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# The influence of bending on weld joint integrity of Refrigeration Tube using x-ray Technique

Ezzet Hameed Abdulsalam
Dijlah university, Department Refrigeration and Air conditioning Technical Engineering

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**ABSTRACT**

In this investigation bending is applied on pure copper pipe with a weld joint made by oxyacetylene welding method to access the integrity and soundness of the weld joint under this type of mechanical testing, the chemical composition inspection of pipes metals is confirmed that is a pure copper (99.96% Cu). Pure copper is known to be weld able and can produce a weldment with good mechanical properties. High achievement weld joint resistance under bending without any evidence of surface defects and internal discontinuities that was confirmed by applying a liquid penetrant examination for the weld surfaces and also using x-ray test to detect internal defects. All tests' processes were confirmed that, all weld rejoin is free from all possible discontinuities after performing bend testing.

## 1. INTRODUCTION

In most engineering applications pure copper pipes is widely metal used in particular air conditioning systems because of its applicable properties such as good corrosion resistance, machinability, ductility and producing a acceptable integrity of weld joint in most pipe systems with free weld defects. The chemical and mechanical properties of this type of metal as known in international standard are listed in table -1,2

Table 1. Chemical composition of base copper pipe

| Zn | Pb | Sn | P | Mn | Fe | Ni |
|---|---|---|---|---|---|---|
| 0.01 | 0.02 | < 0.01 | < 0.003 | Trace | 0.02 | 0.02 |
| Co | Al | Cr | S | Cu | | |
| 0.03 | 0.002 | Trace | None | > 99.5 | | |

Table 2 Physical properties of the Materials

| Yield Stress/MPa | Maximum Strength/MPa | Percentage of Elongation |
|---|---|---|
| 43 | 219 | 50% |

From practical engineering fabrication processes, welding is usually known as a proper method for joining similar metals and dissimilar metals such as, oxyacetylene, brazing, arc welding and different method of welding (1). Achievement of bend resistance of weldment is required parameter be used in air conditioning systems provided implementation standards welding specification procedure (WPS) such as ASME is highly need for soundness weld. It is always known that Welding process may initiate so many forms surfaces defects and internal sharp cracks, voids, deformation, porosity and residual stresses. (2, 3). Oxy-acetylene welding process which was applied in this work to join two parts of copper pipes. Where design as overlap type was selected according to international standard is considered an important process to get a quality of weld soundness joints. Weld position of 6G position is used with a pipe axis angle of 45 with the level of horizontal axis when the pipe is rotating through the run of the welding. The process of pipe welding was depending on all parameters listed on The American Society of Mechanical Engineers (ASME) standard section IX (7,8).

## 2. METHOD

**Metal** in this project is 99.9% copper when this done at the ministry of industry workshop with some other elements as additive to improve properties.
Chemical composition confirmed that the type of the copper metal as pure with some tracing element to improve properties which is mainly applicable and suitable in fabrication of refrigeration pipe systems. Used pipes measurement for preparing test specimens is of 10 mm inner diameter and approximately 15 mm external diameter.

**Welding process**

welding process using overlap joint design is selected and manually by suitable diameter expander as shown in figure (1). According to all welding standard, the Joints surfaces must be cleaned in the beginning before running the welding, that is highly needed to prevent all expected types of surface contaminations. A process type Oxyacetylene welding was used to connect the two pieces of copper pipes. The welding was carried out by skilled welder has a 6G certification and pipe welding permission, that was done after written of proper standard (WPS) as shown in figure (2).

Figure 1. Overlap design of weld joint

Figure 2. Fracture of welded specimen under tension

**Hardness test (BHN)**

Assessment of weld joint hardness compared with base metal is highly required which revel the level of all weld parameter used in this investigation, so that Brinell hardness (BH) instrument is used to do this test, it was found that, the hardness number (BHN) for base copper pipes is 82 while for weldment around 87 which are responsible and very close to the standard values. The (BH) Indentations configuration and specimen with machine set up is shown in figure (3).

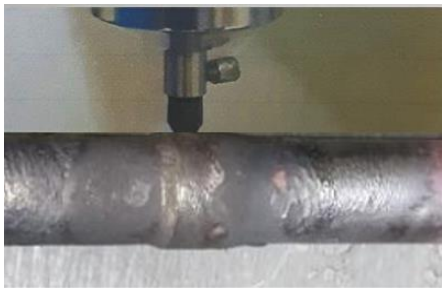


Figure 3. Specimen under Hardness testing

**X-ray Test:**

It is well known that x-ray test is familiar testing process which is always done to discover large numbers internal discontinuities which are very harmful to the level of mechanical properties as a main reason to pipe system failures in particular with pipe system under pressure. Sample of the X-ray test negative implemented in this work shown is Figure (4) bellow which reveled none of any types of internal defects.

Figure 4. Weldment testing by x ray

**Dye penetrant testing (LP)**

The application LP test in many engineering applications is considered as one of many simple and cheap process for discovering many types of surface defects or any type of discontinuities like, that conducted by adding a colored liquid in to weld joint surface when a surface cleaning from contamination is an important parameter in this test before spraying the liquid. This type of surface examination is carfully applied in this work and as seen in the figure (5), so that no indication or any evidence of any sources of defects found in weld joint surface.

Figure (5): Weld joint Surface test by liquid penetrant

**Tensile test**

Pipe specimens with weldment at the middle were done from pure copper pipe with weld region as in Figure (6).The specimens of 19.5 mm diameter and 1.09 mm thickness were chased to be proper and suitable to the machine loading measurement. Test was done at workshops, laboratories of oil ministry, General Company for Engineering Equipment. During the test it is very clear that the welded specimen is starting to be yield at stress of 26MPa while the specimen begin to be cracked outside the weld joint and eventually broken a maximum stress around 164 MPa as in figure (6), Elongation was calculated and found to equal 30% was a. The tensile testing process stress strain curve is represented in figure.7

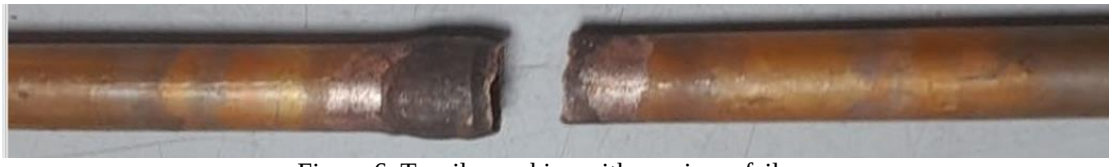


Figure 6. Tensile machine with specimen failure

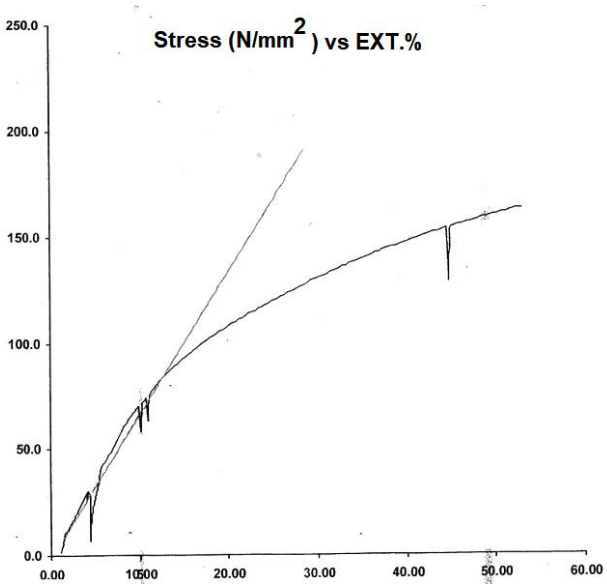
**NEW Tensile Properties of Metals ( XHEAD) Metric**

Specimen ID 1
Test Number 1252
Report Number 1251
Test Date 12/16/2024 10:44:58 AM

| | Test Results |
|---|---|
| Yieldforce (N) | 1,576 |
| Yieldstress (mpa) | 26.00 |
| tensileforce (N) | 9,907 |
| Tensilestress (mpa) | 163.48 |

Testing Machine Smart Series

Preload Value ( N ) 100
Crosshead Speed ( mm / min ) or Rate 20
Extension or Position Measured by XHD_100 ( XHD100 )




| TENSION TEST | | | | | | |
|---|---|---|---|---|---|---|
| Specimen Number | Actual Area For Full Section Specimen | YL | UL | YS | UTS | Type of failure and location |
| | $mm^2$ | KN | KN | $N/mm^2$ | $N/mm^2$ | |
| T | 60.6 | 1.576 | 9.907 | 26 | 163 | Ductile –base metal |

**Figure 7. Stress Strain diagram of Tensile properties**

**Bending test:**
Ductile metal like copper and many other materials are suitable for performing bend face test in particular for weld joint region in order find the measure of weld resistance to cracking, so that in thepresent work face bend was conducted using welded copper tube of 19.4mm diameter at a wall thickness of 1.75mm provide the mandrel diameter around 40mm using U profile angle when the copper pipe is we welded by oxyacetylene method. Finally noticed no cracks or any types of imperfection are formed at the end of the test, complete results are listed in in table-3 below.

| Tested Item Information | | |
|---|---|---|
| **Tested Item** | **Dimension** | **Standards** |
| Copper Tube 3 / 4 " | Ø 19.1 mm , t = 1.07 mm | ASME IX |
| **Equipment Used** | **Type of test** | |
| United 600 KN, Cal. Date 2024 / 2 / 4 | Bend ( Face ) | |

| BEND TEST | | | | | | |
|---|---|---|---|---|---|---|
| Specimen Number | Type | Width mm | Thickness mm | Mandrel Dia. mm | Angle | Remarks |
| FB | Face | 19.1 | 1.07 | 40 | U - Shape | No crack or imperfection |

Table 3. Results of Bending test of weldment

## 3. RESULTS AND DISCUSSION

The importance of bending on weldment in copper tubes is experimentally considered in this work because of highly requirement applications in refrigeration and air conditioning pipe constructions. This work may help the manufacture to know the possibility of formation internal and external defects under different types of loading.
From Figure (5) which represents the profile of stress- strain curve of a different tensile loading in welded copper specimen where a weld region is produced in the middle of the tensile specimen, it can be seen that the crack started at the base metal outside the weld zone. That is an evidence about the integrity and soundness of the weldment after this type of loading. The same result was obtain after the specimen tested under face bending of U shape and eventally no defects or crack are seen after the of the test, the results of this test is listed in table 3.
All of the experimental work results was confirmed by x-ray examination shown in figure (4) is an accurate confirmation about the weld joint quality and integrity where no existence of any type of weld defects are shown. [12,13].
Also in figure (4) is another type of weld surface examinations using liquid penetrant technique for detecting weld surface defects which is considered as nondestructive process of testing, from this test also no evidence of surface defects. It is well known that the type of test is necessary in all structure design, because the existence of ane cavities or crack will cause concentration in these regions and lead to fracturing and eventually system failure at the end in particular under cyclic load.. (13,14,15).

## 4 Conclusions

1- The welding used in this work is proper processes to join these types of materials with no observation of any form of failure.
2- Using a suitable WPS with sleeted joint design results a high quality and integrity of weldment.
3- Failure of specimen under tension outside weld makes sure that the weld metal is not deductive
4- All form of tests gives evidence about the importance of surface and internal examination prior any engineering applications

**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] Ezzet Hameed Abdulsalam, Welding technology and mechanical properties of steel pipes type A106 used for oil refineries, Dijlah Journal, volume (6), Issue (4), 2023.

[5] Sanjeev Kumar, Welding Materials, Fabrication Processes, and Industry 5.0 Welding Materials, Fabrication Processes, and Industry 5.0, London, United Kingdom, ISBN 978-1-83769-871-4, 2025

[6] Ezzet Hameed Abdulsalam, Mechanical Properties of Weld Joint in Refrigeration Tubes Welded by TIG Process. Dijlah Journal, volume (2), Issue. (1), 2019.

[7] Sandra Kalveram; Deputy Editor: Shaoying Cui, Advanced Engineering Materials, Volume 27, Issue 18, September 2025

[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] Ezzet Hameed Abdulsalam, Some Mechanical properties of lap weld joints design in copper pipes, Dijlah Journal, volume (5), Issue. (4), 2022.

[12] Pipeline Technology Journal Ptj. Inspection & Integrity, e-ISSN 2196 -4300 / p-ISSN 2751-1189, 2025

**BIOGRAPHIES OF AUTHORS**

**The recommended number of authors is at least 2. One of them as a corresponding author.**
*Please attach clear photo (3x4 cm) and vita. Example of biographies of authors:*

| | |
|---|---|
| Author 1 picture | **Asst. Prof. Dr. Ezzet Hameed Abdulsalam**, got 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, then at the welding institute for many years, 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 March2010. can be contacted at **email:izzat.hameed@duc.edu.iq** |
| 2 Author 2 picture | Mini cv |
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