Mechanical Properties of Weld Joint in Refrigeration Tubes Welded by TIG Process

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Abstract

This study involves the welding technology of carbon steel pipes which is widely used in many engineering applications, in particular refrigeration systems and boilers. The chemical composition of this metal shows that are close to steel grade A192 according to ASTM standards. This metal shows an excellent weldability and enhanced potential for the use of high strength TIG weld consumable. TIG weld filler type ER70S-6 is used to join two pieces of steel pipes using TIG welding machine. This experimental work also involves the evaluation of the integrity and mechanical prosperities of the weld joint. That was done by conducting a several destructive and non-destructive tests on the weld joints such as, Tensile, bending, hardness, x-ray and Liquid penetrant). The tests program confirmed that, the weld joint maintains a good mechanical properties and acceptable weld defect

Introduction

Welding is an important process in many engineering applications, such as fabrication, maintenance and structures repairs. It is a convenient and quick method for joining similar and dissimilar materials. There are several method of welding available, for example, shield metal arc welding, (SMAW), Tungsten Inert Gas welding (TIG), Submerge Arc Welding, (SAW), Metal Inert Gas welding (MIG)... etc[1].

Excellent mechanical properties for weld joints can be obtained if a suitable Welding Specification Procedure (WPS) is prepared, that mainly depend on an approved welding standard known internationally as ASME standards.

The welding process is quite complex, and the quality of the weld is highly dependent on welder skill, welding procedure and metallurgy. However welding could create so many defects in the structure, such as, slag inclusions, undercuts, distortions, Porosities, lack of penetration, misalignment residual stresses …etc.[2,3].

TIG welding which is the subject of the present work was developed during 1940 at the start of the Second World War. TIG's development came about to help in the welding of difficult types of material such as aluminum and magnesium. The use of TIG today has also spread to a variety of metals like stainless mild and high tensile steels. It shows high quality fabrications.

Like other welding processes the job of the shielding gas is to protect the weld pool from contamination from air, which can cause porosities and defects in the weld. The shielding gas is a pathway for the welding arc and will help in the starting and running of the welding arc.

The most common gas being used for TIG welding is Argon gas. Helium is also being used [4,5].

Argon gives Better arc starting , Good cleaning action, Lower arc voltage, Low gas flows needed, while, Helium This type may be either square or grooved. In pipe welding, there are different basic test positions used. The position of welding. When you are using the 6G position for pipe welding, the axis of the pipe is at a 45-degree angle with the horizontal and the pipe is not rolled. Since the pipe is not rolled, welding has to be done in all the positions— 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, they are identified by the letter G.

gives faster travel, Better penetration, Higher arc voltages. Because of the cost of Helium we are now seeing mixtures of Argon and Helium. This is to gain the best part of each gas [6,7].

The weld joint design is an important factor in welding

processes. The five basic types of weld joints are the butt, corner, tee, lap, and edge, butt joint is used to join two members aligned in the same plane, and this joint is frequently used in plate, sheet metal, and pipe work. A joint of position refers to the position of the pipe, not the welding techniques used and the procedure is also identical to the ASME section IX pipe welding certification [8,9]. Since welding pipe in the 6G position covers all of the pipe welding positions. Information in 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 [10, 11].

Experimental procedure:

The metal used in this study is a carbon steel pipe. All tested specimens are in the form of pipes with the inner diameter of 20 mm, the outer diameter of the pipe is 25 mm. The chemical composition of this metal after

Pipe metal

analysis at the ministry of oil is shown in Table (1), while the mechanical properties of the tested materials are shown in Table(2). All tests were conducted at Ministry of Oil-(HESCO).

Table (1): The Chemical Composition of the Pipe Material

Metal	C	Mn	Si	Cr	Cu
Wt%	0.15	0.46	0.25	0.10	0.13

Table-2: The Mechanical Properties of the Tested Materials

Yield strength MPa	Tensile strength MPa	Young Modulus MPa	Elongation %	Hardness BHN
288	397	217	32	124

Welding Process:

Weld joint design type V-groove has been prepared using mechanical machining as shown in Figure (1)

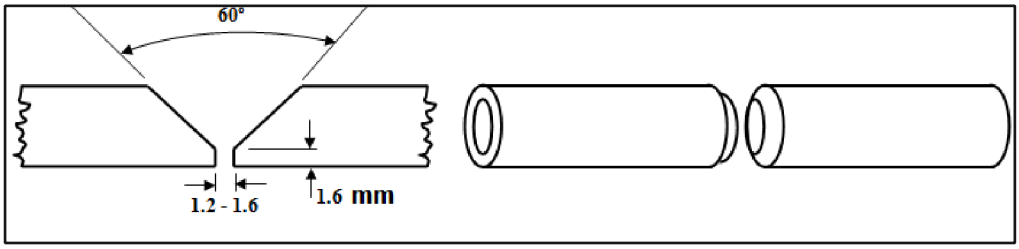

Figure (1): The weld Joint Design Type V-Groove

Before starting the welding process, weld joints were cleaned and until become free and clear from rust, oil, water, and painting or any foreign particles. TIG welding method was used to join the two pieces of the steel pipes. Argon gas with 99.9% purity was used during welding process as a shield gas to protect the weld pool from the surrounding environment, the gas flow rate during welding was 10-12 liter per minute. Direct current straight polarity (DCSP) current of 160 ampere and 30-32 volt was selected during welding. The welding. Processes .were performed by 6G skilled welder using a suitable WPS which is prepared to be convenient to these metals as shown in Figure(2)

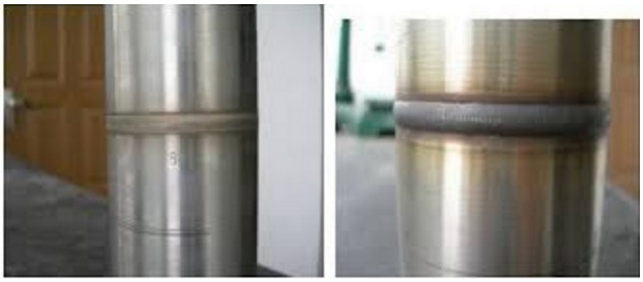

Figure (2): TIG Welding Process Used in Pipe welding.

Welding filler metal types ER70S-6 of a 2 memm diameter was selected to achieve the are required weld properties. The chemical composition and the chanical properties of the welding wire shown in Tables (3&4).

table (3): The Chemical Composition of the Welding Wire.

Weight%	C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
ER70S-6	0.06~0.15	1.4~1.85	0.8~1.15	≤0.035	≤0.025	0.15 max	0.15 max	0.15 max	0.50 max	0.03 max

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

Materials	Tensile strength	Yield strength	Elongation%
ER70S-6	550 MPa	450 MPa	30

Tack welding was conducted at several points to connect the two parts of the steel pipes and to achieve the alignment before running the first welding pass as shown in figure (3).

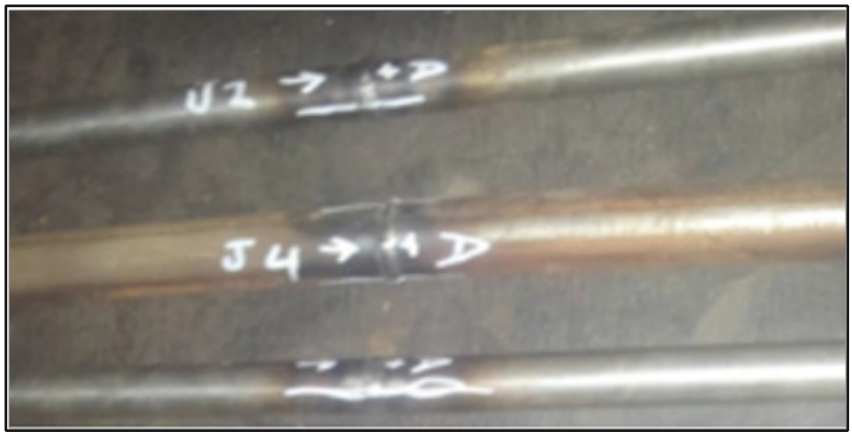

Figure (3): Final Pipe Welding

Destructive tests:

1- Hardness test

Hardness test had been carried out on both base and welded metals using Brinell hardness equipment. Brinell hardness number (BHN) is equal to 124. Brinell hardness test indentations are shown in figure (4)

Figure (4): Brinel Hardness Test Indentation

2- Tensile Test

All tensile specimens were prepared from steel tube so that, the weld joint was situated at the middle of the specimen gauge length. The tensile properties of the welded pipe metal are 288 MPa yield stress, 397 MPa tensile strength, 217GPa Young Modulus as shown in Figure (5)

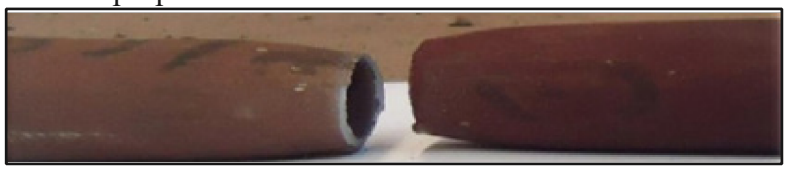

Figure (5): Tensile Testing Specimen Failure.

3- Bending test

Bend tests for ductility provide a simple way to evaluate the quality of materials by their ability to resist cracking or other

Welding is an area where the bend test is popular. A figure (6) show a guided bend test is used to determine how strong a weld is after it has been created. A flat bending specimens were prepared by mechanical cutting of a welded tubes. The weld joint is situated at the middle of the specimen. The bend test for welded specimens is

shown in figure (6).

A special bending device is used to perform the guided bend test. The material must be able to bend up to a specific angle, such as

180 degrees for example, without any cracks appearing. If this happens, the weld has passed the test

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Figure (6) The Guided Bend Test for Welded Specimen

4- X-ray inspection:

Figure (7) shows an x-ray negative for bending test of a welded strips and pipes. 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 samples, that done to detect the the weld joints of all 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

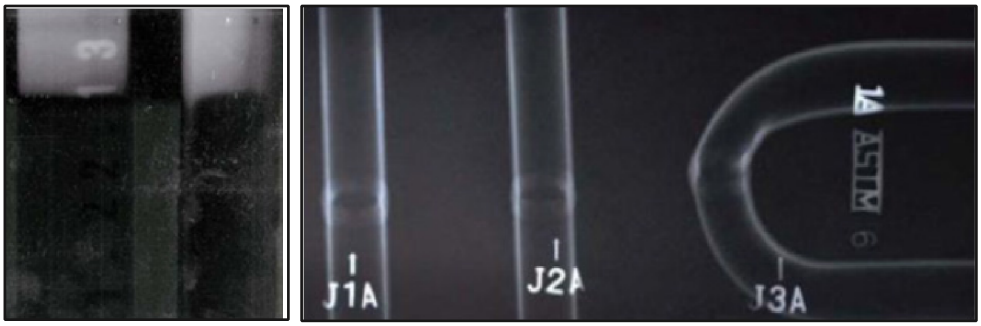

Figure (7) The Image of X-ray Inspection

5- Liquid penetrant testing (LP)

Liquid penetrant testing (LP) Shown in figure (8), Liquid penetrant testing (LP) does not seem to reveal a subtle condition like the internal defect in a butt fusion joint. It is a surface evaluation technique and does not represent the condition of a volumetric fusion joint. Research conducted to date shows that LP only detects certain unacceptable butt fusion joint conditions. The research indicates that LP will not detect many of the conditions that should not go into service.

Figure (8): Liquid Penetrant Inspection

Results and discussion:

The main reason for choosing this research is the large and important need for understanding the welding process in pipes which is essential knowledge for the engineers in this field. The welding process in pipes constitutes an important part in the air conditioning and refrigeration systems. It is known that all mediums of cooling are flowing inside the pipes of system whether large or medium or small size. Hence, from this important point there is a need to get knowledge of the theory and practice for commonly ways of pipe welding, specifically that commonly called Oxy-Acetylene welding and gas tungsten arc welding, also known as Tungsten Inert Gas. So that, several sections of pipe fusion So that, several sections of pipe fusion water). This type of pipes is also existing in manufacturing the tubes bundle of heat manufacturing the tubes bundle of heat 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 close to that for steel A192 according to ASTM standard. This type of pipes metal is widely used in refrigeration and conditioning systems such as icing systems (Ice Factories), also in boilers and condensers in refrigeration systems that using water (chilled bending, hardness, visual, liquid penetrant and x-ray examination were conducted to examine the weld joint quality in order to make sure that, the
weld joints are free from any internal and external defects. All these tests procedure were written and performed according to standards (WPS).

Figure (6) represents the tensile strength of the base plates with weld joints, In welded samples fracture occurred in the fusion zone. The tensile strength and elongation of the joint produced by ER70S-6 filler material were low due to the presence of defect

ER70S-6 filler material was bent till to 180º around the welded strip.

Figure (7) confirmed that, after bending test the welded region does not reveal any macroscopic defects like separation, tearing or fracture, No intermetallic phases and

Table (5): Bending Test Results

Sp. No	Types	Thickness(mm)	Bending angle deg.	Diameter(mm	Results
1	Face	3.5	180	12	Satisfactory
2	Root	3.5	180	12	Satisfactory
3	Face	3.5	180	12	Failure/Gas cavities
4		3.5			
5	Root	3.5	180	12	Satisfactory

Figure (7) represents the macrographs of the bended specimens. The sample welded with

defects formation in the fusion zone of filler materials was the main reason for the high formability of the joints

Figure (7) shows an image of x-ray for the weld zone before and after the bending test, The part of the weld shows no evidence of any internal defects.

In specimen number 3 as shown in table (5) a small defects were in many application such as, Construction work, tanks, truck bodies, farm implements, pipes, steel castings or forgings, shaft build-ups and general shop fabrications [12,13].

Figure (9) 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 (13,14).

Alloy ER 70S-6 contains high levels of manganese and silicon for stronger

found, which 3 of them were in normal inspection area in the root of the weld and 2 clearly outside of inspection volume, areas where penetration was higher than the normal penetration. For these properties, this filler is used deoxidizing power where stringent cleaning procedures are not possible. The high silicon content increases the fluidity of the weld pool, creating a smoother bead appearance and resulting in minimal post-weld grinding. The Alloy ER70S-6 has been designed to provide X-ray quality porosity-free welds and the highest tensile strength (as welded) of the plain carbon steel wires. This wire is excellent where poor fitups or rusty and oily plates may be used. Some typical applications are truck bodies, farm implements, steel castings or forgings, shaft build ups and general shop fabrications

Conclusions

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

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

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.

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