Korean J. of Chem. Eng., 2(2) (1985) *197 – 200*

ELUTRIATION OF FINES FROM A BINARY PARTICLE FLUIDIZED-BED

***Cheong-Song Choi, Ki-Pung Yoo and Hee-Dong Jang**

Department of Chemical Engineering, Sogang University, C.P.O. Box 1142, Seoul, Korea

(*Received 15 July 1985 • accepted 5 August 1985*)

Abstract— It is experimentally found that the region of the batch fluidized-bed is subdivided into a region of perfect mixing and that of segregation when the fine particles are elutriated from the bed. The resulting correlations obtained in the present study which take into account the effect of physical and hydrodynamic characteristics of the bed can be valuable one for the extension to the multi-particle, continuous real fluidization processes.

INTRODUCTION

In recent years, a growing number of gas-solid fluidized-bed has been utilized as an alternative for the heterogeneous noncatalytic and/or catalytic reactors. For an efficient design of such contactors, a knowledge of pneumatic behavior of the fine particles in the freeboard and the subsquent elutriation details from the fluidized-bed is required. Unfortunately, existing elutriation rate data from the various sources of experiments are often inconsistent each other even in the cases of almost identical variable conditions because of the difficulties in representing those of highly complex phenomena of the fluidization systems [1-3]. Direct application of such data to practical design is hindered by the fact that there usually exist a lot of uncertainties between the real systems and the laboratory experimental conditions as well as the analyses of each different experiment.

In these early investigations, little attention has been placed on the effect of shapes and mixing patterns of solid particles[4] that related to the particle concentration near the bed surface. These effects can be crucial one in an actual design of fluidization system.

Presently a series of investigations on the elutriation of the fines from the bed are under progress by the authors as a part of the project, "Fluidized-Bed Technology for the Utilization of Low Grade Coal (I)-Elutriation of Fines from a Fluidized-Bed." In the present work, the effect of shapes and mixing degrees of particles in the bed is concerned as a first approach to the problem.

PREPARATION OF PARTICLES BY CRYSTALLIZATION

For preparing the sample particles, the technique of crystallization is employed. With this method, nickel ammonium sulfate with specific gravity 1.923, are obtained with different sizes and sphericities. The prepared sample are similar in densities with those of ashes from the combustion of the low grade anthracite.

When the crystal growth exceeds up to a certain critical size from the solution in a magma circulating crystallizer with agitator, the crystals appear to become prone to attrition. In this case a mosaic type of growth occurs and the crystals, which are thermodynamically unstable by the Gibbs-Thompson effect, tend to dissolve at the edges and ultimately achieve a rounded shape[5]. The sizes of the crystals and their sphericities of the prepared particles are in the range from 0.68 to 0.95.

EXPERIMENTAL APPARATUS AND PROCEDURES

The experimental equipment used in the present study is shown in Fig. 1. The bed is made of the transparent Plexi-glas with 7cm-IDx150cm-high which consist of 5 to 8 rings that can be removed section by section at a time. The height (150cm) of the fluidized-bed is sufficient for transport disengaging height. The gas distributor is made of the sintered glass filter with medium pore size. The aspect ratio of the bed is fixed below 1.5 in order to minimize the internal circulation of the solid particles in the bed.

In operating the batch fluidized-bed unit, consistent fluidization state is maintained by the following subsequent steps; produces reproduceable fluidization state by opening one of the solenoid valve from the valves arranged in parallel, then switches to the other line which connected to the planned operating conditions. The elutriated fines is separated through the cyclone, sampl-

* To whom correspondence should be addressed.

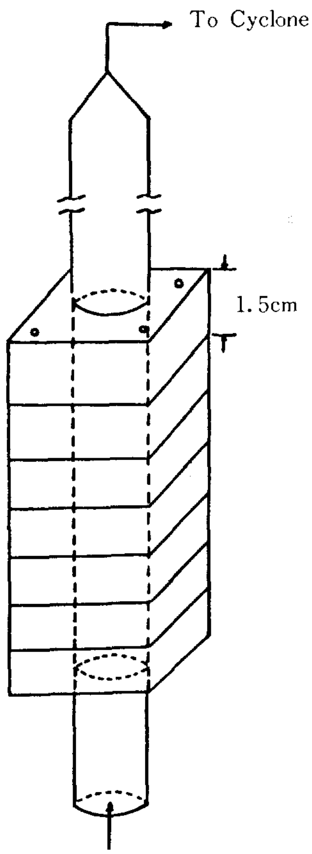

Fig. 1. Schematic diagram of fluidization apparatus.

ed in minute intervals, and weighed by a chemical balance.

Each experiment is carried out with the bed consisting of binary solid mixtures. For the fine particles, the crystals of average size of 0.163 mm with original crystal habit, which means the sphericity of 0.72, is used. While the coarse particles are selected up to 1.546 mm with sphericities in the range of 0.68 to 0.95. The concentration of fines is varied from 5 to 20 percent.

In the negligible range of overall weight reduction of the particles, the elutriation rate constant, E, is estimated by eq. 1.

$$-\frac{W}{A}\frac{dX}{dt}=E\cdot X \qquad (1)$$

Additional experiments on the particle mixing patterns are also carried out with the identical equipment shown in Fig. 1. After making the fines be elutriated for a given time under the same operational conditions described previously in the elutriation experiment, the air flow is shut off rapidly, then the solid particles in each section are sieved to determine the composition of the mixture at a given level of the bed.

RESULTS AND DISCUSSION

Experimental elutriation rate constant, E, is estimated with respect to the ratio of the modified particle Reynolds number (Re_p), defined as $d_p\phi(u_o-u_{mf})\rho/\mu$, over the fines to large particle distributions. The result is shown in Fig. 2. The Re_p ratio is splitted up to two regions in the vicinity of the value of 4. When it comes to examine the dividing aspect from Fig. 2., it is obvious that the modified Re_p ratio is the appropriate criteria for the elutriation test compared with the other dimensionless groups.

Region "A" which shows constant values of elutriation rate constant, E, with respect to Re_p ratio represents almost perfect mixing of the solid particles in the bed. While the region "B" which shows a variation of the value of E, represents the state of the occurrence of the segregation of the fines from the bed. This new result is obviously significant one for the analysis of the elutriation in the beds.

The elutriation rate constant is varied sensitively with respect to the fluidizing gas velocity. The more increase the gas velocity the more increase the transportability of the fine particles from the fluidizing interface to the freeboard. The values of the rate constant also increase with respect to the concentration of the fine particles since in turn it brings about an increase of bubble

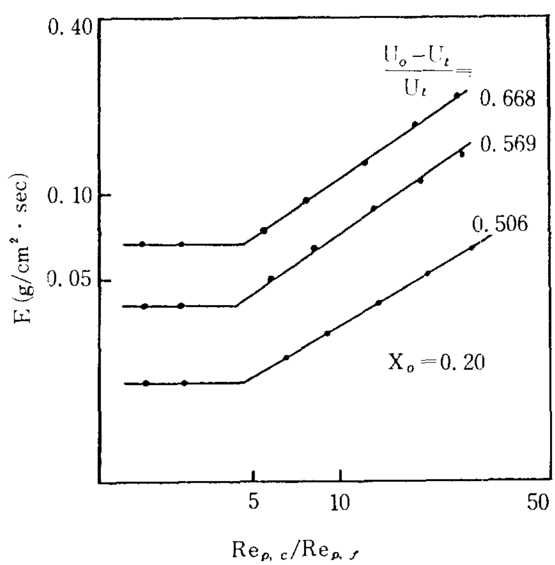

Fig. 2. Effect of Re_p ratio on the elutriation rates.

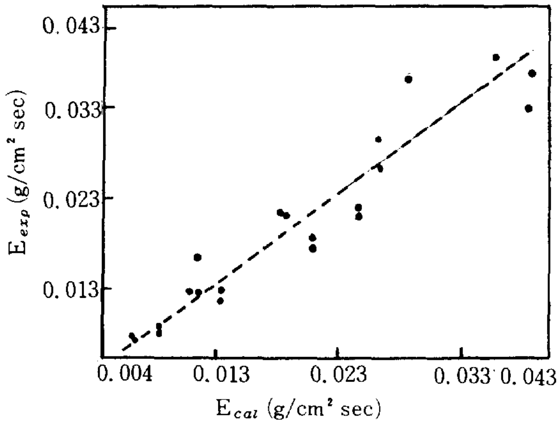

Fig. 3. Comparison of elutriation rate constant with the calculated values(Re_p ratio<4).

flow rate. The increase in fine particle concentration by the segregation of fines to the bed surface causes a blockage of interstitial gas flow channel, allowing high pressure build-ups and, hence, the ejecting of fines to the freeboard increases due to the intense erupting bubbles.

As discussed above the interpreted experimental data on the elutriation of the fine particle from the batch binary particle bed is utilized to correlate the elutriation rate constant as the functions of bed operational variables. The resulting correlations are shown in eq. 2-3 and Fig. 3-4, respectively.

$$E=0.36\left(\frac{u_o-u_t}{u_t}\right)^{3.83}(x_o)^{1.09},\quad Re_p \text{ ratio}<4,\quad (r=0.96) \qquad (2)$$

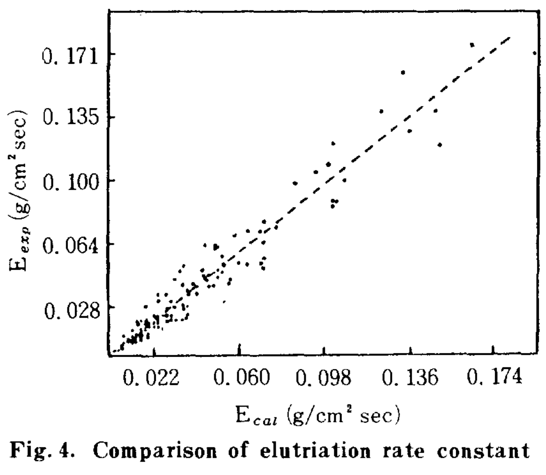

Fig. 4. Comparison of elutriation rate constant with the calculated values(Re_p ratio>4).

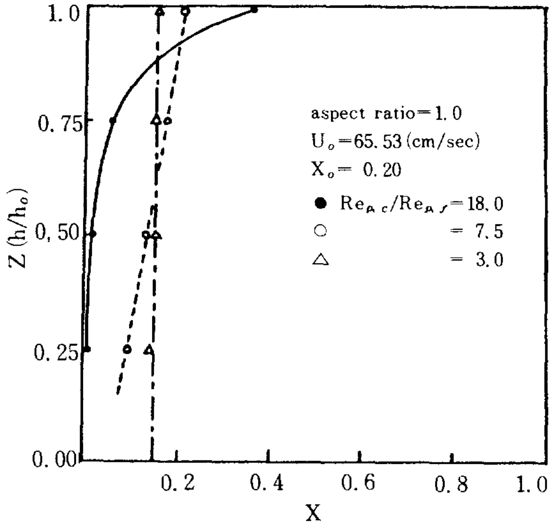

Fig. 5. Effect of Re_p ratio on the concentration profile of fines.

$$E=0.71\left(\frac{u_o-u_t}{u_t}\right)^{4.40}(X_o)^{0.95}\left(\frac{Re_{p,c}}{Re_{p,f}}\right)^{0.69},\quad Re_p \text{ ratio}>4,\quad (r=0.93) \qquad (3)$$

One of the important result can be drawn from the Fig. 2. The interpretation of the elutriation of fines from the binary solid mixtures should be taken into account the effect of hydrodynamic characteristics relative to the physical properties of the particles.

The supplementary test on the effect of axial particle mixing in the bed is carried out in order to verify the earlier interpretation on the elutriation. Axial concentration difference with respect to the variation of Re_p ratio at the fixed fluidizing gas velocity is shown in Fig. 5. Almost all of the perfect mixing state can be achieved on the region of Re_p ratio below 4. However, in the case of Re_p ratio above 4, the segregation is further developed with the increase of the ratio. This result is a sound verification of the early consideration that the analyses of elutriation rate constant should include the effect of axial particle mixing with respect to the hydrodynamic effect of the operational variables.

ACKNOWLEDGEMENT

This article is a part of the project on "Fluidization Technology for Utilization of Low Grade Coal (I)" funded by the Korea Research Foundation. The authors acknowledge with thanks to the foundation.

NOMENCLATURE

A : Cross sectional area of the fluidized-bed, cm^2
d_p : Particle diameter, cm
E : Elutriation rate constant, g/cm^2 sec
r : Correlation coefficient
Re_p : Modified particle Reynolds number, $d_p \phi (u_o - u_{mf}) \rho / \mu$
t : Time, min
u_{mf} : Minimum fluidizing velocity, cm/sec
u_o : Superficial gas velocity, cm/sec
w : Bed weight, g
x : Weight fraction of fines in the bed

Greek Letters

μ : Viscosity, g/cm.sec
ϕ : Sphericity of particles

Superscripts

f : Fine particle
c : Coarse particle

REFERENCES

1. Tanaka, I., Shinohara, H. and Tanaka, Y: *J. of Chem. Eng. of Japan,* **5,** 51 (1972).
2. Lin, L., Sears, J.T. and Wen, C.Y.: *Powder Tech.,* **27,** 105 (1980).
3. Wen, C.Y., Chen, L.H.: *AIChE J.,* **28,** 117 (1982).
4. Tanimoto, H., Chiba, T. and Kobayashi, H.: *J. of Chem. Eng. of Japan.,* **16,** 149 (1983).
5. Mullin, J.W.: "Crystallization", 2nd ed., Butterworth & Co., Ltd. (1972).