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Single-Bubble Dynamics in a Dense Phase Fluidized Sand Bed Biomass Gasification Environment

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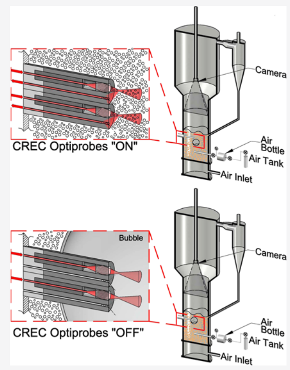
ABSTRACT: Biomass gasification in fluidized beds is a process of important commercial value. The simulation of these fluidized bed units strongly depends on establishing bubble dynamics in dense phase sand fluidized beds. In these studies, the selected biomass pellet dimensions were 2.7 cm in length and 0.8 cm in diameter. To develop bubble dynamics studies in the present research, a combination of CREC-Optiprobes and a video micro-camera were employed. This was done to record bubble velocity and bubble dimensions in a 200−900 μm particle sand fluidized bed. The effects of biomass pellet concentration on the bubble rise velocity and bubble size and shape were evaluated at conditions close to minimum fluidization. On this basis, a theoretical bubble dynamic model was established. This phenomenologically based model included an adjustable bubble wake parameter, with model predictions providing the bubble chord, bubble frontal ratio, and bubble rising velocity.



1. INTRODUCTION

Biomass gasification can be used as a two-way solution. It can produce syngas from a renewable resource helping, at the same time, to reduce the environmental impact of agricultural waste.[1] In this respect, the National Renewable Energy Laboratory[2] estimates that it is possible to reduce 30% of petroleum usage in the United States, if 1.3 billion tons of biomass are produced and used to manufacture fuels. For instance, the pulp from the coffee fruit, designated as broza,[3] can be an ideal feedstock for gasification. In fact, once the coffee seed is removed from the coffee fruit, the remaining waste cannot be left in the soil. If this happens, broza can ferment, releasing both methane, a high-impact greenhouse gas, and other toxic chemical species. Thus, broza gasification is required to provide a sustainable approach to coffee production.

Biomass gasification can be achieved using two main approaches: (a) moving-bed gasifiers and (b) fluidized-bed units.[4,5] The main advantage of the fluidized-bed gasifiers over moving beds is improved mass and heat transfer.[6] The fluidization technology has been considered since the 1920s.[7] However, its practicality and simple implementation are still a challenge, given its complex hydrodynamics. On the other hand, fluidized beds help create close-to-homogeneous conditions in terms of temperature and species concentration.

In this regard, extensive research has been developed on single bubbles in beds of Group A powders in the Geldart classification.[8−10] Studies with important Group B powders in the Geldart classification with densities in the 2000−3000 kg/m^3 range are, however, less frequent, including their interaction with larger bodies such as bubble breakers often called internals. When internals are added to a fluidized bed, the bubbles change their behavior[11−14] by breaking more often and therefore leading to smaller bubble sizes. As the bubbles become smaller, they multiply in number and the contact area between the bubbles and the dense phase increases significantly, greatly helping the mass exchange of chemical species between the two phases.

However, and given the value of fluidized beds in biomass gasification, additional research is required using Geldart type B powders, particularly of those of higher densities ($\rho \geq 2500$ kg/m^3), including fluidized sand beds loaded with biomass pellets. There are, in this respect, few publications in the open literature accounting for particle size, such as the work of Agu et al.,[15] or regarding the biomass effect over bubbles. In this respect, Fotovat et al.[16] were one of the first authors to detect bubbles using parallel fiber optics in the presence of biomass pellets.

Regarding bubble motion in fluidized beds, it has been argued that bubbles may be considered to behave as a bubbling liquid of low viscosity.[9] This leads to the classic model of Davies and Taylor,[17] as expressed in eq 1. According to this view, the bubble rise velocity (BRV) depends only on two factors: the acceleration of gravity (g) and the bubble nose radius (R_n).

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