EFFECT OF THE LENGTH OF DRAFT TUBE ON THE HYDRODYNAMICS OF A CONICAL SPOUTED BED WITH A DRAFT TUBE FOR USING ENERGY OF WASTES

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Abstract

The influence of the length of the draft tube in bed stability of conical spouted beds with a non-porous draft tube located at the bottom of the contactor has been studied and these results have been compared with those obtained with this internal device locating the draft tube at the same level that the upper bed surface in the same experimental conditions.

In order to design the appropriate length of the non-porous draft tube without any instability or operating drawbacks in conical spouted beds, the length of the draft tube located centrally at a height from the bottom of the contactor has been varied up to a maximum values in which the top of the draft tube is at the same level the upper bed surface.

Keywords: spouted bed, conical spouted bed, draft tube, hydrodynamics, length of the draft tube, wastes, using of wastes energy

Resumen

Se ha estudiado el efecto de la longitud del tubo central en la estabilidad del lecho con un tubo central no poroso y los resultados se han comparado con los obtenidos con este dispositivo colocado hasta el mismo nivel que la superficie del lecho y con los obtenidos sin este dispositivo en las mismas condiciones de operación.

Para el diseño de la longitud adecuada del tubo central no poroso que permita operar sin inestabilidades ni inconvenientes de operación en spouted beds cónicos, se ha variado la longitud del tubo, colocado centralmente a una distancia desde el fondo del contactor, hasta un valor máximo en el cual la parte superior del tubo central está al mismo nivel que la superficie superior del lecho.

Palabras clave: spouted bed, spouted bed cónico, tubo central, fluidodinámica, longitud del tubo central, residuos, aprovechamiento de la energía de los residuos

1. Introduction

In spite of the versatility of the conical spouted beds, there are situations in which the gas-solid contact is not fully satisfactory due of the bed instability. In previous papers [1-3] the ranges of the geometric factors of the conical contactor and of the contactor-particle system for stable operating condition have been established [1-3] in order to become the stability.

The insertion of a draft tube in a conventional spouted bed overcomes the limitations of the spouted for improving gas-solid contact. Several advantages of using a draft tube in a conventional spouted bed are the following [4-7]: greater flexibility in the operation; lower gas flow and pressure drop; solids of any size or nature may be treated; narrower residence time distribution; better control of solid circulation; avoids maximum spoutable bed height. Consequently, solid circulation may be controlled by changing independently column diameter, stagnant bed height or particle diameter. Among the disadvantages the following are worth mentioning: lower mixing degree; complexity of design; risk of tube blockage; lower contact between gas and solids; lower heat and mass transfer; longer recirculation time.

Applications of conventional spouted beds with a draft tube cover a wide range of operations and chemical processes including: drying [8-11], combustion [6, 12-14], pyrolysis of hydrocarbon [15], pneumatic conveying [16], pharmaceuticals [17] and mixing [18].

In some papers the results of the effect of non-porous draft tube in conventional spouted beds mainly focussed on: flow characteristics [19], particle circulation [5, 20-22], hydrodynamics [23-24], have been published.

In order to widen the range of the bed stability in conical spouted beds, in this paper the effect of the length of a non-porous draft tube on the bed stability is analyzed in these contactors with a central draft tube.

2. Methodology

The experimental unit, Figure 1, design on a pilot scale is provided with a blower that 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 mass flow meters in the ranges of 50-300 and 0-100 $m^3\ h^{-1}$, with both being controlled by a computer. The accuracy of this control is 0.5% of the measured flow rate [25-26].

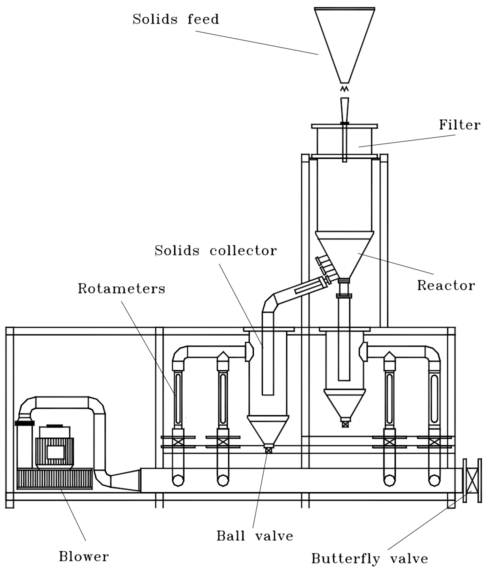

Figure 1. Diagram of the experimental equipment.

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 [25]. 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) have been used. Figure 2 shows the geometric factors of these contactors, 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, Ho, used are in the range between 0.05 and 0.35 m. Operation has been carried out at the minimum spouting velocity and at velocities 20 and 30% above this value.

The influence of the length of the device in each solid particle bed (in the same experimental conditions) has been studied by inserting centrally a draft tube in the contactor and varying the length of the draft tube from a minimum value of 0.02 m to a maximum value in which the top of the draft tube is at the same level that the upper bed surface [27].

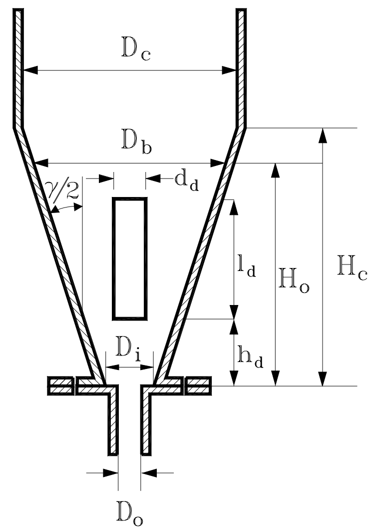

Figure 2. Geometric factors of the contactor and of the draft tube.

The draft tube, Figure 2, is a cylindrical tube made of poly(methyl methacrylate) located centrally at the bottom of the contactor. Figure 2 shows the draft tube geometries. The draft tube diameter, d_d, and height of the entrainment zone, h_d, have been determined experimentally in a previous paper [28] from a viewpoint of stability of spouting and of the clogging of solid particles. The diameter of the draft tube, d_d, was varied from 0.03 m to 0.05 m. The diameter of the draft tube, d_d, was determined experimentally in a previous paper [28] for a viewpoint of stability of spouting and was varied from 0.03 m to 0.05 m. The choice of the upper limit of the draft tube diameter, d_d, was made based on to the average spout diameter, [25], which is between the gas inlet diameter, D_o, and the base diameter, D_i, and in conical spouted beds is nearer to the base diameter, D_i [25]. The entrainment zone, distance between the base of the contactor and the lower base of the device, h_d, has been determined experimentally in a previous paper [28] is in the range 0.01-0.09 m. The length of the draft tube, l_d, has been varied from 0.02 m to a value calculated as $l_d= H_o-h_d$. and it is in the range 0.02-0.34 m.

The solids studied are glass spheres, which corresponds basically to the D group of the Geldart classification [29-30] and their properties are set out in Table 1.

Table 1 summarizes the geometric factors of the conical contactors, the dimensions of the central draft tubes and particle properties of solids studied.

Contactor poly(methyl methacrylate)		
Column diameter	D_c (m)	0.36
Contactor angle	γ (deg)	28, 33, 36, 39, 45
Height of the conical section	H_c (m)	0.60, 0.50, 0.45, 0.42, 0.36
Gas inlet diameter	D_o (m)	0.03, 0.04, 0.05, 0.06
Stagnant bed height	H_o (m)	between 0.03 and 0.35 m
Draft tube poly(methyl methacrylate)		
Inside diameter	d_d (m)	0.03, 0.04, 0.05, 0.06
Tube length	l_d (m)	from 0.02 to 0.34
Distance of entrainment zone	h_d (m)	0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09
Particle (Glass beads)		
Diameter	d_p (mm)	1, 2, 3, 4, 5, 6
Density	ρ_p (kg/m^3)	2420

Table 1. Geometric factors of the contactors and of the draft tube and particle properties.

3. Results

In order to provide the effect of the length of the central draft tubes in conical spouted bed contactors on bed stability, a novel diagram has been proposed in this paper. In this diagram the length of the draft tube, l_d, has been plotted against the gas velocity, u.

In this diagram, Figure 3, the length of the draft tube, l_d, has been plotted against the gas velocity, u, corresponding to a system taken as an example, of contactor angle, γ= 33º, gas inlet diameter, D_o= 0.04 m, with a bed of glass spheres of Sauter average diameter, $\overline{d_S}$ = 2.5 mm and stagnant bed height, H_o= 0.20 m. The draft tube dimensions are: diameter, d_d= 0.04 m, height of the entrainment zone, h_d= 0.05 m and length varied from a minimum length of l_d= 0.02 m to the maximum length of l_d= 0.15 m (corresponding to the level of the stagnant bed, l_d= H_o-h_d).

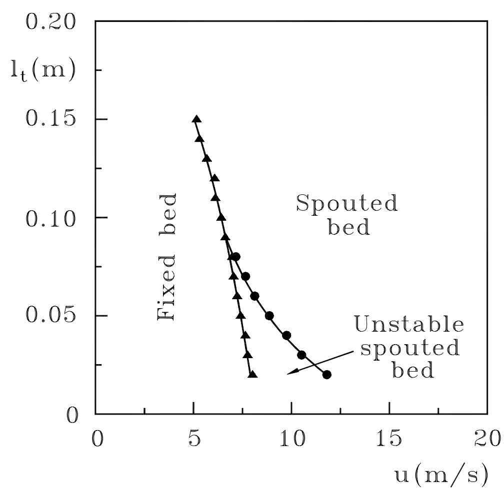

Figure 3. Operating map. System: γ= 33º, D_o= 0.04 m, beds of glass spheres of Sauter average diameter $\overline{d_S}$ = 2.5 mm. Draft tube of d_d= 0.04 m and h_d= 0.05 m.

As is observed, as the length of the central draft tube is increased, the stable spouted bed regime is reached and the minimum spouting velocity decreases. For small lengths of the draft tube there is a slight instability zone. Therefore, the increasing in the draft tube length enhances the stable operating conditions. Thus, with the longest draft tube the maximum range of stable operating conditions is reached.

4. Conclusions

In all the experimental systems studied, the introduction of a central draft tube in the bed improves bed stability in conical spouted beds and this improvement enlarges the range of operating conditions.

The stability of conical spouted beds with draft tube depends on the length of the draft tube. The increasing in the length of the draft tube gives way to a decreasing in the minimum spouting velocity, therefore an increasing in the range of operating conditions in spouting regime. It has been proven that by means of an appropriate design of the draft tube, the range of stable operating conditions in conical spouted beds with a draft tube is wider than without draft tube without any instability or operation drawbacks.

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