Oil & Gas Strategic Technology Committee: Research for 2018

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Introduction

The Oil & Gas Strategic Technology Committee (STC) was established by EWI in 2013. It provides a platform for oil & gas operating companies, steel suppliers, welding equipment and consumable manufacturers, engineering and construction companies, and other stakeholders to collaborate in identifying gaps and needs in materials joining and allied technologies relevant to the energy industry, and it develops technology development programs to address those needs. The objective of these programs is to enhance the safety, integrity and reliability of critical infrastructure used in the exploration, production and delivery of energy products to markets worldwide. The STC is organized and coordinated by EWI with participants from North America, Europe and Asia.

Major projects completed or in-process since 2013 include:

- Characterization of weld properties for arctic service
- Assessment of potential welding approaches for casing materials
- Integrity aspects for unintended subsea pipeline/ flowline blowdowns
- Improved fracture toughness correlations for advanced high-strength steels and forgings
- Weldability of grade 70 and 80 plate steels for offshore structures
- Assessment of Inconel girth-weld strength mismatch effects
- Engineering critical assessment (ECA) guidance for subsea and offshore systems
- Comparison of nondestructive evaluation (NDE) methods for dissimilar metal welds (DMWs)

The results of these projects have provided the industry with 1) valuable insight into optimized welding approaches and selection of materials to ensure adequate in-service performance, 2) updated guidance on performing engineering integrity assessments for offshore infrastructure, and 3) guidance on improved NDE methods. This paper outlines recent work completed as well as work planned through 2018.

Recent Work on The Effect of Constraint on Brittle Fracture of Weld Metal

EWI recently carried out a test program sponsored by the STC on the effect of constraint on brittle fracture. This program began in 2017 and continues through 2018. Resistance to brittle fracture for steel pipes is important to prevent the rapid growth of cracks from imperfections that would compromise safety and integrity.

The material used for this work was API 5L Grade X70 pipe with 1.4-inch wall thickness that had been tested for its own brittle fracture resistance in 2016. The pipe being tacked is shown in Figure 1. The pulsed gas metal arc welds (GMAW-P) using ER80S-D2 filler metal were designed to be similar to tie-in welds for offshore construction with an open 60-degree V groove, as shown in Figure 2.

The testing plan was chosen to examine brittle fracture resistance at temperatures slightly below the lowest design temperatures that could be used for the welds. Testing was completed at -70°C and -50°C for both single-edge notch bending (SENB) and single-edge notch tension (SENT) crack tip opening displacement (CTOD) tests. The bending tests had greater constraint,

Figure 1. Inserting the tack welds at the root.

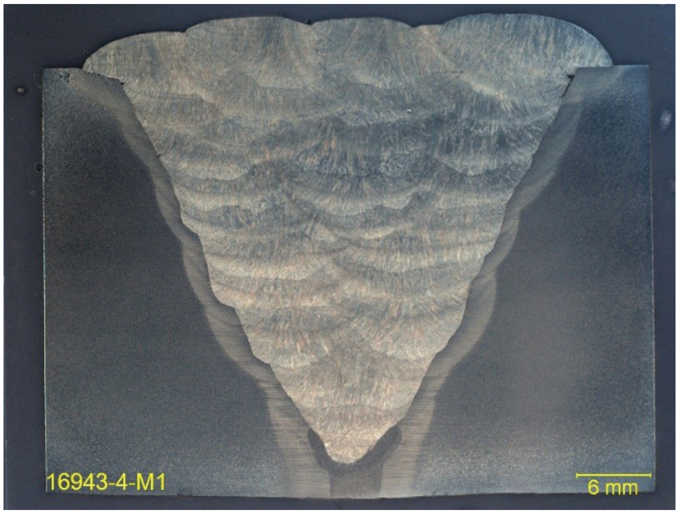

Figure 2. Cross-section of a girth weld.

while the tension tests had lower constraint similar to the constraint expected for most loading conditions for offshore pipelines.

The testing results showed that at both these temperatures the shift to higher CTOD at lower constraint was reliable over the 24 tests, even accounting for the variability expected when testing weld metal from multi-pass welds (see Table 1).

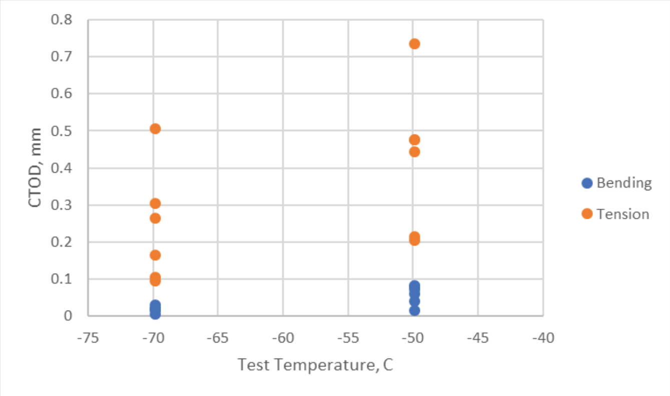

Table 1. CTOD results versus testing temperature.

Projects Planned for 2018

The 2018 STC technical program includes the following projects:

Assessing NDE Methods for Dissimilar Metal Welds

This project will evaluate radiography (RT), phased-array ultrasonic testing (PAUT) and the Full Matrix Capture-Total Focusing Method (FMC-TFM) in their ability to detect, characterize and size a wide variety of flaws in a series of seeded dissimilar metal weld (DMW) defect coupons consisting of an Inconel girth weld in clad X65 pipe.

Work will include a side-by-side comparison of RT and PAUT in detecting, characterizing and sizing up to 30 flaws in each of the three seeded defect weld coupons. Commercial RT vendors will perform a blind study of each defect coupon with results compared to existing PAUT data. Following RT and PAUT comparisons, the same defect weld coupons will be inspected by EWI using an FMC-TFM system consisting of 256 element arrays in a blind study. The results will be compared with RT and conventional AUT data to assess the feasibility of FMC/TFM inspections on Inconel girth welds.

The outcome this project will provide guidance on the reliability of these NDE methods for inspecting DMWs.

Managing Brittle Fracture in Subsea Hardware, Flowlines and Risers (Phase 2)

Subsea equipment in the form of steel forgings and pipe is often used in conditions where the lowest design temperature (LDT) is lower than the lowest anticipated steady-state temperature (LAST), due to transients such as blowdown. Blowdown events, when pressurized gas is evacuated into low pressure regions, can happen multiple times during the operational life of a subsea pipeline system. When the steel is qualified with toughness tests at LAST, the safety factor against brittle fracture will be reduced at the LDT, all other things being equal, due to the ductile to brittle transition of steels.

This project is a continuation of work begun in 2017. The objectives of Phase 2 of this project are to perform representative fracture testing of the base metal and welds in X70 line pipe to examine changes in measured toughness values and behavior due to constraint using SENB and SENT geometries. EWI will use a section of 48-inch diameter 0.985-inch thick wall X70 pipe to fabricate two girth welds. Baseline characterization will be performed, such as chemical composition, tensile properties, Charpy transition curves, and microstructure assessment of the weld region and the fusion line notch position. A transition curve will also be determined for CTOD toughness using single-edge notched bend (SENB) specimens for both the weld centerline and the fusion line position. The toughness transition behavior will be compared with the normal expectation from the master curve. In addition, finite element modeling will be performed to understand the development of plasticity around the crack tip and how that modifies the constraint both for bending and tension CTOD at temperatures consistent with blowdown events.

The outcome of the project will provide guidance on the best approach for characterizing material properties and qualifying materials to ensure integrity under unexpected blowdown scenarios for subsea equipment.

Factors Influencing Copper Contamination of Girth Welds

Copper contamination in girth welds is a concern when welding using copper-backed internal lineup clamps. Contamination can originate from the copper blocks on the lineup clamp or from the welding torch contact tip. Copper may enter the weld pool or be deposited along the side wall due to the contact tip impinging on the side wall or a short circuit or arc blow occurring that melts a portion of the tip leading to liquid copper falling into the weld pool. Copper from the lineup clamp may originate from gulling and/or oxidation of the cooper blocks after some period of use.

While the damaging effects of copper contamination are well understood and field practices to limit its occurrence have been implemented for many years, the specific conditions under which copper may enter a girth weld and create a cracking or hardness issue are not fully understood. The amount of copper and/or its location within a weld joint are not well understood in terms of sensitivity to cracking. Furthermore, correlations between the surface condition of used copper blocks on the lineup clamp and potential for copper contamination do not exist.

This project will identify conditions that give rise to contamination and surface hardness effects resulting from copper. This may aid in developing guidance for field inspection personnel on conditions requiring replacement of used copper blocks. In addition, feasibility studies will be carried out to identify potential automated methods for detecting the presence of copper in the weld pool. Development of automated detection tools, ideally for real time in-process monitoring, offers the potential to consistently identify contamination issues and enable proper field corrective actions to minimize sour service concerns with respect to copper contamination.

Weldability of Low Manganese Line Pipe Steel for Sour Service

In recent years, a new ultra-low manganese X60 line pipe steel has been developed specifically for sour service conditions but has not yet been commercially deployed in a pipeline project. This may be due to the cost associated with the microalloying of the steel, which could increase costs over conventional steels. However, tests performed on the parent pipe from demonstration heats indicate that the pipe can be exposed to severe environments such as a pH of 1.0 and not suffer damage. This opens to the possibility of the low manganese steel being considered as an alternative to clad materials for some applications.

The manganese content of the new steel is about 1/3 or less of conventional X60 line pipe steels. The impetus for this low manganese steel was to improve the ability of older plate steel manufacturing facilities using early generation continuous-casting machines or facilities using high-casting speeds with thin slab casters to enhance production of sour resistant steels. The lower manganese reduces the formation of elongated manganese-sulfide stringers while reducing sensitivity to residual sulfur and reducing reliance on calcium inclusion shape control. To address potential yield strength and hardenability concerns, additions of chromium and niobium are made to control transformation temperatures and austenite formation.

While there has been considerable evaluation of the parent line pipe steel, independent evaluation of the heat affected zone and girth and seam weld performance for sour service has not been done. Objectives of the project are to independently characterize the strength, toughness, hardness and SSC/HIC resistance of the heat affected zones in low manganese X60 – X65 line pipe steels. The deliverables of this project will provide independent mechanical property data and valuable inputs for pipeline design and welding procedure specification for future pipeline projects using this new sour resistant steel.

Development of ECA Guidelines for Subsea and Offshore Systems

Engineering critical assessments (ECAs) are performed to establish a technical basis for setting weld nondestructive examination (NDE) requirements of specific subsea and offshore components. Such components are designed for substantial installation and/or operational loadings that may extend imperfections or pre-existing weld flaws by, for example, fatigue or tearing, and that extension should be addressed in NDE requirements. Such components are commonly referred to as fatigue or fracture critical components, and typical examples are associated with floating production systems: SCR risers, stress joints, and TLP tendons.

Input needed for ECAs are derived from multiple sources, including data for material properties, fabrication methods, installation approaches and operational considerations. For typical offshore projects, necessary input frequently come from multiple organizations, contractors or providers, so clear guidance of what data is needed and how it is to be used should improve ECA execution and reliability. This input is provided by numerous personnel, many of whom have limited knowledge of what an ECA is or how the input data is used. This can hamper the collection of the most relevant input data or result in incomplete data provided to the ECA specialist.

This project will provide a guidance document that will outline the various approaches for performing an ECA, describe the nature and type of data required and the outputs that the ECA can produce, and illustrate how those results are used for inspection purposes and to assure safe operation of critical equipment. The document will not present detailed ECA methodologies but is intended to assist personnel responsible for providing inputs to ECAs in understanding what data is needed.

***Bill Mohr**, Principal Engineer for Structural Integrity, is responsible for initiating, conducting, and reporting research and contract work. He is an expert in the areas of fitness-for-service assessment, design, and fatigue of welded structures. Bill has authored more than 50 technical papers in addition to numerous reports of sponsored projects, failure analyses, and fitness-for-service assessments.*

***Tom McGaughy,** Senior Technical Advisor for Structural Integrity and Materials Evaluation, has specialized expertise in fracture mechanics and materials technologies. He is involved in developing client relationships and technology development strategies with the oil, gas, and petrochemical industries, and is Director of the EWI Strategic Technology Committee (STC) for Oil & Gas.*