DISTRIBUTOR PLATE INFLUENCE ON FLUIDIZATION QUALITY

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Abstract. *Experiments were performed with the purpose of studying the influence of both type and pressure drop of distributor plates, on the fluidization quality of an atmospheric fluidized bed. Three different distributor types were used: perforated perspex, metallic mesh and porous ceramic, with pressures drops ranging from 0.05 to 350 kPa, and superficial air velocities from 0.1 to 2.3 m/s. Three size ranges of silica ballotinis, 355-425, 600-710 and 850-1000 μm were used as bed material. The static bed height was set to 300 mm and divided into 6 horizontal slices of 50 mm high each. For each slice pressure drop values were recorded for* U_0/U_{mf} *ratios from 20 to 1. In order to produce a reference for the pressure drop evolution, a modified two-phase model was introduced, taking in consideration the increase in the average global porosity as well as a change of the ratio of flow through the bubbles versus the flow through the dense phase. Finally, an empirical correlation allowing the prediction of the onset of turbulence, taking in consideration the number of holes of the distributor plate, is presented.*

Keywords: *Fluidization, Fluidized bed, Pressure drop, Distributor plate.*

1. INTRODUCTION

The characterization of fluidization regimes is based, for the general dense phase including particulate, bubbling and turbulent regimes, on the behavior of the bubbles. In bubbling fluidization, typical of Group A, B and D particles, bubble motion becomes increasingly vigorous as the gas velocity increases. Just after U_{mf}, the bubble interaction is dominated by bubble coalescence; as the superficial velocity increases far beyond that value, a high through flow of gas causes the bubbles to become intermittent voids, leading to an incipient entrainment of particles This causes a certain uniformity of the suspension and difficulties in distinguishing the bubbles from the emulsion. This point is often regarded as the onset of turbulent fluidization and is identified by a peak on the variation of pressure fluctuation with the gas velocity. On a basis of direct observation, the bubble interaction is now becoming dominated by bubble breakup (Fan and Zhu, 1998).

The present work analyses the influence of different distributor types (porous ceramic, metallic mesh and perforated perspex) and distributor pressure drops, under different operating conditions, on the fluidization quality of distinct particle sizes. One purpose of this work is, using a corrected bubble's voidage based on the two-phase theory, to assess that quality by means of a dimensionless pressure drop, ΔP^*, evaluated along the bed height.

Most studies reported in the literature on the influence of the gas distributor were carried out at low fluidization velocities. Kunii and Levenspiel (1969) gathered investigation regarding the minimum required pressure drop across the distributor plate to insure a uniform gas distribution over the bed. Concerning the influence of the type of distributor, some investigations were performed at low velocities (U-U_{mf}<0.25 m/s)- Geldart and Kelsey (1968) changed the plate pressure drop by adding sheets of porous materials, and found that the bubble size increases with decreasing distributor pressure drop, when the bed pressure drop is larger than 10 times that value, and remains the same when that value is smaller; Saxena *et al.*(1979) used several slot screens allowing the variation of the open area, and Fan *et al.*(1981), using perforated plates, changed the diameter of the holes- both these studies showed also an increase of the bubble size with a decrease in the distributor pressure drop; Hatate *et al.* (1991), using different distributors with the same open area, but with different number and size of holes, found the same bubble size in all cases. Svensson *et al.* (1996), worked at higher gas velocities (U-U_{mf}>0.5 m/s), and using five different perforated plate distributors with the same orifice diameters, found three bubbling regimes, multiple, single and exploding, and related them to the pressure fluctuations of the air plenum. These investigations showed that the pressure drop across the distributor was of major importance on the bubble regime. No experimental research was found in literature covering that influence on the transition to the turbulent regime.

Most of the fluidized beds in commercial operation are working either under bubbling or turbulent conditions. While the efforts to predict a mechanistic model are still waiting to reach success (Fan and Zhu, 1998), an empirical correlation for Groups B and D particles, taking in consideration the number of holes of the distributor plate, is presented, thus constituting the other main purpose of this work.

2. EXPERIMENTAL

The experimental work was carried out in a 100 mm internal diameter perspex tube, using air at ambient conditions as the fluidizing medium. The pressure drop evolution for the tested gas flow range, and for each distributor plate, was previously measured with pressure probes calibrated against U-tube mercury pressure manometers. To help achieving a uniform air flow distribution over the cross section of the bed, two consecutive primary fixed beds were used in the windbox section (Fig. 1). The first fixed bed was filled with 20 mm and the second with 3 mm diameter silica spheres.

The fluidized bed under analysis was established by fluidizing three size ranges of silica ballotinis, 355-425, 600-710 and 850-1000 μm, previously screened and statistically weighed with *t* tests using SPSS. The air flow rate was measured with orifice plate flowmeters, equipped with a Furness Control FCO18 differential pressure transducer, connected to a data acquisition system. Those measurements had an associated uncertainty of 25.2 Pa (Coleman and Steele, 1999).

The static bed height was set to 300 mm and divided into 6 horizontal slices of 50 mm high each. The measurements considered cumulative values for each layer, *i.e.*, the first layer is the slice 1, the second layer the slice 1 plus 2, and so on until the sixth layer, corresponding to the sum of slices 1 to 6.

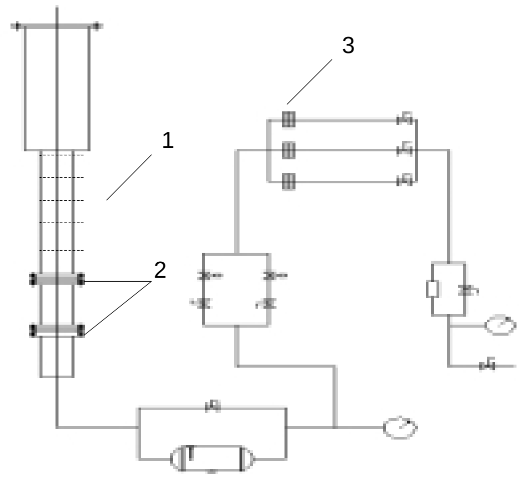

Figure 1- Schematics of the experimental setup.
(1- main bed, 2- primary fixed beds, 3- orifice plate flowmeters battery)

Three pressure probes were used at each slice, set 120º apart, starting just above the distributor plate. U_0/U_{mf} ratios were measured from 20 to 1, using Furness Control pressure drop differential transducers FCO15 and 16, connected to a data acquisition system, with an associated uncertainty of 7.1 and 12.9 Pa, respectively (Coleman and Steele, 1999). All the uncertainty evaluation was performed in accordance with a 95% confidence interval. A more detailed description of the experimental setup can be found in Paiva *et al.* (1998).

The experimental conditions are summarized in Table 1.

Table 1- Experimental conditions

Experimental conditions	Value (-)
Internal bed diameter, D (m)	0.10
Height of the unit, L (m)	3.5
Ambient pressure, P (Pa)	97500
Bed temperature, T (ºC)	15
Bed material	Silica ballotinis
Bed material density, ρ (kg/m^3)	2485
Average particle diameter I (355-425 μm), $d_{pI}=1/(\Sigma x_i/d_{pi})$ (μm)	387
Average particle diameter II (600-710 μm), $d_{pII}=1/(\Sigma x_i/d_{pi})$ (μm)	651
Average particle diameter III (850-1000 μm), $d_{pIII}=1/(\Sigma x_i/d_{pi})$ (μm)	941
Minimum fluidization velocity I, U_{mfI} (m/s)	0.104
Minimum fluidization velocity II, U_{mfII} (m/s)	0.271
Minimum fluidization velocity III, U_{mfIII} (m/s)	0.448
Fluidization velocities, U_0 (m/s)	0.1 … 2.3
Static bed height, H (m)	0.3

The data acquisition system used a sampling frequency of 5 Hz to ensure sufficient accuracy in the statistical analysis, an average of 1000 samples being taken for each spectrum; those readings were then weighed in order to output values corresponding to arithmetically averaged one second intervals. Later on, using a suitable program, these were determined for each position of the flowmeter and the dubious points eliminated according to Chauvenet's criterion (Holman, 1994).

Three different type of distributors were used: perforated perspex, metallic mesh and porous ceramic, with pressures drops ranging from 60 to 300 kPa, and superficial gas velocities going from 0.1 to 2.3 m/s at standard pressure and temperature.

The data for the distributors are given in Table 2.

Table 2- Data on distributors- orifices

Type	Nr of orifices N_{or}	Orifice diameter d_{or} (mm)
Perforated plate with triangular pitch (p#x)	50	0.3
	109	0.3
	199	0.3
	300	0.3
	386	0.3
	948	0.3
Metallic mesh (dyn)		*O* 0.3
Porous ceramic (ker)		*O* 0.3

The metallic mesh distributor plate, by its own nature, had no immediately measurable orifice diameter. It was then decided to calculate an equivalent value that, by means of a correlation based on the measured pressure drop of the other plates, would situate the values of A_0 on the right range of the measured values for the other distributors. The calculated equivalent number of holes for the metallic mesh plate was then the only value that allowed the points situated on Fig. 2, represented in bold and referred to superficial velocities of 0.2, 0.5, 1.0 and 1.5 m/s (see the legend of Fig. 2), to keep the trend line within a common 0.99 R-squared value for the whole range of superficial velocities chosen to make the adjustment.

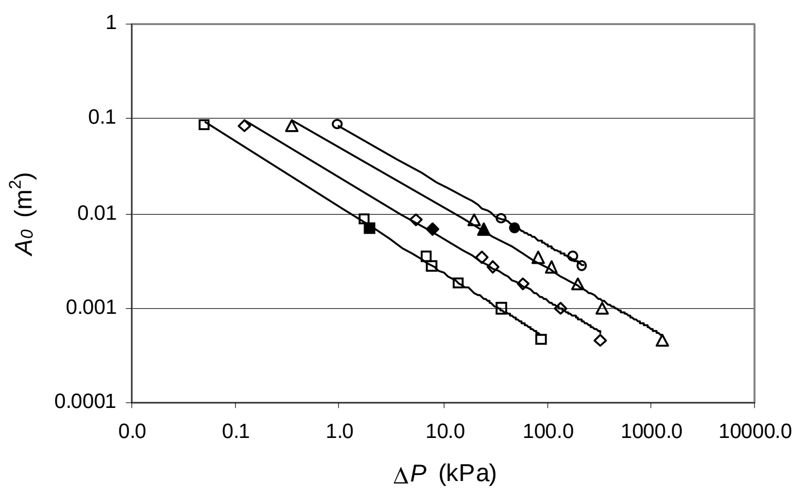

Figure 2- Estimation of number of orifices of the metallic mesh distributor.
(U_0= 0.2-□, 0.5-◇, 1.0-△ and 1.5 m/s -○)

The data on the maximum possible fluidization velocity for each distributor and on the percentage of open area are given in Table 3.

Table 3- Data on distributors- open areas and velocities

Type	Plate reference	Open area (%)	Maximum U_0 (m/s)
Perforated plate with triangular pitch (p#x)	p0x	0.045	0.6
	p1x	0.098	1.0
	p2x	0.179	1.2
	p3x	0.270	1.7
	p4x	0.347	2.0
	p9x	0.853	2.2
Metallic mesh	dyn	0.675	2.2
Porous ceramic	ker	8.482	2.3

3. EXPERIMENTAL RESULTS

The experiments involved two specific stages. The first one concerned the pressure drop in the distributors: each plate was tested three non-consecutive times and the evolution of pressure drop measurements *versus* the superficial velocity can be seen in Fig. 3.

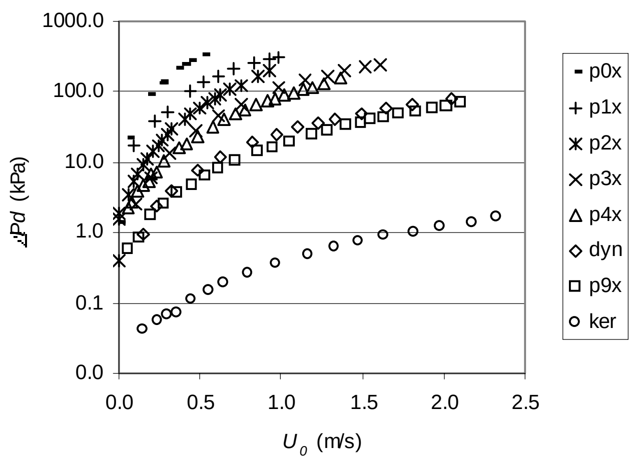

Figure 3- Pressure drop (log values) *vs* superficial velocity, different distributor plates.

The next stage concerned the measurement of the accumulated pressure drop for each slice *i* of the bed, between two fixed probes. Those results are presented in Fig. 4, where these experimental results obtained by measurement are compared with the accumulated values calculated for each of the layers considered. Though the experiments were performed for the six layers and the three size distributions, for the sake of simplicity only the first three layers and the sixth are presented, as they allow sufficiently meaningful comparison between the bottom of the bed and the rest. Only size distribution 355-425 µm is portrayed as results for the other sizes present the same pattern.

4. ANALYSIS AND DISCUSSION

4.1 The influence of the distributor on the fluidization quality

As stated on common literature on fluidization, the point of minimum fluidization is characterized by the following force balance (Kunii and Levenspiel, 1969),

$$\Delta P = (\rho_p - \rho_f)\,(1 - \varepsilon_{mf})\, H_{mf}\, g \tag{1}$$

in which H_{mf} is the height of the bed at minimum fluidization conditions.

Assuming that the dense phase remains at minimum fluidization conditions, according to the two-phase theory (Davidson and Harrison, 1963), any increase in flow rate beyond that point leads to,

$$\Delta P = (\rho_p - \rho_f)\,(1 - \varepsilon_{mf})\, H_f\, g$$