مجلة دجلة • المجلد ٦ ،العدد ٤ (٢٠٢٣)، ص: ١٠٨ - ١١٣
ISSN: 2222-6583

Welding technology and mechanical properties of steel pipes type A106 used for oil refineries

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Abstract

This research is mainly concentrated on the welding technology and properties of a carbon steel metal; the chemical composition analysis of this metal is close to specification type A106 Grade C according to ASME standards. This metal revealed good weld ability and achieved a high strength weld joint. SMAW weld filler type E6010 is used to connect the two parts of steel pipes using Arc welding equipment. This work also shows the achievment of the soundness and mechanical properties of the weld metal. That was carried out by performing a several types of experimental tests on the welded specimens including , tension, bending, hardness, Liquid penetrant and x-ray). All tests results confirmed that, the weld metals are free from defects and achieve a good mechanical properties

Key words: Pipe welding, weld joint, joint design

Introduction

Carbon Steel pipes according to ASTM standard as A106 Grade C is a familiar material in many engineering application in particular in oil refineries and plants, when fluids are flow at high pressures and elevated temperatures. ASTM A106 Grade C Pipes are strong and ductile Pipes with high wearing resistance. These Pipes are manufactured as per ASTM Specification and commercially referred as carbon steel Pipes. The chemical properties of this metal according to the above ASTM standard are mainly of 0.35C, mini 0.1Si, (0.29-1.06)Mn, 0.035P,0.15Mo, 0.4Ni, 0.4Cr, 0.4Cu and 0.08V. While the tensile properties are yield stress 275MPa and tensile strength 485MPa with 12% elongation

It is important to confirm that welding is an important process in this structure, such as fabrication, maintenance and structures repairs. It is a suitable process for joining different types of materials. Many types of welding methods are available, including, tungsten inert gas welding (Tig), shield metal arc welding, (SMAW), metal inert gas welding (Mig), submerge arc welding, (SAW) …etc.(1).

Acceptable mechanical properties for weld joints can be achieved when a welding specification procedure (WPS) is done according to the ASME standards. The main factors which are affected the welding quality are, metallurgy and welding procedure. Welding may create defects in the structure, such as, deformations, slag inclusions, lack of penetration, undercuts, Porosities, misalignment residual stresses..etc. (2, 3) SMAW welding process is used in the present work. It is used to join to a different types of metals like stainless mild and high tensile steels.

The weld joint design which is an important factor for the weld quality needs a considerable attention in welding processes. It is well known that, many basic types of weld joints are

available in this field and confirmed by international standard for example, lap, butt, corner, tee, and edge.

This shape of weld joint can be either square or grooved. In pipe welding, there are several types of test positions**.** The position means that, the place of the pipe, not the place of welding joint. For the 6G position pipe weld, the axis of the pipe should be at angle of 45-degree with the horizontal axis and the pipe is not fixed and not rotate. All pipe weld technique procedure was conducted according to the ASME section IX pipe welding certification standard. This pipe welding procedure of a 6G position gives clear information about all of the pipe welding positions. (7,8).

Experimental procedure:

This work is implemented because of the important need for full understanding of the welding technique in particular at the oil refinery and could help the engineers and technicians to do their job at the field site without any problems.

The welding and inspection processes were performed using workshop and laboratory capabilities at Dura oil refinery- Ministry of oil. There are many destructive and nondestructive test were performed to evaluate the integrity of the weld metal.

Pipe metal The metal used in this research is carbon steel pipe type A106 Grade C according to the ASME standard. The chemical composition analysis of this metal was done at the ministry of oil and was found to be mainly from 0.15% C, 0.65% Mn, 0.22% Si, 0.01%P and 0.01% S as main alloying elements,

From the element percentage it this analysis it is seem that material is close to steel types (A106-02- Grade C) according to ASTM standard. The importance of this work that , this metal of the pipe system is common in fabrication of many structural applications such as boilers, condensers in refrigeration systems that using water (chilled water), icing manufacturing pipe systems. Also pipes in manufacturing the tubes bundle of heat exchanger in refineries and petrochemical plants. All tested specimens are of pipes with the inner diameter of 15 mm and 20 mm outer diameter.

Hardness test:

Brenil hardness tests were done on both base and welded metals. Brinell hardness number (BHN) of (153) is detected and the shape of the test indentation is shown in figure (1).

Figure (1): Brinell hardness test indentation

Welding:

The welding process was carried out using V-groove weld joint design and prepared mechanically as shown in figure (2).The weld joints were primarily cleaned before starting

the welding process until become free and clear from any form of rust, oil, water, foreign particles and painting.

SMAW method welding was conducted to join the two parts of the steel pipes. The weld filler type E6010 was used in this welding process. This electrode is cellulosic coated type which is suitable for welding pipes several positions using all types of current, DC and AC

All welding processes were performed by 6G certified and skilled welder according the WPS which is previously prepared by expert engineer to be suitable to join these metals as shown in figure(2).

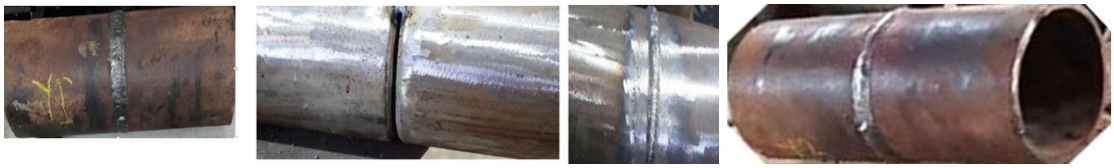

Figure (2): SMAW welding process used in pipe welding.

Tack welding was done at many points on the pipe joint to connect the two parts and to obtain the specimen alignment shown in figure (2).

Tensile Test All tensile specimens of weld joint situated at the middle of the gauge length as shown in figure (3). The tensile properties of the welded pipe metal are 288 MPa yield stress, 397 MPa ultimate tensile stresses, 217 GPa Young modulus as shown in figure (4).

Figure (3): Tensile testing specimen after failure.

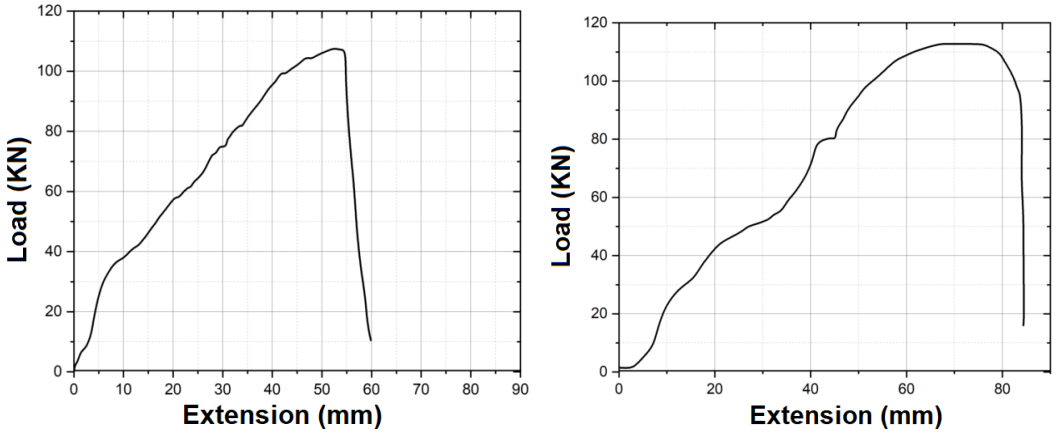

Figure (4): load- extension curve for welded and unwelded specimens

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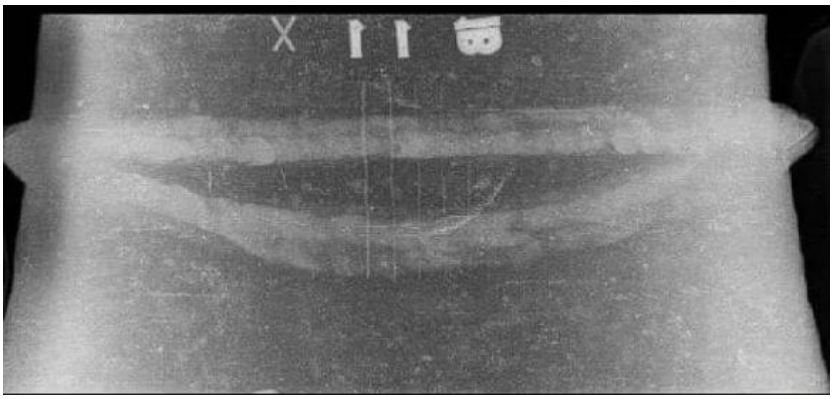
Bending test Bending test is an important examination method to reveal the level of materials ductility and the quality of the weld joint throw the ability to resist cracking or another types of surface defects during a continuous bending.

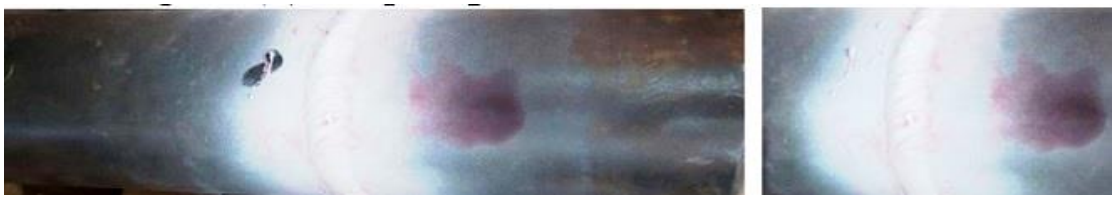
Figure (5) shows the application of on a welded strip when the weld joint is situated at the middle, This test is used to know the strength of the weld metal after it is done on this position. A special type bending machine is used to conduct the guided bend test. The selected material must be has the ability to bend up to a required angle, for example 180 degree without creating any cracks. If this condition occurs, that's mean the weld is passed the bending test. Figure (5) shows a bend test for welded specimen

X-ray test: Figure (6) shows an x-ray negative for bending test of a welded strips and pipes. The X-ray images analysis was performed using software called ImageJ to examine the weld zone in order to detect any internal defects. X-ray technique was used to know the integrity of the weld joints of all samples inorder to make sure if there are any defects in the weld metal 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 (6) shows an image of x-ray



Liquid penetrant testing (LP) Shown in figure (7), was performed to discover all types of surface defects such as cracks and cavities. This test consider as nondestructive test and highly used after weld fabrication. It is simple process, cheap and does not need to much skill.

Figure (7): Liquid penetrant test



Results and discussion:

In this work Destructive examination such as tensile test, hardness test and bending test & Nondestructive examination such as, liquid penetrant and x-ray examination were conducted to examine the weld joint and to evaluate 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 (4) represents the load extension curve for the tensile test of the base metal with weld joints, In welded specimen the fracture occurred in the weld fusion zone, it is also clear from this curve, that the tensile strength and elongation of the weld joint produced by E6010 filler material were low due to the presence of defect.

Figure 6 reveals the macrographs of the bended specimens which was welded with E6010 filler material up to 180º around the welded strip.

This figure also confirmed that, the welded region after bending test does not reveal any macroscopic defects such as, tearing separation or crack. No intermetallic phases and defects formation in the fusion zone of filler materials was the main reason for the high formability of the joints.

Figure (6) shows an x-ray image for the weld joint before and after the bend test. It is clear from the figure that, the part of the weld shows no evidence of any internal defects.

For these acceptable properties, this filler (E6010) is normally used in many engineering application such as, tanks, construction work, tanks, farm implements, truck bodies, pipes, steel castings or forgings, shaft build-ups and general shop fabrications (12,13)

Figure (7) shows another type of nondestructive test known as liquid penetrant test which popular method for detecting surface defects. It is applied for the weld joint and it was not reveal any surface defects such as cracks, cavities or any discontinues. This test is essential in several engineering applications because the presence of any surface defects is considered as stress concentration zone and becomes as a appropriate region for crack initiation and growth which cause the failure in particular under fatigue loading (13,14).

The weld filler type steel A106 Grade C contains high amount of manganese and silicon to achieve a stronger deoxidizing power where the cleaning works are not very difficult. The high level of silicon content causes an increased in the fluidity of the weld joint pool and then

creating a smoother bead shape and resulting in minimize the need to grinding prior to welding.

Conclusions

1- SMAW welding processes were carried out according to welding standard to achieve the required mechanical properties. The welder was pass qualification exam as a 6G skilled welder before conducting the pipes weld joining.

2- Different types of Destructive & nondestructive test such as bending, tensile, die- penetrant X-Ray and ultrasonic were performed in this work to confirm the integrity and soundness of free weld and heat affected regions from any defects which practically achieved.

4- The welding procedure specification (WPS) implemented in this work was found to be applicable for welding of the A106 Gr C steel pipe metal.

5- The test results of x-ray examination conducted in this work confirmed that the weld zone and heat affected zone are free from any defects such as internal cracks, weld inclusion, foreign particles and porosities.

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