


Soil Corrosion and Integrity Management of Buried Pipeline

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FOR a variety of reasons, the topic of soil corrosion experienced by steel pipelines conveying petrochemical products has become a great concern among operators, engineers and researchers. For over a century, soil corrosion has been recognised as one of the factors that contribute to the failure of buried pipelines. In general, soil corrosion is a destructive mechanism due to the reaction with the environment which can degrade pipeline reliability and so reduces both its static and cyclic strength.

Without a proper monitoring system, the dynamic progress of corrosion may cause the pipeline to leak or rupture, and a pipeline failure can cause serious human, environmental and financial losses. A long and sustainable operation life of buried pipelines is expected owing to the potentially heavy financial losses if an ongoing operation has to be suspended to allow for the repair and replacement of the new section.

Buried pipelines face erratic corrosion attack, although maintenance is done regularly, due to factors related to soil conditions. These factors are largely governed by uncertainties, and the problem is these factors do not affect the pipeline equally at all locations on account of the complex phenomenon of soil behaviour. This is a connotation explaining that corrosion does not grow at the same rate throughout a pipeline.

Some parts of the line may be overprotected or under protected since the intensity of the cathodic protection and coating life are uniformly designed for external protection. It is important for the operators to identify corrosion defects which are active or growing, only then can predictions of future corrosion severity for each and every defect can be made.

There is a multitude of variables that influences corrosion in soil which is related to physico-chemical characteristics such as the role of microbes in soil corrosion, pH, temperature, moisture content, soil resistivity, redox potential, soluble ion content, oxidation-reduction potential and chloride content (Cl-) as well as the position of the water table. Although preceding research focused more on the effect of physico-chemical characteristics of soil upon corrosion dynamic, the effect of soil microstructure cannot be neglected. The dynamics of corrosion may vary according to soil types.

Soil engineering properties such as plasticity index, plastic limit, liquid limit, shrinkage limit and the size of particle distribution may contribute to the divergence of corrosivity of soil. For instance, dry, sandy and rocky soils are regarded as high-resistance (low conductivity) soils compared to clays, alluvial and all saline soils, *i.e.* those of low conductivity, which are the least corrosivity [Bayliss and Deacon, 2002; Rim-rukeh *et. al.*, 2006; Ismail and El-Shamy, 2009]. This makes the corrosion process in soil more complex than that in water although the basic electrochemical process is the same [Chance, 2003; Rim-rukeh *et. al.*, 2006; Ismail and El-Shamy, 2009].

External metal loss due to corrosion as experienced by buried pipelines can be monitored and detected through a variety of assessment methods, including In-Line Inspection (ILI) and the direct assessment method. ILI tools such as mechanical pigging operating based on magnetic flux leakage (MFL) or ultrasonic (UT) principles are well designed to provide detailed information about the size, orientation and location of corrosion and other types of anomalies on a pipeline. It also provides information regarding the areas vulnerable to eventual failure. Areas with severe corrosion which could compromise pipeline integrity can be identified, assessed and subsequently repaired. However, since the condition of a pipeline is not a static state, corrosion that is not immediately addressed will continue to grow and may pose a threat to pipeline integrity.

Projecting the future growth of defects in order to determine the likelihood of time to failure of operational pipelines is not a straightforward task. This is due to inherent uncertainties associated with soil properties, material properties and imperfect measurement by the inspection tool. Hence, the monitoring of corrosion growth turns out to be less effective since no reliable prediction can be made due to the complexity of the corrosion mechanism. The need for a reliable empirical model especially for the external condition by the operators intensifies.

A reliable model be it empirical, theoretical or mechanical models is much needed to assess the remaining life of corroding pipelines at the time of inspection as well as in the future. It can also be fully utilised to assist the operators in designing a risk-based maintenance programme, which is more cost-effective and less conservative than the current practice of time-based maintenance program, (pre-set time interval of maintenance period) to secure the reliability of the line against corrosion attack. Risk-based maintenance prioritises inspection and repair activities by

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predicting the future condition of the corroding line.

For over a decade, researchers who have put great effort into developing a reliable predictive model of external corrosion for buried pipelines include DeWaard and Milliams [1993], Nešić *et al.* [2001], Katano *et al.* [2003], Norsok [2005], Velazquez *et al.* [2008] and Alamilla *et al.*[2009], just to mention a few. Current interest in this field shows that ongoing research has a tendency to integrate the empirical analysis of corrosion (laboratory-based experiment) with metal loss data acquired through ILI and maintenance records. The integration is vital since results that solely rely on laboratory tests could not represent exactly the actual corrosion environment on site. The integration method involves the fitting of inspection data with the theoretical model to determine the pattern of corrosion dynamic [Noor *et al.*, 2007].

Corrosion models that take into account the effects of soil physico-chemical characteristics and engineering properties towards metal loss rate may give a clearer picture on the frequency of inspection, as well as determine the level of protection for the cathodic protection, inhibitors and coating along the lines. This is to ensure the pipelines are not overprotected nor under protected since different soil conditions may lead to the divergence of the corrosion rate along the pipeline. Without a profound knowledge of the corrosion rate, any basis for the setting of re-inspection intervals will be badly mislead. The better we understand corrosion dynamic behaviour, the better the integrity planning decisions will be. ■

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