FREE AREA FOR GAS FLOW THROUGH SIEVE PLATES WITH A BUBBLED BED

M. Rylek, F. Kaštánek, L. Nývlt and J. Kratochvíl
Institute of Chemical Process Fundamentals,
Czechoslovak Academy of Sciences, 165 02 Prague 6 - Suchdol

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Dry plate pressure drops of sieve plates with hole diameter 1·6 mm were measured on an experimental section 150 mm ID with free plate areas 0·53, 1·0, 2·0 and 3·0%. Obtained data were correlated by the McAllister Eq. Overal pressure drops with the same plates with a bed of liquid were measured in the range of superficial gas velocities in the range of 0—30 cm/s. By subtraction of the liquid holdup from the overall pressure drop were obtained the apparent dry plate pressure drops from which, according to the McAllister equation, the area of holes through which the gas was flowing were calculated. The in this way obtained free hole areas were correlated empirically in dependence on the gas velocity.

For formation of the heterogeneous bed in bubble-type reactors are at present mostly used sieve plates with a large number of holes. This arrangements have several drawbacks: *1*) manufacture of sieve plates with a large number of small holes is time consuming and expensive, *2*) diameter of holes should be as small as possible in accordance with the requirement of minimum weeping, *3*) from the point of view of homogeneous bubbled bed and its stability is desirous that all holes on the plate be a source of bubbles which for large number of holes is not fulfilled.

Practical result of this contribution is the method for calculation of the minimum number of holes sufficient for formation of a uniformly bubbled bed.

For correlation of dry plate pressure drops a relation has been proposed by McAllister and coworkers[1] in the form

$$\Delta P_d = k_1 k_2(\varphi)\, \varrho v^2 \qquad (1)$$

where the dependence $k_1 = f(t/d)$ is given graphically and

$$k_2(\varphi) = [0{\cdot}4(1{\cdot}25 - \varphi) + (1 - \varphi)^2]/\varphi^2 \quad . \qquad (2)$$

Relation (*1*) has been found[2,3] suitable for plates with $t/d < 2{\cdot}3$.

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From the force and momentum balance for sieve plates[4] results that for small gas velocities the momentum term is negligible so that the relation holds

$$\Delta p_0 = \Delta p_z + \varrho_e g h \,. \tag{3}$$

It is possible, by use of this equation, on basis of simultaneously measured experimental data on overall pressure drop and liquid holdup to calculate the apparent dry plate pressure drop *i.e.* the pressure drop of a plate operated with a part of hole area blocked by liquid (regardless whether the liquid is flowing through the holes or if the holes are only blocked by it). If we apply the assumption made and verified by Kolář and Červenka[5] that the pressure drop of the plate is not affected by the liquid present on it (*i.e.* that Eq. (*1*) holds for $\Delta p_z = \Delta p_d$ as well) then from the apparent dry plate pressure drop calculated from the experiments and from the measured gas velocity, the value of $k_2(\varphi)$ and from it the value of φ can be directly calculated from relation (*1*).

As results from Eqs (*1*) to (*3*) $\Delta p/\varphi v^2$ is a function of φ_g. From the technical point of view (*e.g.* with regard to the magnitude of weeping rates through the plate, to modelling of circulation in the bubbled bed on the plate *etc.*) the size of hole area which is occupied by the flowing through gas φ_g in dependence on v is quite important.

EXPERIMENTAL

The measurements were performed on the glass sectioned column 150 mm ID which is described in detail in the study by Nývlt[6]. The measurements were performed with the water-air system at 25°C with sieve plates with free plate areas $\varphi = 0{\cdot}53$, 1·0, 2·0 and 3·0% at heights of clear liquid from 0·2 to 1·2 m. Superficial gas velocities were up to 30 cm/s. The plates were made of stainless steel sheets 3 mm thick.

RESULTS

Dry plate pressure drop was, for the above given geometrical plate parameters and for $v < 0{\cdot}4$ m/s correlated by the relation (*1*) with the result

$$\Delta p_d/\varrho v^2 = 0{\cdot}45 k_2(\varphi)\,. \tag{4}$$

The given coefficient $k_1 = 0{\cdot}45$ is in a good agreement with the value read off from the graph given by McAllister ($2k_1 = 0{\cdot}80$). For calculation of the coefficients of Eq. (*4*) were neglected the points $\Delta p_d < 20$ N/m^2 for which the measurement is affected by a too large error.

From values Δp_z (calculated according to Eq. (*3*)) were by use of Eq. (*4*) calculated the values $k_2(\varphi)$ (see Eq. (*2*)) and numerically on the computer Tesla 200 the corresponding values φ_g. By relating to the geometrical hole area was obtained a single dependence which in the coordinates $\varphi_{gr} \sim v_0$ is expressing with a good accuracy the experimental data. This dependence is empirically described by Eq.

$$\varphi_{gr} = 1 - \exp\left(-0{\cdot}11 v_0\right). \tag{5}$$

This relation is in agreement with the experimental data with the average accuracy 11 rel.%.

As results from the obtained data only a small part of the hole area of sieve plates is under the considered operating conditions and geometrical plate parameters occupied by the flowing gas. This is demonstrated in Fig. 1 from which the relative free plate areas for the considered plates can be read off.

The proposed relations are representing with a reasonable accuracy the experimental data of dry pressure drops (Eq. (*1*) for small φ and for one $t/d = 1{\cdot}9$. Eq. (*5*) is correlating with a good accuracy the free plate areas through which the gas flows. These results are significant for considerations concerning the distribution plates in use at present and they can be used in the design for determination of the number of holes on the plate which is necessary for formation of a stable and uniformly bubbled bed. Also the range of Δp_0 must be taken into consideration for the considered types of plates (requirement of maximum uniformity and of minimum Δp_0).

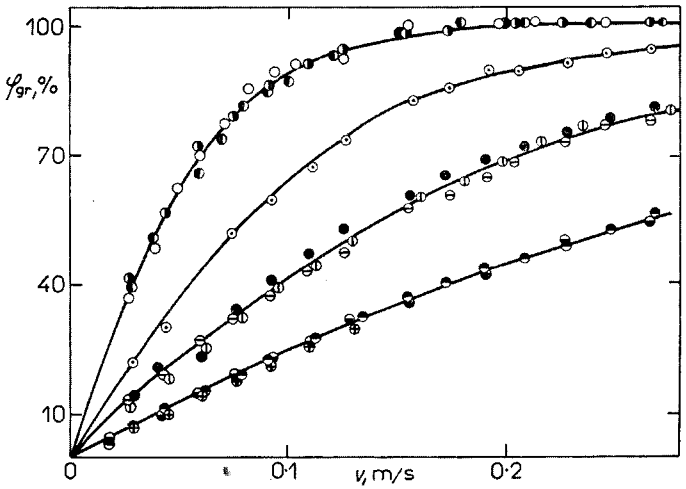

FIG. 1

Relative Free Hole Area through which the Gas Flows in Dependence on Gas Velocity

Plate I ($\varphi = 0{\cdot}53$) ◐ $h = 0{\cdot}4$ m, ○ 1·2 m, ◑ 0·2 m; II ($\varphi = 1{\cdot}0\%$) ⊙ $h = 0{\cdot}2$ m; III ($\varphi = 2{\cdot}0\%$) ⊖ $h = 0{\cdot}2$ m, ● 0·6 m, ⦶ 1·2 m; IV ($\varphi = 3{\cdot}0\%$) ⊕ $h = 0{\cdot}2$ m, ◒ 0·4 m, ◓ 0·6 m.

LIST OF SYMBOLS

g gravitational acceleration $(m\,s^{-2})$
h height of clear liquid bed (m)
k_1 (graphical dependence on t/d^1) coefficient of Eq. (*1*)
k_2 coefficient of Eq. (*1*) given by Eq. (*2*)
Δp_d dry plate pressure drop $(N\,m^{-2})$
Δp_0 overall pressure drop (plate + liquid bed) $(N\,m^{-2})$
Δp_z apparent dry plate pressure drop = pressure drop of plate with part of holes blocked by flowing liquid $(N\,m^{-2})$
v superficial gas velocity $(m\,s^{-1})$
$v_0 = v/\varphi$ velocity of gas related to the geometrical area of holes on the plate $(m\,s^{-1})$
t thickness of plate (m)
ϱ density of gas $(kg\,m^{-3})$
ϱ_l density of liquid $(kg\,m^{-3})$
φ geometrical free plate area
φ_g free area of holes of the plate through which the gas flows
$\varphi_{gr} = \varphi_g/\varphi$ relative free hole area through which the gas flows

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