Journal of Industrial and Engineering Chemistry xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

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

UNCORRECTED PROOF

Drying characteristics of fine powders in an inert medium circulating fluidized bed with binary inert media

Q1 Dong Hyun Kang[a], Sung Il Kim[b], Won Pyo Chun[b], Dong Hyun Lee[a,*]

Q2 [a] School of Chemical Engineering, Sungkyunkwan University, Seobu-ro 2066, Jangan-gu, Suwon, Republic of Korea
[b] Division of Energy Saving, Korea Institute of Energy Research, Gajeong-ro 152, Yuseong-gu, Daejeon, Republic of Korea

ARTICLE INFO

Article history:
Received 10 May 2016
Received in revised form 23 August 2016
Accepted 24 September 2016
Available online xxx

Keyword:
Drying
Fine particle
Inert circulating fluidized bed
Binary solids

ABSTRACT

The effects of two types of inert particles (binary: 180 and 500 μm or mono: 500 μm), inlet gas temperature (40–100 °C), and mass ratio of fine to inert particles (F/I) (0.05–0.2) on the batch type fluidized bed drying characteristics of fine powders were investigated in an inert media circulating fluidized bed (0.087 m-ID × 1.0 m-height). Copper dendrimer powder ($X_0 = 25.0\%$ wet basis, $d_p = 2.7$ μm, $\rho_p = 5980\ kg/m^3$) and aluminum flux (Al flux) ($X_0 = 30.2\%$ wet basis, $d_p = 8.6$ μm, $\rho_p = 2730\ kg/m^3$) were used as the fine humid materials, and glass beads (180 and 500 μm) were used as the inert media particles. The moisture contents of the dried powders were sufficiently low, from 0.2% to 0.7% (wet basis). The result shows that the aggregation phenomenon rarely occurs. Compared with using the mono type inert media fluidized bed dryer, the amount of dried product using an inert media circulating fluidized bed with binary inert media increased by two to three times. The maximum drying rate of the inert media circulating fluidized beds with binary inert media is higher than that of the agitated pan dryer and inert media bubbling fluidized bed dryer (mono type inert). Additionally, the optimum condition ($T_g = 60$ °C, F/I ratio = 0.1, binary inert media) was derived from the energy efficiency.

© 2016 The Korean Society of Industrial and Engineering Chemistry. Published by Elsevier B.V. All rights reserved.

Introduction

Fine particles of most materials are typically very small, ranging in size from several tens of nanometers to a few micrometers. The specific surface area of fine particles and the ratio of the surface area to particle volume are generally higher than those of larger particles; thus, the cohesive force among the particles is strong. Fine particles are mainly produced with liquid solvent for convenience and economy of the manufacturing process. Therefore, drying processes are essential in the post-treatment process for the commercial use of fine particles. However, due to the cohesive force as described above, agglomeration occurs between the particles to form a large aggregate. As a result, there is a high possibility that the desired properties of the particles (such as ultra-fine particle size and large specific surface area) decreased. In summary, the ultimate goal of the drying of fine particles is the removal of the solvent in the mixture produced in the liquid to powder process in order to ensure commercial availability. Other important goals are to obtain the product in powder form while minimizing agglomeration, and to reduce the energy required for the process to a minimum to develop an energy efficient process [1].

In drying the fine particles, it is possible to use fluidized bed drying techniques that have significant advantages such as high water removal efficiency per unit volume and low energy and drying air consumption [2]. However, fine particles belonging to Geldart group C are not able to form a homogeneous fluidized bed and cannot undergo drying because of channeling. Jariwala and Hoelscher [3] reported superior drying properties by dispersing humid material with inert media sand at a mixing mass ratio of 1:1 sand to starch in order to improve the flow characteristics of the starch. Nakagawa et al. [1] analyzed the drying properties of slurry activated alumina (mean diameter: 1.8, 2.6 μm) and SiO_2 flux (mean diameter: 13 μm) when using silica sand as inert media particles. They reported that, while the drying rate is related to the feeding rate, the superficial gas velocity, the moisture contents of the humid material, and the inlet gas temperature, it is not related to the static bed height or the diameter of the inert media particles. Lee and Kim [4] demonstrated that the drying rate of starch with batch type fluidized bed drying increased with the decreasing mixing ratio of humid material (mean diameter: 20 μm) to inert media (0.4, 1.0 mm glass bead) and with the increasing inlet gas temperature and superficial gas velocity. Moreover, the drying rate

---

* Corresponding author. Fax: +82 031 299 4709.
E-mail address: dhlee@skku.edu (D.H. Lee).

http://dx.doi.org/10.1016/j.jiec.2016.09.034
1226-086X/© 2016 The Korean Society of Industrial and Engineering Chemistry. Published by Elsevier B.V. All rights reserved.

Please cite this article in press as: D.H. Kang, et al., Drying characteristics of fine powders in an inert medium circulating fluidized bed with binary inert media, J. Ind. Eng. Chem. (2016), http://dx.doi.org/10.1016/j.jiec.2016.09.034

Nomenclature

$\dot{m}_g$	Mass flow rate of air [kg/s]
A_t	Cross-sectional area of main column [m^2]
d_P	Mean particle diameter; Sauter mean diameter [μm]
F/I ratio	Mass ratio of dried fine particle to inert particle [–]
m_A	Mass of water [kg]
M_A	Molecular weight of water [g/mol]
m_B	Mass of dry air [kg]
M_B	Molecular weight of air [g/mol]
P	Total pressure [Pa]
$P_{A,sat}$	Saturated water vapor pressure [Pa]
Q	Volumetric flow rate of air [m^3/s]
R_D	Drying rate per unit area [kg $H_2O/(m^2s)$]
R_{Dmax}	Maximum drying rate [kg $H_2O/(m^2s)$]
RH	Relative humidity [%]
T_g	Inlet air gas temperature; windbox temperature; dry-bulb temperature [°C]
U_g	Superficial gas velocity [m/s]
V	Humid volume [m^3]
W_A	Mass of removed water [kg]
X_0	Initial moisture content [wt% wet basis]
Y	Absolute humidity [kg H_2O/kg air]
Y_{in}	Absolute humidity of inlet gas [kg H_2O/kg air]
Y_{out}	Absolute humidity of outlet gas [kg H_2O/kg air]
ρ	Particle density [kg/m^3]

of the fluidized bed dryer is approximately 10 times higher than that of the agitated pan dryer. In a study on continuous type fluidized bed drying with inert media particles [5], the drying properties of a PVC paste (mean diameter: 1.0 μm) were analyzed and a drying efficiency correlation equation was derived. In that system, the drying efficiency increased with the increasing feeding rate of humid material, mass flow rate of gas, and mass ratio of humid material to inert media, while it decreased with increasing superficial gas velocity.

In fluidized bed dryers, inert particles are usually used as fluidizing, heat transferring, and dispersing media. Because the stickiness of certain materials can interrupt the detachment process, highly damp fine particles that are difficult to be fluidized are fluidized via the inert media particles, rendering it possible to expect a high heat transfer effect in the beds. Additionally, through fluidization, it is possible to perform intensely efficient drying by increasing the contact area between the humid fines when drying with heated air. As the dried particles entrained with heated gas are collected in a bag filter, the overall heat transfer coefficient can increase. Lee and Kim [4] also reported that the drying capacity of the fluidized bed dryer is high. The particles belonging to Geldart group B, which can be easily fluidized, could be used as an inert media. For example, materials such as glass beads, silica sand, and activated alumina that do not react with other materials have mainly been used as inert media particles.

Nevertheless, if the flow regime of the inert media particles causes bubbling fluidization, various problems can arise, such as the reduction of the amount of product since particles adhere to the inner wall of the apparatus freeboard area, degradation in the quality of the material due to the lengthy drying time, interference with the flow of the drying gas, turbulence, the development of a stagnant region, and particles that have not been dried due to the increased interstitial gas velocity caused by the reduction in the cross-sectional area of the column. Bhagat et al. [6] reported that, with a continuous type fluidized bed dryer, the product adhesion on the inner wall of the apparatus freeboard area can be prevented by brushing the inner wall using an electric motor to dry the particles with a silica aerogel powder. To solve the problem of the inert media in the bubbling fluidized bed dryer, Kim et al. [7] increased the superficial gas velocity to create circulating fluidized bed drying and reported minimal adhesion of the product powders. In contrast, another solution is to induce an exponential increase in the mechanical and heat energy consumed in the drying process by increasing the air flow rate, thus reducing the drying efficiency [1]. The terminal velocity of 327 μm of glass beads relies on a very high value at a superficial gas velocity of more than 1.7 m/s. For this reason, in the circulating fluidized condition, coarse particles cannot be easily used as an inert media. However, coarse inert particles are essential to break the humid complex (the fine inert particles coated with humid material). In order to increase the amount of product of coarse inert media particles while at the same time removing the product adhesion on the inner wall of the apparatus freeboard area, the particle size

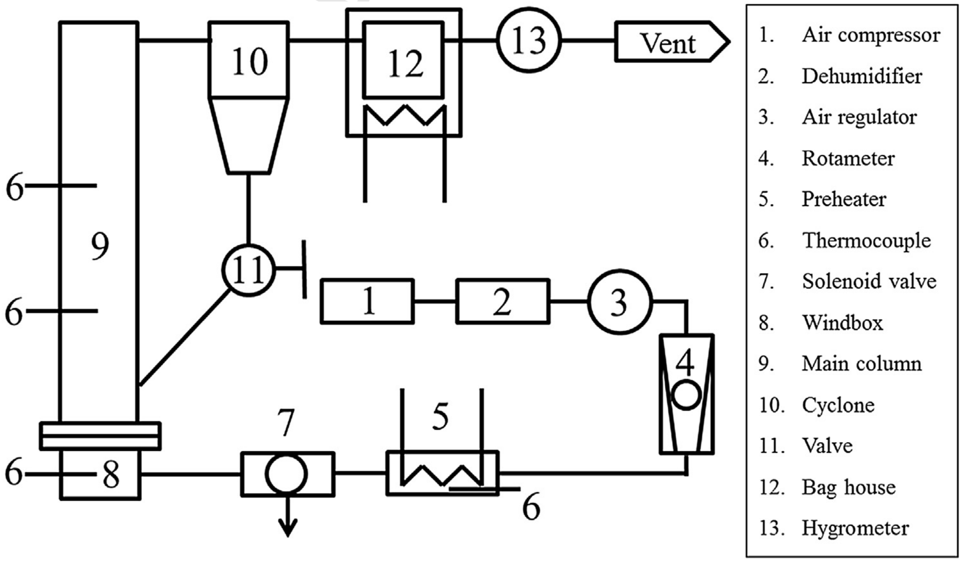

Fig. 1. Schematic diagram of experimental apparatus for inert circulating fluidized bed drying; 0.087 m-ID, 1.0 m height.

Please cite this article in press as: D.H. Kang, et al., Drying characteristics of fine powders in an inert medium circulating fluidized bed with binary inert media, J. Ind. Eng. Chem. (2016), http://dx.doi.org/10.1016/j.jiec.2016.09.034

Download English Version:

https://daneshyari.com/en/article/6669237

Download Persian Version:

https://daneshyari.com/article/6669237

Daneshyari.com