Selection of optimal conditions for preparation of emulsified fuel fluids

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Abstract. The aim of the article is to derive the optimal concept of physical and chemical effects, and its application to the production of water-fuel emulsions. The authors set a research task to attempt to estimate the influence of the surfactant concentration on such indicator as the time before the beginning of emulsion breaking. The analysis, based on experimental data, showed that an increase in the concentration of sodium lauryl sulfate is expedient to a certain point, corresponding to 0.05% of the total mass fraction. The main advantage of the model is a rational combination of methods of physical and chemical treatment used in the production of emulsions.

1. Introduction

At present, the problem of disposal of industrial wastes, as well as oil residues, including hydrocarbon and water-containing components, is acute. One can note the regularity of depressurization of pipelines and tanks at facilities associated with the extraction, transport, storage and distribution of hydrocarbon raw materials. These substances pollute the environment, including water. Elimination of the consequences of such accidents and incidents is extremely resource-costly [7]. In addition, the oil product into which the water has been trapped is no longer suitable for burning or for laboratory analysis. In the work, it is proposed, in case of breach of the integrity of the equipment for transportation and storage of petroleum products, to create water-fuel emulsions from the spilled substances for their subsequent combustion in boiler rooms. This method is also proposed to be used to reduce the level of harmful emissions (for example, nitrogen oxide) resulting from fuel combustion [10].

In this paper, it is proposed to create an emulsion of a hydrocarbon represented by diesel fuel with water by means of a complex physical and chemical effect using thermal and cavitation treatment with preliminary dissolution of the surfactant in the dispersed phase [5]. In order to find the most optimal method of creating emulsions that increases the time of breaking, it is proposed to dissolve the solubilizers in the dispersion medium, with the addition of salt represented by sodium chloride as the most water-soluble one.

A study on the complex effect of physical and chemical treatment was carried out on the basis of an industrial prototype of a cavitation homogenizer (RF patent No. 2620606). The component parts of the structure include an electric motor that provides a mechanical effect for the production of restructured water, which in turn is connected via a pipeline to a storage tank. The prepared water storage chamber is also equipped with a pipeline and a system of uniform water supply to the mixing chamber, the process being carried out by the operation of the process valve. A similar solution has been applied to the supply of a liquid hydrocarbon into the homogenizer chamber. In the process of restructuring the
constituent components of the final water-fuel emulsion, they are uniformly heated. This is done to equalize the viscosity of the components of the prepared mixture. It is possible to install a separate tank providing direct supply of surfactants improving the quality of the final product. The rotor shaft of the mixing grates homogenizer providing rotation is driven by an electric motor. Further, the liquid is discharged into a storage tank, from which samples of the finished water-fuel emulsion are directly taken.

An analysis of the existing literature has shown that the greatest stabilization of water-fuel emulsions can be achieved by using anionic-type surfactants with a hydrophilic-lipophilic balance (HLB) index of 10.5, which corresponds to the optimal index for creating emulsions with oil and petroleum products of low viscosity [8]. It should be noted that surfactants, creating the necessary hydrophilic properties, are not readily available in the existing market. Due to this, it is proposed to use a mixture of emulsifiers to obtain the required parameters. The possibility of using the most common emulsifier in the industry with the maximum possible number of HLB, 40, of sodium lauryl sulfate (SLS) is also considered. When the equilibrium concentration in the aqueous phase is reached with the given surfactant, the breaking rate will vary inversely proportional to the logarithm of the total concentration of sodium ions that are included in the emulsifier [8], as well as in the previously added sodium chloride, and the equation takes the form:

\[
\vartheta_{omc.} = \frac{1}{\ln c_{Na^+}}
\]  

(1)

There is an opinion regarding the application of ultrasonic treatment for the purpose of carrying out a repeated process of cavitation [2] as a necessary condition for the creation of a water-fuel emulsion that is not dissolved over a long period of time. In the installation used by the authors, it is envisaged to use the equipment for this treatment as an intermediate stage between the primary and secondary purging of the components of the mixture.

2. Materials and methods

The effectiveness of the use of a surfactant, sodium lauryl sulfate, is shown in the graph (Fig.1). The dependence of the emulsion breaking time on the concentration of the emulsifier taken on the total mass fraction in percent is shown.

![Figure 1. Dependence of time before breaking on emulsifier concentration](image)

One should note the advantages and design features of the device designed for improved dispersion of liquid hydrocarbon raw materials with water [1]. In the pilot installation, it was possible to eliminate the appearance of a transit flow, while increasing the efficiency of the rotor apparatus and improving the homogeneity of the medium being processed by pulsing the flow velocity. The creation of these conditions naturally increases the degree of homogenization. The high quality of the homogeneity of the liquids to be mixed is achieved by first equating the viscosities of the dispersed
phase and the dispersion medium by heating them to different temperatures, as well as restructuring the original components that passed the preliminary filtration [4].

When the rotor rotates, the rotor grates in close proximity to each other create a pressure corresponding to the boiling point of the liquids at a given temperature. As a result of induced cavitation, there are water and hydrocarbon balls, which subsequently collapse on a conical plate, the coalescence rate being determined by the formula:

$$\theta = K_1 \left( \frac{0.24\psi^2 - \Theta_f \sum H}{RT} \right)$$

where $K_1$ – hydrodynamic collision factor, equal to $4Fkr/3\eta_c$; $\eta_c$ – aqueous phase viscosity; $B$ – a constant equal to 0.24, which is derived empirically from the theory of coalescence kinetics; $\psi$ – surface potential; $\Theta_f$ – proportion of the surface of particles coated with emulsifiers (if present in liquids); $\sum H$ – total energy barrier.

The power required to break a total energy barrier is minimized by a reduced number of revolutions per minute, and is in the standard range of 0.1-10 hp for this type of installation [6].

The application of cavitation emulsification is due to the need to reduce the surface tension of particles to simplify their intermolecular interaction. In addition, this increases the contact area between the dispersed phase and the dispersion medium [3]. The optimum position of the rotor relative to the stator and the possibility of varying the speed of rotation eliminates the need to create overpressure, which in turn leads to optimization of the energy inputs required for the operation of this experimental installation. Depending on what type of hydrocarbon fuel will be used to produce the emulsion, and therefore what common energy barrier will have to be destroyed, the number of revolutions per minute varies from 1000 to 3000 steps per 500 rpm.

3. Conclusion
Based on the results of pilot tests, it was possible to establish that during the preparation of the fuel fluid, a finite equalization of viscosities, creation of commensurate polymer chains, stabilization of the physical and chemical properties of the sample occurred on this device.

Further, this method is planned to adapt to various types of hydrocarbons, including other fuel fluids represented by fuel oil, furnace fuel, oil sludge, etc. Also, the resulting water-hydrocarbon emulsion is proposed to be subjected to ultrasonic cavitation and repeated homogenization to reduce the size of micellar formations, and an increase in the breaking time.

The indicators achieved through physical processing, expressed by cavitation, correspond to laboratory studies on the production of water-fuel emulsions using surfactants. It should be noted that the approximate equality in the breaking time indicates that the technological process proved to be no less effective, in contrast to the chemical process. Taking into account the difference in the indirect purpose of cavitation in this area, and the direct role of emulsifiers in the formation of emulsions, it can be concluded that the time before breaking will further increase when these methods are applied in order to achieve the best result.

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