HYDROCARBON ENGINEERING®

Effective corrosion monitoring

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In this special report for *Hydrocarbon Engineering*, Krishna Uppuluri, mPACT2WO, reveals how effective corrosion monitoring at scale can prevent catastrophic events and ensure the safety of critical assets in the downstream industry.

Corrosion monitoring is crucial to ensure the safety and integrity of process piping, alkylation units, fluid catalytic cracking (FCC) units, hydrocracker overheads, and other mission critical assets in downstream operations in oil and gas refining and petrochemical facilities. Plant inspectors typically gather thickness measurements in-person using portable ultrasonic equipment at designated measurement locations called condition monitoring locations (CMLs), formerly referred to as thickness monitoring locations (TMLs). However, relying solely on traditional manual ultrasonic inspection methods has its downsides, such as the potential for inaccuracies and imprecisions due to human errors, leading to high safety margins, uncertainties, and unnecessary expenses.

Permanently installed thickness monitoring solutions provide a more reliable and accurate alternative to manual ultrasonic inspection methods. Although such solutions may come with a higher initial cost, they offer numerous benefits over traditional inspection methods that are worth considering. In addition, the data quality provided by permanently installed thickness monitoring solutions allows users to correlate thickness data with process data to develop additional operational insights. However, user adoption at scale has been persistently limited for the following reasons:

- High variability of thickness trends due to distorted waveforms (A-Scans).
- Dashboards that do not present information enhancing existing inspector work practices.
- Time-intensive, manual method to analyse thickness trends.
- Maintenance and standardisation of sensor systems.

Therefore, it is essential for the industry to embrace new technologies and solutions to improve safety and efficiency while reducing costs.

A new approach

The convergence of artificial intelligence (AI) and machine learning (ML) with the industrial domain has led to the emergence of the Artificial Intelligence of Things (AIoT), which democratises the use of these technologies in the industry. Another concept that is revolutionising the industry is NDE4.0, which is a non-destructive evaluation method that uses digitalisation, networking, communication, and processing tools, such as AI and ML, to detect flaws and imperfections in materials and ensure structural integrity. These concepts are paving the way for a paradigm shift in corrosion monitoring, leading to better safety, efficiency, and cost-effectiveness in the industry.

Continuous and automated corrosion monitoring provides several distinct values to plant operators:

- Firstly, it helps to increase the overall safety of the plant by identifying potential corrosion-related issues before they become serious problems. This is accomplished by analysing accurate data to identify and report on any unusual patterns or trends that may be indicative of corrosion.
- Secondly, it can improve the efficiency of maintenance operations by reducing the number of unscheduled shutdowns or repairs that are necessary due to unexpected corrosion-related issues with relevant contextual insights to aid in decisions.
- Finally, it can help to extend the lifespan of critical components and infrastructure by allowing plant operators to implement proactive maintenance strategies that are based on accurate and up-to-date information about the condition of their assets.

To operationalise continuous and automated corrosion monitoring, the following three key areas play a pivotal role in driving adoption.

Trusted and accurate insights

Corrosion and erosion can cause changes to the metal surface, which can influence the reflection properties of ultrasonic waves. This often results in backwall echoes on the A-Scan decreasing in amplitude and broadening, and sometimes even leading to separate peaks in one echo. To ensure automatic monitoring of thickness trends, it is important to have features such as dynamic gates that can automatically adjust to the changing A-Scans over time. This helps to ensure accurate and reliable measurements without requiring manual adjustment or intervention.

Active corrosion and erosion can modify the reflecting metal surface, which in turn changes the waveforms in the amplitude scan (A-Scan). When using fixed gates shown in black and green (Figure 1) to determine the time-of-flight references (red dots), the waveform changes are not accommodated. As a result, the time-of-flight references used to calculate the thickness vary significantly, leading to the typical step-function characteristics of the thickness trend shown in the middle panel. These distorted trend lines significantly affect the confidence in any subsequent analysis, as the calculation of the remaining life becomes less precise.

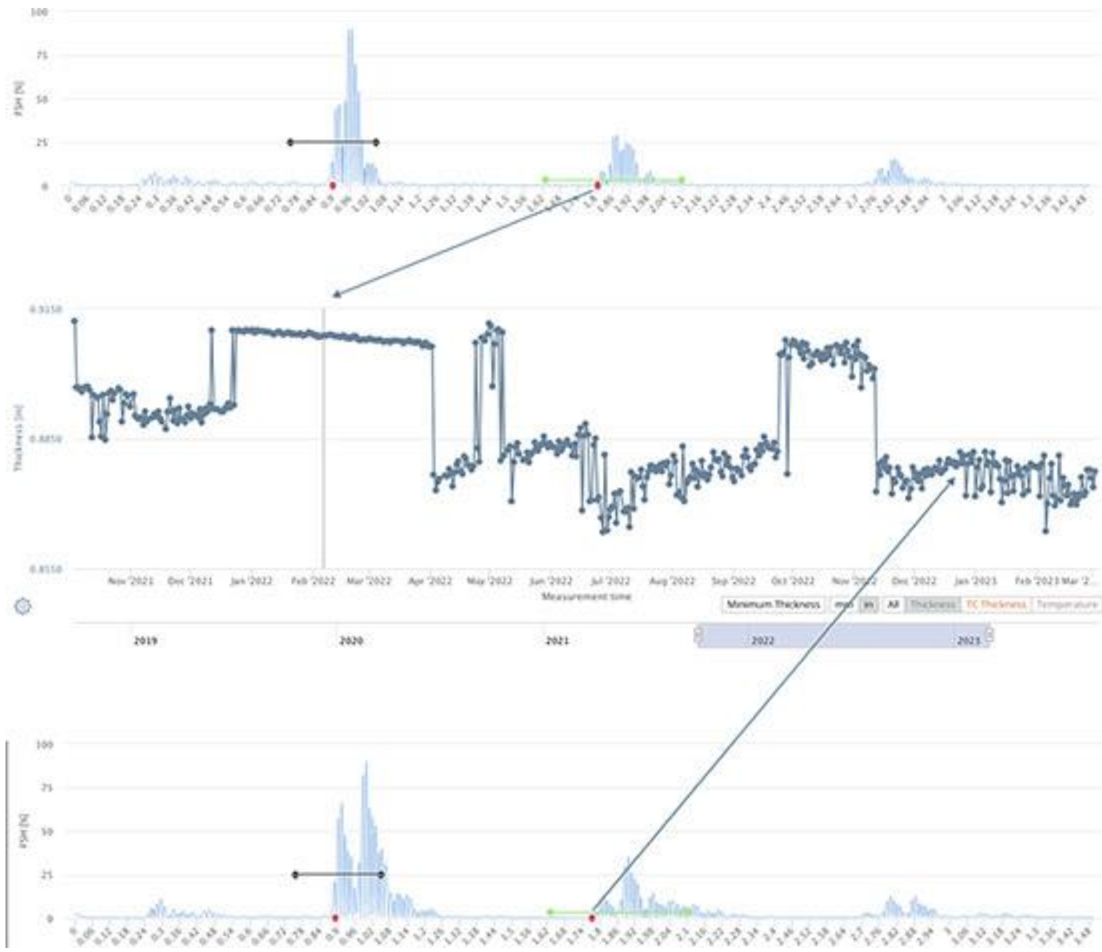

Figure 1. Thickness trendline without dynamic gates.

For accurate and reliable measurements, it is essential to have features like dynamic gates that can adjust to the changing A-Scans over time. By using the A-Scans from Figure 1 and applying dynamic gates, the true decreasing thickness trend of a component can be revealed. This clean thickness trend allows the remaining life of a component to be determined with high confidence. Such a capability will help achieve accurate and reliable measurements, without requiring manual adjustment or intervention.

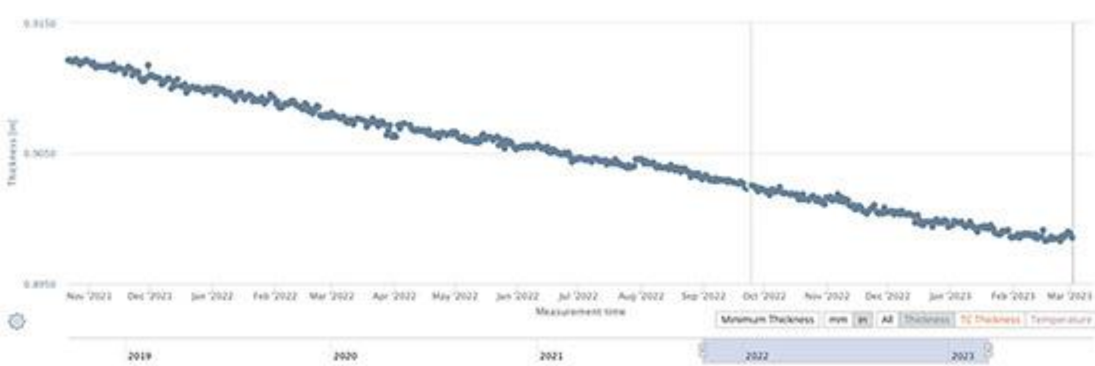

Figure 2. Thickness trendline with dynamic gates.

Circuit-based contextual operational information

Managing corrosion monitoring at scale requires measuring thickness data with process data once per day or even more frequently, which can generate an overwhelming amount of sensor data to manage. Traditionally, dashboards for limited installations displayed thickness measurements over time and corresponding A-Scans for each sensor, TML/CML. Email or text message notifications were available for user-defined threshold breaches, but the slow corrosion process limited their usefulness. Therefore, users would manually evaluate thickness trend lines and A-Scans by logging into dashboards to identify sensors with the highest corrosion rates or the lowest remaining life, according to standards like API 570. However, managing large amounts of sensor data can be a complex task, especially when measurement periods are infrequent. Although dashboards that display thickness trends and A-Scans are useful in providing detailed information on material characteristics, corrosion processes, and sensor health, they may not be adequate for gaining a comprehensive overview of a circuit or unit.

Figure 3. Circuit-based hierarchy with thickness trendlines and parameters.

To effectively manage corrosion monitoring at scale, it is crucial to have dashboards that offer both status overviews and detailed information about thickness trends and A-Scans. Figures 3 and 4 show how a dashboard helps users in assessing rapid root causes for corrosion thickness analysis. The dashboard includes appropriate contextual information that enables the user to easily access circuit hierarchy, thickness trends, corresponding A-Scans, and relevant parameters calculated per industry standards, such as API 570 or the settings used to acquire the A-Scans.

Widgets play a key role in helping customers to easily monitor their assets' health and make informed decisions based on the data provided. The choice of widget depends on the customer's specific use case. For instance, list widgets are suitable to monitor the remaining life of circuits for repair or replacement. On the other hand, the number widget helps on correlations of process data and thickness trends to investigate why particular process settings cause higher corrosion rates.

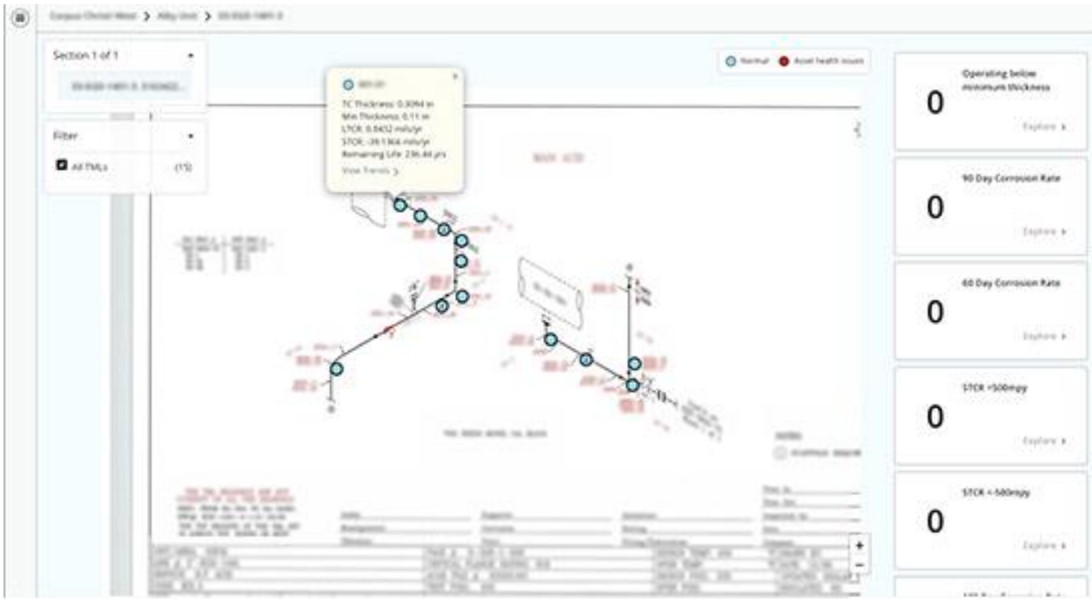

Figure 4. Circuit and sensor health dashboards.

Business model to enable adoption

In the past, plant operators faced challenges with the traditional business model of a one-time hardware purchase and a separate subscription model for the software. While the installation of permanently installed sensors is usually planned out and executed well by the partner – mainly due to the limited scale – issues can arise during the service periods when sensors start to fail outside the typical warranty period which is very often only one year. It is also important to note that a warranty period of only one year does not speak for the partner's confidence in its design of a permanently installed sensor solution and it is usually the customer's responsibility to order and install replacement sensors. While the interest in technology and its application usually helps to mitigate this burden, it increases the plant operator's workload and usually leads to a permanently installed solution with fewer functioning sensors over time until the solution is completely abandoned. It is therefore better to choose a partner who can provide a service model that addresses the entire solution – hardware, software, and services – over the length of the contract to ensure operators can stay focused on what matters the most for their plants or facilities.

Case study

mPACT2WO's mCluez™ for corrosion monitoring is successfully being used by one of the largest oil and gas refineries in the US to avoid over-monitoring and over-maintenance of fixed assets from unexpected corrosion, catastrophic events, and unplanned maintenance. In a critical instance, a 2 in. dia. spool had to be exchanged every three months, and manual measurements taken every couple of weeks showed a linear trend that did not provide enough time resolution to correlate the thickness trend with process data.

By using the corrosion monitoring solution, the customer was able to establish a correlation between certain process settings and routings and the thickness trend, as illustrated in Figure 5. The corrosion trend acquired with an ultrasonic sensor installed on the spool elbow revealed a non-linear trend with changing corrosion rates. After the spool was replaced, a corrosion rate of approximately 800 mils/year was observed, followed by a period with a moderate corrosion rate of only 50 mils/year. Measurements were taken every four hours before the measurement period was remotely extended to eight hours. The ability to distinguish between different periods of corrosion activity enabled the customer to understand the root cause of the high corrosion rate, in this case, the diversion of the process flow from another unit into the monitored unit.

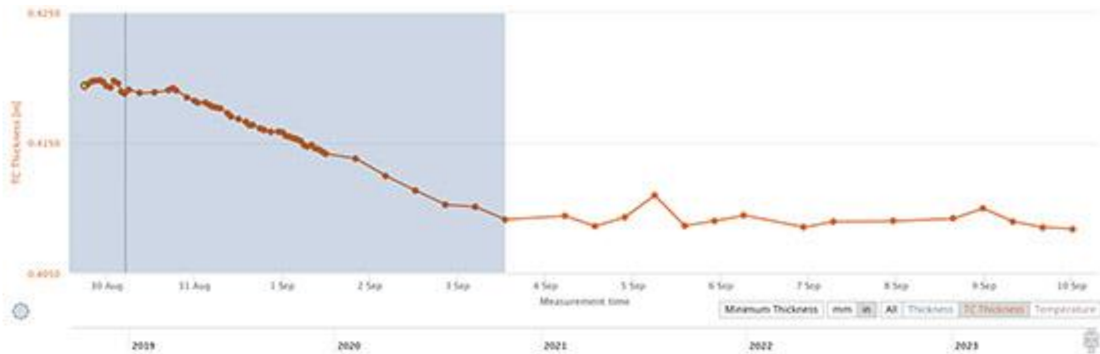

Figure 5. High resolution thickness trend of a spool elbow.

Conclusion

To ensure successful implementation of ultrasonic corrosion monitoring at scale, it is crucial to look at new technologies and applications that offer advanced corrosion monitoring enabled by AIoT and NDE4.0, featuring automated monitoring capabilities and adaptive features, such as dynamic gates. Additionally, configurable dashboards tailored to different use cases can help inspectors and operators prioritise critical issues.

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