5. L. M. Nikitina, Thermodynamic Parameters and Coefficients of Mass Transfer in Moist Materials [in Russian], Énergiya, Moscow (1968).
6. A. U. Franchuk, Tables of Thermotechnical Indicators for Structural Materials [in Russian], Nauch.-Issled. Inst. Stroit. Fiz., Moscow (1969).
7. G. I. Berezin, A. A. Kozlov, and L. V. Kuznetsova, "Calorimetric studies of phase transition of capillary consensate," in: Surface Forces in Thin Films and Disperse Systems [in Russian], Nauka, Moscow (1972), pp. 202-209.
8. A. V. Kiselev and V. V. Kulichenko, "Adsorption of benzene vapor by adsorbents of various structures above and below their melting point," Zh. Fiz. Khim., 29, No. 4, 663-667 (1955).
9. I. N. Votyakov, "Relation between unfrozen water content in frozen soil and hygroscopic moistness of soils," Izv. Sib. Otd. Akad. Nauk SSSR, No. 3, 17-25 (1960).
10. L. G. Kachurin and V. G. Morachevskii, Kinetics of Phase Transitions of Water in Air [in Russian], Leningrad State Univ. (1965).
11. M. P. Vukalovich, S. L. Rivkin, and A. A. Aleksandrov, Tables of Thermophysical Properties of Water and Water Vapor [in Russian], Standartov, Moscow (1969).
12. M. F. Kazanskii, R. V. Lutsyk, and V. M. Kazanskii, "Determination of specific heat of evaporation of liquids from disperse materials over wide temperature range," Inzh.-Fiz. Zh., 11, No. 5, 589-594 (1966).

PRODUCTION OF A FLUIDIZED BED MOVING ALONG AN INCLINED GAS-DISTRIBUTING GRID

A. V. Barakov, N. M. Barannikov, and A. V. Zhuchkov

UDC 532.5.001.57:66.096.5

Results are presented from analytical and experimental studies on how the height of a fluidized bed is dependent on the major parameters when it moves up an inclined gas-distributing grid.

It is very promising in many technological processes [1-4] to move a fluidized bed along a gas-distributing grid with a flow of fluidizing gas oriented in the direction of motion by the grid. One of the most important parameters of this process is the bed depth, which has a quite definite relation to the gas flow speed, the angle of entry of the gas into the fluidized bed, the density and particle size of the solid phase, the grid inclination, and various other parameters. Here we consider how the bed depth is related to these parameters.

Preliminary experiments and published data show that gas jets curve in the direction of least resistance in a fluidized bed (Fig. 1).

If we neglect the interaction between particles, the projection G_x of the mass of a particle on the X axis at the surface of the bed at $y = h$ should be equal to the projection of the aerodynamic resistance force N_x. Particles in the range $y > h$ roll down along the layer since for these $G_x > N_x$. Therefore, a necessary condition for the existence of a moving fluidized bed of depth h is $G_x \leq N_x$ for $0 < y < h$, with the sign of equality corresponding to the upper boundary of the bed.

To determine h, we first have to establish the gas-velocity distribution in the bed. As the treatment is one-dimensional, we take the gas as incompressible and write the equations of continuity and the Navier-Stokes ones for the gas phase:

$$\frac{dv}{dy} = 0; \quad (1)$$

Voronezh Polytechnical Institute. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 46, No. 2, pp. 261-264, February, 1984. Original article submitted September 20, 1982.

$$v\frac{du}{dy} = g_x + \nu\frac{d^2u}{dy^2} + F_x; \tag{2}$$

$$v\frac{dv}{dy} = g_y - \frac{1}{\rho_r}\frac{dp}{dy} + \nu\frac{d^2v}{dy^2} + F_y. \tag{3}$$

If we neglect the friction of the fluidized bed on the walls of the channel, then the projection of the pressure force exerted on the gas by the suspended particles is determined as the projections of the weight of the particles held in 1 kg of gas on the X and Y axes:

$$F_x = -\frac{1-\varepsilon}{\varepsilon}\frac{\rho_p}{\rho_g}g_x; \tag{4}$$

$$F_y = -\frac{1-\varepsilon}{\varepsilon}\frac{\rho_p}{\rho_g}g_y. \tag{5}$$

It follows from the equation of continuity of (1) that v does not vary over the bed depth. Then (3) on the basis of (1) takes the form

$$\frac{1}{\rho_g}\frac{dp}{dy} = F_y + g_y. \tag{6}$$

This expresses the familiar fact that the pressure difference in a fluidized bed is due to the weight of the fluidizing agent and of the particles contained in it.

We can estimate the orders of the terms in (2) for all conditions of technical interest ($u \approx \nu \approx$ 5-15 m/sec, h = 0.02-0.2 m, $\nu \approx 10^{-5}$ m²/sec $F_X \approx$ 50-1000 N/kg) which shows that the first two terms on the right in (2) are unimportant by comparison with the others, so this equation can be simplified:

$$v\frac{du}{dy} = F_x. \tag{7}$$

The boundary condition for (7) is

$$u = u_0 \text{ at } y = 0. \tag{8}$$

The solution to (7) with (8) is

$$u = u_0 + \frac{F_x}{v}y. \tag{9}$$

Therefore, u decreases linearly as y increases (F_X is a negative quantity), and at the boundary at y = h

$$u_h = u_0 + \frac{F_x}{v}h. \tag{10}$$

The condition $N_X = G_X$ for a particle at the upper boundary implies that

$$C_D\frac{\pi d^2}{4}\rho_g\frac{u_h^2+v^2}{2}\frac{u_h}{\sqrt{u_h^2+v^2}} = \frac{\pi d^3}{6}\rho_p g\sin\alpha. \tag{11}$$

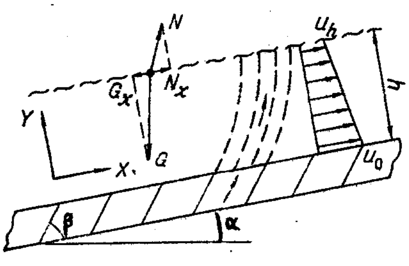

Fig. 1

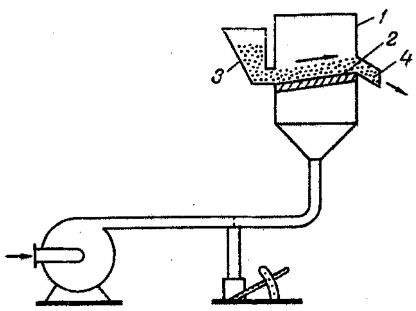

Fig. 2

Fig. 1. Scheme for the forces determining the formation of the fluidized bed.

Fig. 2. Essential scheme for the apparatus.

From (4), (10), and (11) we get a unique solution having physical significance for h:

$$h=\frac{\varepsilon}{1-\varepsilon}\,\frac{\rho_g}{\rho_p}\,\frac{u_0 v}{g_x}\left\{1-0.707\,\frac{v}{u_0}\left[-1+\left(1+7.11\left(\frac{g\rho_p d\sin\alpha}{C_D\,\rho_g v^2}\right)^2\right)^{0.5}\right]^{0.5}\right\}. \tag{12}$$

A test was performed on (12) with the special equipment whose general scheme is shown in Fig. 2.

The working element is a chamber 1 of rectangular cross section and dimensions 50 × 525 mm and height 520 mm. The side walls were made of lucite to enable the results to be seen. The interchangeable gas-distributing grid 2 was supported in the chamber on special holders at an angle of 19°. To prevent loss of particles, there was a steel grid with an effective clear cross section of 60% above the distributing grid. The air was supplied to the chamber by a high-pressure blower of type TS 10-28. The dispersed material (packing) was supplied to the chamber from a loading bunker 3, and it then moved up the distributing grid and was taken off along the channel 4. The packing consisted of particles of cubic shape made of V-95 aluminum alloy with equivalent diameters of 2.88 and 5 mm, or else spheres of silica gel (d = 2.47 mm) and cast iron (d = 1.13 mm).

In the experiments we measured the air flow rate, the porosity of the fluidized bed ε, and the depth h. The angle of inclination β of the louvers in the different grids varied from 20 to 40°, with the step in the louvers 25 mm and the height of the louvers 41.5 mm.

In all we examined 150 states. The standard deviation of the experimental data from values calculated from (12) did not exceed 40%. The frontal resistance coefficient C_D was taken as 0.48, since Re > 800 in all the experiments [5].

NOTATION

h, bed height, m; α, angle of inclination of gas distributor, rad; β, angle between the gas velocity vector and gas distributor plane, rad; G, particle weight, N; N, drag force, N; u, v, gas velocity vector projections on X and Y axes, m/sec; g, gravitational acceleration, m/sec^2; p, pressure; Pa; ν, kinematic viscosity, m^2/sec; F, force exerted by gas on the side of particles, N; ε, fluidized bed voidage; C_D, particle drag coefficient; d, equivalent particle diameter, m; ρ_g, ρ_p, densities of fluidizing gas and packing material, respectively, kg/m^3; u_0, u_h, gas velocity vector projections onto X axis at y = 0 and y = h, respectively, m/sec.

LITERATURE CITED

1. N. I. Syromyatnikov, "Theory of slagging in furnaces and gas generators containing fluidized fuel beds," Vestn. Inzh. Tekh., No. 4, 139 (1950).
2. Japanese Patent No. 48-38 495: "A drier for a bed moving in the transverse direction," Izobret. Rubezhom, No. 3, 68 (1974).
3. A. P. Neganov, "Regenerative air heating in an apparatus with a fluidized bed of intermediate heat carrier," Prom. Eng., No. 12, 28 (1976).
4. I. A. Burovoi and V. I. Korsunskii, "A method of removing large depositing particles from a fluidized-bed apparatus," Khim. Prom., No. 6, 453 (1965).
5. M. É. Aérov and D. M. Todes, Hydraulic and Thermal Principles of Operation in Equipment with Stationary and Fluidized Granular Beds [Russian translation], Khimiya, Leningrad (1968).