Segregation of Binary Mixtures of Biomass Wastes in Clean Technology of Spouted Bed

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ABSTRACT

The radial and longitudinal segregation of beds consisting of binary mixtures of biomass wastes of different size and shape has been quantified in clean technology of Spouted Bed of different geometry (contactor angle, and gas inlet diameter) and in different operating conditions (stagnant bed height, particle diameter and gas velocity). Spouted bed technology has a good performance for clean treatment of beds consisting of binary mixtures of biomass wastes of different size and shape, which a reduced segregation.

Keywords: spouted beds, conical spouted beds, clean technology, biomass wastes, waste mixtures.

1 INTRODUCTION

Spouted bed technology is suitable for the thermal treatment of biomass by combustion [1] (San José et al., 2002) and by pyrolysis [2-4] (Aguado et al., 2000, 2002; Olazar et al., 2001). Therefore, it would be adequate for the thermal treatment of mixtures of biomass wastes with non appreciable segregation, due to the ability to handle granular and fibrous materials and mixtures of different sizes and textures with the low segregation because of the cyclic movement of solid particles [5] (San José et al., 1994).

In a previous paper [6] (San José et al., 2009), the hydrodynamics of beds consisting of biomass mixture wastes of different characteristics in spouted beds of different geometry (contactor angle, and gas inlet diameter) and in different operating conditions (stagnant bed height, particle diameter and gas velocity) have been studied. In this paper, the radial and longitudinal segregation has been quantified in beds consisting of binary mixtures of biomass wastes of different size and shape.

2 EXPERIMENTAL

The experimental unit designed at pilot plant scale, shown in Figure 1, allows for operation with contactors of different geometry. It consists of a blower that supplies a maximum flow rate of 300 Nm$^3$h$^{-1}$ at a pressure of 15 kPa, and two high efficiency cyclones in order to collect fine particles. The flow rate is measured by means of two mass flowmeters in the ranges of 50-300 and 0-100 m$^3$h$^{-1}$, both being controlled by a computer. The accuracy of this control is 0.5% of the measured flow rate.

The operation has been carried out at gas velocities over the minimum spouting velocity (10% and 20% over the minimum spouting velocity).

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, $\gamma$, 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 0.05 and 0.25 m. Operation has been carried out at the minimum spouting velocity and at velocities 20 and 30% above this value.
The biomass wastes used have been sawdust, shaving and wood chips, of density \( \rho_s = 560 \text{ kg/m}^3 \) of Sauter mean diameter \( \bar{d}_S = 1.5, 1.9, 2.5 \) and 3.1 mm.

In order to quantify the segregation, solid sampling, at different bed levels in the bed, has been carried out by means of a probe connected to a suction pump, provides of a computer-coordinates displacement device, Figure 3. The optimum sampling duration was estimated between 3 and 5 s, as shorter times give way to errors inherent in withdrawal of small amounts of sample. Longer times, corresponding to considerable quantities of sample with respect to the inventory, alter the bed composition. Each sampling is repeated three times at each position in the bed and the solids are returned to the contactor after each sampling.

The segregation has been quantified by using the mixing index calculated from the experimental values of weight fraction of particles of greater diameter or density in the upper volume half of the bed, \( \bar{X}_B \) and the weight fraction in the whole bed, \( X_B \) (San José et al., 1994) as a function of the geometric factors of the contactor, of bed composition and of air velocity.

### 3 RESULTS

In Figure 4, the weight fraction of the particles of greater effective diameter, \( X_B \), at different radial and longitudinal positions of the bed has been plotted as an example of the results for a mixture without noticeable segregation (corresponding to beds consisting of 50 wt % of binary mixtures of sawdust and shaving of Sauter mean diameter \( \bar{d}_S = 1.5 \text{ mm} \), \( \gamma = 36\circ; D_o = 0.04 \text{ m}; H_o = 0.18 \text{ m} \)) as a function of the geometric factors of the contactor, of bed composition and of air velocity.

It is observed that for low bed levels, \( X_B \) passes thorough a minimum corresponding to the interface between the spout and annular zones. For higher bed levels as the radius increases over that corresponding to the spout, \( X_B \) passes through a maximum value corresponding to an intermediate position in the annular zone and subsequently decreases, reaching a new minimum value in the contactor wall.

Figure 3: Diagrammatic representation of the equipment and of the sampling device.

The weight fraction of the particles of greater effective diameter, \( X_B \), at different radial and longitudinal positions of the bed has been plotted in Figure 5. As it is observed, the minimum corresponding to the interface between the spout and annular zones, as well as, the maximum value corresponding to an intermediate position in the annular zone are more pronounced than for beds of Sauter mean diameter \( \bar{d}_S = 1.5 \text{ mm} \).

The segregation has been quantified by using the mixing index calculated from the experimental values of weight fraction of the particles of greater effective diameter in the upper volume half of the bed, \( \bar{X}_B \) as a function of the geometric factors of the contactor, of bed composition and of air velocity.
In Figure 6, the experimental values of weight fraction of the particles of greater effective diameter, $X_B$, has been plotted against the bed level as an example for a mixture corresponding a to bed consisting of 50 wt % of binary mixtures of sawdust and shaving of Sauter mean diameter $d_S = 1.9$ mm, ($\gamma = 36^\circ$; $D_o = 0.04$ m; $H_o = 0.24$ m).

It is observed that the component of bigger size is in greater proportion in the upper part of the bed.

Nevertheless, mixing index is in the range of 1.0-1.3 in all of experimental systems studied, quantified in beds consisting of binary mixtures of biomass wastes of different size and shape.

4 CONCLUSIONS

From the experimental results is concluded that clean technology of spouted bed has a good behaviour for stable treatment of beds consisting of binary mixtures of biomass wastes of different size and shape which a reduced segregation.

The component of bigger size is in greater proportion at the top of the bed. In addition, for low levels, the weight fraction of the particles of greater effective diameter, passes thorough a minimum corresponding to the interface between the spout and annular zones. For higher bed levels as the radius increases over that corresponding to the spout,
passes through a maximum value corresponding to an intermediate position in the annular zone and subsequently decreases, reaching a new minimum value in the contactor wall.

Besides, segregation decreases as the difference of particles size is decreased. Therefore, it is possible to operate with beds consisting of binary mixtures of biomass wastes of different size and shape without noticeable segregation.

5 NOMENCLATURE

\( D_\text{g} \): diameter of the gas inlet, m
\( \bar{d}_S \): Sauter mean diameter, m
\( H_\text{S} \): heights of the stagnant bed, m
\( u, u_\text{ms} \): velocity and minimum spouting velocity of the gas, respectively, m s\(^{-1}\)
\( X_B \): weight fraction of the greater diameter particles
\( \bar{X}_B \): average weight fraction of the greater diameter particles in the upper volume half of the bed
\( \bar{X}_B(z) \): average weight fraction of the greater diameter particles at z level

*Greek Letters*

\( \gamma \): angle of the contactor, deg
\( \rho_s \): density of the solid, kg m\(^{-3}\)

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7 REFERENCES