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STUDY, ANALYSIS AND COMPARISON OF TWO DISSIMILAR METALS ALUMINIUM 6061 ALLOY WITH 99 COPPER BY USING TWO DIFFERENT PROBES IN FRICTION STIR WELDING

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Abstract: Dissimilar high-strength aluminum 6061 alloy with 99 copper, which are difficult to weld with traditional welding techniques with a non consumable tool with a pin is made to traverse through the joint line of the material to be join. Friction Stir Welding (FSW) an energy-efficient solid-state is capable of joining dissimilar metals, has enormous potential in the future of various industries. Heat is produced due to friction between tool shoulder and work piece which softens the material around the pin and produces a few micro structural changes in and around weld zone. In this paper comprehensively related to aluminum 6061 alloy and Copper will be experimentally employ with dimensions 100*2*60 mm (width x length x thickness) for butt joint. In this two different probes are using such as cylindrical and hexagonal to complete the weld. By effectively joining dissimilar aluminum and copper, the unique properties of composite formed by these metals can be adequately addressed after their welding such as welding strength, welding parameters, welding micro structural structure and welding speed etc. Friction stir welding is not only a solid-state joining method used mostly for metals and alloys, but also used for joining various polymer composite materials also. Process parameters have a great influence on the quality of the weld joints. After completion of joining, samples are collected from welded area by cylindrical probe and hexagonal probe for measuring of welding strength, analyzing microstructures, bending strength & impact strength etc. Additionally, several recommendations for future scope of research are proposed to facilitate the advancement and success of Al 6061 alloy and Cu friction stir welding studies.

Keywords: FSW (Solid State welding), Aluminum 6061 alloy, 99 Copper , Welding Properties.

1. Introduction:

Welding is a vital component of several industries such as automotive, aerospace, robotics, and construction. Without welding, these industries utilize aluminum alloys for the manufacturing of many components or systems. However, fusion welding of aluminum alloys is challenging due to several factors, including the presence of non-heat-treatable alloys, porosity, solidification, and liquation of cracks. Many manufacturers adopt conventional in-air friction stir welding (FSW) to weld metallic alloys and dissimilar materials.Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing work pieces without melting the work piece material. Heat is generated by friction between the rotating tool and the work piece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is capable of joining aluminium alloys, copper alloys, titanium alloys, mild steel, stainless steel and magnesium alloys. More recently, it was successfully used in welding of polymers. In addition, joining of dissimilar metals, such as aluminium to magnesium alloys, has been recently achieved by FSW. Application of FSW can be found in modern shipbuilding, trains, and aerospace applications. Welding defects can be reduced and welding performance can be improved. In particular, the issue of tool design is a subject of study in itself (material, coating, pin design etc.). Because, factors such as the necessary friction heat generation, mixing the material, compressing the material, and ensuring the material flow properly should be examined in detail. Different pin profiles used in this welding method are shown schematically. Most of the researches are on understanding these parameters and determining their optimum process values. Friction stir welding process of the dissimilar metals and the process of the heat is producing the tool and metals. Usman Abdul et.al were studied on Friction stir welding of Al and Mg alloys and concluded that the strength of Al/Mg friction stir weld ment depends on the evolved interface, which is primarily characterized by micromechanical interlocks, type, and intermetallic compounds (IMCs) distribution. Pragya Nandan Banjare et.al were experimented on friction stir welding process between AA6063 and copper alloys and concluded that low RPM improves the material mixing and joint properties. Finally also they studied and investigated on microstructure, phase constituents and mechanical properties of FSW joints through optical metallography, SEM, X-ray diffraction, micro hardness, and tensile tests. Xia-wei LI et.al were investigated on dissimilar friction stir welding of pure copper and 1350 aluminum alloy sheet with a thickness of 3 mm with rotating pin was inserted into the aluminum alloy side through a pin-off technique and finally concluded that sound welds were obtained at a rotation speed of 1000 r/min and a welding speed of 80 mm/min. Complicated microstructure was formed in the nugget, in which vortex-like pattern and lamella structure could be found. No intermetallic compounds were found in the nugget. The hardness distribution indicates that the hardness at the copper side of the nugget is higher than that at the aluminum alloy side, and the hardness at the bottom of the nugget is generally higher than that in other regions.

The ultimate tensile strength and elongation of the dissimilar welds are 152 MPa and 6.3%, respectively. The fracture surface observation shows that the dissimilar joints fail with a ductile-brittle mixed fracture mode during tensile test. Jianbo Zhou et.al were studied and experimented between aluminum and copper on Pin profile exerts an important influence on heat production and material flow in friction stir spot welding, thereby affecting microstructure evolution and mechanical properties of the welded joint. They were also studied and designed three types of tools with different pin profiles to join aluminum and copper by friction stir spot welding. Optical microscope, scanning electron microscope and X-ray diffraction were conducted to characterize macrostructure and microstructure in welded joints. Raghuram Pradhan et.al were studied and investigated on MIG & TIG welding on SS- 202 and SS -304 materials to calculate welding strength and other parameters. M.R. bin Muhamad et.al were studied and investigated on dissimilar materials joining between AZ31 magnesium alloy and SPHC mild steel with Al–Mg powder additives were successfully produced by the friction stir welding process. Al–Mg powder additives were set in a gap between AZ31 and SPHC specimen's butt prior to welding. The experiments were performed for different weight percentages of Al–Mg powder additives at welding speeds of 25 mm/min, 50 mm/min, and 100 mm/min with a constant tool rotational speed of 500 rpm. The effect of powder additives and welding speed on tensile strength, microhardness, characterization across welding interface, and fracture morphology were also investigated. R. SaravanaKumar et.al were investigated on underwater FSW procedure (UWFSW). That was totally innovative and futuristic mechanization. In this research, armour grade aluminum alloy AA5083 with dimensions of 150×100×6.35 mm were friction stir welded under water, in order to improve the joint strength and finally indicated that the tensile strength improved up to 191.3 MPa., the superior granule arrangements, elevated dislocation thickness and firm elucidation intensification significantly improved the hardness in the minimum hardness location (MHL).Again this resulted in further improvement of the UWFSW's tensile strength. The high dislocation density and the elongation were found to probably decrease between NZ and TMAZ. C.K. Sivakumar et.al were investigated on Friction stir welding of AA6061-T6 specimen sets of welding parameters and the elements to determine the mechanical properties like hardness, tensile strength, micro structural properties and chemical composition. The set of welding parameters varied are tool rotations per minute, tool feed per min, load/pressure applied on weld. The tool used is H13 on frictional stir welding machine and weld type selected is butt weld on 6 mm sheets of AA6061-T6 and concluded that after-welding test results were compared against before welding properties of the material. On an average 75% of the mechanical properties were found to be matching with the original material properties.

Aluminium 6061 alloy plate

Aluminium alloy 6061 is a medium to high strength heat-treatable alloy with astrength higher than 6005A. It has very good corrosion resistance and very good weldability although reduced strength in the weld zone. It has medium fatigue strength. The 6061 aluminum alloy is one of the most common and versatile for extrusion. It is generally referred to as structural aluminum since its strength makes it ideal for structural applications. However, because of its good combination of properties, it can also be used in a variety of project types.6061 Aluminium alloy composition by mass as shown in below table:

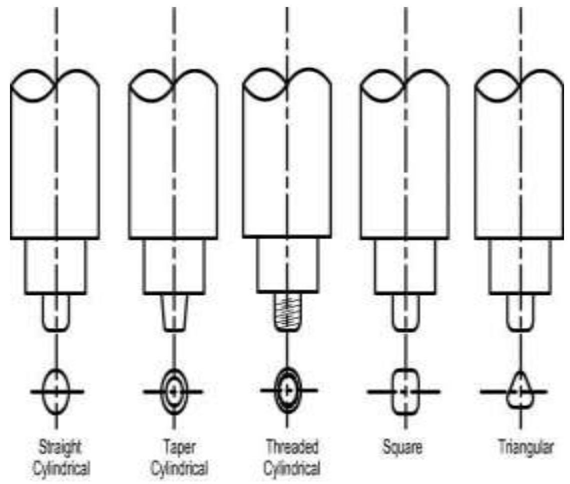
Constituent Element	Minimum (% by weight)	Maximum (% by weight)
Al	95.85%	98.56%
Mg	0.80%	1.20%
Si	0.40%	0.80%
Fe	0	0.70%
Cu	0.15%	0.40%
Cr	0.04%	0.35%
Zn	0	0.25%
Ti	0	0.15%
Mn	0	0.15%
(others)	0	0.15% total (0.05% each)

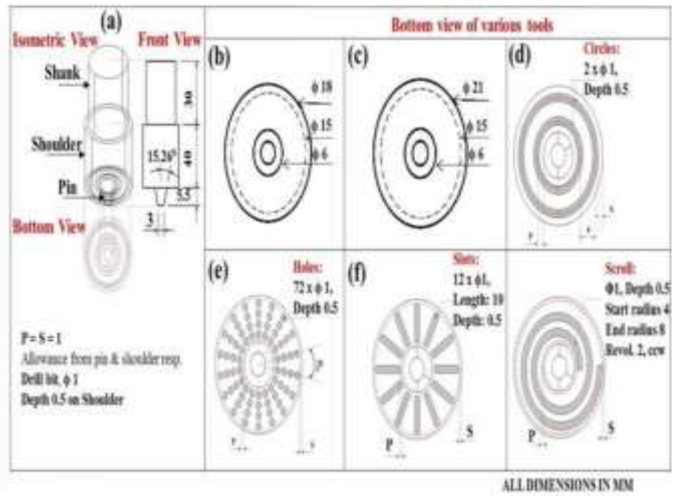
COPPER PLATE

Copper is a chemical element, it has symbol Cu (from Latin Cuprum) and atomic number of 29.It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a pinkish-orange color._For the FSW process to be done on copper plate, it requires high heat input to the welding surface area.This can be achieved by slowing the welding traverse speed so more heat generated. Tool rotation speed should be increase to produce a better surface finish.

DIFFERENT SHOULDER AND PIN

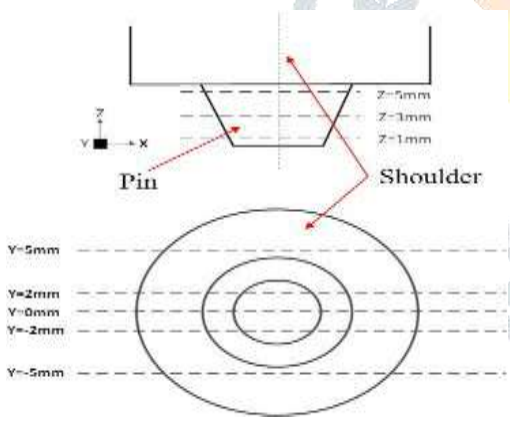
Pin profiles such as square, hexagonal, cylindrical, threaded, and tapered affect the grain size and structure, hardness, heat generation and appearance of the weldment. Concave, convex, and flat shoulder profiles affect particle distribution and microstructure. The weld joint quality is determined by the combined effect of the pin and shoulder profile. The effect of various pins and shoulder profiles on friction stirs welded joints. Empirical relationship between pin diameter, shoulder diameter and sample thickness as well as most commonly used dimensions for tools have been shown here.

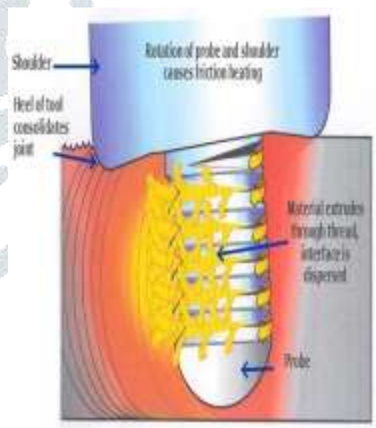




SHAPE OF THE SHOULDER AND PIN

The process of the mechanism of shoulder and pin that a shoulder diameter is critical while the shoulder produces most heat and its pressure on plasticized materials mostly determines the flow field of materials. Float as well as stay produce heat, while material flows are induced by stays. The material should be properly lubricated, the machine must carry enough on the plasticized surface for a reasonable FSW operation, the combined torque and energy to be navigated should not be high.





TYPES OF PROBES AND MATERIALS

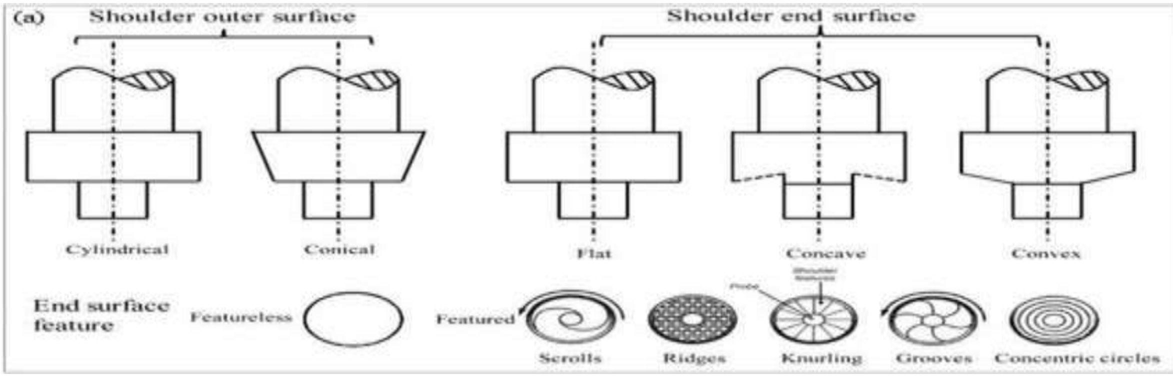
There are several tool materials known as probe that have been used in the FSW process. These materials include but are not limited to; tool steels, high speed steel (HSS), Ni- alloys, metal carbides and ceramics. Aluminum Alloy, Copper and Magnesium alloys and can weld up to 50 mm in these materials

1. Circular Probe 2.Cylindrical Probe

3.Spherical Probe 4.Pentagonal Probe

5.Tapered Probe 6. Square Probe

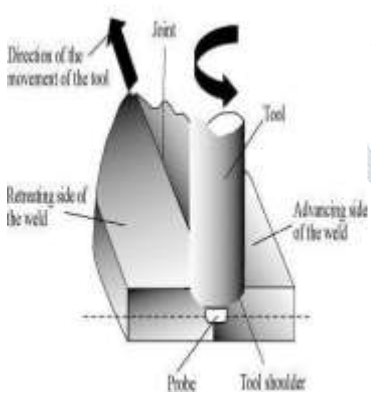
7.Hexagonal Probe

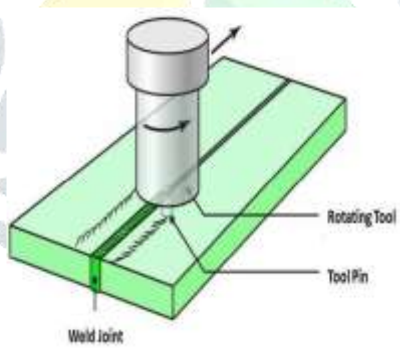


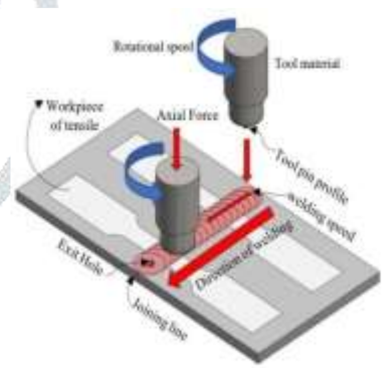
SHOULDER OUTER AND END SURFACE

FRICTION STIR WELDING

Friction stir welding machines produce reliable and consistent results in cold plates and heat sinks. Friction stir welding thermal products is more reliable than traditional methods. In friction stir welding; a rotating tool is used to applied friction and pressure force at the plates. This tool rotates at its own axis and move longitudinally at the plates interface which generates heat by friction between rotating tool and work piece. This heat deformed the interface surface and diffuses the two piece of work piece into one another by applying a high pressure force. This joint is created due to thermo mechanical treatment at the interface surface.







3. MATERIALS AND METHODS

Materials Used **:** Aluminum 6061 alloy and 99 copper

Materials Dimensions **:** 100*2*60 mm (width x length x thickness)

Joint Type **:** Butt Joint.

Probe Used **:** Cylindrical and Hexagonal Type

Welding Properties & Physical Properties: Below Methods are used for measuring of welding strength, analyzing microstructures, bending strength & impact strength etc.

CIRCULAR PROBE **HEXAGONAL PROBE**

WELDING SPEED ON CYLINDRICAL PROBE

Experiment No	Combinations	Specifications
1	AA 6061-99 Copper	Spindle Speed: 1100 rpm, Feed Rate: 3 mm/min

WELDING PARAMETERS OF CYLINDRIACL PROBE AND JOINING

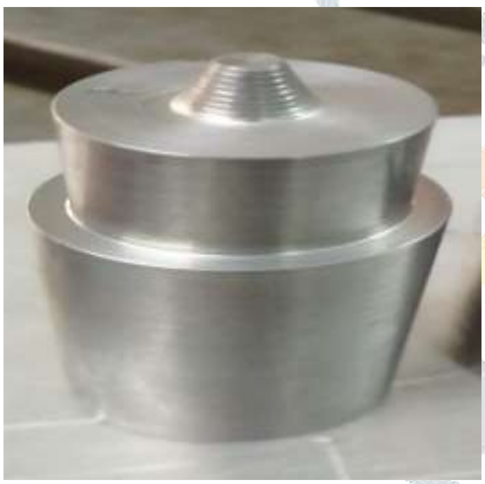
SL.NO	Parameters	Values
1	Spindle speed	1100 rpm
2	Current (ampere)	100
3	Feed depth	20
4	Tool Diameter	H.13
5	Dwell Time	6S
6	Rotation Direction	Clockwise
7	FSW Control	Vertical Direction

WELDING SPEED ON HEXAGONAL PROBE

Experiment No	Combinations	Specifications
1	AA 6061-99 Copper	Spindle Speed: 1100 rpm, Feed Rate: 3 mm/min

WELDING PARAMETERS OF HEXAGONAL PROBE AND JOINING

SL.NO	Parameters	Values
1	Spindle speed	1100 rpm
2	Current (ampere)	100
3	Feed depth	20
4	Tool Diameter	H.13
5	Dwell Time	5.5 S
6	Rotation Direction	Clockwise
7	Fsw Control	Vertical Direction

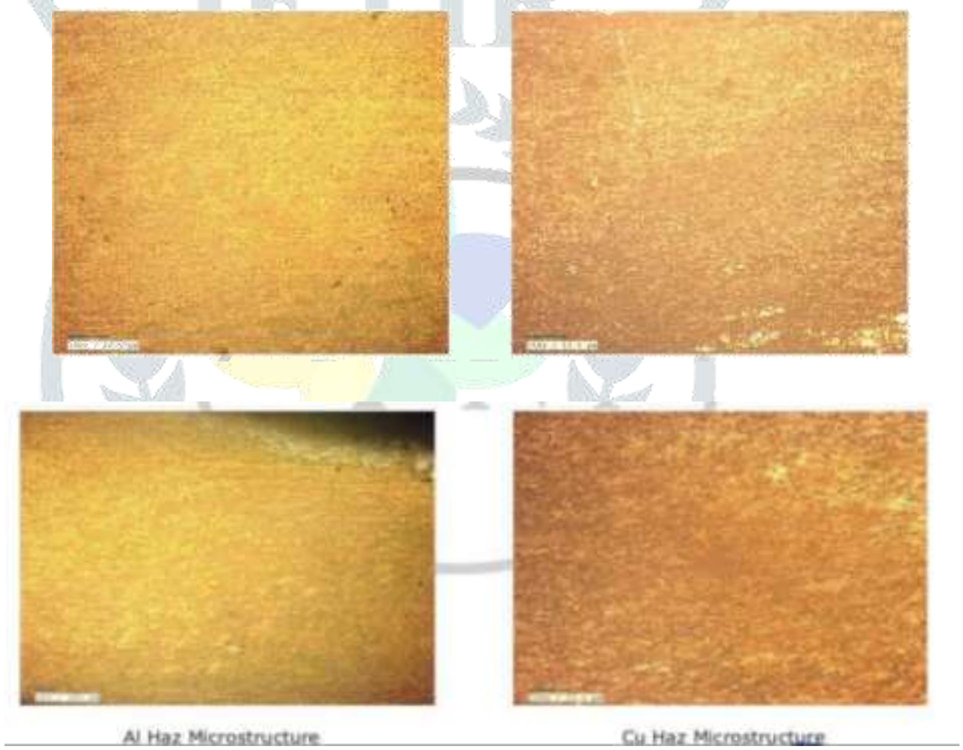



SAMPLE COLLECTED BY CYLINDRICAL PROBE FROM WELDED AREA FOR MEASURING OF WELDING STRENGTH

SAMPLE COLLECTED FROM HEXAGONAL PROBE WELDED AREA FOR MEASURING OF WELDING STRENGTH

SAMPLE COLLECTED BY CYLINDRICAL PROBE FROM WELDED AREA JOINING FOR MEASURING FOR MICROSTRUCTURE

SAMPLE COLLECTED BY HEXAGONAL PROBE FROM WELDED AREA JOINING FOR MEASURING FOR MICROSTRUCTURE



WELDING STRENGTH OF BOTH PROBES

S.NO	Test Parameter	Unit of Measure	Sample-1 Results
1.	Tensile strength	Mpa	27.60
2.	Yield strength	Mpa	22.52
3.	Elongation	%	0.46

WELDING STRENGTH OF CYLINDRICAL PROBE

S.NO	Test Parameter	Unit of Measure	Sample-2 Results
1.	Tensile strength	Mpa	19.80
2.	Yield strength	Mpa	16.80
3.	Elongation	%	0.38

WELDING STRENGTH FOR IMPACT TEST [Charpy Impact test on both probes samples]

Length of the work piece = 50 mm

Width of work piece = 1.5mm

Thickness = 2mm

Applying load =2.5

CYLINDRICAL PROBE SAMPLE:

The bending point = 2.1

HEXAGONAL PROBE SAMPLE:

The bending point = 1.75

CYINDRICAL PROBE SAMPLE:

Initial value = 8

Final value = 17.5

Final value – Initial value

=17.5–8=9.5

HEXAGONAL PROBE SAMPLE:

WELDING STRENGTH FOR BENDING TEST

Bending Test on both probes sample:

Length of the work piece = 11.2mm

Width of work piece = 2mm

Thickness = 2mm

Applying load =2.5 N

Results and Discussion

Out of the two probes used in friction stir welding such as cylindrical probe and hexagonal probe. Cylindrical probe is given the better result in terms of welding speed, welding parameters, welding strength, welding micro structure. Additional research is needed to optimize processes and select cost-effective FSW tools for high-quality joining. The advancement of this method is critical fields of study for industrial applications, including dissimilar materials**.** In this paper all testing work were carried out in Hyderabad.

Future Scope

1. Critical factors such as some other welding tool materials (probes) and their geometry, material flow pattern, and micro structural analysis need further more studies while joining aluminum 6061 alloy with copper by FSW process.

2. The application of interlayer and additive reinforcements in the dissimilar FSW joining of Al–Cu should be more explored. Early research indicated that a decline in strength is linked to numerous factors. Thus, further systematic studies should be carried out to decrease and cope with the drawback of low strength. Therefore, some literature has shown that the addition.

3. Further parameter studies can be done such as on thrust force, other force components and torque while joining aluminum 6061 alloy with copper by FSW process.

4. There is considerable space for studying heat input, heat distribution, and stress flow on advancing/retreating and top/bottom sides. Additionally, temperature distributions associated with stress flow are established under various unfavorable conditions, necessitating careful interest in future studies.

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