Remotely Controlled Hyperbaric Welding of Subsea Pipelines

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Abstract

The hyperbaric welding technology and system for tie-in and contingency repair welding of subsea pipelines, as used in The North Sea by Hydro and Statoil since the 1980s is presented. It is based on TIG U-butt welding remotely controlled from a surface vessel, with the assistance of divers for installation set-up work inside the welding habitat on the sea bed. Statoil, with this technology, has been selected by Nord Stream AG as supplier of the hyperbaric welding services on the new Nord Stream pipeline in the Baltic Sea. To cover the repair contingency for pipelines at sea depths beyond the depth limit where divers can operate, Statoil is now developing a fully remote controlled repair welding system. The MIG welding process is selected based on better performance under higher pressure, and it is found to be less sensitive for variations in the ambient pressure. This new system, based on MIG fillet welding of an outer sleeve connecting the pipe ends, is also briefly described. Finally, the results of initial experiments on MIG butt welding against copper backing, is presented.

1 Introduction

Tie-ins and repair of pipelines at the seabed by dry hyperbaric manual welding has been performed and continuous developed since the late 1960s. SINTEF has carried out research and development in this area since the 1970-ties /1/. Hydro was developing the Oseberg field in the North Sea, and was a driving force in the research and development of hyperbaric welding of pipelines in Norway. Through a German – Norwegian collaboration, an advanced station for mechanized hyperbaric welding of pipes, SIMWELD, was installed at SINTEF in 1983. Hydro decided that tie-ins and repair of pipelines should be made using remotely controlled mechanized TIG welding. This decision launched a program for research and development of the technology required to go offshore and perform hyperbaric tie-in welding operations at the Oseberg field in 1988. To share the development and operating costs, the Pipeline Repair System (PRS) pool, was established and Statoil was appointed to manage PRS. The PRS base was established in Haugesund, at the western coast of Norway, close to the North Sea. SINTEF Hyperbaric Welding Laboratory has been a partner in the PRS collaboration since the beginning, and is still the main supplier of hyperbaric TIG welding technology and qualified procedures to PRS/Statoil. To day, about 13000 km subsea pipelines is signed as members in the PRS Pool operated by Statoil. Nord Stream AG, with the new gas pipeline under construction from Russia to Germany, has also become a member in the PRS Pool to cover both the repair contingency in future and the hyperbaric welded midline tie-ins during the construction phase.

2 The PRS hyperbaric TIG welding technology and performance

The PRS hyperbaric TIG welding technology is based on mechanized cold wire TIG welding, controlled from a surface diving vessel. The welding is performed inside a habitat pressurized to the actual pressure with helium added about 0.5 bar oxygen, which also is breathing gas for two divers assisting during the operation. Beveling is performed wet at the seabed or inside the habitat by the divers. Manipulating and alignment of the pipes are done by H-frames controlled from the surface. The final alignment of the pipe ends is done after installation of the habitat using clamps integrated in the habitat. Welding bladders or similar in each pipe end enable evacuation of the water from the welding area inside the pipe. In Figure 1 an illustration of the PRS spread at the sea bed is shown. Figure 2 shows the welding habitat during installation for welding at the Langeled pipeline.

Figure 1 Illustration of the PRS spread in operation at the seabed.

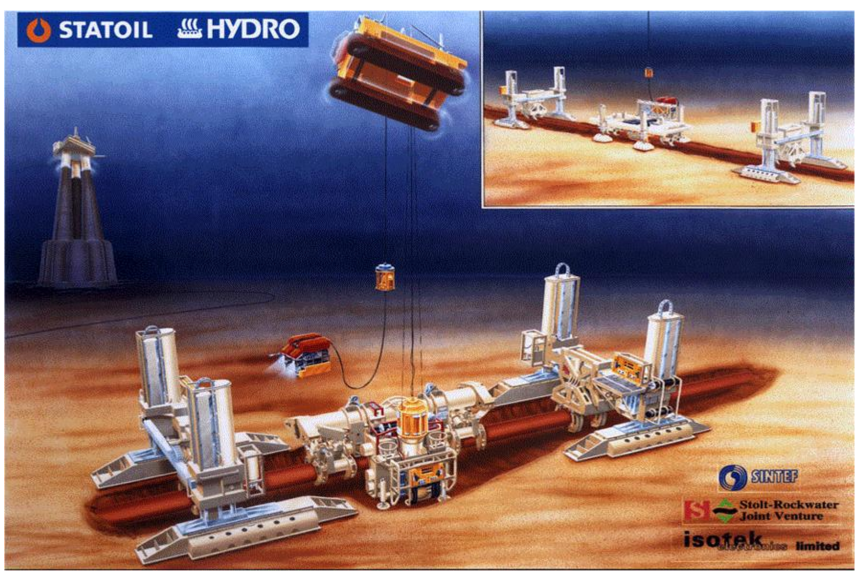
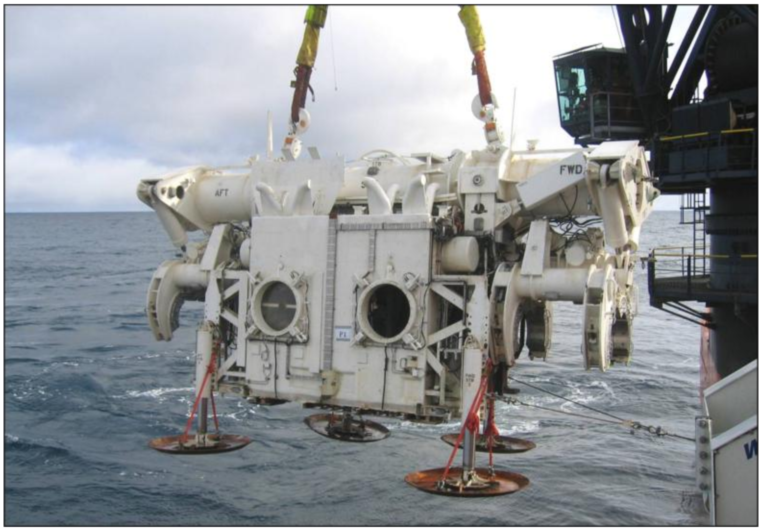


Figure 2 PRS welding habitat during installation for welding at the Langeled pipeline.



In the control cabin at the surface vessel, a team comprising of a welding operator and a welding engineer control the welding. The process is monitored through cameras giving a front and rear view of the welding arc and weld pool. The preprogrammed welding parameters can within qualified tolerance limits be adjusted during welding. A welding team during tie-in welding at the Langeled pipeline, is shown in Figure 3. After completion of the weld, the quality is tested by automatic ultrasonic testing.

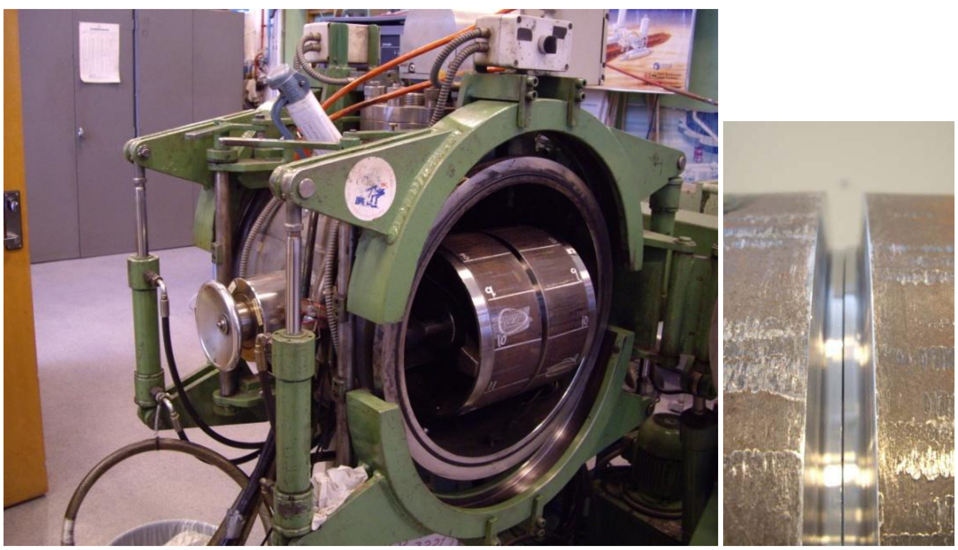
Figure 3 Control of welding at the seabed from the control cabin at the surface vessel during the Langeled operation.

3 Development and qualification of welding procedures

The development and qualification of the welding procedures are performed by the SINTEF Hyperbaric Welding Laboratory. The welding is executed in a chamber of volume 182 liters, designed for 100 bar, on pipe test coupons with maximum length 300 mm and diameter 330 mm cold reformed of the actual pipeline steel material. The welding chamber in open position with a test coupon, is shown in Figure 4. The chamber is pressurized to the actual pressure with the same gas mixture as used in the welding habitat offshore. To use this small volume chamber and test coupons is more cost-effective compared to full scale welding. It is proved through a great number of successful projects that the welding parameters for procedure developed in the small chamber without any corrections can be used in field welding.

The welding head is similar to the PRS welding head in all essential mechanical functions, and the welding control system and software interface to the welding operator are also identical. Therefore, this system simulator is also used for training and qualification of the welding operators and engineers performing the welding offshore.

Figure 4 Pressure chamber for hyperbaric TIG welding of test coupons for development and qualification of welding procedures for subsea pipelines. The welding groove is shown to the right.



The welding groove is of U-shape, as shown in Figure 4. The nominal root face is 2.7 mm and the groove wall angle is 7^{o}. The shielding gas is a mixture of 70 % helium and 30 % argon. The most critical phase of the welding is the performance of the root pass, where variations in root gaps and high/lows have to be coped with. It is a balance between burn-through and incomplete penetration and requires exact tuning of the welding parameters. The maximum allowable root gap and high/low (misalignment) are normally set to 1.0 mm and 1.5 mm, respectively. One procedure is valid for an ambient pressure range of +/- 1 bar, corresponding to +/- 10 msw (meters of sea water).

4 The Nord Stream pipeline project.

Nord Stream AG selected Statoil/PRS as supplier of the hyperbaric welding services on the two parallel 48 inch gas pipelines under construction from Vyborg in Russia to Greifswald in Germany. The pipeline route is shown in Figure 5. Two tie-in welds on each pipeline are to be performed at 76 and 110 msw. The welding procedures are developed and qualified at SINTEF and the tie-ins on the first pipeline are planned to be performed in spring/summer this year (2011) and on the second pipeline next summer. A macro section of a qualification weld on pipe with wall thickness 34.6 mm, for the 76 msw tie-in weld, is shown in Figure 6.

Figure 5 The Nord Stream pipeline route (green) with the hyperbaric tie-in weld locations (red).

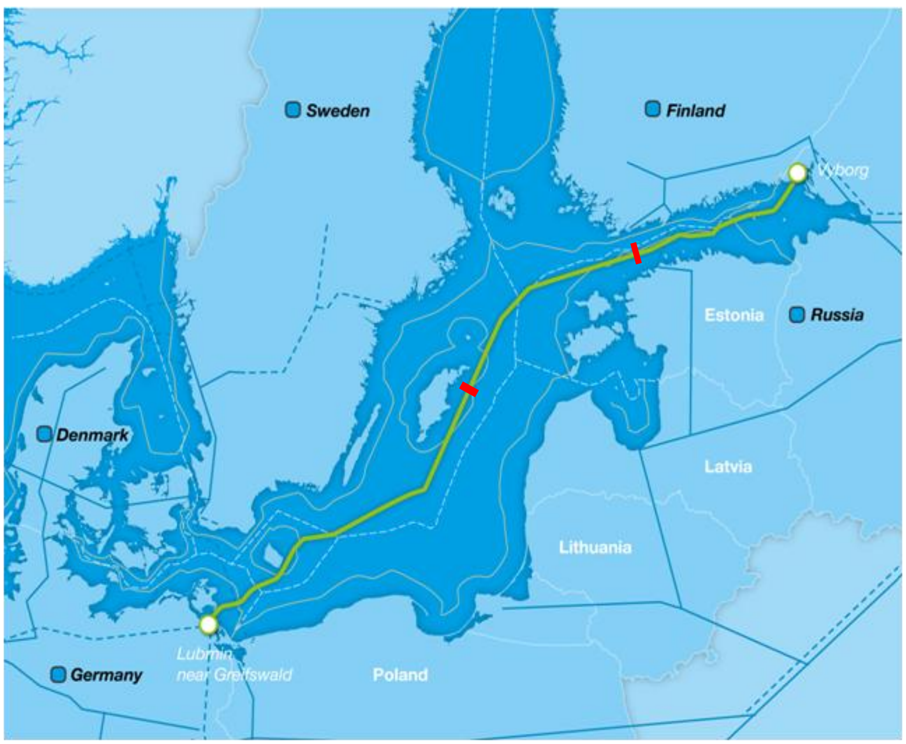
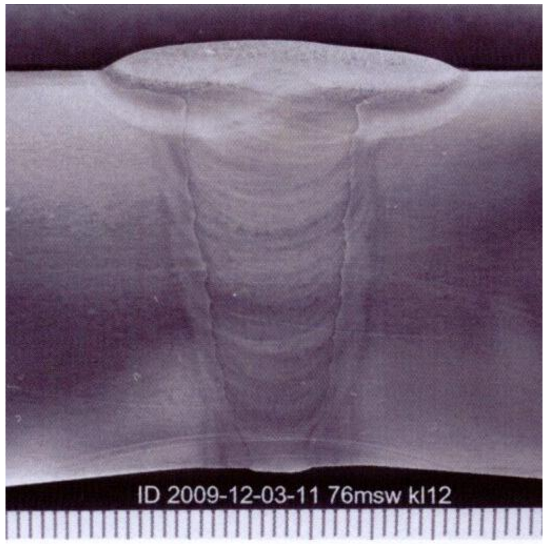


Figure 6 Macro cross section of a qualification weld on pipe with wall thickness 34.6 mm, for the 76 msw tie-in weld.



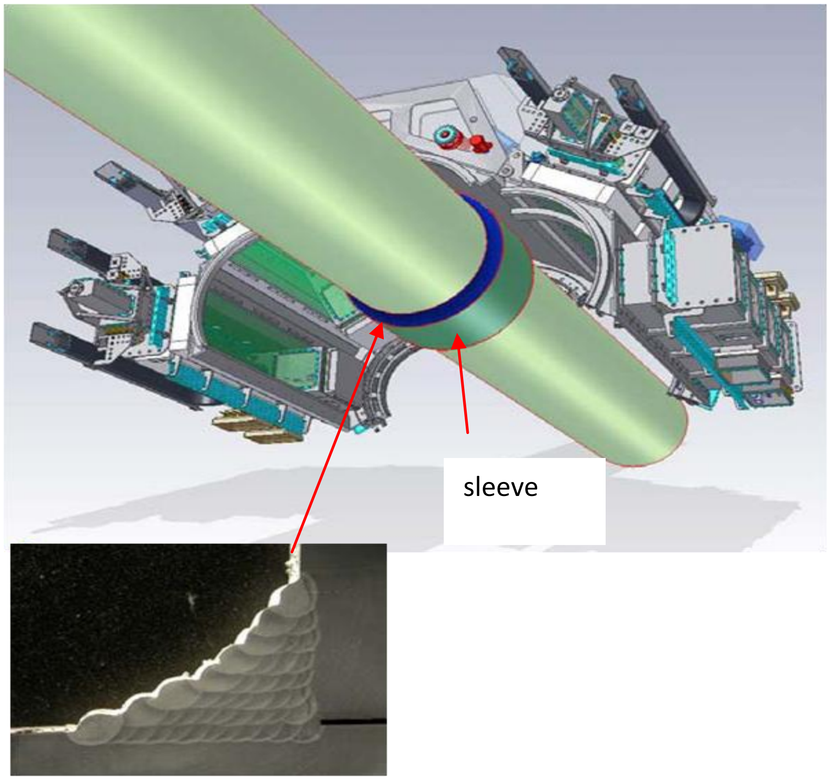
Nord Stream AG has also entered the PRS pool and Statoil/PRS will be responsible for possible repair welding in the future. As part of the contingency, three additional welding procedures on different pipes material origins and selected depths are developed and qualified, to reduce the amount of work required for qualification of a welding procedure for an actual weld repair.

5 Hyperbaric welding at deeper waters without diver assistance

5.1 The welded sleeve concept

Due to safety reasons, the seawater depth limitation for use of divers in the North Sea is set to 180 msw. Therefore, to cover the required contingency for pipeline repair at deeper waters, Statoil is developing a fully remote controlled weld repair system designed for 1000 msw, referred to as Remote PRS /2/. With this system, the pipe ends are connected with an outer sleeve with length 600 mm, which is fillet welded to the pipes with the MIG (Metal Inert Gas) process. A principle sketch of the welded sleeve concept, is shown in Figure 7.

Figure 7 The remotely controlled welded sleeve concept.



The fillet weld is designed to provide a smooth transition between the thick wall sleeve and the relative thin wall pipe such to avoid high stress concentration in the toe of the fillet weld. Since the root area of a fillet weld always will be suspect of a crack-like root defect, the weld design is considering such a root defect and crack growth over a 50 years lifetime. All the design and full scale testing of the sleeve joint is completed. The MIG hyperbaric welding procedures are qualified using simulated condition in a pressure chamber. The prototype welding system is built and recently deep water tested at 370 and 940 msw in Sognefjorden, Norway, see Figure 8. There are still more development work to be completed before the system is proven and qualified for offshore operations.

Figure 8 Remote PRS in Deep Water Test down to 940 msw in Sognefjorden in Norway.

5.2 MIG butt welding

Based on extensive research and development on deep water hyperbaric welding down to 2500 msw, performed by Richardson et al. at Cranfield University /3/, MIG was selected as the most suitable welding process for future deep water welding operations. The MIG process proved to be more insensitive to the ambient pressure compared to TIG, and the welding parameters can be kept constant over a wider depth range.

However, due to its process characteristics, one-sided full penetration root pass welding, as used in the PRS diver assisted TIG welding, was found to be too challenging with MIG, i.e. the robustness was too low. Since robustness is of crucial importance in deep water operations, the conventional butt welding was replaced with the sleeve solution, where the welding operation itself is more robust without any risk of burn-through.

Comparing a sleeve joint, consisting of two large fillet welds, with a butt joint, it is obvious that the butt joint is advantageous both with respect to functionality and welding time. The net welding time (arc time) for a typical pipeline joint, for instance on the 42 inch Langeled pipeline, can be reduced to about 1/10 by changing to butt weld. Therefore, there is a motivation for developing technology for hyperbaric MIG butt welding of pipelines, and in the future, replace the sleeve method.

This work has started as part of a 5 year (2009-2013) research program, DEEPIT, initiated and managed by SINTEF, and sponsored by The Research council in Norway, Statoil, Gassco, Technip and EFD Induction. After initial testing of different root welding techniques with and without internal weld backing, it is concluded that the best way of achieving acceptable robustness, is to utilize some kind of internal weld pool support. Then the challenge is to achieve acceptable root pass quality over the range of root gaps and high/lows (misalignment of pipe ends) which have to be coped with. These are set to maximum 2 mm for both, which are larger groove deviations than normally are accepted in 1 bar pipeline welding with internal backing.

So far, welding trials in a U-groove with 10 mm x 30 mm copper bar backing with different groove deviations and welding positions are performed at 10 and 25 barg, with promising results. In Figure 9 the weld macro cross sections of root passes welded in the flat position (corresponding to 12 o'clock position on pipe) at 10 barg, with different combinations of root gaps and high/lows, are shown.

Figure 9 Macro cross section of MIG root passes welded against copper backing. Left: Gap 0 mm. Middle: Gap 2 mm. Rigth: Gap 2 mm, High/low 2 mm.

In addition to achieve acceptable robustness regarding penetration, the surface quality of the weld bead is critical. The main challenge seems to be to achieve the required smooth transition between the root weld bead and the base material. A typical root weld bead from the initial testing, seen from the backing side, is shown in Figure 10. Irregularities along the weld toe, in addition to some copper adhered to the weld, shows that further development is required.

Figure 10 Typical MIG root weld with backing seen from the backside (backing removed).

Summary

Diver-assisted remotely controlled TIG butt welding of pipelines has for many years proved to be a reliable and cost effective method both for tie-ins and repair. To cover the depth-range beyond the diving limit, a fully remote controlled system for repair welding of pipelines, is under development. This new concept is based on MIG fillet welding of an outer sleeve, and is well underway to be qualified for pipeline operations offshore down to 1000 msw. The Last years research and development of the MIG welding process shows a great potential to apply this welding process down to water depths of 2500 meters. It is also started a development work on MIG butt welding of subsea pipelines.

References

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