# A STUDY OF THE POSSIBILITIES OF CONTROLLING THE HYDRODYNAMICS OF A FLUIDIZED BED TO INTENSIFY EXTERNAL HEAT EXCHANGE

A. P. Baskakov, N. F. Filippovskii,
A. V. Sokolov, O. M. Panov,
and A. A. Zharkov

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The influence of various inserts, controlling the motion of gas bubbles in the fluidized bed, on external heat transfer from the walls of the apparatus and from cylinders submerged in the bed is studied experimentally.

It is known [1, 2] that high values of the coefficients of heat transfer in a fluidized bed of relatively fine particles (d = 0.05-0.5 mm) are achieved through heat transfer from the surface to the particles which, during the intensive mixing, carry the heat accumulated by them into the core of the bed. However, stagnant zones of fine-grain material or, conversely, zones with a very low particle concentration are frequently formed near the heat-transfer surface (or individual sections of it). In this case the heat-transfer intensity proves to be low, since the stagnant zone thermally insulates the surface from the core of the bed in the first case, while ordinary convective heat exchange with the pure or dusty gas occurs in the second case. This leads to uneven heating (cooling) of articles in a fluidized bed and to the overheating and breakdown of electric heaters mounted in it.

Either special mixers [3] or the movement of the heat-transfer surface itself in a weakly fluidized bed [3, 4] have been used in a number of works for the intensification of particle motion relative to the surface.

The coefficient of heat transfer from a wall can grow if extra gas is supplied right next to it [5, 6]. Such methods allow one to improve the heat exchange but are not always suitable for actual technological apparatus. The methods offered in the present paper for the intensification of heat exchange through control of the motion of gas bubbles, which are natural sources of particle mixing in a fluidized bed, seem more acceptable.

Under ordinary conditions gas bubbles depart from vertical surfaces, such as the walls of the apparatus, into the core of the bed, as a result of which a zone of particles with little or no mobility forms near the surface. This is displayed most clearly in a bed of fine particles ($d \leq 0.1$ mm). The coefficients of heat transfer from the wall of the apparatus (Fig. 1, curve 1) are found to be considerably lower than those from small particles submerged in the core of the bed. A calculation by Zabrodskii's equation [1] gives $\alpha_{max} = 580\ W/m^2 \cdot {}^\circ K$ for these conditions.

For the basic solution to this problem a louver grill of inclined plates was set up near the wall (Fig. 1). This did away with the need for an extra gas supply to the wall; the grill itself directed gas into the zone near the wall from the core of the bed. Visual observations in the apparatus with a cross section of 280 × 60 mm (discharge cross section of gas-distributing grid $f_g = 0.18\%$), transparent side walls, and a bulk height of the corundum (d = 0.12 mm) bed of 420 mm showed that vigorous fluidization with predominantly rising motion of the particles occurs in the gap between the wall and the louver grill even at very low fluidization numbers. In these experiments the louver grill consisted of plates with a width of 30 mm and a length equal to the width of the apparatus (60 mm), mounted at a 45° angle spaced 30 mm apart. The distance from the louver to the narrow side wall of the apparatus was 15 mm. The average and local coefficients of heat transfer were determined by the method of constant heat flux using an α-calorimeter made of Nichrome ribbon 0.1 mm thick and 25 mm wide. In this case the intensity of heat transfer from the calorimeter was considerably higher than

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S. M. Kirov Ural Polytechnic Institute, Sverdlovsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 34, No. 4, pp. 600-603, April, 1978. Original article submitted March 21, 1977.

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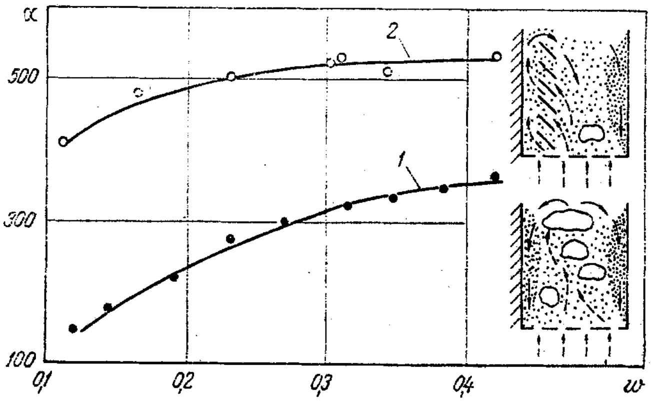

Fig. 1. Effect of filtration velocity w on coefficient of heat transfer (α) from the wall of an apparatus of cross section 60 × 280 mm and character of the circulation of fine-grained material in a free bed (1) and in a bed with a louver grill (2). Diameter of corundum particles d = 0.12 mm. w, m/sec; α, W/m²•°K.

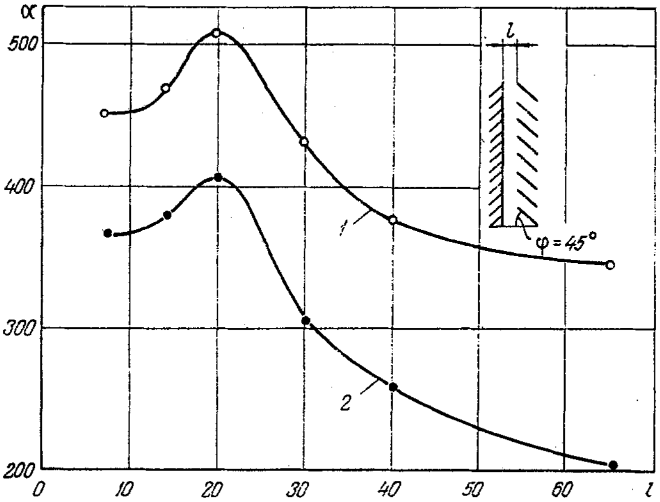

Fig. 2. Variation of the coefficient of heat transfer α between the vertical wall of an apparatus of cross section 240 × 260 mm and the bed as a function of the distance $l$: 1) w = 0.144; 2) 0.046. Diameter of corundum particles d = 0.06 mm. $l$, mm; w, m/sec.

in a free bed, especially at low fluidization velocities (Fig. 1, curve 2). A louver grill of similar construction was also tested in an apparatus with a cross section of 240 × 260 mm. The length of the plates was also equal to the width of the apparatus (240 mm). Upon installation of the louver the intensity of heat exchange from the wall of the apparatus was practically the same as in the 280 × 60 mm apparatus. At the same time, the values of α were lower in the free bed in the narrow apparatus, evidently because of constraint of the motion of the material and the gas bubbles.

Special experiments showed that it is best to locate louvers of the given construction at a distance $l$ = 20 mm from the wall of the apparatus (Fig. 2).

Through control of the flow of gas bubbles one can intensify the heat transfer not only from the walls of the apparatus but also from submerged bodies. For example, a stagnant zone of fine-grained material, which degrades the heat transfer, forms above a horizontal cylinder of large diameter (220 mm). To eliminate it we used a deflector (Fig. 3) which deflects the flow of gas bubbles toward the upper generatrix of the cylinder. Observations in a transparent

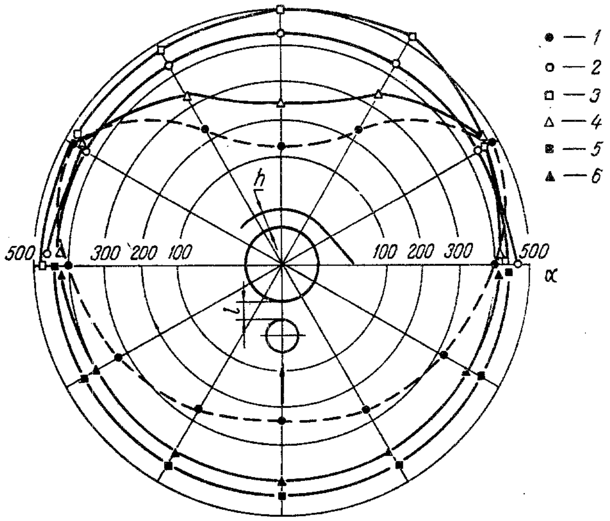

Fig. 3. Distribution of heat-transfer intensity $\alpha$ over the perimeter of a horizontal cylinder 220 mm in diameter upon the installation of a deflector: 2) h = 40; 3) 20; 4) 60; upon installation of a round insert: 5) $l$ = 60; 6) 20; 1) in the absence of inserts. Diameter of corundum particles d = 0.3 mm, filtration velocity w = 0.7 m/sec. h, $l$, mm.

apparatus showed that when the deflector is placed 10-40 mm above the cylinder the fluidization proceeds in a piston mode in the gap between them.

This assures the sufficiently rapid exchange of particles and high values of the heat-transfer coefficients in the rear zone (with respect to the gas motion) of the cylinder. When the deflector is installed at a greater height above the cylinder its influence on the heat transfer decreases. The low values of the coefficients of heat transfer from the front zone (with respect to the gas motion) of the horizontal cylinder are explained by the larger fraction of the time of contact of the surface with gas bubbles. Various inserts were mounted below the cylinder to eliminate this. In the transparent apparatus their shape and size were chosen in such a way that the fine-grain material did not depart from the front sections of the cylinder surface and at the same time was sufficiently mobile; i.e., the exchange of material between the front zone and the core of the bed would occur often. The best results were achieved with the use of inserts of round and triangular cross section (the triangle was equilateral with sides equal to half the diameter of the main cylinder), and the distance from the top point of the insert to the cylinder must be no less than 10 mm.

Then the intensity of heat transfer from the front zone of the cylinder (insert diameter D = 100 mm) became practically the same as that from the side zones (Fig. 3).

The work performed makes it possible to indicate ways of intensifying external heat exchange in a fluidized bed through control of the hydrodynamic boundary region.

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