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EXPERIMENTAL STUDY OF A BINARY MIXTURE OF SUGARCANE BAGASSE AND SAND ON A BUBBLING FLUIDIZED BED REACTOR

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Abstract. *There is a growing interest in the use of biomass as a renewable energy because of the existing environmental problems and limitations of fossil fuel feedstock. One way of using biomass is through the thermochemical process in bubbling fluidized beds. In this work, a defined proportion of sugarcane bagasse and inert was tested in order to determine the minimum fluidization velocity in a bubbling fluidized bed. The percentage of biomass in comparison to the total mass is 10%. Fluidization parameters such as minimum fluidization velocity, pressure drop and bed expansion were determined. The value of minimum fluidization velocity was compared to the empirical equation that is available in the literature. It is necessary to consider more physical properties of particles on experimental correlation for obtain more accuracy.*

Keywords: *bubbling fluidized bed, biomass, minimum fluidization velocity.*

1. INTRODUCTION

The need for renewable energy is growing especially due to a combination of gradual reduction of fossil fuel feedstock, the increase in world energy demand and the environmental problems that many of the current fuels can cause (Ashraf, et al., 2014). Biomass is one of the possible solutions as an alternative energy source which can be considerably explored in Brazil. It is important to consider that almost 86% of the sugar production of the world is distributed between 16 countries of which Brazil and India produce together 60% of that value (Alderetes, 2016). Therefore, the amount of sugarcane bagasse is considerably large and could be used to produce energy, biofuels and chemicals.

Taking into account all the thermochemical decomposition processes available for the sugarcane bagasse, fluidized bed reactors are a consistent choice because they provide good solids mixing and a high rate of heat and mass transfer (Sharma, et al., 2014). Moreover, fluidized bed reactors are a considerably new and unexplored technology in Brazil (Alderetes, 2016) and they have a wide range of applications in the industry, varying from chemical to physical processes, such as catalytic reactions, coating, drying, pyrolysis, gasification and combustion (Kumoro, et al., 2014).

In these types of reactors, the fluid dynamic behavior of the solid and the gas phases influence directly on the efficiency of the process. However, these interactions become considerably complex and difficult to predict when the solid is heterogeneous, which is the case of the biomass, irregular in size and shape. Moreover, a second different solid, such as sand, is usually mixed with it in order to improve the fluidization process, turning the fluidized bed into a binary solid system (Kumoro, et al., 2014). Consequently, the solid phase is characterized by particles of different shapes sizes and densities, increasing the possibility of vertical segregation and unstable fluidization (Karmakar, 2013).

For that reason, a better understanding of the hydrodynamics of the reactor, including the minimum fluidization velocity (*Ufm*), pressure drop and bed expansion, are critical in the design and operation of the fluidized beds (Karmakar, et al., 2013; Uddin and Coronella, 2017; Monazan, et al., 2017). Although there are many works investigating the *Umf,* only a few of them explore the mixture of biomass and sand (Kumoro et al., 2014).

The primary objective of this research work is to analyze the fluidization process of a binary mixture for different proportions of sugarcane bagasse and sand. The proportion used was 10% of mass fraction of bagasse. For that purpose, it was used a cold fluidized bed made of acrylic. The parameters obtained experimentally are minimum fluidization velocity, pressure drop profile and bed expansion. These data were compared to the empirical correlations obtained by Rao and Bheemarasetti (2001).

2. MATERIALS AND METHOD

2.1 Binary mixture

In the experiments, the binary mixture used as the solid phase in the bubbling fluidized bed is composed of sand and biomass. The sand used as an inert material was provided by the Institute for Technological Research (IPT) which has a narrower particle size distribution. The material used as biomass was sugarcane bagasse. Both materials are shown in Fig. 1.

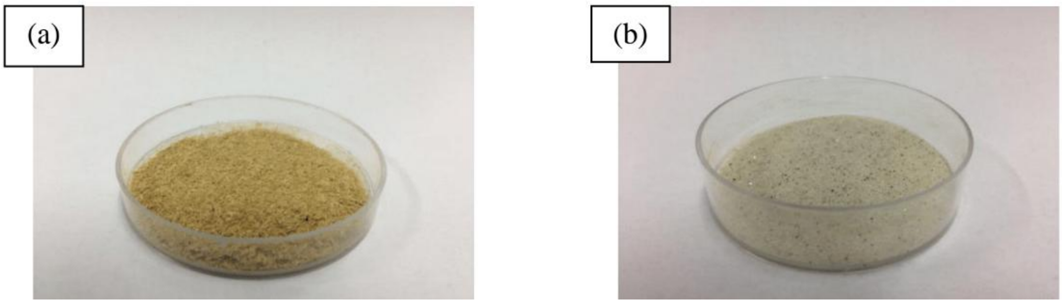

Figure 1. Materials used inside the bed (a) Sugarcane bagasse (b) IPT sand

The physical properties of the biomass and the inert material are depicted in Table 1. These properties and the properties of the air (ρ = 1,2 kg/m^3 e 17,2 × 10^{-6} g/m^3) were used to determine the minimum fluidization velocity

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Table 1. Physical properties of the materials

Material	dp (µm)	ρ (kg/m^3)
Sugarcane	1000	2500
bagasse	275	916
IPT Sand		

2.2 Cold fluidized bed

In Fig. 2, it is shown the schematic of the cold fluidized bed. The acrylic part of the bed has a height of 1.5 m and a diameter of 0.17 m. A perforated plate gas distributor was used together with differential (DP) and static (SP) pressure transducers. In order to process the pressure signals, the LabView software was used. As for the supply of air, an Artek one blower ACR - 7.5 (7.5 HP. 6.3m^3 / min, 5150 mmH_2O) was connected to the system.

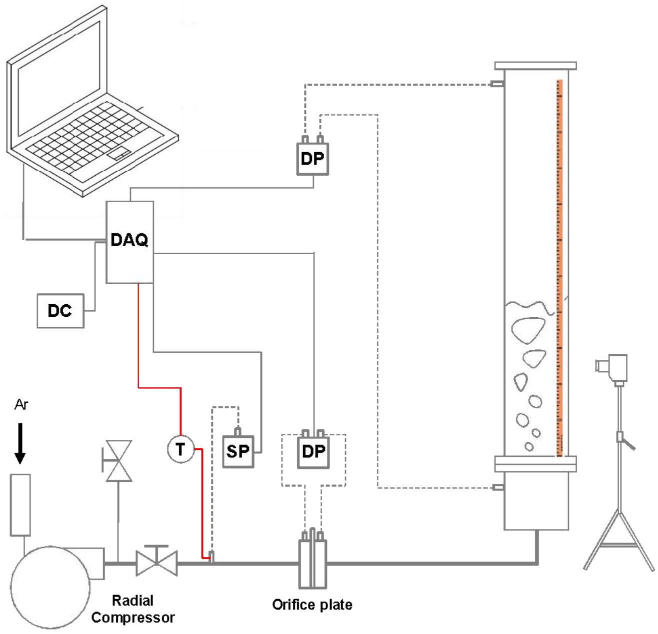

Figure 2. Schematic of the experimental unit

2.3 Minimum fluidization velocity for binary mixtures

The minimum fluidization velocity (U_{mf}) is one of the main parameters for the fluidized bed reactors. They are used to determine the flow of air that goes into the equipment and, consequently, it assists in the choice of the compressor most suited for the situation. For that reason, there are many correlations available in the literature that can be used to determine U_{mf} for systems consisting of a single material or binary mixtures such as biomass and sand. It is possible to visualize in Table 2 the correlations proposed by Rao and Bheemarasetti (2001) in order to estimate the U_{mf} for binary mixtures. The experimental results of U_{mf} will be compared with the results of these equations.

Table 2. Correlation used to determine U_{mf}

Correlation	Equations	
Rao & Bheemarasetti (2001)	$U_{mf} = \dfrac{d_{eff}^2(\rho_{eff} - \rho_g).g}{1650\mu_g}$	(1)
	$\rho_{eff} = x_1\rho_{p1} + x_2\rho_{p2}$	(2)
	$dp_{eff}^2 = k' \left\{ d_{p1} \left[\left(\dfrac{\rho_{p1}}{\rho_{p2}} \right) \left(\dfrac{d_{p2}}{d_{p1}} \right) \right]^{w_{p2}/w_{p1}} \right\}^2$	(3)
	$k_1 = (20d_{p1} + 0.36)^{0,5}$	(4)
	$k_2 = (20d_{p2} + 0.36)^{0,5}$	(5)

3. RESULTS AND DISCUSSION

In the study of fluidization of binary mixtures, in order to avoid the premature formation of sluggings and attain a regular bubbling regime, the ratio of the bed height (L) of the inert material to the bed diameter (D) was considered to be of approximately 1 (L/D = 1). A higher proportion of inert was used when compared to the biomass in order to ensure the fluidization of the material inside of the equipment. During the procedures of the tests, the materials were premixed. Figure 3 shows the pressure drop in function of the fluidization velocity and it is possible to perceive that the pressure drop increases with the increase of the gas velocity. According to Kunii and Levenspiel (1991), this profile is a characteristic of the polydispersed systems. The velocity when the materials inside of the bed begin to demonstrate a partial movement is defined as the initial fluidization (U_{if}). As the gas velocity increases, a bubbling fluidization regime and a complete fluidization regime (U_{cf}), in which particles move up completely, can be achieved.

Figure 3 shows the procedure to determine the minimum fluidization velocity. The complete procedure is described by Formisani, et al. (2008). The minimum fluidization velocity for binary mixture is between U_{if} and U_{cf}, therefore, the intersection of the two lines indicates U_{mf} for the binary mixture. The overall behavior of the graph shown in Figure 3 is very similar to the one presented by Oliveira, et al. (2013). It is important to note that fluid dynamic behavior between U_{if} and U_{cf} have shown no significant difference. However, as the gas velocity increased above 0.2 m/s, it was possible to perceive a few problems concerning the mixture of the materials.

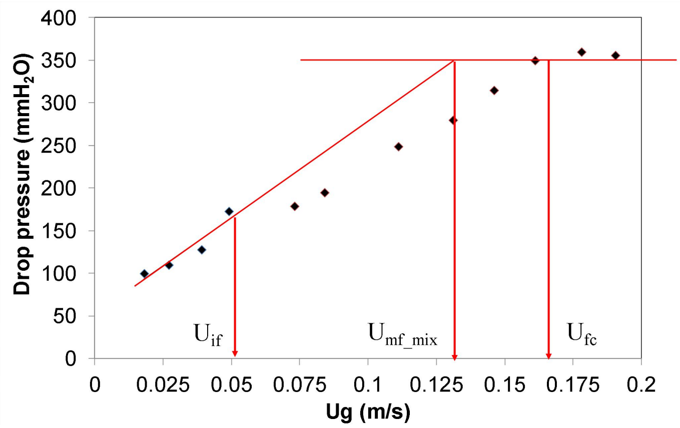

Figure 3. Pressure drop as a function of superficial gas velocity

The U_{mf} obtained from the experimental method was of approximately 0,13 m/s while the one obtained from the Rao and Bheemarasetti (2001) correlation was of 0,093 m/s. Comparing both results, it is possible to observe that the value calculated by the correlation is slightly below the experimental one. That might have happened because of parameters that were not considered by the correlation such as particle sphericity and size distribution. As stated before, the minimum fluidization velocity is a parameter that is directly related to design and definition of the air compressor used in the fluidized bed.

The bed expansion is another important parameter on the design of the fluidized bed. The bed expansion allows to estimate the height of the fluidized bed in function of the fluidization regime. It should be noted that the expansion of the bed is applied specifically to the flow from the bubbling regime to the turbulent regime, respectively, in which the latter is difficult to determine. The bed expansion of the binary mixture is observed before reaching U_{if}. as shown in Fig. 4. However, if compared to monodisperse systems, binary systems present a different behavior. The superficial gas velocity which the fluidization of the bed begins is not the same value of the minimum fluidization velocity.

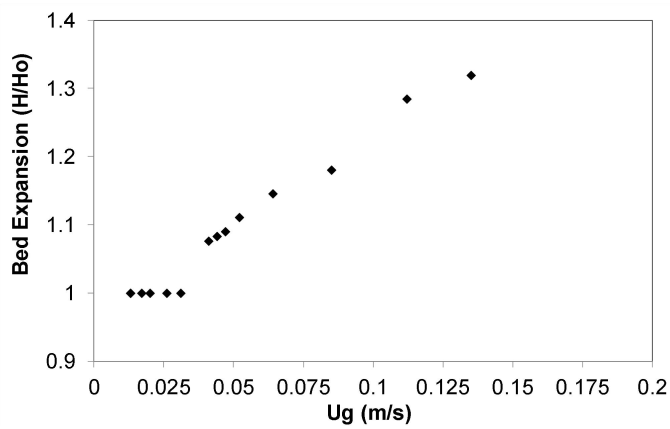

Figure 4. Bed expansion as a function of superficial gas velocity.

4. CONCLUSION

In this work, the behavior of a binary mixture of sugarcane bagasse and sand was studied. The experimental correlation used to estimate the U_{mf} of binary mixture has demonstrated a good performance. In order to improve the mixture of biomass and sand in the bed, alternatives such as the use of biomass pellets must be evaluated. However, more studies are needed to evaluate different conditions and parameters.

5. ACKNOWLEDGEMENTS

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