



Effect of changes in particle size on the hydrodynamics of gas-solid fluidized beds through wall vibration



Fatemeh Alamolhoda, Reza Zarghami, Rahmat Sotudeh-Gharebagh, Navid Mostoufi *

Multiphase Systems Research Lab, School of Chemical Engineering, College of Engineering, University of Tehran, P.O. Box 11155/4563, Tehran, Iran

ARTICLE INFO

Article history:

Received 17 July 2016

Received in revised form 16 October 2016

Accepted 23 November 2016

Available online 01 December 2016

Keywords:

Fluidized bed

Agglomeration

Vibration signature

Wavelet transform

Principal component analysis

ABSTRACT

Vibration signatures of a wall of a bubbling fluidized bed were measured in order to investigate the effect of change in particle size on fluidized bed hydrodynamics. Vibration signatures were analyzed using wavelet transform and decomposed into three scales: micro-, meso- and macro-scales. Principal component analysis (PCA) was employed to gain a deeper insight into the dynamic behaviour of each sub scale. Bubble and emulsion phases were distinguished by the PCA as first and second components.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Fluidized bed reactors have several advantages over conventional reactors, like excellent gas-solid contact, high heat and mass transfer rates, uniform temperature distribution and easy temperature control. These advantages have made fluidized reactors an excellent choice for variety of applications in chemical industries such as catalytic reactions, gas-phase polymerization, solid fuel conversion and drying. However, a major drawback that can affect employing gas fluidized beds is the formation of agglomerates in these reactors. The bed hydrodynamics may change drastically when agglomerates begin to form. In severe cases (i.e., significant change in the particle size distribution), complete defluidization of the bed may occur which can result in production loss, a costly cleanup [1] and hard shutdown. Defluidization may occur during gasification or combustion of coal, granulation of powders and polymerization of olefins. This can be prevented if agglomerate formation is detected in an early stage when adequate actions can still bring the system back to normal [2]. Therefore, a reliable method sensitive to the mean particle size changes is required for monitoring the agglomerate formation, not only for the safety of the process but also for its economics, operating at optimal conditions and avoiding unscheduled shutdowns [3].

Several techniques have been developed for early detection of agglomeration in fluidized beds. Pressure fluctuations have been used by many researchers for determining changes in the mean particle size

[4,5], predicting the onset of defluidization [6] and early detection of agglomeration [7–11]. Detection of agglomeration using temperature measurement was also proposed by Lau and Whalley [12] and Scala and Chirone [1]. Other methods based on acoustic emissions were also developed by Wang et al. [13], Zhou et al. [14] and Savari et al. [15]. A non-intrusive technique based on measuring the vibration signature of the bed wall was proposed by Abbasi et al. [16] to determine the minimum fluidization velocity in gas-solid fluidized beds. Vibration signature of the wall of a fluidized bed contains useful information about its hydrodynamics. In addition to growth and movements of bubbles, these signals can also originate from particle-wall interactions and particle size changes. Azizpour et al. [17] and Shiea et al. [18] used this method for determining regime transition. Azizpour et al. [19] used analysis of vibration signature of a lab-scale two-dimensional fluidized bed to detect sudden changes in fluidization state and Alamolhoda et al. [20] detected agglomeration of inactive polyethylene particles by this method in early stages in a fluidized bed operating at moderately high temperature and pressure.

Although vibration signatures of the wall of a fluidized bed have been used to explore the hydrodynamic of the bed as well as determining transition velocities, this technique has not been employed for detection of agglomerate formation in such reactors. The present study focuses on using these vibration signatures to detect changes of particle size in the bed as the origin of agglomeration. Stepwise changes in the mean particle size were employed in the experiments to simulate the hydrodynamics of a fluidized bed in agglomerate formation conditions. Wavelet transform was applied for analyzing vibration signatures showing the dynamic behaviour of fluidization. Moreover, principal

* Corresponding author.

E-mail address: mostoufi@ut.ac.ir (N. Mostoufi).

component analysis (PCA), as a new technique in this area, was used to detect the effect of changes in the mean particle size on the hydrodynamics of a fluidized bed. ACF was employed for further investigation.

2. Experiments

Schematic diagram of the experimental set up is shown in Fig. 1. Experiments were carried out at ambient conditions (1 atm., 25 °C). The column was made of Plexiglas with internal diameter, height and wall thickness of 15 cm, 200 cm and 0.6 cm, respectively. The column was fixed at distributor level and the upper part of the bed to a metal frame mounted on ground. The gas distributor was a perforated plate containing 435 holes of 7 mm in a square pitch. Air was supplied by a compressor and its flow rate was measured by an orifice meter. A cyclone was placed at the gas exit of the column to return the entrained solids back to the bed.

Size of particles in the bed was changed using various mixtures of two sizes of sand particles (density of 2640 kg/m³). The experiments were started with sand type 1 (mean particle size of 235 µm). Afterward, sand type 2 (mean particle size of 911 µm) with mass fractions of 0.025, 0.05, 0.1 and 0.15 were partially replaced with sand type 1. In each fractional addition of sand type 2 to type 1, the total mass of particles in the bed was kept unchanged. Mean particle size and properties of these mixtures are given in Table 1. Minimum fluidization velocity calculated according to Wen and Yu [21]. Height of the bed at rest was set to 30 cm (aspect ratio of 2) and the superficial gas velocities of 0.4, 0.6 and 0.8 m/s were used in the experiments.

A DJB accelerometer with sensitivity of 100 mV/ms⁻² and the cutoff frequency of 25 kHz was used to measure vibration of the bed wall. This probe was mounted on the outside surface of the wall at 5 cm above the distributor level. Abbasi et al. [16] showed that the vibration signatures do not depend on the measurement location. In fact, although the intensity of vibration may change from point to point, its signature is the same all over the wall. To ensure the reproducibility of the sampled vibration signals, the measurements were repeated three times in each operating conditions. The sampling frequency was set to 25 kHz to prevent information loss associated with the vibration content of the

Table 1

Particle properties of the sand used in the experiments.

Sand	d_p (µm)	U_{mf} (m/s)
S1	239	0.048
S2	244	0.050
S3	254	0.054
S4	264	0.058

signals which calculated based on the Shannon–Nyquist criterion which is much more than the maximum frequency component within the frequency spectrum [22] and the measurement time was considered 60 s in each test.

3. Data analysis

3.1. Wavelet transform

There are many methods used to characterize time dependent signals of fluidized beds in the frequency domain as the most distinguished information are hidden in the frequency content of the signal. Among these methods, Fourier transform can be used for stationary signals to show the existence of spectral components in the signal, but not their location. There are other methods which simultaneously provide time and frequency representations of the signal, such as wavelet transform (WT) and short time Fourier transform (STFT). The WT was developed to overcome the shortcoming of the STFT which gives a fixed resolution at all times, whereas the WT uses the variable sized windows by which higher frequencies are better resolved in time and lower frequencies are better resolved in frequency. Therefore, this method has received a considerable attention in the area of digital signal processing [23].

The wavelet transform of a signal, $x(t)$, is defined as:

$$W_f(a, b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} x(t) \phi_{a,b}^* \left(\frac{t-b}{a} \right) dt \quad (1)$$

where, $W_f(a, b)$ is the wavelet coefficient, $\phi_{a,b}^*$ is a basic (mother) wavelet function, a and b are dilation (scaling) and translation

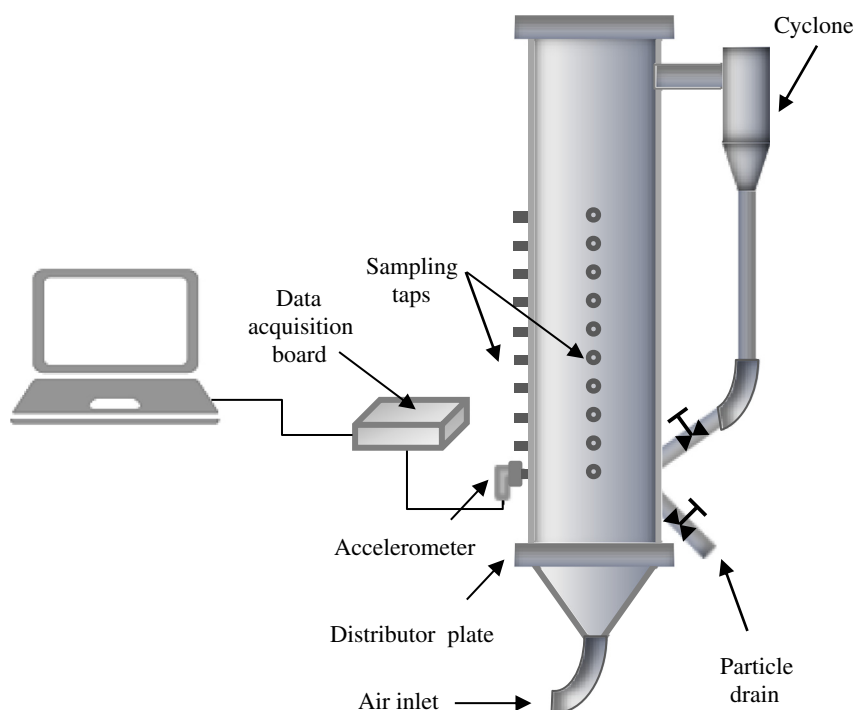


Fig. 1. Schematic of the experimental fluidized bed set-up.

Download English Version:

<https://daneshyari.com/en/article/4910761>

Download Persian Version:

<https://daneshyari.com/article/4910761>

[Daneshyari.com](https://daneshyari.com)