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Study of the Process of Oil Sludge Purification from Mechanical Impurities in a Centrifugal Field

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ABSTRACT: Today, a number of works are carried out in the world on cleaning oil sludge and obtaining products from them, including in this article, with the aim of rational use of oil sludge, purified from mechanical devices under the influence of centrifugal force, its components. It identified: heavy naphtha reformate, gasoline, and the amount of oil products determined by their content, and the change in the concentration of solid particles in the composition of oil sludge depending on the ratio of solvent to oil products are presented in tables and graphs.

KEYWORDS: oil sludge, hydrocarbon solvent, heavy naphtha, reformate, gasoline.

I. INTRODUCTION

Mechanical impurities are contained in crude oil in the form of sand, clay minerals and various salts that are in a suspended state. When studying oils, a high content of mechanical impurities can significantly affect the correctness of determining such indicators as density, molecular weight, coking ability, sulfur content, nitrogen, resinous-asphaltene substances and microelements. Therefore, before entering the oil for analysis, it is necessary to free it from them by settling or filtering. During the refining of oil, corrosion products of equipment and pipelines, catalyst dust, tiny particles of bleaching clay, mineral salts can get into the oil products. Contamination of oil and oil products can also occur during storage and transportation [1].

Oil sludge accumulated in significant quantities is one of the most dangerous pollutants of almost all components of the natural environment - surface and underground water, soil and vegetation cover and atmospheric air. Due to the significant oil content in the composition of oil sludge, the latter can be classified as a secondary material resource. Therefore, the search for technological methods of processing (utilization) of oil sludge into finished products (for example, as raw material for the production of bitumen, waterproofing materials, components of boiler fuel and commercial oil) contribute to an increase in the depth of processing of hydrocarbon raw materials, the introduction of low-waste technological processes and an increase in the effectiveness of environmental protection measures, since this undoubtedly achieves a certain environmental and economic effect [2].

II. SIGNIFICANCE OF THE SYSTEM

By centrifuging gasoline, diesel, kerosene and mechanical particles with different properties containing different amounts of petroleum products, the mechanism of separation of mechanical particles in the mixture was studied. It has been proven that there are mixtures of light naphtha, heavy naphtha reformate and gasoline in the composition of oil sludge. The study methodology is explained in Section III, Section IV contains the experimental results of the study and Section V discusses the future study and conclusions.

III. METHODOLOGY

The process line consists of a tank for feeding a diluting agent 1, a tank for mixing oil sludge with diluents 2, hydrocyclones for separating mechanical impurities 3,4, pumps for feeding a liquid flow 7,8. In order to determine the pressure and temperature of the process, the process line is equipped with pressure gauges 5 and thermometers 6, valves

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for regulating the flow 11, after cleaning the oil sludge mixture from various impurities, bunkers for the collected mass 13,14 are installed, and airlocks 12 are installed for unloading the collected mass[3].

During the experiments, tank 2 with mixer 9 was filled with oil sludge, diluent was poured from tank 1 into tank 2 to dissolve oil sludge (gasoline, reformate, gas condensate, etc.) in proportions of 10÷60%, then mixed for 10 min to 60 min. The temperature was changed within the range of 40÷80 0C, after which, using pump 7, the diluted fraction was fed into hydrocyclone 3 for the purpose of deep cleaning of diluted oil sludge from mechanical impurities in a centrifugal field and fed to the second hydrocyclone 4 through pump 8. The thickened phase (sludge) formed during the process was continuously unloaded into bunkers 12, 13. In addition, the process line is equipped with control and measuring devices. In this case, the consumption of the initial raw material was measured using a flow meter, and the hydraulic resistance of the hydrocyclone and the hydraulic pressure of the liquid in it were determined using pressure gauges 6.

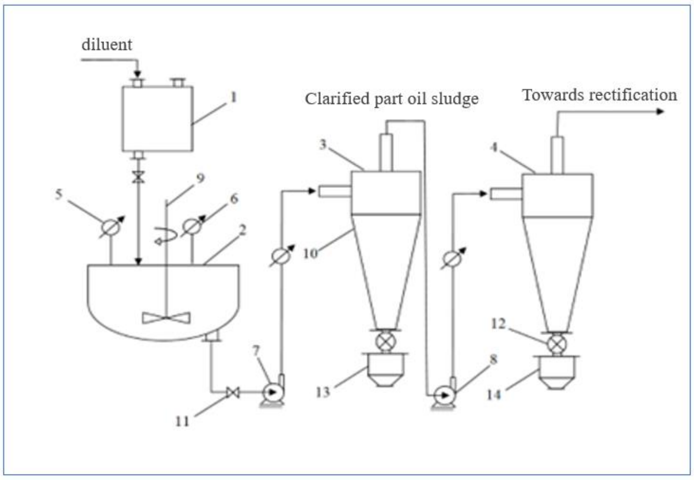

Fig. 1. Experimental setup for preparing oil sludge for processing: 1- solvent feed tank; 2- oil sludge tank with mixer; 3,4- hydrocyclones; 5- thermometer for determining process temperature; 6- pressure gauge for determining process pressure; 7,8- pumps for feeding diluted oil sludge; 9- mixer; 10- conical part of hydrocyclone; 11- gate valve; 12- airlock; 13,14- bins for collected mass.

IV. EXPERIMENTAL RESULTS

To determine the hydraulic resistance of the hydrocyclone, the liquid flow velocity was varied within the range of 10÷20 m/s. The results of the studies are shown in Fig. 2.

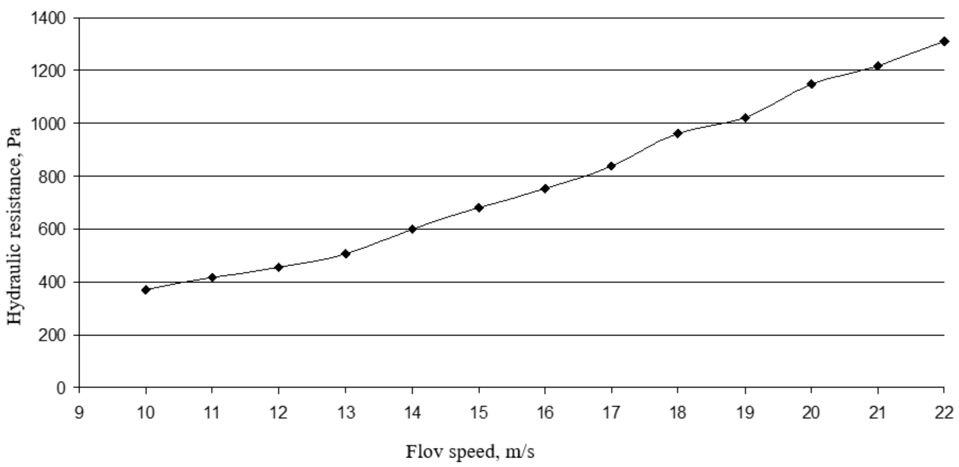

Fig.2. The influence of flow velocity on the hydraulic resistance of a hydrocyclone

From Fig. 2 it is evident that with an increase in the speed of diluted oil sludge within 10÷22 m/s, the hydraulic resistance of the hydrocyclone also increases from 370 Pa to 1310 Pa. This is explained by the fact that the hydraulic resistance of the device depends on the speed of the liquid flow.

In addition to the flow rate, the efficiency of separation of mechanical impurities from oil sludge is also affected by the temperature of the mixing process. Various diluents were selected for diluting the oil sludge. The series of experiments conducted on the effect of the temperature of the mixing process on the efficiency of cleaning oil sludge from mechanical impurities is given in Table 1.

Table 1

The influence of the mixing process temperature on the efficiency of cleaning oil sludge from mechanical impurities

Process temperature, °C	Names of thinners				
	Light naphtha	Hydrocarbon solvent	Heavy naphtha	Reformat	Petrol
	Residual concentration of mechanical impurities, %				
40	4,01	0,18	2,0	1,54	2,98
50	3,22	0,11	1,77	1,41	2,75
60	2,81	0,02	1,52	1,16	2,31
70	2,30	0,02	1,24	1,04	2,13
80	2,10	0,02	1,02	0,91	1,98

With an increase in the mixing process temperature from 40ºC to 80ºC, the residual concentration of mechanical solid particles in the composition of the diluted oil sludge also decreases (Table 1). The results of the conducted studies are illustrated in Fig. 3.

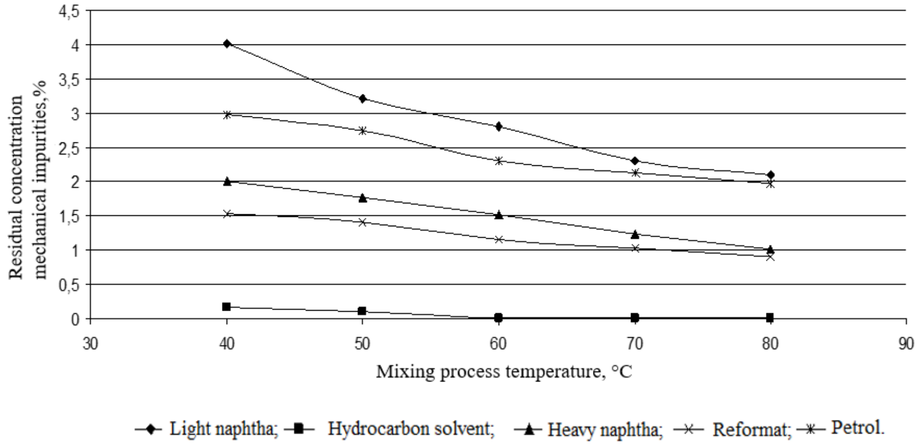

Fig.3. Effect of mixing process temperature on the efficiency of cleaning oil sludge from mechanical impurities.

When diluting oil sludge with light naphtha at 40°C, the residual concentration of solid particles of mechanical impurities was 4.01%, and at 50°C this figure was 3.22%, and with a further increase in temperature to 80°C, the concentration of mechanical impurities was 2.10%, when diluting oil sludge with heavy naphtha at 40°C, the residual concentration of solid particles was 2.0%, and at 80°C this figure was 1.02%, further dilution of oil sludge with reformate at temperatures from 40°C to 80°C, the concentration of solid particles of mechanical impurities changes within the range of 1.54÷0.91%, and with dilution with gasoline, the concentration of mechanical impurities will change from 2.98 to 1.98%. During the course of experimental studies, the most suitable diluent for diluting oil sludge was selected, i.e. a hydrocarbon solvent.

We also determined the coefficient of hydraulic resistance of the hydrocyclone at different velocities of diluted oil sludge. The results are given in Table 2.

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From Table 2 it is evident that with the increase of liquid flow velocity from 10 m/s to 22 m/s inside the hydrocyclone pipeline its hydraulic resistance also increases from 370 Pa to 1310 Pa. When diluting oil sludge with light naphtha at the velocity of 10 m/s the hydraulic resistance coefficient of the apparatus was 2.14, with heavy naphtha 2.10, with gasoline 2.06, with reformate 1.88, and with hydrocarbon solvent this indicator was 2.01. With a further increase of liquid flow velocity to 20 m/s this indicator was 6.76 with light naphtha, 6.53 with heavy naphtha, 6.42 with gasoline, 5.86 with reformate, and 6.25 with hydrocarbon solvent. This is explained by the fact that in addition to the liquid flow velocity, the hydraulic resistance coefficient is also affected by the type of solvent.

Table 2
Hydraulic resistance coefficient of a hydrocyclone at different liquid flow rates

Flow velocity, ω, m/s	Hydraulic resistance, ΔP, *Pa*	Coefficient of hydraulic resistance, ξ				
		Hydrocarbon solvent	Light naphtha	Petrol	Reformat	Heavy naphtha
10	370	2,01	2,17	2,06	1,88	2,10
11	415	2,25	2,44	2,31	2,11	2,35
12	455	2,47	2,67	2,54	2,32	2,58
13	505	2,74	2,97	2,82	2,57	2,86
14	600	3,26	3,52	3,35	3,06	3,40
15	680	3,69	4,0	3,79	3,46	3,86
16	755	4,10	4,44	4,69	4,28	4,77
17	840	4,56	4,94	4,69	4,28	4,77
18	960	5,21	5,64	5,36	4,89	5,45
19	1020	5,54	6,0	5,69	5,20	5,79
20	1150	6,25	6,76	6,42	5,86	6,53
21	1215	6,60	7,14	6,78	6,19	6,90
22	1310	7,11	7,70	7,31	6,68	7,44

We conducted experimental studies to determine the density of the original fraction and the change in the density of diluted oil sludge when diluted with various solvents (in a ratio of 50% solvent and 50% oil sludge) at a standard temperature of 20 ºC.

Table 3
Change in density of diluted oil sludge depending on the diluent (initial density of oil sludge 1200 kg/m^3)

№	Names of fractions	Density, ρ, kg/m^3	
		Density of the original fraction	50% oil sludge + 50% thinner
1	Hydrocarbon solvent	780	920
2	Light naphtha	650	850
3	Petrol	740	895
4	Reformat	820	980
5	Heavy naphtha	720	880

When diluting oil sludge with a hydrocarbon solvent, its density changes from 1200 kg/m3 to 920 kg/m^3 (Table 3), with light naphtha - from 650 kg/m^3 to 850 kg/m^3, and with gasoline it changes from 740 kg/m^3 to 895 kg/m^3, this indicator in reformate is from 820 kg/m^3 to 980 kg/m^3, with heavy naphtha it is from 720 kg/m^3 to 880 kg/m^3. During the experiments, changes in the size of solid particles of mechanical impurities were determined due to the turbulent flow before and after the hydrocyclone. The results are given in Table 4.

Table 4
Change in the size of solid particles of mechanical impurities

Fraction <0.25 mm, sample weight 100 g						
Particle size	<250 mkm	< 200 mkm	<100 mkm	<50 mkm	<25 mkm	Σ
	Before the hydrocyclone					
%	0,2	0,7	2,7	5,4	91,0	100,0
	After the hydrocyclone					
%	58,4	31,0	8,6	1,2	0,8	100,0

The composition of oil sludge mainly contains <25 mkm particles up to 91% (Table 4), and the largest particles <250 mkm make up 0.2%. This is explained by the fact that fine particles do not settle due to their imperceptible resistance to the environment, because of this they practically do not settle. When cleaning oil sludge from solid mechanical impurities in a centrifugal field, the sizes of fine solid particles up to <25 mkm adhere to each other and their size increases, while lumps of solid particles are formed, due to this, the concentration of coarse solid particles <250 mkm increases due to turbulent flow inside the hydrocyclone to 58.4%. This is explained by the fact that coarse solid particles are captured by fine particles along the way due to their tendency to coagulate.

V. CONCLUSION AND FUTURE WORK

Thus, when using a hydrocarbon solvent at a temperature of 40 °C, the residual concentration of solid particles of mechanical impurities in the diluted oil sludge is 0.18%, and at 50 °C this figure was 0.11%, with a further increase in the temperature of the mixing process from 60°C to 80°C, the concentration of solid particles of mechanical impurities in the oil sludge remains unchanged, i.e. this figure is 0.02%. The experiments indicate that the optimum temperature of the mixing process is 60 °C and the most suitable diluent for diluting oil sludge is a hydrocarbon solvent, and the optimum speed of the liquid diluted oil sludge was 20 m / s, while the hydraulic resistance of the hydrocyclone reached 1150 Pa. When diluting oil sludge with various solvents, its density also changes from 850 kg/m^3 to 980 kg/m^3. Fine solid particles of mechanical impurities of oil sludge are prone to coagulation, i.e. their size increases due to turbulent flow, the percentage of coarse particles <250 mkm from 0.2% to 58.4%, this is explained by the fact that coarse solid particles are captured by fine particles along the way.

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