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Use of a Fine Air Bubble Generator for Flotation Water Purification from Oil Products

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Abstract
This paper outlines the results of the laboratory studies on the efficiency of using a jet film air bubble generator for flotation purification from oil products. The ability of generating fine (less than 100 microns) air bubbles with high concentration of them in the water volume using a jet film bubble generator has been demonstrated. The ability to transport fine air bubbles in the low velocity (less than 2 m/min) water stream has been studied. A laboratory test of the efficiency of flotation purification due to a reduction in the air bubble size and, as a consequence, an increase in the contact area with oil product has been carried out. Taking into the account the properties of formation oil and water emulsions, it appears to be promising to use the proposed method for their purification.
Keywords: purification, oil and water emulsion, flotation, bubble generator, recycled water

INTRODUCTION

Oil is the most important energy source in the world; it takes 33% of the world energy consumption. It has high energy capacity and is suitable for transportation, which makes it an almost irreplaceable energy resource [1]. The global energy demand continues to grow owing to the population growth and also due to the economic welfare growth, which enables consumers in developing countries to increase consumption of more energy consuming products. A number of hydrocarbon deposits are situated in separately ranging lenses, which hinders access to them [2]. The oil recovery is also affected by the heterogenic composition of the rocks. In order to recover such oil as pumped and recycled fluid, it is recommended to use increased quality water.

Currently, the main manufacturers of equipment for purification of formation oil and water emulsion in formation pressure support systems are M-I SWACO, Exterran, Pall Corporation, etc. However, the equipment supplied by them, in particular, to the Russian market, does not always satisfy consumers in such parameters as purification efficiency, working life, filtration fineness, costs, etc. In this connection, the development of new methods for purification of formation oil and water emulsion competitive in the world market is an important problem.

At determination of the parameters of pumped and recycled water, special attention is given to the presence of dissolved oil therein, the percentage of which is determined by the collector properties of the rocks [3].

The presence of oil droplets in recycled waters leads to a drastic decrease in the intake of productive and adsorbing formations [4]. Therefore, prior to the pumping of recycled waters into productive and adsorbing formations, their additional purification is required [5].

The purification of recycled waters from oil products is quite a complex process because oil dissolved in water forms emulsion, which is often impossible to completely remove using mechanical methods. In this connection, one of the most efficient is the method of flotation water purification wherein the removal of oil products occurs due to injection of gas (air) into the oil and water emulsion stream [6].

The main advantages of flotation are the continuity of the process, a wide application range, low capital and operational costs, equipment simplicity, a high degree of water purification from oil products, over 96%, a possibility of colleting oil and its transportation to further processing [7].

The efficiency of flotation depends on producing in the recycled water of air bubbles with high dispersity degree with minimal size. The less the size of air bubbles, the finer the residual hydrate layer at the interface of the bubble with a floated oil particle, and the higher the interface wetting angle and, therefore, the stronger the attachment of oil balls on the interface of the recycled water – air bubble [6]. This is also facilitated by attraction of oil particles having a negative charge and positively charged air bubbles. Moreover, the finest air bubbles have low floating velocity, which creates beneficial conditions for attachment of oil balls on the surface of air bubbles at their contact [8-9]. The size of air bubbles depends on the surface tension of the recycled water and on the air dispersing method.

MATERIALS AND METHODS

This paper reviews a new design of a jet film generator of air-gas mixture bubbles allowing for producing air bubbles with a less than 100 micron size in water, which provides for an increase in the efficiency of retention and flotation of oil products in the liquid being purified.

In order to study the process of dispersion and air bubbles formation, a dummy device for flotation purification of oil and water emulsions has been developed and manufactured (Figure 1). The housings of the installation are made out of transparent polycarbonate in order to visualize the processes of formation, coagulation, transportation and flotation of fine air bubbles in the model oil and water emulsion.

Figure 1 – A device for flotation purification of oil and water emulsions

In order to purify the model oil and water emulsion from oil products, a new design of a jet film bubble generator has been developed allowing for producing air bubbles less than 100 microns in size in water. The use of this generator provides for maximum saturation of oil and water emulsion with air and increases the oil product removal efficiency. The generator developed and reviewed in this paper has the following technical advantages:

- A possibility of automated control of the required amount of air to exclude formation of excess gas saturated with vapors of combustible and explosive accompanying oil gas;
- An increase in the surface and time of contact of air with oil and water emulsion and correspondingly, an increase in the depth of oil products removal;
- Absence of mobile parts;
- Absence of fine pores prone to clogging;
- High operation durability, energy efficiency, low metal capacity.

The operability of the device was carried out using the model oil and water emulsion with the following characteristics: salt content – 382.5 mg/l; pH – 7.2; total hardness – 4.5 mg-eq/l; alkalinity – 6.1 mg-eq/l; chlorides – 62.8 mg/l; total iron – 3.5 mg/l; oil product content – up to 2000 mg/l. The flow of the oil and water emulsion in the developed dummy and at carrying out the tests was 1 m^3/h.

Model solution preparation sequence:

- In order to provide for a prolonged tests, the preliminarily prepared vessel 1 m^3 in volume was filled with purified tap water;
- To the tap water was charged with the volume of oil products V_o, mg/l, which was calculated according to the formula:

, where

C_o – was the concentration of oil products in the solution, mg/l;

V_l – was the solution volume, l;

ρ_o – was the density of the oil products, mg/l;

- using a centrifugal pump, it was stirred for 1.5 hours in order to provide for the uniformity of the obtained oil and water emulsion. The model solution was prepared directly prior to the test and in order to prevent separation it was constantly stirred using a pump.
- the concentration of oil in water was determined using IT spectrophotometry by isolating the oil components emulsified and dissolved in water by extraction with carbon tetrachloride, chromatographic separation of the oil products from the accompanying other classes of organic compounds using a column filled with aluminum oxide with subsequent quantitative determination of their weight percentage according to the intensity of C-H bond absorption in the infrared spectrum.

The accuracy of the oil product concentration determination was ± 5%.

The tests were carried out at an output of 100 l/h, a temperature of 20 °C for 30 min.

RESULTS AND DISCUSSION

The results of comparative tests of purifying the model solutions from the oil products at the presence of an air bubble generator, in its absence and at flotation through porous materials are outlined in Table 1.

Analyzing the obtained comparative test data, one can make a conclusion that at using the bubble generator the efficiency of liquid medium purification from the oil products is 78 to 80-fold higher than at natural separation of oil and water due to the difference in densities and 5-fold higher that at flotation through porous materials.

It has been found at carrying out the laboratory tests of a jet film bubble generator that:

- A large amount of bubbles with a size of ~ 100 micron is formed in water;
- The rate of air bubble removal (rate of the bubble saturation boundary shift) from the water is from 0.3 to 0.9 m^3/hour.

Figures 2 to 3 are the photos of bubble formation at using the jet film generator.

Figure 4 represents photos of the starting oil and water emulsion and the one after flotation.

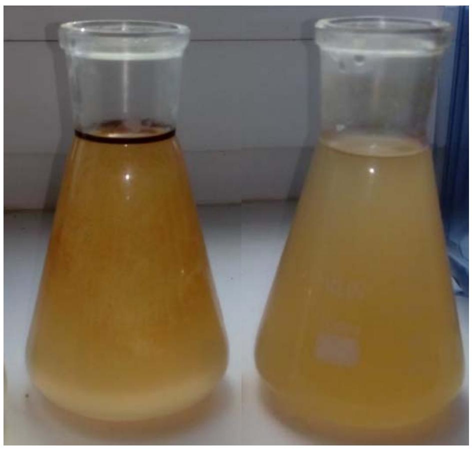
Figure 2 – Disperser in action

Table 1 – Results of purifying the model solutions from oil products without a floater and in the presence of a floater

No.	Final oil product contents without floater, mg/l	Final oil product contents with floater, mg/l	Final oil product contents at flotation through porous materials, mg/l
1	800 ± 40	10 ± 0.5	50 ± 2.5
2	740 ± 37	9.4 ± 0.47	46.3 ± 2.3
3	740 ± 37	9.4 ± 0.47	46.1 ± 2.3
4	722 ± 36.1	9.2 ± 0.46	45.1 ± 2.2
5	592 ± 29.6	7.5 ± 0.38	37.1 ± 1.9
6	777 ± 38.9	9.9 ± 0.45	48.5 ± 2.4
7	740 ± 37	9.4 ± 0.47	46.2 ± 2.3
8	722 ± 36.1	9.2 ± 0.46	45.4 ± 2.3
9	703 ± 35.2	8.9 ± 0.45	43.8 ± 2.2
10	722 ± 36.1	9.2 ± 0.46	45.1 ± 2.3

1 2 3

Figure 3 – Appearance of the obtained bubbles after using the jet film generator and time of their removal from water (1 – 1 min, 2 – 2 min, 3 – 3 min)



1 2

Figure 4 – Oil and water emulsion: starting one (1) and after flotation (2)

CONCLUSION

The laboratory tests reviewed in the paper have shown that:

– at using a bubble generator, the efficiency of liquid medium purification from the oil products is 78- to 80-fold higher than at natural separation of oil and water due to the difference in densities and 5-fold higher that at flotation through porous materials;

– the provided design of the device for flotation purification of liquid media provides for continuous saturation of the purified liquid medium with fine air bubbles which leads to at least 1.6-fold decrease in the adsorption time and flotation of oil products.

– However, biological possibilities for oil destruction in natural waters should also be taken into account: recent studies proved the active role of aquatic macrophytes in this process [10, 11].

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