Petroleum and Coal

Article Open Access

WAYS OF IMPROVING THE EQUIPMENT FOR PRIMARY PETROLEUM REFINING

Nabil Abdul Sater[1], Andrey Grigorov[1], Alena Tulskaya[1], Tatiana Ovsiannikova[1], Alexey Sytnik[2]*

[1] *National Technical university "Kharkiv Polytechnic Institute", Kharkiv, Ukraine*
[2] *Ukrainian State Coal-Chemistry Institute, Kharkiv, Ukraine*

Received January 7, 2019; Accepted March 19, 2019

Abstract

The general ways of improvement the primary petroleum refining rigs have been described in this article. It has been proposed to consider the operational control of primary petroleum refining processes as the most perspective branch of petroleum industry due to its comparatively cheap implementation. Operational control has a significant influence on the safe operation of equipment, products quality and amount of harmful emissions. Electrical conductivity and relative permittivity have been defined as the specific parameters for effective operational control.Primary oil refining rigs are the most important part of any petroleum refinery. Despite the Nelson complexity index which is only 1,0 for refineries it should be considered that they have a strong impact on the secondary refining rigs. That's why one of the most important task in the petroleum refining industry worldwide is improvement of primary oil refining rigs.

Keywords: *primary petroleum refining processes; relative permittivity; electrical conductivity; control parameter; level of separation; fraction; emulsion; salts.*

1. Introduction

Primary petroleum refining equipment, as a rule, include the following technological parts: raw material treatment (removing of salts, water and mechanical admixtures), gasoline fraction separation, distillation, vacuum treatment of fuel oil. All these parts are in strong connection. So improvement of one or several parts affect the general equipment efficiency.

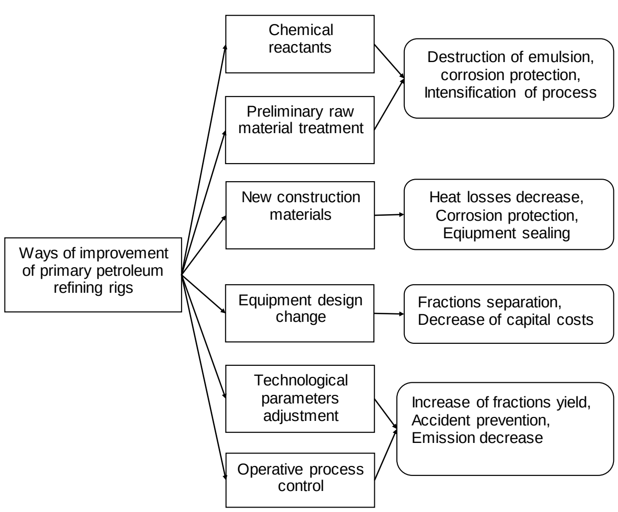

Fig.1. Structural model of improvement the primary petroleum refining process

One of the most significant criterion of efficiency for primary petroleum refining rigs evaluation is depth of separation of light fractions and refining of heavy fractions. According to [1] fuel oil vapor contains about 5 % of diesel hydrocarbons and tar contains about 10 % of vacuum distillate fraction [2]. Very important performance measure of equipment is durability which is caused by corrosion protection and harmful emission decrease.

General directions of improvement the primary petroleum refining equipment, that can provide its long durability and decrease of harmful emissions, may be performed in Fig. 1. Each of these directions will be observed in details below.

2. Results and discussion

Addition of various chemical demulsifiers is widely used in petroleum refining industry and mainly at electro desalting and electro dehydrating rigs. The following demulsifiers are most popular in Ukraine and Russia:
- Dissolvan 4411 and Separol 25 (Germany);
- NALCO EC, Basorol E2032 and L-1632 (USA);
- R-11 and X-2647 (Japan);
- Servo 5348 (Holland);
- Kemelix 3448x (Great Britain)

But search of the most effective and comparably cheap demulsifiers has not been finished yet. The examples of researches devoted to the current problem ale presented below.

For dehydration of crude oil from Basra, Iraq there have been applied demulsifiers based on industrial foundry oil. There has been compared the efficiency of two types of demulsifies: industrial RP/6000 and ammonium sulphonate from castor oil. The best results for the separation of emulsion (15 % of water, 3 % of NaCl) were obtained at the highest pH rate and highest concentration of ACS demulsifier [3].

Authors of [4] have described the research devoted to the application of different water-soluble and low-soluble demulsifiers for oil and water separation. Etoxylate of fatty alcohol, triethanolamine have been considered as the most effective from the water-soluble group and Basorol E2032, Basorol PDB 9935 and TOMAC from low-soluble group.

It has been found out that increase of demulsifier concentration, salt content and temperature up to 350 K encourages the separation degree at pH 5-9.

It has been also found out that the most effective composition that provides almost 90 % separation of oil and water, consists of triethanolamine – 16%, etoxylate of fatty alcohol – 20%, Basorol E2032 – 6 %, Basorol PDB 9935 – 8 %, TOMAC – 12 % and aromatic dissolvent – 39 %. Besides this new composition was more effective than industrial demulsifiers (VZB 1413 provides 65 % separation and VZB 1414 – 72 % separation). Moreover, addition of light hydrocarbon dissolvent encourages the destruction of oil-water emulsion and reduces the viscosity [5]. Authors of [6] proposed the new composition of demulsifiers that contain 25 – 48 % of surfactant "Sinterol" («Синтерол»), 3-8 % of modifying additives and dissolvent (methanol – aldehyde fraction). Level of oil dehydration with the proposed demulsifier can be raised up to 96 %. To protect the industrial equipment from corrosion destruction there has been proposed to add the following chemical reactants: amides, aliphatic amines and, in particular, nitrogen-containing inhibitor – polyhexamethylenguanidine – hydrate (5 – 20 g per 1 ton of raw material). Current inhibitor provides the 95-98 % protection [9]. To prevent the corrosion of equipment at oil and gas fields, pipelines and refining systems there should be applied an inhibitor of metal corrosion that contains 70 – 99,9 % of synthetic oil (as a by-product of benzene hydration and further oxidation of cyclohexane by air and dehydration of cyclohexanol) and 0,1 -30 % of carbamide [10].

Chemical reactants are widely used for preparation of crude oil and gas condensate for transporting. Authors of [11] recommend to perform the preparation of sulfur-containing crude oil through its low-pressure separation or in additional separation column at 300 – 350 K and 0.1 – 0.5 MPa. The aim of proposed method is to reduce the acidity and corrosion activity of crude oil. In [12] there has been described numerous compounds that may be applied as the corrosion inhibitors for steel in acidic solutions. It has been shown that acetylene alcohol is the most active component for corrosion protection.

Design change for refining equipment is one of the most complicated direction for improvement the primary petroleum refining rigs which demands considerable investments. At the same time, there are two determining factors of effective separation of petroleum fractions – design of contact devices and constant temperature gradient in distillation column. Bubble-cap trays and valve collars are the most widely used devices in atmospheric distillation columns [13]. Replacement of bubble-cap trays with ejection trays provides the increase of tray efficiency up to 20 % [20]. Replacement of grooved tray with ejection valve trays encourages the decrease of distillate fractions content in fuel oil by 7 % in average [15]. According to [16] the regular structured nozzles by "Sulzer" are the most effective comparing to tray contact devices. Replacement of trays with stationary valves with regular structured nozzle "Sulzer" provides the increase of equipment productivity and decrease the content of C_7 –hydrocarbons in low-boiling fraction 350 K down to 0.43 %. In [17] authors describe the varying of sections diameter in packed columns. This approach allows to decrease energy costs for separation in distillate columns.

Methods of pretreatment of raw material aim the increase the yieldt of light fractions, encourages the destruction of oil-water emulsions and can be implemented for the preparation of oil before the electrodesalter and electrodehydrator. In [18] there have been presented the results of activation of viscous crude oil by rotary pulsating apparatus by waves from infrasound to ultrasound. As a result – the content of gasoline fraction raised up to 10 % comparing to unprocessed crude oil.

In [19] there has been described a research devoted to desalting and dehydration of crude oil with pretreatment in electromagnetic field at 0,1375 Tl and linear flow speed 1 m/s which has shown the increase of dehydration level by 5-30 % and 2 times decrease of emulsifier consumption comparing to traditional technologies.

Implementation of technological refining of crude oil includes the exploitation of equipment under extremely hard conditions, i.e. wide temperature and pressure rate, corrosion destruction etc. Thus, construction materials of pipes, heaters, coils, valves and pumps play the crucial role. There are widely used different types of steel that contain Cr, Mo, Mn, Si, Ti, Ni etc. These components improve strength and hardenability and corrosion resistance of steel. Nowadays the most popular types of steel are produced by JFE Steel Company [21]. Also there are widely used metal and non-metal matrices with the specific location of hardeners. One of the most promising construction sealants in petroleum refining industry is expanded graphite [22]. Due to its high adsorption capacity expanded graphite can be applied for removing of fuel oil, heavy metals and other organic substances from water. The main benefit of expanded graphite is its self-regeneration. 1 gram of expanded graphite can adsorb up to 80 grams of organic substances [23]. Carbon materials can be applied for production of complicated high-temperature heaters including flexible pipes, high-temperature heat shields etc. [24]

Technological parameters of primary oil refining such as temperature, pressure and infinite reflux can be considered as the powerful tools to improve the production efficiency [25]. Each type of raw material, that is supposed to be processed at refinery, has a considerable level of technological parameters. For example, boiling point is the crucial factor for construction materials choose. Heat balance of equipment depends on the temperature of raw materials and refining products. Pressure has the huge influence on boiling point of liquids and on separation of liquid and gas fractions in separators. Infinite reflux is an important factor that defines temperature range of column. Also temperature and pressure have an influence on construction materials, design of refining equipment and environmental safety.

Operational control of refining processes is the developing branch of petroleum industry. Nowadays the operational control at most of the refineries in Ukraine and Russia is based on laboratory analysis of samples, taken from the definite key points of rig. In this case there should be defined around 3-5 quality parameters which are supposed to be defined as soon as possible. Ideally there should be a specific integral parameter to characterize the composition and structure of raw material and products. Specific conductivity (δ) and relative permittivity (ε) have been proposed as the specific integral parameter [26-27]. Choose of parameter should be based on origin of analyzed material. Thus, primary oil refining field can be divided into two areas (Fig. 2). Preparation area includes the separation of water, salts and mechanical admixtures from crude oil. Refining area includes stabilization of oil and fractional separation in distillate column.

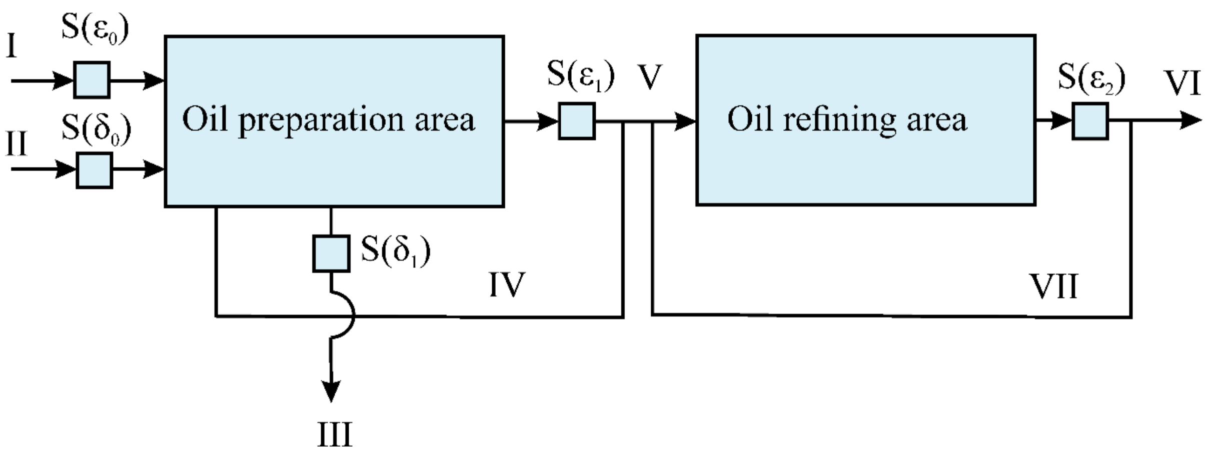

Fig 2. Structural scheme of primary petroleum refining:
I – crude oil, II – fresh water, III – waste water, IV – insufficiently prepared crude oil, V – prepared oil, VI – final product, VII – substandard product

Considering the fact that crude oil and products of it refining are non-polar dielectrics, it is quietly reasonable to control these substances by permittivity ε. For this purposes on I, V and VI fields there have been located the sensors $S(\varepsilon_0)$, $S(\varepsilon_1)$, $S(\varepsilon_2)$ to measure this parameter. Also, parameter ε may be used for determination of water in prepared crude oil. Since the increase of boiling point of petroleum fractions leads to increase of relative permittivity, sensor $S(\varepsilon_2)$ may be used to get the reliable information about the level of fractions separation.

Considering the electric conductivity it should mentioned that its value always depends on the amount of conductive components that are removed with water in preparation area (flow III). In this case salts and mechanical admixtures are conductive components that have been removed from crude oil. In the preparation area the proportion $\delta_1>\delta_0$ is always constant so to control the removal of salts and admixtures in II and III flow there have been set special sensors $S(\delta_0)$, $S(\delta_1)$.

Based on sensors $S(\varepsilon_1)$ and $S(\delta_1)$ readings if the prepared oil is unfit for further refining and refining, it should be taken back to preparation area. Similarly, for refining area – if the high level of separation has not been reached, the products should be mixed with crude oil for repeated refining.

3. Conclusion

The general ways of improvement of primary petroleum refining rigs were presented. In our opinion, one of the most perspective directions is operative process control. This system is based on primary diagnostic information received from sensors that have been set at the general material flows of the rigs. The operating principle of sensor is based on the measuring of electrical conductivity and relative permittivity in different areas. The presented scheme provides the realibility of equipment exploitation, reduces the harmful emission and minimize the time for correction of technological parameters.

References

[1] Akhmetov SA. Tehnologiya glubokoy pererabotki nefti i gaza, Moscow, 2002, 217 p.
[2] Kapitonova OV. Nalozhenie neftyanyih fraktsiy pri razdelenii mazuta pod vakuumom. Vestnik tehnologicheskogo universiteta. 2015. Vol.18, №20: 88-90.
[3] Ali HAAR. Preparation and evaluation of demulsifiers agents for Basra crude oil. Applied Petrochemical Research. 2012; 1(1-4): 29–33.
[4] Hajivand P. Optimization of demulsifier formulation for separation of water from crude oil emulsions. Brazilian Journal of Chemical Engineering, 2015; 32(01): 107 – 118.
[5] Salam KK. Improving the Demulsification Process of Heavy Crude Oil Emulsion through Blending with Diluent. Journal of Petroleum Engineering, 2013; 1: 96 – 102.

[6] Yasakov E. Issledovanie svoystv izvestnogo i razrabotannogo deemulgatorov dlya obezvozhivaniya i obessolivaniya vodoneftyanyih emulsi. Neftegazovoe delo, 2010; 2: 1-13.

[7] Fazulzyanov RR. Primenenie reagentov na ustanovkah pervichnoy pererabotki nefti. Vestnik Kazanskogo tehnologicheskogo universiteta, 2013; 6: 192-195.

[8] Farhutdinova AR, Mukatdisov NI, Elpidinskiy AA, Grechuhina AA. Sostavyi ingibitorov korrozii dlya razlichnyih sred. Vestnik Kazanskogo tehnologicheskogo universiteta, 2013; 4: 272- 276.

[9] Tomin VP. RF Patent 2108409, C23F11/173, 10.04.1998.

[10] Moiseeva LS. RF Patent №2151818, C23F11/12, 27.06.2000.

[11] Fahriev AM. RF Patent №2529677, C10G19/02, C10G29/06, 20.09.2006.

[12] Finšgar M. Application of corrosion inhibitors for steels in acidic media for the oil and gas industry: A review. Corrosion Science, 2014; 86: 17-41.

[13] Skoblo AI. Protsessyi i apparatyi neftegazopererabotki i neftehimii, 3rd ed.; Nedra-Biznestsentr: Moscow, 2000; 677 p.

[14] Bogatyih KF. Konstruktivno-tehnologicheskiy podhod k vyiboru kontaktnyih ustroystv dlya realizatsii resurso-energosberegayuschih tehnologiy. Aktualnyie problemyi tehnicheskih, estestvennyih i gumanitarnyih nauk: materialyi Mezhdunarodnoy nauchno-tehnicheskoy konferentsii. UFA, May 2005: 65-68

[15] Almabekov OA. Sovershenstvovanie kontaktnyih ustroystv rektifikatsionnyih kolonn. Almatyi tehnologiyalyi, 2014; 2: 16-19.

[16] Kagan AM. Sravnenie tarelchatyih i nasadochnyih kontaktnyih ustroystv kolonnyih apparatov. Himicheskoe i neftegazovoe mashinostroenie, 2007; 1: 9 - 10.

[17] Churakova SK. Razrabotka resurso-energosberegayuschih tehnologiy fraktsionirovaniya na osnove konstruktivno-tehnologicheskogo podhoda. Tehnologii nefti i gaza, 2013; 4(87): 8-14.

[18] Hamidullin RF. Uvelichenie vyihoda svetlyih distillyatov pri pomoschi aktivatsii neftyanogo syirya. Himiya i tehnologiya topliv i masel, 2016; 6(598): 29-34.

[19] Takaeva MA. Intensifikatsiya protsessa podgotovki i pererabotki groznenskih neftey. Materialyi mezhdunarodnoy nauchno-tehnicheskoy konferentsii «Aktualnyie problemyi tehnicheskih, estestvennyih i gumanitarnyih nauk». UFA: UGNTU, 2010: 47-50.

[20] Brand AE. Gidrodinamicheskaya kavitatsionnaya obrabotka kak sposob snizheniya vyazkosti vyisokovyazkih neftey i povyisheniya effektivnosti transportirovki. Sovremennyie problemyi nauki i obrazovaniya, 2015; 2-3: 1-5.

[21] Masamura Katsumi Steel Products for Energy Industries. JFE Technical report No. 18, March 2013: 1-11.

[22] Burleshin M. Grafit prihodit na smenu asbesta. Vestnik Mosenergo, 2001; 9: 3-4.

[23] Inagaki M. Exfoliation of graphite via intercalation compounds. Chemistry and physics of Carbon, 2004; 29: 1-69.

[24] Leng Y. Influences of density and flake size on the mechanical properties of flexible graphite. Carbon. 1998; 36: 875- 881.

[25] Golden SW. TECHNOLOGY Temperature, pressure measurements solve column operating problems. Oil & Gas Journal, 1995; 93: 45- 49.

[26] Peinado-Guevara H. Relationship between chloride concentration and electrical conductivity in groundwater and its estimation from vertical electrical soundings (VESs) in Guasave, Sinaloa. Cienc. Inv. Agr., 2012; 39(1): 229-239.

[27] Ajienkaa JA. Measurement of dielectric constant of oilfield emulsions and its application to emulsion resolution. Journal of Petroleum Science and Engineering, 1993; 9(4): 331-339.

To whom correspondence should be addressed: Professor Alena Tulskaya, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine