ASPECTS REGARDING OF OIL SLUDGE CLEANING FROM CRUDE STORAGE TANKS USING ROBOTS

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Rezumat: *Una dintre problemele industriei petroliere este acumularea de șlam pe fundul rezervoarelor de stocare a țițeiului. Şlamul petrolier obţinut din rezervoarele de stocare a ţiţeiului este un deşeu semisolid. De fapt, este o emulsie complexă formată din numeroase hidrocarburi petroliere, apă și particule solide sau impurități minerale provenite din rocă. Şlamul petrolier este generat în timpul stocării producției de țiței, dar și în timpul transportului, depozitării, rafinării țițeiului. Prin natura sa - organică și anorganică, de culoare brun închis/negru și starea fizică de semifluid- este un deșeu foarte periculos, deoarece include multe substanțe otrăvitoare, precum: hidrocarburi aromatice policiclice, xilen, benzen, etil benzen, toluen, dar și metale grele. Prin urmare, depunerea slamului petrolier este un proces dinamic, pe termen lung și în continuă schimbare. Autorii, sub egida AOȘR și AGIR, prezintă - prin această lucrare științifică - o tehnologie modernă utilizată pentru curățarea cu succes a șlamului petrolier din rezervoarele de stocare a țițeiului și, evident, poate fi o recomandare pentru organizațiile din industria petrolieră..*

Abstract: *One of the problems of the oil industry is the accumulation of sludge at the bottom of crude oil storage tanks. Oil sludge obtained from crude oil storage tanks is a semi-solid waste. It is actually a complex emulsion made up of numerous petroleum hydrocarbons, water and solid particles or mineral impurities from the rock. Oil sludge is generated during the storage of crude oil production, but also during the transportation, storage, and refining of crude oil. Through its nature - organic and inorganic, dark brown / black in color and semi-fluid physical state - it is a very dangerous waste, as it includes many poisonous substances, such as: polycyclic aromatic hydrocarbons, xylene, benzene, ethyl benzene, toluene, but also metals heavy. Therefore, oil sludge deposition is a dynamic, long-term, and ever-changing process. The authors, under the auspices of AOȘR and AGIR, present - through this scientific paper - a modern technology used for the successful cleaning of oil sludge from crude oil storage tanks and, obviously, it can be a recommendation for organizations in the oil industry.*

Keywords: *oil sludge, tank, manual cleaning, mechanized cleaning, automated cleaning, robotic cleaning.*

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1. Introduction

It is known that crude oil extracted from the deposit contains, along with hydrocarbons, variable amounts of water with organic salts, but also mineral impurities from rock, such as: sand, clays, crushed rock. Also, crude oil contains components with high freezing temperatures and limited solubility in the mass of liquid hydrocarbons (for example: heavy paraffins, asphaltenes, carbenes, carbohydrates, asphaltogenic acids etc.) which tend to separate from the liquid mass and encompass mineral impurities. Thus, over time, a semi-solid layer is formed at the bottom of the tank that can no longer be drained, and crusts consisting of mineral impurities embedded in paraffin and other similar products are formed on the pipes of the heating coil inside the tank that copolymerize under the influence of temperature, strongly adhering to the surface of the metal. These deposits that can no longer be drained from the tank are called oil sludge. Through definition oil sludge is a hazardous waste of organic and inorganic nature that separates from crude oil and settles on the bottom of the tank following the technological storage process.
Regarding the methods or techniques of oil sludge cleaning, obviously, several techniques for cleaning crude oil tanks are known, such as: manual cleaning, mechanized cleaning, or automated cleaning. [1],[2],[5],[6].

2. Physico-chemical characteristics of oil sludge

The physicochemical characteristics of oil sludge are necessary to determine the appropriate waste treatment process, such as: thickening, heat treatment, dehydration. As for the physicochemical parameters of the waste, they are: flash point, calorific power, density, inflammation point, water solubility, polychlorinated diphenyls, polychlorinated triphenyls. At the same time, other properties are useful, such as: pH and plumb. Table 1. presents information on the physico-chemical parameters of oil sludge. [3],[6]

Table 1. Information on physico-chemical parameters of oil sludge [3],[6]

Nr. crt.	Parameter	U.M.	Value	Observations
1	Flash point	*ºC*	240- 260	-
2	Calorific power	*$kcal/m^3$*	1031 - 9371	-
3	Density, at 20ºC	*kg/m^3*	817.0 – 970.7	-
4	Inflammation point	*ºC*	60 - 95	-
5	Water solubility	*mg/l*	-	*in excess water forms a heterogeneous polydisperse system*

6	pH	-	6.4 – 8.1	-
7	Plumb	*mg/kg*	< 1 - 114	-
8	Polychlorinated diphenyls	*mg/kg*	< 0.3 - 1	-
9	Polychlorinated triphenyls	*mg/kg*	< 100	-

As regards the composition of the waste, the information on the components shall be as follows:

- Hydrocarbons (55 to 91 % m/m);
- Sediments (0.5 – 10.8 % m/m);
- Water (5 – 28.5% m/m).

3. Industrial tanks for the storage of crude oil

In the petroleum industry, there are different types of tanks that store or process fluids. Currently, the most widespread tanks are metal ones.

Metal tanks for storing liquid hydrocarbons are containers with capacities greater than 3 m^3, of different shapes and sizes, made of a wide range of materials, all working at atmospheric pressure.

However, due to their simple and inexpensive construction, vertical cylindrical tanks are the most widespread. Figure 1 shows a tank storage with capacities between 1,500 m^3 and 50,000 m^3, of metallic construction, cylindrical, located vertically, aboveground, with fixed or floating lid, with automatic measurement system of the quantity of crude oil stored and with fire extinguishing system, respectively.

Fig. 1. Tank storage for storage of crude oil [11]

Of course, depending on the position of the bottom relative to the surface of the earth and the position of the maximum liquid level, metal tanks can be classified into:

a) above-ground (surface) tanks;
b) under-ground reservoirs (semi-buried or buried);
c) tanks with floating lid.

Vertical above-ground cylindrical tanks have bottoms at the surface of the earth, laid on concrete ring foundations or sand platforms and can be constructed with a fixed or floating roof (lid).

Underground vertical cylindrical tanks have fixed roofs and all components below the natural level of the terrain. Covering the reinforced concrete "tank vault" with earth is a current method of protection against external thermal or mechanical aggression, given that they contain flammable products. As for the thickness of the coating, it must be at least 1 m.

The vertical cylindrical tanks with floating lid (see Fig. 2.) have a floating roof, provided with floats on the surface of the stored liquid (thus, when increasing the volume rises, and when decreasing the volume decreases), being a response to the need to diminish, as much as possible, the leakage of volatiles during storage (losses by evaporation of light fractions).

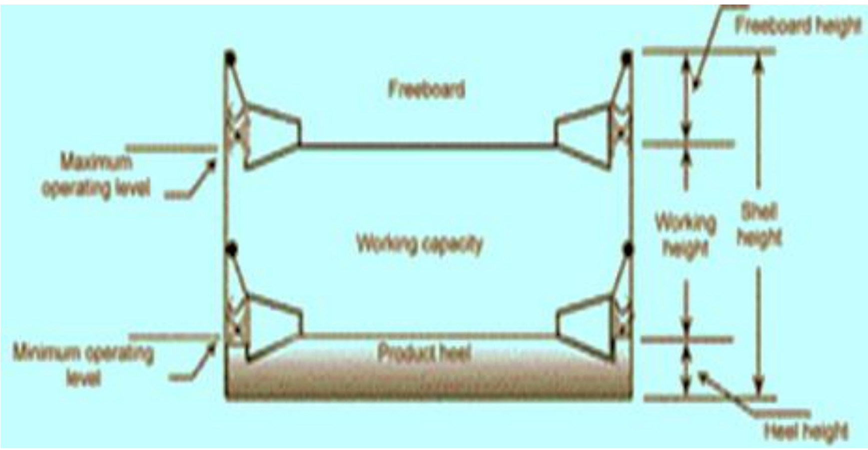

Fig. 2. Scheme - Vertical cylindrical tank with floating lid [6],[9]

One of these is the crude oil reservoir, which can be seen in Figure 3. (for example: the tank has a capacity of 50,000 m^3, is equipped with a floating metal lid, has a height of 18 m, a diameter of 60 m and a bowl of 10,000m^2).

Fig. 3. Overview - Vertical cylindrical tank with floating lid [1],[10],[11]

It is worth mentioning that the type of tank, dimensions and material vary depending on the storage conditions of the crude oil (pressure, temperature), the properties of the crude oil (composition, toxicity) and, obviously, the amount of storage required (operating volume).
Its main parts, are: housing, bottom, roof (fixed or floating), nozzles, pipes and tools, double sealing system, fire protection system, cathodic protection system and steel structures for personnel service. [1],[4],[6],[8]

4. Types of oil sludge

Oil sludge generally varies depending on where and how hydrocarbon deposits are formed. Hydrocarbons are mainly alkanes, cyclo-alkanes and aromatic hydrocarbons.
Therefore, four main types of hydrocarbons are found in crude oil:

1) paraffins (15-60%);
2) naphthenes (30-60%);
3) aromatic (3-30%);
4) asphalt (the rest).

So, oil sludge varies depending on the elemental composition of oil. Therefore, based on the physicochemical characteristics and percentage of each component, sludge can be: asphalt, naphthenic, naphthenic-aromatic and paraffinic.
Currently, sludge extraction from crude oil tanks is done manually and/or mechanized using an appropriate pump. Otherwise, if the sludge has various characteristics that make it non-pumpable (for example: high viscosity), manual intervention is required - qualified human intervention (see Fig. 4) - which,

obviously, involves high costs and a series of risks, both from the point of view of labor protection for the working personnel and for the equipment.

Fig. 3. Manual intervention **-** Oil sludge at the bottom of the crude oil tank [6],[8]

The existence of large sludge deposits in crude oil tanks leads to the following negative effects:

- introduction of errors in measuring the quantity of crude oil received;
- entrainment of impurities in the flow of crude oil entering desalinators;
- ingress of solid impurities into heat exchange equipment;
- decrease of the heat transfer coefficient of the coil inside the tank;
- reducing the temperature in the tank, decreasing the settling rate and the amount of decanted impurities;
- blocking large storage spaces by reducing the useful capacity of tanks.

Given the negative effects listed above, a modern and effective technology for cleaning crude oil tanks, without human entry into the tank, could be cleaning with the help of robots (robotic cleaning). [6]

5. Robotized cleaning

In a global context, robotic cleaning is a modern technology that, in recent years, has been applied in the oil industry for cleaning tanks, cylindrical vessels, pits, etc. This technology replaces human cleaning work and does not require the permanent presence of specialized personnel in confined spaces (e.g. in the tank), because the equipment is handled from outside.

The robotic cleaning system is usually removable and houses the necessary equipment in containers (three semi-trailers). Thus, all equipment is easy to transport by truck and therefore the robot is maneuvered to enter the tank by performing the cleaning operation – so, it is used to break and remove oil sludge from the bottom of the tank (see Fig. 4 and Fig. 5).

Fig. 4. Overview - Robotic cleaning [11]

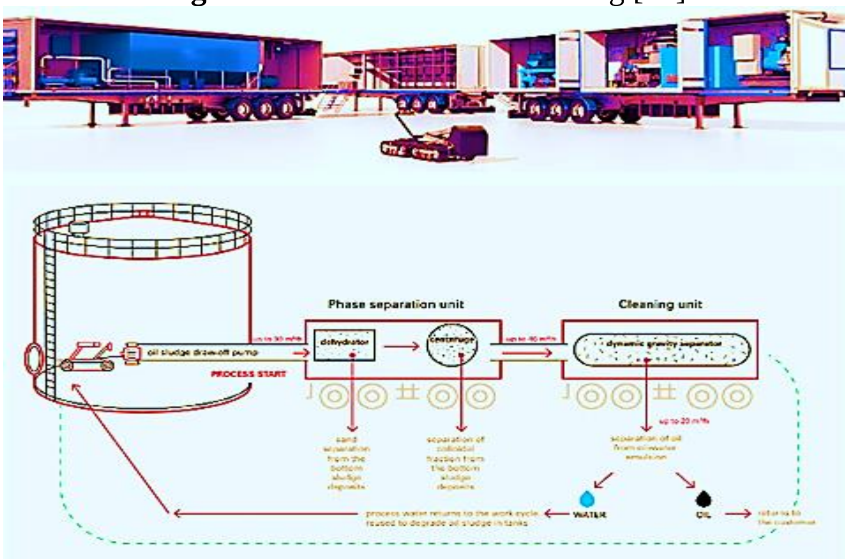

Fig. 5. Process diagram- Robotic cleaning [10],[11]

As for the basic components of the robot, these are as follows: hydraulic motor, cylinder, gas detector, explosion-proof junction box, solenoid flow control valve, explosion-proof infrared lamp, explosion-resistant/dust ignition chamber, explosion-proof fuel, wipers, water jet, video camera and vat.

Mode of operation

After installation, the robot is prepared on a ramp to enter through the manhole into the tank, moves to the bottom of the tank to begin the operation of cleaning the oil sludge (see Fig. 6).

Fig. 6. Photo image - Cleaning process preparation

The constructive dimensions of the robot are shown in Figure 6 as follows:

- length: L = 1100 mm;
- width: l = 400 mm;
- height: h = 450 mm;
- height with camera raised: h1 = 960 mm;
- diameter: D = 18 inches (457.2 mm);
- weight: G = 250 mm.

The system is fully automated. Thus, from the outside, from a control remote panel existing in the first container, the entire cleaning operation is performed and monitored by a specialized and experienced operator (see Fig. 7). Everything is done in a closed circuit, and residues are collected in a tank located in the second container.

Fig. 7. Photo image - Execution and monitoring of cleaning process

Therefore, it can be concluded that a robot for cleaning oil sludge from crude oil storage tanks ensures optimal quality, durability, efficiency, safety and ease of use.

Conclusions

Regular cleaning of crude oil storage tanks is essential to maintain the absolute quality of the product inside, namely health and safety standards.
Cleaning oil sludge from crude oil storage tanks using robots (robotic cleaning) is less expensive than manual and automatic cleaning.
The equipment is installed in three semi-trailers and transported by truck. It can be installed on any terrain thanks to its flexible hydraulic system. The installation takes place in a very short time (3–5 hours) and does not require the use of other machines, such as cranes.
Systems and robots operate in extreme conditions, are resistant to hazardous waste and chemicals.
As a general conclusion, robotic cleaning, in addition to being a modern technology, is so effective that even the most difficult parts inside the tank can be cleaned, eliminates the need for human penetration into confined spaces, reduces the cost of transportation and the risk for working personnel, and increases overall safety. It is a very environmentally friendly technology.

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