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Using dynamic pressure signals to assess the effects of injected liquid on fluidized bed properties

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Abstract

A liquid injected in a fluidized bed may spread on the bed particles, increasing their cohesivity and reducing the bed fluidity. The liquid may also result in the formation of wet agglomerates that settle at the bottom of the bed. The objective of this work was to use easily obtained dynamic pressure signals to quantify the bed fluidity and the formation of large wet agglomerates, with specific reference to fluid coking reactors.

Operating the fluid cokers at reduced temperatures increases liquid product yield and reduces sulphur oxide emissions. However, lower temperatures may lead to a wetter bed and consequently, local zones of poor mixing and/or local defluidization, with detrimental effects on reactor performance and stability.

The bed fluidity was quantified from the dynamic pressure measurements, using the *W* statistic. The experimental results obtained in both a laboratory column and a large hot pilot plant validated this method.

The formation of wet agglomerates was quantified by combining dynamic pressure and bed deaeration measurements.

Keywords: Fluid bed cokers; Fluidized bed; Bed fluidity; Wet agglomerates; Dynamic pressure signals

1. Introduction

Monitoring the fluidization quality represents an operating challenge for many processes in which a liquid is sprayed into a gas-fluidized bed, such as fluid coking, fluid catalytic cracking, gas-phase polymerization, agglomeration and drying. Although the presence of liquid will generally have an adverse effect on fluidization, there are often strong incentives in operating with high liquid loadings. For the fluid coking process, for example, operating at lower reactor temperature increases yield and reduces emissions but increases the bed wetness, which may lead to local zones of poor mixing, local defluidization and a reduction in fluidization quality, compromising the reactor performance and stability.

McDougall et al. [1] developed reliable laboratory methods to quantify the eventual degradation of the bed fluidity and/or formation of agglomerates that resulted from the injection of a liquid in a fluidized bed. There is a strong need, however, for methods that are quicker in detection of changes in bed fluidity and that could be used in industrial reactors. Such methods should give results that can be generalized to any liquid, column size and gas velocity. They also need to use data that can be easily and reliably collected without perturbing reactor operation.

Pressure measurements can be easily and reliably obtained in high-temperature industrial reactors. Several investigators analyzed pressure signal fluctuations to characterize the fluidization quality of fluidized beds [2]. Tardos et al. [3] and

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Strusch et al. [4] used the time-averaged bed pressure drop to investigate destabilization and defluidization of fluidized beds due to agglomeration. However, this method cannot provide early warning of poor bed fluidity. van Ommen et al. [5] and Schouten and Van den Bleek [6] detected changes in particle size distribution from chaos analysis of the bed pressure drop fluctuations. van Ommen et al. [8] presented an enhanced attractor comparison method based on pressure fluctuation measurements for an early warning of agglomeration in fluidized beds which they validated using a 0.1 m diameter fluidized bed. Van der Schaaf et al. [7] evaluated origin, propagation and attenuation of pressure waves in gas–liquid fluidized bed using the time series analysis method. Van der Schaaf et al. [9] used the coherence between time series of pressure fluctuations measured simultaneously in a fluidized bed along the column height to determine the gas bubble size. Guo et al. [10] investigated the dynamics of pressure fluctuation in a bubbling fluidized bed at high temperature using power spectral density function. Many of these methods, which were tested by Briens et al. [2], can distinguish between extreme conditions but do not provide reasonable resolution over a wider range of conditions. Briens et al. [2] recently found that bed fluidity problems in a 1 m diameter pilot fluid coker could be detected from bed dynamic pressure fluctuations, using a new tool called *W* statistic.

In the present work, experiments were performed with liquids that have different wettability behavior on the coke particles. Dynamic pressures were recorded and correlated to measurements of fluidization quality and agglomeration with deaeration and falling ball methods from McDougall et al. [1]. Correlations were developed to evaluate bed fluidity and agglomeration.

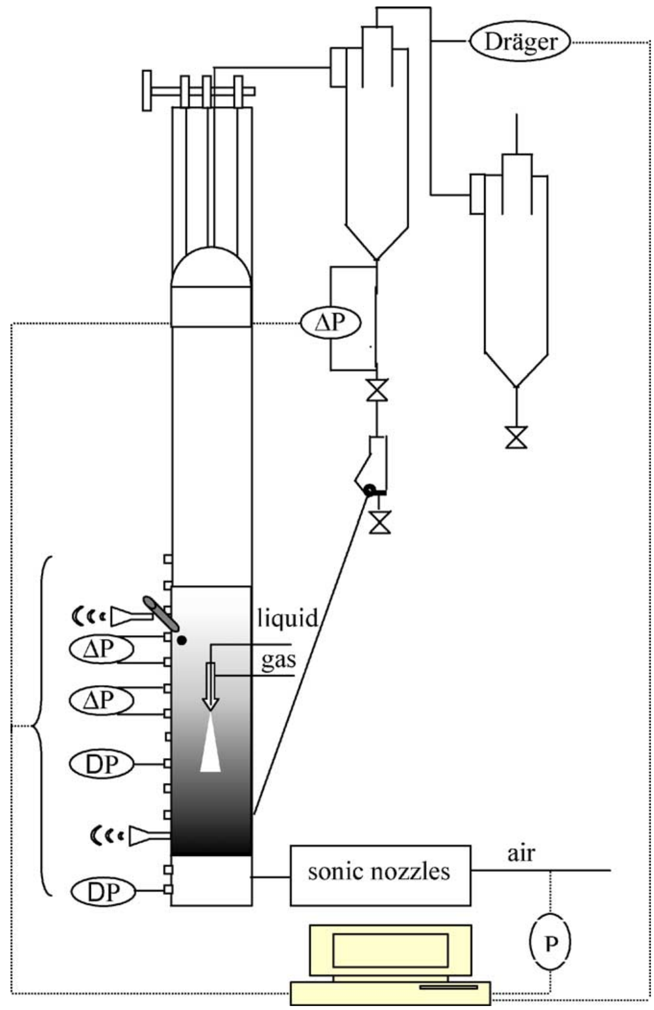

Fig. 1. Experimental set-up.

2. Experimental unit

The test facility, as shown in Fig. 1, consists of a 0.3 m-diameter and 3 m-tall column, equipped with four 2.2 kW electrical band heaters, a two-phase injection nozzle as well as static and dynamic pressure transducers that are linked to a data acquisition system.

The mass flow rate of the fluidizing gas is precisely controlled using a bank of sonic flow nozzles ranging from 0.01 to 0.12 kg/s. The main gas supply enters the bottom of the wind-box through five 25.4 mm-diameter tubes and is distributed into the bed through a perforated stainless steel plate, 0.02 m thick with three hundred 1 mm-diameter holes. The bottom of the grid is wrapped with a 325-mesh stainless steel screen to prevent the coke particles from draining into the wind-box after an abrupt shut off of the gas. The top section of the column is connected to two cyclones in series. The dipleg of the primary cyclone runs outside the column and re-enters the column at 0.1 m above the grid.

The injection nozzle is shown in Fig. 2. It has a tip diameter of 0.62 mm and is inserted vertically in the bed 0.4 m above the grid. The liquid enters the interior tube and is atomized by the gas that enters the annular section of the tubes. A tiny

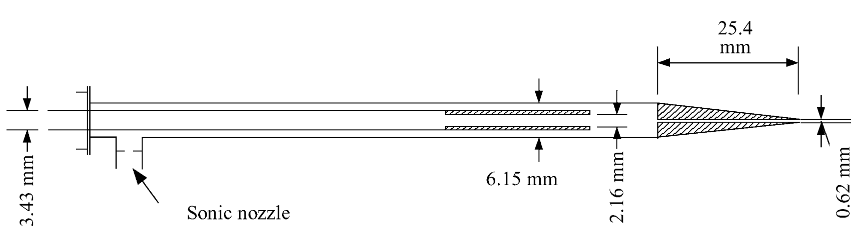

Fig. 2. Nozzle with internal mixing.