Spout fluidized bed : hydrodynamic studies with multiscale modelling approach

SPOUT FLUIDIZED BED: HYDRODYNAMIC STUDIES WITH MULTISCALE MODELLING APPROACH

Vinayak S. Sutkar[1], Niels G. Deen[1], J.A.M. Kuipers[1], Vitalij Salikov[2],
Sergiy Antonyuk[2] and Stefan Heinrich[2]
[1]Multiphase Reactors Group, Department of Chemical Engineering and Chemistry, Eindhoven university of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands.
[2] Institute of Solids Process Engineering and Particle Technology, Hamburg University of Technology, Denickestrasse 15, 21073 Hamburg, Germany

Summary

Nowadays spout fluidized bed reactors are gaining immense attention of scientific community, due to the unified characteristics both from the spouted and the fluidized bed reactors. In the present work, we study the hydrodynamic behaviour (flow regime map) of a spout fluidized bed reactor with draft plates. Furthermore, the effect of variation of the physical properties of the particles, entrainment height and the bed aspect ratio on the overall flow development has been investigated by experimental and numerical means. The experimental investigations were performed through particle image velocimetry and digital image analysis, and the obtained results were compared with a discrete particle model.

Keywords

Spout fluidized bed; Hydrodynamics; Particle image velocimetry; Discrete particle model

Introduction

There are a number of illustration where spout fluidized bed reactors are effectively used in gas solid operations, such as in pharmaceutical, fertiliser, detergent, drying, coating and food industries. This is not only due to the unified characteristics both from the spouted and fluidized bed reactors but also due to efficacy to handle varying particles sizes. However, it should be noted that, the performance of the spout fluidized bed highly depends on the operating parameters. Small change in theses parameters dramatically changes the performance of the reactors. This inadequacy in the operation of the reactor can be overcome by inserting draft plates in the reactor. Furthermore, draft tube insertion also results in accretion in maximum spoutable height and flexibility in adjusting the particle circulation rate.

This paper aims at investigating the hydrodynamic behaviour (flow regime map) of a spout fluidized bed reactor with a draft tube by experimental and numerical means by considering the effects of physical properties of particles, bed aspect ratio and entrainment height (R) on overall flow development.

Experimental set-up

Experiments were carried out in a pseudo 2D spout fluidized bed reactor of dimension W x D x H = 0.14 x 0.02 x 1 m^3, as shown in Figure 1. The front wall of the reactor consists of glass plate to achieve visual observation of the particle motion inside the reactor domain and the back wall is made of aluminium.

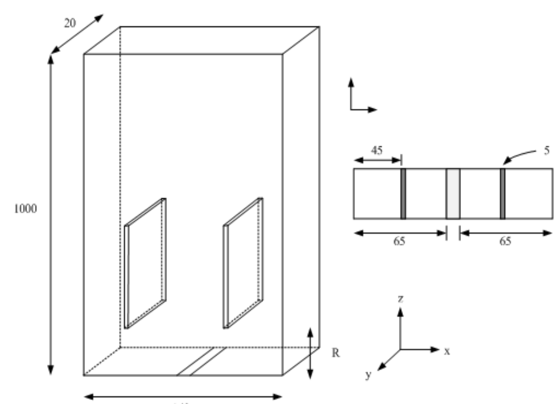


Figure 1. Schematic representation of the geometry for the pseudo 2D spout fluidized bed with draft tube (all dimensions are in mm)

Moreover, two draft plates of each dimension equal to W x D x H = 0.005 x 0.02 x 0.32 m^3 are placed inside the reactor at a distance of 0.045 m from the side wall and R can be varied in the range of 0.03 to 0.05 m from the bottom. Pressurised air is fed to the bed via three separate sections with a flow rate up to 150 m^3/hr. Here it should be noted that the electrostatic forces of attraction between particles are overcome by maintaining the relative humidity of the inlet air approximately equal to 90%. Digital images are recorded by using a high speed camera (LaVision Imager pro HS) and pressure fluctuations are measured by using two pressure sensors located in the spout and annular region.

Experimental techniques

Particle image velocimetry (PIV)
Particle image velocimetry is an optical nonintrusive measurement technique applied to produce instantaneous velocity data [1]. In this work, particle velocity in the reactor has been quantified by capturing a series of images form the front side of the reactor.

Digital image analysis (DIA)
Digital image analysis has been initially developed for the detection of the bubbles by Agarwal et al (1997) and Link et al (2005) successfully applied this technique for the spout fluidized bed. In this work an algorithm has been adopted for spout fluidized bed with draft tube to quantify particles fluxes.

Test cases

The objective of this work is to study the hydrodynamic behaviour of the spout fluidized bed reactor with draft plates. For this purpose, experiments were carried out in the spout fluidized bed reactor by considering two particles: glass beads and γ-alumina oxide. Table 1 summarises the physical properties of the particles.

Table 1. Physical properties of the particles

Property	Glass beads	γ-alumina oxide	Unit
d_p	1.017 +/- 0.02	0.9-1.1	mm
ρ_p	2526	1040	kg/m^3
e_n	0.87	0.65	--
u_{mf}	0.87	0.74	m/s

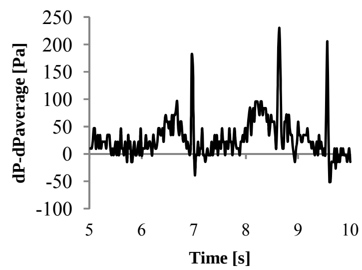
Furthermore, the effect of change in the bed aspect ratio and entrainment height on overall flow development has been investigated. The obtained experimental results were compared with numerical simulations by considering the discrete particle model (DPM) with same reactor dimension and inlet velocities. The numerical settings are listed in Table 2.

Table 2. Numerical setting for simulation

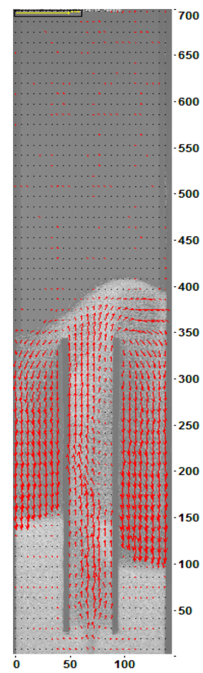
Property	Value	Unit
N_x	56	--
N_y	8	--
N_z	400	--
Δt	10^{-3}	s
t_{end}	20	s
$N_{p,Glass}$	10.10^4	--
$N_{p,AlO}$	8.10^4	--

Results and discussion

The identification of various flow regimes is achieved by capturing images and measuring pressure fluctuations. One of the identified regimes designated as spouting with aeration has been shown in Figure 2 with along with a pressure fluctuation signal.



(a)



(b)

Figure 2. Spouting with aeration regime with fluctuation in pressure signal (a) and velocity data (b)

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