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Internal Bore Welding of Tubes to Tubesheet Joints in 5G Position

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Abstract

Tube to tubesheet welds are very important for functioning of any heat exchanger. Generally, corner or fillet type of joint design is used for these welds. However, both type of joint design is undesirable in certain applications since it leaves "crevice" between tube and tubesheet which acts as potential site for initiation of corrosion. Moreover, volumetric examination of weld is also not feasible. Hence, for very critical applications, tubes are welded to tube sheet using "full penetration – butt joint" which eliminates crevice and makes volumetric examination of weld feasible. Welding of this type of joint is termed as "Internal Bore Welding" since welding is made from inside of tube. Mostly, automatic GTAW process is used. L&T is manufacturing a stainless steel heat exchanger wherein tubes were to be butt welded using internal bore welding technique. This heat exchanger consists of more than 4500 tubes of 15.75 mm inside diameter and 1.65 mm thickness to be welded to tubesheet of thickness greater than 150 mm. 100% Visual Examination from outside and inside, dye penetrant testing from outside surface of weld, radiography examination (PQR) and helium leak testing are required for these joints. Special torch is developed to facilitate IBW for such small diameter of tubes. Welding without filler wire addition is done in 5G position to produce weld metal having acceptable visual appearance. This paper describes selection of welding machine, special considerations for IBW, development of welding procedure.

Keywords: Welding; Internal bore welding; Tube to tubesheet welding; 5G welding.

1.0 Introduction

In conventional heat exchangers, tubes are inserted through entire tube sheet thickness and welded to tube sheet using "corner or fillet joints". This type of configuration leaves "crevice" between tube and tube sheet. If shell side fluid is highly corrosive, it leads to failure of tube to tube sheet joint. In heat exchangers of nuclear plants, corner or fillet type of tube-to-tube sheet joints are not desirable because volumetric examination of tube to tube sheet joint cannot be done and there are chances that radioactive material can get trapped in crevice of tube to tube sheet joint and leads to dangerous conditions.

Therefore, for very critical service applications, tubes are butt welded to tube sheet so that crevice can be avoided, and volumetric examination of weld is possible. Welding of such joints can be done only through inside of tubes and therefore welding in such joints is termed as "Internal Bore Welding - IBW". Being a remote joint, welding of this joint is difficult. Any decrease in tube diameter and/or any increase in tube sheet thickness make it much more difficult. Normally, such types of joints are made without filler wire addition. Special type of torch is required, and strict welding procedures shall be established to achieve required quality of welding.

L&T is awarded with an order to supply a heat exchanger which requires butt welding of tube and tubesheet without filler wire addition. Material of construction for this equipment is stainless steel 304H grade. It involves more than 4500 tubes of 1200 mm length with 15.75 mm inside diameter and 1.65 mm thickness. Tubes are to be butt welded to tubesheet of more than 150mm thickness with triangular pitch of 25.4 mm. **Fig. 1** shows joint configuration.

Several quality checks are required on completed joint such as 100% visual inspection from both inside and outside surface, PT examined from outside, Radiographic examination, Ferrite testing and 100% Helium leak test of individual joint. No undercut suck back and Lack of fusion were allowed in visual inspection.

2.0 Selection of Welding Equipment

Automatic pulse-GTAW process was the obvious choice for welding. Special torch is developed in-house to suit Tubesheet thickness and reach Tube to Tubesheet weld from Tubesheet Face. Welding is performed from Inside of tube without addition of filler wire **(Fig. 2)**. It is an air-cooled torch without AVC facility. Torch is connected to a motor which facilitates rotation of torch and the entire torch with motor is mounted on tube sheet surface and is supported with a mechanically locking type plunger arrangement. A pulsed current power source is used with assistance of in-house developed control panel to weld with programmable welding schedule. Split type glass back purging fixture is used to provide inert gas purging on outside surface of weld.

3.0 Special Considerations for IBW

Apart from welding parameters, several other points which can affect the quality & progress of welding were thoroughly considered before finalizing the production plan. It includes selection of weld edge preparation and position of welding, finalization of fit-up tolerances, optimum welding sequence etc.

Different types of WEPs were discussed. For ease in fit-up and possibility of in-situ correction in case problems encountered while doing production welding, "cup and cone" type weld edge preparation is selected.

Due to certain limitations welding had to be done in 5G position, i.e. tubesheet was kept in vertical position and tubes were in horizontal position which further increased the complexity of the process.

Fit up of tube & tubesheet projection was considered very critical to achieve sound weld quality. Higher root gap may result into "burn through" whereas higher offset may produce "lack of fusion" and therefore it is decided to optimize root face and off-set during fit-up. After taking several trials, tolerances on root face & off-set are finalized. Accordingly, machining of tube ends, and spigot is done with very stringent tolerances. Also, arrangements are developed for in-situ machining of tube or tubesheet projection to achieve desired fit-up. With higher length and smaller diameter of tubes passing through multiple baffles, which increase rigidity, jacking arrangement is done from the nearest baffle. However, special care must be taken in setup since improper setup could lead to issues like lack of fusion in final weld.

Any interruption in welding, due to power failure, can make tungsten stick to weld pool. In such conditions, removal of torch from such a small diameter tube without any damage will be extremely difficult. Also, restarting at the same location, with precisely locating earlier stop, will be a challenge. Therefore, arrangements are made to provide uninterrupted power supply.

4.0 Development of Welding Procedure

Several trials were taken on mock-up tube sheet to develop optimum welding program. Initially, wide range of welding parameters such as like current (peak/back ground), travel speed, voltage, pulsing rate were selected, and resultant weld beads were inspected. Subsequently, narrow ranges of parameters were finalized for production welding to achieve desirable and consistent weld quality. Shielding / backing gas pressure and tungsten position, with respect to parting line, were also finalized to optimize bead profile. **Fig. 3** shows cross section of trial sample welded using final welding parameters. Procedure qualification record is made in accordance with ASME Sec IX. **Fig. 4** shows some of the joints welded.

5.0 Conclusion

Internal bore welds in such small diameters and 5G position can be produced using state-of-art equipment. Development of correct welding procedure and strict adherence to special precautions during manufacturing can lead to consistent and high quality of weld joints.

References

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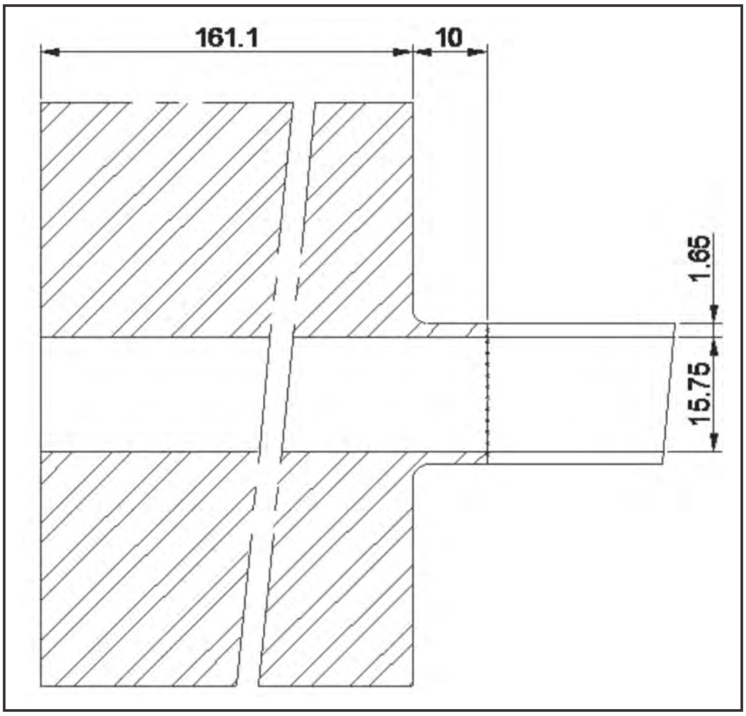

Fig. 1 : Joint configuration

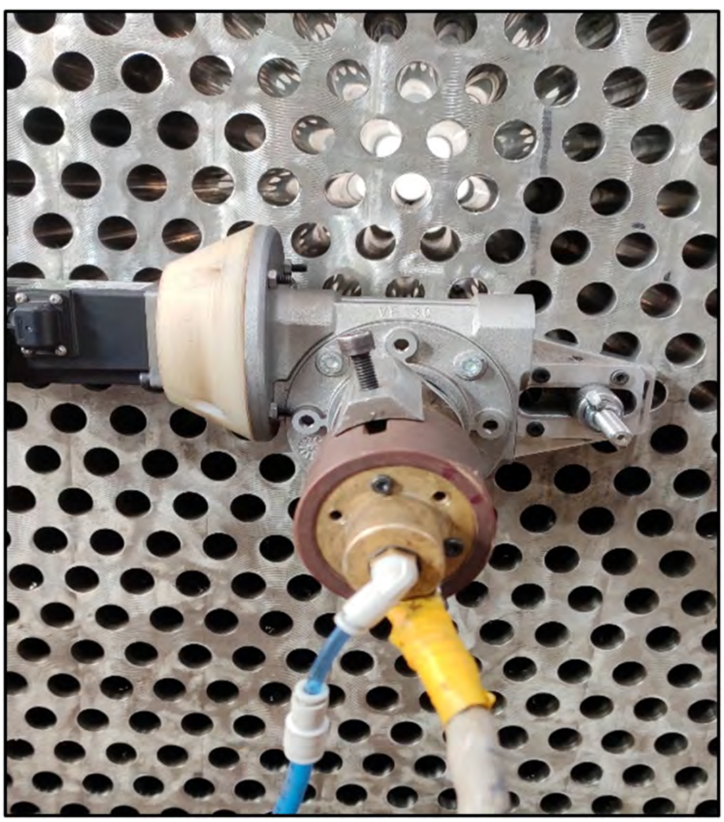

Fig. 2 : Welding Torch

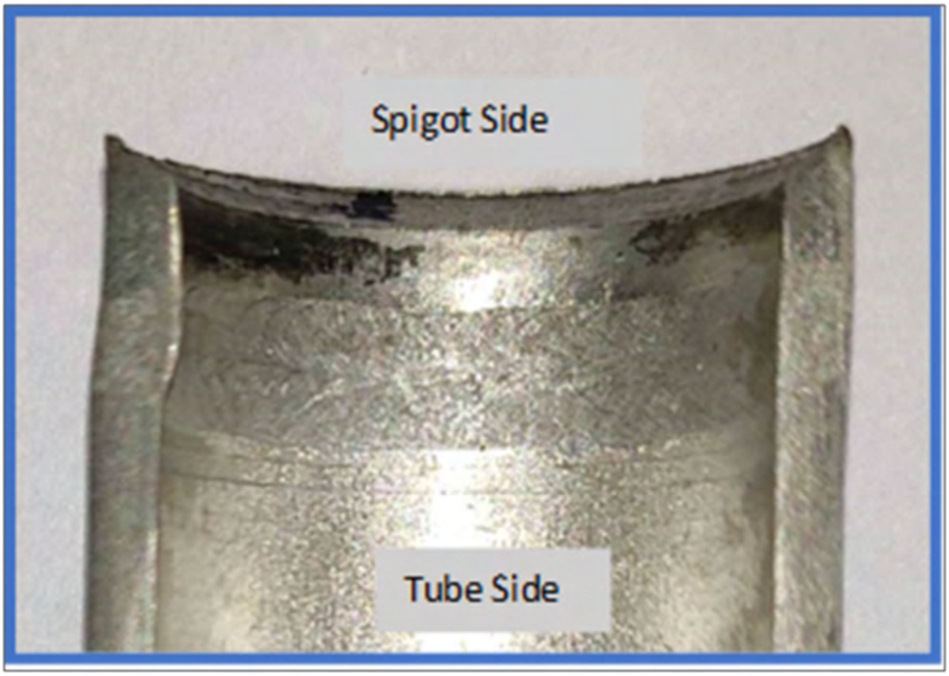

Fig. 3 : Cross section of sample Weld

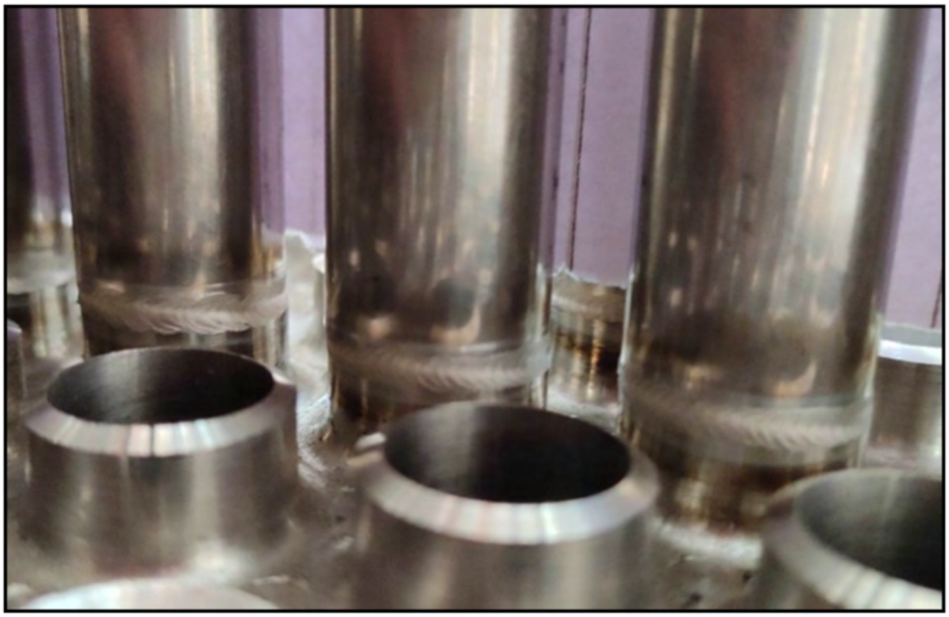

Fig. 4 : Production Welds