

## **Some Mechanical properties of lap weld joints design in copper pipes**

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### **Abstract**

This study deals with the welding of copper pipes which are mainly used in construction of different refrigeration pipe systems. The chemical composition analysis of the pipes materials confirm that are a pure copper (99.9%Cu). This type of copper metal exhibits an .excellent weldability, bending, forming and cutting

In this experimental study oxyacetylene welding method is used to join two pieces of copper pipes. The weld joint integrity and its mechanical prosperities were evaluated by performing a number of destructive and non-destructive tests on the weld joints such as, Tensile, bending, hardness, x-ray and Liquid penetrant. The test results confirmed an excellent integrity of the weld metal with no internal or external defects and achieved .acceptable mechanical properties

**Keywords:** Copper, Weld joint, X-Ray, Destructive test, refrigeration pipe

### **1-Introduction**

It is well known that joining by oxyacetylene welding process is used in many engineering applications, such as fabrication, maintenance and structures repairs. It is a suitable method for joining most types of materials. other welding method are also available and used in industrial production processes, such as, shield metal arc welding, (SMAW), Tungsten Inert Gas welding (TIG), Submerge Arc Welding, (SAW), Metal Inert Gas welding (MIG)...etc.[1]. A required mechanical properties for weld joints can be achieved by preparing the suitable Welding Specification Procedure (WPS) for each type of materials, that need a to depend on an internationally approved welding standard such as ASME. [2].It is important to mention that the quality of the weld is highly dependent on many parameters such as welder skill, welding procedure and a good knowledge in

metallurgy. Welding process may create so many types of internal and external defects in the structure, such as, slag inclusions, undercuts, distortions, Porosities, lack of penetration, misalignment residual stresses..etc. These defects are hardly harmful effects on the level of weld joint mechanical properties[3]. Oxyacetylene welding which is used in this experimental work is one of the industrial metal joining process in particular in refrigeration pipe system

It is one of the oldest welding technique and widely used in many fabrication processes such as joining mild steel and copper. Oxyacetylene gas welding is working by mixing of oxygen and acetylene, the mixture of the two gases burns as to form a concentrated flame, at a temperature around 3,500C. When the flame becomes in contact with any metal, it melts the surface and producing a molten pool, allowing welding to take place [4]. Oxyacetylene is also used for brazing, cutting, bronze welding and as a heating source for metal forming, forging and bending

This method of welding is used in joining of refrigeration copper pipes which is the subject of this study. The welding techniques used and the procedure is also conducted according to the standard known ASME section IX pipe welding certification [5]. Since welding pipe in the 6G position covers all of the pipe welding positions the information on this page can be applied to welding pipe in any position. The 6G position is a combination of all of the structural and pipe welding positions [6,7]. The main feature of oxy acetylene welding technology is the motion of the weld filler and torch is manually by welder hand, so that the welder skill plays an important role for producing a soundness weld with suitable integrity. In this process a proper flux in the form of liquid, past, powder, powder and solid materials must be added to the molten weld pool for protection from oxygen in the weld environment. Oxygen is considered as main causes for formation oxides in the weld and produces a defective weld joint

The main attributions of this work in the term of originality is to use overlap weld joint design instead of butt design which is normally used in pipe joining in many engineering applications, this design will help for easy weld of external fillet weld and will achieve better mechanical properties for the weld. Also this design will give more flexibility for different to use different types of destructive and nondestructive test in particular the detection of internal discontinuities by x-ray which are harmful for the mechanical properties. This procedure will also give a good knowledge for engineers and technicians to write the suitable welding procedure specification (WPS) and to achieve weld soundness in many fabrications processes in particular for refrigeration pipe system

## 2-Copper and Copper Alloys

Pure copper is known to be malleable, extremely ductile with low hardness, the standard physical properties of this metal are, 1083C melting temperature, 117GPa modulus of elasticity, 8.9 g cm<sup>-3</sup> Density and 391 W m-K<sup>-1</sup> Thermal conductivity. copper is a famous metal and used in many applications, mainly in refrigeration pipe a system be-

cause of its important industrial properties such as high electrical conductivity, corrosion resistance to many type environment, also its nice appearance with good resistance and high tendency to be fabricated in different types of welding process such as oxyacetylene, brazing and soldering and tungsten inert gas (TIG), Gas Metal Arc Welding when argon is used as a shielding gas to protect the welding pool from contamination for both types of these welding processes, one of the important parameter for using argon as a shield gas .is giving better starting electric arc than helium

these type of welding processes was found to produce a soundness weld with high integrity, it is important to mention that, the preheat is not required prior to welding because .copper and its alloy characterized with high thermal conductivity

Copper with other element can form several types of alloys including copper-Tin alloy .known as bronze, copper-nickel, copper-zinc which is called brass

### 3-Joint Design

The basic shapes of weld joints implemented in many weld fabrication process are, overlap, butt, corner, tee and edge design for most of welding processes, all of the previous joints design are normaly used for pipes and plates welding, a samples of these design are .[shown in figure (1) according to ASME section 1X [8

lap joint design which is used in this work seem to be very simple in particular in pipe welding. In this joint part of any material is placed over another from the same materials or sometimes different materials could be used like copper to aluminum, this type of joint .design was found to create high efficiency

The main parameter in this joint design that the applied loads can transfer from one part of the pipe to another part as in figure 2

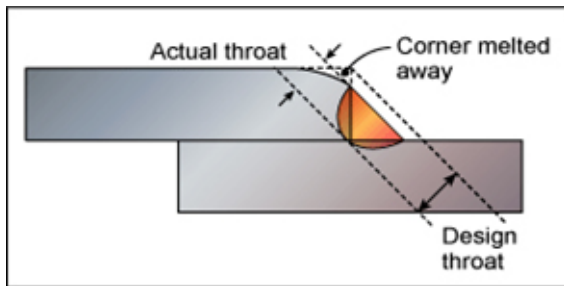


Figure. 2 The lap weld joint design

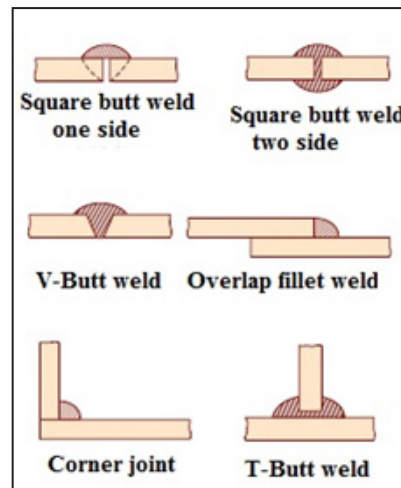


Figure. 1 The types of weld joint design

However in butt joint, the two parts to be connected by welding must be aligned in the same line and plane. It also important to mention that in butt joint it necessary to produce a groove in different shapes such as V- groove, double V-groove, V-groove with root and U-groove while in lap joint it is used as a fillet weld

The required mechanical properties of any weld joint for different manufacturing processes can be existed if the proper Welding Specification Procedure (WPS) is written by experts and qualified technicians mainly 6G qualified in particular for pipe welding to conduct the welding processes, that mainly depend on an approved welding standard [known internationally as ASME standards [9

#### 4-Welding Safety

Safety for people doing a job is considered as a normal concern in the process of construction industry in order to achieve a safe work for worker and instrumentation. Serious injury or death can be avoided by using right tools and the entire requirement to protect eyes and body from danger, that because most of welding processes is normally generate a high level of temperature and also need high electric current and voltages so that safety is represented an issue and need to be considered before running the welding process, however this concerns could be reduced by running several training programs for all of the workers and that will definitely decrease the number of injuries and accident

Eye protection can be done by using safety glasses to avoid flying particles from the operations such as welding and grinding to go direct to the eye also safety glasses protect from welding spark which is very harmful to eyes health, however face shield and gloves are important need to add another way to protect the face during welding, grinding, chemical and cutting processes

To protect the rest of your body such as hands, feet and skin, it is also recommended to wear special shoes and leather apron to avoid weld heat and spattering which may burn the skin in exposure region. In all cases a first aid with basic medical component is important to be available in the work field in order to treat the minor accident and injuries. Fire systems with trained worker in the workshops such as foam, water and dry chemical are highly recommended to be available to treat any fire accident from the beginning

A suitable natural ventilation or mechanical system is highly required in welding workshop to create a healthy environment for workers. Fume extraction hoods system also required and important to get away all of the contamination gases near the welder for all types of welding processes such as gas welding or arc welding. In addition to all of above requirements, it is highly important to make sure that welding workshop must be cleared from any types of flammables gases or any other materials so that the fire watch must not leave the working area until all means of preventing and treating accidents are [available[9,10

## 5-Experimental

### 5.1-The specimen

All tested specimens are obtained in the form of copper pipes with the inner diameter of 20 mm, the outer diameter of the pipe is 25 mm. From the chemical analysis of the pipe metal shown in table (1). It is confirmed that the material is a pure copper (99.9%Cu). All types of test tests were done at the General Company for Engineering Inspection and (Qualification (ministry of industry

Table 1.The chemical composition of the pipe material

Zn%	Pb%	Sn%	P%	Fe%	Ni%	Mn%	Si%	Cr%	S%	Sb%	Al%	Cu%
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

### 5.2-Welding Process

Single Lap weld joint design type has been prepared using mechanical diameter expanding process, the design sketch and the real pipe specimen joint design are shown in (figure 4

Cleaning the weld joints before starting the welding process is essential processes, weld joints were cleaned mechanically using stainless steel brushes and chemically by acetone until the joint surface becomes free and clear from rust, oil, water, and painting or any .foreign particles

Oxyacetylene welding method was used to join the two pieces of the copper pipes. The welding processes were performed by 6G skilled welder using a suitable welding procedure specification (WPS) which is prepared to be convenient to these metals as shown in figure 5

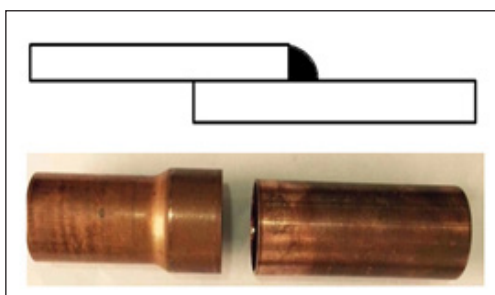


Figure. 4 The Single lap Joint Design

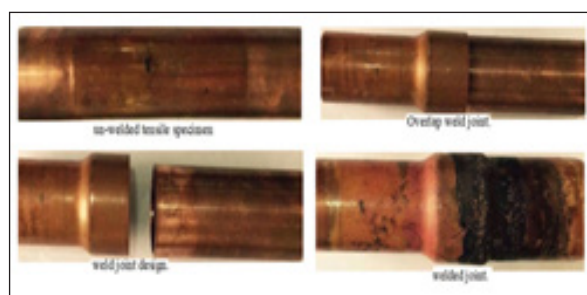


Figure. 5 Oxyacetylene Pipe Welding Process

### 5.3-Destructive tests

Destructive testing is a type of testing conducted until the specimen failure, the ob-

jective is evaluating the relative mechanical properties of the material. For example A tensile test is performed to determine the mechanical properties of the material such as its .ultimate tensile strength, yield point or proof stress, young modulus and ductility

**5.4-Hardness test**

Hardness test was conducted on flat specimens machined from copper pipe for base and welded metals using Rockwell hardness machine as shown in figure (6) and figure (7). The hardness of the welded metal & the base metal is determined using the equipment at ministry of industry, (General Company for Engineering Inspection and Qualification) and the results are shown in table 2

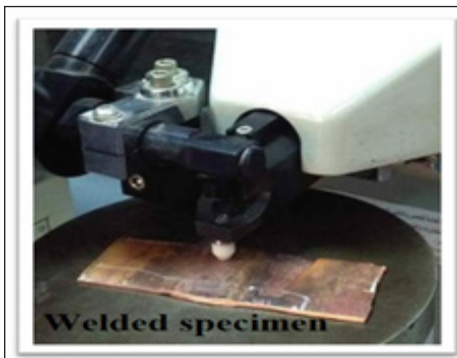


Figure. 6 Hardness test of welded metal.

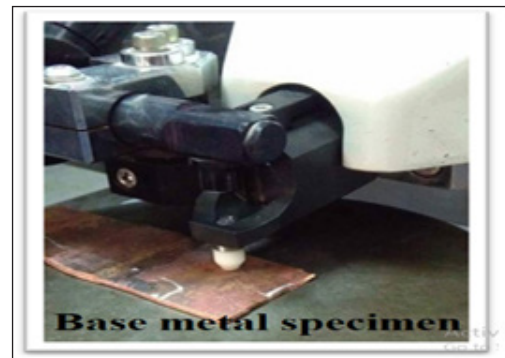


Figure. 7 Hardness test of base metal

The Rockwell hardness test is a common method for evaluation of the materials hardness, it consists of indenting the test material with a diamond cone. The indenter is forced into the test material under for a selected load. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. The hardness of the welded metal & the base metal is determined using the equipment at ministry of industry, (General Company for Engineering Inspection and Qualification) and the results are shown in table 2

Table 2. Rockwell Hardness Number Rc.H.N

Type of metal	Rockwell Hardness Number (Rc.H.N)
Weld metal	15-20
Base metal	5-10

**5.5-Tensile Test**

The tensile specimens strips welded and unwelded were machined out from copper pipe provided that, the weld joint is located at the middle of the specimen gauge length. The specimen was gripped in the tensile testing machine, the broken specimen are shown

in figure(8) and. The stress strain curve for the test is obtain as shown in figure (9) and the test mechanical properties are in table 3



.Figure (8):Broken Tensile specimen after test

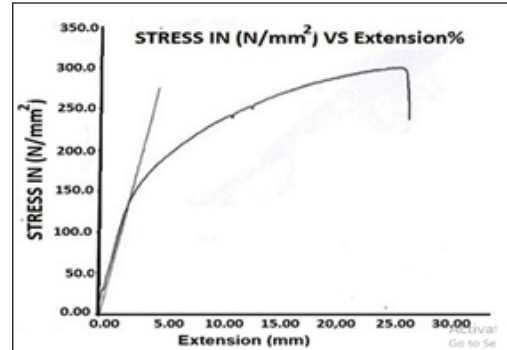


Figure (9). Stress Extension curve for weld

Table-3: The mechanical properties of the tested materials

Yield Force (N)	Yield strength (MPa)	Tensile forces (N)	Tensile Strength (MPa)	Crosshead speed (mm/min)
2890	137.63	6412	305.35	20

**6-Nondestructive test**

Non-destructive testing allows examination of structures without destroying the engineering parts, that always done in many structures such as aeroplanes, ships, trains, bridges, pipelines, pressure vessels require regular testing to ensure that cracks do not grow to a size that threatens the safe operation of the structure

**7.1-Visual inspection**

Visual inspection is normally known as the use of eyes, light and sometimes a need to magnification glasses to examine of any part of materials as simple and low-cost method for detecting the surface defects such as dimensions, discontinuities, wear, cavities and normal fit.. It is considered as nondestructive type of examination. The level of quality of this test is highly affected by lighting, eyes and the level of detector training. this test was done as in shown in figure where the detector stand about 60cm from the surface to be examined and maintain the angle of viewing around to be within 600mm of the surface being inspected to be in a position to give a viewing angle of not less than 30° or more than that. According to that, visual tests were conducted to all of welded specimen and no .any type of surface defects were noticed as in figure 10

**7.2 Visual inspection**

It is a surface testing technique which does not detect any internal defects of a weld joint. From figure(11) where the weld rejoin is sprayed by a special liquid penetrant, it

is clear that (LP) will not reveal any surface defects. In this test the surface of the metal must be cleaned from any kind of contaminations such as oil, grease, dust and paint then the liquid is applied to the surface for a certain time. After that time, the penetrant liquid must be removed from the tested surface and a special developer is also sprayed to the surface, so that the pentrant which drawn in any tipe of surface defect will be collured .such as cracks, void or any surface discontiuties

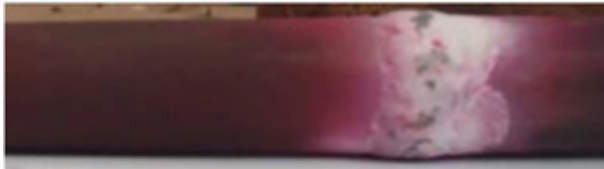


Figure (11): Liquid Penetrant Inspection

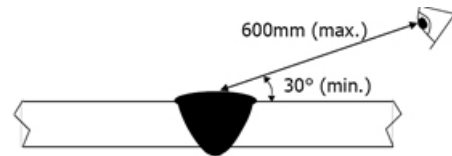


Figure. 10 Visual examination set up

### 7.3-X-ray inspection

The presence of any weld defect such as slag inclusion, 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. X-ray radiation is produced from high energy source either short wave length wave and seem to be as visible light. The test is conducted by placing the tested specimen between the x-ray source and a film. From the difference of the darkness of the film, the type of internal defect can be known, the film darkness differences give an indication about the amount of x-ray radiation that arrived the film through the specimen thickness

Figure (12) shows an x-ray negative for a welded pipes. The analysis of the X-ray images was done using software called ImageJ to test the weld joint in order to find any internal defects. X-ray test was used to confirm the integrity of the weld zone of all samples



Figure (12) Shows an Image of X-ray Inspection

### 7-Results and discussion

This experimental study shows an important need for understanding the welding process in pipes which is essential knowledge for the engineers in this field in particular at the construction of pipe system. The selection of welding process need a high level of skill and experience which is an important factor in construction of the refrigeration and air conditioning systems. It is well known that all cooling gasses are flowing inside the pipes of system will be effected by the pipe size weather large or small. From this impor-

tant point there is a need a good knowledge of the theory and practice for mainly methods used for pipe welding, such as Oxy-acetylene welding and gas tungsten arc welding. So that, several sections of pipe fusion zone were prepared for mechanical testing. These specimens were sent to Ministry of oil and ministry of industry for testing. Various destructive evaluation (DE) methods have been applied to the evaluation of the quality of the fusion weld joints. Mechanical tests include mainly the bend back test and the tensile test. This chemical composition of the tested material is pure copper (99.9%Cu). This type of pipes metal is widely used in refrigeration and conditioning systems, that due to many excellent industrial properties such as, an easy for welding, cutting, bending, forming and high corrosion resistance. Destructive & Nondestructive tests such as tensile, hardness, visual, liquid penetrant and x-ray examination were carried out to examine the weld joint quality to make sure that, the weld joints are free from any internal and external defects and that objective was achieved for all types of examination. All these tests procedure were written and performed according to standards (WPS). Figure (9) represents the tensile strength of the welded strip with weld joints, in welded samples fracture occurred in the fusion zone. The tensile strength and elongation of the joint produced by oxyacetylene process was acceptable compared to base metal due to establishing a free defect weld joint. Figure (12) shows that the liquid penetrant test for the weld joint does not reveal any surface defects such as cracks, cavities or any discontinues, that is very important in engineering applications when the presence of any surface defect could act as stress concentration region and becomes as a suitable place for crack initiation and growth which cause the failure

The non defective and sound weld achieved in this work results from taking into account the effect of small additive element on the microstructure and their effect on the weld integrity. Welding of copper and copper alloys need preheating is also because of the high thermal conductivity of copper. This may causes fast loss of the heat from the welding joint, so that The welding procedure must contain some steps reduce the rate of heat lost which may cause discontinuity in the copper microstructure in particular for copper alloys when the alloying elements have different melting temperatures which increase the probability of melting and boiling before copper. High heat input and use of preheat are desirable features due to this reason. Copper is known as a high conductive materials so that heat lost through will be very fast. These results in very quick solidification process and lead to produce fine grains microstructure in the weld region compared with that of heat affected zone

## 8-Conclusion

1-Oxy-acetylene welding process is suitable method to joint copper pipes which are mainly used in construction of refrigeration pipe system

2-Tensile properties and Rockwell hardness number (RC.H.N) of the Weld joint shows good means the welding procedure specification (WPS) is applicable and compatible to international standard

3-The nondestructive test such as liquid penetrant test and x-ray test revealed the high .level of weld integrity and soundness due to weld free from any defects

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