocesses using statistical and numerical approaches andconcluded that modeling; control of the process parametersand optimization of different welding processes can beachieved using different statistical tools. The aim of this studyis to conduct statistical analysis on the weld data obtainedfrom dissimilar FSW of aluminium and copper in other to gaininsight and understanding into the interaction between theprocess-properties of the resulting welds.

II. RELATED WORKS

JiahuOuyang et al. [5] studied temperaturedistribution and microstructural evaluation of thefriction stir welding of 6061 aluminium alloy tocopper. They found that there are severalintermetallic compounds such as CuAl2, CuAl,Cu9Al4 together with small amounts of α-Al and thesaturated solid solution of Al in Cu. The peaktemperature measured in the weld zone is up to580oC.They carried experiments in range of 151-1400 rpm and 57-330 mm/min for rotational and tooltraverse sppedrespectively.Concluded that directFSW of 6061 aluminum alloy to copper has proveddifficult due to the brittle nature of the intermetalliccompounds formed in the weld nugget, also theyproved Copper and Aluminium have a high affinityto each other at temperatures higher than l20^{o}C andproduce brittle, intermetallics on the interface.M SatyaNarayana Gupta et al. [6] studied dissimilarfriction stir welded joint of pure aluminium and purecopper. They have done thermo-mechanical finiteelement analysis of friction stir welded Al/Cubimetallic lap joints. They performed Friction stirwelding at a rotational speed of 1500 rpm and weldspeed of 30 mm/min.They found the maximumtemperature is in the range of the 300 °C to 400 °Cand which is below the melting point of the basemetal. The maximum thermal stress is 10 MPa andwhich is far less than the yield strength of the basemetals.

Esther T. Akinlabi et al. [7] developed butt welds ofaluminium alloy and copper alloy by Friction StirWelding by varying the feed rate and keeping allother parameters constant. The welds were conductedat speed of 600 rpm and the feed rates were 50, 150and 300 mm/min. They investigated microstructureand fracture surfaces of the joint interfaces. Thestrongest weld was produced at the highest feed rateemployed at 300mm/min. Concluded that goodjoints can be achieved at a high feed rate.There is no work reported on dissimilar Friction StirWelding of AA6101 Aluminium alloy and pureCopper is done at lower tool traverse speed11mm/min. In this study experiment is conducted at11mm/min tool travers speed and 700mm toolrotational speed.

Koilraj et al [12] optimized FSW process with respect totensile strength of the welds and the optimum settings.Furthermore, the optimum values of the rotational speed,transverse speed, and D/d ratio are 700 rpm, 15 mm/min and 3respectively. In addition, they concluded that the cylindricalthreaded pin tool profile was the best among the other toolprofiles considered. Palanivelet al [13] examined the influenceof tool rotational speed and pin profile on the microstructureand tensile strength of the dissimilar friction stir weldedaluminum alloys AA5083-H111 and AA6351-T6. The weldsfabricated using straight tool profiles had no defects while thetapered tool profiles caused a tunnel defect at the bottom ofthe joints under the experimental considered conditions.

Furthermore, three different regions namely unmixed region,mechanically mixed region and mixed flow region wereobserved in the weld zone [13].Furthermore, Palanivel et al [14] joined AA5083-H111 andAA6351-T6 using tool rotational speed of 950 rpm andstraight square pin profile which resulted into obtaining thehighest tensile strength of 273 MPa. Moreover, the variation inthe tensile strength of the dissimilar joints was attributed tomaterial flow behaviour, loss of cold work in the HAZ ofAA5083, dissolution and over aging of precipitates ofAA6351 and formation of macroscopic defects in the weldzone. Da Silva et al [15] investigated the mechanicalproperties and microstructural features as well as the materialflow characteristics in dissimilar 2024-T3 and 7075-T6 FSWjoints. The welds were produced at fixed feed rate (254mm/min) varying the rotation speed in three levels (400, 1000and 2000 rpm).Da Silva et al [15] clearly stated that, typicalmicrostructural features of FSW welds such as SZ, TMAZ andHAZ regions were seen. A sharp transition from theHAZ/TMAZ to the SZ has been observed in the advancingside; while in the retreating side, such transition is moregradual. They found that the minimum hardness value ofnaturally aged samples in the HAZ at the retreating side wasabout 88% of 2024-T3 base material. Furthermore, 96% ofefficiency in terms of tensile strength was achieved using 1000rpm rotational speed. Fracture of the weld specimens occurredin the HAZ at the retreating side (2024-T3).

Aval et al [16] investigated the microstructures andmechanical propertiesin similar and dissimilar friction stirwelding of AA5086-O andAA6061-T6 using thermomechanicalmodeland experimental observations. Theyconcluded that the hardness in AA5086 side mainly dependson recrystallization and generation of fine grains in the weldnugget whereas hardness in the AA6061 side varies with thesize, volume fraction and distribution of precipitates in theweld line and adjacent heat affected zone as well as the agingperiod after welding. Aval et al [16] further observed grainrefinement in the stirred zone for all their samples; however,the finer grain size distribution is achieved within the AA6061side where higher strain rates are produced.

III. MATERIALS AND METHODS

1) Methodology: In this work frictional stir welded AA6101-T6Aluminium and pure Copper specimens arecompared for mechanical properties. In this studyFSW specimens are prepared at 11mm/min feed rateand at 700 rpm spindle speed.In this experiment plate size of aluminium andcopper are same and having 100 mm length, 50 mmwidth and 5 mm thickness. H13 material is used tomanufacture the tools. [9] Tool has pin diameter of 6millimeter size. **Tool dimensions:** ShoulderDiameter- 18mm, Pin Diameter- 6mm

2) Experiment Design: Following are materials and parameters used forexperimentMaterial: AA6101-T6 Aluminum, Pure CopperSheet Thickness: 5mm

Tool: Cylindrical

Spindle Speed: 700 rpm

Welding Speed: 11mm/min

The FSW process was carried on vertical millingmachining centre.

Machine Specification:
Make: HASS Technology (P) Ltd.
Spindle motor power : 30kW
Maximum Spindle speed : 12000 rpm
Maximum Cutting feed : 5000 mm/min
Table area : 500x300 mm
Travel (X, Y, Z) : 500x300x200 mm
Main electrical power supply : 40 Kva

Specimen of 100mm long and 50 mm wide were cutout of base metal by using a power hacksaw. Theedges of the specimen were machined to obtain aperfect square butt joint configuration. The testpieces were clamped in machine bed by using specially designed fixture. At advancing side Cu andat retreating side AA6101 Aluminiumworklpiecesare clamped on milling machine table. Straightcylindrical pin tool is used. Tool was mounted in avertical arbor with a suitable collate.The joint is formed as shown in figure2.

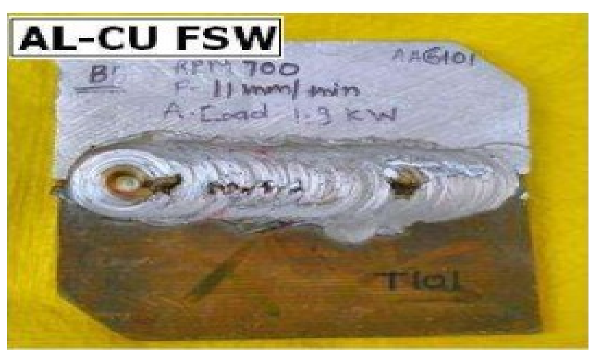

Figure:2Photograph of Dissimilar joint Copper andAluminium AA610

IV. RESULTANALYSIS

Testing of Specimen

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1. Visual Inspection: From figure2 following are the observations:

a) Dissimilar joint of Copper and AluminiumAA6101 found satisfactory in visualinspection.

b) Cavity like defects are present at the surfaceof joint.

2. Tensile Test: Tensile test was performed in order to evaluate thestatic properties of the welded joints. These testswere executed at room temperature using an UTM.Tensile testing specimen was made as per thedrawing shown in figure3 Care was taken during thisstage to align the centre of the weld with the centre ofthe tensile specimen. Tensile testing was carried outon an UTM.

UTM Specification- Tests carried on ComputerizedUniversal Testing Machine.UTM Specifications: Model No. TUE-CMaximum Capacity (KN):- 400KN

Measuring Range (KN): 0-400

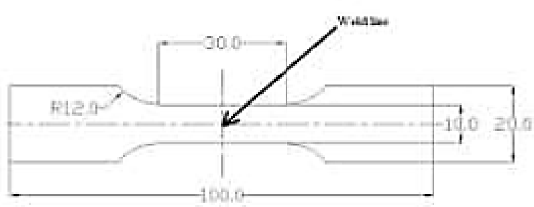

Figure:3Tensile Test Specimen [10]

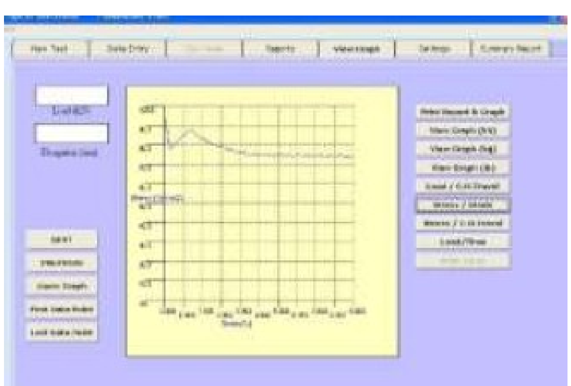

Figure:4Stress vs Strain graph of Dissimilar Joint

Material	Tensile Strength N/mm²
Dissimilar Joint	93.2
AA6101 –T6 Aluminum	284.4
Copper	220

V. CONCLUSION

In conclusion, an overview of friction stir welding ofdissimilar materials focusing on aluminum to other materialshas been conducted.Copper and Aluminum AA6101 distinctivefriction stir welded butt joint is fashioned and it's farbrittle in nature. This statement is just likeJiahuOuyang et al. For formation of sturdy butt joint, it calls forextra downward pressure and higher welding velocity,rotational velocity mixture.Extensive experimentation is required to studyimpact of above parameters on residences ofdiverse Cu-Al friction stirs welded specimen.

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