Hungarian Journal
of Industrial Chemistry
Veszprém
Vol.1. pp. 493-512 (1973)

STUDIES ON THE HYDRODYNAMICS OF FLUIDIZED LAYERS III. CALCULATION OF LAYER EXPANSION IN SYSTEMS FLUIDIZED WITH A LIQUID

Z. ORMÓS and T. BLICKLE

(Research Institute for Technical Chemistry of the Hungarian Academy of Sciences, Veszprém)

Received: April 5, 1973.

The equations for the calculation of the void fraction of layers fluidized with a liquid, most widely known from literature, and those derived from the first paper of the series are briefly described. The equations are transformed to a form which can readily be applied in practice even in the case of porous particles. The mean values of the "constant coefficients" of the equations, and the dependence or independence of the different "constants" on the various parameters was studied. The calculation methods are evaluated by the comparison of void fraction values determined experimentally and calculated by the proposed equations.

The expansion of fluidized layers can - among others - be characterized by the void fraction [1]. A number of calculation methods are known for the determination of the void fraction of layers fluidized with a liquid on the basis of the flow rate of the liquid, the diameter of the particles and other parameters. In the previous paper of the present series, an equation was derived in a theoretical manner which enables the void fraction of layers fluidized with a liquid to be calculated [2].

The present paper briefly summarizes the most important equations for the calculation of void fractions known from literature. Equations taken both from literature and proposed by the authors are evaluated critically. In the course of the latter, the dependence or independence of the "constant coefficients" of the equations on the parameters of the liquid and of the particles was studied, and the applicability of the equations was put to a trial by the comparison of results obtained, on the one hand, by calculation with the equations, and, on the other, by experimental measurements.

METHODS FOR THE CALCULATION OF THE VOID FRACTION OF LAYERS FLUIDIZED WITH A LIQUID

When deriving equations for the calculation of the void fraction of fluidized systems and studying the laws of such systems, a number of researchers have come to the conclusion that the void fraction is proportional to the flow rate of the fluid and the falling rate of the individual particles.

To a considerable degree, RICHARDSON and ZAKI [3] promoted the theories related to the expansion of fluidized layers known up to now. The equations they proposed describe the dynamic equilibrium of the individual particles as a function of the particulars of the layer and of the apparatus. The following groups were determined by analysis:

$$\frac{U'}{u_e} = f\left(Re, \frac{d}{D}, \bar{\varepsilon}'\right) \qquad (1)$$

The data relating to layer expansion were given in the following form:

$$\frac{U'}{u_e} = \bar{\varepsilon}_c'^{\,a_1} \qquad (2)$$

According to the above equation, the function flow rate of the liquid vs. void fraction, when drawn in a lg-lg co-ordinate system, gives a straight line whose slope is a_1. The experimental data were examined by this method and the following equations were presented for the calculation of a_1:

$$a_1 = (4.35 + 17.5 \frac{d}{D}) Re^{-0.03}, \quad \text{if } 0.2 < Re < 1 \tag{3}$$

$$a_1 = (4.45 + 18.0 \frac{d}{D}) Re^{-0.1}, \quad \text{if } 1 < Re < 200 \tag{4}$$

$$a_1 = 4.45 \cdot Re^{-0.1}, \quad \text{if } 200 < Re < 500 \tag{5}$$

$$a_1 = 2.39, \quad \text{if } 500 < Re < 500 \tag{6}$$

The Reynolds-number contained in these expressions is the following:

$$Re = \frac{U' \; d \; \rho'}{\mu'} \tag{7}$$

JOTTRAND [4] proposed two equations for the calculation of the void fraction of fluidized layers. One of these is essentially identical to Equation (2) described in the foregoing, whereas the other is the following:

$$lg \frac{u_e}{U'} = a_2 (1 - \bar{\varepsilon}'_c) \tag{8}$$

Equation (8) represents, according to the author, a good approximation if the void fraction is within the range of 0.7 to 1 and the value of a_2 is 2.63.

In his book on fluidization, BLICKLE [5] proposed - among others - the following expression for the calculation of the void fraction:

$$\bar{\varepsilon}'_c - \varepsilon'_m = \frac{U' - U'_m}{u_e} \tag{9}$$

It has already been pointed out in connection with the examination of the above Equation that a better agreement with experimental data can be obtained by application of the following supplemented formula [6]:

$$\bar{\varepsilon}_c'^2 - \varepsilon_m'^2 = a_3 \frac{U' - U_m'}{u_e} \qquad (10)$$

SAXTON and his co-workers [7] proposed an equation for the calculation of the void fraction of layers fluidized with a liquid based upon the cell-model theory of homogeneous fluidization:

$$(1 - \bar{\varepsilon}_c')^{-1/3} - (1 - \varepsilon_m')^{-1/3} = 18.8 \text{ Re Ar}^{-0.86} \qquad (11)$$

where the Reynolds-number is equal to Equation (7) and the Archimedes number is the following:

$$Ar = \frac{(\rho - \rho')\rho' d\ g}{\mu'^2} \qquad (12)$$

Connections describing the streaming of the fluid, the motion of the particles and the layer expansion in systems fluidized with a liquid were derived, starting from the physical model; these were described in the first paper of the present series [2]. The following equation was obtained for the expansion of layers fluidized with a liquid [2]:

$$\bar{\varepsilon}_c' = 1 - 0.75\ (1 - \frac{U'}{u_e})^{3/2} \qquad (13)$$

In the practical application of the above equation it was found that the value of the constant differs in practice from the theoretically derived value of 0.75 to a considerable degree, and consequently the equation can be written in the following form [6, 8]:

$$\bar{\varepsilon}_c' = 1 - a\ (1 - \frac{U'}{u_e})^{3/2} \qquad (14)$$

Considering that Equation (14) is valid even at the minimum fluidization rate, the following equation can be given for the calculation of the void fraction [2]:

$$\bar{\varepsilon}'_c = 1 - \frac{1 - \varepsilon'_m}{(1 - \frac{U'_m}{u_e})^{3/2}} (1 - \frac{U'}{u_e})^{3/2} \tag{15}$$

In the following, the applicability of Equations (2), (8), (10), (11), (14) and (15) is examined according to the two points of view mentioned in the introduction of the present paper. Naturally, in addition to these equations, a large number of calculation methods have been described in literature [5, 6, 9, 10, 11, 12, 13, etc.]. However, the description and evaluation of these is outside of the scope of the present paper whose intention is only to illustrate the applicability of a few of the more widely known calculation methods and to compare them with the Equations (14) and (15) derived by the authors.

EXPERIMENTAL AND MEASUREMENT TECHNIQUES

The technique based on the determination of layer height was applied for the determination of the mean void fraction in the experimental studies on the expansion of layers fluidized with a liquid. The experiments were carried out in a cylindrical glass apparatus with a diameter D = 0.04 m which contained a fritted glass disk of the porosity of G2 in order to sustain the fluidized layer. The height of the latter was measured, to an accuracy of a few millimetres, by means of a scale secured to the wall of the apparatus and the mean void fraction was calculated with the following formula:

$$\bar{\varepsilon}'_Y = \frac{Y - \frac{G}{\rho F}}{Y} \tag{16}$$

The quantity of the streaming liquid (water) was measured with a rotameter. The linear flow rate was calculated from the volumetric flow rate and the cross sectional area of the apparatus.

The minimum void fraction values were calculated from the minimum fluidization layer height by means of Equation (16). The minimum layer height was determined by measuring the layer height produced upon slow reduction of the liquid flow rate.

The minimum fluidization rate was obtained from the measured mean void fraction-flow rate values by extrapolation of the flow rate to the minimum void fraction.

The mean falling rate of the tested particle fractions was determined, having plotted the liquid flow rate against the measured mean void fraction values in a lg-lg plot, by graphical extrapolation of the liquid flow rate to the value of $\bar{\varepsilon}' \to 1$.

The mean porosity of the particles was determined by application of a technique, based on the identical space filling properties of particles of similar shape, proposed by the authors of this paper [14].

EXPERIMENTAL RESULTS

The experiments on layer expansion were carried out with a total of 29 particle fractions prepared of 5 different materials. The streaming liquid in the experiments was tap water of 12 - 14 ^{o}C temperature. The extent of layer expansion was determined with each particle fraction at 13 to 15 different flow rates. The dependence of the void fraction of the layer on the flow rate of the liquid is not presented in detail, merely the most important data are summarized in tabular form.

The most important physical properties of the examined granular materials (such as density, and porosity), the mass of the material weighed in for the experiment, the mean size and the size limits of the tested grain fractions, as well as the experimental data pertaining to the minimum void fraction, minimum fluidization rate and the mean falling rate of the particles are summarized in Tables 1. to 5. shown in the following.

Table 1. System glass beads—water

$\rho = 2960\ kg/m^3$, $\varepsilon_p = 0$, $G = 0.08\ kg$

	$\bar{d} \cdot 10^3$ (m)	ε'_{mt}	$U'_m \cdot 10^2$ (m/sec)	$\bar{u}_e \cdot 10^2$ (m/sec)
1	0.15	0.44	0.06	2.0
2	0.18	0.44	0.12	2.5
3	0.25	0.44	0.20	3.2
4	0.42	0.44	0.30	4.2

Table 2. System sand—water

$\rho = 2635\ kg/m^3$, $\bar{\varepsilon}_p = 0$, $G = 0.05\ kg$

	$d \cdot 10^3$ (m)	ε'_{mt}	$U'_m \cdot 10^2$ (m/sec)	$\bar{u}_e \cdot 10^2$ (m/sec)
1	0.10 - 0.20	0.51	0.08	1.2
2	0.20 - 0.32	0.51	0.13	2.5
3	0.32 - 0.40	0.51	0.19	3.9
4	0.40 - 0.50	0.51	0.26	5.0
5	0.50 - 0.63	0.51	0.39	5.9
6	0.63 - 0.80	0.51	0.64	7.0
7	0.80 - 1.00	0.51	1.10	9.0

Table 3. System hematite—water

$\rho = 4150\ kg/m^3$, $\bar{\varepsilon}_p = 0.12$, $G = 0.09\ kg$

	$d \cdot 10^3$ (m)	ε'_{mt}	$U'_m \cdot 10^2$ (m/sec)	$\bar{u}_e \cdot 10^2$ (m/sec)
1	0.10 - 0.20	0.56	0.10	1.5
2	0.20 - 0.32	0.56	0.30	4.0
3	0.32 - 0.40	0.55	0.60	6.0
4	0.40 - 0.50	0.55	0.95	7.5
5	0.50 - 0.63	0.56	1.30	9.5
6	0.63 - 0.80	0.57	1.70	12.0
7	0.80 - 1.00	0.57	2.20	15.0

Table 4. System porous nickel spheres—water

$\rho = 7450\ kg/m^3$, $\bar{\varepsilon}_p = 0.32$, $G = 0.13\ kg$

	$d \cdot 10^3$ (m)	ε'_{mt}	$U'_m \cdot 10^2$ (m/sec)	$\bar{u}_e \cdot 10^2$ (m/sec)
1	0.20 - 0.32	0.60	0.5	7.0
2	0.32 - 0.40	0.59	0.8	12.0
3	0.40 - 0.50	0.59	1.1	18.0
4	0.50 - 0.63	0.59	1.4	25.0
5	0.63 - 0.80	0.58	1.8	33.0

Table 5. System burnt clay-water

$\rho = 2420\ kg/m^3$, $\bar{\varepsilon}_p = 0.50$, $G = 0.03\ kg$

	$d \cdot 10^3$ (m)	ε'_{mt}	$U'_m \cdot 10^2$ (m/sec)	$\bar{u}_e \cdot 10^2$ (m/sec)
1	0.20 - 0.25	0.75	0.12	1.4
2	0.25 - 0.32	0.75	0.18	1.8
3	0.32 - 0.40	0.76	0.25	2.4
4	0.40 - 0.50	0.76	0.36	3.2
5	0.50 - 0.63	0.76	0.45	3.8
6	0.63 - 0.80	0.76	0.55	4.6

APPLICATION AND EVALUATION OF THE CALCULATION METHODS

The starting point in the examination of the formulas proposed for the calculation of the void fraction is that these enable determination of the free volume or liquid-filled volume fraction. There is no problem in the case of materials consisting of compact granular materials; however in the case of porous particles the void fraction values determined in practice experimentally refer not only to the free space between the particles, but also include the pore space of the particles filled with the liquid. This is brought about by the fact that the density of the particles is determined in most cases with the pycnometer technique with the application of a liquid which has good wetting properties and in which the material of the particles is insoluble. This means that by this technique practically the density of the solid forming the material of the particles is determined and only the closed pores and channels, or those of such small dimensions as to be impermeable for the liquid may cause some deviation. Moreover, it often occurs that the density values are simply taken from literature or from handbooks; however, such data most frequently refer to the compact material. Whether it is a density value determined by a pycnometer, or one taken from literature that is substituted into Equation (16), the obtained (experimentally determined) void fraction values include the total volume permeable by the liquid. The aforesaid should be taken into consideration in the evaluation of the calculation methods, because in the case of heap of porous particles this is the only reliable method of evaluation.

Starting from the definition of the void fraction and based on geometric considerations, the following connection between the two kinds of void fraction values may be written:

$$\bar{\varepsilon}'_t = \varepsilon_p + (1 - \varepsilon_p)\, \bar{\varepsilon}'_c \tag{17}$$

Accordingly, in order to be able to carry out the calculation, the mean porosity of the heap of particles has to be known. A simple measuring technique, which can be utilized in an easy way, has been developed by the authors [14].

In the application of Equation (2) described by RICHARDSON and ZAKI [3] the first question is the following: which is the equation that is to be used for the calculation of the "constant" a_1. Calculations were carried out in this respect and it was concluded that in the case of the models encountered in practice it is Equation (4) that is most frequently applicable. Accordingly, on the basis of Equations (2), (4) and (7) the following can be written:

$$\bar{\varepsilon}'_t = \varepsilon_p + (1 - \varepsilon_p)\left(\frac{U'}{u_e}\right) \frac{Re^{0.1}}{4.45 + 18\,\frac{d}{D}} \tag{18}$$

The next question which is encountered is whether the Reynolds number is to be calculated for each separate liquid flow rate. The above problem is unequivocally settled by the data presented in Table 6.

Table 6. System sand—water

$d \cdot 10^3$ (m)	a_1 calculated $\bar{\varepsilon}' = 0.6$	a_1 calculated $\bar{\varepsilon}' = 0.8$	a_1 calculated $\bar{\varepsilon}' = 1$	a_1 measured (mean)
0.10 - 0.20	5.1	4.5	4.3	4.1
0.20 - 0.32	4.4	4.0	3.8	3.7
0.32 - 0.40	4.1	3.8	3.6	3.4
0.40 - 0.50	3.9	3.6	3.5	3.2
0.50 - 0.63	3.8	3.5	3.4	3.0
0.63 - 0.80	3.6	3.4	3.3	2.9
0.80 - 1.00	3.5	3.3	3.2	2.8

As it is apparent from Table 6, the agreement between the a_1 values determined experimentally on the one hand, and calculated with Equation (4) on the other, is best if $\bar{\varepsilon}' = 1$, i.e. if the mean falling velocity of the particles is substituted into the equation.

Considering this fact, Equation (18) can be written in the following form:

$$\bar{\varepsilon}_t' = \varepsilon_p + (1 - \varepsilon_p)\left(\frac{U'}{u_e}\right)\frac{(u_e\ d\ \rho')^{0.1}}{\mu'^{0.1}(4.45 + 18\ \frac{d}{D})} \qquad (19)$$

Fig. 1 shows the difference between the void fraction values determined experimentally and calculated by Equation (19), plotted against the experimentally determined value. It can be concluded from the Figure that the relative deviation is in all cases lower than ± 10 %, and in the overwhelming majority of the cases it is lower than + 5 %. Computer evaluation led to the conclusion that the mean relative deviation is ± 2 %.

Equation (8), described by JOTTRAND [4], can - considering Equation (17) - be written in the following form:

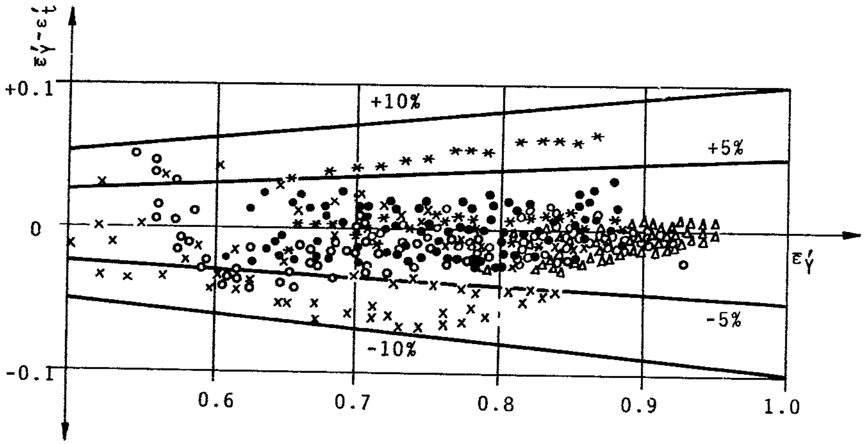

Fig.1. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porous burnt clay

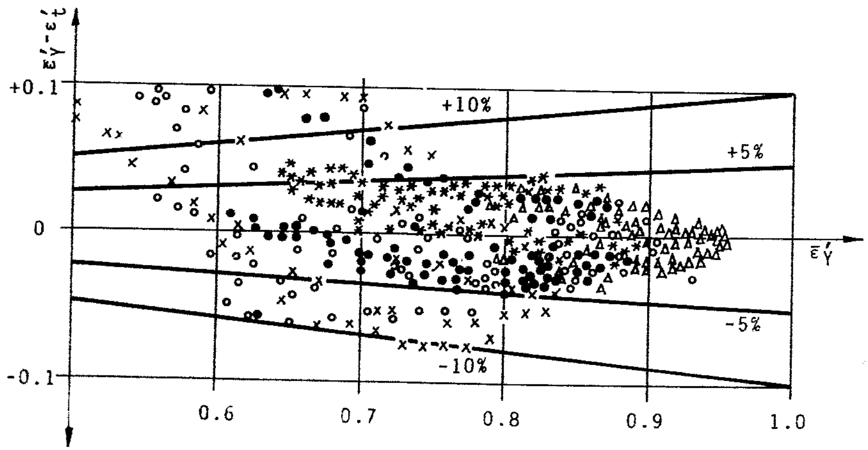

Fig.2. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porous burnt clay

$$\bar{\varepsilon}'_t = 1 - \frac{1 - \varepsilon_p}{a_2} \lg \frac{u_e}{U'} \tag{20}$$

The value of the "constant" a_2 of the equation was determined for the model substances used in the experiments in about 400 cases and $a_2 = 1.75$ was obtained as a mean value. The mean scattering of the "constant" a_2, as a function of flow rate, was found to be $\sigma = \pm 9$ %, whereas the scattering depending on a particle size was $\sigma = \pm 13$ %.

The difference in void fraction values determined experimentally and calculated by Equation (20) ($a_2 = 1.75$), plotted against the experimentally determined value is shown in Fig. 2. It is apparent from the Figure that the relative deviation is, in most cases, lower than ± 10 % and the average relative deviation is +5 and -3 %.

On the basis of Equation (10) [5] and taking Equation (17) into consideration, the following equation can be written:

$$\bar{\varepsilon}'_t = \varepsilon_p + (1 - \varepsilon_p) \left(\frac{\varepsilon'_{mt} - \varepsilon_p}{1 - \varepsilon_p}\right)^2 + a_3 \left(\frac{U' - U'_m}{u_e}\right)^{1/2} \tag{21}$$

The mean value of the "constant" is $\bar{a}_3 = 1.15$, its mean scattering depending on the flow rate of the liquid is $\sigma = \pm 18$ %, its mean scattering depending on the particle size is $\sigma = \pm 16$ %.

The difference in void fraction values determined experimentally and calculated by Equation (21) ($a_3 = 1.15$), plotted against the experimentally determined value is shown in Fig. 3. It can be concluded from the Figure that except for a few cases the relative deviation is lower than ± 10 %. The mean relative deviation was found to be ± 4 %.

In the examination of Equation (11) derived by SAXTON and his co-workers [7] it was found possible to bring it to a simpler form by substitution of Equations (7) and (12):

$$(1 - \bar{\varepsilon}')^{-1/3} - (1 - \varepsilon'_m)^{-1/3} = \frac{U'}{u_e} \tag{22}$$

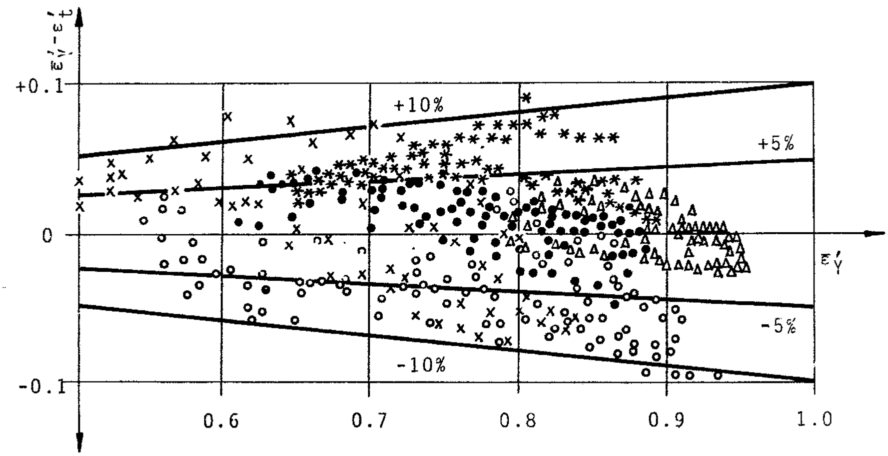

Fig.3. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porous burnt clay

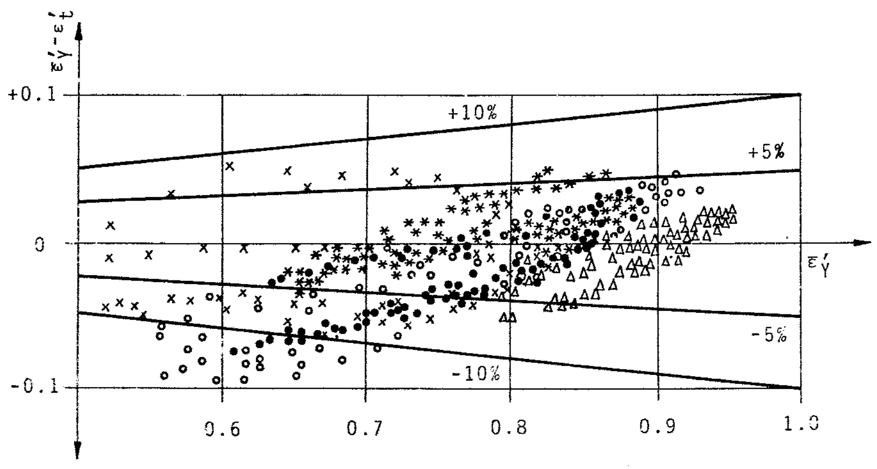

Fig.4. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porous burnt clay

On the basis of Equations (22) and (17), the following formula can be written for the calculation of the void fraction:

$$\bar{\varepsilon}'_t = 1 - \frac{(1 - \varepsilon'_{mt})(1 - \varepsilon_p)}{[(1 - \varepsilon_p)^{1/3} + (1 - \varepsilon'_m)^{1/3} \frac{U'}{u_e}]^3} \tag{23}$$

The difference in void fraction values determined experimentally and calculated by Equation (23), plotted against the experimentally determined values, is shown in Fig. 4. It is apparent from the Figure that in the overwhelming majority of the cases the relative deviation is lower than +5 and -10 %. The mean relative deviation is +2 and -5 %.

Taking Equations (14) [2] and (17) into consideration the Equation derived by the authors is the following:

$$\bar{\varepsilon}'_t = 1 - a_4 \ (1 - \varepsilon_p)(1 - \frac{U'}{u_e})^{3/2} \tag{24}$$

It was found in the experiments that the mean value of the "constant" $\bar{a}_4 = 0.55$, its average scattering depending on the flow rate is $\sigma = \pm 6$ % and its average scattering depending on the particle size is $\sigma = \pm 10$ %. Accordingly, Equation (24) can be written in the following form:

$$\bar{\varepsilon}'_t = 1 - 0.55 \ (1 - \varepsilon_p)(1 - \frac{U'}{u_e})^{3/2} \tag{25}$$

The difference in mean void fraction values determined experimentally and calculated by Equation (25) plotted against the experimentally determined value is shown in Fig. 5. It is apparent from the Figure that the relative deviation is in all cases lower than ± 10 % and in the overwhelming majority of the cases lower than ± 5 %. The average mean deviation is +3 and -2 %.

Equation (15) [2], as written on the basis of Equation (14) derived by the authors can be brought to a simpler form:

$$\bar{\varepsilon}'_t = 1 - (1 - \varepsilon'_{mt})(\frac{u_e - U'}{u_e - U'_m})^{3/2} \tag{26}$$

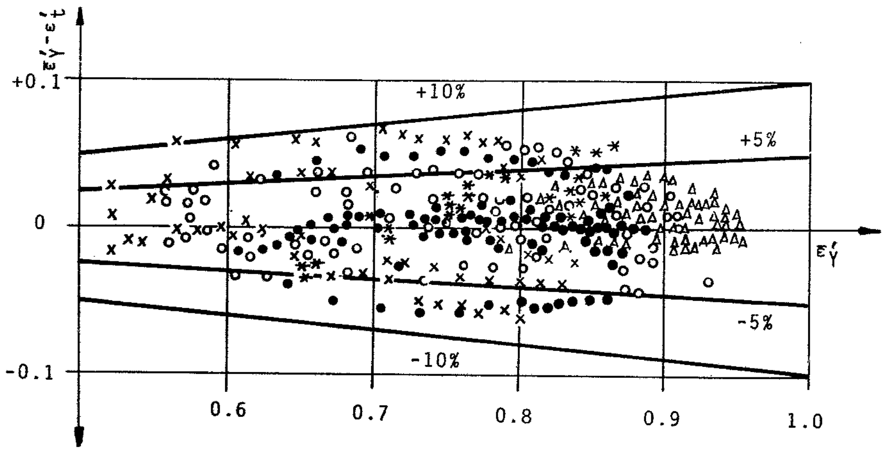

Fig.5. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porous burnt clay

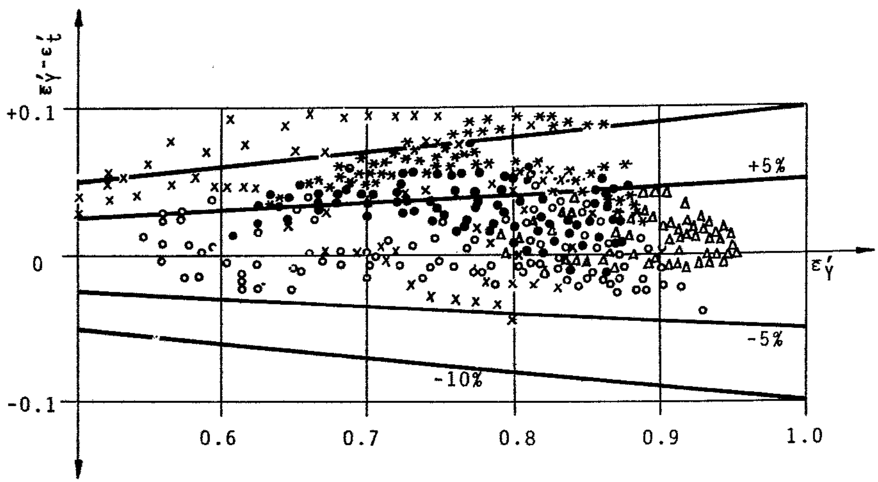

Fig.6. x - glass beads; o - sand; • - hematite; * - porous nickel spheres; Δ - porcus burnt clay

The difference in the void fraction values determined experimentally and calculated by Equation (26), plotted against the experimentally determined values, is illustrated in Fig. 6. It can be concluded from the Figure that the relative deviation of the measured and calculated values is in the overwhelming majority of the cases lower than +10 and -5 %. The mean relative deviation is +4 and -2 %.

Summarizing the aforesaid it can be concluded that from among the formulas used for the calculation of the void fraction of layers fluidized with a liquid, Equation (19) derived from the Equation (4) of RICHARDSON and ZAKI [3], and Equation (25) derived from the Equation (14) by the authors of the present paper [2] are those yielding results which best approximate the values determined experimentally.

The agreement was also fairly good in the case of the other examined formulas; however, in case of these the mean relative deviation was on the one hand higher, e.g. Equations (20) and (21), and on the other the higher deviation is asymmetrical, e.g. with Equations (23) and (26). It is to be noted that from among the above Equations (20) and (23) yield values which at higher layer expansions show a good agreement with the experimental data. Equations (19) and (25) describe the layer expansion correctly in the whole range and consequently the application of these is recommended for the calculation of the expansion of fluidized layers.

SYMBOLS USED

a_1, a_2, a_3, a_4 constans

Ar Archimedes-number [cf. Equation (12)]

d diameter of the particles (metre)

$\bar{d}$ mean diameter of the particles (metre)

D diameter of the apparatus (metre)

F	cross sectional area of the apparatus (m^2)
g	gravitational acceleration (m/sec^2)
G	mass of the particles present in the layer (kg)
Re	Reynolds-number [cf. Equation (7)]
u_e	falling rate of the particles (m/sec)
$\bar{u}_e$	mean falling rate of the particles (m/sec)
U'	linear flow rate of the liquid as referred to the total cross sectional area of the apparatus (m/sec)
U'_m	minimum fluidization liquid flow rate (m/sec)
Y	height of the layer (m)
Y_m	minimum layer height (m)
$\bar{\varepsilon}'$	mean void fraction of the layer
$\bar{\varepsilon}'_c$	calculated mean void fraction of the layer
ε'_m	minimum void fraction of the layer
ε'_{mt}	minimum total void fraction or liquid volume fraction of the layer
ε_p	pore volume fraction of the particles
$\bar{\varepsilon}_p$	mean pore volume fraction of the particles
$\bar{\varepsilon}'_t$	calculated mean total void fraction or liquid volume fraction of the layer
$\bar{\varepsilon}'_Y$	mean total void fraction or liquid volume fraction, determined on the basis of layer height measurement
μ'	dynamic viscosity of the liquid (kg/sec·m)
ρ	density of the particles (kg/m^3)
ρ'	density of the liquid (kg/m^3)

REFERENCES

1. BLICKLE, T., ORMÓS, Z., Hung. J. Ind. Chem. 1, 31 (1973)
2. BLICKLE, T., ORMÓS, Z., Hung. J. Ind. Chem. 1, 185 (1973)
3. RICHARDSON, I.J.F., ZAKI, W.N., Trans. Inst. Chem. Engrs. 32, 35 (1954)
4. JOTTRAND, R., Chem. Eng. Sci. 4, 12 (1954)
5. BLICKLE, T., A fluidizációs eljárás készülékei, alkalmazásai és számitásai. (Apparatuses, Applications and Calculations of the Fluidization Technique.) Akadémiai Kiadó, Budapest, 1963.
6. ORMÓS, Z., D. Techn. Thesis.Veszprém University of Chemical Engineering, 1968.
7. SAXTON, J.A., FITTON, J.B., VERMEULEN, T., AIChE Journal 16, 120 (1970)
8. BLICKLE, T., D. Sc. Thesis. Budapest, 1967.
9. SZOLCSÁNYI, P., Magyar Kémiai Folyóirat, 67, 171 (1961)
10. BRÖTZ, W., Chem. Ing. Techn. 24, 57 (1952)
11. BERÁNEK, J., KLUMPAR, J., Chem. Listy. 50, 1673 (1956)
12. LEWA, M., Fluidization, McGraw-Hill Book Company, New York, 1959.
13. HETZLER, R., WILLIAMS, M.C., Ind. Eng. Chem. Fundamentals 8, 668 (1969)
14. ORMÓS, Z., Hung. J. Ind. Chem. 1, 207 (1973)

РЕЗЮМЕ

В данной статье авторы кратко ознакамливают с имеющимися в литературе наиболее распостраненными уравнениями, а также с выведенными ими в предыдущей статье данного цикла зависимостями, для вычисления доли свободного объема псевдоожиженных посредством жидкости слоев. Указанные зависимости приводятся к виду, практически непосредственно применимому, распостраняющемуся даже на случай пористых частиц. Авторами определены средние значения имеющихся в уравнениях "постоянных сомножителей", кроме того, "постоянные" были проверены на зависимость от различных параметров. Была проведена проверка расчетных методов посредством сравнения полученных экспериментально и рассчитанных по уравнениям значений доли свободного объема.