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Determining the Effect of Welding Parameters of Friction Stir Welding on Aluminum and Copper

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Abstract

The experiments described mainly about the procedures for the joining of Al (AA8050) and Cu with the help of solid –state stir welding procedure. The setup of joining the two dissimilar metals is mainly due to the increase in demand at industrial level application. A hybrid structure and reducing the cost to weight ratio of the component. These experiments also give a scope on weld ability of Al and Cu withvarying melting points and its effect on welding parameter suchas rotational speed, welding speed to achieve the prefect joint. Acomparative study is performed on tool pins, which is designedand manufactured for welding the Al, and Cu. E-dx (Energy- dispersive X-ray spectroscopy)is performed to analysis the effect and to understand the micro structural behavior of thejoints.

Keywords—Aluminum(Al); (Cu)Copper; mechanical properties; friction stir welding; melting points; circular; taper ;tensile hardness, RPM(revolution per minute);microstructure;

1. INTRODUCTION

This paper discusses the combining of two different metals utilizing the manufacturing technique of welding, which uses high heat to melt the pieces binding and allowing them to cool, resulting in fusion. The challenge of producing high strength, fatigue, and fracture resistant welds in a variety of welding processes led to Thomas Wayne's discovery of FSW (Friction stir welding) in 1991, which was well recognized at the time. Welding all aluminum alloys, even some that cannot be bonded using standard fusion welding processes, such as aluminum-lithium alloys. It is also possible to combine dissimilar aluminum alloys.

1.1 Weldingof dissimilar metals

In conventional or fusion welding, the material must be melted and resolidified, but in FSW, the junction is always solid and never melts. Instead, the joint is formed under high plastic deformation conditions. The primary contrast between FSW and fusion welding (apart from the lack of melting) is the ability to regulate peak temperatures through the use of special welding parameters.

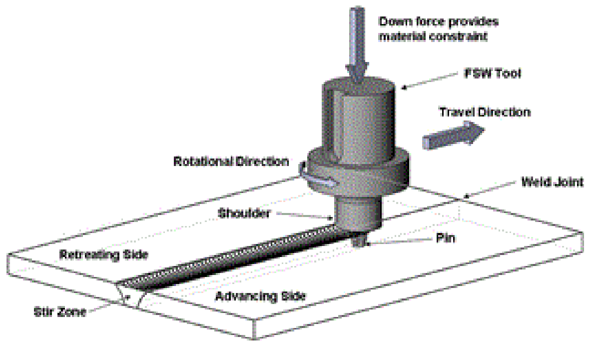

Fig:1:(FSW) Friction stir welding used for joining the two dissimilar metals[15]

This may be accomplished precisely by simulating the process with simulation software such as ANSYS10.0. This will shorten the simulation time. FSW allows you to alter the properties of steel and adapt them for specific applications, as well as maximize tensile strength, fracture toughness, or fatigue resistance based entirely on the application.

1.2 Friction stir welding

Friction stir welding has piqued the curiosity of people all over the world due to its benefits over traditional joining processes. FSW is essentially a local thermo-mechanical metal working process that affects local characteristics while leaving the remainder of the structure alone. Metal deformation causes additional adiabatic heating throughout this process. The tool's pin and shoulder can be modified in a variety of ways to influence material flow and the formation of microstructures, as will be explained later. [8] A rotating tool with a pin and shoulder is used to penetrate the material to be treated, which is then moved along the line of interest (Figure-1).FSW is performed by shifting the tool and the processing area so that the tool crosses the region in overlapping passes until the entire area is processed. Friction Stir welding has enabled the induction of directed, localized, and controlled material characteristics in any arbitrary place and pattern, resulting in revolutionary capabilities in high-value-added components. Friction stir welding allows you to thermo-mechanically treat specified spots on the structure's surface and to a significant depth (>25mm) to improve certain qualities. This element of automotive technology is receiving more attention in terms of research. For example, automotive suspension and drivelines are composed of cast aluminum alloys such as A319, for example.

A fine, equi-axed grain morphology with a banded, bimodalgrain size of 1 to 5 microns is produced by FSW. When subjected to super plastic circumstances of high temperature and dynamic strain, the microstructure of friction stir-welded aluminum alloy is typically stable. High-angle grain boundaries can improve super plasticity and related grain boundary sliding. However, a homogenous distribution of equiaxed grains with a minimal grain size is necessary for optimal super plasticity. For any particular set of treatmentsettings, FSW microstructures do not have a uniform grain size distribution. The size of the grains vary from top to bottom and from the side that is moving forward to the sidethatisretreating. Numerous researchers have shown the capability of friction stir welding to modify the local microstructure through thermo-mechanical functioning. [10]The heat produced at the point where the tool and work piecemeet is one of the crucial components in the FSW process. This heat is what propels the FSW process forward. The heat flow must be maintained at maximum levels while the temperature in the work piece remains low enough to preventmelting and high enough to make the material pliable enough for the pin to stir. According to Tangential measurements, themaximum temperature produced by the FSW process rangesfrom 70% to 90% of the melting point of the work piecematerial (1988) and Cole Grove et al. (2000), so that welding flaws and the significant distortion that is frequently connected to fusion welding are reduced to a minimum or eliminated.[5] The friction and deformation process predominantly produces the heat flux in friction stir processing. Both the tool and the work item are subjected tothis heat transfer. A successful process is determined by thequantity of heat transferred into the work piece, which is in turn determined by the quality, form, and microstructure of the processed zone, as well as the residual stress and distortion of the work piece. The life of the tool and its capacity to generate a high-quality processed zone are determined by the amount to heat applied to the tool. For instance, in adequate heat produced by friction could due to the material not being sufficiently soft, causing the tool' spin to shatter. Understanding the friction stir welding process heat transport component is crucial for both science and optimizing the uniqueness of the process. For instance, this template's head margin is proportionately larger than usual. This measurement and others are intentional; they follow guidelines that assume your paper will be a component of the full procedure and not stand alone.[3]

1.3. Types of Friction stir welding tool materials.

Materials with the potential (in terms of high temperature strength) to be utilized as FSW tool probes for welding aluminum alloys include inter metallic alloys, silicide, Laves phase alloys (two phase Nb-Ti-Cr alloys), iridium alloys, and ceramics. The majorities of these materials, however, haveverypoor fracture toughness and break quickly via brittle fracture when employed as friction stir tools, according to earlier research at TWI. These materials are both difficult to source and difficult to manufacture using the FSW probe geometrics that are currently thought to be required to produce high-quality welds. Frictions stir welding tool materials for Alloys

1. Hot work tool steels (AISIH13HWTS has been used extensively)
2. High speed steels.
3. Super alloys (Ni-and-Co-based)
4. Cemented carbides(WC-Co-have limited use)

2.1Tooldesign

2.1.1 EXPERMENTAL PROCEDURE

In order to understand the bonding of welding metals firstly we should know the selection of metals according to the introduction

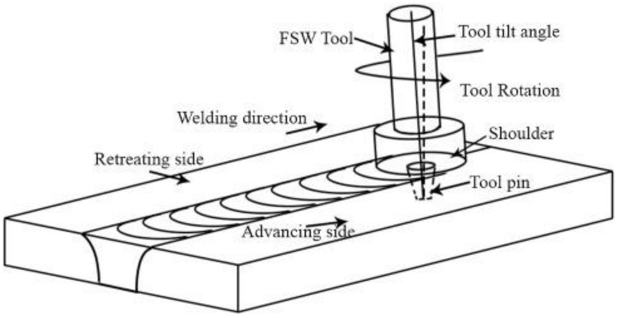

Fig:2:(FSW)Tooldesignwithitsabbreviations[16]

Background

Over the past 30 years, a huge variety of Friction Stir Welding (FSW) tool probe and shoulder designs have been created all over the world, many of which have been successfully employed and some of which have even been patented. However, standards and specifications like BSENISO25239-1:2020 friction stir welding aluminum and AWSD17.3/ D17.3M:2016 specification for friction stir welding of aluminum alloys for aerospace applications have never included a standard FSW tool probe shoulder design. Thereare already a few businesses offering "off the shelf" FSWtools, despite the fact that there is no standard probe shoulderdesign for FSW instruments. However, the bulk of FSW users regard the designs of their FSW tools as confidential, and as a result ,there are every few articles in the public domain.

2.1.2 Basic Principles

In order to discuss how a FSW tool is designed, we first mustunderstand its various roles. In order to create a solid-stateweld between two pieces of metal, the FSW tool probe andshoulder combination is rotated and inserted into the interface between two plates or sheets while being applied axial force, as shown in Figure 3. This keeps the FSW tool in the proper position throughout the weld cycle. It is crucial that the plates or sheets are held in place in a clamping fixture by a steelbacking bar on the underside. This bar serves as a response tothe axial force. In order to prevent the plates or sheets fromsplitting when the FSW tool travels along the weld contact,side clamping is also necessary. When the aluminum alloy has been sufficiently softer, the tool is moved over the weldinterface. Rotation of the tool causes frictional heating andsoftens the weld interface region. The thread form on theprobe body disrupts the softened weld zone material as it rotates and moves across it. [13] It also crushes and dispersesany oxide layer at the joint surfaces. Complex forging andextrusion take place, and softened material is transported 180degrees from the leading edge to the trailing edge of the probe. Because of time, temperature, and pressure, a solid-state weld is produced. A compressive force is applied to the surface of the plates / sheets while the rotating shoulder (illustrated inFigure3)travels along the weld contact ,heating and confining the softened material underneath. The plates/sheets can be joined using lap welding or butt-welding approaches.

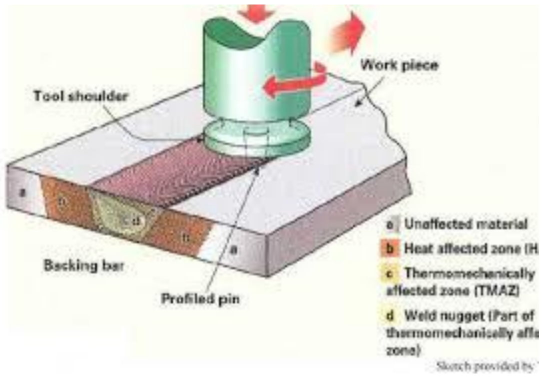

Figure3.FSW Working

2.1.3 EarlyDevelopments

The starting point for the design of the FSW tool setter was asimple parallel-sided (cylindrical) threaded probe body that became the first commercially successful probe in 1995.Since then, TWI has gradually developed his family of FSW tool setters as shown in Fig. 3. The thread profile is cut to the left of the probe body.[8]

2.1.3 Tool-Design-Evolution

As FSW development progressed, commercial users of the process required higher welding speeds in much higher strength aluminum alloys, hence the MX-Triflute™ probe. Aversion of the MX-Triflute™ probe is shown in Figure 3. It isnot obvious, but the body tapers slightly. The tapered probebody shown in Figure 2b and the three evenly spaced spiralgrooves move much less material during the welding cycle than the original cylindrical body probe, thus maintaining high quality. While achieving much higher welding speeds. The three tip flutes and the MX thread form broke the material in the weld more actively, generating frictional heat faster and improving the efficiency of the FSW process.

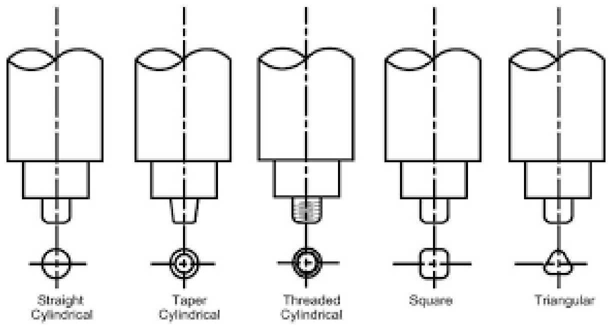

Figure4.[12]

[2]The MX-Triflate™ FSW Tool Probe is typically used for thin welds<15mm>15mm.FSW tool shoulders are generally simpler in design than probes. The tool shoulder is not necessarily parallel to the workpiece surface. For simple straight welds, the tool is often tilted, causing the trailing edge of the shoulder to penetrate the workpiece and apply additional forging pressure. Doseetc.(1995) developed a concave shoulder design that works reliably at an operating angle (tooltilt) of 2–3degrees (Fig.3a).The desire to improve the welding speed of 5xxx series aluminum alloys led to the development of the spiral shoulder (Figure 3a-b).This shoulder face has a spiral machined into the shoulderface that pulls material from the outside edge of the shoulderinto the root. Probes (Dawes et al Thomas, 1999). The idea was developed to facilitate vertical flow of material ,but initial trials showed that such design changes also enabled the use of vertical(zero-pitch) tools rice field. This shoulder design is commonly used today for applications requiring weld paths in two and three dimensions. The shoulder profileof the tool greatly influences the generation of frictional heatduring FSW. A tool shoulder profile that restricts materialflow such as B. Snail provides maximum heat delivery due toincreased surface area. Therefore, a reduced volute shoulderdiameter can be used. This has proven particularly beneficial as joint designs and weld paths become more and more complex. Tooling design is often driven by joint geometry constraints.

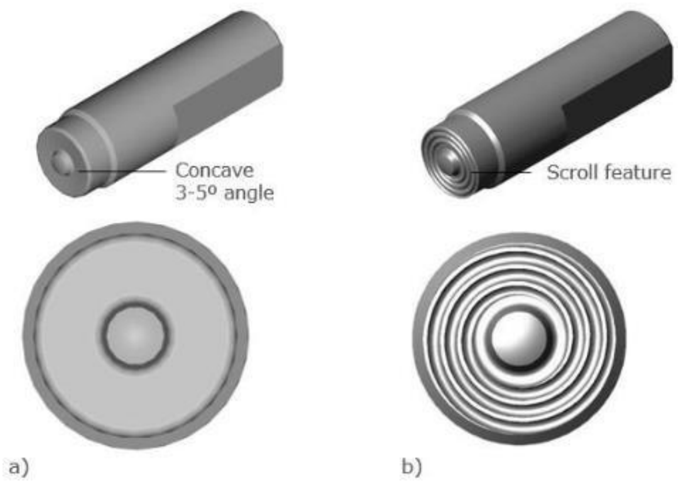

Figure5.

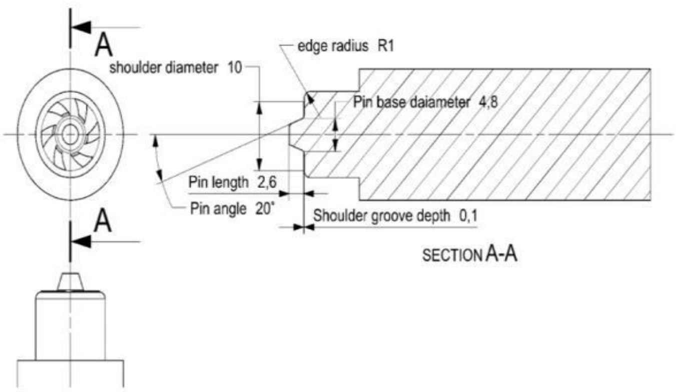

Fig6.Existingtool

3.1 Experimental procedure for FWS

3.1.1 Types of Friction stir welding tool designs (Developed tool designs)

1. Straight circular threaded.
2. Taper circular threaded.

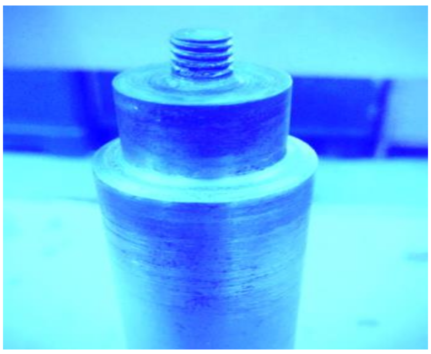

Fig7.Straight circular threaded

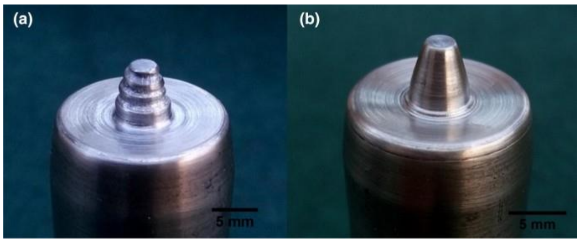

Fig8.Taper Circular threaded

Table1.ToolSpecifications.

Specifications.	**Stir circular thread.**	**Taper circular threaded.**
Shoulder diameter	High speed steel	High speed steel
Pin diameter	18mm	18mm
Pin length	6mm	6mm
Thread orientation	5.7mm	5.7mm
Thread angle	Anti-clockwisedirection	Anti-clockwisedirection
Thread pitch	60degrees	60degrees
Thread pitch	1mm	1mm

3.1.2 Material High Speed Steel.

A typical HSS Composition features chromium (4%), tungsten (approx.6percentage), molybdenum (upto10%), vanadium (around 2%), cobalt (up to 9%) and carbon (1%).The different grade types depend on the varying levels of elements added. Chromium improves hardenability and prevents scaling. Basic grades of HSS and their applications are summarized in Table 2.

Table2.Grades of high-speed steels (general ISO designation :SW-Mo-V-co)

General description	**ISO/Germany/USA steel description**	**Material no.(steel code)**	**Range of application**
HSS	S6-5-2(DMo5/M2)	1.3343	Standard tool material for most common applications
HSS-Co	S 6-5-2-5(EMo5Co5/M35)	1.3243	High heat resistance, especially suited for roughing or when Coolant insufficient
HSS-E	S 6-5-3(EMo5V3/M3)	1.3344	High friction resistance and cutting-edge stability, especially important for reaming operations
HSS-EM42	S2-10-1-8(M42)	1.3247	Increased heat resistance and hardness, suitable for difficult-to-machine materials
P/M HSS-E	S6-5-3-9	1.3207	High hardness, heat resistance and cutting-edge stability

The preparation of the specimens for the experimentation of FSW (friction stir welding)

Figure9Machinesetup

4.1 Conventional machining tools

In terms of system functioning, the FSW approach is similar to other technical production procedures like as machining, deburring, grinding, and drilling. All of these techniques involve moving a spinning tool through a component, causing dragging of material that makes up the painting piece. As a result, it is reasonable to expect that FSW can be performed using a standard machine tool equipped with a Milling system. However, the hundreds created by the FSW Technique have additional significance when this equipment is employed. The loads involved in FSW are greater than the loads generated by milling. As a result, classic device gear should be strengthened if their load and rigidity capabilities are to be increased.As a result, there are options for modifying existing equipment to perform FSW. Changes to the device can be made on several levels, including structural, flexibility, decision-making, and sensing. The structural modifications are made to make the equipment more resilient (certain equipment components, such as Methods, guides, rails, vehicles, spindles, and so on., may be modified).

4.2 Experimentation done according to the table

The ability may be expanded by the addition of more motors that provide the equipment with further levels of flexibility. Because of the enormous loads involved in the FSW process, most of the solutions have used force control to avoid device damage, ensure human safety, and achieve real weld quality. The device's decision-making may still be stepped ahead, allowing movement in additional guidelines at the same time. Aside from that, the machine may be outfitted with a few of sensors to collect remarkable data that can be utilised to operate the gadget via an embedded manage solution.

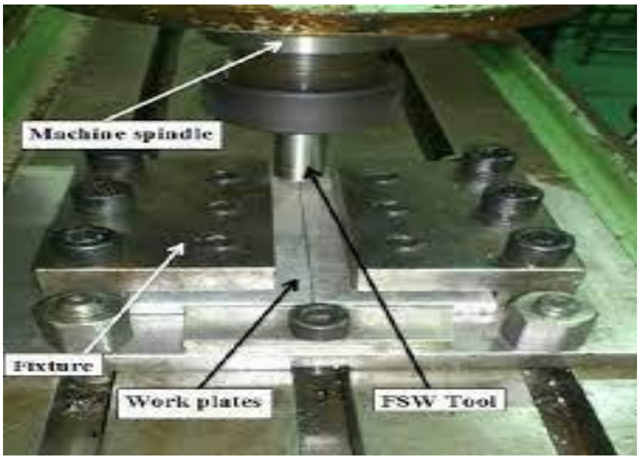

Figure10Machinesetup

Gadget that is utilized in (FWS) presented with one-of-a-kind traits which concerns to its bodily configuration that's specially relied on the application of welding joint. The system and gear, which displays the maximum appropriate to uses need to be selected according to unique technical skills which include accuracy, sensing selections making and versatility these talents are understood in detail in the following phase.

PROCESSPARAMETERS				OUTPUTRESPONSE				
TOOLUSED		TOOL ROTATIONAL	WELDING	TENSILETEST	ROCKWELLHARDNESS			
		SPEED	SPEED	(N/mm²)				
	JOINTS	(Rpm)	(mm/min)					
					IMP1	IMP2	IMP3	AVG

TAPERED	JOINT1	800	10					
CIRCULAR	JOINT2	850	10					
	JOINT3	900	12	49.595	62	64	60	62
THREADED	JOINT4	950	12					
	JOINT5	1000	12					
STRAIGHT	JOINT1	800	12					
CIRCULAR	JOINT2	850	12	32.468	66	64	66	65.33
	JOINT3	900	12					
THREADED	JOINT4	950	12					
	JOINT5	1000	12					

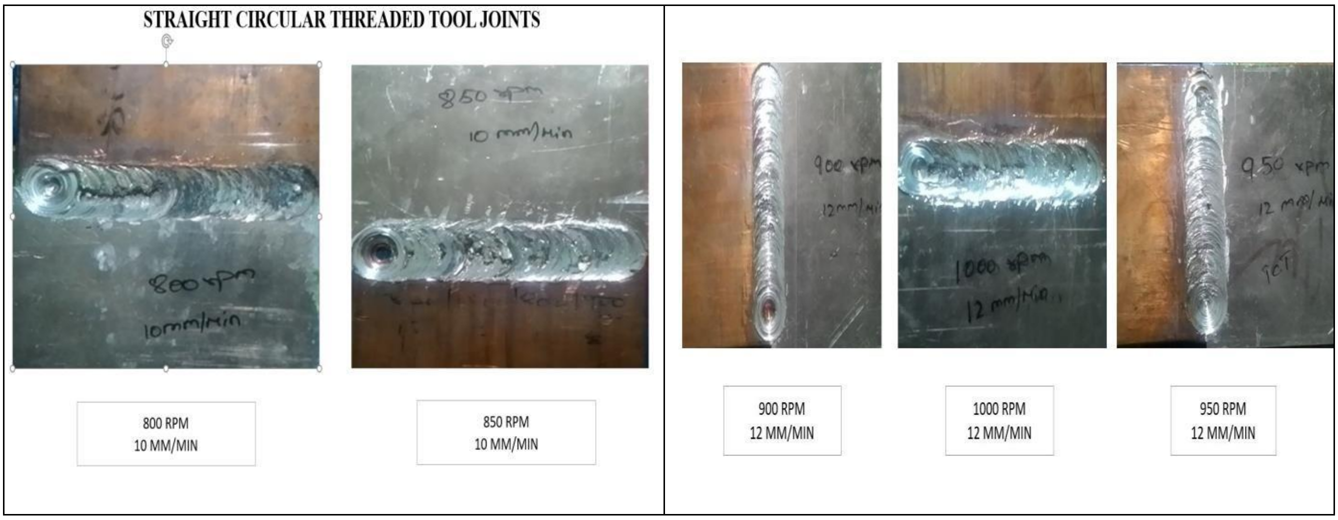

Fig11.At every 800,850,900,950 RPM the two materials are FWS is done as we can see in the Picture where the parts are welded at varying speed with straight circular thread joint

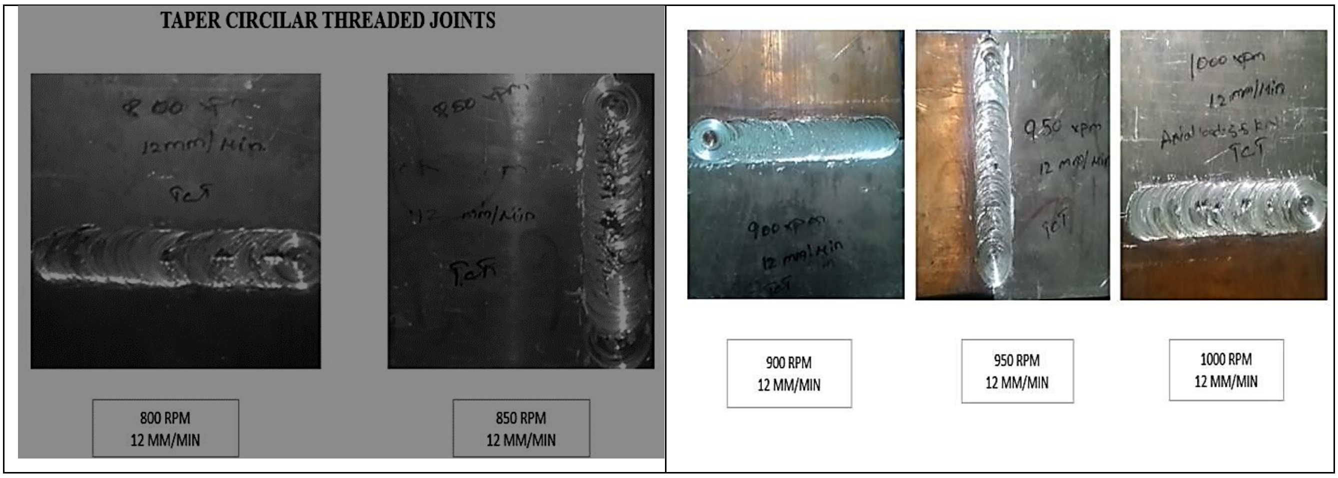

Fig 12 . At every 800,850,900,950 RPM the two materials are FWS is done with taper circular thread joint

5.1 Summary

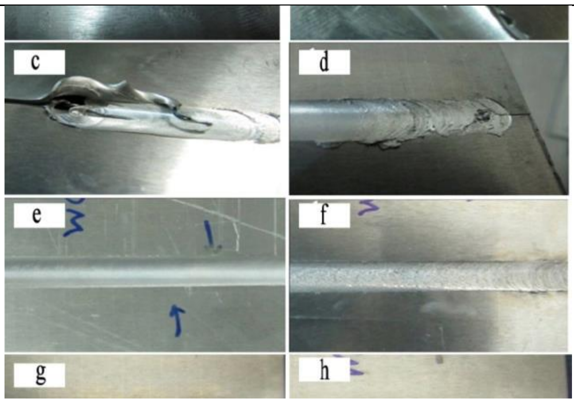	
Fig 13. Defect are formed at high RPM due to this the cracking and surfacetunnelingis formed	Fig:14 Defect are formed at high RPM due to this void and cracks are formed and we have compared it with micro structural images

6 Results

The SEM study of the joints formed of Taper threaded circle tool reveals voids and fissures. The inappropriate stirring of Al and Cu results in the formation of voids and fissures. According to the EDS study, the junction created of Taper threaded circular tool has more aluminum than copper, resulting in a higher tensile strength than the other joint. No faults are generated in the other joint made of Straight Cylindrical Threaded tool. According to the EDS study, the joint built of Straight Cylindrical threaded circular tool has an equal amount of aluminum and copper, resulting in a very low tensile strength. Defects like cracks, surface tunneling, voids are formed they occur due to less heat input and welding parameters.

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