Dijlah Journal of Engineering Science (DJES) Vol. 2, No. 1, March, 2025, pp. 12-19
ISSN: Printed: **3078-9656, Online: 3078-9664**, paper ID: 24

Mechanical Properties of Weld Joint aluminum to copper pipes in refrigeration system

Ezzet Hameed Abdulsalam
Department of refrigeration& Air condition Technical Engineering, University of Dijlah, Baghdad, Iraq

Article Info

Article history:

Received Feb. 12, 2025
Revised Feb. 28, 2025
Accepted March, 3, 2025

Keywords:

Copper
Aluminum
Welding
Destructive test
Non- destructive test

ABSTRACT

This work is dealing to the welding technology of joining copper pipe with aluminum pipe which are widely used in refrigeration systems and boilers. The chemical composition analysis of both metals show that are close to pure copper and aluminum. Experimentally this work prove that those metals show a good weldability integrity.

A weld filler type ER4047 is used to join two pieces of pipes using oxyacetylene welding process. This experimental work is also involving the achievement of weld integrity and mechanical prosperities by performing several destructive and non-destructive examination on the weld region such as, Tensile, bending, hardness, x-ray and Liquid penetrant). From all of the previous tests it was confirmed that, the weld joint maintains a excellent mechanical properties and acceptable weld defects.

Corresponding Author:

Ezzet Hameed Abdulsalam
Department of refrigeration& Air condition Technical Engineering, University of Dijlah, Baghdad, Almasafi street, Baghdad, Iraq
Email: izzat.hameed@duc.edu.iq

1. INTRODUCTION

The two pipes connection by Welding is an important process in many applications, such as fabrication, maintenance and structures repairs because it is a suitable and fast method for joining similar and dissimilar types of materials . It is well known that, there are so many method of welding available in this field, for example, the shield metal arc welding, (SMAW), Tungsten Inert Gas welding (TIG), Submerge Arc Welding, (SAW), Metal Inert Gas welding (MIG)...etc.[1].
The required mechanical properties for any weld joints can be obtained when a standard Welding Specification Procedure (WPS) is used such as ASME standards.
The welding process is not easy to do and the quality of the weld is highly depended on the welder skill, welding procedure and metallurgy. However, it is possible that welding could form so many defects in the structure, such as, slag inclusions, undercuts, distortions, Porosities, lack of penetration, misalignment residual stresses...etc. [2,3].

The weld joint design is an important factor in welding processes. The design types of any weld joints such are butt, corner, lap, and edge, butt joint which are used to join two sections aligned in the same line, that used in plate, sheet metal, and pipe system work. [4,5].
For pipe welding, different basic test positions used. The position revealed the position of the pipe, not the
position of welding. When using the 6G position for pipe welding, the axis of the pipe is at a 45-degree angle with the horizontal while the pipe is not rotate. Since the pipe is not rotate, welding will be done for all the positions such as flat, vertical, horizontal, and overhead. If you can weld pipe in this position, you can handle all the other welding positions. Since most pipe welds are groove welds, these are known by the letter G. [6,7].

The joining of pipe techniques applied in this work and also the welding procedure is done by using ASME section IX standard for pipe welding certification [8,9].When the welding pipe of the 6G position related to all types of the pipe welding positions. [10, 11].

2. Materials and Method

The pipes metal analysis in this work are found to be as a pure copper and aluminum. Tested specimens in this work are in the form of pipes of inner diameter of 20 mm, outer diameter of the pipe is 25 mm. This analysis of metals composition was done at the ministry of oil laboratory, the percentage of elements are shown in Table (1).

Sample	Si%	Fe%	Cu%	Mn%	Mg%	Cr%	Ni%	Zn%	Ti%	P%	Pb%	Al%
انبوب الالمنيوم (Ø16,t=1.5) mm	<0.8	0.194	0.027	0.0144	0.385	0.019	0.0127	0.0107	0.014	0.001 <	0.0095	98.5

Sample	Zn%	Pb%	Sn%	P%	Fe%	Ni%	Mn%	Si%	Cr%	S%	Sb%	Al%	Cu%
انبوب نحاس (Ø16,t=1)mm	0.003 <	0.0003	0.0009	0.0268	0.01	0.0014	0.0004 <	0.0008 <	0.0013	0.0019	0.0068	0.0182	99.9

Table (1): The Chemical Composition of the Pipes Materials

A. Welding Process:

Lap Weld joint design type had been prepared using mechanical forming as shown in Figure (1).

Figure (1): The lap weld Joint Design

Before the beginning of welding process all weld joints were highly cleaned to be free and clear from any types of contamination such as, foreign particles rust, oil, water, and painting. Oxyacetylene welding method was implemented to join the two pieces of the copper and aluminum pipes. The torch was directed to the copper pipe because its melting temperature is higher than the that of aluminum, the welding wire applied at an angle of 45 degrees with the welding torch, where, they are both perpendicular to the pipe to be welded. Sample of welded pipes are shown in figure (2).

Figure (2): Aluminum to Copper Pipes welding.

B. Filler welding Rod:

This aluminum copper brazing alloys which is normally applied for brazing Aluminum metal with copper metal is AI-SI flux-cored wire to be identified as similar to ER4047.
It's particularly convenient for brazing parts of aluminum in building different refrigeration system. This brazing filler are, known to be high resistance to corrosion with good fluidity and high wetting spreading

The chemical composition and the mechanical properties of the welding wire are shown in Tables (3&4).

Table (3): The Chemical Composition of The Welding Wire **AWS A5.10**.

Standard: AWS A5.10 ER4047	Chemical Composition %								
	Si	Fe	Cu	Mn	Mg	Zn	AL	Other Each	Other Total
Grade ER4047	11 – 13	⩽ 0.8	⩽ 0.3	⩽ 0.15	⩽ 0.1	⩽ 0.2	Rest	⩽ 0.05	⩽ 0.15

Table (4): Some of The Mechanical Properties of The Welding wire.

Density kg/dm3	**Melting temperature ℃**	**Electric conductivity % IACS**
2.65	**573---585**	**41**

Weld Mechanical Properties (reference value)		
Tension Strength(MPa)	**Yield Strength(MPa)**	**M**
160--190	70--85	10--15

It is important to mention that, the alignment of the two pipes was achieved before running the welding operation. Weld join was cleaned using alcohol-based cleaner (acetone) clean the surface of the parts to be welded in order to removing dirt, oil, dust and other impurities.

Then the copper pipe was expanded mechanically to be suitable for the diameter the aluminum pipe and to achieve the overlap joint. That because the melting point of copper is higher than that of the aluminum as shown in figure (3).

Figure (3): Final Pipe Welding

C. Hardness test

Hardness test also being done for base and welded metals using Brinell hardness equipment. The Brinell hardness number (BHN) is found to be equal to 48 for aluminum and 66 for copper pipes materials. Brinell hardness test indentations shape is shown in figure (4)

Figure (4): Brinel Hardness Test Indentation

D. Tensile Test

The tensile specimens were done from welded copper to aluminum pipes where the weld joint was positioned at the middle of the specimen gauge length as shown in Figure (5). The tensile properties test shows that the aluminum pipe breaks at a tensile stress of 7760.8 MPa while the yield stress occurred at 5814.75 MPa.

Figure (5): Tensile Testing Specimen Failure at aluminum pipe.

E. X-ray Test:

From Figure (6) which shows an x-ray film for weld joint. The analysis of the X-ray images was done using software called ImageJ to examine the weld zone in order to detect any internal defects. X-ray technique was used to examine the integrity of the weld joints of all samples the integrity and the soundness of the weld joint is an important parameter for the achievement the required mechanical properties in many services engineering systems. that done to technique throw the detection of the presence of any weld defect such as slag inclusion, foreign particles, cracks, porosity or any other weld

defects will harm the weld joint and finally effects the mechanical properties of the weld, and that could make system failure after fabrication.

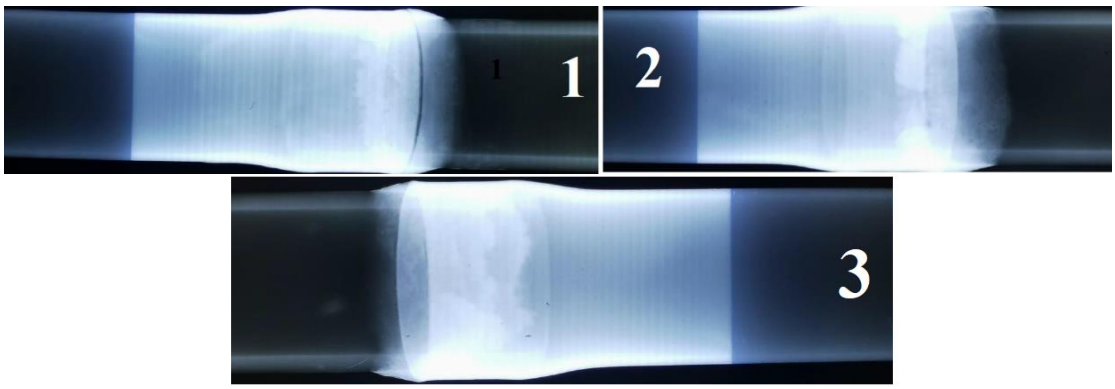

Figure (6) Shows an Image of X-ray Inspection

F. Liquid penetrant testing (LP)

The technique of Liquid penetrant examination was applied to all copper-aluminum the weld joint shown in figure (7), which does not seem to reveal any internal defect in fusion joint. It is mainly used as a surface evaluation technique and does not represent the whole volumetric condition of a weld joint

Figure (7): Liquid Penetrant Inspection

G. Pressure Test:

It is carried out by applying a compressing air to the maximum operating pressure normally used for cooling devices which is to be around (17 bar) and equal to (250 psi), the equipment used in this test is as shown in figure (8). No failure occurred after this grade of air pressure.

Figure (8). The set up of pressure Test of Welded Specimen

3. RESULTS AND DISCUSSION

The main purpose for selecting this work is the large and important need for understanding the welding process of dissimilar metals in in the form of pipes which is highly essential knowledge for the engineers working in many engineering constructions in particular the refrigeration pipe systems.

The welding process of pipes considered an important activity in all air conditioning and refrigeration of fabrication systems. It is known that the cooling fluid is flowing inside the pipes of system, so that a highly need knowledge of the theory and experience in pipe welding technology, for example, Oxy-Acetylene welding and gas tungsten arc welding, which is also called Tungsten Inert Gas.

For this purpose a several sections of copper to aluminum pipe weld zone were prepared to perform many mechanical testing procedures. welded specimens were sent to Ministry of oil and ministry of industry for testing using standard equipment. Various destructive evaluation (DE) have been conducted to make sure about the quality of the weld joints.

Destructive & Nondestructive tests such as tensile, bending, hardness, visual, liquid penetrant and x-ray examination were conducted to know the weld joint integrity in order to proof that, all weld joints are free from any internal and external types of defects. Tests procedure were prepared and according to the international standards known as welding procedure specification, (WPS).

Figure (5) represents the tensile strength test of the copper to aluminum with weld joints at the middle of the specimen, it is clear that fracture occurred in the aluminum pipe outside of fusion zone. The tensile strength and elongation of the joint produced by ER4043 filler material were large enough in addition of high qulity and integrity of the weld joint also no presence of any types of defects in the weld zone.

From the figure (7) which is shows an image of x-ray for the weld zone after the welding. The image of the weld shows no indications of any types internal defects.

For these properties, this filler is used in many applications such as, Construction work pipes fabrications in particular in cooling pipe system are widely used in particular when a qualified skilled welder with international standard are based on performing this joining process [12,13].

Figure (4) shows that the evidence of liquid penetrant test implemented for copper to aluminum, it easily can be noticed that weld joint does not shows any evidence of any types surface defects such as cracks, cavities or any discontinues, this result is very important in engineering applications because the surface defect is harmful and could act as stress concentration region and resulted as a suitable place for crack initiation and growth which is became a cause for the part failure (13,14).

4. Conclusions

1-From this study, it can be confirmed that, as part of the quality-assurance process, all welding procedures must be qualified and welding must be controlled to strict specifications also each welder must pass qualification tests in order to do welding on pipeline job, and each weld procedure must be approved accordance with welding standards.

2- Oxyacetylene welding processes were carried out according to welding standard, that resulted in a required mechanical property.

3- The integrity and soundness of the weld joints are highly dependent on the welder skill. Qualified welder (6G) performed all the welding processes and that was important factor to avoid the welding defects.

4- Destructive & non –destructive test such as tensile bending, X-Ray, die- penetrant and ultrasonic were used in this research to detect any defects in the weld and heat affected regions, the results confirmed a sound weld with a required mechanical property.

5- The variables of the welding procedure specification (WPS) used in this research was found to be suitable for welding of the present pipe metal.

6- x-ray inspection technology occupies an important position in the weld quality detection method, test results showed that all weld joints are free defects.

REFERENCES

[1] Welding handbook, For Gas Shielded Arc Welding, Oxy Fuel Cutting &Plasma Cutting, Sarajevo, 2023.
[2] Arc Welding Processes Handbook, Scrivener Publishing by John Wiley & Sons, USA and Scrivener, 2021.
[3] Welding Skills, Processes and Practices for Entry-Level Welders, First Edition, Book One Larry Jeffus/Lawrence Bower, 2010.
[4] Welding of Pipelines, API standard 1104api standard 1104, nineteenth edition, October 31, 2001
[5] MD.Ibrahim Kan, welding science & Technology, book, 2007
[6] S. L. Crawford, PACIFIC NORTHWEST NATIONAL LABORATORY, US, May 2008
[7] Dongkyu Lee1 and Soomi Shin2, Advances in Materials Science and Engineering, Article ID 264798, 13 pages, 2015
[8] Hoobasar R., Pipe welding procedures, 2ndEdition, New York, 2002.
[9] Dzevad Hadzihafizovic, Welding Pipelines & Piping systems Procedures and Techniques, Welding International, Sarajevo, January, 2023
[10] Wu Xiamen, Proceedings of the International Symposium, 2009
[11] China, May 22-24, pp. 273-275,2009.
[12] 11-Kyle Zaffino, In-line inspection technology to detect, locate, and measure pipeline girth weld defects, California Energy Commission, February, 2015.
[13] Steven E. Hughes. A Quick Guide to Welding and Weld Inspection (Woodhead Publishing Series in Welding and Other Joining Technologies), 2009.
[14] Applied Metallurgy and Corrosion Control, book. Amiya Kumar Lahiri, Indian Institute of Metals Series, 2017

BIOGRAPHIES OF AUTHORS

Author 1 picture	**Asst. Prof. Dr. Ezzet H. Abdulsalam**, Received His MSc. degree in the materials science engineering from University of Manchester (UMIST), United Kingdom in 1988 and Doctor of philosophy in mechanical engineering from University Salford United Kingdom -1991. He has been a part-time lecturer in many Iraqi universities . He also worked as senior researcher in the Research and Development center since 1991., Currently, He is now a full -time lecturer and head of refrigeration and air conditioning technical engineering department in Dijlah University College, Baghdad, Iraq, since March 2010. can be contacted at email: izzat.hameed@duc.edu.iq.