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Mechanical Properties of Welded Steel Pipes Type 213 Gr T5 used in Heat Exchangers

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ABSTRACT

This work is concerned to the welding process for joining pipes made from alloy steel which is widely used in heat exchangers structures. The chemical composition analysis of this steel type close to 213 Gr T5 according to ASTM standard. This work shows that this metal has a good weldability and high level of weld metal integrity. Weld filler type ER 502 of 2.4 mm diameter is used in this welding method to join sections of pipes by using Tungsten Inert Gas welding (TIG) process. This investigation is covered the approving of weld integrity assessments and mechanical prosperities by doing a number of tests for weld joint, for example, tensile testing, bending, hardness, x-ray and Liquid penetrant tests). Eventually it was confirmed that, the weld metal has a reasonable joint mechanical property and no series weld defects.

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1. INTRODUCTION

Metals fabrication by Welding is an important factor in the welding field in construction many engineering structures like structures repairs, fabrication and maintenance. It is important to mention that, there many methods of welding methods exist in this field, such as, Metal Inert Gas welding (MIG), shield metal arc welding, (SMAW), Submerge Arc Welding, (SAW) and (TIG) welding. [1].

TIG method which is the used in the present work was firstly started around 1940 at the beginning of the World War II at 1945. It is development may help in solving so many the metals welding difficulties such as aluminum, alloy steel and magnesium. using of TIG welding process is widely spread today for join variety of ferrous and nonferrous materials in fabrications due to the weld quality and mechanical properties.

Argon used in this because of many advantages where it gives better electric arc through starting stage, good cleaning weld surface with Lower requirement of arc voltage and gas flows during welding process [2].

All required properties of the weld joint can be created if a depend according Welding Specification Procedure (WPS) is suggested such as ASME standards.

The welding is difficult job to do because; the required quality of the weld zone is highly which is depended on many requirements such as welder skill and certification, (WPS) and good information in the engineering materials. The materials joining by welding could create a large number of surface and internal discontinuities through the structure fabrication [3].

Selection of the suitable joint design is considered as main factor in achieving a proper welding joint with a required mechanical property. The selection of a proper joint design types prior to weld definitely results a high level of joint strength which is mostly familiar in field of welding plate, sheet metal, strip and pipes. [4].

When welding pipe at 6G position it means covering all of the pipe welding positions. Information in this article can be applied in welding pipe in any type of position. The 6G position is used as a combination of all fabrications of the structural and positions of pipe welding [5].

In the process joining pipes by welding, there are different weld positions to be used which are shows the position of the pipe, but not the weld joint position. For example, in 6G welding position, the pipe is with angle about 45° related the horizontal level provided the pipe is not allowed to rotate, so that while the pipe is not allowed to be rotate, the welding process can be run in all the positions. It is important to mentioned that, most pipe welds design are groove welds and named by letter G. [6,7].

The weld joining technique of applied this pipe in this work and the written welding procedure is done by method mentioned in ASME section IX standard used for pipe welding certification process [8,9]. It is important to mention that, the 6G position pipe welding is normally related to all types of the pipe positions. [10, 11].

2. MATERIALS and Method

The pipes metal was identified of this research by doing a chemical composition test analysis at the ministry of oil laboratory and found to be as close to 213 Gr T5 according to ASTM standard. The percentage of all elements is listed in Table (1).

Table (1): The Chemical analysis for Composition of the tested Pipes

Element	Mn	Cr	Ni	Mo	Fe
Percentage	0.39%	4.8%	0.00%	0.5%	93.6%

A. Welding Process:

V grove joint design was machined from steel pipe with 60° angle and root of 2.5mm as in figure (1).

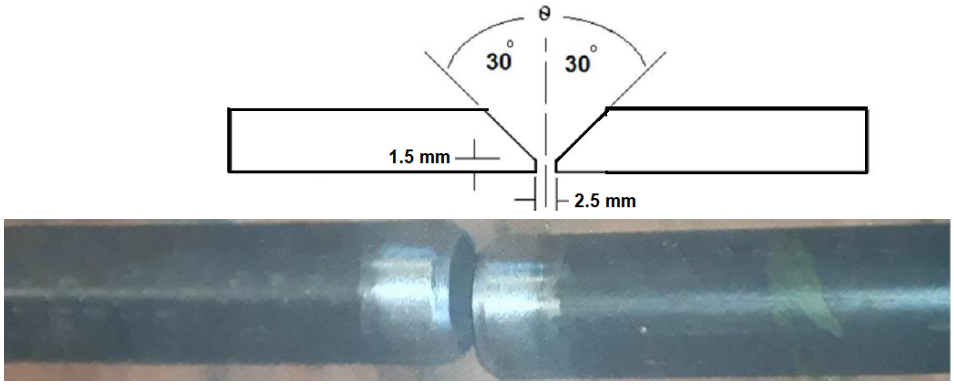

Figure (1): V- Grove Design of the weld Joint

The first step required for performing the welding process all faces of the weld joints must be highly cleaned using alcohol-based cleaner (acetone) to remove all types of contamination including, oil, grease, foreign particles, rust, painting, and water. The welding process was conducted using filer type ER502 according to AWS standard, chemical composition and also mechanical properties of this type of weld filler is listed in table (2). Argon welding method (TIG) type tungsten inert gas of 99.9% purity was used to join the two pieces of steel pipes specimen t a current range of 160 to 180 ampere of direct current straight polarity (DCSP) with voltage range of 28 to 30 volts. Welding torch stay at 45° with pipe axis using weld filler type ER502 according to the ASTM standard as shown in figure (2). Preheating at 200C° was conducted before starting the welding and stress relief of 675C° at heating rate of 150C°/hrs. with furnace cooling.

Figure (2): Steel Pipes after welding.

Chemical analysis composition with Mechanical properties of the welding wire according to AWS Specification: AWS A5.9 ER 502 are shown in Tables (2 & 3).

Table (2): Chemical Composition or **ER502**

C	Si	Mn	Cr
0.09	0.36	0.48	5.75

Table (3) the mechanical properties Wire **ER502**.

Tensile Strength N/mm^2 (Ksi)	Yield Point N/mm^2 (Ksi)	Elongation %
520 (75)	380 (55)	29

B. Hardness test (BHN)

The hardness test was conducted for both base and weld by Brinell hardness instrument. From the test, (BHN) is equal to 81.5 for the base metal and 89 for the weld metal. Hardness indentations morphology is shown in figure (4)

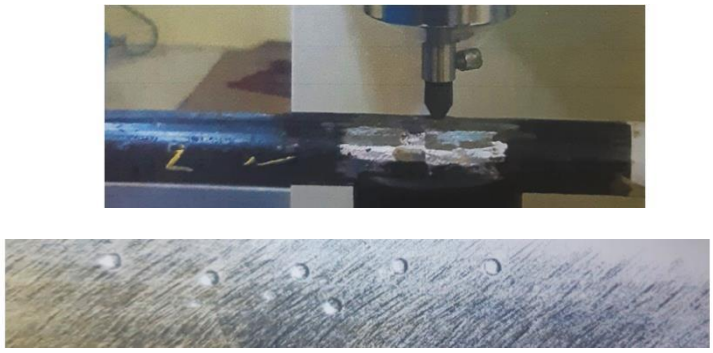

Figure (4): The indentation shape of Brinel Hardness Test

C. Tensile Test

Number of specimens was manufactured from welded steel pipe; the weld was selected to be in the middle of the specimen as in Figure (5). The specimen's dimensions were implemented by the ministry of oil according to the machine loading capacity. During the tensile test it was observed that the pipe is started fractured after a maximum tensile stress of 452 MPa while the yield stress was started at 367MPa with a final elongation of 30%. Axial loading was continued up to failure and found to be occurring at the base metal while the weld joint did not reveal any type of defect.

Figure (5): Tensile Testing Specimen after fracture.

D. X-ray Test:

This test of was conducted by using special software known as ImageJ to inspect the weld joint rigidity and integrity so that, it can be detected any types of internal defects. That test was done for the find any types of internal discontinuities or any other weld defects will cause harm effect on the weld joint mechanical properties and that may make system failure after its fabrication. It is important mention that The Alloy of ER502 has been designed to give defect free weld with highest tensile strength of many other alloy steel wires. This wire alloy is good where sometimes a poor fit ups or may be rusty or oily plates surfaces may be need to be used. This filler wire provides various advantages in numerous applications ranging from furniture manufacturing to petrochemical industry
apparatus and oil industry. Figure (6) Shows an Image negative of this Inspection.

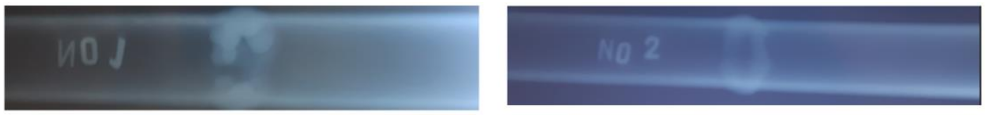

Figure (6) The X-ray Inspection Image

E. Liquid penetrant testing (LP)

This process is always used to detect any type of surface defects such as cavities, lack of penetration, cracks using special types of colored liquid. In the test the tested surface is strongly cleaned from any types of contamination then the liquid is carefully applied and eventually colored defect is identified as joint shown in figure (7), in the present test on the weld zone reveal no obvious of any types of surface defects.

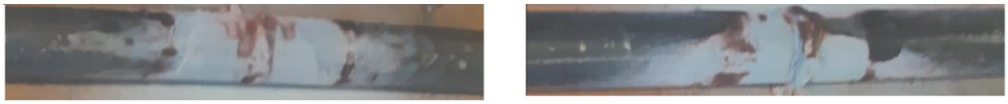

Figure (7): Liquid Penetrant Inspection

3. RESULTS AND DISCUSSION

This work is chosen at this time because of the highly importance and required process for explain the welding process in oil industry of many applications metals in particular of steel pipes joining by welding which is the subject of this work. The joining of pipes by welding considered as an important process in all systems when the fluid is flowing through the welded pipes net, so that need a strong knowledge in quality control for pipe welding technology, for example using (TIG) which is used in this work and achieved an excellent result in term of weld metal integrity and soundness.

For these reasons a several sections of steel pipes zone design were prepared to do many types of engineering testing processes. Welded specimens inspected at Ministry of oil and using standard machine. Destructive examinations have been done to detect integrity of the weld metal from any types of weld defects.

Different types of destructive and nondestructive tests were carried out to reveal the weld joint quality that is for the approvement if the weld metals are not have any types of i defects or discontinuities. The procedure was written by expert engineer done and done depending on international standards which is called (WPS).

Figure (5) is described the tensile test of steel specimen metal which has a weld joint at the middle, fracture happened in base metal outside of fusion zone that confirmed the quality of the weld rejoin. The weld joint strength produced by ER502 wire is quite enough to produce this good results with weld joint soundness and integrity and no evidence of any types of discontinuities in the weld.

Figure (7) which is represent an x-ray image for the welded specimen.
It is clear from this image there is no indications of any crack or all types internal weld defects, that because of the weld carried by expert welder and selection the suitable wire filler type ER502 according to ASTM standard catalogue. [12,13].

Also, from figure (4) which shows the application of dye penetrant inspection for steel specimen after welding, from this nondestructive test it is so easily to notice that by checking the weld surface no any evidence of all types of discontinues, this test is always needed because, it is familiar in a lot of structural applications in particular in oil industry. Because any surface defects because may cause stress concentration site and become as a proper point for crack to start initiation and later on growth and became a reason for the any engineering failure in particular when it becomes under fatigue loading which are widely happens in welded structure (13,14).

4. CONCLUSIONS

1-This research investigation confirmed that, the implementation of quality-assurance arguments for all welding procedures through work by certified welder with standard welding procedure specification (WPS), according to this information the weld region in this work highly supported the load without failure.

2- Argon welding processes were used to connect the two pieces of steel metal approved that this method is suitable and gives a mechanical property very close to the base metal according to welding standard.
3- The soundness and the high quality of this weld joints are achieved in this welding process because all of wps considerations were taken in the account including stress relieve by tempering.
4- Non –destructive with some destructive tests including X-Ray, die- penetrant, ultrasonic, tensile and hardness tests were implemented in this research to examine if there are any internal or external defects in the weld zone.
5- The welding variables were selected carefully and written by expert engineer in welding this type of steel which is widely used in heat exchanger industry in particular in oil applications industries.

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] MD.Ibrahim Kan, welding science & Technology, book, 2007
[6] Ezzet Hameed Abdulsalam, Mechanical Properties of Weld Joint in Refrigeration Tubes Welded by TIG Process. Dijlah Journal, volume (2), Issue. (1), 2019.
[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] Ezzet Hameed Abdulsalam, Some Mechanical properties of lap weld joints design in copper pipes, Dijlah Journal, volume (5), Issue. (4), 2022.
[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