УДК 66.045

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DEPENDENCE OF HEAT EXCHANGE EFFICIENCY DURING CONDENSATION OF A VAPOR-GAS MIXTURE ON THE SOLID PHASE CONCENTRATION USING THE EXAMPLE OF A MULTICOMPONENT EXTRACTION GASOLINE MIXTURE

Abstract: Condensation of extraction gasoline vapors with microparticles on tubes with annular grooves was studied. It was found that increasing the solid phase concentration to 3-3.5% leads to an increase in heat exchange intensity, after which it stabilizes. Experiments showed that decreasing the groove pitch (t/D=0.25) significantly increases the heat transfer coefficient.

Keywords: condensation, heat exchange, extraction gasoline, microparticles, annular grooves.

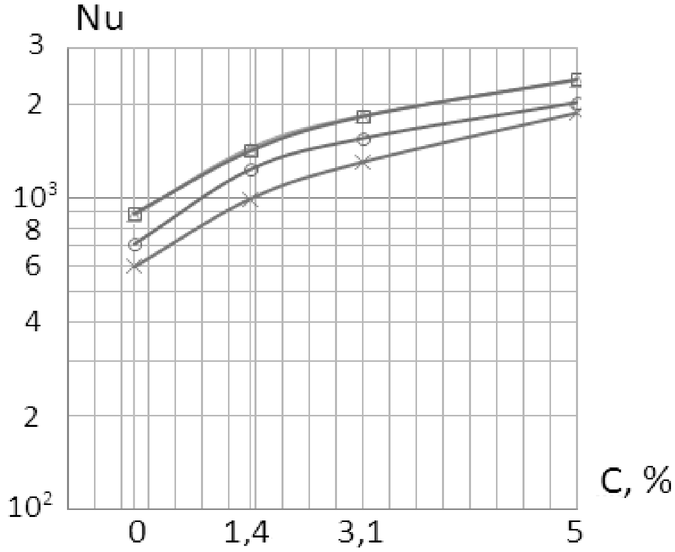
In the chemical industry, it is often necessary to condense vapors of extraction gasoline containing microparticles up to 100 microns in size. The existing sludge traps in the technological chain do not provide a high degree of purification and the multicomponent mixture contains up to 5-7% of particles [1].

It is well known that the presence of fine solid particles usually leads to an increase in the number of condensation nuclei, thereby intensifying the process of condensation of vapor-gas mixtures. In several studies, surfactants, inactive particles, and dust particles have been used as additional condensation nuclei to significantly intensify the condensation process [2].

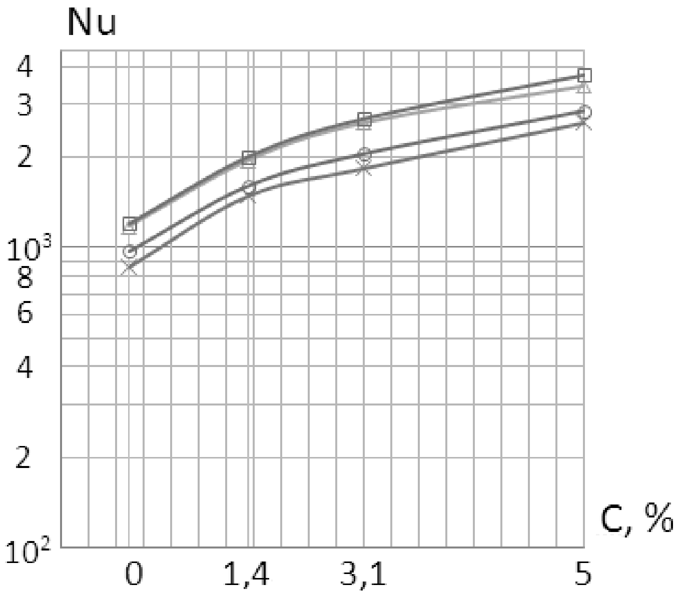
The condensation process generally occurs on a surface at a temperature where the saturated vapor pressure is lower than the partial vapor pressure in the vapor-gas mixture. This process can take place on some cooled surface or within the mixture volume-on condensation nuclei, i.e., dust particles, ions, droplets, etc. Condensation always begins on the surface of some nuclei. To enhance the process efficiency, conditions are created for vapor condensation deposition on the surface of microparticles [3].

To intensify heat transfer during the condensation of a mixture of extraction gasoline, water, and oilcake particles, an experimental setup was installed, and studies were conducted on tubes with annular grooves across a wide range of operating parameters [4].

The water temperature at the inlet varied from 8 °C to 14 °C, and the velocity ranged from 0.05 to 2.5 m/s. The velocity of the vapor-gas mixture at the inlet varied in the range of w_{vgm}=0.1-11 m/s, corresponding to Reynolds numbers $Re_{vgm}=(0.22\text{-}20)\times10^3$. The solid phase concentration in the vapor-gas mixture ranged from c=0-5%.



d/D=0,93; t/D=0,44



d/D=0,88; t/D=0,25

Figure – Dependence of heat exchange intensity Nu on the solid phase concentration of a multicomponent vapor-gas mixture of extraction gasoline during film condensation
×-Re = 3500; ○-Re = 7800; ∆-Re = 12000; □-Re = 20000;

The figure presents results on the film condensation of extraction gasoline vapors containing a solid phase on smooth surfaces and tubes with annular grooves as a function for various Re, d/D, and t/D values.

From the graphs, it is evident that with an increase in the concentration of oil cake particles in the mixture, an increase in heat transfer intensity is observed across the entire flow velocity range. For the tube with d/D=0.93 at Re=12000 and c=0%, the heat transfer coefficient Nu=1450, at c=1.4%, the Nusselt coefficient Nu=1680, at c=3.1% Nu=1890, and at c=5% the coefficient Nu=1870. A sharp increase in Nu occurs up to c=3-3.5%, after which the growth slows significantly. This trend was recorded for all experimental tubes and Re values.

Comparison of the values of the functions Nu=f(c) for tubes with t/D=0.44 and t/D=0.25 at relatively similar d/D=0.93, Re=12000, and c=1.4%, shows that the Nu value is higher at an annular groove spacing of t/D=0.25. For instance, at t/D=0.44, Nu=1550, while at t/D=0.25, Nu=2110, an increase by a factor of 1.36.

Experimental studies and visual observations have shown that starting with a solid phase concentration of more than 3% in a multicomponent vapor-gas mixture, the increase in the heat transfer coefficient slightly slows down. This is likely due to the saturation factor of droplet formation centers, i.e. condensation. Notably, due to the intensified heat within the tubes, the temperature of the cooling water and the tube wall is much lower than during condensation on smooth tubes. This eliminates the adhesion of microparticles to the heat exchange surface due to the lower wall temperature.

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