DETERMINATION OF THE CONTACT TIME OF PHASES OF AN INHOMOGENEOUS FLUIDIZED BED WITH A PLATE IMMERSED IN IT

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UDC 621.785:66.096.5

It is shown that a thin gas interlayer occurs near a plate immersed in a fluidized bed and that the local structural-hydrodynamic characteristics of the boundary zone are different.

It was noted as long ago as 1959 [1] that gas streams can be interrupted near bodies placed in a fluidized bed and that the porosity of the boundary layer differs noticeably from the average throughout the entire volume. This was supposed to be taken into account when working on problems of external heat and mass transfer in fluidized media. However, in the "packet" theory of heat transfer [2] that recently gained popularity the actual structure of the boundary zone was not taken into consideration, which led to errors, noted in [3].

Determination of the timewise average structural-hydrodynamic characteristics of the boundary zone was accomplished for the first time in [4–6], but the true (instantaneous) values of the porosity of the fluidized bed were not determined in these studies.

In the present investigation by means of photography with an exposure time of 1 : 125 sec we were able not only to confirm the actual picture of the phenomenon [1, 3] but also to determine the local values of the contact time of individual portions of the plate with different phases of the inhomogeneous fluidized bed.

The investigations were carried out with a 20 × 30 × 80-mm plate placed vertically in a 150 × 30-mm rectangular apparatus with transparent walls. The distance from the perforated lattice to the lower end of the plate was 25 mm. Fluidization of the bed of chamotte with an equivalent diameter of 0.7 mm was done by air at room temperature. The photographs were taken with a "Zenith-S" camera installed so that its optical axis coincided with the line of intersection of the lower and one of the side surfaces of the plate. Shading of the leading edge of the plate by the thin boundary interlayer of gas at these surfaces was thereby eliminated.

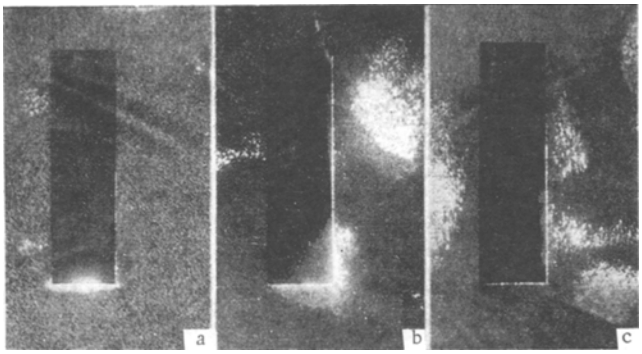

Fig. 1. Flow past a plate immersed in an inhomogeneous fluidized bed: a) W = 1; b) 2; c) 5.

S. M. Kirov Ural Polytechnic Institute, Sverdlovsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 23, No. 6, pp. 998-1000, December, 1972. Original article submitted March 27, 1972.

TABLE 1. Relative Frequency of Change of "Phases" near Plate

W	1					2				
No. of points	1	2	3	4	5	1	2	3	4	5
f_0	1,00	0,84	0,48	0,20	0,00	0,81	0,81	0,76	0,30	0,00
$f_{\text{от}}$	0,00	0,13	0,26	0,19	0,00	0,19	0,16	0,15	0,46	0,00
$f_{\text{т}}$	0,00	0,03	0,26	0,61	1,00	0,00	0,03	0,09	0,24	1,00

W	3					5				
No. of points	1	2	3	4	5	1	2	3	4	5
f_0	0,84	0,83	0,69	0,31	0,00	0,90	0,85	0,55	0,50	0,00
$f_{\text{от}}$	0,10	0,13	0,22	0,56	0,00	0,10	0,15	0,40	0,35	0,00
$f_{\text{т}}$	0,06	0,04	0,09	0,13	1,00	0,00	0,00	0,05	0,15	1,00

Transillumination of the bed during photography was done with diffuse light from the opposite side of the apparatus. The interval between frames was 5 sec. We took at least 35 successive photographs at fluidization numbers 1, 2, 3, and 5. More than 200 photographs were treated statistically. Three of them obtained for the boundary zone near the right side and lower surfaces of the plate for W = 1, 2, and 5 are shown in Fig. 1. Similar photographs were obtained also for the left side of the plate, which indicated the same probability of phase alternation near its side surfaces.

We see from Fig. 1 that a thin gas interlayer whose thickness is commensurable with the size of the fluidized particles forms near the side surfaces of the plate. In addition, we see that the inhomogeneous fluidized bed is not in a two-phase state, as is commonly considered [2], but in a three-phase state [3]. The photographs clearly show that any portion of the plate surface (except the upper horizontal surface) alternately contacts the discrete phase (gas interlayer, gas bubbles), diluted phase (eddies, spouting, air transport), and continuous phase ("packets"). The frequency of the change of phases and the time of their contact with a given unit surface of the plate are far from the same.

A determination of the numerical values of the relative contact time of the discrete phase f_0, diluted phase f_d, and continuous phase f_c with the plate was made near its lower end surface (point 1), near the side surface at a distance of 10, 35, and 60 mm from the lower edge (points 2, 3, and 4 respectively), and near the upper end surface (point 5). Some results of this determination are given in Table 1, from which we see that when $W \geq 2$ more than two-thirds of the lower part of the plate (points 1, 2, and 3) contacts mainly not the "packets" of particles ($f_c < 0.99$) but the gas bubbles and gas interlayer ($f_0 > 0.55$) and local eddies ($f_d > 0.15$). On the stern part of the plate (point 5), conversely, a gas layer was not recorded ($f_c = 1.00$).

The photographs permit, in addition to the numerical values of f_0, f_d, and f_c, determining the velocities of the particles and the direction of this movement on the basis of the clearly observed dashed lines (tracks of the particles during time 1:125 sec). It was found that the velocity of the particles near the plate in the observed eddies is of the order 0.5-1.5 m/sec and for individual particles reaches 3-4 m/sec, which indicates high velocities of the air near the plate.

The results obtained permit the conclusion that the frequency and contact time of the active part of the plate with the continuous phase ("packets") are appreciably less than commonly considered [2] and that there is no sense to express analytically the coefficients of external heat and mass transfer in terms of the volume-averaged ("point") fluctuation characteristics of the fluidized bed.

NOTATION

w	is fluidization number;
f_0	is the relative time of discrete phase and plate contact;
f_d	is the relative time of diluted phase and plate contact;
f_c	is the relative time of solid phase and plate contact.

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