The Scale-up of Large Pressurized Fluidized Beds for Advanced Coal-Fired Power Processes

Semi-Annual Progress Report

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DISCLAMIER

SCOPE

Pressurized fluidization is a promising new technology for the clean and efficient combustion of coal. Its principle is to operate a coal combustor at high inlet gas velocity to increase the flow of reactants, at an elevated pressure to raise the overall efficiency of the process. Unfortunately, commercialization of large pressurized fluidized beds is inhibited by uncertainties in scaling up units from the current pilot plant levels.

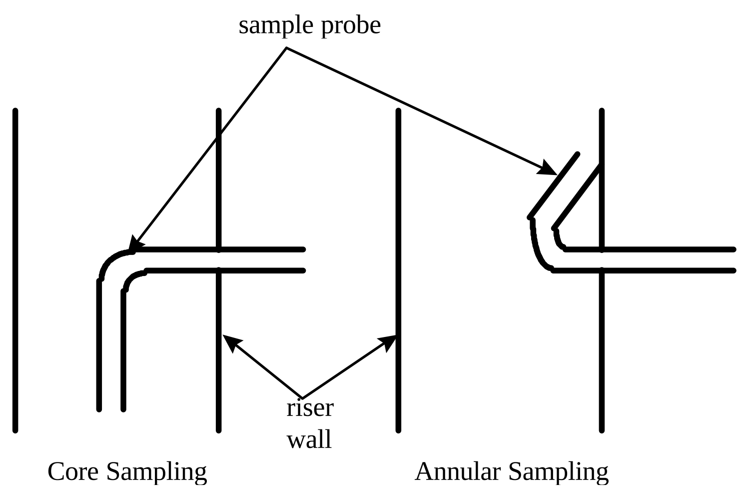
In this context, our objective is to conduct a study of the fluid dynamics and solid capture of a large pressurized coal-fired unit. The idea is to employ dimensional similitude to simulate in a cold laboratory model the flow in a Pressurized Circulating Fluid Bed “Pyrolyzer,” which is part of a High Performance Power System (HIPPS) developed by Foster Wheeler Development Corporation (FWDC) under the DOE’s Combustion 2000 program.

PROGRESS

MIT

Over the past six months our progress towards a better understanding of the hydrodynamics of binary mixtures in circulating fluidized beds has continued. Previous experiments have investigated solids mixing and segregation in the core region of the pyrolyzer using an isokinetic core sampling technique. This was done with the aid of sampling probes inserted at various locations along the riser height: 16%, 37.2%, 56.4%, 72.3% as well as at the exhaust of the primary cyclone in the return leg section. Particle size distributions (PSD) studies were performed with samples collected at these ports.

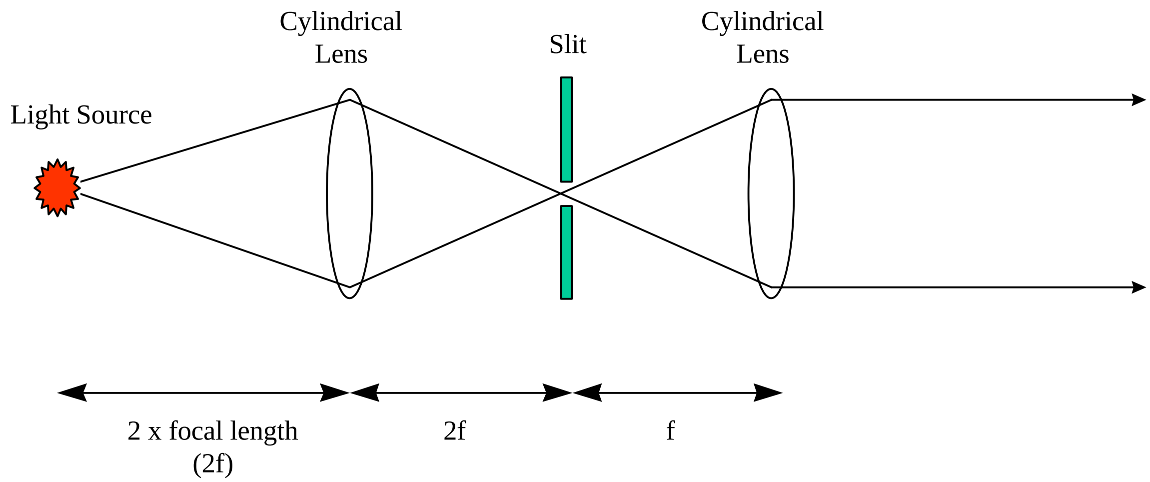
We have extended our investigation to cover the annular downward flow of particles. In an annular-core flow model of circulating fluidized beds, particles are blown upwards at the core of the riser and flow downwards at the wall region. In order to capture these hydrodynamics, four more sampling probes have been installed. Three additional solenoid valves have been purchased and are in operation in the higher elevations of the riser. The following figure illustrates the difference between annular and core sampling. Note that in annular sampling it is of crucial importance that the probe be touching the riser walls at all times.



Core and Annular Sampling

Experiments are currently under way. The experimental results will be compared to a numerical prediction based on previously determined Lateral Dispersion Coefficients developed by one of the authors for the dilute region (Hyre and Glicksman, 1998). The model will be modified to account for binary species behavior.

In addition to this quantitative analysis, a more qualitative approach to the hydrodynamics is in progress. An optical carrier and cylindrical lens have been purchased from Melles Griot, Inc. for visualization of the flow structure in the dilute region of the bed. A high intensity light source has been used to generate a sheet of light; this has yet to be tested on the riser. The following schematic illustrates our apparatus:



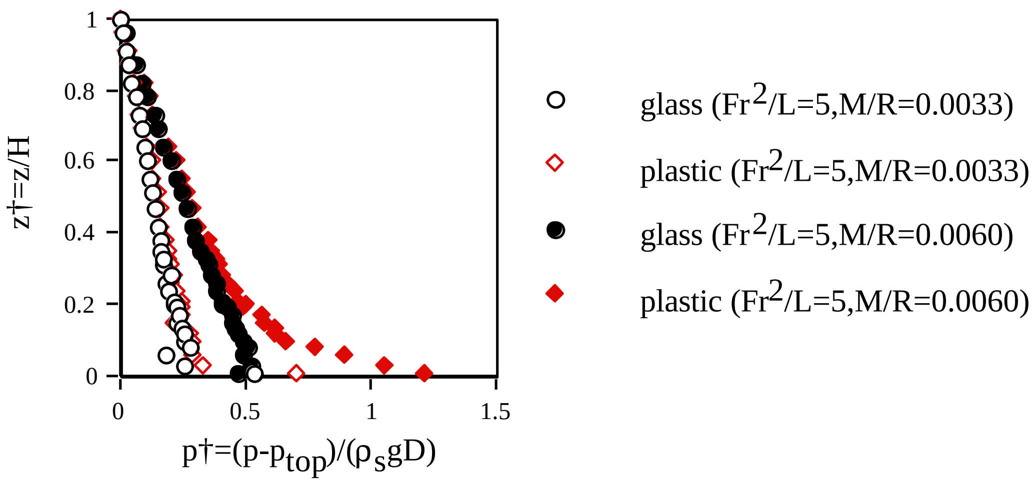
Optical Setup for Flow Visualization

The sheet of light will penetrate the riser at various heights and illuminate the flowing particles. Images will be recorded via a high speed digital camera. Horio and Kuroki (1994) have previously performed a series of experiments on three dimensional flow visualization of fluidized beds. They used a 10mW He-Ne laser in conjunction with a glass rod lens to produce the desired sheet of light. This may be necessary if our white light is of inadequate intensity.

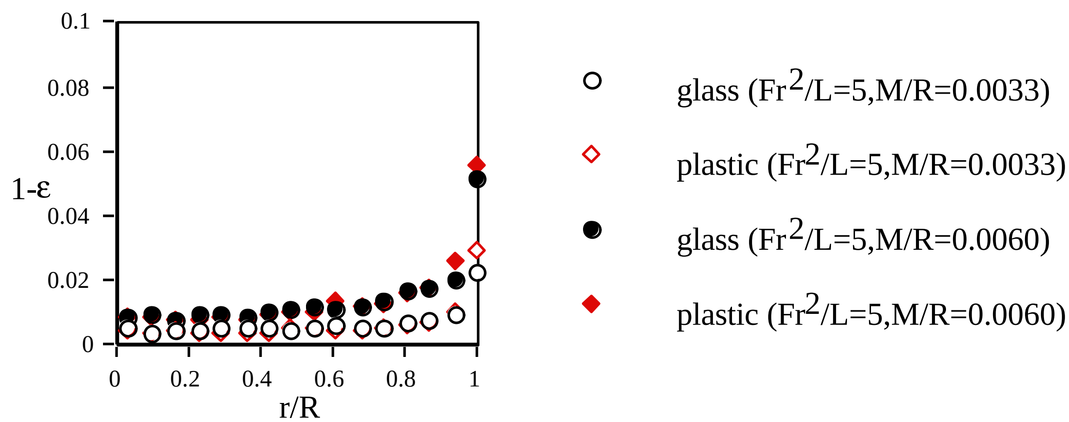
CORNELL

In the past six months, we have completed the verification of Glicksman's reduced scaling laws for the hydrodynamics in the riser of a circulating fluidized bed. We have also completed a study of the performance of cyclone collectors.

Our study of pressure profiles and radial solid volume fraction profiles (measured at mid-riser height) over a range of operating conditions has shown that the reduced scaling laws preserve global and local similarities in the fully developed part of the flow which, for values of the solids loading M/R < 0.006, extends from the bottom to the top of the riser. As the Figs. indicate, the pressure and radial profiles are typically self-similar. They depend strongly on M/R but weakly on the modified Froude number Fr2/L. For values $\geq$ 0.006, the pressure profiles in plastic show a denser region at the bottom of the bed than the corresponding profiles in glass.



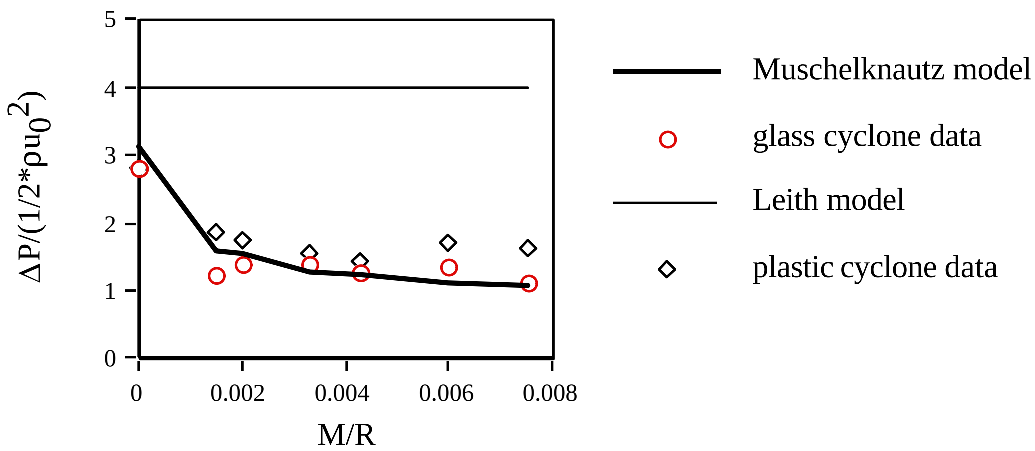
Axial pressure profiles



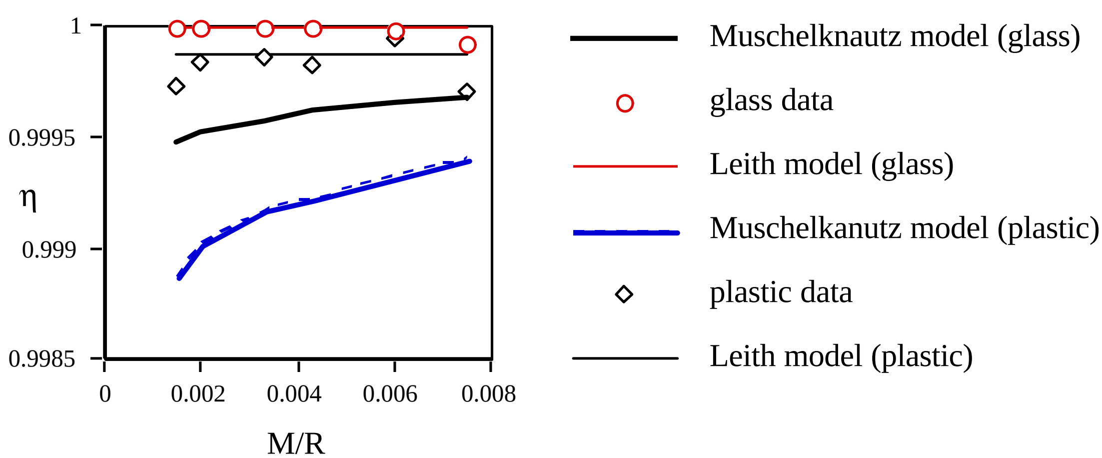
Radial profiles of solid volume fractions.

After a complete study of the facility, including the pressure loop around the CFB and a one-dimensional model of the riser hydrodynamics, we found that the difference observed between the glass and plastic at the bottom of the bed is most likely due to the interaction between the downcomer and riser. This type of interaction was not observed in the atmospheric simulations of Chang and Louge (1992), possibly because they used a different mechanical valve that constricted the return flow of solids more than our pressurized simulations.

In addition, we showed that the pressure drop through the cyclone, when made dimensionless by the gas kinetic energy, is similar between the glass and plastic sets of experiments. The experimental values were well predicted by the solids loading-dependent model of Muschelknautz, but largely overpredicted by the classical (non solids loading-dependent) model of Leith, including at zero loading. However, the model of Muschelknautz did not agree with the prediction of the overall cyclone efficiency, whereas the model of Leith & Licht predicted those values successfully. For this reason, we employed the simpler model of Leith & Licht to compare experimental data and predictions for cyclone grade efficiencies. Those were reasonably predicted except for the smallest size class where the efficiency was overpredicted by several orders of magnitude. We attribute this effect to the entrainment of smaller particles by larger ones. Finally, because the glass particles exhibit higher Archimedes or Stokes numbers, the overall efficiencies observed in glass were higher than in plastic.



Pressure loss through the cyclone.



Cyclone efficiency