Press Release

Heat exchangers – components for various utilisations require sophisticated welding techniques

INTRODUCTION

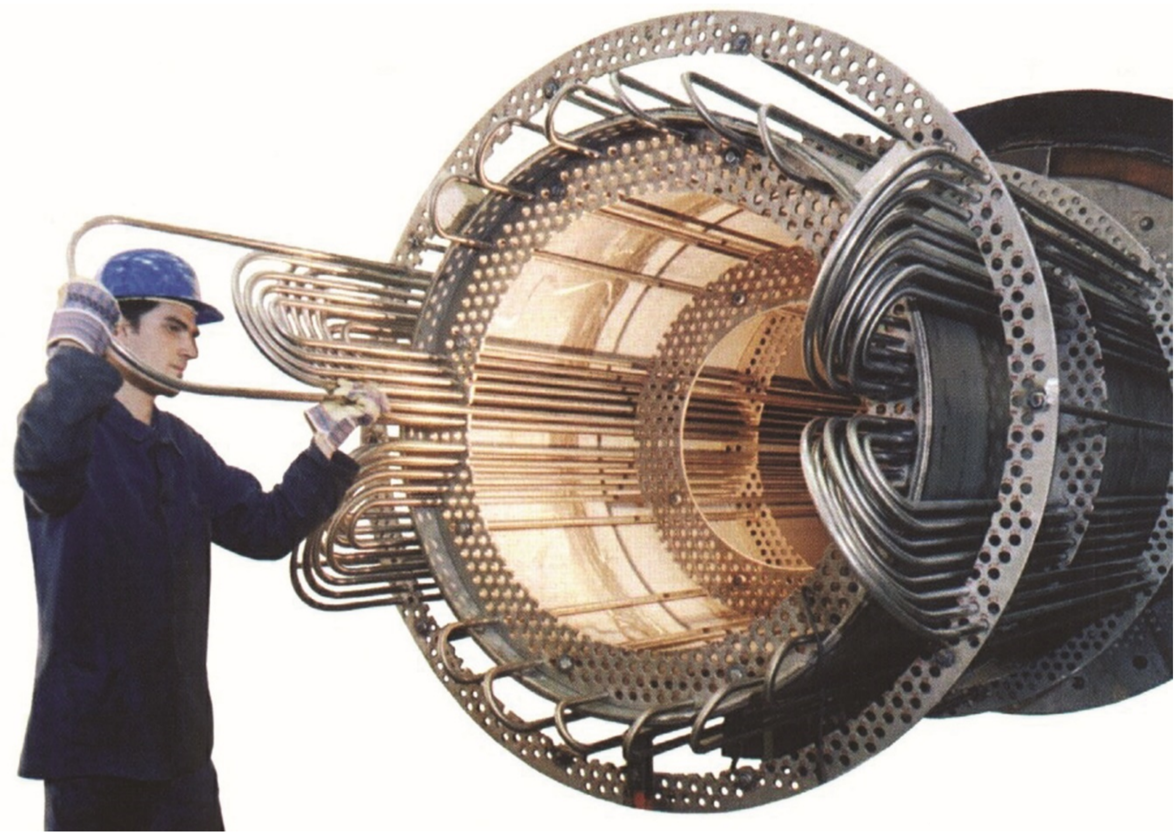

Fig. 1: An example of a heat exchanger with an intricate design

Heat exchangers are important components for processing industries and plants. Whether in pharmaceutics, food and beverage preparation, chemistry, petrochemistry, water treatment or energy production – in nuclear reactors or by the combustion of fossil fuels – liquids and/or gases must be heated up, evaporated, cooled down or condensed. Depending on the individual area of operation, the design of a heat exchanger has to meet numerous different requirements. In the pharmaceutical industry, during the production of purified water or even WFI water for injection purposes, any contamination of clean fluids must be avoided. In fact, minute traces of corrosion can spoil the whole batch of a finished product. In food and beverage preparation, the presence of micro-organisms is strictly limited. Dead volumes in the vessels are absolutely forbidden, but mould growth can occur in crevices or on rough surface areas. Chemical processes, such as the production of uric acid, are often based on quite aggressive agents, in combination with elevated

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temperatures and high pressure inside the apparatuses. Therefore, the walls and joints must continuously withstand severe attacks and substantial forces. A wide variety of heat exchangers can be found in power stations. Most notable are always the walls of a fired boiler or a nuclear reactor, but regenerative or recuperative systems for air heating or to recover heat from the flue gas and conduct it to the feedwater draw attention as well, and to see a powerful air-cooled condenser it is not necessary to enter the premises of a plant.

PARTICULAR HEAT EXCHANGER DESIGN

Generally, heat exchangers can be assembled from plates or designed as tube or pipe systems. As welded constructions or screwed together, plate heat exchangers have been used successfully for over a century, particularly in the food processing and chemical industries. However, if it comes to higher pressure, tube heat exchangers are preferred. The most recognized types are tube bundle heat exchangers with tubesheets and tube bundle heat exchangers with U-tubes.

TUBE BUNDLE HEAT EXCHANGERS WITH U-TUBES

The tubes inside this type of heat exchanger are linked to each other by elbows or return bends and connected by welded joints. Generally, butt welding of tube-to-tube, tube-to-elbow or tube-to-return-bend connections is a common task in pre-fabrication or on site. However, since the tubes of such a heat exchanger are situated extremely close together, manual welding is often excluded because of restricted access to the working area. Furthermore, most of the non-destructive testing methods cannot be applied on these welds.

In any case, to get excellent results mechanized welding could be an appropriate choice. The fittings are positioned manually and fixed by manual tack welding. An orbital welding head is then clamped on the tube, the weld is carried out automatically, interventions of the operator are not necessary.

An open orbital TIG (Tungsten Inert Gas) welding head consists of a U-shaped housing, a clamping device and a rotating plate with the torch fixed on it. With the rotating plate in its “home position”, the slot of the housing is open and can be slid over the tube to be connected. The clamping device enables individual adjustment to the particular tube diameter. If locked, the orbital welding head is reliably maintained in the desired position. Each open orbital welding head fits a certain range of different tube diameters.

The TIG torch bears a non-consumable tungsten electrode, which is centered in a gas lens and surrounded by a ceramic nozzle. An electric arc is struck between the electrode and the workpiece; the released heat provokes the creation of a pool of molten metal. To protect the hot electrode, the weld puddle, and the heated zone of the workpiece from the oxygen of the ambient air, a laminar flow of shielding gas streams through the gas lens. The rotating plate supports the torch and various adjustment slides, allowing exact positioning of the tungsten electrode above the welding gap and correct setting of the distance between electrode and workpiece. During the rotation of the plate the torch revolves on a circumference of a circle around the tubes to be welded. The distance between the electrode and the workpiece (and hence the arc length) is kept constant either by a mechanical sensor or by a motorized slide.

Fig. 2: For reliable connections between tubes, elbows and return bends in a tube bundle heat exchanger, orbital TIG welding is applied

To achieve consistent weld quality, the operator must thoroughly follow the instructions of the Welding Process Specification (WPS). The set-up of the equipment, the exact designation of consumables and spare parts, the preparation of the workpieces, the realization of the weld; for each individual step during the workflow detailed descriptions are given in the WPS. The welding parameters are determined in advance, and after approval the distinct weld cycles are stored as programs in the memory of the power source and referred to in the WPS. Generally, all programmable welding parameters can be modified by means of a control pendant, but to ensure that the operator does not disregard the specified limits the software can prevent access to certain parameters or set threshold values.

In contrast to other processes, TIG welding does not release any smoke or splatter. The beginning and end of a weld seam are free of craters or other defects, and a TIG welding cycle can be interrupted and continued if necessary. If filler material is needed, additional wire can be fed into the molten weld puddle. Tubes with a large wall thickness require their ends to be machined before joining. A J-preparation is preferable for mechanized TIG welding. Multipass welding can be carried out without interruption, as there is no need for cleaning or grinding operations between the layers. To keep the distance between the electrode and the workpiece constant, a motorized slide can be mounted on the orbital welding head. Controlled by the arc voltage control (AVC), the device adapts the torch position successively after each revolution around the workpiece as the diameter increases. Therefore, multilayer welding can be carried out continuously in a single pass.

In the recommended configuration of an orbital head for multilayer welding, a cross-slide generates the movement of the AVC device and a reciprocating motion of the torch perpendicular to the welding direction. This feature is called torch oscillation (also known as weaving), and allows adaptation to the width of the weld seam according to respective needs.

TUBE BUNDLE HEAT EXCHANGERS WITH TUBESHEETS

This type of heat exchanger is usually designed as a cylinder with one or two tubesheets fixed inside. Numerous tubes are installed with their ends slotted into the matching bores of these tubesheets. The joints between the tubes and the tubesheet are always welded from the front side; absolute tightness during long periods of service is of paramount importance. For added safety, it is not uncommon to apply two independent joining methods: the welding operation is preceded or followed by roller or hydraulic expansion.

Orbital welding heads for tube-to-tubesheet welding are equipped with a centering mandrel which is introduced into the tube which will be joined. The tube can be held in position manually by the operator or automatically by a pneumatic clamping system. The self-holding system allows an operator to run a couple of welding heads at the same time. In a case where several thousand joints must be realized at one heat exchanger, this feature can be a cost-effective solution to gain repeatability, time and money.

A collector inside the orbital tube-to-tubesheet welding head is used to bring welding current, shielding gas and cooling liquid to the torch. Endless rotation, without further need to wind up the cable bundle before each welding cycle, contributes to maximum efficiency. A wire feeding system for 4" mini spools can also be mounted on the welding head. Extended periods of uninterrupted service are promised by external wire feeders with 15 kg rolls.

TUBESHEETS WITH FLUSH TUBES

Joining of tubes which fit flush with the front face of the tubesheet can be advantageously carried out by orbital welding. Thin walled tubes for heat exchanger applications (wall thickness less than 1 mm) are often made of materials which are particularly endangered by the atmosphere (e.g. titanium or zirconium), in some cases the front face of the tube sheet is protected by a similar coating. During the whole welding cycle, specific "closed" orbital welding heads with a particular gas chamber provide 100 % protection against heat tint. These heads are exclusively designed for autogenous welding – they are operated without wire feeding equipment.

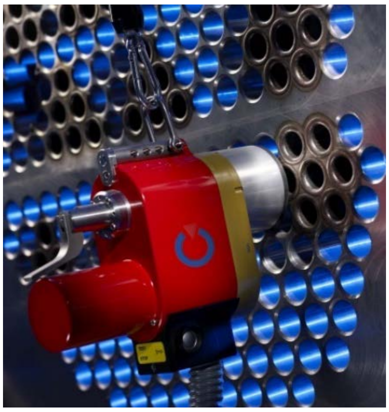

Fig. 3: Closed orbital welding head with a particular gas chamber in position to connect flush tubes to the tubeplate. Heat tint of titanium alloyed materials can be reliably avoided

The seal welds of low-pressure apparatuses are commonly carried out without the addition of filler wire. For aseptic heat exchangers, the characteristics of the smooth surface can be refined further by electro-polishing.

Fig. 4: Aseptic heat exchangers require greater surface quality

Larger weld profiles can be obtained by fusing down a tube projection of 1 - 1.5 mm or by specifically machined weld preparations of the tubesheet.

Fig. 5: Proven weld preparations of the tubesheet for flush tubes

TUBESHEETS WITH PROTRUDING OR RECESSED TUBES

In cases of high working pressure and elevated process temperatures, the tube-to-tubesheet connections must meet stringent requirements. Their absolute leak tightness must remain intact during the whole service life of the device, despite severe mechanical loads due to suppressed thermal expansion and periodically changing operating conditions. If improved mechanical strength of the tube-to-tubesheet connection becomes necessary, protruding or recessed tubes are employed.

To exclude incipient melting of the ends of the protruding tubes by the joining process, they should extend at least 3 - 4 mm beyond the tubesheet, typically 5.5 mm. The fillet weld is composed of a tight pass without wire, here a full penetration of the tube wall is not allowed. To sustain the occurring mechanical strain, the following resistance weld is carried out with filler wire. By means of an orbital tube-to-tubesheet TIG welding head with AVC and wire feeder, both passes can be laid within the course of one single weld cycle. Interruptions for readjustment, cleaning or other manual interventions are not necessary. The tempering effect of the continuous heat input supports the formation of a fine grain structure of the weld.

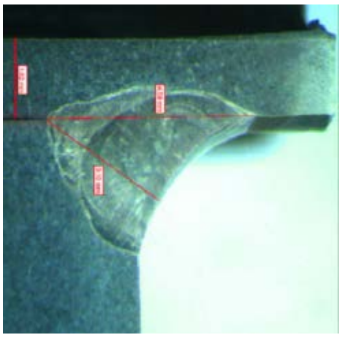

Fig. 6: Intact projecting tube end, connected to the tubesheet by a tight pass and a resistance weld with addition of filler metal

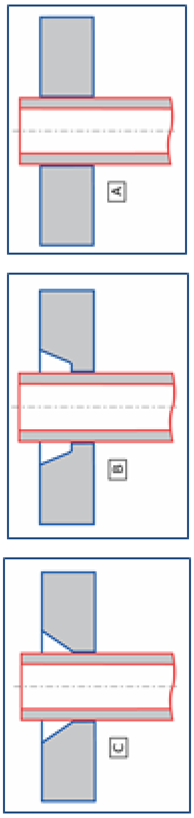

Fig. 7: Proven weld preparations of the tubesheet for protruding tubes

If projections of the tubes beyond the surface of the tubesheet interfere with the function of the heat exchanger, recessed tubes can be installed instead. In contrast to the previously described approach, where the ends of protruding tubes remain unaffected by the joint, the extremities of recessed tubes become an integrated part of the weld. Due to a tight pass without wire and a following resistance pass with filler metal, a perfectly smooth transition between tube and tubesheet is obtained. Recessed tubes qualify very well for orbital tube-to-tubesheet TIG welding. During the shortest possible time, a large number of identical joints can be produced in an economical way. For increased productivity, several welding heads can be used at the same time.

Fig. 8: Recessed tube with a perfectly smooth transition to the tubesheet

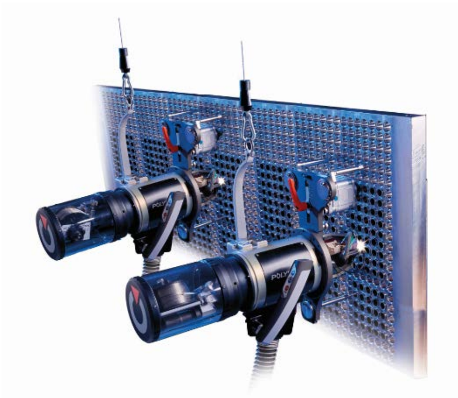

Fig. 9: Several orbital TIG welding heads on duty. A large number of recessed tubes have to be joined to the tubesheet

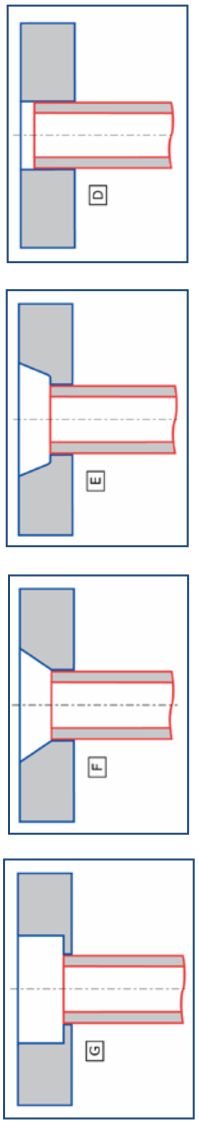

Fig. 10: Proven weld preparations of the tubesheet for recessed tubes

GAPLESS TUBE-TO-TUBESHEET WELDING

Welded joints at the front face of the tubesheet regularly entail an annular gap between tube and bore at the opposite side. Whenever corrosion inside this gap becomes a matter of concern, full penetration of the weld has to be achieved at the rear side of the tubesheet. Because of the close pitch of the tubes it is impossible to carry out welding operations from this side, hence gapless tube-to-tubesheet welding is synonymous with in-bore welding.

For gapless tube-to-tubesheet welding, a welding lance is mounted on the orbital head. The lance is introduced into the bore of the tubesheet. The tungsten electrode or, if the tube diameter is larger, the torch, must be positioned accurately over the joint to be welded. The course of the weld cycle must be entirely controlled by the welding equipment as the lack of visibility excludes any intervention from the operator.

The joints of small tubes have to be welded without filler wire, a rather delicate task because of the dissimilar heat distribution over the comparatively thick tubesheet and the thin wall of the tube. Adequate joint preparation by milling matching grooves into the rear side of the tubesheet can help to improve the results. In every case, precisely machined and positioned workpieces with extremely narrow tolerances are essential keys to success.

Larger tube diameters allow the use of a welding lance with a wire feeding device. The addition of filler metal limits the risk of overheating the tube wall. The formation of a coarse grain structure can be avoided by continuous welding of all layers without interruption.

Fig. 11: Longitudinal section of a tubesheet and tube. The orbital TIG welding head is positioned at the front side. The welding lance is introduced into the bore of the tubesheet and partially into the corresponding tube

Fig. 12: Gapless tube-to-tubesheet welding with filler wire

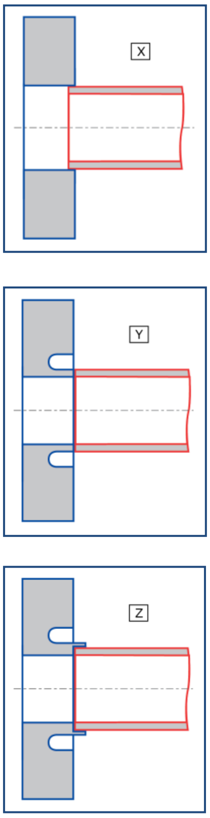

Fig. 13: Proven weld preparations of the tubesheet for gapless welding

DOUBLE PLATE HEADER BOX TUBE-TO-TUBESHEET WELDING

A challenging task in the field of mechanized welding is to realize tube-to-tubesheet welds in the closed header box of an air-cooled heat exchanger. For example, such devices are used to cool down natural gas, which comes from a well before it is passed to a compressor unit.

The rear wall of the header box serves as a tubesheet, where the tube ends are inserted into the designated bores. The orbital tube-to-tubesheet welding head is equipped with an adapter, which is passed through a corresponding hole in the front wall of the header box. With the centering mandrel introduced into the tube, the weld can be carried out. Usually, tubes in this type of heat exchanger are flush with the tubesheet, but there are also cases where recessed tubes must be connected.

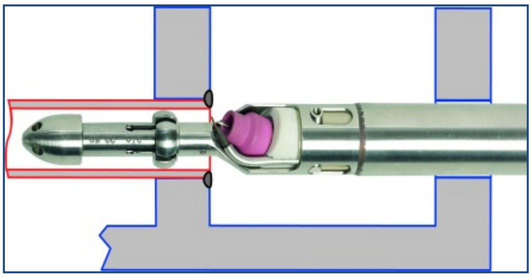

Fig. 14: Schematic representation of orbital welding with filler wire at the rear wall of a header box

Fig. 15: TIG welding head with wire feeding device positions to weld a flush tube at the rear wall of a header box

CONCLUSION

Heat exchangers have to cope with the distinct requirements of various fields of application, therefore they can differ considerably in size, material, design, type, etc. Excellent availability is regularly a concern, as they are always an important part of a processing unit or plant and in case of a fault the whole production has to be interrupted, resulting in significant financial losses. To guarantee the expected quality, the construction of heat exchangers should be carried out exclusively by experienced, approved manufacturers.

A top standard of the welded joints between tubes, elbows, return-bends and tubesheets contributes considerably to the reliability and length of the service life of each heat exchanger. Mechanized orbital TIG welding allows for consistent joint quality at the desired level. Indeed, the process is often recommended or stipulated in the specifications. Compared to manual welding, the realization of a joint does not depend on the individual skills of the welder, and an unlimited number of welding cycles can be repeated in exactly the same manner. Consequently, expensive and time consuming repair work can be reduced to a minimum or even eliminated.

Orbital welding heads for tube-to-tubesheet welding are developed with respect to the requirements of the particular targets which have to be attained: the operator is spared the tiresome business of winding up the cable bundle before each welding cycle by an in-built collector; welds can be carried out with or without the addition of filler metal; an AVC device allows multilayer welding without interruption for adjustment; increased productivity can be achieved if several welding heads with a self-holding clamping system are used at the same time; and oxygen-sensitive materials can be protected reliably against heat tint, to name just a few of the most important features.

Whenever heat exchangers have to be manufactured, orbital TIG welding is a reliable joining process and supports fast, efficient and economic assembling during prefabrication and on site.

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