THE LEAKAGE GRID IN THE MOVING FLUIDIZED BED*

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The experimental results are used to demonstrate the effect of feeding granular material between the distributing grid and the top of the fluidized bed. The conditions existing above the feed point are such that a thicker fluidized bed may form there than the one below the feed. As a consequence, the thicker fluidized bed subsides below the feeding point bringing about considerable axial mixing of particles around the feed. Axial mixing in turn causes the effectiveness of fluidized separation in the moving fluidized bed to decrease considerably. 9 various modifications of leakage grid were used to suppress the undesirable effect by hydraulic separating the space above and below the feed. The leakage grids were placed immediately below the feed. The experimental results are discussed qualitatively.

This communication is a continuation of the preceding papers[1-3]. As has been shown earlier[1] the moving uniform fluidized bed of monodisperse particles may be described by the following equations

$$w = w_f - u_c\varepsilon/(1 - \varepsilon)\,, \quad \varepsilon = f(\text{Re, Ar}) \qquad (1), (2)$$

and

$$w_f = \dot{V}_f/S\,, \quad u_c = \dot{V}_s/S\,, \quad \varepsilon = V_f/(V_s + V_f)\,. \qquad (3)-(5)$$

For positive direction of motion of the particles and the fluid we take the direction opposite to the gravity. The quantities used for description are scalar quantities as we are dealing with a unidirectional motion of both the particles and the fluid. The area of cross-section of the column, S, is assigned the same sign as that of the mean velocity of fluid, w_f, or the particles, u_c.

From analysis of Eq. (*1*) for various arrangements of the fluidized beds as well as the results of our work it follows that under certain conditions a thicker fluidized bed may form on top of the thinner one. Such situation may be expected for instance if the feed is located in the middle part of the separating column. This configuration

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of the two beds gives rise to considerable non-uniformity of the fluidized bed and axial mixing of the particles which are both detrimental to the efficiency of the separation process. To remove the undesirable sinking down of the particles from the thicker into the lower, thinner part of the bed various leakage grids enabling free passage of both the fluid and the particles were tested. The leakage grid is essentially a perforated plate penetrable by both the fluid and the solid particles which serves to separate the two spaces and distribute evenly the fluid and the particles over the column cross-section.

EXPERIMENTAL

The effect of the feeding of the granular material and the separating effect of the leakage grid were studied by observing the course of porosity (void fraction) along the column height. The experimental technique and equipment used have been described in the earlier paper[1] (the inner diameter of the fluidized bed was 50 mm) and the fluidized particles were two narrow fractions of sand fluidized by water at constant temperature of 23°C (material F3, Ar = 2 549; F4, Ar = = 4 300; see ref.[1]).

During experiments the granular material was withdrawn from the column either at the top or the bottom (just above the supporting grid). This corresponds to two experimental arrangements: In the former there exists a region above the feed of cocurrently moving fluidized bed and a non-moving bed below. In the latter case, there is a non-moving bed above the feed and a counter-currently moving bed below.

To assess the effect of the feed on the axial mixing of particles several experiments without the leakage grid were performed using the sand 4F (Ar = 4 300) fluidized by water at the velocity of $w_f = 6{\cdot}9$ cm/s.

In order to verify the separating ability of individual leakage grids, *i.e.* the ability to restrict or suppress penetrating of the solid aggregates from the top fluidized bed of lower void fraction into the bottom higher void fraction part, several experimental runs were performed using sand F3 (Ar = 2 549, see ref.[1]) at velocity of water $w_f = 5{\cdot}5$ cm/s and approximately constant feed rate of the solid particles $m_s = 11{\cdot}5$ g/s ($u_c = 0{\cdot}22$ cm/s). The leakage grids were placed one at a time immediately below the feed, *i.e.* roughly at the boundary between the co-currently moving fluidized bed and the non-moving one. A total of 9 modifications of the separating grids were used. Seven of them were made of copper sheet 0·5 mm thick; two of phosphor bronze mesh. More detailed information is supplied in Table I.

DISCUSSION

Fig. 1 shows the results of several experimental runs when the granular material was being withdrawn at the column top and no leakage grid was used. The figure indicates the course of porosity, ε, along the height of the bed at constant flow rate of water and five different mass flow rates of the particles, $\dot{m}_s$. Owing to the axial mixing the porosity of the non-moving fluidized bed below the feed was the lower the greater was the mass flow rate of the solids in the co-current fluidized bed above the feed. The porosity of the fluidized bed corresponding to uniform expansion

TABLE I

Designation and Characteristics of the Leakage Grids

Designation	ζ	φ	Description
LG 1	2·73	0·587	circular 4·0 mm holes
LG 2	6·40	0·403	circular 4·0 mm holes
LG 3	2·59	0·570	circular 2·5 mm holes
LG 4	7·90	0·379	circular 2·5 mm holes
LG 5	2·09	0·597	circular 6·0 mm holes
LG 6	1·38	0·650	4·0 mm slots
LG 7	0·98	0·640	2·5 mm slots
LG 8	1·10	0·640	mesh, 4·0 mm square openings
LG 9	1·75	0·530	mesh, 2·0 mm square openings

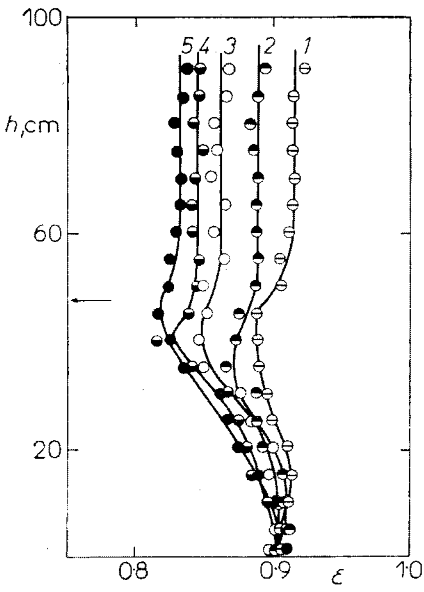

FIG. 1

Course of Fluidized Bed Porosity ε along the Height h at Constant Flow Rate of Water and Various Flow Rates of Sand $\dot{m}_s$ (g/s)

1 1·54, *2* 4·87, *3* 8·83, *4* 12·83, *5* 16·09, → feed point.

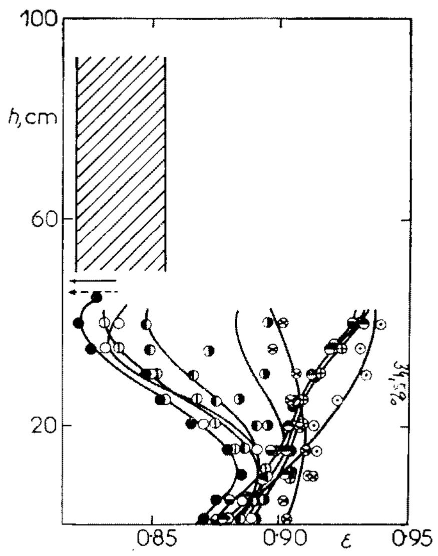

FIG. 2

Course of Fluidized Bed Porosity ε along the Height h for Various Leakage Grids LG

● Without grid, ⊗ LG 1, ⊙ LG 2, ◓ LG 3, ◒ LG 4, ◐ LG 5, ○ LG 6, ◑ LG 7, ⦶ LG 8, ⊖ LG 9, → feed point, ← positions of leakage grid, ///// region of moving fluidized bed.

of non-moving bed was recorded only in region close to the distributing grid at the column bottom.

Fig. 2 shows the observed distribution of the porosity along the bed height, h, at the same arrangement of the flows in the fluidized bed as in Fig. 1 but with the leakage grids installed. For the sake of clarity, all results obtained in the region of moving fluidized bed, *i.e.* above the feed, are shown by a shaded strip. The width of the strip is determined by the limiting values of porosity found in individual experiments. The feed rates of granular material in individual experiments were slightly different as the width of the feed slot did not allow the chosen feed rate of the granular material to be set accurately. The results from the region of non-moving fluidized bed, *i.e.* below the feed point, are marked by circles, distinguished according to the type of the leakage grid used (LG), and fitted by curves. The experimental technique used[1,2] in experiments with the leakage grids did not permit the porosity to be determined in the narrow region close to the feed point. The corresponding points could not be therefore shown in Fig. 2.

From the obtained information it can be concluded qualitatively that the effect of the leakage grid is the combined effect of the size of the openings and the relative free area of the grid, φ, combined. The tested leakage grids, according to Fig. 2, may be divided roughly into three groups. Relatively strongest separating effect was displayed by the grids LG 2, 3, 4 and 9. The second group with a minor, yet clearly detectable separating effect consists of the grids LG 1 and 7. The grids LG 5, 6 and 8 exhibit negligible separating ability and the system behaves essentially as that without the leakage grid as may be apparent from Fig. 2. A comparison of the obtained results with the characteristics of the leakage grids in Table I reveals that the separation ability increases with decreasing characteristic size of the openings and decreasing relative free area of the grid under otherwise identical physical conditions. It further turns out that the separating ability of the grid increases on average with increasing magnitude of the friction loss coefficient of the grid ζ. A more detailed answer to this question, however, requires additional study.

Apart from the experiments with the co-current arrangement we performed also some experiments with the counter-current arrangement of the flows when the non-moving fluidized bed existed above the feed and below there was a bed moving from the feed toward the discharge just above the supporting grid. In this case too, in agreement with Eq. (*1*), the porosity of the bottom part is higher than that at the top. The course of the porosity, ε, along the height of the bed is similar as that corresponding to the co-current arrangement. Under the counter-current arrangement of the flows the suitable leakage grids located below the feeding point exercised desirable separating effect with a more uniform fluidized bed existing within a short distance from the feeding point as a result.

It is thought that the presented initial study of the separating ability of the leakage grids has shown a way of separating the two fluidized beds of different porosities.

Such measures can further improve the efficiency of fluidized separators for separation of the solids and decrease the necessary height of the equipment.

LIST OF SYMBOLS

Ar Archimedes number
d particle diameter
g gravity acceleration
h distance above the supporting grid
Re Reynolds number
S area of cross-section of bed
m_s mass flow rate of solids
Δp pressure drop of the grid
u_c velocity of moving compact bed of solids ($\varepsilon = 0$) defined by Eq. (*4*)
V volume
$\dot{V}$ volume flow rate
w mean relative superficial velocity of fluid relatively to particles in an ideal uniform moving fluidized bed in Eq. (*1*)
w_f mean superficial velocity of fluid defined by Eq. (*3*)
ε porosity (void fraction) given by Eq. (*5*)
ϱ density
φ relative free area of the grid
$\zeta = \frac{2\Delta p}{w_f^2 \varrho_f}$ friction loss coefficient of grid

Subscripts

f fluid
s solid

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