Fracture Toughness Testing of Steel Welds Subject to Sour Service

PUBLISHABLE SUMMARY

NA00533

Background

Fracture toughness is a critical input parameter for Engineering Critical Assessment (ECA) of planar (crack-like) flaws. The presence of hydrogen in steel can lead to a significant reduction in fracture toughness due to its embrittling effects; such a reduction can have a significant influence on the flaw tolerance of hydrogen-containing components. This may in some cases result in maximum tolerable flaw sizes being smaller than would be accepted according to workmanship criteria

Standards such as BS 7448, BS EN ISO 15653, and ASTM E1820 provide detailed guidance on performing fracture toughness tests on non-charged materials in air and inert environments. However, at present there are no accepted or well established procedures for determining the fracture toughness of steel components relevant for assessing flaws exposed directly or indirectly to a hydrogen charging source.

This Joint Industry Project is aimed at the development of robust procedures for fracture toughness testing and ECA of CMn pipeline steels that contain hydrogen associated with sour service. Given that tearing analysis (using R-curves) can help reduce conservatism in fracture assessments of flaws in ductile materials, the project will include an appraisal of whether such an approach can be used for assessing flaws in hydrogen-embrittled materials. The project will also determine whether data normally obtained from conventional constant-load tests, in sour environments, can be inferred from R-curves obtained from rising load tests conducted under low strain rates in the same sour environment.

The results of this project will help improve quality and safety and promote best practice in fracture toughness testing and ECA of steels in sour service. The results will be relevant to companies concerned with the integrity management of steels in sour service (onshore, offshore and subsea).

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Fracture Toughness Testing of Steels Subject to Sour Service

Objectives

The objectives of the full programme are:

- To develop and validate test procedures for determination of fracture toughness required for the assessment of surface and embedded flaws in steel components containing hydrogen associated with sour service;
- To develop and validate methods for fracture assessment of planar flaws in steel components containing hydrogen due to sour service, including the validity of using R-curves in such assessments.

Project Benefits

- Data on the effects of a number of key variables on fracture toughness and flaw tolerance of pipelines operating in sour environments;
- Data on whether K_{ISSC} determined from conventional constant-load tests can be inferred from resistance curves determined in the same sour environment under low strain rates. This could potentially offer an efficient and quick method for generation of fracture toughness data for sour service ECAs;
- Data on whether K_{ISSC} determined from tests on small-scale specimens correlates well with the behaviour of large-scale pipe samples.
- Improved and validated guidance on determination of fracture toughness and fracture assessment of flaws in CMn pipeline steels exposed to sour service.

Participants

The Sponsor Group currently comprises:

- ExxonMobil;
- ConocoPhillips;
- Chevron

Scope of Work

Current scope of work includes a range of small-scale tests and up to two large-scale tests on X65 pipe material as follows:

- Baseline fracture toughness tests in air;
- Fracture toughness tests in sour environment to determine the effects of strain rate and constraint;
- Resistance curves determined using SENB and SENT specimens in sour environment;
- Fracture toughness tests in sour environment to determine the effects of environment, temperature and crack tip bluntness
- Estimation of K_{ISSC} from constant-load tests;
- Large-scale tests on pipe sample.

If additional Sponsors join the project, the scope of work will be enlarged to consider a wider range of variables relevant for determining fracture toughness from small-scale specimens and validation against large scale tests.

Price and Duration

The project has a duration of two years and an initial budget of US$600,000 (for a reduced work scope), which is two thirds of the funds required to conduct the full programme. At present, there are 3 Sponsors, each making a contribution of US$ 150,000; and additional sponsors are being sought. TWI is also providing a contribution of US$150,000.

Further Information

For further information on how a Joint Industry Project (JIP) runs please visit:

http://www.twi-global.com/services/research-and-consultancy/joint-industry-projects/

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