Subsea production and injection network composed of several hundred kilometres of pipelines, injection lines and umbilicals.

Successful and safe offshore crude oil exploration and production depends for a large extent on the high quality welding and weld overlay cladding of tubes, pipes and manifolds. TIG/GTAW weld overlay cladding and welding for offshore production systems offers the guarantee of zero-defects combined with sustainable safe production.

By Jürgen Krüger for Polysoude

Tubes and pipes play a fundamental role in the field of offshore crude oil exploration and production activities. As structural parts of platforms, derricks and hoisting devices they provide high mechanical resistance and lasting stability to the equipment. Sets of drill pipes are needed to bore holes in the ocean bed. A particular vertical pipe, called a Marine Drilling Riser, encloses the rotating drill pipe and establishes the connection between the well and the platform above. Auxiliary lines externally attached on the marine riser facilitate the control and operation of the BOP (Blowout Preventer); its huge valves must be closed off if drilling into gas, oil or water containing geological formations which could cause a build-up of pressure inside the well.

The Subsea Wellhead Systems, commonly known as Christmas trees, include a choke for flow adjustment of well fluids, chemical injection ports, further valves, fittings and equipment for remote control and monitoring purposes. The production fluids of multiple wells in varying positions are extracted via a network of delivery lines, which are gathered together in a manifold centre. A flow line spans the distance between the manifold and the platform, and at the seafloor it is joined to a Steel Catenary Riser (SCR). This assembly of pipes allows the flow of fluids from the ground to the surface of the sea. Suspended almost vertically from the platform, the pipes follow the shape of a catenary line and arrive horizontally on the seabed.

Umbilical lines are duplex stainless steel tubes or bundles of electrical cables, hoses and conduits inside such a steel tube (Figure 1). Umbilicals supply electric and hydraulic power to maintain...
wellhead, Christmas tree and manifold control functions, and allow the injection of chemicals as fluidity improver or to suppress the formation of scale and hydrates in the production stream and allow communication or bidirectional data transfer between platforms or subsea installations.

**Oil Country Tubular Goods (OCTG)**

Hailing from the early days of prospecting, the expression Oil Country Tubular Goods (OCTG) includes casing and tubing manufactured for oil well drilling operations, line pipes, risers, umbilicals and other pipe and tube types essential for the production and transport of crude oil. Drill pipes and related drilling equipment are designed for frequent removal. ‘Making a round trip’, i.e. pulling out the drill string, unscrewing the threaded joints of drill pipe, and, after a repair or maintenance operation, reassembling and running it back in, is a common procedure in well drilling. Subsea production systems are engineered for on-going exploitation and are usually expected to offer a service life of over 30 years. Upgrades, modifications and repair require complex and expensive interventions. Operators often prefer to anticipate and invest in the best material, sophisticated technology and proven quality for their production equipment.

**Automated welding**

Time-savings and increased productivity at lower cost can be achieved if welding processes are carried out in conjunction with semi or fully automated equipment. Two joints of pipes, which are manufactured e.g. with a length of 12 m each, can be welded together to get 24 m joints. This is valid for line pipes but also for dissimilar drilling pipes and other workpieces. As these workpieces can be rotated around their longitudinal axis, economically joining by automated TIG/GTAW...
welding with addition of filler material in the form of Cold or Hot Wire can be realized. TIG welding often becomes necessary if high-strength steel pipes have to be joined or the corrosion-resistance of clad pipes must not be altered.

Automated welding, commonly called GMAW or, if necessary, TIG/GTAW is accomplished by welding carriages called bugs or welding heads. Bugs and welding heads carry the welding tools, i.e. torches and accessories like slides for oscillation and arc voltage control, wire spools etc. and trail the cables and hoses for supply and data transfer. Toothed rails or bands are fixed besides the welding area to guide the bugs or welding heads when travelling around the tubes. Based on the enhanced repeatability of the process, reliable results are achieved and reduce inspection efforts. Recent automated TIG/GTAW welding installations are designed to meet specifications for 100% defect-free welds, i.e. the occurrence of pores of any size or the smallest lack of fusion provokes rejection.

As onshore welding entails significantly lower expenses than welding on a barge, as many as joining activities as possible are carried out onshore. Whenever feasible, pipes are joined together in a shop and concurrently coiled on a big spool which is often directly mounted on a docked barge. Common diameters of the coiled pipe range from 2” to 12” with a total length of up to 80 km. The offshore lay method by unwinding the pipe from the spool on the barge is known as “Reel Lay”, the important pipe length which can be laid without interruption ensures high efficiency and a short lay time. However, Reel Lay procedures induce important mechanical loads on the coil and require outstanding quality levels of pipes and welds.

**Corrosion resistant alloys (CRA)**

A line pipe, i.e. pipes produced to be joined together to a pipeline, is usually made of high strength low alloy steel (HSLA). Another example is all kinds of forged, casted or solid manifolds. In many applications this type of steel does not meet the requirements of sufficient resistance against corrosion and abrasion which are caused by the chemical composition of well fluids and mechanical impacts of rock particles from the well. A number of alloys with a long record of successful application are known to provide satisfactory protection against crude oil and accompanying constituents. To achieve lasting wear protection, the selection of a matching CRA must rely on a precise analysis of the particular corrosion conditions. If the flow line is intended for ‘sour service’, chloride ions, hydrogen sulphides and carbon dioxide are the most important agents for increased corrosion. Also temperature, pressure and flow velocity of the production stream have to be taken into account. In many cases it turns out that a member of the nickel base alloy family would be the best choice. To give an idea of typical wear, an average loss of wall thickness at the inside of a properly designed CRA flow line during a service life of 30 years is estimated to be 0.15 mm.

**CRA lined or clad steel pipe**

Generally, two types of line pipes are distinguished: the pipe is referred to as lined if the outer host and the inner CRA segment are joined together by a mechanical bond. In case of a clad pipe,
the connection between host and CRA is established by a metallurgical bond. If a pipe with a smaller diameter, a liner, is introduced into another one with a slightly larger diameter and expanded afterwards, the residual stress causes mechanical bonding. This is the principle of manufacturing lined pipes. Weld overlay cladding is also widely used to produce clad line pipes. A standard steel pipe of matching material and dimensions is used as substrate, the CRA layer at the inside is deposited by automated welding operations.

**Improving characteristics of CRA lined pipe**

Joining of a CRA liner with a sleeve of carbon-manganese steel by hydraulic expansion is a classic manufacturing method for CRA lined steel pipes. Modern manufacturing methods allowed a considerable increase of the application properties of mechanically bonded CRA pipes. During production, the liner ends are not flush with the outer pipe, the retract difference of about 100 mm at each extremity is covered by a high-quality TIG weld overlay weld on the inside. Thus, the mechanical properties of the zone where the pipes are finally to be joined together are virtually the same as that of clad pipes.

**Unique features of CRA clad pipes**

If clad plates of the required material combination are purchased as semi-finished product, opposite edges must be prepared to form the future welding gap. Rolling operations are used to get the plate into a cylindrical shape; the remaining gap is closed by longitudinal welding. Depending on the pipe dimensions SAW, GMAW including CMT or, if 100% defect-free welds are required, TIG/GTAW/Plasma welding from the inside and/or from the outside are applied. Improved corrosion resistance can be achieved by a final TIG overlay weld which covers the joining zone of the CRA layer. Applicable on standard steel pipes, internal CRA cladding can advantageously be carried out by overlay welding. The horizontally positioned pipes are rotated around their longitudinal axis; the torches with the attached wire feeding devices are mounted at the end of a welding lance and guided along the inner wall. A bi-cathode TIG/GTAW cladding process recently developed by Polysoude SAS France named TIG™ stands for a smooth surface of the corrosion-resistant layer, low dilution rates between deposit and substrate, reliable results and improved productivity. Based on two separately with current supplied tungsten electrodes, situated next to each other in one welding torch, the resulting combined arc offers unique features concerning high deposition rates without any loss in quality.

**Conclusion**

Successful and safe offshore crude oil exploration and production depends for a large extent on the high quality welding and weld overlay cladding of tubes, pipes and manifolds. Different welding and weld overlay processes can be applied during the production of tubular goods. Successful efforts have been made to increase the productivity of automated TIG/GTAW welding and circumferential welds of unattended quality can be realised at affordable costs. The TIG™ technology recently developed by Polysoude SAS France allows the production of fatigue and load resistant components by inside cladding of steel pipes with corrosion resistant alloys. Whenever weld quality has the highest priority, the advantageous application of automated TIG/GTAW processes and its variants should be taken into account.