Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-365

Microstructure and Mechanical Properties of Similar and Dissimilar Weld-bonded Material

Nusrat Sharmin[1] ,Mihir Dutta[2] , Susmita Das Puja[3]

[1]Dept. of Mechanical Engineering, Sonargaon University,Dhaka,Bangladesh
[2]B.Sc. in Mechanical Engineering, Khulna University of Engineering & Technology,Khulna,Bangladesh
[3]B.Sc. in Mechanical Engineering, Khulna University of Engineering & Technology,Khulna,Bangladesh
nushrat.keya@gmail.com, mihirdutta53@gmail.com, pujapuja96.pp@gmail.com

Abstract-*Welding of similar and dissimilar metal joints are widely applied in engineering structure material. When melting point difference is low, gas welding is the best choice for welding different metals but when melting point difference is high, sound welding can't obtained by gas welding, in this situation TIG welding is considered as the best choice. While testing mechanical properties of different joints by gas and TIG welding, it is observed that tensile strength and Rockwell hardness scale of gas welding joints are higher than TIG welding joints. It is also observed that in every welding sector sound welding is found in similar metal joints as compared with dissimilar metals joint. Similar metal joints show strong bond and for this reason, their mechanical properties is higher than dissimilar metal joints. Microstructure of similar and dissimilar metal joints of different welding is also analyze.*

Keywords: Gas welding, TIG welding, Mechanical property, Microstructure.

1. INTRODUCTION

Welding is an effective technology used widely in advanced construction and equipment, especially in the automotive industry to join the parts. Similar metal can be welded by any kind of welding process such as arc welding, gas welding, gas metal arc welding etc. But in dissimilar metal welding the properties of three metals need to be considered, the two metal being joint and the filler metal used to join them. In this type of welding, base metals do melt and partially dissolve in the filler metal and create a metallurgical bond [1].Mild steel-Mild steel and cupper-cupper flat bars are joined by gas welding. Due to great difference in the physical and chemical properties of mild steel and cupper, the dissimilar combination of cupper and mild steel is generally more difficult and many problems occurred such as oxidation, cavities and cracks. So this dissimilar metals are joined by gas welding in high temperature [2]. Copper and aluminum have been widely applied as engineering structure materials due to their good comprehensive properties such as excellent corrosion resistance, ductility, heat and electric conductivity [3-4]. When aluminum and copper flat bars are selected, it is more challenging to accomplish Al-Cu dissimilar welding in view of the large differences of electrical conductivity, thermal expansion coefficient, melting point etc. Al-Cu flat bar is joined by TIG welding at 150^{o}C temperature [5].

For analyzing mechanical property of welding joint, tensile and hardness test is observed. Perhaps the most important test of a material's mechanical response is the tensile test. Universal testing machine is used to observe the tensile strength of different welding joint. Hardness is a measure of resistance of metal to various kinds of permanent shape change when a compressive force is applied [6]. Rockwell hardness test is done to observe the hardness of welding joint. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload [7].Microstructure is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification. To analysis microstructure of similar and dissimilar welding joint, the fracture surface need to be cut by 1 inch in length and 1 inch in width for the benefit of observation. Then the surface is polished and optical microscope is used.

2. METHODOLOGY

In similar metal welding, mild steel-mild steel and cupper-cupper joint are done by gas welding. Mild steel-cupper joint is also develop by gas welding. In gas welding heat is required to melt the surfaces of metal which is supplied by a high temperature flame obtained by a mixture of acetylene (C_2H_2) and oxygen gas. The

welding process is done by lap joint [7]. When melting point difference is too high, then TIG welding is the best choice to join dissimilar metal. For similar metal joint, Al-Al work pieces are joined by the heat obtained from an electric arc struck between a non-consumable tungsten electrode in which Al alloy is mixed and the work piece in the presence of an inert gas atmosphere [7]. Cu-Cu joint is also developed by the same process. For Al-Cu joint various alloy like zirconium, thorium, lanthanum etc. are alloyed with tungsten to improve arc stability, better current carrying capacity, resistance to contamination etc. The diameter of the electrode varies from 0.5-6.4mm [5]. For both welding process, a standard size for materials is selected. The length of each material is 11 inch, width is 1 inch and thickness is 4mm. After lap welding, the length of the similar and dissimilar metal becomes 18 inch. The welding joint is 2 inch in length and the thickness of each joint becomes 8 mm.

Tensile test of each joint is carried out at room temperature using a Universal tensile testing machine. Load is applied to the material gripped at one end while the other end is fixed. The load is increased by 5 kN while at the same time measuring the change in length of the specimen. Then the deformation of each specimen is observed and strain is calculated. In hardness test, a preliminary test force is applied to a joint using a diamond indenter [7]. After the preload, an additional load, call the major load, is applied to reach the total required test load. This force is held for a predetermined amount of time to allow for elastic recovery. This major load is then released and the final position is measured against the position derived from the preload, the indentation depth variance between the preload value and major load value. This distance is converted to a hardness number.

In order to determine microstructure of welding joint, the fracture surface of each metal is reduced to 1 inch in length. Surface layers damaged by cutting must be removed by grinding. Polishing procedure involves several stages, using a finer emery paper (higher number) for each successive stage. Each polishing stage removes the scratches from the previous coarser paper. Polishing machine is used after rough polishing of the surface over fine emery paper [3]. A shinning mirror like surface is required after polishing the specimen. Etching removes the thin, highly deformed layer introduced during grinding and polishing .For etching mild steel, nitric acid is used. This is applied using a cotton bud wiped over the surface for a few times .The specimen should then immediately be washed in alcohol and dried. For etching copper-copper and Ms-Cu bond, a saturated aqueous solution of ferric chloride, containing a few drops of hydrochloric acid is used. For etching Al-Al bond, hydrofluoric acid is used.

3. RESULTS AND DISCUSSION

3.1 Mechanical Property

For calculating stress and strain of welding joints, we use

$$\text{Stress} = \frac{load}{area} = \frac{load}{width * thickness} = \frac{F}{A}$$

$$\text{Strain} = \frac{deformation}{previous\ length} = \frac{\delta}{L}$$

3.1 .1 Tensile strength (Gas Welding)

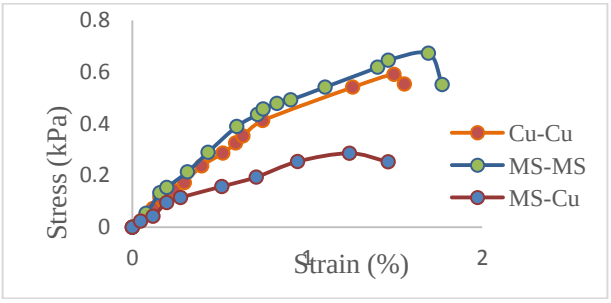


Fig.1: Stress-Strain diagram of welding joint by gas welding

In stress-strain diagram, MS-MS joint shows higher stress and deformation occurs slowly. In Cu-Cu joint, the bond breaks at lower stress than MS-MS bond but it can be observed from the graph that MS-Cu joint shows lower stress and deformation occurs rapidly in this situation.

Tensile Strength (TIG welding)

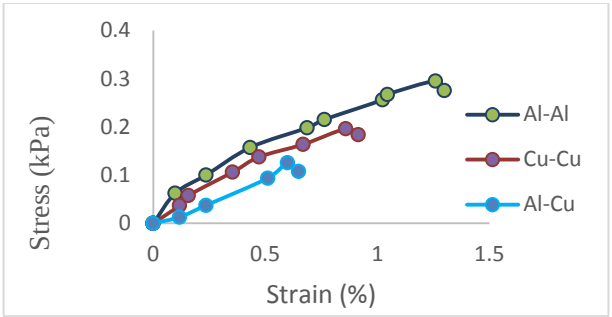


Fig.2: Stress-Strain diagram of welding joint by TIG welding

When TIG welding is used for the metals of high melting point difference, then similar and dissimilar metal require lower stress than the stress of metal joined by gas welding. In Al-Al similar metal joint, stress is increased gradually and deformation occurs slowly before yield point. Beyond yield point, deformation occurs rapidly with the increase of load by 5 kN. In dissimilar metal joint, deformation occurs rapidly and Al-Cu joint breaks at lower stress.

3.1 .2 Breaking Stress Analysis (σ) (Gas Welding)

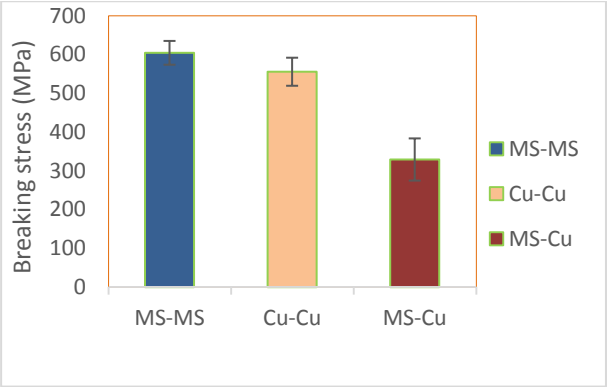


Fig.3: Breaking stress of different joint by gas welding

In breaking stress bar chart, standard deviation is analyzed for different joint which is 30.71 for MS-MS, 36.21 for Cu-Cu and 54.47 for MS-Cu joint.

Breaking Stress Analysis (TIG Welding)

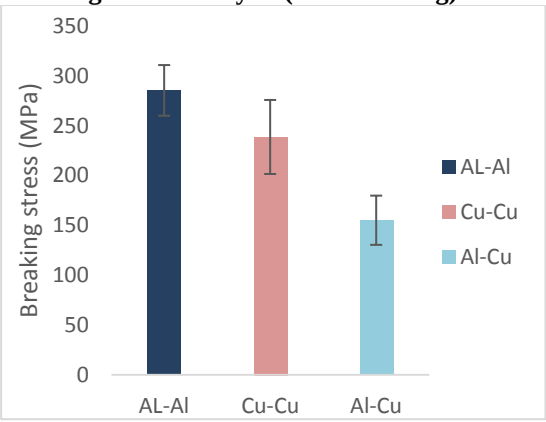


Fig. 4: Breaking stress of different joint by TIG welding

For Al-Al welding joint stress is 285.43 MPa and standard deviation for this joint is 25.41. For Cu-Cu joint breaking stress is 238.61 MPa and here deviation is too large. For dissimilar metal joint breaking stress is 155.075 and standard deviation is 24.72.

3.1 .3 Hardness Test (Gas Welding)

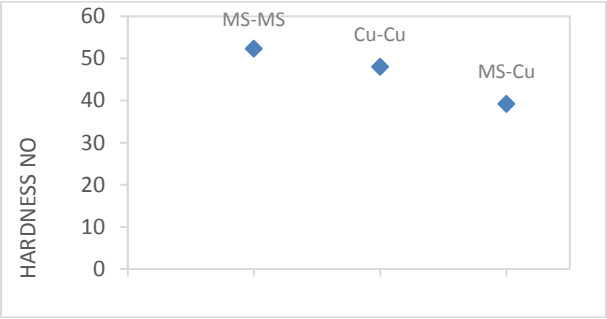


Fig.5: Rockwell hardness no for gas welding

For gas welding, the hardness scale of similar metal joint is higher than dissimilar metal joint as the bond of similar metal is much stronger than dissimilar metal. Hardness scale of MS-MS joint is 52.3 and Cu-Cu joint is 48 but when MS-Cu joint is analyzed, the hardness scale reduces and the value of hardness is 39.29.

Hardness Test (TIG Welding)

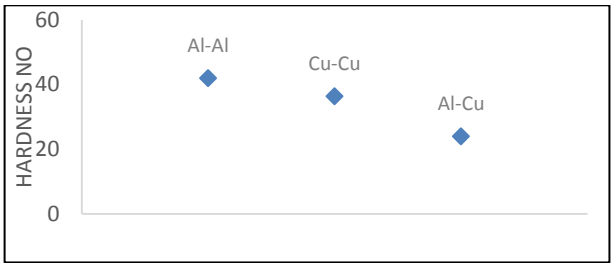
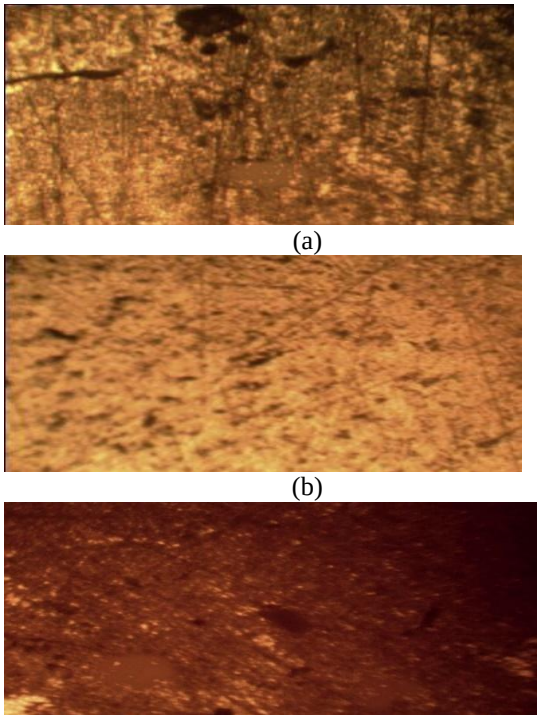


Fig. 6: Rockwell hardness no for TIG welding

Here Al-Al bond shows the hardness value of 42 and Cu-Cu shows hardness value of 36.3.The lowest hardness value observed at dissimilar joint which is 24.

3.2 Microstructure Analysis (Gas Welding)



(a)

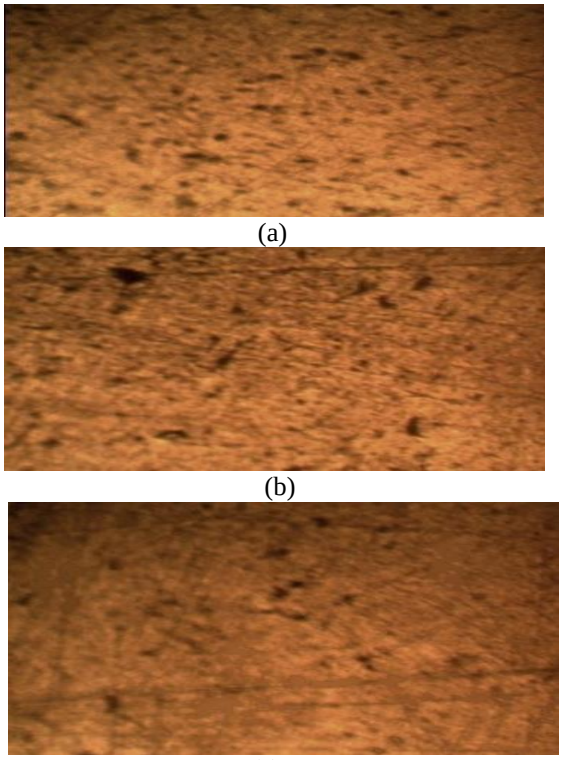
(b)

(c)

Fig.7: Microstructure of (a) MS-MS joint (b) Cu-Cu joint (c) MS-Cu joint

In MS-MS joint by gas welding, higher stress is required to reach the ultimate position where the metal fails. So the fracture surface is too much rough. When fracture surface is analyzed in optical microscope, it is seen that the atoms are scattered on the surface. In Cu-Cu joint, the surface is also rough but the roughness is not like MS-MS bond. This bond is quite smooth than MS-MS joint.

Microstructure Analysis (TIG Welding)



(a)

(b)

(c)

Fig. 8: Microstructure of (a) Al-Al joint (b) Cu-Cu joint (c) Al-Cu joint

The bonds which are joined by TIG welding shows a smooth fracture surface than gas welding. Deformation of these joint are rapidly occur, for this reason ultimate stress of similar and dissimilar metal is also low. Between two types of welding, Al-Cu fracture surface is smooth than similar metal welding. Al-Al surface is quite rough as higher stress is needed for this joint.

4. CONCLUSION

Similar metal joints are much familiar in mechanical engineering sector but sometimes dissimilar metal joints are necessary for any kind of automobiles sectors, shipyard and factories. Recently joining dissimilar materials is of great interest in engineering applications because of their technical and beneficial advantages. When metals are chosen of low melting point difference, then gas welding can be used but when melting point difference is high, then gas welding is not the best choice to weld metal. In this situation TIG welding can be chosen to weld similar and dissimilar metal. TIG welding shows low mechanical properties than gas welding i.e. breaking stress and Rockwell hardness scale are low for TIG welding. So while choosing metals for different welding joint, melting point difference need to be low and metals need to be joined by gas welding instead of TIG welding.

5. REFERENCES

[1] Honeycombe,R.W.K &Bhadeshia, H.K. ,Steel Microstructure and Properties, 2nd Ed.,Edward Arnold, London, 1995

[2] Y Zhu-Mechanical Properties of Materials.Retype www.mae.ncsu.edu/zhu/courses/mae316/lecture/1b-Materials

[3] WEIGL M, ALBERT F, SCHMIDT M. (2011), Enhancing the ductility of laser-welded copper−aluminum connections by using adapted filler materials

[4] ZHANG,Q.,GONG,W. and LIU,W.(2014), Microstructure and Mechanical Properties of Dissimilar Al−Cu Joints by Friction Stir Welding.

[5] WANG, X, SUN,D,YIN, S.,LIU, D. (2015), Microstructures and Mechanical Properties of Metal Inert-gas Arc Welded Mg−Steel Dissimilar Joints

[6] MANCHANDA V.K., NARANG G.B.S. (2005), Materials and Metallurgy,KHANNA PUBLISHERS,DELHI

[7] JAIN, R.K (2006), Production Technology, KHANNA PUBLISHERS, DELHI

6. NOMENCLATURE

Symbol	Meaning	Unit
F	Load	(kN)
A	Area	(mm^2)
L	length	(mm)
δ	Deformation	(mm)
σ	Breaking stress	(MPa)