International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

INVESTIGATION OF MECHANICAL PROPERTIES OF DISSIMILAR METALS BY FRICTION WELDING

K. Murali[1], A. Ajeetha[2], S. Ganeshkumar[3], R. Praveen Kumar[4], M.Viswanathan[5]

[1]Teaching Fellow, Department of Mechanical Engineering, University College of Engineering Arni-632 326, Tamil Nadu, India.
[2-5]UG Students, Department of Mechanical Engineering, University College of Engineering, Arni-632326, Tamil Nadu, India.

---***---

ABSTRACT: Joining of dissimilar metals is one of the most essential needs of industries. Dissimilar metal Mild steel, Copper both measuring 19mm diameter and length of mild steel 265mm, length of copper 82mmhas been investigated in the present work. In friction welding, two dissimilar rods are welded together by holding one of them, while rotating the other under the influence of a forge load which creates frictional heat in the interface. The tensile strength of the joints was determined, using a conventional tensile test machine. Ultimate tensile strength, percentage elongation of the welded joints and hardness variations across the weld interface has been reported.

Keywords: Rotary Friction welding, Dissimilar Metals, Tensile Test, Hardness Test.

1.INTRODUCTION

Friction welding is a solid state process for joining materials, especially dissimilar materials, which involves generation of heat by the conversion of mechanical energy into thermal energy at the interface of the work pieces without using electrical energy or heat from other sources during rotation under pressure [1]. Copper has excellent ductility, corrosion resistance, thermal and electrical conductivity, and has been widely used to produce engineering parts such as electrical component and radiator. Many ferrous and non-ferrous alloys can be friction welded. Friction welding can be used to join metals of widely differing thermal and mechanical properties. Often combinations that can be friction welded cannot be joined by other welding techniques because of the formation of brittle phases which make the joint poor in mechanical properties. The sub-melting temperatures and short weld times of friction welding allow many combinations of work metals to be joined [2]. Main advantages of friction welding are high material saving, low production time and possibility of welding of dissimilar metals or alloys [3]. Sahin et al. [4] joined steel and copper using friction welding process in their studies. They determined that maximum heat is away from the center, close to but not exactly at the surface during the welding process. However, due to the difference of chemical, physical and mechanical properties between the components to be welded, the welding of dissimilar materials is generally more difficult than that of homogeneous materials. High-quality Copper and mild steel dissimilar joint is hard to be produced by fusion welding techniques due to the large difference of melting points, brittle intermetallic compounds existence and crack formation [5-7]. Mohammadet al. [8] joined alumina and mild steel using friction welding at low rotational steel. They concluded that the strength of alumina–steel bonding is much dependent on the wet ability of the alumina surface by the partially molten aluminum interlayer and the existence of mechanical interlocking between the interlayer and mild steel. Many authors have recently conducted extensive investigation into the friction welding of dissimilar materials. The main reasons for dissimilar joining are due to the combination of good mechanical properties of one material and the low specific weight, good corrosion resistance, and good electrical properties of a second material. During the friction welding of dissimilar materials, significant cost saving is possible because engineers can design bimetallic parts that use expensive materials only where needed. Expensive forgings and castings can be replaced with less expensive forgings to bar steel, tubes, plates and suchlike. Duffin and Bahrani [9] carried out a series of experiments on the friction welding of mild steel tubular specimens to study the variations in resisting torque, axial force, and axial shortening when the angular speed and axial force are varied.

In this work, dissimilar friction welding of commercial pure copper and mild steel rods was carried out, and the mechanical properties of the dissimilar joints wasinvestigated. Based on the experimental results, the formation of the dissimilar joints was discussed.

2. ROTARY FRICTION WELDING

Friction welding process is classified by the American Welding Society (AWS) as a solid state joining process in which bonding is produced at temperatures lower than the melting point of the base materials (MaldonadoZepeda, 2001). All heating responsible by the union is mechanically generated by friction between the parts to be welded. This heating occurs due one part that is fixed, be pressed on the other that is in high rotation (Wainer, Brandi and Homem de Mello, 2002). The friction between the surfaces makes possible a rapid temperature rise in the bonding interface, causing the mass to deform plastically and flows depending on the application of pressure and centrifugal force, creating a flash. With this flash, impurities and oxides are removed from the surface, promoting the creation of a surface with excellent physical and chemical adhesion. The increase of temperature in the bonding interface and the application of pressure on that surface originate the diffusion between the two materials, and hence their union. The main parameters used to perform the set up are: Pressure P1 and time t1 – heating phase; Pressure P2 and time t2– forging phase; and rotation per minute (RPM). Figure 1 shows the phases of the process.

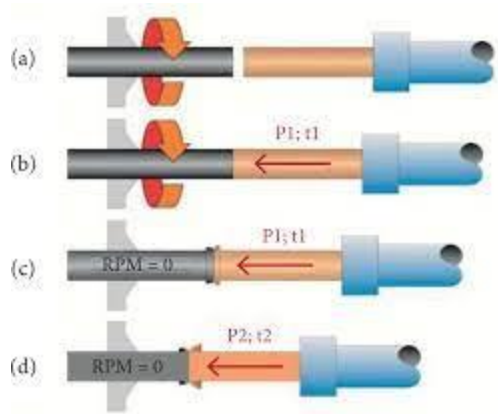


Figure 1: Phases of conventional friction welding process. (A) Period of approximation; (B) P1, t1 application; (C) end of P1, t1 application, and braking of the machine (RPM = 0); (D) P2, t2 application and finish welding

Figure 2 shows the basic layout of RFW equipment. Usually the structure is fairly rigid to provide stability to the equipment working at high speeds and is driven by high pressure forging. Modern equipment is automatic and allows all the parameters be adjusted, controlled and monitored directly on the control panel.

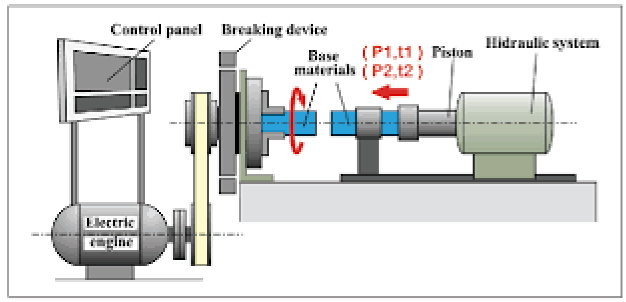


Figure 2: Equipment of rotary friction welding.

3. EXPERIMENTALPROCEDURE

Materials Commercially available pure copper and mild steel were used, and the chemical compositions of the experimental materials are listed in Table 1. The materials used in the experiments were mild steel and copper rods both measuring 19mm in diameter and 82mm in length of copper,265mm in length of mild steel. By using rotary friction welding both the materials are welded together with different welding parameters such as spindle rotation speed, friction load, friction time, forge load, forge time and cooling time.

Table 1. Chemical Compositions of Mild Steel and Pure copper

Material	Mild steel	Copper
C	0.175	-------
Si	0.118	-------
Mn	0.394	-------
Ni	0.016	0.009
Cr	0.02	-------
Cu	0.022	99.957
Fe	99.1	0.009
Zn	--------	0.025

ROTARY FRICTION WELDING MACHINE

3.1MACHINE SPECIFICATION

Machine number: MEEQ-066

Machine name: Friction welding machine

Maker-RV machine toolsWelding capacity – Ø 8 to 25mm in steel

Machine overall dimension-2200×1900×1000mm

Spindle tape-A26

Spindle motor-serve motor (MAD130C-0150) (REXROTH)

Feedback encoder-spindle servo motor in built (REXROTH)

Motor torque /max-117Nm/275nm

Spindle power-15Kw

Spindle speed-1500rpm (max 2500RPM)

Spindle drive-poly V-belt drive

FW chuck-3B-Ø 250 FWC (GMT) Hydraulic closed cylinder-CH-22-65 (GMT)

Z-axis thrust force -10tonZ-axis travel -200mm

Z-axis motor -23Nm/2200rpm Z-axis rapid speed-300mm/min

Z-axis gear box-8:1 right angle planetary

Z-axis ball screw-40×10R×6.4(REXROTH)

Z-axis LM guide-RG-H-45-CA-2-R-640-ZO-H-AA-DD(H1W1N)

Z-axis-15ton load cell (ADI ARTECH)

Max/min holding diameter- Ø 50mm/8mm

No of cylinder-2

Cylinder diameter- Ø100mm

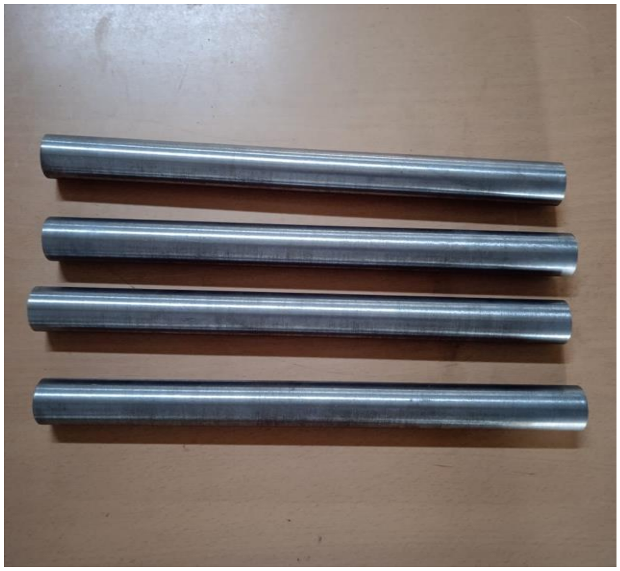
Rod diameter- Ø 80mm

Stroke-15mm

Z-axis-200mm

Power pack-HYDRO SOLUTION

COPPER



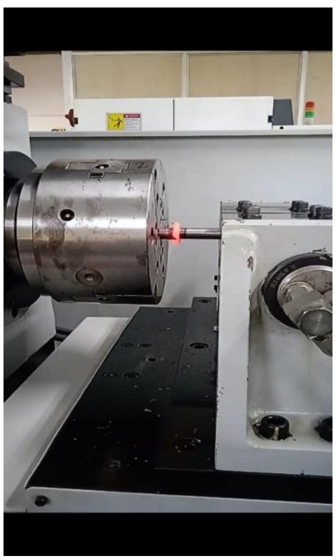
MILD STEEL

3.2 PARAMETERS

Sample	Spindle Rotational speed (rpm)	Friction load(NM)	Friction time (sec)	Forge load(NM)	Forge time (sec)	Cooling time (sec)
1	1200	1000	10	3000	5	5
2	1200	900	9	2500	5	5
3	1200	800	8	2000	4	5
4	1200	1100	11	3300	6	5

During friction welding process these different welding parameters were used to join copper with mild steel material. Copper is placed in the headstock which rotates the workpiece by spindle motor and mild steel in tailstock which is stationary part. After this parameters setup value was entered in the system (Automatic operation mode) to weld the copper with mild steel automatically.

BEFORE FRICTION WELDING



DURING FRICTION WELDING

WELED SPECIMEN

AFTER FRICTION WELDING

4.MECHANICAL TESTING

After friction welding the four welded specimens were carried out by tensile testing and Rockwell hardness testing to find its mechanical properties.

4.1 TENSILE TEST:

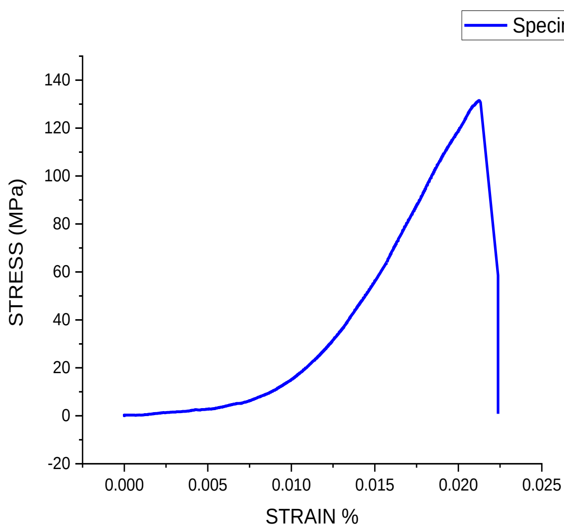
Tensile test is used to find out how strong a material is and also how much it can be stretched before it breaks.

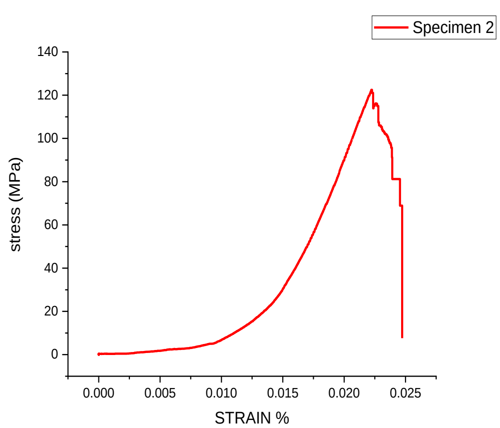
Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension.

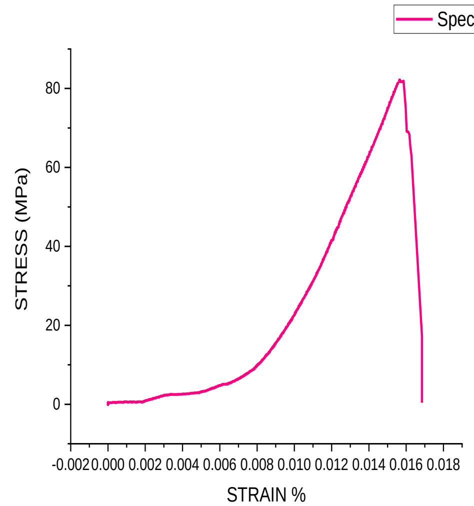
The strength of a material often is the primary concern. The strength of interest may be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. These measures of strength are used, with appropriate caution (in the form of safety factors), in engineering design. Also of interest is the material's ductility, which is a measure of how much it can be deformed before it fractures. Rarely is ductility incorporated directly in design; rather, it is included in material specifications to ensure quality and toughness.

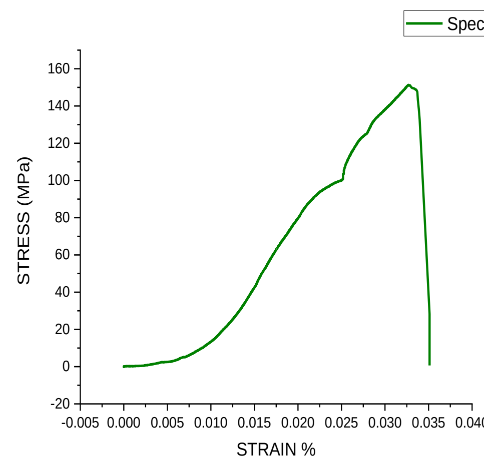
Low ductility in a tensile test often is accompanied by low resistance to fracture under other forms of loading. Elastic properties also may be of interest, but special techniques must be used to measure these properties during tensile testing, and more accurate measurements can be made by ultrasonic techniques.

Tensile test is one of the most important mechanical property evaluation test. In this test a cylindrical or a plate shaped specimen is deformed by applying a uniaxial force as shown in the figure below. One end of the sample is fixed in a static grip while the other end of the specimen is pulled at a constant velocity. The load is continuously monitored during the test. It is usual to conduct this test until the sample fractures.







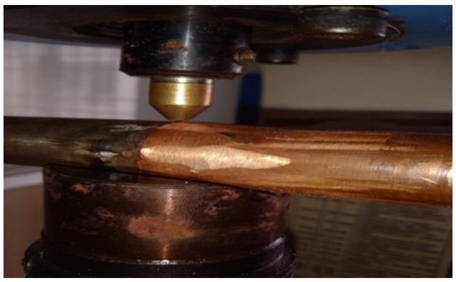


4.2 ROCKWELL HARDNESS TEST

The **Rockwell hardness test method,** as defined in ASTM E-18, is the most commonly used method. The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods. The Rockwell test method is used on all metals, except in condition where the test metal structure or surface conditions would introduce too much variations: where the indentations would be too large for the applications: or where the sample size or sample shape prohibits its use.

The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is applied to a sample using a diamond or ball indenter. This preload breaks through the surface to reduce the effects of surface finish. After holding the preliminary test force for a specified dwell time, the baseline depth of indentation is measured.

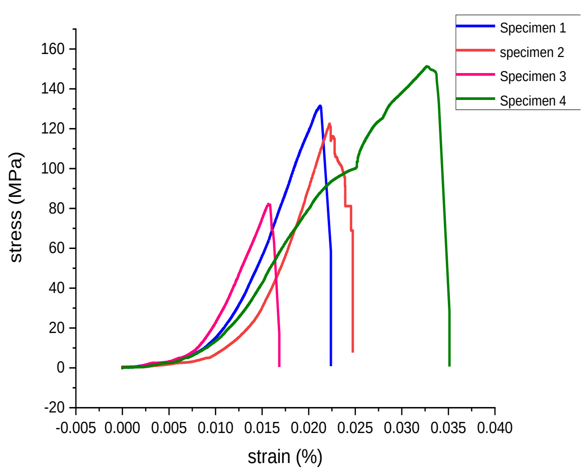
After the preload, an additional load, call the major load, is added to reach the total required test load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This major load is then released, returning to the preliminary load. After holding the preliminary test force for a specified dwell time, the final depth of indentation is measured.



SPECIMEN	LOAD	RHN
1.	**100**	**74.5**
2.	**100**	**59.5**
3.	**100**	**83.5**
4.	**100**	**56**

5. RESULT AND DISCUSSION

5.1 Tensile Test graph result



SPECIMEN	TENSILE STRENGTH (MPa)	RHN
1.	126.55	74.5
2.	117.217	59.5
3.	81.235	83.5
4.	149.571	56

By analyzing the tensile test graph result it shows specimen 4 has highest tensile test of149.571MpA and Elongation of 1.78% (Constant speed 1200RPM, Friction load 1100NM, Friction Time 11sec, Forge load 3300NM, Forge time 6sec, cooling time 5sec).

By analyzing the Rockwell hardness test of ball indentor it shows specimen 3 has highest hardness of 83.5RHN (Constant speed 1200RPM, Friction load 800Nm, Friction time 8sec, Forge load 200NM, Forge time 4sec, cooling time 5sec).

CONCLUSIONS

1. Friction welding process was successfully done on the Dissimilar joints such as
2. The highest Tensile Strength obtained in the weld joint was 149.571MpA and Elongation of 1.78% (Specimen 4).
3. The highest Hardness obtained in the weld joint was 83.5RHN (Specimen 3).
4. The hardness in the welded zone was higher than heat affected zone.
5. This parameters shows that the friction load and Forge load plays an important role in making the strong diffusion with the surfaces of material.

REFERENCES

- Dalip Kumar, AntarikshaVerma, SankalpKulshrestha, Prithvi Singh "Microstructure and Mechanical Properties of Mild Steel-Copper Joined by Friction Welding, 2013".
- MrityunjoyHazra, and G Madhusudhan Reddy "Microstructure and Mechanical Properties of Explosive Weld Copper-Mild Steel Joint". Indian Welding Journal [Volume 51 No.1, January 2018].
- Anushakankanda, SridathKotturu, RevanthMylarusetty, ShaikFroz"Weldability of Aluminium to Mild Steel using Friction Welding Process" Oct-2016.
- Arjun G., Atheena J. R., Nithin V., Vyshakh P., Mebin T. K., James Valder and Rijesh M. "welding Feasibility of Copper and Mild Steel using TIG Welding"(2K16) Thalassery, 8-9 Augest, 2016.

- JeswinAlphy James, **Sudhish. R “Study on Effect of Interlayer in Friction Welding for Dissimilar Steels: SS 304 and AISI 1040” Procedia Technology 25(2016) 1191-1198.
- P. VenkatKoushik, and D. Avinash, “Experimental Investigation of Friction Welding using Aluminium with Mild Steel.” International Research Journal of Engineering and Technology, 3(12), pp. 680-685, 2016.
- D. Ananthapadmanaban, “Mechanisms of friction and their correlation to bond strength of friction welded Ti-6Al-4V similar welds, Low Carbon steel-Stainless steel and Aluminium- Copper dissimilar welds” International Journal of Innovations in Engineering and Technology (2018).