Early-stage detection of HTHA in carbon steels

JOINT INDUSTRY PROJECT OUTLINE

PROP302145

Background

High Temperature Hydrogen Attack (HTHA) of carbon steels used in refinery equipment has been identified as an urgent issue following an industrial incident in April 2010 at the Tesoro Anacortes refinery in the USA. The US Chemical Safety and Hazard Investigation Board (CSB) investigation into the incident concluded that the current guidance for operating conditions should be reconsidered. In particular their report recommended *"… a new boundary for the carbon steel Nelson curve…. This boundary would prohibit carbon steel equipment at process conditions … above 400 ºF, and … greater than 50 psia hydrogen partial pressure."* If HTHA below the current Nelson curve conditions is possible, as indicated by CSB, then it puts swathes of plant in a precarious position.

An important aspect of preventing similar incidents is the effective inspection of components at risk. One of the conclusions of the May 2014 report into the Tesoro incident by the CSB identified the current severe limitations to inspection practice on refinery plants, concluding that: "*Inspection is therefore not sufficiently reliable to ensure mechanical integrity and prevent HTHA equipment damage.*"

Now is the time to address the issues raised in the CSB report and develop an inspection system (technique, instrumentation and procedures) capable of detecting and monitoring early-stage HTHA.

TWI proposes to assess and validate front running ultrasonic techniques for inspection and prevention purposes. In addition to the multi-disciplinary expertise, including inspection and metallurgy, TWI has the unique capability to build and operate a welded vessel at elevated pressure and temperature such that damage can develop in a realistic way. The vessel will be designed to present similar challenges to the monitoring and inspection of such damage on-site.

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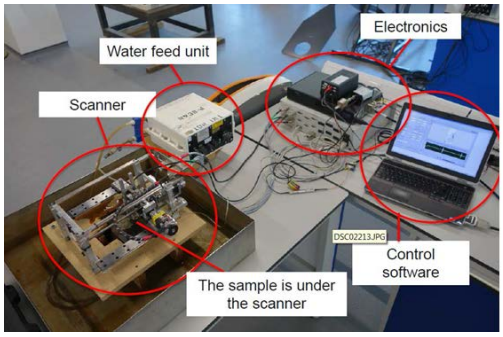
Project Concept

The key aim of this proposal is to validate leading NDT technologies for inspection of carbon steel plant deemed to be at risk of HTHA. It was commented in the CSB report that "*Successful identification of HTHA is highly dependent on the specific techniques employed and the skill of the inspector, and few inspectors have this level of expertise.*" Thus, the key technical challenge is to develop and implement a technique that is sensitive to early-stage HTHA that is also practical for industry to use in the field. This means provision of portable, robust instrumentation suitable for petrochemical sites, as well as simple, effective procedures for implementation by existing site personnel.

The work will make use of TWI expertise in NDT and also its capacity to build large scale pressurised test pieces that can be operated until failure if necessary. Different weld types and orientations can be incorporated into a mock pressure vessel and the temperatures and pressures monitored throughout the experiment. Periodic inspection will allow the practical demonstration and validation of front running NDT methods for detection of HTHA and could include a number of providers from industry. Metallography after final inspections will allow calibration and validation of the techniques investigated. This exercise can be complemented with any forthcoming samples from industry that feature HTHA damage.

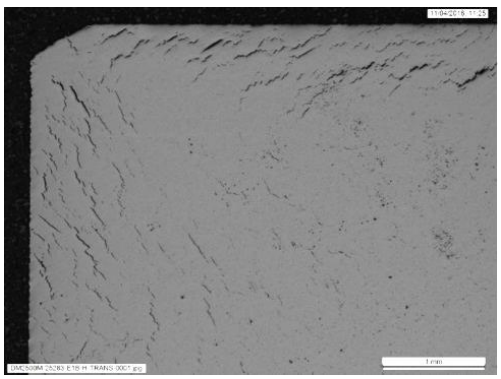


Prototype system for detection of early-stage creep damage in steels for high temperature thermal power plants

TWI has an excellent overview of current NDT practice and is also developing cutting-edge ultrasonic techniques for detection of early-stage creep damage that is applicable to the problem of HTHA. Furthermore, TWI has expertise in residual stress measurement, modelling, fracture and metallurgy. This could also be harnessed in order to provide further benefits, such as improving the understanding of aggravating factors and fitness-for-service aspects.

Objectives

- To validate leading NDT technologies for the detection of HTHA in welded carbon steel components.
- To provide industry with a practical solution for detection of early-stage HTHA.



Differing levels of HTHA damage in a specimen generated in TWI laboratory

Benefits

- Identification of early-stage HTHA in components at risk, allowing for effective plant management.
- Improved confidence in inspection programmes, which will not impose excessive cost penalties or require personnel training far beyond current requirements.
- Meet regulatory requirements for operation of ageing plants.
- Reduced equipment replacement costs.

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TWI pressure pit facility to be used for the large scale pressurised tests on a representative vessel

Approach

The work programme will be divided into a number of tasks to meet the objectives of this proposal.

- Task 1: Identify, review and understand leading NDT technologies available for evaluation and the characteristics of current inspection programmes in petrochemical plants. The JIP Sponsors will be invited to provide information on existing procedures, costs, personnel and instrumentation being used on their plants.
- Task 2: Identify materials at risk of HTHA damage in existing plant components. Input from JIP Sponsors will be sought to ensure the relevance of the selected materials.
- Task 3: Produce small scale laboratory specimens to provide a range of specimens containing differing levels of damage for assessment and optimisation of ultrasonic techniques. Damage levels in the specimens will be verified by metallography.
- Task 4: Design and build of large scale test. This will be constructed from the materials of interest and a variety of weld types will be incorporated. The vessel will be operated at temperatures and pressures that lead to HTHA within the project time frame, i.e. it will be an accelerated test. The vessel will be operated in TWI's pressure pit facility and can be operated until failure, if required.
- Task 5: Monitor development of HTHA in vessel welds. This will involve interrupting the test on several occasions to allow inspections to be carried out. Service vendors or Sponsors' own NDT teams will be granted access as required.
- Task 6: Carry out metallography of welds selected from NDT evaluations to allow sizing and characterisation of the HTHA damage developed.

- Task 7: Validate the inspection system. The information and knowhow from the large scale test and monitoring exercise, together with any samples from service, will be used to define the extent over which the inspection methods can be considered valid. A guideline for industry will be created to provide a practical inspection system for HTHA.

Deliverables

- A review of the currently used ultrasonic techniques for detection of HTHA damage, including identification of any key gaps to be addressed in this project.
- An ultrasonic system and specimens for its calibration for industrial inspection programmes. The system will include a technique, field-operable instrumentation and procedures for use by existing personnel.
- A report on the validation of the system, including its calibration using the specimens generated in the laboratory, the results of its use on the large scale test vessel and on any serviced-exposed material or components from operating plants.
- A final report including guidelines for on-site inspection.

Price and Duration

The overall estimated price for the work is £600,000 (excluding VAT), which requires £50,000 per company per annum for 2 years (£100,000 total) from each of the 6 Sponsors. It is anticipated that the project will commence with an agreed scope of work with a minimum of 4 Sponsors.

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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