SIMULATION OF PRESSURE FLUCTUATIONS IN BUBBLING FLUIDIZED BEDS.

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ABSTRACT.

Bubbling Fluidization has very characteristic fluctuations in the differential pressure measured between two vertically separated points: one of them just on the distributor and the other at the bubbling zone (figure 1). The pressure difference is due mainly to the weight of the mass of particles between these two points, which can be called hydrostatic, and depends on the density of the bed of solid. The fluctuations in this differential pressure can be as great in magnitude as the medium value of the pressure, and depends mainly on the pass of bubbles, that is to say, on the global porosity of the bed that includes volume of gas between particles and the volume of bubbles.

Bubbles growth from the distributor because the coalescing phenomena. This phenomenon must be studied dynamically, because the number, position, diameter and ascensions velocity of bubbles are variables that varies with time, and depends on a great number of variables: Gas flow, physical gas properties, distributor design, particle characteristics, bed dimensions, as the main important.

In this study the dynamic simulation of the flow of bubbles is presented, using a model that allows the visualization of a two dimensional bubbling fluidized bed, and calculates the differential pressure between two points with time. The results are compared with registered experimental results obtained with pressure transducers and shows very good agreement between calculated and registered data, and this happens with a large number of bubbles of different diameters, not just an isolated bubble.

INTRODUCTION.

The bubbling fluidized beds are still today calculated with empiric models that consider several phases (Kunii 91). One of them is a dense phase, the emulsion, and the other a diluted phase, the bubbles, that go accompanied by an aureole, named cloud, and a wake which can be considered as a new phase.

The presence of these bubbles is the main difficulty for the calculation of the behaviour of the system, since they appear on the distributor of the BFB in variable number with the time, and during the ascension through the bed they increment its size by coalescence (Horio 87). The coalescence takes place when one bubble finds in its trajectory another bubble, that is to say it should have an intersection of its aureoles that leads to the formation of an only bubble by means of the union of the previous ones. The recirculating currents of gas that give place to the existence of the bubbles according to the pattern of Davidson (Davidson 71), should be added to ascend like an only entity displacing the solid particles.

An empiric model exists based on the conservation of mass of gas (Horio 87) that ascends in form of bubbles, that provides the variation of the size of the same ones with the height of the fluidized bed. But this model supposes that there exists only one bubble diameter at each bed height. This is a simplification, since in fact a distribution of sizes is given, and they are not constant in the time. That is to say the population of bubbles varies as much in size as in number for each height. A test of this is the fluctuation of differential pressure that occurs in the BFB, and whose study is postulated as a means to check a new method of dynamic calculation of the population of bubbles, based on a series of simple rules.

DIFFERENTIAL PRESSURE IN THE BFB.

Experimentally, if a pressure transducer is placed between two points of a BFB as shown in figure 1, and the frequency of answer of this measure element is sufficiently high, a graph is obtained as those shown in the figures 3 and 4.

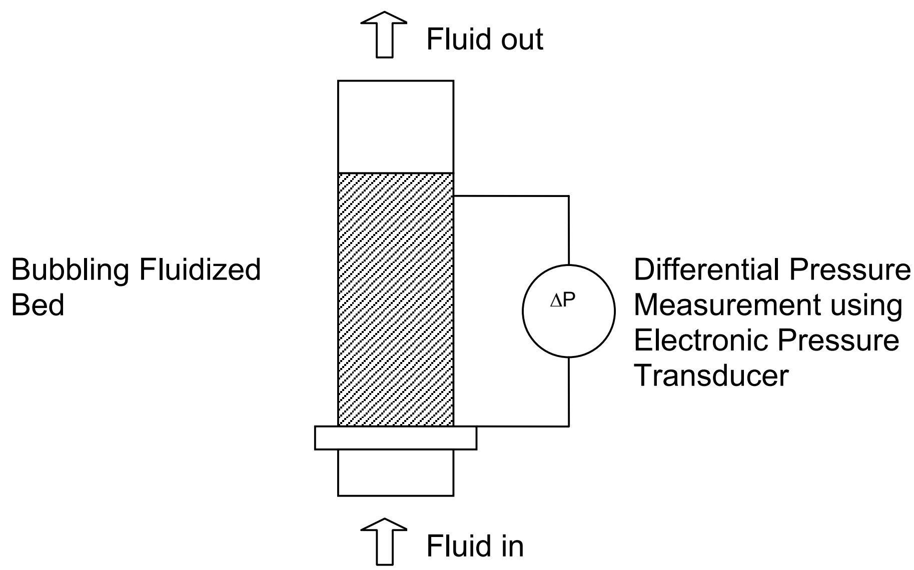

*Figure **1***. Situation of a pressure transducer in a BFB.

It is observed that exists a medium value that stays, horizontal line, and that they are a series of picks of different value, with a quite constant frequency. These picks would correspond to the step of bubbles that cause an increase of the porosity when going by the area in which the pressure is measured, and therefore a decrease of the differential pressure. The different volume of bubbles that exists in each instant among the points of measure of pressure, causes that the values of the picks are also different.

BFB MODELLISATION.

A dynamic model has been developed. They have been defined the points of formation of bubbles spacely, in those that would be created in an aleatory way, with the only restriction that the gas that enters to be part of the bubbles is the one that surpasses the minimum flow corresponding to the minimum fluidization velocity, u_{mf} (Wen 66). This speed depends on the physical characteristics of the particles that compose the bed (size, density and shape factor), and of the fluid that is used (density and viscosity), according to the equation (1) that relates the numbers of Reynolds and Archimedes.

$$Re_{mf}=[(K_2/2K_1)^2 + (1/K_1) \ Ar]^{1/2} - (K_2/2K_1) \qquad (1)$$

Once initiate the cavity that will give place to the bubble, can continue growing if it continues entering gas for that same point, until reaching the minimum size that allows it to take off the distributor. This happens when their speed of ascension is superior to the minimum fluidization velocity, u_{mf}. The speed of ascension is obtained with the equation (2) (Davidson 71), universally accepted.

$$u_{br}= 0.711 \ (g \ d_b)^{1/2} \qquad (2)$$

When it ascends already separated of the distributor, or even when it is still growing in the same one, the coalescence takes place with other bubbles if they are completed a certain condition: that the aureoles or clouds intersect. This gives place to bubbles that add the volumes of gas, and that they possess bigger speed of ascension. The coalescence process doesn't stop until the bubbles reach the surface of the bed of particles. It is not determined ahead of time what bubbles will coalesce; it depends on the relative position of the same ones, and of the corresponding ascent speeds.

In any moment of the dynamic simulation there are a population of different bubbles, in which varies the position, the size and the number of the same ones.

The situation of the surface of the fluidized bed also varies in function of the volume of bubbles that contains in its interior. Therefore the height of the fluidized bed that the bubble must travel until reaching the surface changes an instant to another.

The differential pressure between two separate points a certain vertical distance, can be calculated with the equation (3).

$$\Delta P= \rho \ H \ g \qquad (3)$$

The density is the one pondered between that of the solid and that of the gas, according to the equation (4):

$$\rho= \rho_s \ (1-\varepsilon) + \rho_g \ \varepsilon \qquad (4)$$

With this model the results of evolution of the differential pressure are obtained that are shown in the following section.

MODELLING RESULTS.

The fluctuations of pressure, or porosity, can be studied along the time, just as it is presented in figures 3 and 4.

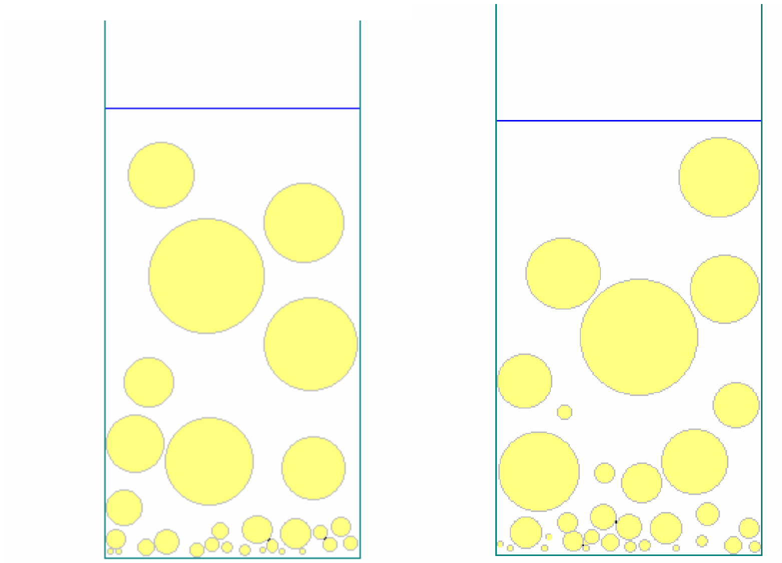

Figure ***2****.* Examples of bubble size distribution, obtained with two snap-shots during the calculation.

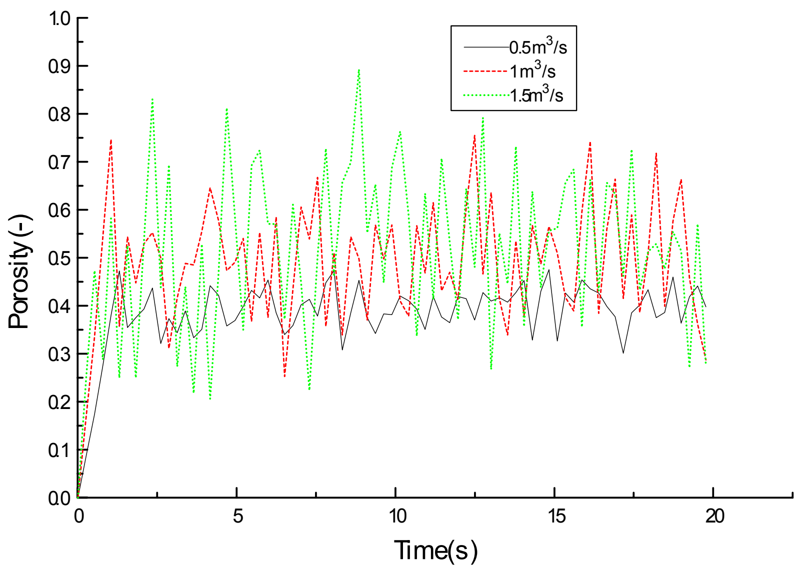

Figure ***3****.* Fluctuations of the porosity in a two-dimensional bubbling fluidized bed for three gas flows. u_{mf}=0.1 m/s, ε_{mf}=0.4. The fluctuations of pressure would be the inverse one of those of porosity.

It is observed that the medium porosity increases with the speed of the gas, just as it happens experimentally, since the expansion of the bed grows with this speed. The frequency of the variations seems also to increase. Taking two bed heights, it is obtained that although the medium porosity remains constant, the fluctuations of pressure become bigger, as well as it is experimentally observable.

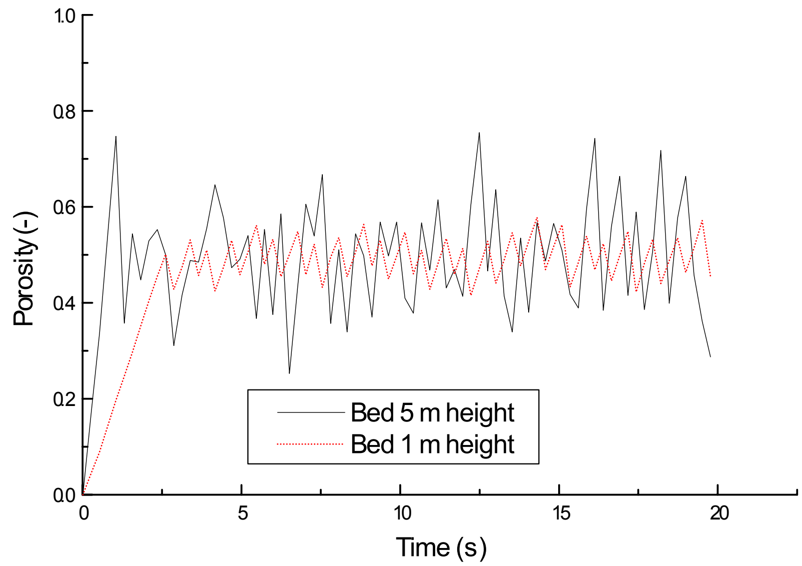

Figure ***4****.* Fluctuations of the porosity in a two-dimensional bubbling fluidized bed for two bed heights. u_{mf}=0.1 m/s, ε_{mf}=0.4.

To this model other empirical rules can be added looking for a behaviour with more verisimilitude. The advantage of the same one is that it presents little calculation complexity, and therefore little time of calculation. The balance of mass this way implemented it is always completed, as much for the gas as for the solid. The disadvantage of the method is that regime changes, the entrance in turbulence or in transport, must be implemented equally with rules, that is to say, the superior end of its range of application must be fixed previously.

CONCLUSIONS.

A new model have been presented that implements some few basic equations, universally accepted, in a dynamic modellisation that allows to obtain a population of bubbles that varies as much in size as in number or position along the time, inside a fluidized bed. This can contribute to the improvement of the calculation of the BFB in those that the coefficients of mass and heat transfer are related with the size of the bubbles, and that up to now they suffered of only using a medium size of bubble for the entire fluid bed for their calculation, or an only size for each fluid bed height (Horio 87).

NOMENCLATURE.

Ar	:	Archimedes number (-)
d_b	:	Bubble diameter (m)
g	:	Gravity acceleration (m s^{-2})
H	:	Bed height (m)
K_2, K_1	:	Constants (-)
P	:	Pressure (bar)
Re_{mf}	:	Reynolds number (-)
u_{br}	:	Bubble rising velocity (m s^{-1})
u_{mf}	:	Minimum fluidization velocity (m s^{-1})
ε	:	Bed porosity (-)
ρ	:	Fluid bed density (kg m^{-3})
ρ_s	:	Solid particle density (kg m^{-3})
ρ_g	:	Gas density (kg m^{-3})

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