Field Tube to Tube Butt Welding Procedure for Coiled Tubing

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Abstract. Coiled tubing with higher strength and larger diameter is widely used in oil and gas engineering. Local damage generated during its working operation will decrease the fatigue life and strength, but replacement will introduce with extra cost. In order to repair the damaged part with lower cost or obtain longer coiled tubing, tube to tube butt TIG welding is adopted. This paper described characteristics of field butt welding and summarized welding sequence. Groove type and preparing, type and diameter of welding wire, welding position, type and flow rate of shielding gas and diameter of welding electrode are all determined. Grain refinement measurements, heat input and welding thermal cycle control method are specified. The welding process has excellent repeatability, the soundness and integrity of weld joint can be guaranteed. The experiment results showed that lower heat input and multi-layer welding can increase fatigue life of welded joint.

Introduction

As oil and gas well coiled tubing operation involve increasingly higher grades , larger and longer sizes coiled tubing (CT) , the ability for extending their working life becomes of increasingly greater economic and safe importance. Not only do larger tubing sizes and higher grades exhibit inherently lower fatigue lives, but also their replacement cost is considerably greater. In the appliance process of CT, field tube to tube butt welding becomes an indispensable technology due to the damages such as dents or ovality and development length. Efforts are underway elsewhere for developing CT repair strategies for recovering some of the CT fatigue life. But such local repair methods have both material and practical limitations. The capability to remove finite section(s) of tubing that has been damaged, would be of significant benefit rather than force the retirement of the complete tubing string. Remove undesirable sections of the tubing and subsequent replace new sections without discarding the complete tubing or extend the CT string length with performing reliable on-site girth-welded connection(s) in coiled tubing.

However, the weakest points and the most unreliable portions in a CT string are at the but welds. A research project was performed to get better welding joint. the results of the research are important to got a good weld.

The characteristics of field welding (GTAW) for CT

Relative to the factory and laboratory welding, field welding basically has the following characteristics.

1. Field work environment is relatively poor, that is belong to outdoor work. Welding operation and welding quality are vulnerable to weather conditions and the construction site conditions.
2. After released, the CT will bent or even reverse because of the internal force. Assembling CT before welding in the free state is affected by the site size.
3. In order to obtain qualified welding joint, welding fixture which can meet the need of the field welding is required.

Field Tube to Tube Butt Welding Procedure

The usability of CT depends on the quality of welding joint. CT butt welding is a precision welding .GTAW is adopted on-site tube to tube butt welding. Below is a step-by-step procedure for welding CT.

1. Straighten both ends of tubing to be welded. Cut ends of tubing square or machine a bevel using a beveling tool,grinder, or file. Deburr all cut edges.
2. If the tubing is wet inside, place a small amount of soluble tissue or toilet paper about 300mm from the end of the tube to stop seepage.
3. Using a small flat/curved tip chisel, or a small round/curved file, taper/remove the inside weld bead 5mm-10mm from the end of the tube. A chisel ground with a curve similar to the ID of the pipe works best for this procedure. Extreme care should be taken not to nick or cut the ID of the pipe. If a nick or cut is made into the tube wall, or any of the pipe wall is filed off, cut that section off and start over. It may be necessary to remove the bead before doing the final weld preparation in step 1.
4. Polish the end of the tube using emery cloth or a fine wire brush about 50mm back from the end on the O.D. and about 25mm back from the end on the I.D. The final appearance should be mooth shiny metal on the O.D. and I.D. of the tube. Circumferential grooves and grinding marks significantly decrease fatigue life and should be polished smooth using emery cloth or a fine wire brush. Please assure that all sand paper and emery cloth is NOT aluminum oxide.
5. Use alcohol or other appropriate degreasing agent to clean the inside and outside of the tube. Assure that the surfaces near the weld prep are clean and dry. Do not use gasoline.Avoid contaminating the clean surfaces during alignment in step 6. Re-clean if necessary after alignment.
6. Position tube ends in a fixture so that the ends are butted together. Use a straight edge (at least 200mm long) to assure alignment on all axes. In order to maintain the proper gap width, use a small piece of weld consumable between the two pipes during the alignment process. It is also recommended that you leave the spacer wire in while welding the first side of the tube to prevent the gap from closing. Remove the spacer before welding the other side.

NOTE: It is extremely important to assure that the tubes are butted squarely and the tube lengths adjacent to the weld are straight.

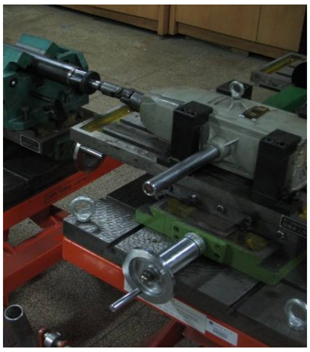
7. Position chill blocks (heat sinks) on either side of the joint to be welded. For groove welds, the chill blocks may be moved to the edge of the groove during the root pass, and then moved approximately5mm away from the edge during subsequent passes. Chill blocks for material thicker than 5mm or grades greater than 80 should be water-cooled for maximum heat extraction. For square butt welds, the chill blocks should be placed about 5mm from the edge of the tube.
8. Wind curtains shall be positioned to insure there is no air movement in the vicinity of the weld during the welding process, which could interrupt the cover gas.
9. The full penetration weld shall be accomplished using the GTAW (a.k.a. TIG) process with high frequency start and a 2.4mm thoriated tungsten electrode. Scratch starting may contaminate the weld and is not recommended. A 75%Helium/25%Argon shielding gas mixture works well for this type of full penetration weld. Welding parameters should be DCEN, 50-100 AMPS, 9-12 VOLTS, and 1-2.5 ipm, however these may vary slightly based on the welding machine you are using. 100% Argon shielding gas is suitable but will require higher amperages for full penetration, and may increase hardness of Heat Affected Zone (HAZ) . Coiled Tubes recommends using AWS ER70S-2 or ER70S-6 Φ1.6mm diameter weld consumable for all welds on 90 grade tubing and below. For 110 grade coiled tubing, AWS ER80SD-2Φ1.6mm diameter filler material is recommended. The weld shall be made using a single-pass stringer bead with a 7 -13mm overlap on the start and stop. Proper cleaning between each pass is recommended for heavier tubing. A small amount of oscillation may be necessary to assure tie in of both sides of the weld. However, large amounts of oscillation should be avoided as wide beads tend to decrease fatigue resistance of the string.
10. Remove chill blocks and allow to cool to touch after each pass. When using water-cooled chill blocks, leave blocks in place, and allow blocks to cool to touch before proceeding.

11. After the weld is complete, remove chill blocks and dress the weld bead to within 0.000/+0.100mm of the tube surface.The finish shall be smooth with no nicks or cuts.
Note: do not remove material from the parent tube surface.Factory welds are dressed with a small hand grinder to remove the cap of the weld, and then filed smooth with a flat file.Final finishing is done with emery cloth until smooth. It is necessary to remove the cap prior to radiography to ensure a full penetration weld.
12. It is vital that X-rays be made of each weld. A procedure following ASME Section V, Article 2 using the double-wall, double-viewing technique for complete coverage and capable of very high quality (2T-hole #7 penetrameter) is recommended for detecting small defects. Experience has shown that lack of penetration and even very small defects can lead to sudden failure. Welds are rejectable for any defect: porosity, undercut,lack of penetration, lack of fusion, cracks or underfill.

Welding fixture

Welding fixture is the assurance of accomplish welding and welding joint quality. According the welding procedure, during the welding, the welding fixture include straightening device，rounding device, grooving device, chill blocks,internal Gas circulating device, assembling device. Some devices are illustrated in Fig.1.


a. straightening device


b. rounding device


c. grooving device


d.chill blocks

Fig.1 Welding fixture

Low welding heat input and multi-layer welding

Coiled tubing is supplied as a heat-treated product, therefore, minimum heat input and careful control of preheat and interpass temperatures during welding is essential. Although the carbon equivalent of CT steels (typically 0.35 for CT70, 0.40 for CT80/CT90 and 0.55 for CT100/CT110) would indicate some preheat requirements, delayed hydrogen cold cracking has not occurred with CT 70 and CT80 tubing at room temperature.High heat input introduces undesirable profile gradients that, together with the increased section stiffness, will concentrate fatigue crack initiation on an already weakened HAZ. An ideal root pass profile is essential, obtained without preheat and optimum heat input.
Another important aspect of temperature control in CT field welding, involves the influence on the mechanical properties of the HAZ. The yield strength of coiled tubing can be adversely affected by the

welding heat input and thermal cycle. For this reason, copper chill blocks are commonly used to draw away the welding heat and increase the effective cooling rate of the HAZ.
An analysis of the transient temperature distribution in the HAZ of girth butt welds led to the procedure modification in which the interpass temperature between successive weld temperatures, is allowed to drop to the minimum preheat temperature. Multi-layer welding is necessary to improve the weld joint microstructure, illustrated in Fig.2.The last weld bead will affected the previous bead heat input and refine the grain, showed in Fig.2.

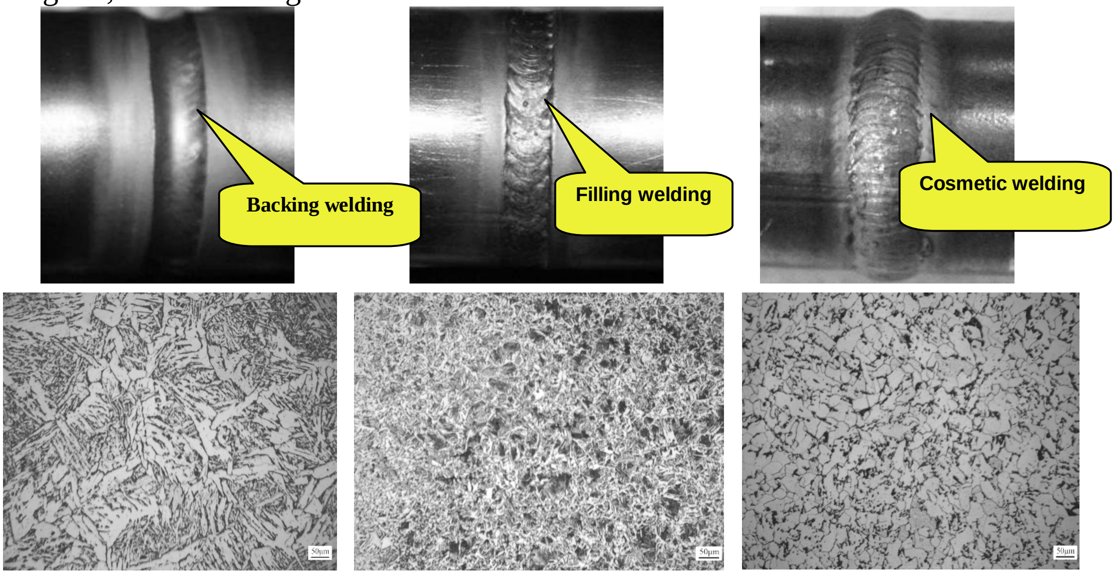


Fig. 2 Microstructure of weld in multi-layer welding

Edge Preparation

The initial tubing cut can be performed satisfactorily with a conventional hand-operated pipe cutter.The rough-cut edges must then be de-burred with a hand file or internal reaming tool, to avoid any grinding marks or heat checks that may result from the use of a powered grinder. Any CT ovality must be removed with a tubing circularizer. This operation must be performed first if an internal reamer is to be used to de-burr the pipe cut edges and remove the internal flash of the ERW seam weld. The internal reaming tool incorporates a shallow cone cutter that enables the machining of a gradual tapered profile for the internal welding flash.Since premature fatigue cracks can readily initiate at coarse grinding marks, the use of powered hand grinders must be avoided during weld groove edge preparations. The preparation of the welding grooves is one of the most critical aspects of achieving a high fatigue life in coiled tubing girth weld joints. This applies particularly to orbital TIG welds for which an edge preparation is required, even for thinner gauge material, because the arc penetration is more limited with this process. A single “V” edge preparation should be used in most cases.The vertex of the single-V preparation should contain a blunt edge or square face known as a “land”. Sharp or feathered edges have sometimes been employed, particularly when the first or “root” pass is deposited manually.
Feathered edges can make joint alignment more difficult and can result in burn through when tack welds are used to hold the tubing members firmly together at the start of welding.
The inner surface of the tubing joint will affected the fatigue life. The bigger backside melting width and the lack of penetration on the back caused by incorrect edge preparation will generating crack or reducing load capacity. So obtaining qualified groove is necessary. To ensure accuracy and repeatability as well as minimize the labor and preparation time, weld edge preparations must be mechanized using a powered pipe lathe as illustrated in **Fig. 1(c)**. Before commencing with welding, the completed edge preparation must be thoroughly cleaned and free of sources of hydrogen and other contaminants.

Consumable Selection

The selection of welding consumables or filler metals for coiled tubing TIG welding, is primarily dictated by the desired mechanical properties and chemical composition of the weldment. Other welding electrode characteristics, such as root penetration, rate of metal deposition and positional welding capabilities, are governed by the choice of electrical parameters and shielding gas composition. Conventional weld joint design, the filler metal tensile strength is selected to match that of the base metal at the upper end of the range of tensile strengths.This generally results in a weld metal whose yield and tensile strengths are higher than the base metal. Indeed, this practice is carried through in many coiled tubing welds performed by others. For plastic loading,however, this inequality in tensile properties leads to undesirable material property gradients across the weldment. It will be recalled that in the ideal case, the plastic bending strains are distributed uniformly across the weldment and along the tubing. This condition can only be approached if the yield strength and plasticity of the filler metal are similar to those of the base metal. Since the welding thermal cycle always causes a finite reduction of yield strength in present heat-treated coiled tubing steels, localized necking will tend to concentrate in the narrow HAZ of a full body tensile test specimen. This illustrates that the HAZ is the ultimate weak link that will limit the tubing weld joint in achieving the same fatigue life as the base metal. By selecting a consumable with an as-deposited yield strength somewhat less than the tubing, an allowance can be made for the reduction in tubing yield due to this annealing in the HAZ as well as due to work softening of the base metal. In this way, the effective percent elongation or ductility of the weld joint will be increased substantially compared to the effective elongation of the HAZ alone. The strain energy distribution from plastic loading will now occur over a larger volume of material within the weldment and therefore result in an increase of plastic fatigue life.

Conclusions

The guideline may be used to qualify weld procedures for all gauges and grades of coiled tubing up to and including CT 90. The success or failure of butt welds on coiled tubing is highly dependent on the skill of the welding personnel, the type of welding equipment used, the method of heat extraction during welding, and the level of non-destructive examination after the weld is complete. Caution should be exercised when using strings containing butt welds because the quality of the weld affects the yield strength and the resistance to environmental cracking. As with all welding procedures, CT recommends qualifying a weld procedure by mechanical testing samples prior to welding on actual strings. All the things above-mentioned must be considered prior to welding coiled tubing.

Acknowledgements

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