EFFECT OF FRICTION STIR WELDING ON MECHANICAL PROPERTIES OF ALUMINIUM2024-PURE COPPER JOINTS

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Abstract- **The aim of the present work is to investigate the mechanical properties and microstructure of butt joints friction stir welded (FSW) of dissimilar material specimens welded with single pass. The material used is AA2024 aluminum alloy and pure commercial copper. The welded specimens to be tensile, fatigue tested at room temperature to analyze the mechanical properties. The microstructure of the welded specimen is to be studied by employing optical microscopy. Micro-hardness examination is also to be performed on the welded specimens.**

I. INTRODUCTION

Welding of two different kinds of metals / alloys, (e.g., Cu and Al) is termed as dissimilar metal joining. A dissimilar metal weldment may differ from the composition of either of two parent metals that has been welded together. There are two major types of dissimilar metal joints.

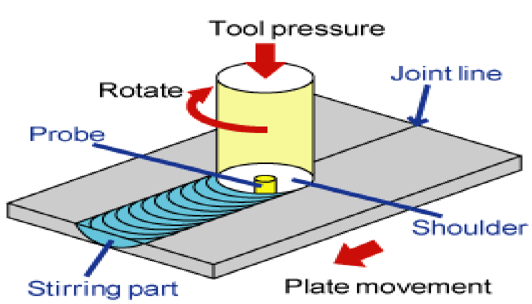
Joining between metals which are differing in the nature of their major constituents.

E.g. copper and aluminium.

Joining between metals which are differing in the nature of their alloying elements.

E.g. copper and brass, nickel and Inconel.

II. FRICTION STIR WELDING



Friction-stir welding (**FSW**) is a solid state joining technique in which the joined material is plasticized by heat generated from friction between the surface of the plates and the contact surface of a special, non-consumable tool [1]. FSW is one of the best techniques for dissimilar metal joint [2]. In FSW the variables include tool rpm, weld speed, normal load or tool plunge, tool tilt angle and tool geometry.

III. WELDING PARAMETERS

- **Tool Rotation and Traverse Speeds**:

There are two tool speeds involved in friction-stir welding; how fast the tool rotates and how quickly it traverses the interface. These two parameters are important and must be chosen with care to obtain a successful weld.

- **Tool tilt and plunge depth**:

The plunge depth is defined as the depth of the lowest point of the shoulder below the surface of the welded plate and has been found to be a critical parameter for ensuring weld quality. Plunging the shoulder below the plate surface increases the pressure below the tool and helps ensure adequate forging of the material at the rear of the tool. Tilting the tool by 2-4 degrees, such that the rear of the tool is lower than the front, has been found to assist this forging process.

An excessive plunge depth may result in the pin rubbing on the backing plate surface and the lowest one may raise the flaws at the time of welding.

- **Tool design:**

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed.Hot-worked tool steel such as AISI H13 has proven perfecty acceptable for welding aluminium alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for highly abrasive metal matrix composites or higher melting point materials such as steel or titanium.

PROPERTIES OF AluminiumAA2024

Density : 2.78 g/cm³ (0.1 lb/in³)

Electrical conductivity: 30% IACS

Young's Modulus : 73 GPa

Composition of AA2024 in wt%

Cu	Mn	Mg	Si,Zn,Cr,Pb&Bi	Al
4.3-4.5%	0.5-0.6%	1.3-1.5%	<0.5%	Rest

IV. EXPERIMENTAL SETUP

FSW Machine

In this machine, the base metal to be joined is fixed in vertical position. The parts have to be clamped rigidly onto a backing bar in a manner that prevents the butting joint faces from being forced apart. In the first experiment aluminium was positioned on the advancing side. In the second experiment copper was placed on the advancing side. In both the experiments axis of rotating tool was maintained on the advancing side. An optimal distance of 1.5mm was used for the two experiments.The parameters used in this work were (a) welding speed of 800rpm, (b) pin speed of 50 mm/minute (c) a tilt angle of 2 degrees and (d) plunge depth of 4.85 mm. Subsequent to welding the joints were comprehensively examined in a light optical microscope.

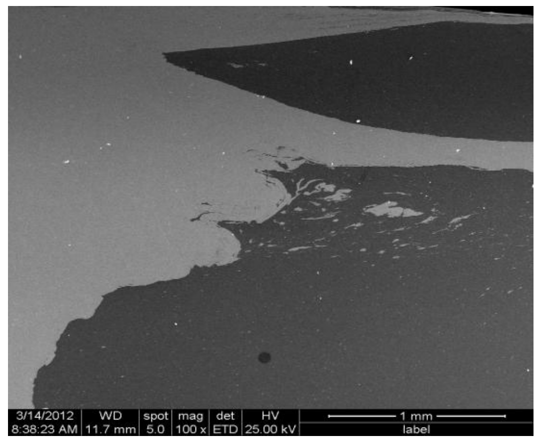
ESEM Quanta 200

Microstructural studies of this work were done by using optical microscope with an image analyser. Olymbus GX71 optical microscope along with microcam 4.0 image analysis system.

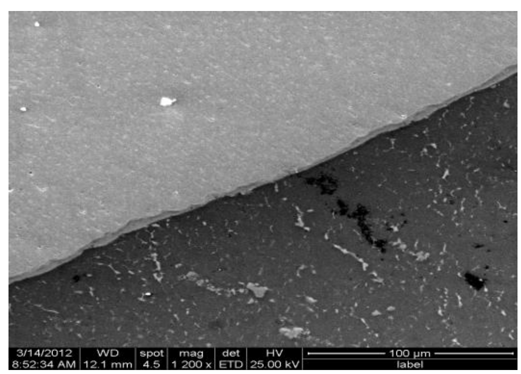
V. RESULTS AND DISCUSSION

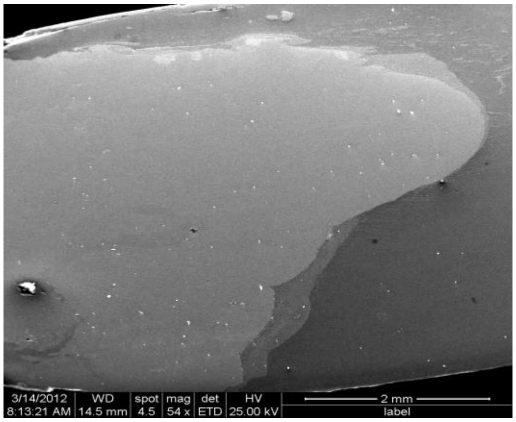
SEM Results

Cu-Al weld interface

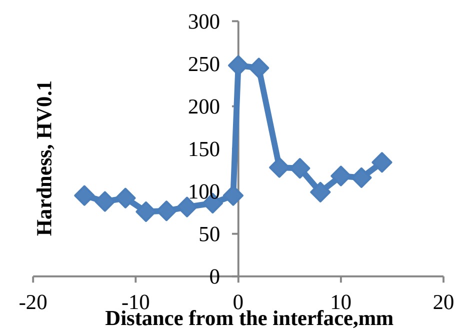


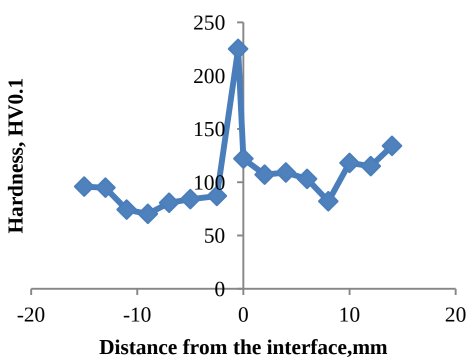
Al-Cu weld interface





Measurement of Hardness

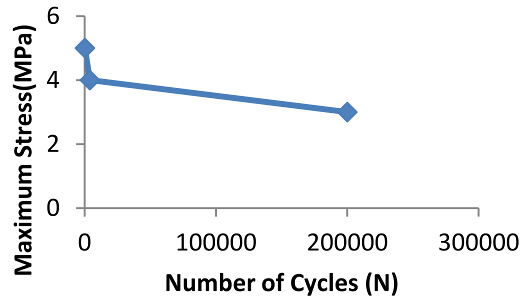




The micro-hardness was found to be maximum at immediately adjacent to the interface and to gradually decrease away from the interface on both the advancing side (AS) and the retreading side (RS) for both the aluminum alloy-copper weld and the copper-aluminum alloy weld.

Fatigue Test

The copper- aluminium joint did not have sufficient tensile strength. But it possesses sufficient fatigue strength. It did not fail for more than $2x10^5$ cycles at 3 MPa stress level. The brittle sample showed cleavage fracture at the interface, because of diffusion bonding at the interface.



Details of sample taken for discussion

variables	Plate position		Pin position		Joint mechanism at the interface
Sample no	Advancing side	Retreading side	Exact at interface	Offset on advancing side	
Sample 1	Al	Cu	Yes	-	Intermixing
Sample 2	Cu	Al	Yes	-	Intermixing
Sample 3	Al	Cu	-	1.5mm	Interdiffusion
Sample 4	Cu	Al	-	1.5mm	Interdiffusion

Aluminium can easily form eutectic alloy with copper. It is represented by phase Position of the pin on copper side enables diffusion of copper into the aluminum alloy (AA 2024) such that a eutectic phase forms and is present on the aluminum alloy side of the interface. So in Al-Cu weld the joint is made by the formation of eutectic phase at interface.Position of the pin on aluminum alloy side facilitates diffusion of aluminum into copper such that a diffusion layer was present on the copper side at the interface.In Cu-Al weld, diffusion zone of nanometer thickness is formed and it acts as joint mechanism in it.If a small amount of a second element enters into solid solution in a pure metal, the solution is called a primary solid solution. At higher concentrations, it is possible for different crystal structures to be formed and these are known as secondary solid solutions.

VI. CONCLUSION

The following conclusions are drawn from the present study:

- The optimum value of rotating speed is found to be 800 rpm.
- The optimum value of traverse speed is found to be 50mm/min
- Better weld performance is found when aluminium is on the advancing side.
- Weld performance is better for plain tool than the other two tools.
- Defect free Cu-Al joint by FSW is obtained by Plain tool plunge on aluminium plate with 1.5mm offset distance for the parameters i) tool speed of 800 rpm ii) weld speed of 50mm/min iii) plunge depth of 4.85mm, iv) tool tilt angle of 2^o. Weld joint is made by the formation of diffusion layer.
- Maximum micro-hardness value of 242HV at100 Kg load is obtained at the interface regions of Al-Cu and Cu-Al weld.
- Fatigue limit of Cu-Al weld is $2x10^5$ cycles at 3Mpa stress level.

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