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The analysis of possibility in nanofluid application as the heat carrier for increase in efficiency of heat supply systems

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***Abstract:** The article is about the possibility of applying nanofluids in heat supply systems as a coolant. The most effective nanofluids were selected by analyzing the thermal conductivity, concentration, size, mass, and velocity of nanoparticles. It is presented the dependences of the heat transfer coefficient of a nanofluid on the Reynolds number and the heat transfer coefficient on the volume concentration. According to calculations, with the addition of 1% vol. of nanotubes to the coolant path that gives heat in the evaporating section of the heat pump, the heat transfer coefficient of a nanofluid increases by 100%.*

***Keywords:** nanofluid, nanoparticles, heat supply system.*

The use of nanofluids in heating and ventilation systems can give a significant increase in heat transfer.

For the use of nanofluids as a coolant it is necessary to have the knowledge of their thermophysical properties. For this purpose we have worked on analysis of nanoliquids researches.

In works [1, 3, 4] on the study of heat transfer in nanofluids it is demonstrated heat conductivity of suspensions of ultradisperse oxides of aluminum, silicon and titanium in water at volume concentration about several percent, exceeds the thermal conductivity of pure liquid by tens of percent.

Results of experiment with nanoparticles of various size show that heat conductivity of liquid on the basis of larger particles is rather well de-scribed by theory of Maxwell [2].

First of all, the obtained data were correlated with theoretical models, for describing the thermal conductivity of coarse-dispersed suspensions[9]. The first model of this type was created by Maxwell [5], who obtained a relation between the coefficients of thermal conductivity of the suspension λ and the carrier fluid λ_0 . The experimental data showed a duality: the thermal conductivity of nanofluids depend not only on the concentration and thermal conductivity of the nanoparticles, but also on the material and the size of the nanoparticles.

Considerable increase of heat conductivity of nanoliquids is possible even in small concentration of particles[10]. At the same time, extent of this increase significantly depends on the mass of nanoparticles and the square dependence of growth of heat conductivity on the mass of nanoparticles shows the square of dependence on density: $\Delta \lambda \approx (\rho_d / \rho_m)^2$, where ρ_d – density of material of nanoparticles.

On the Setaram Sensys EVO TG-DSC installation the specific heat of the nanopowders SiO₂ and SiC was determined by experimental data [6] in the range of temperatures from 30 °C to 80 °C. With increase of temperature specific heat increases as well.

According to the experimental data [7], the heat capacity of the nanofluid is well described by the expression (1):

$$C_p = \frac{\lambda}{\alpha \times \rho} \quad (1)$$

where λ is the thermal conductivity of the sample, $W / (m \times K)$; α -thermal diffusivity, m^2 / s ; ρ -density of the sample, kg / m^3 ;

The results of calculating the heat capacity of the samples are given in table 1 [7].

Table 1

Thermal capacity ($C_p, J/(kg \times K)$) of the studied heat carriers depending on concentration of nanoadditives.

Concentration, %	Name of coolant		
	Water + graphite	Water + carbon nanotubes	Water solution ethylene glycol + carbon nanotubes
0,2	3706,8	5204,4	2076,9
0,3	3748,2	5338,9	2037,8
0,35	3753,5	5444,8	1993,0
0,4	3774,2	5465,4	1950,5

The obtained results show that the heat capacity of the nanofluid exceeds the heat capacity of pure water and the growth dependence increases with increasing nanoparticle concentration.

The analysis of results [8] and table 1 showed that the use of nanofluid with carbon nanotubes is most effective.

Due to the theory of similarity we will calculate liquid thermolysis coefficient – waters and nanoliquids - water + carbon nanotubes. Let us consider the set-in turbulent flow of liquid with constant physical properties in a round cylindrical pipe. Initial data: $d = 40$ mm; $T_{zh} = 105^{\circ}\text{C}$; $T_c = 95^{\circ}\text{C}$; $l = 4.4$ m. at $v = 0.3$ m / s; $Re = 42253$; $Nu_{zh,d} = 131.20$.

The heat transfer coefficient is determined by Nusselt's number, at the same time heat conductivity of liquid is calculated at temperature equal to average of temperatures on an entrance and an exit.

When $Nu_{zh,d} = 131,2$ and the concentration of carbon nanotubes is 1% vol., the heat transfer coefficient, according to formula (2) and (3) are:

$$\alpha_{zh} = \frac{Nu_{zh,d} \times \lambda_{ж}}{d} = \frac{131,2 \times 0,55}{0,04} = 1804,0 \frac{\text{Вт}}{\text{м}^2 \times \text{с}} \quad (2)$$

$$\alpha_{н} = \frac{Nu_{н,d} \times \lambda_{н}}{d} = \frac{131,2 \times 1,1}{0,04} = 3608,0 \frac{\text{Вт}}{\text{м}^2 \times \text{с}} \quad (3)$$

thus, the heat transfer coefficient of a nanofluid increases by 100%, and with addition of 2% vol. or 3% vol. by 200% and 300%, respectively.

According to the calculations, in the figure 1 the dependence of the relative heat transfer on the volume concentration of nanotubes is presented.

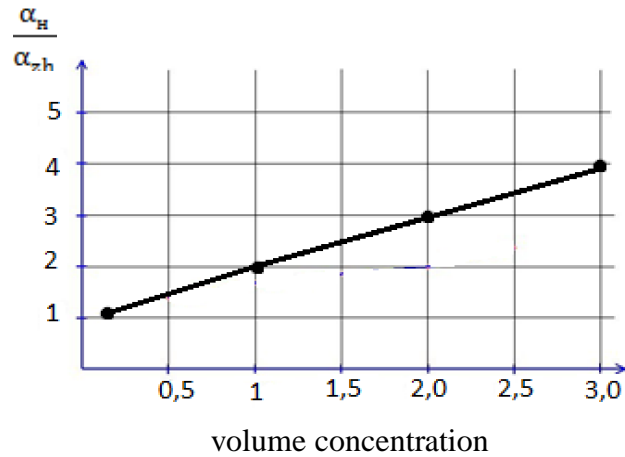


Figure 1. Dependence of the relative heat transfer on the volume concentration of nanotubes in the heat carrier

It can be seen from graph 1 when the concentration of nanoparticles increases, the heat transfer coefficient increases as well in comparison with pure water. It means that it is possible to reduce the surface area of heating of heat-gas supply systems' heatexchange devices.

The dependency graph of the heat transfer coefficient of nanofluid water / carbon nanotubes on Reynolds number is submitted in the figure 2.

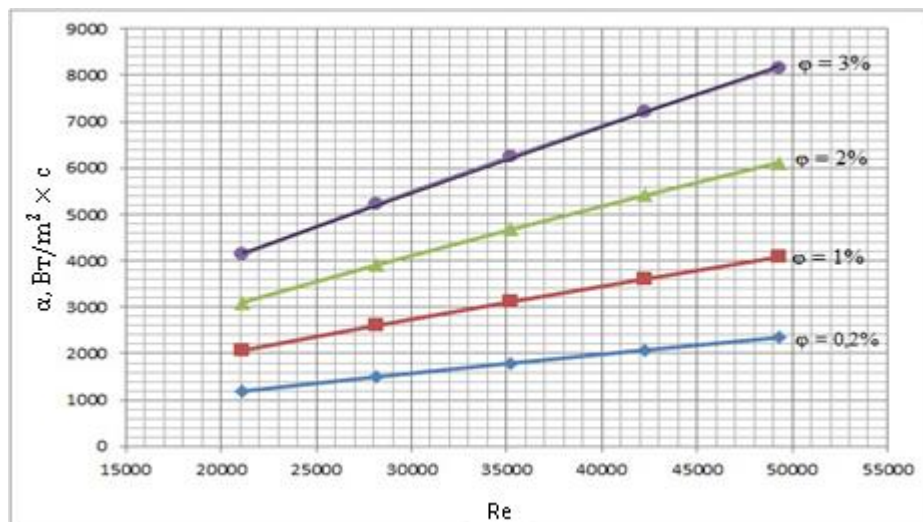


Figure 2. Dependence of the heat transfer coefficient of a nanofluid on the Reynolds number

The obtained dependences show that a significant increase in the heat transfer coefficient is possible with a slight increase in the Reynolds number. At the same time, the degree of this increase essentially depends on the concentration of nanoparticles and their velocity.

On the basis of the study, it can be assumed that the use of nanofluids has good prospects for improving heat exchange devices and improving the energy efficiency of heat supply systems. The most effective is the use of a nanofluid with carbon nanotubes.

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