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Corrosion inspection and management in OKTA crude oil refinery

The appearance of corrosion presents a major issue in the petroleum industry. The corrosive deterioration is the main cause for the equipment and piping breakdown and failure, which reduces the process efficiency and increases the costs significantly. Also, failures due to corrosion pose a threat for the personnel, as well as for the environment. For these reasons, the corrosion inspection and management is an essential aspect of the management of every petroleum refinery.

The subject of this paper is the analysis of the main causes and the most common types of corrosion present in OKTA, as well as corrosion management. The corrosion detection is primarily done by visual inspection. The condition of the material is inspected with ultrasonic thickness measurement and defectoscopy, and hardness measurement. The equipment subjected to high-temperature conditions is inspected with IR camera. The inspection reports are used for corrosion rate determination, remaining life calculations and fitness for service.

Key words: *refinery, corrosion, inspection, corrosion management*

1. INTRODUCTION

Due to the different nature of the process fluids and various enviroments found in petroleum refining, corrosion is an inevitable part of the operating proecss. The various aspects of corrosion and its accompanying processes are responsible for the most of the equipment failures and damage. In addition, corrosion reduces the efficiency of the process and increases the operating and maintenance costs significantly. Based on national and company surveys, the cost in corrosion in refining ranges from \$0.14/bbl to \$1.34/bbl, with an average value of \$0.89/bbl [1].

As a result of the extremely hazardous nature of the fluids and gases processed in refineries, the safety and well being of both plant employees and the public are put at risk by corrosion. Equipment failures could result in severe damage to entire process units, as well as the environment. It was determined that corrosion was a factor in 21.5% of all reported accidents in refineries [2,3].

The cost reduction, health and safety of the personnel, as well as the protection of the environment are the three main causes for corrosion inspection and management.

2. TYPES OF CORROSION

There are many systems for classifying corrosion, but the most widely accepted categorization is the one of M. Fontana [4], which includes the following types of corrosion: uniform attack, galvanic (two-metal) corrosion, pitting, crevice corrosion, intergranular corrosion, selective leaching, erosion corrosion, stress corrosion and hydrogen damage. The advantage of this classification is that the corrosion type can be indentified visually, without laboratory analysis.

The corrosion manual from NALCO categorizes the corrosion according the chemical cause – carbon dioxide, oxygen, hydrogen sulfide, microorganism influenced, hydrochloric acid and naphthenic acid corrosion [5]. According to API RP 571, there are 63 different corrosion mechanisms occurring in refinery equipment [6]. Regarding the form, there are 15 types of corrosion in the petroleum industry [7].

However, there are several most common types of corrosion that can be found in OKTA Crude Oil Refinery: uniform corrosion, pitting, erosion and crevice corrosion. Crevice, galvanic, microbial corrosion and other types have also been detected.

3. CORROSION INSPECTION

Corrosion is determined and inspected by the following methods:

- Visual inspection,
- Ultrasonic thickness measurement,
- Ultrasonic defectoscopy,
- Hardness measurement,
- Infrared thermography.

The ultrasonic thickness measurement is done with 4 thickness gauges, Krautkramer DM4, the ultrasonic defectoscopy is done with phased array ultrasonics, Krautkramer Phasor XS, the hardness measu-

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rement is conducted with hardness metrer, Krautkramer DynaMIC, and the IR inspection is done with a camera, FLIR T-200.

The listed inspection methods are, usually, done in combination with each other, following the pattern showed of figure 1. The purpose of using of multiple methods is the obtaining of a more complete picture of the inspected equipment.

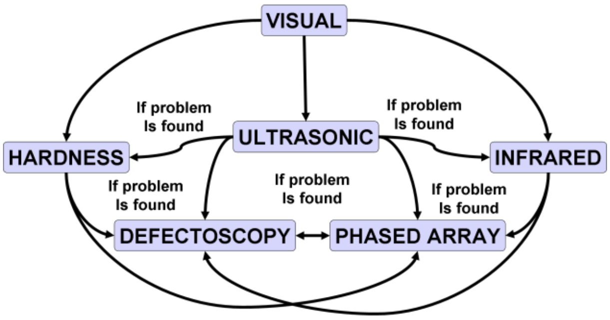


Figure 1 - Scheme for conducting equipment inspection

The first step is the visual inspection, which represents the basis for determinig whether a corrosion problem exists or not. If a problem is found, the next step is the inspection is the ultrasonic thickness meausrement. Depending of the temperature environment of the equipment, for high-temperature conditions, hardness measurements or IR inspection is done. If the problem is more complex, ultrasonic defectoscopy or phased array are applied.

In many cases, the corrosion damage of the equipment is internal. Then, the ultrasonic thickness measurement is the first step for detection of corrosion. The following steps are the same as the ones regarding external corrosion.

3.1. Visual inspection

The visual control is the first, basic step, but also it is the most important activity done on every inspection. The successfulness of the inspection depends primarily on the quality of the visual inspection; it is a determining factor of the direction which the inspection will take. After the visual inspection, it is decided whether additional activities are needed.

Depending of the type of equipment, accessibility, operating environment, etc., the visual inspection can be done externally or internally. The inspection of the external side reveals the corrosion caused by environmental influences, and the internal inspection can determine corrosive damage caused by the fluid used.

During the inspection, every evidence of corrosion is photographed, and the appearance and location of the surface in question is noted. Examples of external and internal visual inspection are given on fig. 2, showing the surface affected by corrosion under insulation on a heat exchanger head and the product-induced corrosion in a distillation column, respectively.

a) External

b) Internal

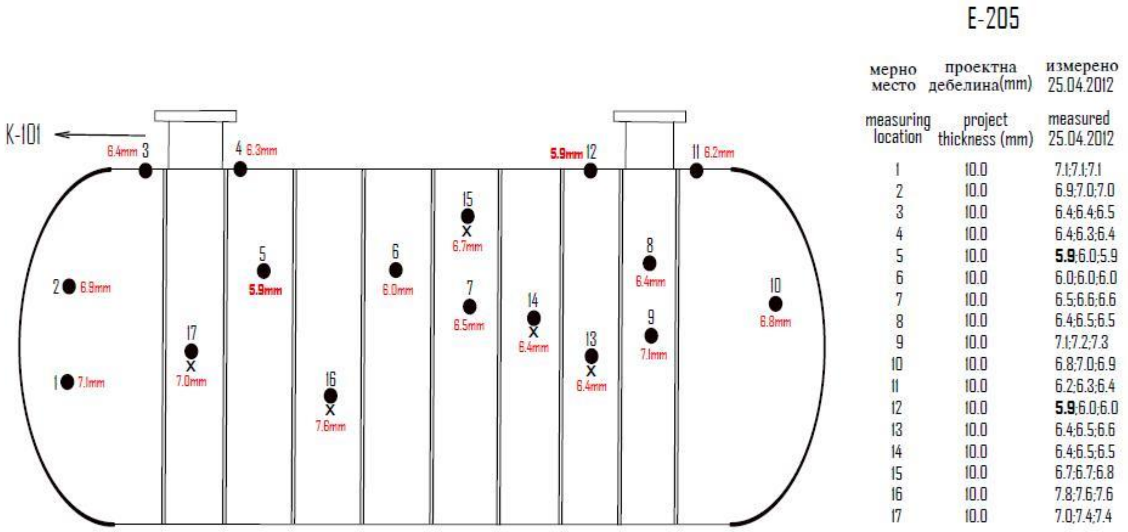
Figure 2 - Examples of visual inspection

The visual control, as a method of inspection, is a standard practice in all of the API (American Petroleum Institute) inspection standards [8-12], which are used in OKTA.

3.2. Ultrasonic thickness measurement

The ultrasonic thickness measurement is a basic method for determining a thickness reduction as a result of erosion or corrosion of the metal material. The thickness measurement is done on the most critical locations on the equipment, on specifically determined places. The determining of these locations is done both by experience (on equipment with previously established corrosion problems) and by the inspection standard requirements.

These ultrasonic thickness measurement results are not only providing an insight in the current state of the equipment, but the thickness chronology can also serve for determining of the corrosion rates, i.e. metal wall loss during operation, as well as for prediction of the remaining life of the vessel. An example of an ultrasonic thickness measurement report is given on figue 3.



E-205

мерно место measuring location	проектна дебелина(mm) project thickness (mm)	измерено 25.04.2012 measured 25.04.2012
1	10.0	7.1;7.1;7.1
2	10.0	6.9;7.0;7.0
3	10.0	6.4;6.4;6.5
4	10.0	6.4;6.3;6.4
5	10.0	**5.9**;6.0;5.9
6	10.0	6.0;6.0;6.0
7	10.0	6.5;6.6;6.6
8	10.0	6.4;6.5;6.5
9	10.0	7.1;7.2;7.3
10	10.0	6.8;7.0;6.9
11	10.0	6.2;6.3;6.4
12	10.0	**5.9**;6.0;6.0
13	10.0	6.4;6.5;6.6
14	10.0	6.4;6.5;6.5
15	10.0	6.7;6.7;6.8
16	10.0	7.8;7.6;7.6
17	10.0	7.0;7.4;7.4

Figure 3 - *Ultrasonic thickness measurement report for a pressure vessel*

The ultrasonic thickness inspection is regulated with the standard EN 583 [13], while the characterristic inspection areas on each type of equipment are separately given in the API standards [8-12].

3.3. Ultrasonic defectoscopy

This ultrasonic defectoscopy is used for determining of the type of defect, after it is found by another inspection method. This method allows us to discover defects in the base material and especially in the welds. The phased array mode of operation is an advanced inspection technique; it produces a 3D imaging of the defect, which gives a real representation of its type and location.

Sometimes, the thickness gauge records a thickness reduction in the metal, which is actually due to defect in the base material (inclusion, pore, etc.) and not a result of corrosion damage. In these cases, the ultrasonic defectoscope enables us to determine the true cause of the obtained thickness reduction result.

3.4. Hardness measurement

The measurement of the hardness is used when inspecting equipment exposed to high-temperature operating conditions. The hardness itself is not a direct indication of corrosion; however, the increase of the hardness results in increasing of the tensile strength and decreasing of the toughness and ductility of the metal. The impairment of some of the mechanical properties means that the calculated minimal thickness of the equipment is no longer valid. In fact, it could be drastically higher than the one calculated for a material not affected by high-temperature conditions.

Because of this, the inspection of the hardness is an important, if non-direct, method for assessment of corrosion damage.

3.5. Infrared thermography

Another non-conventional method for corrosion detection used in OKTA is the infrared thermography. Its primary use is for detection of thinned walls on pipes, compressors, etc. operating under high-temperature conditions. The advantage of the IR thermography is that it enables us to scan the pipes relatively fast and detect the locations with reduced thickness via the higher temperatures reported in these areas. The determined areas can then be evaluated in terms of thickness reduction with ultrasonics. However, this method is limited only to high-temperature, uninsulated equipment, which is not common in the oil refineries. Also, the corrosion damage on the walls has to be sufficient, so that a temperature gradient appears, which can be recorded with an IR camera.

The infrared thermography can also be used as a method for corrosion prevention. Its ability for detecting temperature differences enables us to find poorly insulated areas on the piping, which, if not repaired, can lead to collecting and trapping of water. This, in turn, can cause appearance of corrosion.

4. CORROSION PREDICTION AND INSPECTION PLANNING

The information regarding the equipment corrosion are collected, analyzed and stored in the Technical Inspection database. In the electronic database, there is a file referring to each piece of process equipment, containing the following information:

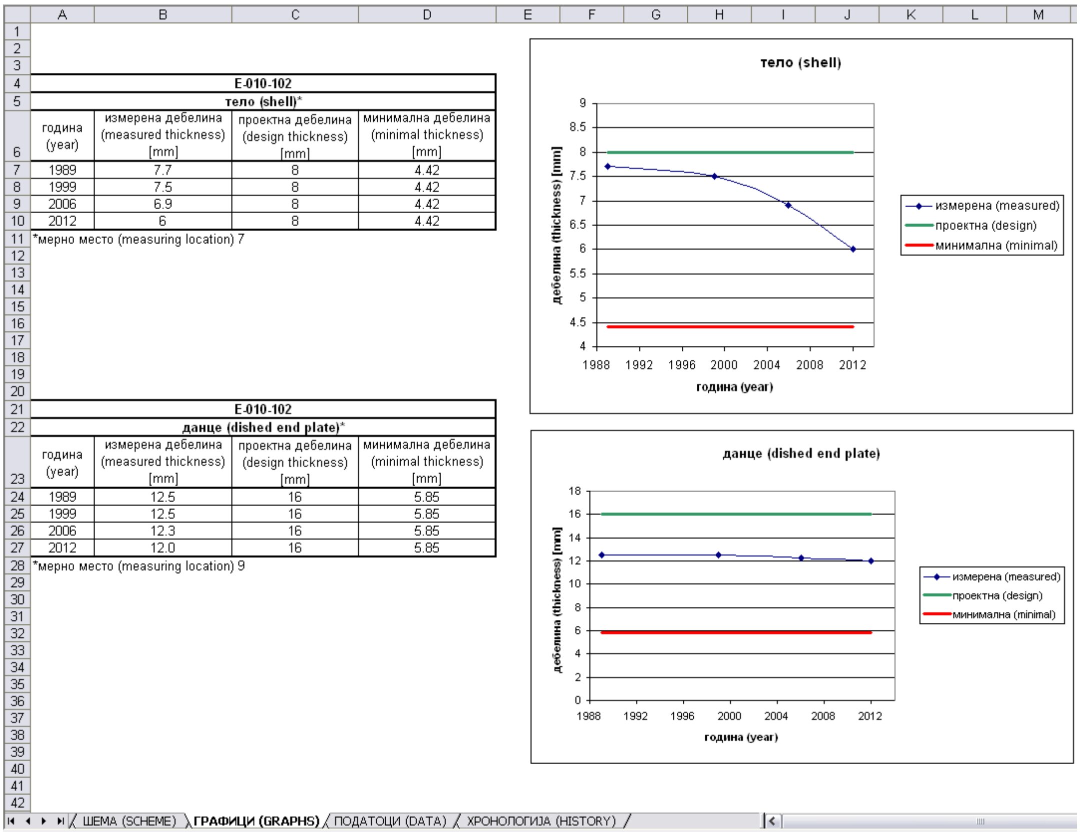
1. Technical data. This section contains the technical and technological data of the vessel – production year, steel grade, maximal operating temperature, operating and test pressure, type of product, etc. Also, the types of corrosion affecting the vessel according to API 571 [6], as well as the aggressiveness of the fluid, are included.

2. Technical drawing. The drawing contains the dimensional properties of the vessel, as well as the measuring locations.

3. Chronology of thickness measurements. This section contains the measuring locations, design thickness, minimal allowed thickness, and a column with the measured thickness and the date of the measurement. The minimal thickness is calculated according to ASME Code, Section VIII – Division 1 [14].

4. Graphic presentation of the data. Here, the measured values, i.e., one measurement from every characteristic location on the vessel (head, shell, nozzle, etc.) with the largest thickness reduction are taken as reference points. An example of the graphic presentation of the chronological thickness data is given on fig. 4.

5. Vessel history data. This section contains several basic types of information, but it is designed to accommodate any type of data that is considered important. For instance, information such as the dates of the vessel hydro-testing, inspections done by third-party companies, repairs of the insulation and/or paint coating, installing, replacement or repair on major vessel parts (or minor ancillary equipment), etc. are included here.



E-010-102			
тело (shell)*			
година (year)	измерена дебелина (measured thickness) [mm]	проектна дебелина (design thickness) [mm]	минимална дебелина (minimal thickness) [mm]
1989	7.7	8	4.42
1999	7.5	8	4.42
2006	6.9	8	4.42
2012	6	8	4.42

*мерно место (measuring location) 7

E-010-102			
данце (dished end plate)*			
година (year)	измерена дебелина (measured thickness) [mm]	проектна дебелина (design thickness) [mm]	минимална дебелина (minimal thickness) [mm]
1989	12.5	16	5.85
1999	12.5	16	5.85
2006	12.3	16	5.85
2012	12.0	16	5.85

*мерно место (measuring location) 9

Figure 4 - Graphic presentation of thickness reduction on the shell and head of a pressure vessel

This data can serve for scheduling of the inspection activities, as well as for risk-based inspection. Risk-based inspection (RBI) is a method for using risk as a basis for prioritizing and managing the efforts of an inspection program, in accordance with the risk associated with a certain piece of equipment [15]. When the risk of a vessel is calculated, multiple factors should be taken in consideration – corrosion rate, operating conditions, the aggressiveness/hazardousness of the fluid, etc. Usually, a vessel is considered to be of medium or high risk when, according to the other conditions and the corrosion rate, the inspection interval should be shorter than the one given in the inspection standards.

The graphically presented data can show the condition of the equipment from aspect of corrosion. With the adding of a mathematical trendline, depending of the obtained curves, the remaining life of the equipment can be easily calculated. This is presented on figure 5.

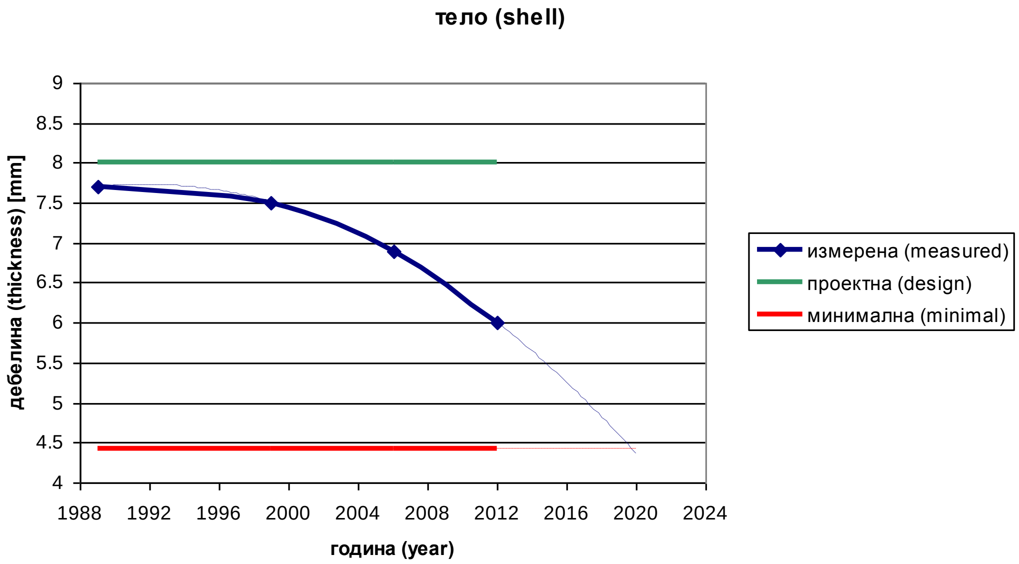


Figure 5 - Calculation of remaining life of a pressure vessel

Often, the data points are not forming even curves – some of the points can be higher, in comparison to the expected values by the overall trend of the curve. This is due to the nature of the ultrasonic measurement; it is very difficult to make the measurement on the identical location as previously. This variation of the thickness can present a problem for calculating of the remaining life, if there are not sufficient history data for the vessel. However, in most of the cases, the data from the previous years of measurement is more than enough for establishing the correct remaining life.

Nonetheless, this method of collecting and presenting of the thickness reduction data gives invaluable information regarding the corrosion. In turn, the information is essential for inspection planning.

The managing of corrosion is done mainly by identifying and minimizing of the causes. For this purpose, the previously collected and analyzed corrosion data are used.

5. CONCLUSION

The corrosion inspection of the equipment in OKTA Crude Oil Refinery is one of the key factors for providing continuous production process and safe working environment. The corrosion inspection and management is accomplished with the following activities:

Inspection of the equipment, which includes quantitative and qualitative assessment of the corrosion and corrosion associated damage i.e., is corrosion present and what is the degree of its severity.

Analysis of the equipment data, which involves a few steps. First, the corrosion rate is determined, by comparing the latest and previously collected data regarding the equipment in question. Then, considering the corrosion rate, amongst other risk factors, the risk category of the equipment is determined. Based on the corrosion rate, the remaining life of the equipment is calculated. Finally, depending on the previous two activities, it is decided whether the equipment is fit for service.

The following of this procedure for inspection and data analysis gives us a detailed picture of the current state of the equipment, as well as a good idea for the future measures and activities that should be taken for prevention and minimizing of corrosion and corrosion-related issues.

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IZVOD

INSPEKCIJA I UPRAVLJANJE KOROZIJOM U RAFINERIJI NAFTE OKTA

Pojava korozije predstavlja veliki problem u naftenoj industriji. Oštećenja usled korozije su glavni razlog za pojavu defekata opreme i cevovoda, što utiče na smanjenje efikasnosti procesa i značajno uvećava troškove. Takođe, defekti prouzrokovani korozijom predstavljaju opasnost za zaposlene, kao i za okolinu. Zbog ovoga, inspekcija i upravljanje korozijom pretstavljaju ključni aspekat menadžmenta svake rafinerije nafte.

Tema ovog rada je analiza glavnih uzroka i najčešćih tipova korozije koji se sreću u rafineriji OKTA, kao i upravljanje korozijom. Detekcija korozije se uglavnom obavlja putem vizuelne kontrole. Stanje materijala se ispituje ultrazvučnim merenjem debljine i defektoskopijom kao i merenjem tvrdoće, dok se oprema podložena visokotemperaturnim uslovima ispituje infracrvenom kamerom. Inspekcijski izveštaji se koriste za određivanje brzine korozije, proračune preostalog vremena upotrebe opreme i ispitivanje pogodnosti za korišćenje.

Ključne reči: *rafinerija, korozija, inspekcija, upravljanje korozijom*

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