Improving the Efficiency of Foam Separation of Diamond-Bearing Raw Materials by Using a Combined Collector Based on the Naval Fuel Oil and Activated Oil-Water Emulsions

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Abstract. As a result of the completed studies, a solution was provided for the urgent issue of increasing the efficiency of foam separation of diamond-bearing kimberlites through the use of a combined collector based on an activated water-oil emulsion and the naval fuel oil F-5.

With the selected ratio of components under the conditions of experimental tests, an increase in the extraction of diamonds into concentrate by an average of 5% was ensured, with a decrease in the consumption of the collector reagent by 1.5-2 times and the foaming agent OPSB by 15-34%.

1. Introduction

In the situation of growing demand for technical diamonds explained by its use in high-tech industries, the objective to increase effectiveness of foam separation processes used for their extraction in schemes for enrichment of the diamond-bearing raw material becomes more relevant [1].

Quite low values of foam separation enabling extraction of technical diamonds from the source raw material that are less than 2 mm big are partially explained by the decreased effectiveness from the applied collecting agent that is the naval fuel oil characterized by the low collecting ability and the unstable contents.

The prospective method to solve the issue to increase extraction of technical diamonds by the foam separation method is the application of combined collecting agents based on the mixture of oil products with various molecular weight, density and viscosity which contents provide for water-repellency of the diamond surface, their effective attachment to the well-developed interphase liquid-gas borderline and the consequent extraction into the relevant concentrate [2, 3].

To produce this type of collecting reagents taking into account specific logistics and storage under Extreme North conditions, the quite prospective raw material is oil sludges extracted together with diamond-bearing kimberlites.
2. The purpose and objectives of the study
The purpose of the research work is to develop the effective combined collecting agent based on oil products for conditions of foam separation of diamond-bearing kimberlites.

The following issues are solved to achieve the purpose:

- the structure of oil-water emulsions (OWE) is studied;
- rules of the process are determined and parameters of the vibro-stream magnetic activation of oil-water emulsions are explained providing for their effective collecting features for foam separation of the diamond-bearing material;
- the technological mode of vibro-stream magnetic activation (VMA) for the oil-water emulsion provided for effective water-repellency of the diamond crystal surface before the foam separation procedure is developed and tested by semi-industrial trials.

3. Principal part
The average contents of the oil hydrocarbon fracture (the oil-water emulsion) extracted from the fluid of oil slurs from diamond-extracting mines is the typical oil with the relatively low freezing temperature (-20°C).

The analysis of the IR spectrum for the organic phase of the oil slur sample (Figure 1) obtained on the laboratory IR Fourier spectrophotometer Vertex 7 shows the existence of absorption strips characteristic for methyl and methylene groups (1380, 725 cm⁻¹), stretching vibration strips of C=C arene ring bonds (1609-1603 cm⁻¹). The IR spectrum data allows one to draw the conclusion that the organic part of the sample is represented by the mixture of saturated and non-saturated hydrocarbons as well as by aromatic compounds characteristic for the traditional oil.

![Figure 1. The IR spectrum of organic fraction in the oil slur sample.](image)

The dependence of the sample's viscosity from the temperature is also characteristic for oil products and it diagnoses the freezing temperature of about -30°C (Figure 2).
Figure 2. Dependence of kinematic viscosity of the organic phase in oil slur samples from various mines (1,2) and the naval fuel oil F-5 (3) from the temperature.

To obtain quantitative characteristics of the OWE sample contents, thermogravimetric measurements were done using the thermal analyzer DNG-60 AH. The analysis of thermograms showed that studied OWE samples are characterized by the contents of water (3-10%), light boiling (20-30%), medium (40-50%) and heavy fractions of hydrocarbons (8-14%) modifying from sample to sample. The results of the analysis, the confirmed data of IR spectroscopy determined that oil-water emulsions contain unmixed optically transparent, colored phases of liquid substances, clots of non-transparent substances, the water phase of the various stage of dispersion, mineral grains (Figure 3 a, b). The discovered volume instability of the OWE contents is the main reason for decreased collecting features.

To stabilize the OWE contents and features, the technology of vibro-stream magnetic activation (VSMA) was used. Treatment of OWE samples was done using the VEMA-0.3 device for 1-3 min. Studies of the effect from vibro-stream magnetic activation on the colloid-disperse condition of oil-water emulsions was done by the visual metric analysis of photos under a microscope.

When the VSMA treatment lasts for 3 minutes, the average size of water phase drops and solid particles in the three-phase system decreases up to 50.1 and 45.1 µm respectively (Figure 3 c). At this, the whole scope of the selected sample is characterized by uniformity of the contents explained by mutual dissolution of light and heavy hydrocarbon fractions [4].

Figure 3. Oil slurs before (a, b) and after (c) treatment with VEMA-0.3 device during 3 minutes where: a – water lenses in the heavy oil fraction; b – water phase drops, mineral salt and asphaltene clot grains; c – thinly dispersed water phase micro-drops and thinly dispersed slur grains and water phase drops.
Therefore, vibro-stream magnetic activation results in decreased sizes of both the water phase and mineral grains. The measurement outcomes given in the Table 1 confirm that the water phase of the emulsion preserves the high aggregative stability during 10 days (Table 1).

| Terms of sampling and storage | Average drop size, % at the treatment period, min |
|------------------------------|-----------------------------------------------|
| Treatment for 3 minutes      | 171.5 74.5 61.4 50.1                           |
| 5 days of sedimentation      | 172.0 74.5 61.5 53.2                           |
| 10 days of sedimentation     | 171.5 77.4 67.5 54.3                           |

After vibro-stream electromagnetic treatment, kinematic viscosity of the oil-water emulsion decreases at 10-12% while density decreases at 0.7%. Decreased density and viscosity confirms manifestation of the intermolecular interaction effect during mutual dissolution of hydrocarbon fractions.

Thus, the results obtained show the significant modification and stabilization of the colloid-disperse conditions of the oil-water emulsion due to its vibro-stream magnetic activation in VEMA-0.3 device.

Collective abilities of source and activated oil-water emulsions on the first stage of studies were compared in the laboratory by the method of Hallimond tube flotation. Laboratory flotation studies showed that the growth of diamond extraction when using the activated OWE is from 2.4 to 6.1% (Figure 4).

**Figure 4.** Diamond extractions from the consumption rate and the temperature of the collecting agent where: 1 – the naval fuel oil; 2 – the source sample of the oil-water emulsion (OWE); 3 – the activated OWE sample.

The results of comparison of the collective ability of OWE and the naval fuel oil F-5 show that vibro-stream magnetic activation of the OWE significantly increases its collecting features and the diamond extraction achieves the values corresponding to the process when the naval fuel oil is used.

The second stage of studies is made on the experimental foam separator using ore charges that are 1.0+0.2 mm big and the natural diamond collection that is -2+1.2 mm big. The ore extract prepared from the kimberlite ore was used as the water phase.
The results of comparative flotation experiments using the naval fuel oil F-5 and oil-water emulsions activated at various times of impact as collecting reagents confirmed that the increase in activation time increases their collecting ability. The data given in the Table 2 show that the application of activated OWEs provides for the increased diamond extraction at 5-6.2%.

**Table 2.** Diamond extraction with the varied consumption rate of the collecting agent.

| Name of the collecting agent | Diamond extraction with the consumption rate of the collecting agent: |
|------------------------------|---------------------------------------------------------------------|
|                              | 190 g/t | 570 g/t | 760 g/t | 950 g/t |
| F-5 (the Naval fuel oil)      | 54.0    | 76.7    | 87.2    | 95.4    |
| OWE – not activated          | 34.1    | 55.5    | 83.9    | 88.9    |
| OWE – activated for 1 min    | 33.3    | 54.4    | 86.3    | 91.6    |
| OWE – activated for 2 min    | 33.3    | 54.4    | 86.3    | 91.6    |
| OWE – activated for 3 min    | 47.8    | 66.7    | 88.9    | 95.1    |

The obtained data analysis confirmed that diamond extraction using the source OWE is 5-20% lower that while using the naval fuel oil and during experiments with activated OWEs the diamond extraction achieves 88-95% that corresponds to extraction using the naval fuel oil F-5.

The naval fuel oil F-5 supplied on enriching factories of AK ALROSA is the comprehensive collecting agent consisting of the fuel oil M-40 and the diesel fuel. The mass fraction of gums and asphaltenes in the naval fuel oil F-5 is about 10%.

Studied samples of oil-water emulsions contain significantly more gums and asphaltenes (27%-45.9%) that characterizes them as “medium” and “heavy” oils respectively. Significant viscosity hampers their separate use but facilitates the application in combination with oil products of low viscosity as additives. In current studies, the oil product – the naval fuel oil F-5 is used as the “solvent” of OWE additives. It is characterized by the initial reduced viscosity due to the low contents of gum and asphaltene fractions.

At the next stage of the study, the composition based on activated OWEs and the naval fuel oil F-5 in various proportions are researched as combined collecting agents. Experimental bench trials of diamond extraction using created compositions of combined collecting agents were carried out. The analysis of obtained results showed that the greatest diamond extraction into the concentrate of foam separation is observed when the OWE share in the combined collecting agent is 7.5-12.5% (Figure 5). When the consumption rate of the collecting agent is 760-950 g/t (the factory mode data), the application of the combined collecting agent provided for the 4.7-7.9% increase in diamond extraction compared with the diamond extraction when the fuel oil F-5 is used as the collecting agent [5].

**Figure 5.** Dependence of diamond extraction into the concentrate on the fraction activated by OWE in the combined collecting agent where the consumption ratio of the collecting agent, g/t: 1 – 190; 2 – 380; 3 – 570; 4 – 760; 5 – 950.
4. Conclusion
Therefore, as a result of completed studies, the following principal results are obtained:

1. When vibro-stream magnetic activation is used, the scope of the oil-water emulsion gets the homogenous contents characterized by the complete mutual dissolution of organic components. When the impact of VSMA on the oil-water emulsion lasts for 3 minutes, the average size of aquatic drop particles is reduced from 171.5 to 50.1 µm and 45.1 µm while its kinematic viscosity is 6-9% reduced and its density is 0.7% reduced.

2. Natural oil-water emulsions of diamond-extracting mines have the unstable contents and provide for the diamond extraction in the concentrate of foam separation that is 34.1-88.9%. Activation of emulsions by vibro-stream magnetic treatment (VSMA) increases its collecting ability. When the oil-water emulsion is used that has been activated for 3 minutes at the temperature of 35°C, the diamond extraction in the concentrate increases at 6.1% that corresponds to the value achieved when the standard collecting agent – the naval fuel oil F-5 – is used.

3. Application of compositions made of the naval fuel oil F-5 and activated oil-water emulsions OWE as combined collecting agents where the OWE fraction is from 7.5 to 12.5% increases the diamond extraction at 4.7-7.9% compared with the standard mode implying application of the naval fuel oil F-5 as the collecting agent.

The selected proportion of components under terms of experimental trials provided for the average 5% increase of diamond extraction in the concentrate while the consumption rate of the collecting reagent was reduced in 1.5-2 times and of the PGMEF foam-generating agent – on 15-34%.

5. References
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