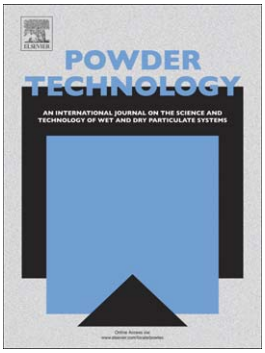

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Diana Carolina Guío-Pérez, Florian Dietrich, Jorge Nicolay Ferreira Cala, Tobias Pröll, Hermann Hofbauer

PII: S0032-5910(17)30370-4
DOI: doi:10.1016/j.powtec.2017.04.062
Reference: PTEC 12526

To appear in: *Powder Technology*

Received date: 20 May 2016
Revised date: 26 March 2017
Accepted date: 27 April 2017

Please cite this article as: Diana Carolina Guío-Pérez, Florian Dietrich, Jorge Nicolay Ferreira Cala, Tobias Pröll, Hermann Hofbauer, Estimation of solids circulation rate through magnetic tracer tests, *Powder Technology* (2017), doi:10.1016/j.powtec.2017.04.062

Estimation of solids circulation rate through magnetic tracer tests

Diana Carolina Guío-Pérez*[a], Florian Dietrich[b], Jorge Nicolay Ferreira Cala[a], Tobias Pröll[c], Hermann Hofbauer[b]
[a] Department for Mechanical Engineering, Universidad Nacional de Colombia; Carrera 30 No 45A-03, Bogotá, Colombia
[b] Institute of Chemical Engineering, Vienna University of Technology; Getreidemarkt 9/166, 1060, Vienna, Austria
[c] Institute of Energy Technology and Process Engineering, University of Natural Resources and Life Sciences; Peter-Jordan-Str. 82, 1190, Vienna, Austria
* Corresponding author: dcguiop@unal.edu.co

ABSTRACT

This work assesses the solids circulation rate in a circulating fluidized bed cold model based on measuring the particles mean residence time (τ). The tracking method detects fluid-dynamically similar ferromagnetic tracer particles, and is based on inductance changes of a coil due to changes in the concentration of ferromagnetic particles in its core. A section of the model was selected to perform the tracer measurement, such that the variations in the solids volumetric fraction and the solids velocity were negligible, and a correlation between the circulation rate and the mean residence time of solids could be established. The circulation rate was calculated in this manner for a range of operation conditions, variations of riser fluidization velocity and total inventory were performed. The results were validated measuring the circulation rate by the accumulation method as well, the results show a satisfactory correlation between the tracer and the accumulation methods. The magnetic tracer method appears thus to be suitable for the measurement of solids circulation rates in low temperature applications. This method offers as advantages the possibility for on-line measurement, good sensitivity, non-intrusiveness, cost efficiency, and does not require a calibration.

KEYWORDS: Solids circulation rate, Solids mass flux, Solids mass flow rate, Circulating fluidized beds, Accumulation method, Tracer measurement.

1. INTRODUCTION AND BACKGROUND

One important parameter in the study of circulating fluidized beds (CFBs) is the solids circulation rate, since mass and heat transport are usually associated to the solids mass flows. Solids circulation rate often determines gas-solids contact time and conversion as well [1]. Accurately measuring the mass flow rate is fundamental to improve the economy of operation, maintain operation safety, guarantee technological stability of the processes, as well as to control the hydrodynamics in CFBs operation [2]. Regardless of the scale, continuous measurement of solids flow rate is always desired but still a problematic subject in many CFB units [3]. Accurate and continuous methods for the measurement of circulation rate have been constantly sought for both, experimental and industrial applications [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. The measurement of the circulation rate should, besides being accurate and inexpensive, ideally not interfere with the operation of the unit (especially fluiddynamics), i. e. be non-invasive, require no calibration, be implementable on-line, and have an adequate sensitivity. For industrial application, the method should also have a broad range of operation, be capable to operate at high temperatures and pressures, and offer the possibility for scaling-up. The absence of one or more of these characteristics in most of the methods available reduces significantly the number of reliable techniques [2, 5, 13, 14].

In CFBs, solids circulation rate can either be controlled or be a results of the fluiddynamics in the loop [15, 16, 17, 18, 19]. In either mode, the measurement of the solids circulation rate is required. If solids flow control devices such as mechanical or non-mechanical devices (surge vessels, L-valves, screw feeders for instance) are used to set the solids flow rate, the solids flux and the fluidization velocity (hence gas flux) are independent variables. In spite of the control device, the solids circulation rate still must be measured to calibrate the device. A CFB can also operate with a fixed inventory that circulates freely and continuously inside the loop, devices such as loop seals are used to make the solids recirculation possible, such devices only transfer the solids back into the bed without controlling the solids flow rate. In this operation mode the solids circulation rate is a variable that depends principally on the fluidization velocity, but also on the total solids inventory, the flow resistances in the system, and the carrying capacity of the gas [6, 15]. In particular, most of the double circulating bed systems operate in the fixed inventory mode.

1.1. Solids circulation rate measurement

The direct determination of the solids flow rate is generally linked to the detection of particle motion, which can be performed by means of optical, radioactive, electrical, tracer, acoustical, heat/mass transfer and mechanical methods [1, 11]. Mechanical methods include those based on flow separation (sampling probes) and those based on determination