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Demonstration of increased corrosion activity for insulated pipe systems using a simplified electrochemical potential noise method

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ABSTRACT

Corrosion under insulation (CUI) is a significant issue in industry. When a component is insulated, moisture could become trapped at pipe surfaces and lead to corrosion. The severity of corrosion under insulation could be considered greater than a component without insulation in a similar environment. This belief has not yet been demonstrated or reported in the literature. To understand CUI, the difference in a system under insulation and a system without insulation must be determined to confirm the anecdotally held understanding that corrosion can be more severe under insulation. Experiments were conducted to demonstrate this difference in corrosion severity of pipe surfaces exposed to insulation and surfaces without insulation. Increased mass loss and corrosion rates were found for electrodes under insulation over electrodes without insulation. The increase in corrosion was found using a simplified electrochemical potential noise (EPN) method and confirmed through visual observation and mass loss data.

1. Introduction

Corrosion under insulation (CUI) is a difficult and persistent problem that affects many operations. CUI can lead to serious process safety issues if corrosion is not detected and dealt with before loss of containment. Because of the seriousness of the consequences, study is needed to understand the effects of CUI on process safety (Bjerre et al., 2017; CCPS, 2010; Davis, 2014; De Vogelaere, 2009).

CUI occurs on the surface of a component that is covered by insulation. Insulation is used for many different reasons, most commonly to protect personnel from extreme surface temperatures and to regulate process temperatures. Because the surface is covered from view, detecting CUI is difficult and costly. Visual inspections are only possible through expensive removal of insulation and in most operations the amount of insulation installed makes this prohibitively expensive for routine maintenance plans (Caines et al., 2013).

Alternative non-destructive evaluation methods are available however, again the volume of insulated pipes and components make inspection prohibitively expensive. In the offshore industry, standards and recommended practices (API 579-1/ASME FFS-1, 2007; ASME B31.G, 2012; BS 7910, 2005; DNV-RP-G101, 2002; FITNET, 2006) are used to predict and plan inspection and maintenance schedules. While theses methodologies are comprehensive and widely used in the offshore industry, they do not fully specify corrosion rates under insulation and the user is required to provide appropriate corrosion rates when following the recommended practises and guide lines (Caines et al., 2013).

Corrosion on surfaces exposed to harsh marine environments (non-insulated) is not completely understood as the mechanisms and causes for corrosion initiation and propagation are stochastic and as such cannot be predicted with certainty (Caines et al., 2013; Davis, 2000; European Federation et al., 2008; Roberge, 2008). There are rates and methods for predicting behaviour of exposed pipe surfaces (non-insulated) that allow operators to choose proper materials for components and plan inspection and maintenance schedules (DNV-RP-G101, 2002; Melchers, 2003; Melchers and Jeffrey, 2008; Roberge, 2008; Svintradze and Pidaparti, 2010). The question becomes are these rates of corrosion and predictive measures developed for non-insulated assets applicable to components under insulation?

The first step in understanding and predicting the behaviour of CUI is to understand the effect of insulation on the corrosion

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behaviour. Rates and methods developed for uninsulated materials cannot be directly applied to insulated pipeline without study as the environmental set-up is different and conditions for corrosion are significantly different. Insulation is designed to keep moisture away from the surface however if moisture does penetrate the system, this design feature limits any opportunity for the moisture to escape. The reason for moisture introduction in the annular space is a complicated issue that is beyond the scope of this work but this issue is important to understanding CUI and to developing future preventative strategies.

If a non-insulated pipe becomes wet from rain or the like, there is limited opportunity for the moisture to become trapped and create corrosion conditions at the surface. Ideally, insulated pipe surfaces are protected from moisture however this is not always possible in practice. Once moisture is introduced under the insulation, the moisture can become trapped as demonstrated in Fig. 1.

To assess the corrosion behaviour in these different configurations traditional mass loss evaluation alone is not sufficient to characterise the effects of insulation. Electrochemical methods are available to assess the corrosion behaviour of materials. Linear polarization resistance (LPR), electrical resistance (ER), and electrochemical noise (EN) can be used in corrosion assessments. Linear polarization uses an input potential and measures the resulting current between corroding electrodes. This relationship, R_p, is inversely proportional to the rate of corrosion (Yang, 2008). Electrical resistance measures the change in electrical resistance due to surface changes from corrosion damage. This method is generally used as ER probes to monitor likely corrosion in an environment (Bertocci et al., 2003; Naing et al., 2006). These probes are placed in the environment of interest and the ER rates of the probe material are translated into corrosion rates for the components themselves. Electrochemical noise methods monitor the naturally occurring fluctuations in current and potential. This is a passive technique that does not require the external input required for LPR and ER.

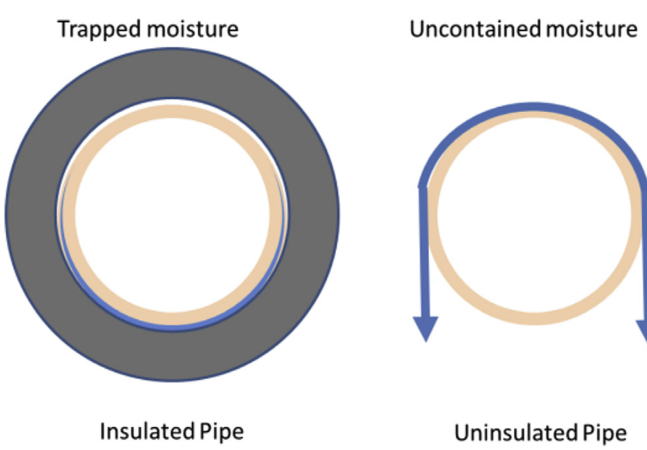

Fig. 1. Demonstration of differences in insulated and uninsulated pipe.

To evaluate the naturally occurring corrosion in piping systems EN methods are desirable over LPN as EN methods do not apply any disturbance to the system under study allowing for direct measurement of corrosion. ER Probes may create changes in geometry of the annular space between the pipe surface and insulation possibly leading to increased corrosion around probe site where EN methods can be applied directly to the pipe surface.

As part of an overarching research plan to study CUI in laboratory and field conditions (Caines et al., 2015), the authors developed a simplified electrochemical noise method to record changes in the naturally occurring potential difference (EPN) between two electrodes (Caines et al., 2017). This simplified method uses a traditional three nominally identical electrode set-up. Unlike traditional three electrode systems that measure the EPN between two of the three electrodes, the simplified method measures the EPN of all electrode pairs to allow for isolation of each electrode. With this simplified method the potential of each individual electrode was found from the coupled time records and it was demonstrated that the relationship between mass loss rate (corrosion rate (CR)) and EPN is proportional. Fig. 2 outlines the steps developed by Caines et al. (2017) for the simplified method of using EPN to estimate corrosion rate.

This method modifies a traditional three nominally identical electrode set-up (step 1) to measure coupled EPN data for all electrodes (step 2). Fig. 3 illustrates this set-up for measuring the coupled EPN (V_{ij}) for one electrode pair (E_i & E_j) against the third electrode (E_k) acting as a reference electrode. This measurement is duplicated for all electrode pairs (E_i & E_k and E_j & E_k) to measure the corresponding coupled EPN (V_{ik} and V_{jk}).

After all coupled electrode EPN is recorded, this data is then separated into individual EPN data for each individual electrode (step 3). This step uses equations (1)–(3) developed by Caines et al. (2017) to isolate EPN information for each individual electrode.

$$V_i = \left(\frac{V_{ij}^2 - V_{jk}^2 + V_{ik}^2}{2}\right)^{0.5} \tag{1}$$

$$V_j = \left(\frac{V_{ij}^2 - V_{ik}^2 + V_{jk}^2}{2}\right)^{0.5} \tag{2}$$

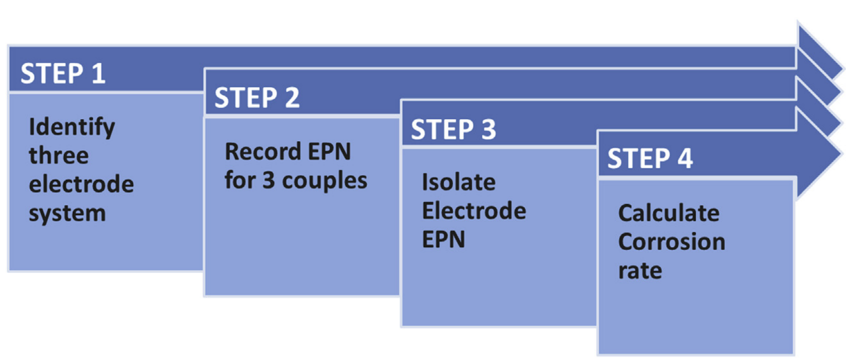

Fig. 2. Simplified EPN method (Caines et al., 2017) to evaluate isolated electrode potential for evaluation of the effect of insulation on the corrosion behaviour of pipe surfaces.