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ADVANCED CORROSION MONITORING TECHNOLOGIES IN PETROCHEMICAL INDUSTRY

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Abstract

Corrosion is one of the most pressing problems in the oil industry today. An effective method for assessing the corrosion state of equipment is corrosion monitoring - a system for observing and predicting the corrosion state of an object in order to obtain timely information about its possible corrosion failures. The article provides an overview of modern advanced technologies for corrosion monitoring of oilfield equipment and subsea pipelines.

Keywords:
Corrosion;
Monitoring;
Fiber optic system.

Introduction

The main task of ensuring the integrity of oil field pipelines is to prevent accidents during the exploitation of the oil field. To reduce their influence, various anti-corrosion measures are being developed and implemented. If these measures are correctly designed and regularly implemented, then their effectiveness will be expressed in trouble-free operation. In order to predict the effectiveness of anti-corrosion measures before the first accidents are recorded, more prompt measures are needed to assess their current effectiveness. One of the fundamentally possible options for such an assessment is a regular diagnostic inspection of pipelines.

The need for corrosion monitoring and its place in an overall pipeline integrity management strategy is illustrated in figure 1.

Corrosion monitoring has four main purposes:

- ensuring the safe operation of systems;
- optimization of the maintenance program;
- assessment of the effect on corrosion of possible changes in operating conditions;
- optimization of anti-corrosion measures.

The monitored parameters for corrosion monitoring can be divided into direct and indirect. Direct parameters are the corrosion rate of samples and sensors and the corrosion rate of the pipeline. And indirect parameters include:

- Pressure and temperature;
- Pipeline performance;
- Composition of products;
- Velocity and hydrodynamic flow regime
- CO_2, H_2S, O_2, Fe_2^+;
- Residual inhibitor content;
- Content of mechanical impurities;
- Technological operations carried out related to well workovers, acid treatments, etc.

The structural unit of the corrosion monitoring system is the corrosion control unit (CCU). The choice of the correct location of the CCU is a responsible operation, the correctness of which, to a very high degree, depends on the adequacy of the results of monitoring and the effectiveness of anti-corrosion measures. At this point, the corrosion rate of sensors and surveillance samples, chemical composition and technological parameters are monitored.

The sequence of selection of the place of control is determined using mathematical modeling. Mathematical modeling is carried out on the basis of passport data of objects, data on accidents and diagnostics. Areas with the maximum corrosion rate are determined. At least one control unit is installed in a critical section with an increased corrosion rate.

Corrosion monitoring can be viewed as a scheme that includes the following elements: design, operation, management.

The main design goal is to develop a monitoring system that best suits the set goals. The design of a corrosion monitoring system is carried out in several stages according to the sequence below.

- selection of monitoring parameters;
- selection of the monitoring site;
- choice of measurement technique, design and sensitivity of the measuring device;
- determination of requirements for

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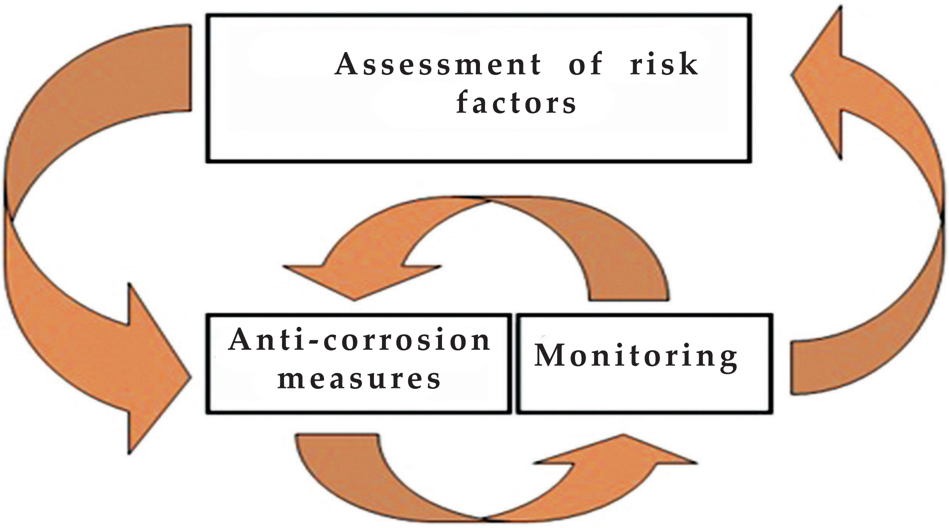

Fig.1. Correlation between elements of integrity management strategy

the frequency of collection and use of information (data);
- development of a detailed corrosion monitoring scheme;
- cost estimation during operation of the monitoring system;
- drawing up regulations.

Corrosion monitoring regulations

Practically at this stage of designing a corrosion monitoring system, a sufficient amount of information is collected in order to form a «Regulation for corrosion monitoring of a pipeline system». The corrosion monitoring regulation is a mandatory document. It should contain the following sections:

- Technological configuration and parameters of the pipeline system;
- Hydrodynamic and corrosion calculations.
- Statistical data on accidents and diagnostic survey data;
- Requirements for inhibitor protection - technology, injection sites, level of corrosion inhibitor availability;
- Determination of the purpose and key parameters of monitoring;
- Identification of hazardous areas - corrosion monitoring sites;
- Choice of measurement methods, performance and sensitivity of instruments.
- Certification of the monitoring system;
- Determining the frequency of measurements and scheduling the execution of operations;
- Establishment of a list of indicators to manage the monitoring process.

Corrosion monitoring methods

The variety of factors affecting the development of corrosion does not allow counting on the existence of a single universal method, using which it is possible to predict the integrity of the pipeline and / or evaluate the effectiveness of the measures being taken. All methods of monitoring form four main groups:

1. Diagnostic - determination of corrosive wear of the pipeline metal using generally accepted methods of diagnostic examinations;
2. Methods for measuring the corrosion rate of carbon steels and its changes over time, based on the readings of sensors placed in a medium moving through a pipeline;
3. Assessment of technological and physicochemical parameters of the environment, characterizing its corrosiveness, and changes in these characteristics over time;
4. Analysis of equipment failure statistics in order to identify areas with the maximum risk of accidents and the most significant factors affecting the accident rate of pipelines.

For the effectiveness of the monitoring program, it is necessary that the data obtained by the methods of all the listed groups be readily available for joint analysis. This is achieved by access to all databases containing the required information and the availability of a suitable software product that provides reliable correlation analysis. For the effectiveness of the monitoring program, it is necessary that the data obtained by the methods of all the listed groups be readily available for joint analysis. This is achieved by access to all databases containing the required information and the availability of a suitable software product that provides reliable correlation analysis.

Novadays, there are a number of methods that make it possible to assess the intensity and determine the nature of corrosion damage:

- Testing coupon for corrosion;
- Electrical resistance sensors;
- Resistance to linear polarization;
- Galvanic monitoring;
- Biological monitoring;
- Ultrasonic thickness control;
- Potential for corrosion;
- Monitoring of hydrogen penetration;
- Chemical analysis.

In practice, the most widespread are the gravimetric method and ultrasonic thickness control.

The most widely used and quite effective method of corrosion monitoring is the use of gravimetric corrosion coupons. It is the simplest and most advanced form of corrosion monitoring that can be applied to all media (eg gases, liquids and slurries). A coupon is a sample that matches the material of the equipment to be monitored. Coupons are placed in the technological environment and removed after some time (for example, weeks or months) (fig.2). It then analyzes: 1) the amount of mass lost, 2) the type of corrosion, and 3) corrosion rate.

This corrosion control method has several disadvantages:

- Indirect measurement. Corrosion of equipment is determined by indirect parameters;
- The intrusive nature of these coupons means that they cannot be installed during normal operation as they require special mounting flanges that must be drilled and welded to the pipeline;
- The intrusive probe creates a disturbance in the fluid flow that can potentially cause corrosion further down the process flow.

Ultrasonic control

The ultrasonic method is based on measuring the transit time of an ultrasonic wave in a solid. The ultrasonic method has been used for 50 years and is characterized by high measurement accuracy and can be used to detect corrosion damage located on the inner surface of the pipe wall. The ultrasonic method is widely used to control the thickness of equipment and piping systems in refineries. Ultrasound penetrates deep into the material and detects defects or metal losses associated with corrosion or erosion. Ultrasonic inspection can be carried out both pointwise and cover large areas, which is possible due to devices of various degrees of mechanization. The most common ultrasonic testing devices used to detect corrosion damage to metal are ultrasonic thickness gauges and flaw detectors.

In addition, being relatively simple, portable ultrasound techniques have the following disadvantages:

- Repeatability and reproducibility errors: successive measurements are unlikely to be carried out at a fixed location by the same supervisor using the same instrument;
- Susceptibility to roughness of the inner surface of the metal: with local pitting corrosion, the use of ultrasonic technology is limited, since minor defects on the inner surface of the metal will scatter the ultrasound and create distortion in the reflected wave. This can manifest itself in a clear increase in the measurements of the thickness of the metal wall compared to earlier data, which, of course, is impossible. Pay attention to the human factor, the inspector will try to smooth out the measurement result by slightly moving the probe to one side or the other until a

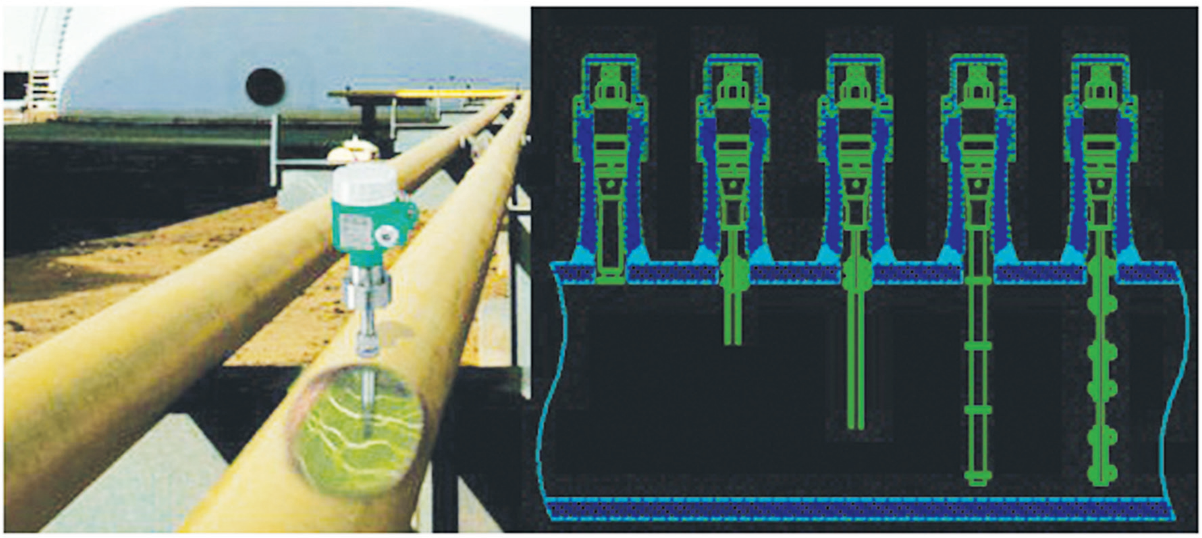

Fig.2. Installation of gravimetric corrosion coupons

«normal» reading is obtained (ie equal to or less than the previous reading). This limitation of ultrasonic testing can lead to the loss of very valuable information about the beginning of changes in the roughness of the inner surface, indicating the presence of corrosive activity;

- Personal injury and equipment breakdown at high temperatures: Temperatures above 100 ° C can permanently damage the electronics of the transmitter. In addition, it is dangerous for personnel to work in close proximity to hot metal structures, even with protective equipment;
- Physical access to the measuring site: the inspector must have access to the equipment at the required measuring points, therefore scaffolding (possibly permanently installed) and insulation dismantling are necessary to provide access to the surface of the metal structure for manual measurements, with associated costs and energy losses.

Advanced corrosion and erosion monitoring technology for more informed decisions. Current approaches to continuous corrosion monitoring are aimed at overcoming the disadvantages of intrusive probes and portable ultrasonic testing. These methods fall into two main categories: point monitoring and monitoring of zones.

Emerson offers complete solutions for continuous corrosion and erosion monitoring using wireless sensors that do not require tapping into the pipeline. These are stationary monitoring systems that are capable of operating in extreme environmental conditions in hard-to-reach areas. Thanks to continuous monitoring, information about the thickness of the pipeline walls is automatically transmitted to the operator's computer and allows you to quickly monitor the stages of corrosion and take corrective measures in a timely manner. Reliable and accurate wall thickness data provided by the monitoring system allows decisions to be made when equipment and piping needs to be maintained and replaced. Measured data can also be used for chemical engineering corrosion protection. The software for viewing and managing data is an integral part of the monitoring system, which shows the current measurements of the sensors, calculates the corrosion rate, predicts the achievement of rejection wall thickness, and provides diagnostic data on the operation of the system.Emerson WirelessHART System benefits are:

- Wireless system: data enters the computer without expensive cables;
- Easy setup: the sensors automatically find the optimal communication channel and adapt to it;
- Maintenance-free: the network recovers and finds new communication channels in the event of any interruption;
- Comprehensive solution: high quality communication and continuous data monitoring.

The data from the sensors are transmitted via the Wireless HART wireless protocol to the database, which processes the signals and receives the final measurement result - the wall thickness of the object at the selected point. The WT series sensors use waveguide technology to provide continuous operation up to 600 °C. The ET series sensors measure wall thickness even through the paintwork. They are magnetically attached, making them quick and easy to install on the line. Dedicated battery packs are designed to power the sensors, reducing installation costs and eliminating the need for cabling. The sensors can be installed in large numbers in the most remote locations. Sensors and battery packs are certified for use in hazardous areas. Once installed, the sensors automatically organize a wireless network through which data from the sensors are transmitted to the gateway along the most reliable route. The gateway transmits data to the server where the Data Manager software is installed, which allows the operator to comprehensively assess the overall corrosion level of the installation and conduct a more detailed analysis at specific points. In addition, data from the database can be transferred to any application used by the customer (fig.3).

Performance characteristics:

- Determination of metal loss: about 10 microns;
- Time for updating readings: standard - 1 time per 12 hours, user-configurable - up to 1 time per hour;
- Battery life: 9 years under standard operating conditions;
- Surface temperature of pipelines: up to 600 °C;
- Minimum wall thickness: 3 mm.

Advanced technologies for monitoring the technical condition, maintenance and repair of subsea pipelines

Monitoring of the technical condition, maintenance and repair of subsea pipelines (SP) are carried out in order to prevent accidents and failures, predict their technical condition, plan repairs and manage their implementation based on the actual technical condition, substantiate a decision on the possibility and conditions of further operation of the SP. In order to monitor the technical condition, maintenance and repair of the SP, a set of methods should be used to obtain the necessary and sufficient information, after processing which, reliable parameters of the SP technical condition can be obtained.

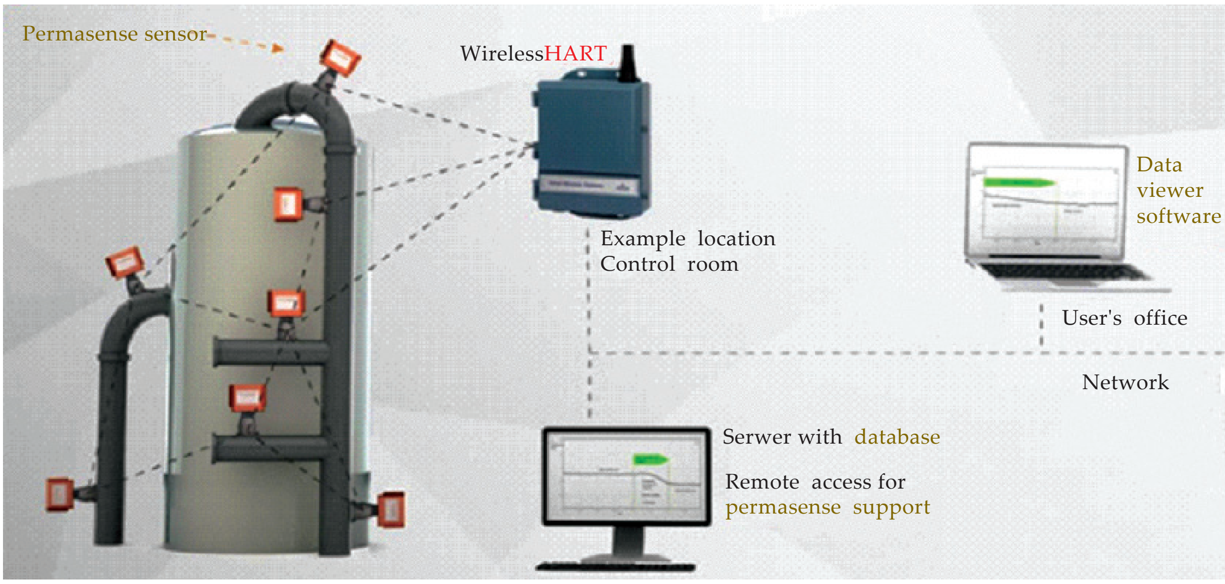

Fig.3. The operating principle of the system WirelessHART®

The choice of methods for monitoring the technical condition, maintenance and repair of fuel tanks is determined by design solutions (the presence of launch-receiving units for in-line shells, the radius of curvature of the bends, changes in the diameter of the underwater pipeline, the type of laying, service life, climatic conditions, the availability of measuring instruments, transport capabilities). Monitoring of the technical condition of the Sp can be carried out using a fiber-optic monitoring system (fig.4).

Fiber optic monitoring system includes:

- continuous monitoring of the integrity of the PT, which allows registering local defects with an accuracy of 1 m, using a special fiber-optic cable installed on the pipeline;
- detection of leaks caused by various reasons, for example, deformation of the pipeline, corrosion or metal fatigue using a temperature sensor cable laid in the ground next to the pipeline;
- geotechnical monitoring to detect ground movements using a special fiber-optic cable laid in the ground next to the pipeline;
- registration of unauthorized access to the PT, using the analyzer, which is located together with the sensor cable laid in the ground;
- monitoring the technical condition of submarine cables using a fiber-optic sensor cable integrated into the structure of the submarine cable.

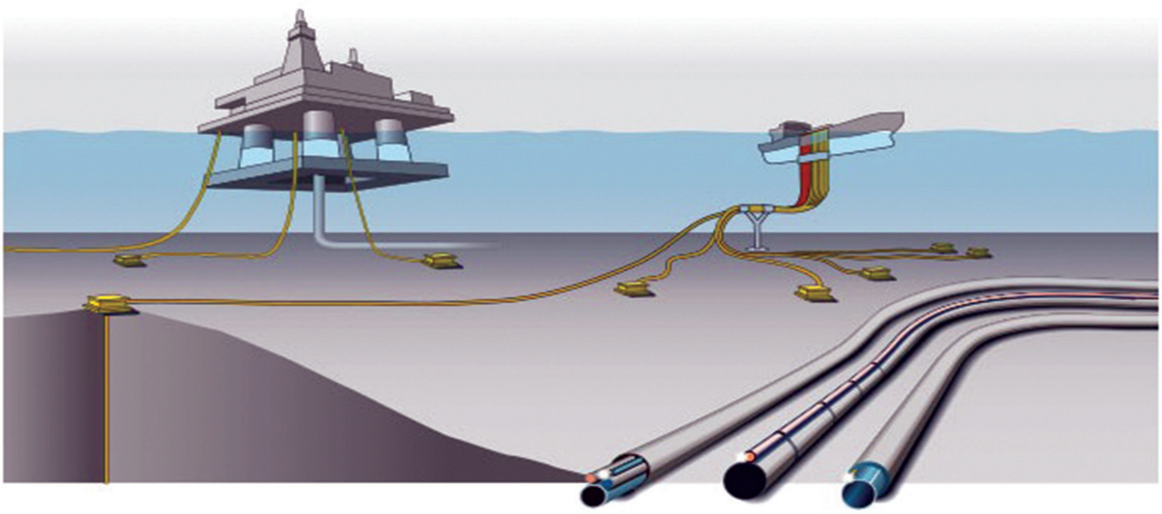

Fig.4. Fiber optic monitoring system

FSM technology

FSM technology is based on the use of a non-intrusive corrosion monitoring tool, which is a geometric matrix consisting of sensitive pins (3 mm diameter each), which are permanently fixed to the outer wall of the pipe by means of capacitor welding. Due to the low heat input and the very small area of the fusion zone, which are provided by turned welding, the metallurgical change in the pipe material is negligible and there is no need for any subsequent heat treatment and stress relief. The matrix cables are summarized in the Sensing Matrix Interface (SMI), which is the interface between the matrix and the FSMlog measurement tool.

The monitoring matrix usually consists of 28 to 386 pins of sensing pins (electrodes). The pins are attached to the outer wall of the pipe together with the conductive cables, temperature sensors and a reference disc.

All of this hardware is connected via a Sensing Matrix Interface (FSMlog) using a set of cables with a junction box mounted in an easy-to-reach location.

The non-intrusive FSM method should be considered as a structural component of the assessment of corrosion mechanisms and the effectiveness of countermeasures.

This corrosion monitoring method is capable of measuring and indicating the presence of processes that are consistently correlated with corrosion at the monitoring site. The non-intrusive method is able to react to reflect the putative mechanisms and morphology of corrosion, for example, to indicate the presence of general or localized corrosion, and is also able to respond in concert with changes in conditions at the monitoring sites, for example, to take into account the interference caused by liquid hydrocarbons, fluctuations in the electrolyte level, presence of solid deposits, countermeasures applied, etc. FSM matrices should be located in locations where the readings of these devices or the results of their corrosion measurements can be extrapolated to other locations with minimal error.

Data is transmitted on-line, transmission medium via Ethernet and GSM, as well as via satellite communication.

Corrosion monitoring in oil refining processes

Technological processes for atmospheric and vacuum distillation of oil

Combating corrosion in atmospheric and vacuum distillation plants is critical to unleashing the full potential of a refinery. Due to significant changes in the operating temperature and process fluid used in this device, different forms of corrosion are observed in different parts of the equipment. Particular attention should be paid to naphthenic acid (localized corrosion) and hydrogen sulfide corrosion occurring in equipment operating at high temperatures. The materials of construction in this equipment affect the efficient operation of the plant. Corrosion is usually a problem in the process, but the risk is especially high during vacuum distillation, when corrosive aggressive components are often concentrated in the hot stream of atmospheric distillate residues fed to the plant. Another area of concern is the suspension system of an atmospheric distillation plant, where steam condenses and condensation corrosion occurs due to the formation of hydrochloric acid. (separation of fractions from the top of the rectification column).

Complex problems related to corrosion

Numerous factors contributing to the development of corrosion:

- This is the first unit to receive hot crude oil;
- The atmospheric vacuum distillation unit supplies all other plant units with feedstock: any breakdown or shutdown will affect the operational readiness of the refinery as a whole;
- Increase in chloride content due to inadequate desalination (especially strongly affecting suspension systems);
- Frequent changes in the technological process, for example, to adjust the ratio of the resulting fractions;
- Increased sulfur content in crude oil;
- Increase in the total acid number due to changes in the feed mixture of crude oils;
- Concentration of «problematic» components during the technological process.

Problems in the implementation of a set of measures to protect against corrosion:

- Inadequate protection means corrosion will not be controlled;
- Overprotection can cause technological problems;
- Lack of proper monitoring of operators' corrosion protection strategy.

Measurement of corrosion parameters in real time

Emerson offers a wide range of corrosion protection products for the refining industry. Real-time corrosion measurement helps to better understand atmospheric and vacuum processes, which are critical to maximizing refinery performance. PERMASENSE ultrasonic wall thickness gauges monitor device integrity and measure actual metal loss, while Roxar built-in gauge gauges measure process corrosivity. This means that the risks of corrosion and the impact of this risk on the device itself can be measured and controlled. Combined with Roxar FSM technology, which detects generalized or localized corrosion in specific risk areas, these solutions provide a complete picture of the corrosion hazard in an existing facility. Analytical data visualization tools help to further embed this information.

Optimization of control and protection against corrosion

Testing and optimizing your corrosion protection strategy is key to maintaining plant availability and productivity. When chemical protection techniques are used to prevent corrosion, real-time monitoring of corrosion mitigation performance allows cost control while adapting to the ever-changing and increasingly aggressive crude oil mixtures used as feedstocks. A balanced view of process corrosiveness and wall thickness changes is always helpful: you simply want to monitor the protection efficiency of heat exchangers equipped with a corrosion inhibitor, or you are trying to optimize a protection program with an expensive maximum. - inhibitor of thermal corrosion in the presence of naphthenic acid.

Corrosion control in alkylation plants

It is very important to monitor the development of corrosion during the alkylation process in real time, since aggressive acids such as fluoride and sulfate are used as catalysts, and in this case, uncontrolled processes can pose a serious threat.

Alkylation is one of the most important processes in modern oil refining. This allows alkylates to be produced by recycling light hydrocarbons from FCC waste, which can then be blended with fuel to produce a higher octane product. This increases the productivity and profitability of the plant. Maintaining the target acid concentration is important both from a safety and economic point of view. If the acid concentration falls too low, there is a risk of an uncontrolled situation - the reactions become unstable, the acid consumption increases rapidly, the corrosion rate increases significantly, and the process equipment can be idle. Alkylates are necessary because they do not contain benzene, other aromatic hydrocarbons or olefins and are practically free of sulfur, that is, they are extremely pure fuel additives. Real-time corrosion monitoring allows you to identify an uncontrolled situation with a decrease in acid concentration and obtain the necessary information about the processes taking place inside the alkylation unit. Roxar CorrLog Ultrasonic Wall Thickness and Corrosion Sensors provide real-time insight into the actual condition of the most critical parts of alkylation devices. This increases the productivity and profitability of the alkylation plant.

Conclusion:

1. Market conditions are forcing refineries to look for new ways to increase profits, for example, refining more aggressive grades of oil, the so-called «profitable grades». This increases the risk of equipment failure due to the effects of corrosion.
2. The proliferation of oil with a high total acid number leads to a choice between increasing the corrosion resistance of plant materials and additional inhibition with good corrosion monitoring. When the budget is limited, the choice falls on chemical inhibition and stricter monitoring. The payback time for the implementation of the inhibition / extended monitoring strategy is about 2 months, assuming the use of a monitoring system of 100 sensors.
3. Intrusive corrosion monitoring probes have the required sensitivity and response speed. However, they are difficult to install and maintain, and pose a high safety risk for the service personnel. Immersion probes use a single point measurement that determines the effect of the corrosiveness of the process fluid on the walls of the equipment. Portable ultrasonic testing methods do not provide repeatable measurements due to variable conditions and human factors. Here, as in all ultrasonic technologies, the received signal can be confused with scattering effects caused by local roughness of the inner surface. Zone monitoring methods do not provide the desired granularity and ease of data interpretation to be used to control naphthenic acid corrosion.
4. State-of-the-art multi-point mount technology provides high temperature resistance, local accuracy and critical area coverage, making it an ideal corrosion monitoring solution. Patented adaptive cross-correlation ultrasonic signal processing enables the onset of localized roughness and pitting to be detected with confidence, solving the ultrasound scattering problems that are insurmountable with all other ultrasonic

techniques. The latest generation of sensors are capable of providing an accuracy equivalent to «highly sensitive» intrusive probes, using temperature compensation, and allowing short-term corrosion rate changes to be measured with confidence, but without the added safety risks of maintenance personnel.

5. Installed in more than 200 sites around the world for more than 10 years, Permasense continuous corrosion and erosion monitoring systems have provided more than 26 million real-time measurements to make informed decisions to optimize and improve process safety.
6. Online monitoring of the technical condition of subsea pipelines is mainly carried out using a fiber-optic monitoring system and a remote corrosion monitoring system.
7. The main types of work during maintenance of subsea pipelines, as a rule, include external inspection, cleaning, measurement of the cathodic potential, thickness measurement, in-line diagnostics, etc. The frequency of these types of work is different. The main equipment performed during maintenance operations is remotely controlled underwater vehicles. Separately, it should be noted that the main scope of work in the maintenance of subsea pipelines is in-line diagnostics using multifunctional in-line inspection devices.
8. For the repair of subsea pipelines, methods of local reinforcement, replacement of a defective section, replacement of a defective section of a pipeline without stopping the flow by means of tapping under pressure, repair with compression composite couplings, etc. can be used, which allow to reliably eliminate most defects in the base metal and welded joints of the pipeline.

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Передовые технологии мониторинга коррозии в нефтехимической промышленности

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Реферат

На сегодняшний день коррозия - одна из самых острых проблем нефтедобывающей промышленности. Эффективным способом оценки коррозионного состояния оборудования является коррозионный мониторинг — система наблюдений и прогнозирования коррозионного состояния объекта с целью получения своевременной информации о его возможных коррозионных отказах. В статье представлен обзор современных передовых технологий мониторинга коррозии нефтепромыслового оборудования и подводных трубопроводов.

Ключевые слова: коррозия; мониторинг; волоконно-оптическая система.

Neftkimya sənayesində qabaqcıl korroziya monitorinq texnologiyaları

F.S.İsmayılov
«Neftqazelmitədqiqatlayihə» İnstitutu, SOCAR, Bakı, Azərbaycan

Xülasə

Korroziya bu gün neft sənayesinin ən aktual problemlərindən biridir. Avadanlıqların korroziya vəziyyətini qiymətləndirməyin təsirli bir yolu, korroziya monitorinqi - korroziyaya uğraması barədə vaxtında məlumat əldə etmək üçün bir obyektin korroziya vəziyyətini müşahidə etmək və proqnozlaşdırmaq üçün bir sistemdir. Məqalədə neft mədən avadanlıqlarının və sualtı boru kəmərlərinin korroziya monitorinqi üçün müasir qabaqcıl texnologiyaların ümumi icmalı verilir.

Açar sözlər: korroziya; monitorinq; fiber optik system.

