DOE/PC/93216--T11

"Fluid Dynamics of Pressurized, Entrained Coal Gasifiers"

Technical Progress Report

Tenth Quarter (April 1, 1996 - June 30, 1996)

by

Michel Yves LOUGE
Cornell University
Sibley School of Mechanical & Aerospace Engineering
Upson Hall
Ithaca, NY 14853

Work Performed under Grant No. DE-FG22-93PC93216

For the

U.S. Department of Energy
Pittsburgh Energy Technology Center
PO Box 10940
Pittsburgh, PA 15236

US/DOE patent clearance is not required prior to the publication of this document.

1. Scope

Pressurized, entrained gasification is a promising new technology for the clean and efficient combustion of coal. Its principle is to operate a coal gasifier at a high inlet gas velocity to increase the inflow of reactants, and at an elevated pressure to raise the overall efficiency of the process. Unfortunately, because of the extraordinary difficulties involved in performing measurements in hot, pressurized, high-velocity pilot plants, its fluid dynamics are largely unknown. Thus the designer cannot predict with certainty crucial phenomena like erosion, heat transfer and solid capture.

In this context, we are conducting a study of the fluid dynamics of Pressurized Entrained Coal Gasifiers (PECGs). The idea is to simulate the flows in generic industrial PECGs using dimensional similitude. To this end, we employ a unique entrained gas-solid flow facility with the flexibility to recycle –rather than discard– gases other than air. By

HH

DISCLAIMER

matching five dimensionless parameters, suspensions in mixtures of helium, carbon dioxide and sulfur hexafluoride simulate the effects of pressure and scale-up on the fluid dynamics of PECGs. Because it operates under cold, atmospheric conditions, the laboratory facility is ideal for detailed measurements.

These activities are conducted with Air Products & Chemicals, Inc., which is a member of a consortium that includes Foster Wheeler and Deutsche Babcock Energie- und Umwelttechnik AG.

2. Progress

In the eleventh quarter of this project, we completed a series of experiments with glass beads fluidized with pure sulfur hexafluoride to simulate pressurized entrained gasifiers of relatively large diameter. First, these data are compared with earlier experiments, where plastic grit fluidized in an CO_2/SF_6 mixture simulates a pressurized unit of smaller size (Fig. 1).

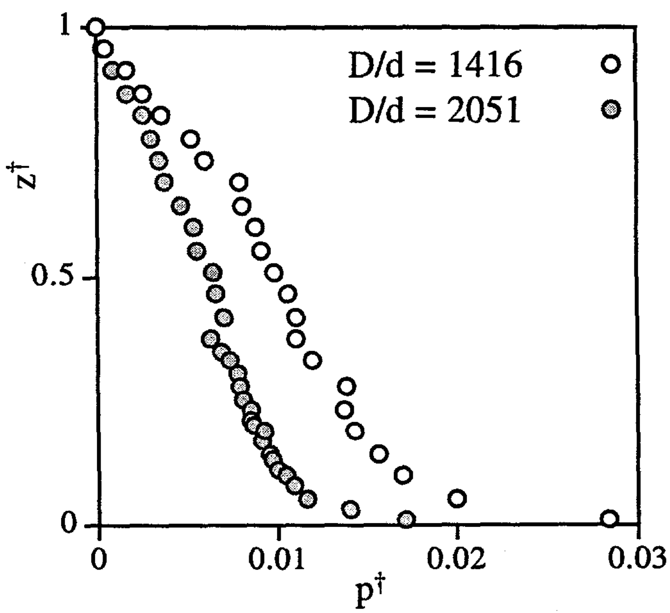

Fig. 1. Relative pressure profile $(p - p_{top})/\rho_s gH$ versus relative elevation z/H for dimensionless conditions Fr ≈ 170, m ≈ 1.6 and mixture parameters R = 410, Ar = 550. The solid and open circles represent data with glass beads (relative riser diameter $D/\phi d = 2051$) and plastic grit ($D/\phi d = 2051$).

Upon preliminary inspection of the dimensionless data, we conclude that, unlike atmospheric suspensions, pressurized risers of smaller size have greater pressure losses, suggesting a greater role of wall stresses.

In another comparison with earlier data, we confirmed with risers of relatively large scale that the dimensionless pressure profile is independent of gas density in the upper region of the riser (Fig. 2), and thus that the flow lies in the viscous limit in the fully-developed region of the bed.

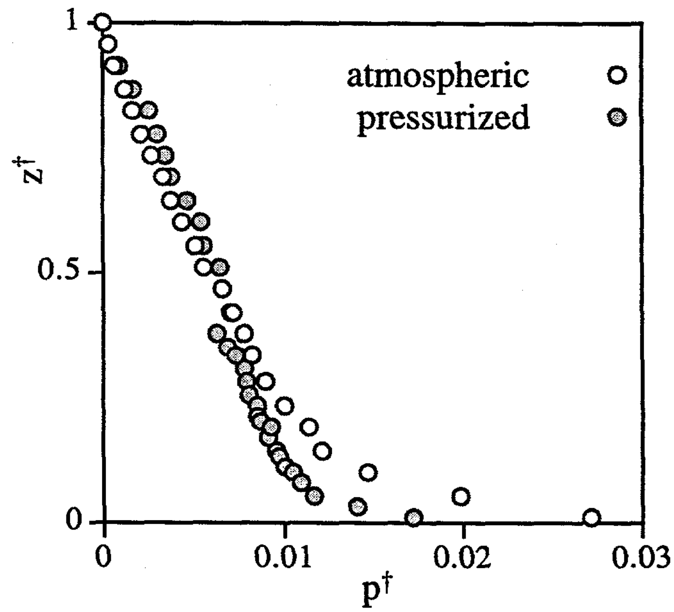

Fig. 2. Effect of density on the vertical profile of average dimensionless pressure. The experiments have identical value of Fr = 170, m/R = 0.004 but different gas densities; the closed and open circles represent R = 4820 and 410, and Ar = 47 and 560, respectively.

Despite these promising results, and because of the importance of our conclusions for designers of pressurized risers, we decided to repeat all experiments under simulated pressurized conditions. For this objective, we have requested a no-cost extension of this project.

Finally, in an attempt to substantiate turbulent closures frequently invoked in modeling riser flows (Sundaresan and Jackson), we have measured temporal correlations between the dimensionless pressure gradient $\alpha \equiv \dfrac{\partial p^{\dagger}}{\partial z^{\dagger}} = \dfrac{1}{\rho_p g}\dfrac{\partial p}{\partial z}$ measured with a fast differential pressure gauge and the solid volume fraction $\phi \equiv (1-\varepsilon)$ recorded at the wall using a capacitance probe. Typical data is shown in Fig. 3.

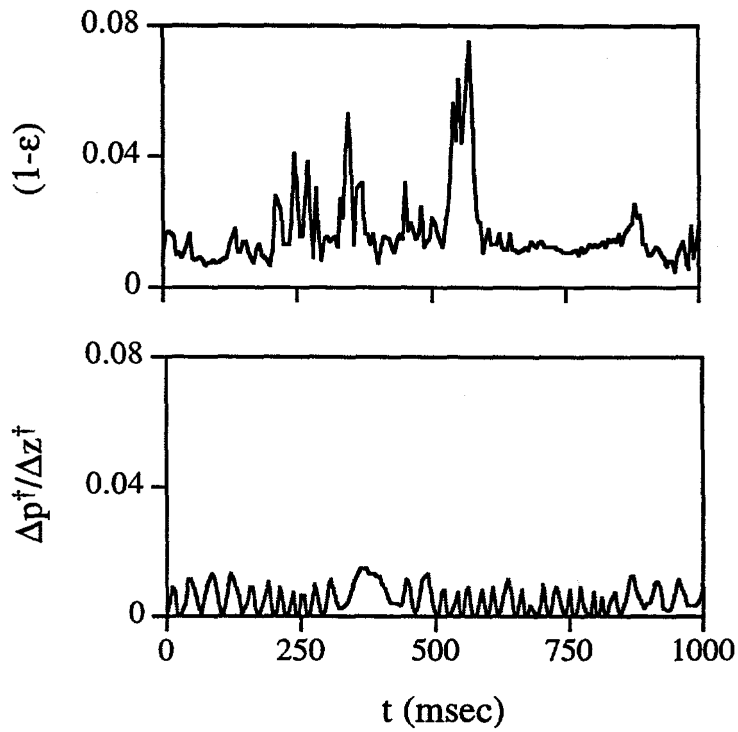

Fig. 3. Simultaneous measurements of solid volume fraction at the riser wall and dimensionless pressure gradient for the conditions $Fr = 170$, $m = 0.68$, $Ar \approx 560$, $R \approx 410$ and $D/\phi d \approx 2050$. The data was sampled at 180Hz and the gradient was recorded over a vertical distance $\Delta z = 23$cm.

There, we find relatively little correlation between the fluctuations of pressure gradient and the corresponding fluctuations of solid volume fraction at the wall. For the conditions of Fig. 3, we obtain

$$\overline{\alpha'\phi'} \sim 0.02\ \overline{\alpha}\ \overline{\phi} \sim 0.01\ \overline{\phi}^{2} \sim 0.02\ \overline{\phi'\phi'}\ .$$

A chief reason for the relative lack of correlation is that gas pressure is propagated throughout the column at the speed of sound, while solid volume fraction is an inherently local variable. Our expectation is that our data will inform models of riser flows based on closures resembling those of turbulent flows.