Wet and Hyperbaric Underwater Welding

PUBLISHABLE SUMMARY

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Background

Underwater welding is used in the repair of offshore structures and pipelines, ships, submarines and nuclear reactors. The difficulty of achieving high integrity repairs underwater has led to on-going efforts to improve the available technology, with varying approaches in the different industry sectors. Some critical issues associated with underwater repairs are:

- Depth limitations.
- The risk of hydrogen-assisted cracking in steels with high carbon equivalent.
- The risk of potential welding defects such as porosity, lack of fusion and cracking.
- The potential for inadequate weld metal mechanical properties (notch toughness and ductility) and weld joint integrity, including fatigue life.

TWI has carried out a work programme on underwater welding, as a Joint Industry Project, in which several wet and dry hyperbaric underwater welding processes were investigated/developed.

Objectives

Underwater wet welding

- Identified and defined technological boundaries or limitations for wet underwater welding through a 'state-of-art' review, including experience with the NEPSYS® system and Underwater Laser Beam Welding (ULBW).
- Evaluated underwater wet welds made using rutile electrodes and a controlled deposition technique, as well as using oxyrutile electrodes, against the requirements of AWS D3.6.

Dry hyperbaric welding

- Compared the traditional and state-of-the-art Gas Metal Arc Welding (GMAW) processes for heat input and spatter generation at different metal deposition rates under optimised conditions;
- Explored the Cold metal Transfer (CMT®) and laser assisted CMT® processes to evaluate changes in cooling rate, metallurgical phases formation and optimisation of the process;
- Studied the effect of moisture on hydrogen content when welding with the CMT® and laser assisted CMT® processes.
- Applied coldArc® and forceArc® power source in a hyperbaric chamber;

Benefits

The 'state-of-art' review is an essential aid in establishing the knowledge and experience available to contractors considering wet underwater welding. The assessment of underwater wet welding procedures showed the potential of oxyrutile electrodes for the repair primary and secondary members of offshore platforms. The development work on dry hyperbaric welding represented the first step to allow Sponsors to apply variations of standard arc welding processes to dry hyperbaric repairs and modifications of pipelines, such as tie-in and hot tap welding, for cost effective linking of new oil fields to existing infrastructure

Participants

The Sponsor Group comprised:

- BP
- Petrobras

Scope of Work

Underwater Wet Welding

Previous work carried out by TWI (available to the JIP sponsors) showed that the underwater wet welding techniques listed below may be capable of achieving Class A to AWS D3.6. The work programme for underwater wet welding includes Options 1 and 2 below, which were considered the most promising.

1. Controlled bead deposition technique to further reduce HAZ hardness, particularly in the weld cap, and HAZ hydrogen cracking.
2. Buttering with oxidising electrodes to eliminate the minor hydrogen cracking observed and reduce cap HAZ hardness.

Option 1 evaluated different sets of welding parameters and bead positioning to obtain effective tempering of the HAZ, hence reducing the hardness below the 325HV10 limit required by AWS D3.6 for class A welds. These tests showed that acceptable hardness values can be achieved in butt welds, however, the results are not sufficiently reliable to provide the necessary confidence to transfer the developed welding procedures onto field applications.

Option 2 was investigate using oxyrutile WETWELD 70 electrodes, recently developed by ESAB. These electrodes represent a compromise between the traditionally rutile-based electrodes and iron oxide-based (oxidizing) electrodes. The former have good arc stability and other running characteristics as well as tensile strength and toughness, whereas the latter have low diffusible hydrogen content (Hdif) and poor operability, hence reduce the risk of hydrogen cracking. The oxyrutile electrodes were applied to prepare complete welds, as well as to deposit a buttering layer, followed by fill+capping runs made with rutile electrodes.

Dry Hyperbaric Welding

The work programme for dry hyperbaric welding is divided into four work packages, as follows:

1. Study of Thermal Cycle and Metallurgical Phase Formation with Varying Chamber Pressure in the Present Hyperbaric GMAW Process
2. Process Characteristics of Traditional and Controlled Dip Transfer GMAW at One Atmosphere
3. Laser-Assisted Cold Metal Transfer (CMT®) Trials at One Atmosphere
4. Preliminary Investigation of an Advanced GMAW Power Source (coldArc® and forceArc® processes) under Hyperbaric Condition

Deliverables

- A paper based state-of-art review of underwater wet welding for the repair of offshore structures, including Nepsys® and ULBW.
- A report including results of previous work carried out by TWI on underwater wet welding using the MMA process.
- A report on the experimental work described above.
- A report on the assessment of laser-assisted Cold Metal Transfer (CMT®) welding under Hyperbaric Condition
- A report on the Preliminary Investigation of an Advanced GMAW Power Source (coldArc® and forceArc® processes) under Hyperbaric Condition

Project Budget

The project had a duration of three years and a budget of £200,000. It was funded by two Sponsors each making a contribution of £100,000. The fee for additional companies buying-back into the project results is £100,000.

Further Information

For further information on how a Joint Industry Project (also known as a Group Sponsored Project) runs please visit:

www.twi-global.com/joint-industry-projects

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