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

M.J. San José, S. Alvarez, L.B. López, H. Altzibar

Departamento de Ingeniería Química. Universidad del País Vasco. Facultad de Ciencia y Tecnología. Apartado 644. 48080 Bilbao. Spain. Tel: 34-94-6015362 Fax 34-94-6013500. e-mail: mariajose.sanjose@ehu.es

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^3h^{-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).

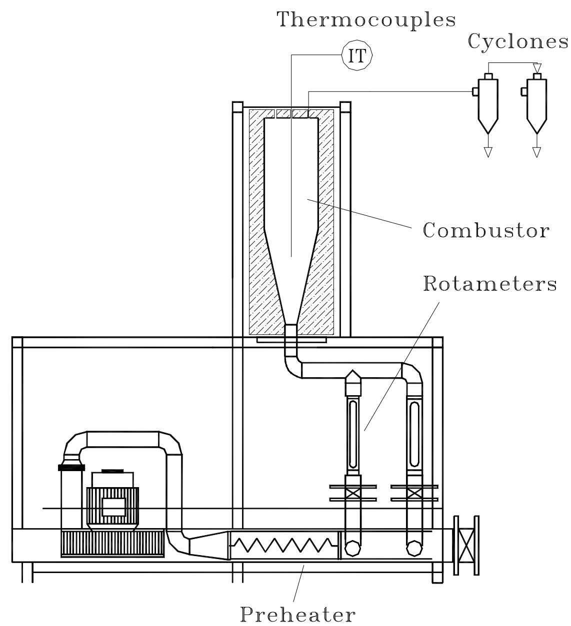

Figure 1: Experimental equipment

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, 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 ρ_s= 560 kg/m^3 of Sauter mean diameter $\overline{d}_S$ = 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.

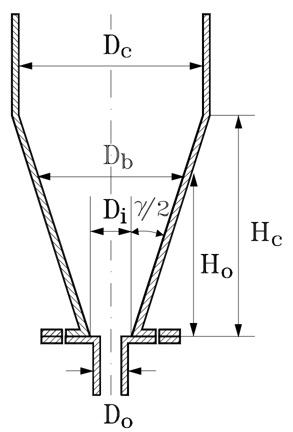

Figure 2: Diagrammatic representation of the equipment and of the sampling device.

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, $\left(\overline{X_B}\right)_u$ and the weight fraction in the whole bed, $\overline{X_B}$ (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 $\overline{d}_S$ = 1.5 mm, (γ= 36º; D_o= 0.04 m; H_o= 0.18 m). 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.

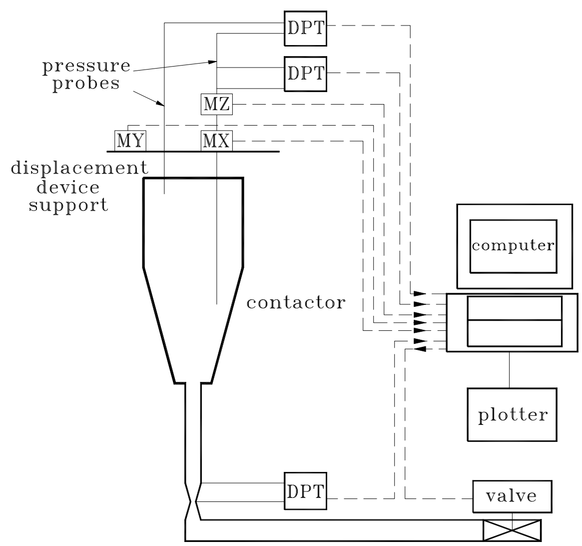

Figure3: Diagrammatic representation of the equipment and of the sampling device.

The weight fraction of the particles of greater effective diameter, X_B, at different radial and longitudinal positions of the bed 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 $\overline{d}_S$ = 3.1 mm, (γ= 36º; D_o= 0.04 m; H_o= 0.18 m) 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 $\overline{d}_S$ = 1.5 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, $\left(\overline{X_B}\right)_u$ as a function of the geometric factors of the contactor, of bed composition and of air velocity.

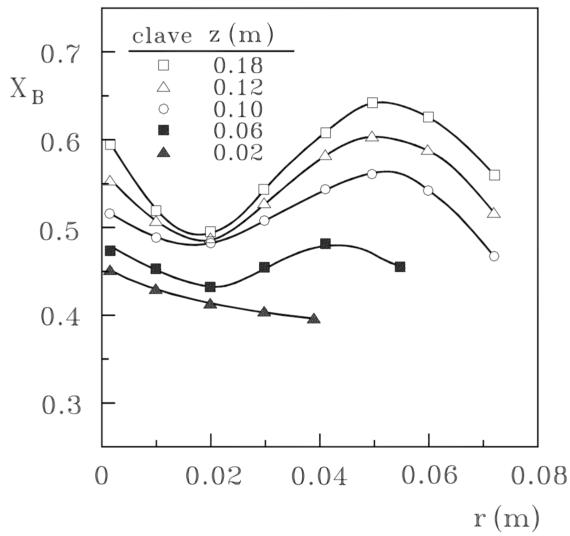

Figure 4: Weight fraction of the particles of the greater particle, X_B, at different radial and longitudinal position of the bed. System binary mixture (50 wt % of sawdust and shavings of $\overline{d}_S$ = 1.5 mm.

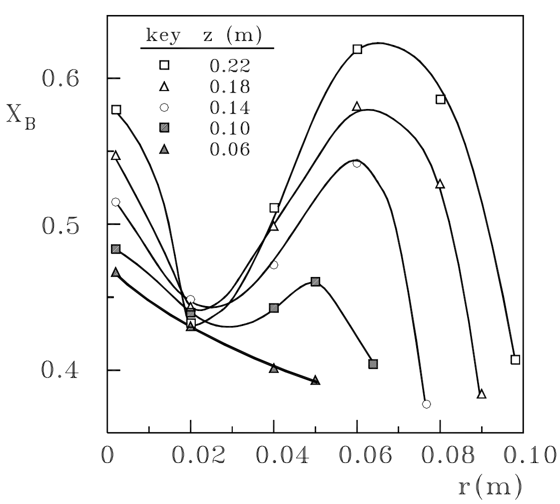

Figure 5: Weight fraction of the particles of the greater particle, X_B, at different radial and longitudinal position of the bed. System binary mixture (50 wt % of sawdust and shavings of $\overline{d}_S$ 3.1 mm.

In Figure 6, the experimental values of weight fraction of the particles of greater effective diameter, $\left(\overline{X}_B\right)_z$, 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 $\overline{d}_S$ = 1.9 mm, (γ= 36º; 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.

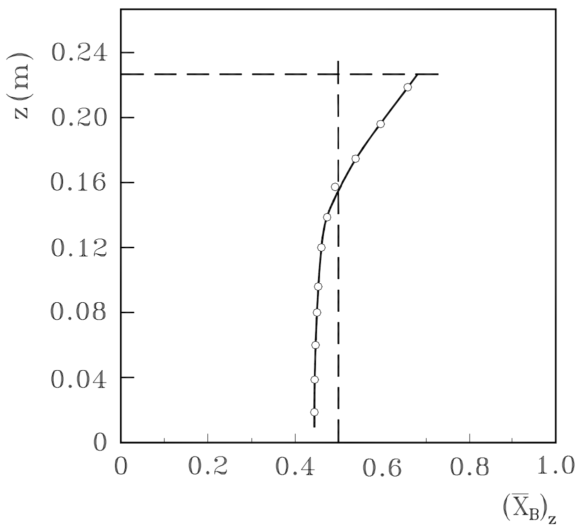

Figure 6: Average value of weight fraction of the greater particle, at different levels. System: 50 wt % binary mixture of sawdust and shavings of Sauter mean diameter $\overline{d}_S$ = 1.9 mm, γ= 36º; D_o= 0.04 m; H_o= 0.24 m.

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,

NSTI-Nanotech 2010, www.nsti.org, ISBN 978-1-4398-3415-2 Vol. 3, 2010

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_o: diameter of the gas inlet, m

$\overline{d}_S$: Sauter mean diameter, m

H_o: heights of the stagnant bed, m

u, u_{ms}: velocity and minimum spouting velocity of the gas, respectively, m s^{-1}

X_B: weight fraction of the greater diameter particles

$\left(\overline{X}_B\right)_u$: average weight fraction of the greater diameter particles in the upper volume half of the bed

$\left(\overline{X}_B\right)_z$: average weight fraction of the greater diameter particles at z level

Greek Letters

γ: angle of the contactor, deg

ρ_s: density of the solid, kg m^{-3}

6 ACKNOWLEDGEMENTS

This work was carried out with the financial support of the University and of the County Council of Biscay (Project DIPE 07/09) and of Spanish Science and Innovation Ministry (Project TRA 2009_0318).

7 REFERENCES

[1] San José, M.J., Alvarez, S., López, L.B., García, I., Operating Conditions of binary mixtures of biomass wastes in spouted bed contactors for using energy, Clean Technology, 109-112(2009)

[2] Aguado, R., Olazar, M., San José, M.J., Aguirre, G., Bilbao, J., Pyrolysis of sawdust in a conical spouted-bed reactor. Yields and product composition, Ind. Eng. Chem. Res., 39, 1925-1933(2000).

[3] Aguado, R., Olazar, M., San José, M.J., Gaisan, B., Bilbao, J., Wax Formation in the Pyrolysis of Polyolefins in a Conical Spouted Bed Reactor, Energ. Fuel, 16(6) 1429-1437(2002).

[4] Olazar, M., Aguado, R., San José, M.J., Bilbao, J., Kinetic study of fast pyrolysis of sawdust in a conical spouted bed reactor in the range 400-500C, Chem. Technol. Biotechnol., 76(5), 469-476(2001).

[5] San José, M.J., Olazar, M., Peñas, F.J., Bilbao, J., Segregation in Conical Spouted Beds with Binary and Ternary Mixtures of Equidensity Spherical Particles, Ind. Eng. Chem. Res., 33(7), 1838-1844(1994).

[6] San José, M.J., Aguado, R., Alvarez, S., Olazar, M., Combustión de Serrín y Residuos Agroforestales en Lechos de Borboteo Cónicos (Conical Spouted Beds), Inf. Tecnol., 13(2), 127-131(2002).