입자운동론에 의거한 기체/응집성 고체입자들의 유동층 반경 변화에 따른 유동현상에 관한 연구

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Study of Gas/Cohesive Particles Flow Behavior using Kinetic Theory Approach in Two CFBs with Different Riser Radius

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Introduction

Recently, the dynamics of inter-particle collisions in gas/non-cohesive particles flow systems have been reconsidered and non-cohesive particles flow models were developed for the application to the particulate flow based on the concept of the Chapman and Cowling's kinectic theory[1] by several researchers [2-4]. However, these models do not have the capability of describing flow behavior for cohesive particles systems, since the most significant characteristic of the gas/cohesive particle flow is the formation of clusters or agglomerates which considerably affects the flow patterns. To overcome this problem, Seu-Kim[5] developed a new set of governing equations for gas/cohesive particles flow model based on the criteria of agglomeration and kinetic theory: The result of numerical simulation by Seu-Kim and Arastoopour[6] showed the cohesive model was capable of describing gas/particles flow behavior as well as the particle's diameter variation due to agglomeration. Parallel to the theoretical study, the experimental studies of cohesive and semi-cohesive particles flow were performed and showed significantly differnet flow patterns compared to non-cohesive particles flow due to the agglomeration and/or cluster formation [7,8]. However, most of the experimental study was performed using a smaller size CFB unit compared to the commercial CFB unit, and we expect that the results from the experimental studies may not be appropriate when used for scaling up purposes due to the complexity of flow patterns as a result of the significant agglomerations or cluster formations. In this study, to understand the dependency of the particle size distribution of cohesive particles on the ratio of the initial particle diameter to radius of the riser, a computer code was developed based on the cohesive model[5], numerical simulations of gas/oil-shale particles flow experiment by Knowlton and Findley[8] were performed using two different riser radius, and the results of two simulations were compared reasonably well.

Simulation Results and Disscussion

Fig.1 shows the effect of the riser radius on the axial variation of pressure and particle diameter. The increase in riser radius results in the increase in average particle size throughout the bed. We expect this increase is due an increase in frequency of particles collision in the larger bed. The presence of the stationary wall decreases the rate of the chaotic flow and interaction of particles around the wall boundary in which the effected zone is a much larger fraction of the cross sectional area of the bed in the small bed than the larger bed. Thus, the bigger fraction of the particles in the larger bed flow in the zones in which velocity and fluctuation velocity of the particles are not damped due to the wall. Furthermore, in the larger bed, the particle concentration increases more and plays a dominant role in the lower section of the riser, and the flow behavior is also more chaotic. Thus, we expect more variation of the flow parameters as a result of increase in particles interactions in locations around $5m$ and below in the riser section. Fig.1 confirms this expectation, it shows higher pressure drop and increase of particle diameter at $5m$ and below for the larger bed. However at the entrance region to the bed ($0.3m$), the predicted particle diameter in both beds are very close to each other, and even slightly lower values are predicted for the larger bed. This may due to the higher radial velocity toward the wall in this location which makes the collision with the wall as significant as inter-particle collisions in spite of the larger radius of the bed. It also may be due to the high initial axial velocity which carries more particles to the upper zones in the larger bed since the wall is farther and its effect is less than the small bed. From $6.0m$ to $13m$, predicted particle diameter of the small bed is also smaller although the effect of inter-particle collision probably decreases in both beds throughout this zone. This is probably due to the more kinetic energy dissipation caused by the collision with the wall. Since the kinetic energy dissipation due to the collision with the wall is inversely proportional to the particle diameter imposing the breakage of the particles due

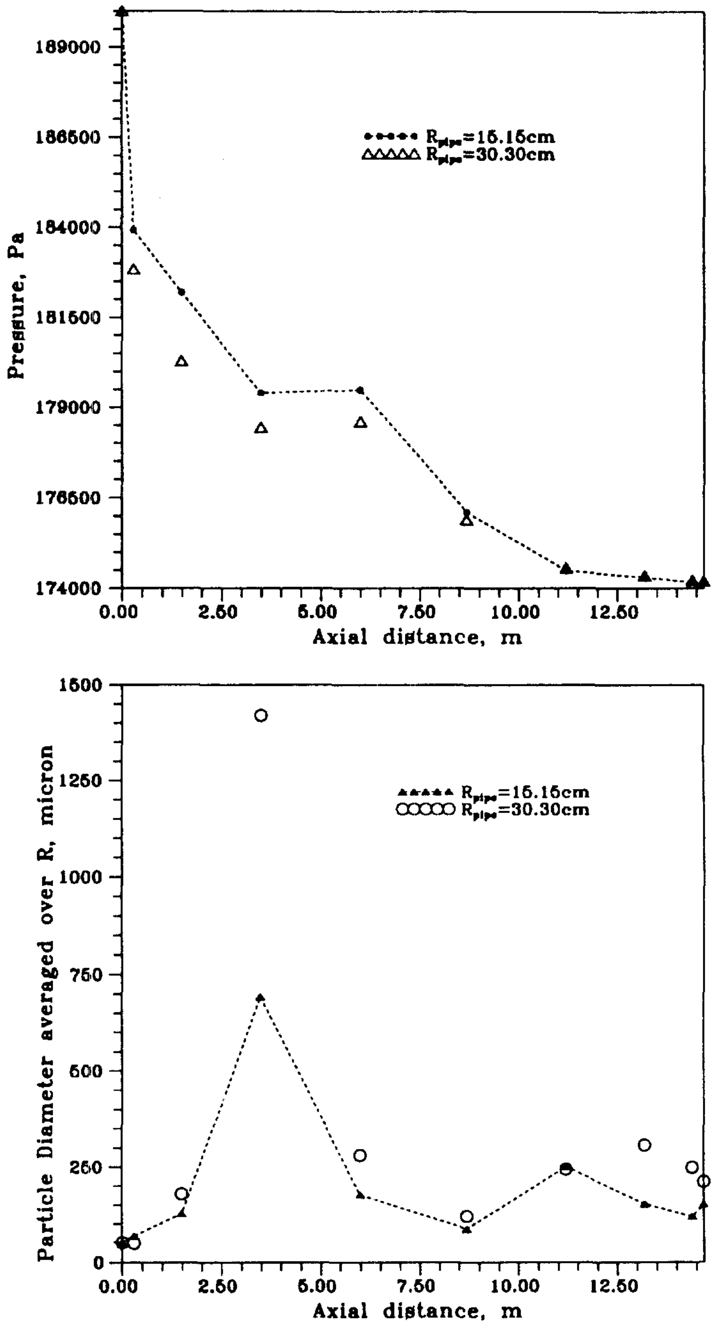

Figure 1. Effect of Riser Radius
on Pressure and Averaged Particle Diameter

to the collision with the wall. From $13m$ to outlet, the predicted pressure variation is almost the same in both beds and the pressure itself slightly decreases showing a pneumatic transport situation in both cases. In this zone due to the very low solid inventory and insignificant radial velocity of particles in the pneumatic transport regime, collision with the wall no longer has a significant effect. However the flow in the bed with the larger riser radius shows the development of the inter-particle collisions again due to the predicted slightly higher radial velocity towards center axis and lower axial velocity. Thus the predicted particle diameter becomes higher than that in the small bed.

References

1. Chapman,S. and Cowling,T.G.: "The Mathematical Theory of Non-Uniform Gases", 3rd ed., Cambridge Univ. Press(1970).

2. Ding,J. and Gidaspow,D.: "A Bubbling Fluidization Model Using Kinetic Theory", *AIChE J.*, **36**, No.4, 523(1990).

3. Johnson,P.C. and Jackson,R.: "Frictional-Collisional Constitutive Relations for Granular Materials with Application to Plane Shearing, Sheared in an Annular Shear Cell", *J. Fluid Mech.*, **176**, 67(1987).

4. Sinclair,J.L. and Jackson,R.: "Gas-Particle Flow in a Vertical Pipe with Particle-particle Interactions", *AIChE J.*, **35**, 1473(1989).

5. Seu-Kim,H.: "Analysis of Cohesive and Non-cohesive Particles Flow in the Fluidized Beds using Kinetic Theory", PhD thesis, Illinois Institute of Technology(1994).

6. Seu-Kim,H. and Arastoopour,H.: "Simulation of FCC Particles Flow Behavior in a CFB using Modified Kinetic Theory", *Can. J. Ch.E.*, in press(1995).

7. Arastoopour,H. and Yang,Y.: "Experimental Studies on Dilute Gas and Cohesive Particles Flow Behavior using Laser Doppler Anemometer", *Fludization VII*, ed. by P.E.Porta and R.J.Dry, Engineering Foundation. 723-730(1992).

8. Knowlton,T.M. and Findley,J.: "Determination of Flow-Regime Boundaries for Cohesive Particles", DOE Final Report under Contract No. DE-AC22-88PC88951(1992).