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An Application and Solutions Perspective on Refinery Corrosion and Integrity Management in India

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ABSTRACT

The focus on corrosion and integrity management in the refining industry today is increasing. Drivers for this are the need for improved operational safety for plant, personnel and the environment, as well as the need for increased plant uptime and extended equipment life. Finally, a good corrosion management program can increase the operating window. For example, it can allow the increased blending of low cost crudes, lower inhibitor consumption and reduce plants' operational costs.

Refineries today have a range of corrosion challenges, such as naphthenic acid corrosion and sulfuric acid corrosion. Efficient monitoring requires a combination of monitoring technologies and solutions. This paper gives an introduction to intrusive and non-intrusive monitoring technologies applicable in a plant, and how they can be combined into an integrated solution. The paper will also examine other refinery monitoring applications and field data examples for different monitoring technologies will be provided.

The paper will also look at the challenges in data management and how the standardization of new communication solutions, such as WirelessHART offer a significant shift in the convenience, quality

of data and real time information provided, allowing remedial actions to be taken before damage takes place.

Keywords: corrosion, integrity management, data management

INTRODUCTION

Corrosion prevention, maintenance and control are hugely significant to the lifecycle of downstream oil & gas assets in India today. Refineries are complex chemical plants, with a range of processes and materials that provide a mixture of corrosion-related issues. According to the Saudi Aramco Journal of Technology, 36% of all maintenance costs in refineries can be linked to corrosion repairs {1}.

From naphthenic acid corrosion to sour water corrosion, hydrogen induced cracking (HIC) and sulfide stress cracking (SSC), corrosion can take many forms in refineries and other downstream assets and can have a highly negative impact on operational integrity, running costs and, of course, the eventual lifetime of the asset.

Naphthenic acid corrosion (NAC), for example, is a form of corrosion that takes place in the high temperature parts of a plant, typically in primary and vacuum distillations units, as well as associated pipework. NAC corrosion increases when there is higher Total Acid Number (TAN) and sulfur content in the crude and therefore grows when there is more blending of opportunity crudes. NAC is also often triggered by velocity, and therefore often found in bends in the actual area.

It's against this context that issues particularly relevant to Indian plant operators include:

- ***Safety***. Industrial accidents are often related to uncontrolled corrosion with an effective corrosion and integrity management program reducing the risk of unexpected accidents, and improving operational safety for the plant, personnel and the environment.
- ***Increased Plant Uptime***. A good corrosion and integrity management program will ensure that asset conditions are known, maintenance and repair strategies planned, and unplanned production stops avoided.
- ***Corrosion Inhibitor Verification and Tuning.*** The use of corrosion inhibitors is a common way of controlling corrosion with corrosion monitoring vital in determining the effect of such inhibitors, ensuring that the correct chemicals are used and at optimal concentrations.
- ***Optimizing the Use of Opportunity Crudes.*** Crude oil purchasing today represents over 90% of the cost structure of a refinery and is therefore a major area for achieving profitability and reducing costs. The optimal blending of high TAN crudes and conventional crudes can therefore significant improve refinery profitability as long as the effects of corrosion are closely monitored.

INTEGRITY MANAGEMENT VERSUS PROACTIVE CORROSION MONITORING

One key differentiation is between monitoring as a part of an ongoing integrity management program and 'pro-active' corrosion monitoring or corrosion management. In integrity management, the main objective is to verify the condition of the piping and process equipment to ensure safe operations and to make structured plans for maintenance and repairs – timely and regular inspections that are crucial to asset integrity.

Pro-active corrosion monitoring, on the other hand, is targeted at detecting changes in corrosion rates *before* significant metal loss takes place. Such changes in corrosion rates might be down to the fast tracking of corrosion inhibitor efficiency and consumption, or changes due to the processing of high TAN opportunity crudes. For such proactive corrosion management, sensitivity and fast response is essential. So what technologies are available and what technology is best suited for each application?

IN-LINE CORROSION MONITORING & SUITABLE APPLICATIONS

In-line corrosion coupons are the original way of monitoring corrosion. Samples, pre-weighed to 0,1 mg, are inserted in the pipe or vessel for a given period (say 3-6 months). Upon retrieval, coupons are cleaned, weighed again, and from the weight loss the corrosion rate is calculated. In addition, the coupon surface is analyzed with respect to localized attacks (pits) and possible deposits.

Electrical Resistance (ER) probes have also been commonly used over decades for monitoring corrosion. ER probes (figure 1 illustrates how an ER probe is installed on the pipe) are based on measuring changes in electrical resistance as the thickness of the probe's measurement element decreases due to corrosion. Today's ER probes, available for process temperatures at up to 450 ^{o}C (842F) - combined with modern instrumentation, provide the highest sensitivity (low nanometer range) and fastest response to changes in corrosion rates available.

Electrochemical probes, like Linear Polarization Resistance (LPR) probes, have an extensive history for direct corrosion rate measurements. More sophisticated electrochemical methods like harmonic distortion and electrochemical noise are also available, providing more extensive information about the process and corrosion mechanisms. Electrochemical methods need an electrolyte and are mostly used in water systems.

The key benefits of in-line corrosion monitoring include their sensitivity, the immediate quantification and fast responses to corrosion rate changes. and the ability to put in place early corrective actions. Typical locations for corrosion probes are in side-streams, low temperature process piping and heat exchanger inlets. Such instruments are particularly well suited to proactive process control and inhibitor tuning where high sensitivity and fast responses are so important. In-line corrosion monitoring can also provide long-term corrosion rates assessment, information on deposits and bacteria as well as fast response on changes in corrosion rates in water, for example.The use of intrusive probes should be avoided in cases where internal composition is chemically aggressive, such as in alkanizing unit side-streams. For such locations, non-intrusive ultrasonic devices are a good alternative.

INTERNAL, NON-INTRUSIVE CORROSION MONITORING

The Field Signature Method (FSM) technology - an internal, non-intrusive corrosion monitoring technology, is based on feeding an electric current through a monitored section of a pipe, pipeline or vessel. The applied current sets up an electric field that is monitored as voltage drop values between a set of sensing pins installed on the external pipe wall.

Fig 1: A Retractable (moderate pressure, high temperature) ER probe (right), and probe installed with retractor tool through packing gland and full bore valve (left).

The initial measurement sequence measures the voltage drop between all pairs of sensing pins, and is called the Field Signature. Later measurements are compared to the Field Signature, where general corrosion can be seen as a uniform increase in voltage drops between all pin pairs, and localized corrosion can be seen as a local increase in the values.

FSM data can be plotted as metal loss versus time for the efficient tracking of changes in metal loss versus changes in process (inhibitors, opportunity crude mix), or in 3D plots that show the distribution of corrosion over the monitored area. Typical sensitivity for FSM is 0,1% of wall thickness for general corrosion, corresponding to 10-20 micrometer in most cases. Figure 2 illustrates FSM being installed in an Indian refinery where the purpose of monitoring and data are presented in previously presented joint paper {2}.

There are a number of possible applications for non-intrusive corrosion monitoring:
For example, localized corrosion and high temperature applications, such as naphthenic acid corrosion (NAC) in refineries would point to a technology that has the ability to reliably detect localized corrosion. The FSM method has a unique ability to detect localized corrosion.

In addition, in areas that are difficult to access for monitoring locations, such as the bottom of underground pipelines, non-intrusive methods installed directly on the pipeline would probably be best. Again, FSM is a good solution for direct installation on the pipeline.

Finally, in the case of opportunity crudes, where corrosives vary from batch to batch – internal corrosion monitoring technologies will ensure that operators have maximum crude selection flexibility, can monitor the effect of varying crudes, and can blend the maximum amount of opportunity/high TAN crudes into the crude mix without a detrimental effect on corrosion.


Fig 2: An FSM sensing pin matrix being installed on a high temperature bend in a refinery, India (left), FSMLog instrument (right)

NON-INTRUSIVE, HIGH TEMPERATURE ULTRASONIC (UT) WALL THICKNESS MEASUREMENTS

Ultrasonic measurements are another valuable tool for corrosion monitoring. Ultrasonic measurements are used for wall thickness measurements and for detecting defects over several decades. Installing UT sensors permanently on the pipe for regular measurements at the spot provides increased stability and sensitivity. Sensitivity for UT measurements in a field is typically 10-20 micrometers for changes in wall thickness. It is also possible from the form of the wave signal to determine surface conditions inside the pipe. UT can now be deployed on pipes or vessels with temperatures at up to 600 ^{o}C. Wireless communications also makes installation and data collection rapid and cost-effective. Arrays of UT sensors are also used to cover for uneven corrosion in the monitored area.

In particular, UT measurements are ideal for integrity management/permanent inspection points where ultrasonic wall thickness sensors can be widely distributed. Today, UT sensors are used in all types of refinery units. With the low installation cost per location, high temperature UT allows for the application of permanent wall thickness monitoring at a high number of selected locations around a plant - useful for an efficient asset integrity management program.

USING CORROSION MONITORING TO BLEND OPPORTUNITY CRUDES – AN APPLICATION EXAMPLE

One application not mentioned to date in this paper is ensuring the optimal blending of opportunity crudes and the matching of crude properties with refining capabilities. As mentioned previously, crude oil purchasing today represents over 90% of the cost structure of a refinery and is therefore a major area for achieving profitability and reducing costs.

High TAN (Total Acid Number) crudes – which tends to have a TAN of 1.0 or higher – is an aggressive but cheap form of crude which has high levels of acidity and includes naphthenic acid content - a mixture of naturally occurring cycloaliphatic carboxylic acids recovered from petroleum distillates. Other elements of high TAN crudes include fewer light components, high density and viscosity, high gel asphalt content and high salts and heavy metals content. Such crudes also have the potential to cause greater corrosion to key refinery assets. Other problems might include emulsion instability, increased fouling and asphaltene precipitation, API variability and volume shrinkage, and unintended crude switch disturbances.

The cost benefits of high TAN crudes, however, are clear at approximately 80% the price of conventional crude oil. The optimal blending of high TAN crudes and conventional crudes can therefore pay a key role in refinery profitability *as long as* the effects of corrosion are closely monitored. For example, an increase in opportunity crudes with an additional 1% in a refinery with a capacity of 250,000 barrels/day, for example, could result in savings of more than 5 million US dollars per year based on a 6-dollar price difference.

Some refiners follow a strategy of blending to ensure that the TAN of the blend is less than 0.5%. Some refiners, who have a substantial supply of high TAN crudes, upgrade the metallurgy that is fully resistant. Some refiners, who have access to high TAN crudes, utilize the availability of corrosion inhibition chemicals to protect their assets against corrosion, along with more intensive corrosion monitoring.

In such cases – where corrosives vary from batch to batch – internal corrosion monitoring technologies will ensure that operators have maximum crude selection flexibility, can monitor the effect of varying crudes, and can blend the maximum amount of opportunity/high TAN crudes into the crude mix without a detrimental effect on corrosion. A baseline can be defined, for example, before introducing high TAN crudes and the effects of changing inhibitor programs can then be monitored. In such cases, corrosion control is critical to plant integrity, maintenance and economic performance.

TWO INDIAN APPLICATIONS

One example of corrosion monitoring in the blending of opportunity crudes is the Reliance Refinery at Jamnagar India that has been strategically processing high TAN crudes and where corrosion is monitored during these periods using state-of-the-art tools, such as electric field signature measurements. Electric field technology measurements provide data about variations in actual thickness values directly onto the location and hence provide an accurate trend of corrosion rates and help in maintaining the asset's integrity {3}.

Another example is Essar Oil's Vadinar Refinery in the Indian state of Gujarat. The refinery processes a large proportion of opportunity crudes to maximise refinery margins. With the increased acid content in opportunity crudes having the potential to corrode refinery equipment, an effective corrosion monitoring system was critical to ensuring the sustainability of the refinery infrastructure. To this end, Essar Oil employed three different corrosion monitoring technologies including the Field Signature Method (FSM), Permasense UT system and in-line probes with the system providing continuous data on metal loss occurring in the equipment due to the corrosive nature of the crude {4}.

THE CHALLENGES OF COMMUNICATION AND DATA MANAGEMENT

Yet, for all the wide array of corrosion monitoring technologies suitable for different plant applications, one of greatest challenges facing corrosion today is that of communications and data management. Traditional corrosion monitoring solutions were most often based on off-line data collection, using portable instruments. This resulted in many of the monitoring locations in a plant being at locations where access is difficult, and collecting data being time-consuming and unpleasant (high temperatures, climbing ladders etc).

It’s against this context that on-line systems (e.g. with the FSM technology) are providing significant benefits to plant operators, such as more frequent measurements and better data management tools. Experience shows that on-line systems where data has been collected with a high frequency are considered to perform better.

One challenge that remains in communications, however, is the cost of cabling. The cost of cabling in the past often made upgrades to on-line and efficient corrosion monitoring impossible to justify. However, we are now seeing greater use of wireless technology that allows the implementation of new technologies at an affordable cost.

The WirelessHART protocol, for example, allows different monitoring applications to be combined in the same wireless mesh as well as including other wireless tools and instrumentation. Emerson recently introduced a WirelessHART transmitter. The system, can be installed in a number of refinery applications, including side streams, cooling systems and in addressing naphthenic acid corrosion in high temperature distillation processes, is flexible with respect to positioning in the plant, as well as in data communications and management.

Raw data can be provided to a special application software, but calculated data can also be transmitted to more or less any user or database, including Emerson’s Asset Management System (AMS). The system consists of electrical resistance (ER) and linear polarization resistance (LPR) probes (monitored by the same instrument) and weight loss coupons – all coming with high temperature ratings. ER probes come with high resolution (10-100 nanometers) and fast response times.

Specialized software tools are also available, collecting data from all sensors and monitoring tools installed, providing status windows for each sensor, tools for data analysis and reporting, alarm setting, and providing key information to the plant control system. Figure 4 provides details of such a data management system.

Combined with the FSM technology, refinery operators will be able to use the new system to access more comprehensive corrosion information and corrosion rates. The result for operators will be optimal production processes and reduced refinery downtime; the ability to understand the process conditions that may be influencing corrosion; and effective inhibitor programs. The fact that the system is wireless-based will also enable access to the plant’s most critical and often inaccessible areas.

Fig 4: Data management software – left, status window for each sensor in the plant, color-codes state condition at each location. Right, detailed analysis of FSM data, showing the presence of localized corrosion within the monitored area.

SUMMARY – ASKING THE RIGHT QUESTIONS

What this paper has demonstrated is that the wide array of corrosion monitoring technologies that have advanced over the last few years to meet an array of different applications. The benefits of combining such systems are also clear to see, resulting in:

- Increased reliability through corrosion data provided by independent technologies, avoiding false alarms and providing a better understanding of corrosion conditions.
- A combination of high sensitivity/fast response technologies for the immediate tracking of corrosion rate changes, combined with direct wall thickness change monitoring for confirmation and verification of asset conditions.
- A combination of comprehensive monitoring solutions for critical conditions (e.g. distillation area) and less costly monitoring solutions spread over a plant integrity/inspection management support.
- The combining of total area coverage for localized corrosion with direct assessment of pipe/vessel wall thickness.

It's now up to Indian plant operators to ask the right questions to ensure that they adopt the best suited corrosion monitoring technology. Such questions include:

- *What are the key corrosion challenges I am facing in my corrosion and erosion monitoring strategy? What is the information needed, and how should it be used - process optimization, integrity management etc?*
- *How can corrosion and erosion management add value to the specific plant, pipeline or platform, with respect to safety, the environment, reducing operational costs and maximizing production rates?*
- *What is the information needed to meet the objectives above, and how will that information be used?*
- *And finally, how can information be provided in a form that makes sure that it is used in decision-making?*

With the right decision-making framework and the right technologies, Indian operators can take full control of their refinery and assets.

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