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REMAINING LIFE DETERMINATION FOR PRESSURE VESSEL IN A REFINERY

PROCENA PREOSTALOG VEKA POSUDE POD PRITISKOM U RAFINERIJI

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Keywords
- pressure vessel
- remaining life
- inspection
- welding

Abstract

Repair and inspection has been performed on a pressure vessel in the oil refinery for downstream treatment of crude oil in Iraq, without technical documentation. Two different approaches have given totally different results for further operation of the vessel. One option is to put the vessel out of service, while the other is to keep the vessel in operation. The remaining life is determined in accordance with API standards.

Ključne reči
- posuda pod pritiskom
- preostali vek
- inspekcija
- zavarivanje

Izvod

Prikazana je inspekcija i popravka posude pod pritiskom u rafineriji u Iraku, za koju nije postojala tehnička dokumentacija. Dva različita pristupa su dala suprotne zaključke o daljoj upotrebi posude. Jedna varijanta je da se posuda isključi iz dalje upotrebe, a druga je da se nastavi njena upotreba. Preostali vek je procenjen na osnovu API standarda.

INTRODUCTION

Pressure equipment in all Middle East region is under jurisdiction of the American Petroleum Institute (API) standards /1-3/, whereas the Pressure Equipment Directive (PED) is valid for Europe, including Serbia. Inspection has been performed for pressure vessels for removing salts from crude oil, i.e. a desalter. The desalter unit is positioned between the first and the second separator. Inspection is difficult due to missing technical documentation, including previous inspection records and design calculations. Data for minimum necessary thickness (t_{min}) is not available, as well. With variation of these data, results could be both positive and negative in terms of allowable usage of the desalter. The design standard and t_{min} are one of necessary data for the Fitness For Service (FFS) evaluation.

DESALTER

Technical data

Main technical data for a desalter is presented in Table 1.

Inspection of desalter

Inspection has been performed by a contractor in the presence of an owner representative, API 510 inspector. Two NDT methods are carried out: the ultrasonic testing method (UT) for volumetric irregularities; and the magnetic particle testing method (MT) for surface and near surface irregularities. The UT method has not found any irregularities, but the MT method has located 32 cracks including both local single cracks and net of cracks (mesh of cracks). Cracks are shown in Figs. 1-8. Results of inspection have demanded necessary repair in accordance to /1/.

Table 1. Technical data.

Manufacturer	HEAVY ENGI. EQUIPM.
Year of Construction	2008
Shell Material Specific	ASTM A 516 Gr 70
Head Material Specific	ASTM A 516 Gr 70
Design Pressure	13.24bar
Design Temperature	100 °C
Working Fluid	Hydrocarbons
Welding process	SAW / SMAW
Max Tested Pressure	17.41 bar
Volume	150 m3
Diameter internal	3400 mm
Orientation	Horizontal
Construction Code	ASME VIII Div 1
Nominal Shell Thickness	26 m
Nominal Head Thickness	27 mm
Corrosion allowance	3 mm
Isolation	50 mm
Heat treatment	NO
Type Heads	Ellipsoidal
Flange class	150÷300#
Tangent length	13500 mm

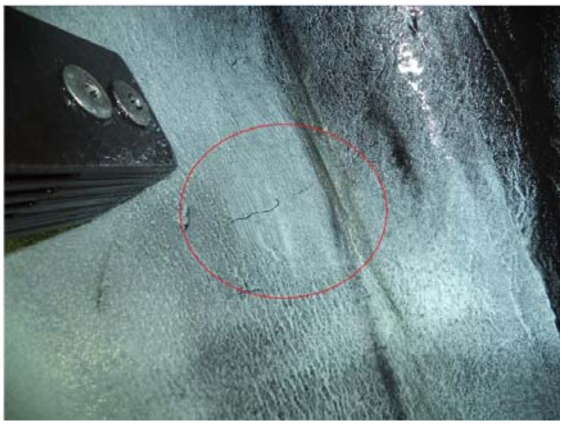
Figure 1. Crack detected by MT.


Figure 2. Crack detected by MT.


Figure 3. Crack detected by MT.


Figure 4. Crack detected by MT.


Figure 5. Crack detected by MT.

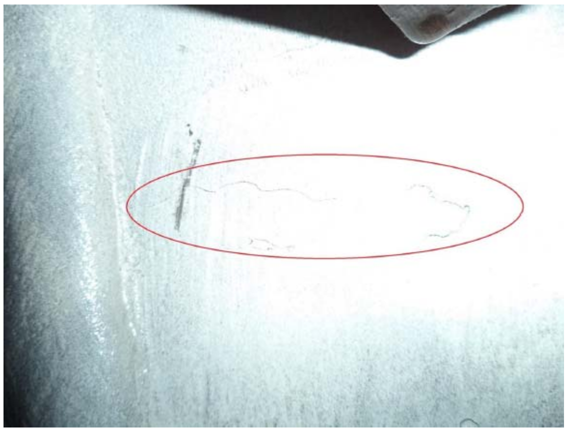
Figure 6. Crack detected by MT.


Figure 7. Crack detected by MT.


Figure 8. Crack detected by MT.

CLASSIFICATION OF CRACKS

Cracks are classified in accordance to /2/ as carbonate stress corrosion cracking (often referred to as carbonate cracking). It is the term applied to surface cracks that occur adjacent to carbon steel welds under the combined action of tensile stress in systems containing a free water phase with carbonates, where some amount of H_2S is also present. It is a form of Alkaline Stress Corrosion Cracking (ACSCC).

This type of damage has also been observed in other environments which are outside the scope of this paper. Those environments include the outside surface of buried pipelines; and piping and equipment containing aqueous carbonate solutions (e.g. potassium carbonate) used in the carbon dioxide (CO_2) removal facilities associated with hydrogen reformers.

PROCEDURE FOR CRACK REPAIR

Cracks have been repaired by a four steps procedure:

1. Mechanical removal of cracks by grinding. Drilling holes is necessary only if hardness is high. Start grinding without drilling. If crack continues to expand, perform drilling before grinding, otherwise, do not.
2. Perform MT for 100% of removal area to confirm cracks are removed and the area is completely sound.
3. Perform welding of in removal area in accordance to qualified Welding Procedure Specification (WPS).
4. Perform MT and UT for 100% welding of removal area.

MINIMUM THICKNESS REQUIREMENTS

To evaluate the remaining life of any equipment, minimum thickness is necessary. As mentioned in the introduction, data is not available. The minimum required thickness is presented in Tables 2 and 3 below. Calculation bas been done according to two standards: ASME Section VIII Division 1 and EN 13445-3, with variation of joint efficiency (E). Joint efficiency is a function of NDT. Only values for shell and heads are analysed.

Inputs:

$t_{required}$ – minimal required thickness (in)
P – design pressure (psi)
R – inside radius (in)
S – maximum allowable stress value (psi)
E – joint efficiency

Shell

$$t_{required} = \frac{P \cdot R}{S \cdot E - 0.6P} = \frac{192.02 \cdot 66.93}{20000 \cdot 1 - 0.6 \cdot 192.02}$$

$t_{required}$ = 0.647 in. ($t_{required}$ = 16.43 mm)

Heads

$$t_{required} = \frac{P \cdot D}{2S \cdot E - 0.2P} = \frac{192.02 \cdot 133.86}{2 \cdot 20000 \cdot 1 - 0.2 \cdot 192.02}$$

$t_{required}$ = 0.643 in. ($t_{required}$ = 16.33 mm)

Table 2. Shell minimum thickness (mm).

Joint efficiency	ASME Section VIII Division 1	EN 13445-3
$E = 1$	16.45	14.21
$E = 0.85$	19.37	16.73
$E = 0.7$	23.55	20.34

Table 3. Heads minimum thickness (mm).

Joint efficiency	ASME Section VIII Division 1	EN 13445-3
$E = 1$	16.37	16.01
$E = 0.85$	19.26	16.01
$E = 0.7$	19.26	16.01

During inspection activities, ultrasonic measurement of thickness is performed. The minimal measured value is 17.18 mm.

CORROSION RATE

In order to calculate the remaining life, the data for corrosion rate are necessary. Hereunder is presented the determination of the corrosion rate for the shell and heads in accordance to /1/.

Corrosion rate for shell – long term, CR(LT):

$$\text{CR(LT)} = \frac{t_{initial} - t_{actual}}{\text{time between } t_{initial} \text{ and } t_{actual} \text{ (years)}}$$

$$\text{CR(LT)} = \frac{26 - 17.18}{6.2} = 1.42 \ \frac{\text{mm}}{\text{year}}$$

The initial thickness, $t_{initial}$, is taken from manufacturing data for both shell and heads. The actual thickness, t_{actual}, is the measured value during inspection activities.

Corrosion rate for shell – short term, CR(ST):

$$\text{CR(ST)} = \frac{t_{previous} - t_{actual}}{\text{time between } t_{previous} \text{ and } t_{actual} \text{ (years)}}$$

$$\text{CR(ST)} = \frac{20 - 17.18}{2.2} = 1.28 \ \frac{\text{mm}}{\text{year}}$$

$t_{previous}$ is taken from one single available inspection report from date 14.12.2012 for both shell and heads.

Corrosion rate for heads – long term CR(LT):

$$\text{CR(LT)} = \frac{t_{initial} - t_{actual}}{\text{time between } t_{initial} \text{ and } t_{actual} \text{ (years)}}$$

$$\text{CR(LT)} = \frac{27 - 21.34}{6.2} = 0.91 \ \frac{\text{mm}}{\text{year}}$$

Corrosion rate for heads – short term CR(ST):

$$\text{CR(ST)} = \frac{t_{previous} - t_{actual}}{\text{time between } t_{previous} \text{ and } t_{actual} \text{ (years)}}$$

$$\text{CR(ST)} = \frac{22.8 - 21.34}{2.2} = 0.66 \ \frac{\text{mm}}{\text{year}}$$

REMAINING LIFE

Remaining life (RL) for shell:

$$\text{RL} = \frac{t_{actual} - t_{required}}{\text{CR(ST)}} = \frac{20 - 16.43}{1.28} = 2.8 \text{ years}$$

Remaining life for heads:

$$\text{RL} = \frac{t_{actual} - t_{required}}{\text{CR(ST)}} = \frac{22.8 - 16.33}{0.66} = 9.8 \text{ years}$$

REFERENCES

1. Standard API 510 Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, American Petroleum Institute, 2014.
2. Standard API RP 571, Damage Mechanisms Affecting Equipment in Refining Industry, American Petroleum Institute, 2011.
3. Standard API RP 572, Inspection of Pressure Vessels, American Petroleum Institute, 2011.

16TH INTERNATIONAL CONFERENCE ON NEW TRENDS IN FATIGUE AND FRACTURE – NT2F16 – *Fatigue and Fracture at all Scales*

Dubrovnik, Croatia, May 24 - 27, 2016

NT2F16 brings together scientists and engineers from around the world to discuss how to characterize, analyze, predict and asses the fatigue and fracture of structural materials and components. NT2F16 intends to be a forum for discussion of the present and future trends in experimental, analytical and numerical fracture mechanics, fatigue, structural integrity assessment, failure analysis, and other important topics in the field. Special focus will be given on multi-scale and multi-physics approaches, applications to new materials and environmental effects.

A two-days School on fatigue and fracture modeling and analysis will be organized prior to the Conference, along with a roundtable discussion on how to teach fracture mechanics in the future.

Topics

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- Low, medium and high cycle fatigue
- Simulation and testing of crack propagation at all length scales
- Finite elements methods and their application
- Damage mechanics and models
- Microstructure scale computational modeling
- Macro scale fatigue prognosis techniques
- Multiscale materials modeling
- Multiaxial/mixed mode loading
- Fatigue crack path prediction
- Effect of residual stresses
- Fatigue and fracture of weldments, welded components, joints and adhesives
- Fracture and failure criteria
- Analytical Models
- Probabilistic Fracture Mechanics
- Reliability and Life Extension of Components
- Corrosion, environmentally enhanced degradation and cracking, corrosion fatigue
- Fracture and damage of cementitious materials
- Fatigue and fracture of polymers, elastomers, composites and biomaterials
- Advanced crack monitoring techniques
- Reliability and integrity of engineering structures
- Applications to components and structures

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Plenary Lectures

Guy Pluvinage, Prof. Emeritus, Metz University, ENIM-LaBPS, France
'The CTOA as a Parameter of Resistance to Crack Extension in Pipes Submitted to Internal Pressure'

Siegfried Schmauder, Prof. Dr. rer. nat., University of Stuttgart, Institute for Mater. Testing, Mater. Science and Strength of Materials (IMWF), Germany
'Recent Trends in Multiscale Materials Modelling'

Neil James, Prof., University of Plymouth, School of Marine Science & Engineering, Co-Editor of the Int. J of Fatigue
'Damage Assessment and Refurbishment of Steam Turbine Blade/ Rotor Attachment Holes'

Yury Matvienko, Prof., Russian Academy of Sciences, Mechanical Engineering Research Institute
'Two Basic Approaches in a Search of the Crack Path'

Publications

Accepted abstracts will be published in the Book of Abstracts.
Full papers will be published on electronic media with an ISBN number.
Authors of selected papers will be invited to submit extended versions for publication in peer reviewed special issues of supporting journals.
Selected papers presented at the NT2F16 Conference will be published in a Special Issue of *Fatigue & Fracture of Engineering Materials & Structures* (FFEMS), and also in a Special Issue of *Materialwissenschaft und Werkstofftechnik / Materials Science and Engineering Technology*.

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