Powder Technology 328 (2018) 26–37

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Inductive heating of fluidized beds: Spray coating process

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ARTICLE INFO

Article history:
Received 30 March 2016
Received in revised form 21 December 2017
Accepted 9 January 2018
Available online 17 January 2018

Keywords:
Inductive heating of fluiized beds
Coating
Layer porosity

ABSTRACT

Spray fluidized bed coating is an established process for the treatment of solid particles. Commonly fluidized beds are heated convectively. Another method is inductive heating by electrically conductive particles. In this work spray coating with inductive heating is investigated. Coating experiments with convective or inductive heating and different process parameters (temperature, spraying rate, initial particle diameter, initial bed mass) were realized. Moisture content, particle size distribution and apparent density of the particles were measured, as well as the thickness and porosity of the layer created on the initial particles. Similar results can be obtained by both heating methods, advantages of inductive heating are discussed as well as limitations.

1. Introduction

A fluidized bed is achieved when a fluid (gas, liquid) flows through a solid bulk material and fluidizes the particles. Due to their high mass and heat transfer, as well as their good mixing properties, fluidized beds are often used in industrial processes. According to Werther [1], today's fields of applications are chemical processes (heterogeneous catalyzed gas-phase reactions, non-catalyzed reactions) and physical processes (e.g. granulation, drying, heating, adsorption).

Fluidized beds are used to produce particles with pre-defined properties; e.g. spray coating produces coarse, nearly spherical granules by size enlargement. During spray coating a solution or suspension is sprayed on carrier particles. Then the liquid part of the solution or suspension is evaporated from the surface of the particles, creating solid deposits. Repeating this procedure leads to a growth of the particles. Another example, spray granulation is applied for the agglomeration and drying of, e.g. salts, fertilizers, food and detergents [2].

Required heating of the fluidized bed is commonly realized by preheating the fluidization medium in a heater, positioned before the fluidized bed chamber. Inside the fluidized bed chamber the fluid transfers its heat to the particles by convection. Another common approach to enhance heat transfer to the fluidized bed is by contact heating using vapor-heated pipes inside the chamber or the heating of the apparatus walls.

Alternatively, inductive heating of electro-conductive, chemically inert particles enables energy input into a fluidized bed. In inductive heating, the main heat source is not a fluid or heated surfaces, but results from interaction of moving conductive objects in an electromagnetic field, which results in heating the objects. A classical field of industrial application of inductive energy input is the use in the processing of metallic work pieces, which are annealed, welded, melted etc. [5].

In this work, electro-conductive particles are placed in the fluidized bed chamber, which is surrounded by an induction coil. If the coil is charged with an alternating current, a closed alternating magnetic field is generated around the windings of the coil. On the surface of the electro-conductive particles the induction current is induced. Because of electric resistances, the particle surface is heated and it transmits its heat to the fluidization medium [3,4]. An advantage of this method is the high energy input per square meter of particle surface area, which results in fast heating and cooling. Moreover, the gas temperature inside the fluidized bed chamber is precisely controllable. Applications of inductively heated fluidized beds can be found in foods and pharmaceuticals, for example in the process of roasting coffee, where good results can be achieved regarding the quality and color of the roasted coffee. Due to a slight intensification of the drying process [14], inductive heating can also be applied to the process of destructive coating of solutions in fluidized beds.

The first investigations about the influence of an external magnetic field on magnetizable particles in a fluidized bed have been conducted by Filippov in the 1960s [6]. Rosensweig has influenced ferromagnetic particles or a mixture of them with non-ferromagnetic particles by a constant, axial magnetic field and has obtained a broader gas velocity range in which the fluidized bed is stable and no bubbling is observed [7]. Further investigations about stabilized fluidized beds have been carried out by Hristov [8] in the 1990s. Stable fluidization of the particles has been obtained using a homogenous magnetic field, which has the

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https://doi.org/10.1016/j.powtec.2018.01.017

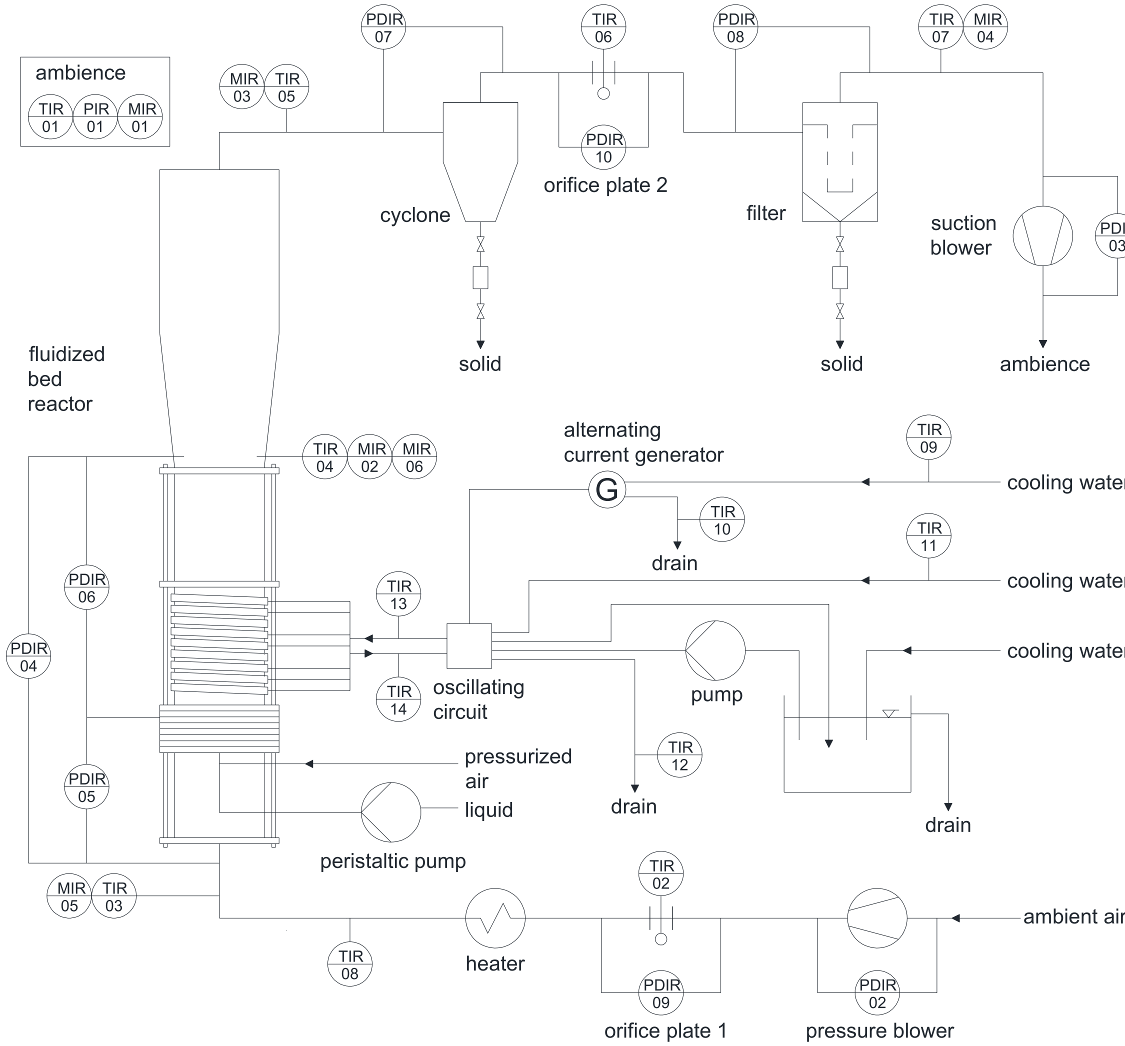

Fig. 1. Schematic representation of the experimental plant.

same flow direction as the fluidization medium or which is vertical with respect to the fluidization medium. These experiments aimed at influencing the fluidization behavior of the particles.

Efforts to use inductive heating for chemical reactions have been reported by Ceylan [10]. Therein different reactions have been performed in a flow reactor with magnetic materials (steel beads, iron oxide nanoparticles covered with silica gel). To evaluate the results, the experiments have also been performed with convective and microwave heating, in which inductive and microwave heating created comparable results.

Stresing et al. [11] have successfully investigated contactless energy input into fluidized beds by induction. As electrically conductive material iron hollow balls (IHB) have been utilized which are heating up the fluidization medium by convective heat transfer. Short heating and cooling times has been observed. Roßau [12] has noticed a change in the fluidization behavior of the IHB with increasing inductive energy input: an initially bubbling fluidized bed starts to vibrate and finally agglomeration of the conductive particles occurrs, resulting in the stagnation of the fluidized particles.

Further investigations on the inductive energy input in fluidized beds were performed by Idakiev et al. [13]. In this publication, it is reported that the inductive heating of the fluidized bed requires co-fluidization of conductive inert particles (IHB as a heat exchanger) and non-

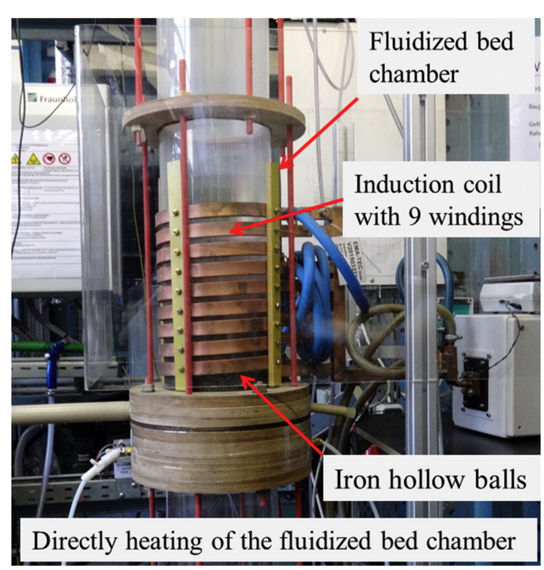

Fig. 2. Fluidized bed chamber with an induction coil.