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INTENSIFICATION OF HEAT TRANSFER IN A TUBE IN A SUSPENDED FLUIDIZED BED

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Abstract:
The results of experimental studies on increasing the intensity of heat transfer from the heat transfer surface to the fluid flow using dispersed systems as an intermediate heat carrier have been carried out

Keywords: The fluid flow, intermediate heat carrier, fluid flow using dispersed systems

Interest in heat transfer processes in a suspended fluidized bed liquefied by a droplet liquid is caused by the desire to maximize the heat transfer between the surface and the fluid flow. In particular, the fluidized bed can be used as an intermediate heat carrier in tubular heat exchangers. It is known that the introduction of suspended particles into the ascending fluid flow, that is, the formation of a fluidized bed of particles, significantly increases the heat transfer between the heat exchange surface and the fluid flow. In contrast to gas systems, fluidized beds liquefied by a droplet liquid are systems with homogeneous fluidization, in which the absence of a tendency to channel formation, high heat capacity of the medium, high thermal conductivity relative to the gas, as well as frequent collisions of particles due to the denser structure of the layers, dramatically change the picture of heat transfer [one].

We have experimentally investigated the average heat transfer from the inner surface of a heat exchange tube 34 mm in size to a layer of particles with an irregular shape of a polydisperse material fluidized with water. The heat transfer coefficient was averaged over the pipe height, and the experimental data were processed for the average heat transfer coefficient.

The intensity of heat exchange in the channels can be increased both by changing the characteristics of the fluidized bed and by changing the hydrodynamic situation near the heat-transfer surface. In the conducted experimental study, heat transfer from the wall of a heat-exchange tube to a fluidized layer of polydisperse material was studied.

The defining parameters were the average temperature of the fluidizing medium, the velocity in the space between the particles, equal to the filtration rate divided by the average porosity of the fluidized bed. The determining geometrical size - the equivalent diameter of the channel dpc formed by the pores is determined from the equation [2].

$$d_{п.к}=\Phi d_э \mathcal{E}_0/(1- \mathcal{E}_0)$$

where Φ- coefficient taking into account the dependence of the equivalent particle diameter $d_э$ from its form; $\mathcal{E}_0$- porosity of a fixed layer of granular material.

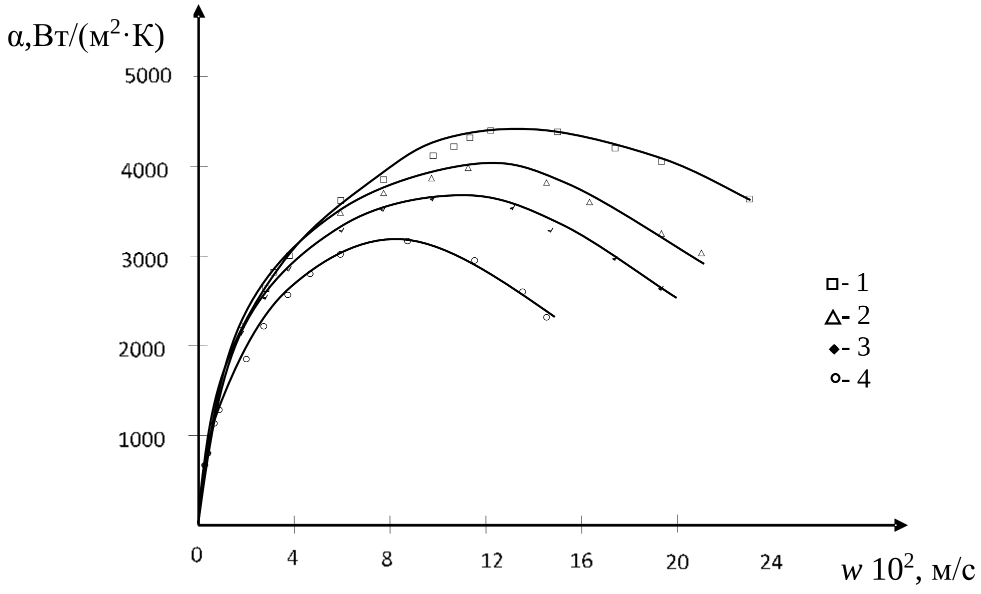
The experiments were carried out in series, characterized by the constancy of the heat load at a gradually increasing water velocity at a stationary thermal regime.

The dependence of the heat transfer coefficient on the speed of the fluidizing agent was studied for 12-15 stationary modes for each fraction. The speed of the water, the degree of expansion and the height of the fluidized bed varied, respectively, in the range of 0.001-0.3 m / s and 50-300 mm.

We have experimentally found that with an increase in the filtration rate, the heat transfer coefficient passes through a fairly flat maximum. At lower velocities of water movement, the particle size practically does not affect heat transfer. With a gradual increase in the velocity of the fluidizing agent after the onset of fluidization, a significant increase in the heat transfer coefficient is observed (Fig. 1). With a further increase in the speed of the fluidizing agent, ɑ reaches its maximum value, after which the heat transfer coefficient decreases more or less smoothly. At high flow rates, providing a low concentration of solid particles in the bed, the heat transfer coefficients in the case of fluidization by a liquid are significantly reduced. Curve configuration $ɑ=f(w)$ near the maximum depends on both the properties of the working bodies and the parameters of the heat exchange surface.

The intensity of heat transfer in a pipe with a suspended layer of granular material is determined by the intensity of movement of solid particles, "stripping off" the boundary film. Existence of a maximum on a curve $ɑ=f(w)$ is explained by the simultaneous and opposite effect on heat transfer of two main factors: an increase in the intensity of movement of particles near the heat exchange surface and an increase in the porosity of the layer with an increase in the velocity of the fluidizing agent. The first of these factors contributes to the intensification of heat transfer, and the second causes a decrease in ɑ due to a decrease in the concentration of solid particles at the heat exchange surface. Near the onset of fluidization and at relatively low velocities of the liquefying agent, the first factor plays a dominant role, and with an increase in w, the second begins to prevail. Increase in particle speed $w_ч$ with increasing w, it no longer leads to an increase in the temperature head, since the temperature of the particles is already close to the temperature of the core of the layer, and the temperature head to its highest value. The particles move randomly, then, in contact with the heat exchange surface, then moving away from it into the core of the fluidized bed. As a result, growth ɑ slows down and passes through a maximum, and then begins to decrease with increasing speed.

Further intensification of heat transfer due to the acceleration of particle motion becomes impossible. At the same time, as the fluidization rate increases, the porosity of the bed increases, i.e. the fraction of the time that the surface is in contact with the liquid rather than the particle packets. In an apparatus of not very small cross-section, it increases slowly, therefore, the heat transfer coefficient, having reached its maximum, slowly decreases, remaining almost constant in a rather wide range of speeds. It was found that when particles of irregular shape are fluidized, the nature of the movement of particles in the volume of the bed changes dramatically. Intensive mixing and rotation of particles appear throughout the volume of the layer, and as the speed increases, the intensity of their movement increases. It has been experimentally established that the use of polydisperse materials consisting of irregularly shaped grains as an intermediate heat carrier makes it possible to increase the intensity of heat transfer more than spherical particles. This is due to additional artificial turbulization of the boundary zone associated with an increase in the speed of movement of particles and liquid near the surface.



Gravel 1-3.04 mm; 2-2.54 mm; 3-1.98 mm; 4-1.3 mm

Figure: 1. Dependence of the heat transfer coefficient on the speed of water during fluidization

The heat transfer coefficient ɑ from the fluidized bed to the surface or vice versa depends on many factors. Formulas for calculating ɑ, obtained by various researchers empirically or semi-empirically, are valid only for the conditions of the above experiments [3]. In practical calculations, these formulas require significant adjustments. Analysis of literature data showed that the intensity of heat transfer is affected by the structure of the fluidized bed.

Experimental data on heat transfer from the inner surface to suspended particles of irregular shape of polydisperse granular material, such as gravel, glass and lead shot, dependencies $\alpha = f(w)$ were processed in a generalized form Nu=*f*(Re). It is seen that the dependence of the Nusselt and Reynolds criteria is monotonic. This is due to the fact that the fluid velocity and the equivalent pore channel diameter are interrelated.

Our experimental results are generalized with an accuracy of 7% by the equation:

$$Nu_э=0,08Re_эPr^{0,4}$$

Where $Nu_э=\alpha d_{пк}/\lambda$ - equivalent Nusselt test;

$Re_э=Re\cdot\Phi/(1-\varepsilon)$ – equivalent Reynolds test;

$Re=wd\rho/\mu$ – Reynolds criterion, determined by the particle diameter d;

$d_{пк}=\Phi d\varepsilon/(1-\varepsilon)$ – diameter of pore channels of granular material;

λ – thermal conductivity of the fluidizing agent (water);

Ф – particle shape factor;

ε – fluidized bed porosity;

w – water velocity, calculated from the full cross-section of the pipe;

ρ и μ - respectively, density and dynamic viscosity of water.

The equation is valid within the limits $Re_э$=20-1000, Pr=4-8.

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