

Continuous Corrosion Monitoring in HF Alkylation Units Including the Effects of Iron Fluoride Scale Build-Up

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ABSTRACT

Online Continuous Non-Intrusive Corrosion Monitoring is fast becoming industry best-practice in the Refining Industry globally. This technique involves wireless battery-powered sensors placed in the process units which deliver high-quality data directly to the desk of the corrosion engineer. This paper will present a case study and learnings from various refineries from the deployment of non-intrusive ultrasonic wall thickness monitoring systems in HF alkylation units.

Online non-intrusive automated corrosion monitoring of HF alkylation units is valuable due to the safety risks associated with inspection inside these units, as well as the high probability of corrosion events and grave consequences of leakages. The technology discussed in this paper was developed using information from around 300 thickness monitoring sensors installed across 12 HF alkylation units globally. Traditional expectation is that iron fluoride scale layers that build up will not affect ultrasonic thickness results. However, through monitoring using permanently installed ultrasonic sensors, it was observed that the scale layer did negatively affect the ultrasonic signal. Our field experience has led to the development of an advanced signal processing algorithm, designed to be less affected by the effects of ultrasonic distortion due to the scale build-up.

Data examples will be presented to explain this effect and comparisons between traditional signal processing methods and the advanced methods developed for this application. We close with a case study from a refinery who, via online monitoring of their HF alkylation unit, were able to detect elevated corrosion rates and take action to bring the corrosion under control, before any danger.

Key words: online ultrasonic testing, wall thickness, ultrasonic thickness, hydrofluoric acid, corrosion mechanisms, scale (corrosion), safety management

INTRODUCTION

In oil refineries, one corrosion issue occurs each week worldwide that leads to a severe incident such as sudden leakages, e.g., resulting from pipe ruptures.^[1] These facts emphasize the need for corrosion control in refineries. Corrosion monitoring is one important approach to utilize and can maximize equipment integrity and productivity. Other than traditional monitoring techniques (e.g., intrusive probes or manual ultrasonic wall thickness inspection), new wireless sensors were developed in recent years. They monitor pipe or vessel wall thickness and, thus, corrosion online by ultrasonic testing (UT).

One area which is particularly of concern is corrosion in hydrofluoric acid (HF) alkylation units. This is down to both the high risk and high impact that a corrosion incident would cause. This paper aims to highlight some of the risks faced by refiners attempting to maximise their HF alkylation unit, and address how some of these risks can be mitigated using continuous online monitoring.

HF Alkylation units are some of the highest safety risk areas of refineries. Accurate monitoring of these units using a permanently installed monitoring system means that both fewer inspectors must enter these areas as well improved data accuracy. The overall risk is reduced. A system capable of delivering this is desirable but has not yet been demonstrated.

Especially because of the safety risks, recreating this process in a lab environment is dangerous to the extent that it is not viable. Using samples from units also doesn't work. This is due to the iron-fluoride scale layer, which forms during the process, immediately hydrating due to moisture in the air once the pipe is opened. This changes the scale layer's properties, rendering any later analysis meaningless. The authors of this paper are in a unique position with 12 monitoring systems in HF Alkylation units worldwide, which is the only way validate any findings in this domain.

Traditional Corrosion Monitoring

There are several types of instrumentation that have traditionally been used for monitoring corrosion in oil refineries. Two of the most common are corrosion probes and manual ultrasonic inspection.

Intrusive Corrosion (or Electrical Resistance, ER) Probes.

Corrosion probes have been in use since the 1960s and are a very well-established technology. They consist of an intrusive element with a sacrificial tip that sits in the process fluid and is (normally) made from the same material as the surrounding equipment. As the sacrificial tip corrodes, its electrical resistivity changes, which is recorded externally (usually on a locally mounted data logger), but these are also increasingly available for wireless connection. The corrosion of the sacrificial tip is used to infer the level of corrosion being experienced by the surrounding equipment.

Manual Ultrasonic Inspection.

Ultrasound has been used in the oil and gas industry for fifty years and is a well-established technique for measuring metal wall thickness. The technique involves the generation of ultrasound from a transducer that is placed directly onto the metal surface. The ultrasound is transmitted through the metal until it is reflected off the inside metal surface (back wall). The reflected ultrasound signal (or A-scan) is recorded, and the time difference (the 'time-of-flight') between the sending and reflected signals provides the measurement of the wall thickness. While the technique can be reliable, completion of a full set of measurements for a medium-sized refinery with 80,000+ corrosion measurement points is very time-consuming and labour-intensive, such that the wall thickness at an individual location may only be measured every three-five years. This is not an adequate frequency to measure corrosion rates with any

confidence, or to link periods of high wall loss to specific feedstocks or process operations (which requires measurements on the time scale of days to be useful).

In addition, while being relatively simple, manual ultrasound methods have the following disadvantages:

- Poor repeatability and reproducibility - it is highly unlikely that consecutive measurements will be taken in precisely the same location by the same NDE technician. In addition, the equipment used and the skill level of the NDE technician can vary between measurements, introducing high variability to the measurements. Figure 1 shows a graph showing actual thickness against measured thickness for a number of removed corroded steel samples^[2]. The variation in data shows that accuracy and repeatability is poor in manual ultrasound thickness measurement.

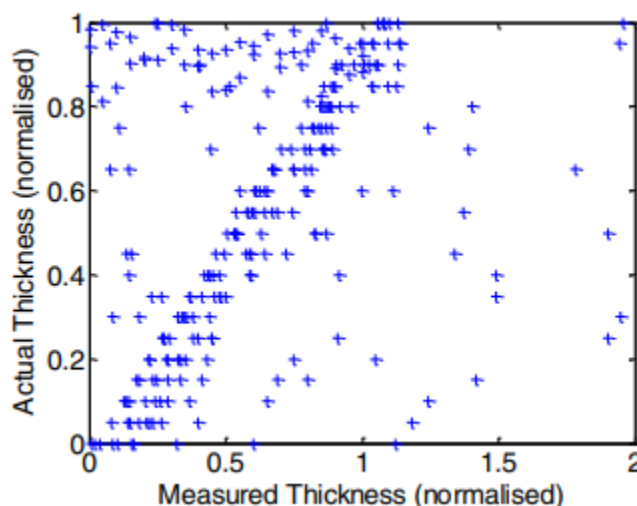


Figure 1: Illustration of measurement errors associated with manual ultrasonic thickness measurements on corroded steel samples

- High temperatures - temperatures above $\sim 100^{\circ}\text{C}$ (212°F) can permanently damage the NDT (Non Destructive Testing) equipment. There are also safety risks to the NDT technician at higher temperature locations.
- Physical access and dangerous locations - the NDT technician needs to have access to the equipment at the measurement location of interest, which requires scaffolding (possibly permanently installed) and stripping of insulation to expose the metal work to make the manual measurements, bringing significant cost. High-risk locations, such as hydrogen fluoride (HF) alkylation units, can be undesirable to send technicians. Although the risk of exposure is minimised using personal protective equipment, the exposure if an incident does occur is incredibly high, and for this reason, many operators are looking for methods to avoid sending personnel to these high-risk areas for online inspection.

Online UT Sensors for Continuous Corrosion Monitoring

Utilising permanently mounted ultrasonic sensors measuring wall thickness and employing wireless data retrieval are fast becoming best practice in refineries.^[3] The sensors are simple and cost-effective to deploy at scale and provide a quality and frequency of data that is otherwise unavailable. The data informs a wide range of operational decisions due to its sensitivity to small changes in wall thickness, robustness to extreme plant conditions, and extended battery life enabling reliable operation over the entire cycle between turnarounds. Data is transferred using industry standard wireless communications to the end users' desk, allowing frequent, reliable and safe wall thickness monitoring.^[3]