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OXY-ACETYLENE BRAZING OF AL-CU METAL TUBESFOR MINIMIZING REFRIGERATION EQUIPMENT COST

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Abstract

Several welding methods such as TIG, LASER were performed on Cu-Al ,with the arc was directed toward the copper as filler wire was added but the joints did not possess the required strength or ductility. It is also difficult to form Al-Cu joints by fusion welding because mutual solubility between Al and Cu in the liquid state but initiation of cracks after solidification. It is due to the significant difference in melting temperature and thermal conductivity of metals. In the present work, Cs-Al-F compounds in the form of white slurry is used brazing flux in the filler core wire. Such flux cored filler wire was found to be suitable for brazing aluminum-copper upto 350psi (2.4mpa) while the pressure encountered in piping of refrigeration system is about 20-200 psi (0.14mpa to 1.4mpa). Brazed combination of Al–Cu in refrigeration system shall provide huge saving in cost of tubing while maintaining the desired mechanical and thermal properties.

Keywords: *Flux core filler rod, welding, brazing, Cu-Al joints*

1.Introduction

In oxy-acetylene welding, oxygen is mixed with acetylene in correct proportions in the welding torch and a lighter is used for igniting. The flame from the torch melts and join the base metals. The flame temperature is about 3300°C and can be used for brazing at around 6000C.Brazing is a process of joining metals without melting the base metal. Dissimilar Cu –Al welding poses welding difficulties due to wide difference in physical properties (Table-1).Recently, procedures were developed to join aluminum to copper by gas tungsten-arc welding; commercially pure aluminum was used as the filler wire but the joints did not possess the required strength or ductility.

Brittle or hard intermetallic compounds of weldment can initiate cracks, due to the significant difference in melting temperature, thermal conductivity and thermal expansion of the base metals (Sun &Karppi, 1996; Posinasetti and Prasad 2005). Khan N.Z. et al.2017 observed the mechanical and microstructural behavior of friction stir welded similar and dissimilar Al sheets alloys. Limitation in the friction welding , clamping and rotating limits is the length and shape of the tube while in the flash welding, weldments forming effect is lesser and weldments must undergo rework(Zhang Y et al.,2010). Conventional flux such as Borax coated fillar rod joints with oxy-acetylene welding equipment provided strength upto 20 psi (0.14 mpa). In terms of in-service life consideration, Al oxide formation poses considerable difficulties. Aluminium.

Property	Copper	Aluminium
Density	8.9 g/cm^3	2.71 g/cm^3
Melting temperature	1083 °C	660 °C
Thermal conductivity	390 W/mK	226 W/mK
Co-efficient of thermal expansion	17/°C.10^6	24/°C.10^6

Table 1: Copper and Aluminum physical properties(1)

is cheaper and its density is 3.28 times lower as compared to copper.
Through a lot of work has been done ,but a sustainable permanent joining Cu-Al process is not available for refrigeration system at present. The Cu-Al joints must be leak proof and able to sustain pressure in the refrigeration system. The aim of the present paper to provide a sustainable Cu-Al tube brazing using flux cored filler wire. The work reported here is to achieve brazing in Cu-Al tubes having strength at the joint far more than the pressure encountered in the refrigeration system.

2. Material and Flux Cored Filler Wire

Copper Alloy: C12200 (ASTM280) is a phosphorus-deoxidized copper (99.9%), with high residual phosphorus (0.02%). Copper refrigeration tubing has the good thermal conductivity of any standard heat exchange material.

Aluminium Alloy AA1060: The commercially pure aluminium i.e. AA1060 is soft, ductile and it has the property of excellent workability after annealing. For this reason AA1060 is picked up for the current study. The chemical composition of AA1060 is shown in Table 2:

Si	Fe	Cu	Mn	Mg	Ti	Ga	V	Others	Al
0.168	0.287	0.014	0.013	0.01	0.012	0.005	0.007	0.084	Balance

Table2: Properties of AA1060

Flux cored wire (FCW)filler: Aluminium alloy Al88Si12（4047）consists of 88% Al and 12% Si. Cesium Flux: Cs-Al-F compounds in the form of white slurry is used in the Cesium brazing flux is most suitable for brazing aluminum-copper. Outer diameter of wire was mm and inner diameter 0.8mm(filled with flux). Flux was cored about 20% in the aluminium alloy. Noncorrosive flux is filled in the core of the wire. This FCW is mainly used for brazing of tubular components or tube shaped parts in automobile / refrigeration industries. Brazing temperature is from 575^{0}C to 585^{0}C. Several advantages include a high deposition rate , can make an “all-position” process and flux-cored wires create clean, pressure tight and high strength welds.

3.Results and Discussion

3.1 Brazing process

Copper and Aluminium metal tubes were hold using pliers and a central rod was used to keep the tubes straight. Gas welding torch was used heat up Cu and Al tubes and melting the flux cored filler wire(Fig.1). Flux core filler wire as the name suggests uses a wire, with a flux based center. As the metal melts, the flux flows out and covers the weld and provides leak proof brazing which is required in refrigeration system.

Fig.1: Gas welding equipment for brazing and Cu, Al samples

Problem with brazing copper to aluminium is that the aluminium has a much lower melting point than copper . The heat transferred from the copper to the aluminium reaches the melting range of aluminum, it will start to burn down very fast, while the copper is still taking the heat. Therefore, the flame is usually directed on the copper. Around 70% heat is supplied to copper. As soon as the filler metal begins to melt from top layer or color change in the aluminum, the flame must be quickly removed. Figure2 shows brazed samples.

Fig.2: Brazed sample

2 Leakage testing

Fig.3: Leakage test rig for brazing fitted with pressure gauge

After brazing with several combination wire, joints were tested in a refrigeration test rig commonly used by refrigeration mechanic (Fig.3) fitted with pressure gauge. A tube attachment was brazed to Cu-Al tubes at one end so as to provide interfacing, while the other end was closed. Pressure sustained was recorded by pressure gauge.

It is observed that in Sr. number 5 , when 70% heat is supplied to copper tube through gas welding equipment, the tube gets it immediately and heated uniformly as it is very good conductor. As a result flux cored Al based filler wire spreads easily into the joint and provide leak proof jointupto350psi (2.4mpa). In Sr. number 4,the filler material flows over Aluminium (not copper) and provide limited spreadability(Table3).
It is established experimentally that this flux cored filler rod for a brazed Al-Cu joint, gives better mechanical properties as compared to other filler wires/rods. Aluminium is cheaper and its density is 3.28 times lower as compared to copper. Brazed combination of Al–Cu in refrigeration system may be provided to increased heat transfer rate through Cu and at lesser important places regarding heat transfer ,Al may be used. This will reduce cost and provide huge saving in cost of metal tubing while maintaining the desired mechanical and thermal properties.

4. Conclusions

Following conclusions were drawn from the Cu-Al brazing experimental work using oxyacetylene welding:

- Slow movement of torch should be avoided, it leads to hole formation.
- About 70% heat should be concentrated on copper and rest on aluminum.
- Clearance between joining parts should be approx 0.25mm for leak proof joint.
- Swaging joints were brazed using gas welding equipment's. It is better to insert copper into aluminium. Sound brazing joint was found using aluminium based flux cored filler rod.

Table3: *Pressure sustainability with various filler rod*

S.No.	Filler wire/Rod	Pressure sustainabilty	Remarks
1	Cu based filler rod	Leaking	Poor fusion
2	Al based filler rod	Leaking	Irregular bead
3.	Al based filler rod with outside flux coated	15 psi (0.105 mpa)	Uniform bead but lesser spreadability in the joint.
4.	Flux cored filler wire(Copper outside and Aluminium inside with 0.25mm clearance)	200 psi (1.4 mpa)	Uniform bead with average spreadability of filler material in the joint.
5.	Flux cored filler wire(Aluminium outside and copper inside with 0.25mm clearance)	350psi (2.4mpa)	Uniform bead with good spreadability of filler material in the joint .

- Flux cored filler rod was found to be suitable for brazing aluminum-copper upto350psi (2.4mpa) while the pressure encountered in piping of refrigeration system is about 20- 200 psi (0.14mpa to 1.4mpa).
- It is observed that in Sr. number 5 , when 70% heat is supplied to copper tube through gas welding equipment, the tube gets it immediately and heated uniformly as it is very good conductor. As a result flux cored Al based filler wire spreads easily into the joint and provide leak proof joint upto350psi (2.4mpa)
- Brazed combination of Al–Cu in refrigeration system shall provide huge saving in cost of tubing while maintaining the desired mechanical and thermal properties.

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