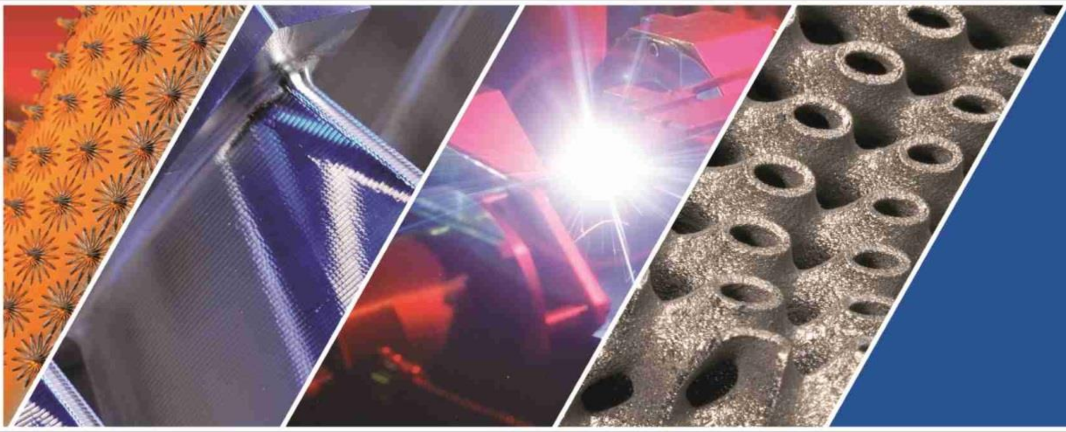
Materials Assessment for Supercritical CO_2 Transport (MASCO$_2$T II)



JOINT INDUSTRY PROJECT OUTLINE

PROP310950

Summary

Carbon capture and storage (CCS) is a crucial technology for Industries looking to reduce CO_2 emissions while carrying out operations that would otherwise release CO_2 to the atmosphere. In the context of CCS, pipeline transportation is widely regarded as the most affordable and generally safe option since it can move substantial volumes of CO_2 under tightly controlled conditions. To maximise the rate of transport, the CO_2 is usually pressurised to a dense phase (either as a liquid or supercritical fluid). Industrial experience of handling CO_2 is extensive and the phase behaviour of such fluids is well documented, however, in CCS the CO_2 is unlikely to be pure and the contaminants arising either from the source where CO_2 was generated, or due to the capture technologies used may change behaviour of the CO_2 stream. Irrespective of the source, corrosive impurities, notably H_2O, NO_x, H_2S etc., are often present in some degree. The generation of carbonic acid in the CO_2-H_2O system is well known, and TWI carried out a JIP (MASCO$_2$T) to understand the behaviour of metallic and polymeric materials in supercritical CO_2-H_2O systems with and without H_2S. The JIP also looked at the degradation of welded metallic materials under applied stress. This type of data is crucial for design.

Nonetheless, the additional presence of oxides of nitrogen may under certain conditions lead to the formation of nitrous and nitric acids. The presence of these compounds in the CO_2 stream increases the corrosivity of the fluid beyond what is generally experienced in the conventional CO_2 transport pipelines, and cracking also becomes an issue when H_2S is present. The interaction between the components in such complex environments is far less thoroughly understood. To ensure the safe functioning of pipelines conveying CO_2 in the presence impurities, data must be generated to understand the effect on performance of the materials that comprise the components, such as pipes, pumps, tubes et cetera.

This Joint Industry Project (JIP) seeks to generate the data needed to boost confidence in material selection for new build design and re-rating of existing metallic components in contact with supercritical CO_2, with impurities.

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Project Concept

The MASCO$_2$T II project will identify, test and assess metallic materials (including welds) for service in environments containing impure CO_2. A key factor is known to be the concentration of water in the CO_2 stream. Evaluation of the range of effect of water under different conditions will require development of systems and protocols for better control of water in the test environment. To ensure value for the sponsors in generating understanding of operational factors, the project will take the following steps:

- Selection of materials and welded systems
- Development/modification of testing systems
- Development of test methods and protocols for control of water
- Testing in selected environments
- Characterisation and Data analysis
- Reporting and possible development of materials selection protocol including boundary conditions where established.

High Pressure, High temperature test facility at TWI

Objectives

- Generate corrosion data for candidate metallic materials in high pressure/supercritical CO_2, with varying types and concentrations of impurities
- Establish a thorough knowledge of the impact of a range of environmental factors (such as pressure, temperature, fluid composition etc.) on (i) the corrosion behaviour of candidate metallic materials including welds, and (ii) the effect of stress on the environmental performance of candidate metallic materials and welds.

Benefits

- Improved confidence in material selection for new build design and re-rating of existing components in contact with high pressure/supercritical CO_2 streams containing impurities. Quantified degradation data will aid in the selection of cost-effective materials by enabling the application of calculated safety margins.
- Reduced possibility of pipeline failure in high pressure CO_2 service, thereby reducing the risk of containment loss, with consequent reduced environmental impact and unscheduled production downtime.
- Test protocols that will serve as the foundation for routine approaches to assessing material integrity while in contact with high pressure/supercritical CO_2 containing impurities. This could contribute to existing standards or help develop new standards on materials for transport of impure CO_2.

Approach

A hybrid kick-off meeting/workshop will be held at TWI to explore the range of operating conditions for existing and anticipated future industrial projects involving high pressure impure CO_2 transport. Information on the proposed materials, test variables and specimen design will be compiled with help from the meeting attendees. This information, along with that acquired from a variety of other sources, such as the MASCO$_2$T JIP, publications and online searches, is expected to assist in filling knowledge gaps in the field. Moreover, a focused study will be conducted on metallic materials that are currently expected to be used in carbon capture and storage (CCS) projects, and employed in existing infrastructure being considered for re-purposing, as applicable. The final materials, test techniques, and testing conditions will be chosen in consultation with the Sponsors.

- Corrosion rates of the specified metallic systems, including welds, will be measured under the chosen conditions. To support weight change and corrosion depth data, electrochemical methods will be employed (where possible) to monitor corrosion during testing in conductive aqueous conditions. On segmented electrodes, preferential weld corrosion data will be generated. The electrochemical approaches may involve measuring parent metal corrosion rates and relative corrosion rates in weld metal, heat affected zone (HAZ), and base metal using linear polarisation resistance (LPR).

- Control of water is known to be critical in transport of CO_2 containing impurities (such as oxides of nitrogen). The formation of acids from acid gases is dependent on the presence of water, hence in the absence of a continuous aqueous layer, the likelihood of general corrosion is greatly reduced. Such conditions do not allow the generation of electrochemical data. For such systems, exposure tests will be carried out under controlled water conditions to generate performance data on selected metallic materials. The data will be generated using detailed microstructural and surface characterisation (electron microscopy, non-contact profilometry etc.) that will allow better understanding of the possible corrosion mechanisms. Where appropriate, ASTM G1 method will be used to quantify corrosion rate.
- As H_2S is frequently encountered in conjunction with CO_2 and H_2O, corrosion experiments are anticipated (settings to be agreed upon with the Sponsors) containing high pressure CO_2 and H_2S in equilibrium with aqueous fluids. After the corrosion test programme is completed, sulphide stress cracking (SSC) tests may be performed, depending on the Sponsor group's interest, to assess the applicability of the oil and gas industry standard practise, which assumes that C-Mn steel welds with a hardness requirement of ≤250HV5 will not suffer from SSC in the presence of supercritical CO_2 with H_2S.

In all cases, the test matrix will be designed so that a variety of circumstances, from mild to severe, will be evaluated, with enough intermediate stages in between to allow material selection data to be obtained in a domain encompassing a wide range of operating conditions.

Deliverables

The main deliverables of the project are:

- Reports detailing the effect of impurities on the performance of metallic materials, including welds, in supercritical CO_2 containing impurities
- Detailed interpretation of results and their implications for materials of construction of CO_2 transport systems
- Quarterly e-mail progress statements and progress meetings at six-month intervals.

Price and Duration

The overall estimated price for the work is £600,000 (excluding VAT), which requires £40,000 per company per annum for 3 years (£120,000 total) from each of the 5 Sponsors. It is anticipated that the project will commence with an agreed scope of work with a minimum of 3 Sponsors.

Further Information

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

https://www.twi-global.com/what-we-do/research-and-technology/current-research-programmes/joint-industry-projects#/

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