

Development of Pitting Corrosion Monitoring Probe for Oil and Gas Internal Pipelines

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Abstract

Several methods for internal corrosion monitoring of oil and gas pipeline have been used and proposed in the last few decades. These monitoring systems may be mainly used for general corrosion and the post-processing of collected raw data is necessary. It is very important for internal corrosion management to show the evolution of corrosion phenomena with real time.

In this paper, patented corrosion monitoring technology for pit detection will be introduced. This pit detection probe system is capable of monitoring real time pitting corrosion in any kinds of environment. In addition, pit penetration rate can be easily determined. Multifunctional probe (pit detection technique+ electrical resistance technique) was also developed which can provide not only pit detection rate but also general corrosion rate.

The comparison results between multifunctional probes and the weight-loss coupons will be shown in this paper. These results of multifunctional probe for both general corrosion and pitting corrosion will be discussed.

Introduction

One of the frequent and major problems encountered in the oil and gas production is the internal corrosion of carbon steel pipelines. Corrosion can be categorized into uniform (or general) corrosion, localized corrosion and erosion-corrosion. Uniform corrosion causes overall metal loss and general thinning of metal. Localized corrosion has the appearance of pits or grooves. Erosion corrosion as the deterioration of the metal surface due to relative motion between the metal wall and the corrosive fluid.

The use of corrosion monitoring systems helps to detect early signs of corrosion before failure so that proper maintenance can be performed to prevent catastrophe. The functions of corrosion monitoring are detection of corrosion problems, determination of corrosion inhibitor effectiveness, estimation of the inspection requirements, and estimation of the useful service life.

There are many corrosion monitoring techniques available. Classification based on the physical principles of the intrusive monitoring techniques is metal-loss techniques (e.g. electric resistance, weight-loss coupons), electrochemical techniques (e.g. linear polarization resistance, electrochemical impedance spectroscopy, electrochemical noise). The major disadvantage of electrochemical techniques is that it can only be performed in conductive media and in aqueous solution. Therefore, ER and weight-loss coupon techniques are widely used in the oil and gas industry.

The weight-Loss Coupon (WL) technique^{1),2)} is the simplest and the most accurate corrosion monitoring method among all the existing corrosion monitoring methods. A corrosion coupon is inserted into a process environment and removed after a certain period of time. A corrosion rate is calculated based on a loss of coupon weight per unit area during the period of time. The advantages of the WL technique are simple to use and usable in any environment. Also, pitting corrosion can be determined from laboratory analysis. Disadvantages of the WL technique are as follows:

- Measurement requires a long exposure time (at least 90 days).
- High corrosion rates for short periods of time cannot be detectable.
- Continuous in-situ monitoring is not possible.
- The effects of corrosion dynamics cannot be isolated.

The corrosion rate is calculated as follows:

$$\text{Corrosion Rate (mm/year)} = \frac{8.75 \times 10^4 \text{ (m m/year)} \times \text{Weight Loss (g)}}{\text{Area (cm}^2\text{)} \times \text{Density (g/cm}^3\text{)} \times \text{Time (hour)}} \quad (1)$$

Electrical Resistance (ER) technique³ is based on measuring the change in electrical resistance of a metal element with time and provide information about the metal loss. When corrosion occurs, the metal thickness decreases, and the resistance (R) increases. The calculation of the ER technique is shown in Equation 2.

$$R = (\rho \cdot L)/A \quad (2)$$

where, R = the electrical resistance of conducting material, ohm

ρ = the specific electrical resistivity of conducting material, ohm.m

L = the length of a sensor, m

A = the cross-sectional area of a sensor, m²

The advantages of ER technique are usable in any environment, continuous in-situ monitoring, detectable in the change of corrosion rate, and much faster response than the WL technique. The disadvantages of the ER technique is as follows:

- Element life is inversely proportional to sensitivity.

- Conductive deposits (e.g. iron sulfide or carbonaceous material) on the sensor elements distort the readings for the corrosion rate.
- Localized corrosion cannot be detected.

An innovative corrosion monitoring system for the detection of pitting corrosion was developed and successfully tested. A certain pit depth (e.g. 20 μm) can be determined using this corrosion monitoring system. The pit penetration rate can be easily calculated since the system can monitor several data points according to pit growth. The monitoring system can be used in any environmental condition. Also, this technique enables continuous in-situ monitoring.

Pit Detection Corrosion Monitoring System

A pit detection corrosion monitoring system (PDMS) consists of a probe, an adapter, a transmitter, and software. The probe has four carbon steel layers. In between each layer, insulators are contained. The insulator is a thin film which is going to be dissolved as soon as layer penetration occur so that two layers become short. Thin film is the key enabling factor to determine the penetration of layers. Thin film is applied to each layer by semiconductor processing-based technology. High quality and consistent deposition are necessary for semiconductor coating application.

Each layer in the probe has a setting voltage value and the voltage source is connected to a circuit in the transmitter. When the first layer is penetrated by pitting corrosion, the insulator between the first layer and the second layer is going to be a breakdown and the two layers are electrically shorted. The values of voltage changes in each layer transfer to the software and are analyzed to determine the layer penetration.

Figure 1 shows various types of corrosion detection probe (flush-type) and a transmitter developed. Probe head diameter is 3.175 cm. The probe can be installed on an existing weight-loss coupon or electrical resistance (ER) probe ports.

Multi-functional probe for both general corrosion and pitting corrosion was also developed. General corrosion rate is calculated using the principle of ER technique. The Multi-functional probe provides information for both general corrosion rate and pitting corrosion phenomena in real-time. Some tests for multi-functional probe were performed in high pressure condition, and in different temperature condition.