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Corrosion inspection and protection of diesel storage tank

The standard corrosion inspection of the process equipment in the OKTA Crude Oil Refinery in Skopje include control of all pressure vessels and storage tanks in the refinery. As a part of the standard inspection activities, an inspection of storage diesel tank was done. The inspection consists of visual control and ultrasonic thickness measurements during the course of time. The obtained thickness values on predetermined locations were than compared to the required standard values.

After that, an analysis of the causes of corrosion was done. The possible corrosion mechanisms that appear on some sections of the tank were determined. The tank is constructed from two types of structural carbon steel, which makes it more susceptible to corrosion.

At the end, the critical sections of the tank were repaired, with replacing of the corroded steel sheets with new, and a suitable corrosion protection with coating was made.

The obtained results expanded our knowledge about the appearance of corrosion on these types of storage tanks. This way, the acquired experience for these inspection activities present a good basis for future mre efficient corrosion protection of tanks.

Key words*: corrosion, diesel storage tank, characterization, protection.*

1. INTRODUCTION

The storage tanks in OKTA Crude Oil Refinery are designed for storage of derivatives. The tanks are constructed from steel, located on open space and with that, susceptible to corrosion over the course of time. The tank is exposed to atmospheric corrosion on the external surfaces [1]. The interior of of the tank is exposed to the influence of the water collecting on the tank bottom [2-4]. The appearance and expansion of corrosion is also helped by sulphur reducing bacteria present in the diesel fuel [5-7].

The entire tank is constructed from large number of rectangle and circular steel sheets, welded together, which means that the welded connections are especially susceptible to corrosion. From the internal tank surface, the most threatened is the bottom, constructed in a way for more efficient draining which enables retention of water on the tank bottom. Concerning the external surfaces, the most susceptible to corrosion is the tank's fixed roof, which is exposes to rain and atmospheric conditions [8,9].

It should be emphesized that the tank is in usage from 1982 and that it was not protected against corrosion in any way.

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2. EXPERIMENTAL

2.1. Storage tank construction

The tank is cylindrical in shape, with a height of 19,22 m and a diameter of 28,5 m. The volume of the tank is 10000 m^3. The tank bottom, with circular shape, is constructed from 3 types of steel sheets pie-ces, welded together. The appearance of the tank bot-tom and the layout of the steel sheets is presented on Figure 1 [4].

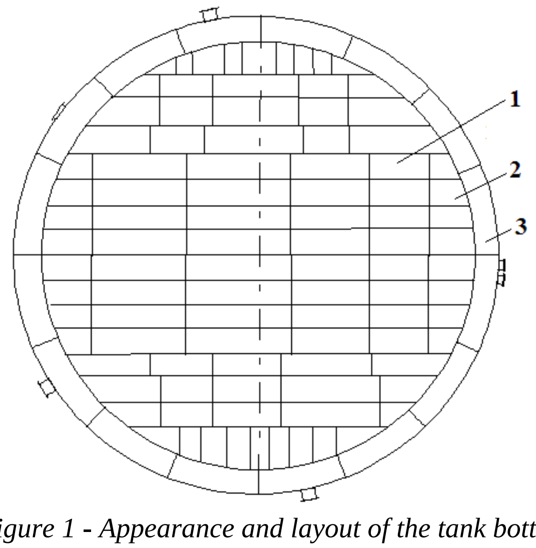

Figure 1 - Appearance and layout of the tank bottom sections; 1- rectangular sheets, 2 - irregular rectangular sheets, 3 - annular ring sheets

There are 50 rectangular sheets with thickness of 5 mm (designated with 1 on Fig.1) and 46 sheets with irregular shape – with three rectangular sides and one semicircular, on the borderline with annular ring (designated with 2 on Figure 2), are also with thickness of 5 mm. Around these sheets, there is an annular ring of 16 steel sheets, with rectangular, vaulted shape (marked with 3 on Fig.1) with thickness of 9 mm. In this way, 112 sheets, welded together, make an ideal circular tank bottom [10-13].

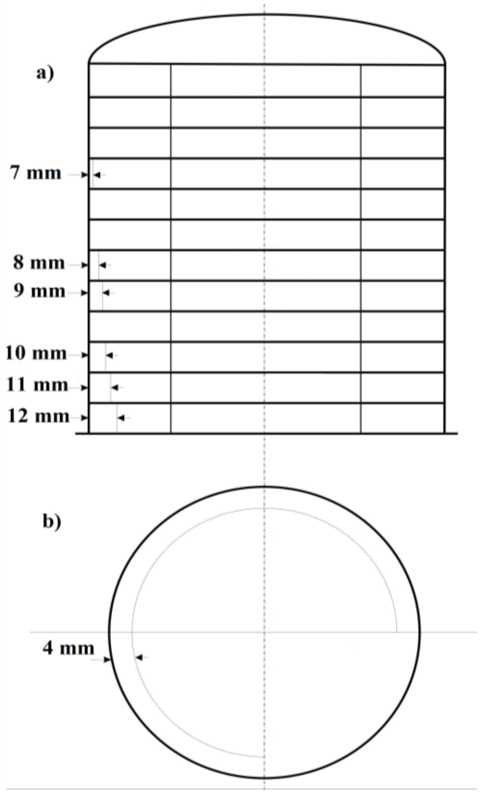

Figure 2 - Shape of the tank a) side view b) top view

The thickness of the shell varies from 7 to 12 mm, starting from the top to the bottom (Figure 2a), while the fixed roof thickness is 4 mm (Figure 2b).

2.2. Storage tank construction material

The storage tank is constructed from 2 types of structural carbon steels. The central section of the tank bottom is constructed from steel Ст3пс, according to the Russian standard ГОСТ 380-71 and it is most similar to A284 Gr. D steel, according to ASTM standards [14, 15]. This type of steel falls in structural carbon steels. The annular ring is constructed from steel Ст3сп, according to the same Russian standard ГОСТ 380-71. It falls in structural carbon steels with normal quality, and its properties and chemical composition are most similar to A283 Gr. D steel, according to ASTM standards. The chemical composition of both steel grades in given in Table I [16].

The mechanical and technological properties of these steel grades are presented in Table II [17]. As can be seen from Table I and II, both steel grades have very similar chemical composition and properties. The Ст3сп steel (A283 Gr. D) has a somewhat lower coper content and slightly higher tensile strength characteristics [17-19].

Table I. Chemical composition of the steel grades used in the storage tank construction

Steel grade	**Content, mass %**					
	C	**Si**	**Mn**	**P, max**	**S, max**	**Cu**
Ст3пс (ГОСТ 380-71) A284 Gr. D (ASTM)	0,14-0,22	0,05-0,15	0,4-0,65	0,04	0,05	0,3
Ст3сп (ГОСТ 380-71) A283 Gr. D (ASTM)	0,14-0,22	0,05-0,15	0,4-0,65	0,04	0,05	0,2

Table II. Mechanical and technological properties of the steel grades used in the storage tank construction

Steel grade	**Reh, MPa**	**Rm, MPa**	**δ_5, %**	**HB, MPa**	**Weldability**
Ст3пс (ГОСТ 380-71) A284 Gr. D (ASTM)	205-245	370-480	23-26	131	Good
Ст3сп (ГОСТ 380-71) A283 Gr. D (ASTM)	205-255	370-490	23-26	131	Good

3. RESULTS AND DISCUSSION

3.1. Visual inspection of the tank

First, a visual inspection of the external and internal steel surfaces of the tank was done. On the external sections there were no notable signs of corrosion, except on a few locations, lightly dented, where the indentation enabled retention of water, which, in return resulted with appearance of corrosion. This of course concerns the tanks fixed roof, which is the most exposed part to atmospheric influences.

Because of the specific construction, apropriate for most efficient draining, the tank bottom's annular ring is the lowest point. Unfortunately, this type of construction also enables the water, which accumulated in the tank during a longer period of time, to retain on the bottom of the tank, increasing the chances for corrosion appearance and expansion. In the interior of the tank, there were notably corroded locations, mostly on the lower tank bottom sections, where water was collecting, as well as on some of the welds, also on the lower sections. Before the inspection, cleaning and sandblasting of the tank bottom was done, to remove the derivative sludge, as well as the corrosion products.

The inspection showed that 37 sheets have lower thickness than the allowed, which is 33% from the total number of steel sheets. On Figure 3 a schematic presentation of the tank bottom is given, with the corroded sections highligthed.

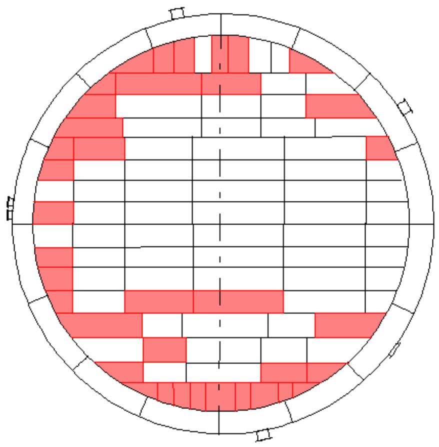

Figure 3 - Scheme of the locations on the tank bottom with expressed corrosion and lower that allowed thickness

As can be seen on Figure 3, the corrosion is located mostly on the lower tank bottom section, next to the annular ring. Some of the characteristic corrosion types are presented in the following section: appearance of corrosion (Figure 4), thickness reduction of the tank bottom caused by corrosion (Figur 5), appearance of pitting corrosion on the tank bottom annular ring, with reduced thickness of 1,4 mm (Figure 6) and corrosion on the central section of the tank bottom, near the welded joint of two sheets (Figure 7**).**

Figure 4 - Tank bottom section with visible appearance of corrosion

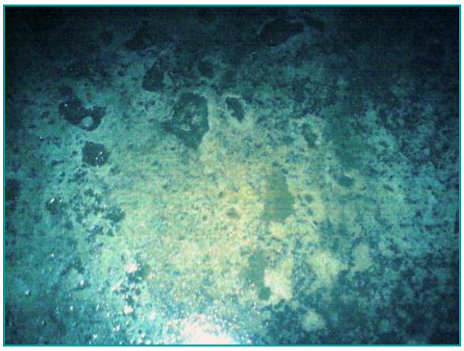

Figure 5 - Appearance of tank bottom section with visible thickness reduction due to corrosion

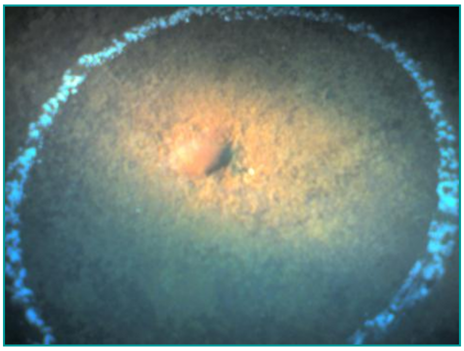

Figure 6 - Appearance of pitting corrosion on the tank bottom annular ring

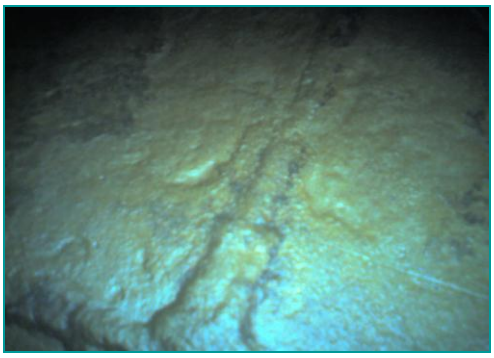

Figure 7 - Corrosion on the welded joint of two steel sheets

3.2. Thickness inspection of the tank bottom, shell and fixed roof

After the visual control of the tank steel sheets, on the locations with established expressed corrosion, thickness measurement was done. For thickness measurement, an ultrasonic thickness measurment device of the type Krautkramer DM-4 was used.

Measurements were done on a total of 269 locations on the tank surfaces (Table III). Most of the measurements were taken on the tank bottom - 232, with each section of the bottom measured at least once and at most three times. On the other parts of the tank, 37 measurements were done. On each measuring location the measurement was repeated 3 times, with the smallest measured value taken as valid. The results from the measurements are presented in Table III.

Table III. Review of the number of measurements and measured values on selected sections of the tank

Tank section	Taken measurements	Measured thickness					
		A - equal with the design		B - between the design and allowed		C - less than allowed	
		No.	%	No.	%	No.	%
Tank bottom, central section	194	40	20,6	137	70,6	17	8,8
Tank bottom, annular ring	38	6	15,8	28	73,7	4	10,5
Shell	31	18	58,6	12	38,7	1	3,2
Fixed roof	6	3	50,0	3	50,0	0	0

For better view of the data, the measured thickness values of selected sections of the tank are shown as histograms on Figure 8-11. Knowing the design thicknesses of the tank and having in mind the minimal allowed standard thickness [9], all measured values are divided in 3 groups: values in accordance with the design thickness and are still equal with them (noted with A on the histograms), values smaller than the allowed (critical) thickness (noted with C on the histograms) and values located between these two groups (noted with B on the histograms).

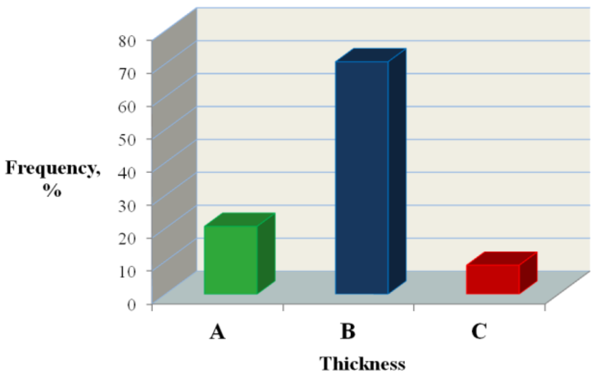

Figure 8 - Values of measured thicknesses on the central tank bottom section

The taken measurements show that the most expressed corrosion is present on the tank bottom: from total of 232 measurements done on the steel sheets, on 186 a thickness reduction due to corrosion was found, which is over 72% (Fig.8). From them, it was necessary to replace 21 sheets, which represents 9,65%. It was noted that the corrosion is most expressed on the peripheral sheets, as well as on the sheets of the annular ring (Fig.9). This is due to the design of the tank bottom itself, which has a high point in the middle and low points on the ends, which enables collecting and retaining of water.

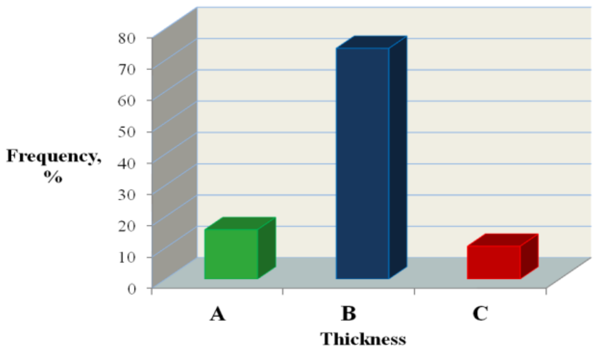

Figure 9 - Values of measured thicknesses on the tank bottom annular ring

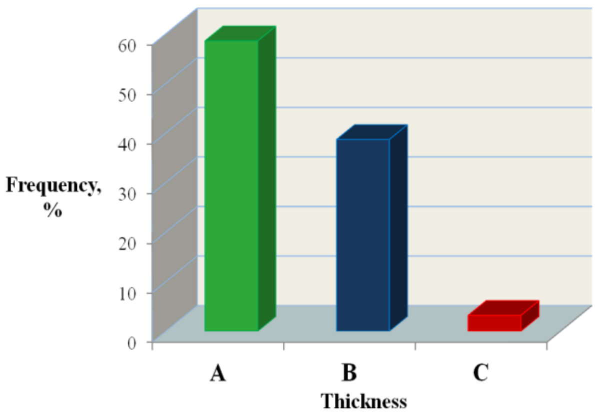

Figure 10 - Values of measured thicknesses on the tank shell

The fixed roof of the tank is in relatively good condition. The thickness remained unchanged on 50% of the measured locations, while on the others the thickness was slightly reduced – from the design 4 mm, the thickness was reduced from 0,1 to 0,3 mm (Fig.10).

The shell of the tank showed the smallest thickness reduction – on 58,6% the thickness remained unchanged, on 38,7% a small thickness reduction was recorded, and only on one location the thickness reduced from the design 12 mm for 0,8 mm (Figure 11).

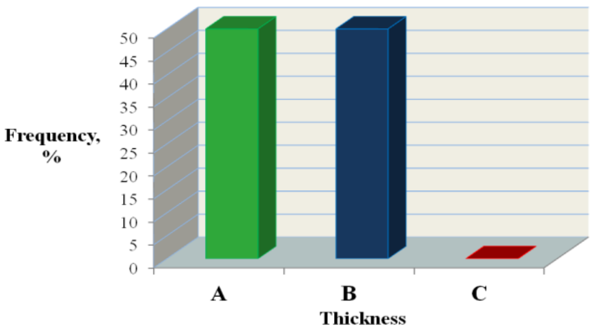

Figure 11 - Values of measured thicknesses on the tank fixed roof

A the end, it should be emphasized that this type of storage tank is designed with operative life of twenty years. With on or only small repairs done after each inspection every five years, the tank is in active usage for 30 years, which, by itself, is a satisfying result by itself.

3.2.1. Corrosion mechanisms

It is well known that corrosion is the main cause for deterioration of the storage tank metal structure. It can be caused by external, atmospheric attack, as well as corrosion mechanism from the interior, caused by the storage product and the condition inside the tank itself [4, 13, 20]. The detected corrosion in the tank is uneven, localized and mostly in the form of pitting corrosive attack. The main cause for appearance of corrosion in the tank Is the presence of water.

On the exterior, the corrosion is mostly expressed on the tank fixed roof, which is directly exposed to atmospheric influence. The water from the atmosphere is collected in the dented surfaces of the roof and other appurtenances (platforms, stairways, ventilation openings etc.). The retention of water on these surfaces causes appearance of local corrosion, which was established during the visual inspection.

In the interior of the tank water can come from the atmosphere, but a part of the water comes from the diesel fuel itself. It is a natural property of diesel to, in relation to other fuels, cause bigger problems related to appearance of moisture in the storage tanks. Diesel fuel is heavier than gasoline and because of that its evaporation point is much lower than the one of the gasoline. The lower evaporation point allows air and moisture to enter the tank much faster than in gasoline storage tanks. Also, because is less refined than gasoline, diesel fuel contains a greater quantity of suspended water. All this water in the tank is collected on the bottom. The presence of water on the tank bottom, especially over a longer period of time, together with the impurities from the fuel, causes localized corrosion. Even the allowed quantity of moisture in the diesel is enough to initiate growth of microbiological colonies. Different analysis have shown that over 100 different types of bacteria, yeasts and filament fungi are present in diesel fuel [21, 22]. Their presence does not influence the quality and properties of diesel, but has a harmful effect on the storage and transport equipment. It is especially misfortunate that the appearance of bacteria in the presence of water and oxygen causes appearance of new bacteria, carbon dioxide and new quantities of water. This way, at the course of time, more and more water is created in the tank, and with that, a better environment for appearance and spreading of corrosion.

4. CONCLUSION

The appearance of corrosion during the regular inspection of a diesel storage tank was analyzed. Visual inspection and ultrasonic thickness measurement were applied.

From a total of 269 measurements, on 25% of the steel sheets a thickness equal with the design was found, on 67% lower thickness than the design, but in the allowed limits was detected and on 8% of the sheets a thickness lower thickness than the standard allowed was found.

The inspection activities done pointed to the most critical sections of the tank in terms of corrosion. The corrosion is most expressed on the tank bottom, less on the roof and it is rarest on the tank shell. The corroded steel sheets with thicknesses lower than the standard allowed were replaced with new.

The corrosion mechanisms detected with the performed inspections are: uneven (local), pitting, bacterial and atmospheric corrosion.

On the basis of the performed inspection, it was established that the tank bottom and the interior of the shell, to the height of 1 m, as the most critical sections of the tank, should be protected with appropriate epoxy protective coating.

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IZVOD

Standardna ispitivanja pojave korozije procesne opreme u rafineriji OKTA u Skoplju obuhvataju kontolu svih posuda pod pritiskom i skladišnih rezervoara u rafineriji. U okviru ovih ispitivanja, izvršen je i pregled rezervoara za dizel gorivo. Ispitivanje se sastojalo od vizuelne kontrole i ultrazvučnog merenja promene debljine rezervoara tokom vremena. Dobivene vrednosti debljina na pojedinim mernim mestima na omotaču, podnici i krovu rezervoara su zatim upoređene sa standardnom zahtevanim vrednostima.

Nakon toga su izvršena ispitivanja uzroka nastanka korozije. Određeni su i mogući mehanizmi korozije koji se javljaju na pojedinim delovima rezevoara. Rezervoar je izrađjen od dva tipa ugljeničnih konstrukcionih čelika, pa je, time, podložan koroziji.

Na kraju je izvedena sanacija kritičnih delova rezervoara tako što su korodirani limovi zamenjeni novim i napravljna je odgovarajuća antikorozivna zaštita premazom.

Dobiveni rezultati proširili su saznanja o pojavi korozije na ovakvom tipu rezervoara. Na taj način, stečena iskustva pri ovim ispitivanjima su dobra osnova za buduću efikasniju zaštitu rezervoara od korozije.

Ključne reči: *korozija, rezervoar za dizel gorivo, karakterizacija, zaštita.*

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