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Manufacture of mortar for plaster from recycling material in a Spouted Bed mixer

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Having as final objective to establish the behaviour of beds consisting of mortars in conical spouted beds contactors to determinate the stability of the bed a study has been carried out, analyzing the evolution of the different regimes. The solid flow characterization has been realized by measuring the following properties of the bed: pressure drop and minimum spouting velocity. Furthermore, the validity of the hydrodynamics correlations, proposed in previous works and papers for glass beads and granular materials, has been proven.

1. Introduction

The recycling of building materials, unthinkable some years ago, has begun to configure as an activity with important expectations. One of the applications of the recycling material is the use for making mortar of brickwork. Some studies have been carried out in which in the making of mortar recycling arid coming from the building have been used (Alvarez Cabrera, et al., 1997). The obtained results are really satisfactory and prove that they had a behaviour similar to mortars made with arid obtained industrially in any quarry.

From the lack in the bibliography, regarding to the use of new systems of mixing for the making of mortar, in this paper, different mortar mixtures coming from virgin material have been carried out. The obtaining of a better mixture would allow obtaining a mortar of optimal physical-chemical properties for its use in building (Hincapie and Aguja, 2003).

With this aim, spouted bed technology (San José et al., 1994) has been chosen as a suitable mixing system of the different components of mortar. The behaviour of beds consisting of plaster mortars with a 9 wt% of water has been studied in spouted beds contactors of different geometric factors and in different operating conditions to consider the contribution of the water in the mixture and its possible hydrodynamics change.

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2. Experimental equipment

The experimental unit design on a pilot scale, Figure 1, basically consists on a blower which supplies a maximum air flow rate of 300 $Nm^3\ h^{-1}$ at a pressure of 15 kPa. The flow rate is measured by means of two rotameter in the ranges of 2.5-30 and of 30-250 $Nm^3\ h^{-1}$, respectively and by means of two mass flow meters in the ranges of 50-300 and 0-100 $m^3\ h^{-1}$, with both being controlled by a computer. A valve system allows selecting the rotameter and the mass flow meter for the desired flow rate. The accuracy of this control is 0.5% of the measured flow rate.

The measurement of the bed pressure drop is sent to a differential pressure transducer (Siemens Teleperm), which quantifies these measurements within the 0-100% range. This transducer sends the 4-20 mA signal to a data logger (Alhborn Almeno 2290-8), which is connected to a computer where the data are registered and processed by means of the software AMR-Control. The software AMR-Control also registers and processes the air velocity data, which allows for the acquisition of continuous curves of pressure drop against air velocity.

Five conical contactors made of poly(methyl methacrylate), Figure 2, have been used whose dimensions are as follows: column diameter, D_c, 0.36 m; contactor angle, γ, between 28 and 45°; height of the conical section, H_c, from 0.60 to 0.36 m; gas inlet diameter, D_o, in the range of 0.03-0.06 m. The values of the stagnant bed height, H_o, used are in the range between 0.10 and 0.30 m. Operation has been carried out at the minimum spouting velocity and at velocities 20 and 30% above this value.

In Table 1 the building materials, employed in the manufacturing of mortars, with different particle diameter are set out.

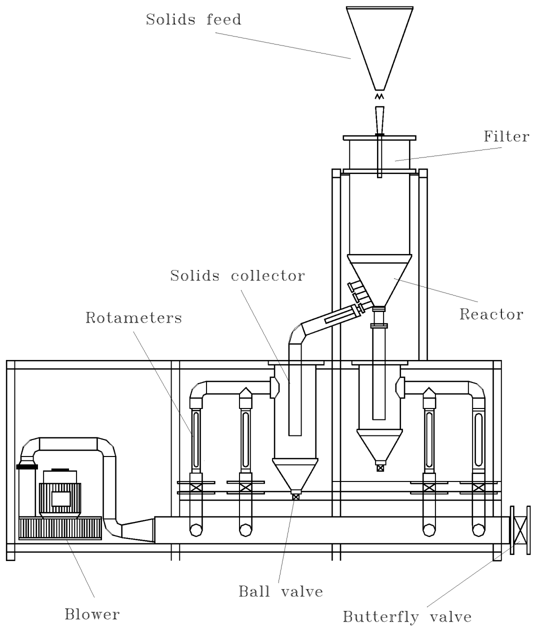

Figure 1. Experimental equipment.

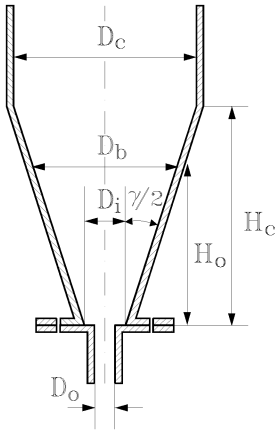

Figure 2. Schematic diagram of a conical spouted bed contactor.

Table 1 Density of building materials

Material	ρ_s (kg/m^3)
Sand	2650
Quicklime hydraulic in powder	850-1150
Portland cement	1400
Coke slag	600
Gravel	1750
Common bricks	1350-1600
Brick powder	1000
Porcelain	2400
Limestone	2700
Plaster powder	1200

3. Hydrodynamic study

In order to determinate the behaviour of beds consisting of mortars in conical spouted beds contactors, some experiments have been carried out by mixing different building materials of different particle diameter.

In Figure 3, the results of the evolution of bed pressure drop with gas velocity for a representative system with a bed consisting of a mixture of plaster mortar with a 9 wt% of water and Sauter average diameter, $\overline{d_S}$, of 1.81 mm for different values of the stagnant bed height, H_o are plotted. The results obtained for beds of plaster mortar are qualitatively similar to that corresponding to beds of materials of higher density (Olazar et al., 1992, 1993) with a pronounced hysteresis when velocity decreases from the spouted bed regime. Pressure drop increases with gas flow up to the value of maximum pressure drop, from this value decreases up to the value corresponding to stable operating, which remains constant with increasing velocity in a relative wide range.

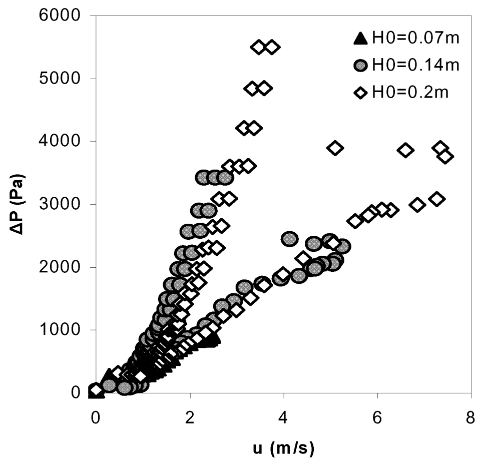

Figure 3. Pressure drop evolution with gas velocity for beds of a mixture of plaster mortar of $\overline{d_S}$ *1.81 mm with a 9 wt% of water. System:* γ*= 28º;* D_o*= 0.03 m.*

Stable operating conditions and operating regimes have been delimited in beds of building materials of different particle diameter and they have been plotted in operating maps. In these diagrams, the stagnant bed height, H_o, has been plotted against the gas velocity, u. The borders between the different regimes, drawn with solid lines, have been obtained experimentally (the points drawn are the experimental base for tracing these borders), by increasing gas velocity for each stagnant bed height.

In Figure 4, as an example, the operating map for a bed of plaster mortar with a 9 wt% of water is shown in order to take into account the contribution of the water in the mixture and the possible hydrodynamic variation. Beginning in the fixed bed, as gas velocity increases the bed passes through a transition regime and increasing gas velocity the stable spouted bed regime is reached. Furthermore, it is noticeable that this system is stable at all studied stagnant bed heights and minimum spouting velocity increases as stagnant bed height is increased, thus operating zone in stable spouted bed regime decreases.

The validity of the equation proposed in previous papers for the calculation of the minimum spouting velocity (Olazar et al., 1992) for beds consisting of mixtures of building materials without noticeable segregation has been proven.

$$(Re_o)_{ms} = 0.126\,Ar^{0.5}(D_b/D_o)^{1.68}[\tan(\gamma/2)]^{-0.57} \tag{1}$$

The equation relates Reynolds module with the geometric factors of the bed and Archimedes module and was proposed as consequence of a wide experimental study. The experimental results fit to the equation with a regression coefficient of r^2 of 0.94 and a relative maximum error of 6%.

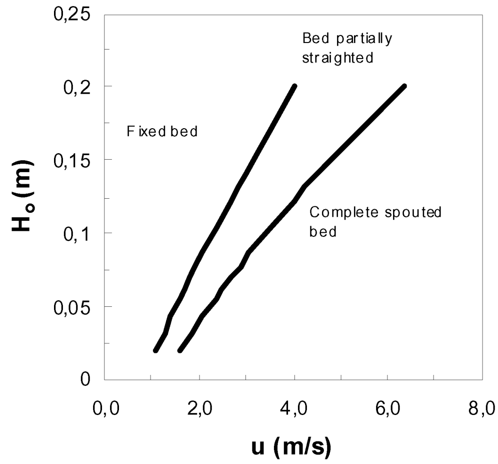

Figure 4. Operating maps for beds of a mixture of plaster mortar of $\overline{d}_S$ *1.81 mm with a 9 wt% of water. System:* $\gamma = 28°$; $D_o = 0.03$ *m.*

As an example of the fitting of the results of minimum spouting velocity to equation (1), in Figure 5 the theoretical values of minimum spouting velocity obtained with equation (1) have been plotted against experimental values for beds of mixtures of plaster mortar of Sauter average diameter $\overline{d}_S = 1.81$ mm with a 9 wt% of water for different values of gas inlet diameter and of stagnant bed height. As it is observed, data fitting approaches to a straight line of slope one, which shows the quality of the fitting.

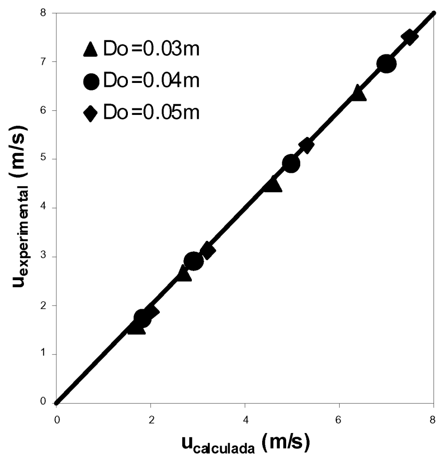

Figure 5. Comparison of the experimental and theoretical values of minimum spouting velocity for beds of a mixture of plaster mortar of $\overline{d}_S$ *1.81 mm. with a 9 wt% of water* $D_o = 0.03$ *m, 0.04 and 0.05 m. for different values of stagnant bed height.*

Conclusions

Bed pressure drop obtained for beds of plaster mortar in conical spouted beds contactors increases with gas flow up to maximum value from which decreases up to the value corresponding to stable operation and remains in a relative wide range. Furthermore, it has a pronounced hysteresis as velocity decreases from spouted bed regime.

Beds consisting of mixtures of building materials are stable for all studied conditions. Thus, conical spouted beds contactors are suitable for the handling of mixtures of building materials in a wide range of geometric factors and operating conditions. Minimum spouting velocity increases as stagnant bed height is increased, therefore operating zone in stable spouted bed regime decreases.

The validity of the correlation determined in previous papers for the calculation of minimum spouting velocity has been proven for beds of mixtures of building materials.

Nomenclature

Ar	Archimedes number, g $d_p^3\rho(\rho-\rho_s)/m^2$
D_b, D_c, D_i, D_o	Upper diameter of stagnant bed height, of the column, of the bed base and of the gas inlet, respectively, Lm
d_p	Particle diameter, m
$\overline{d_S}$	Average particle diameter, m
H_c, H_o	Height of the conical section of the contactor and of the stagnant bed, respectively, m
$(Re_o)_{ms}$	Reynolds number of minimum spouting referred to D_o, $u_o\ \rho\ d_p / \mu$
u	Velocity of the gas referred to D_i, m s^{-1}
ϕ	Particle sphericity
γ	Contactor angle, deg
ρ_s	Solid density, kg m^{-3}
ΔP	Bed pressure drop in the bed, kg m^{-3} s^{-2}

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