DOE/PC/94208--T9

EIGHTH TECHNICAL PROGRESS REPORT

ON

HYDRODYNAMIC MODELS FOR SLURRY BUBBLE COLUMN REACTORS

April - June 1996

JULY 1996

U.S. DEPARTMENT OF ENERGY GRANT
DE-FG22-94PC94208

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ABSTRACT

HYDRODYNAMIC MODELS FOR SLURRY BUBBLE COLUMN REACTORS

The objective of this investigation is to convert our " learning gas - solid - liquid " fluidization model into a predictive design model . The IIT hydrodynamic model computes the phase velocities and the volume fractions of gas , liquid and particulate phases . Model verification involves a comparison of these computed velocities and volume fractions to experimental values .

As promised in the SIXTH TECHNICAL PROGRESS REPORT , January 1996 , this report presents our measurements of granular temperature of Air Products catalyst in our new two dimensional bubble column with controlled jets that roughly approximates the Air Products methanol reactor .

We have observed much higher granular temperatures with gas flow than was the case for liquid flow with Air Products catalyst . This means there is much better stirring caused by the high gas flow ; clearly a desirable feature in a reactor . We have also observed that there exists a maximum in granular temperature at low solids loading . Operationally this means it may not be desirable to operate at very high catalyst concentrations due to reduced stirring at the high catalyst concentrations . This behavior is very similar to that observed by us in a circulating fluidized bed used to make gasoline from coal , a study to appear in the AIChE Journal .

During this quarter 3 papers were presented , partially or fully supported by this project . They are :

1- University of Coal Research Conference Paper , June 4 , 1996 .

2- ASME FLUIDS ENGINEERING Division , Summer meeting , 1996

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" Numerical Stability Analysis for Reactive Multiphase Flow in Slurry Bubble Column Reactors and Solid Propellant Reactors " by R. Pape , D. Gidaspow and S.Y. Wu , pages 257-264 .

3- IBID - page 111

-Summary of INVITED REVIEW PAPER

" Dense Two Phase Modeling Using Kinetic Theory " by D. Gidaspow , L. Huillin and B. Sun .

The next report will present our measurements of radial distribution function determined using our CCD camera . We use this radial distribution function at particle contact to determine the catalyst viscosity . Hence it is important in this study .

Measurement of Granular Temperature in a Multi - Jet Three Phase Bed with Air Products Catalyst

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For better understanding of the Air Products methanol reactor and for a comparison of the simulation results with experimental data , a three phase lab-size fluidized bed has been used to measure the particle granular temperature . See Fig A .

In this study the influence of the solid concentration on the granular temperature has been studied .

The bed consists of seven identical air jets , $7/8 \times 7/8 \times 3$ inches individually equipped with valves used to control the gas flow rate . The liquid is water and the solids are the Air Products 50 μm catalyst particles .

For each run the solid - liquid ratio has been changed . Due to the small particle size a uniform dispersion is assumed to exist in the experiment . With this assumption the average bed expansion has been calculated and in this manner the solid volume fractions were obtained .

In all of the experiments the superficial gas velocity was kept constant and all of the measurements were conducted at the same location of the bed so that the only variable is the solid concentration . See Fig A for bed size and measurement location . The granular temperatures have been calculated from instantaneous particle velocity measurements . These instantaneous particle velocities have been measured using a series of processes utilizing different tools . A CCD camera and built-in hardware were used to capture the trace of particles moving inside the bed . At this stage the illumination techniques and also the camera speed (from 0 to 1/10000 sec) play a significant role to get a sharp image .The captured particle traces were digitized with the aid of an advanced image processing software (IPPLUS®) . Necessary operations such as background correction were performed .The final image was used to measure the length and horizontal angle of the streak lines in order to obtain vertical and horizontal velocities . The histograms were drawn and the variance of the velocities have been calculated . See Fig B for a sample of the histogram . Considering the bed depth , one can assume that the non flow directions have the same granular temperature and so the total granular temperatures can be calculated using the following formula (x and z are the non flow directions and y is upward direction) :

$$\theta=\frac{1}{3}\theta_y+\frac{2}{3}\theta_x$$

This is essentially the same method used in Dr. Mitra Bahary 's Ph.D. thesis , Second Technical Progress Report , January 1995 .

Results and Discussion

Fig C shows the results of these experiments . As can be seen the granular temperature passes through a maximum value around ε_s=0.01 . This result is consistent with the results for the gas - solid system (D. Gidaspow and L.Huillin AIChE Journal , in press) .

For good heat and mass transfer a high granular temperature is desirable . Hence it maybe worth-while to investigate this maximum with a better defined system : glass beads rather than the non-uniform size , small black , hence difficult to see catalyst particles .

A surprising result in Fig C is that the granular temperature is much higher than that measured for the Air Products catalyst in liquid system . These data are given in the 6^{th} Technical Progress Report , January 1996 . There the highest granular temperature was only one $(cm/sec)^2$, one hundred times lower .

Hence the high gas flow produces the desirable stirring .

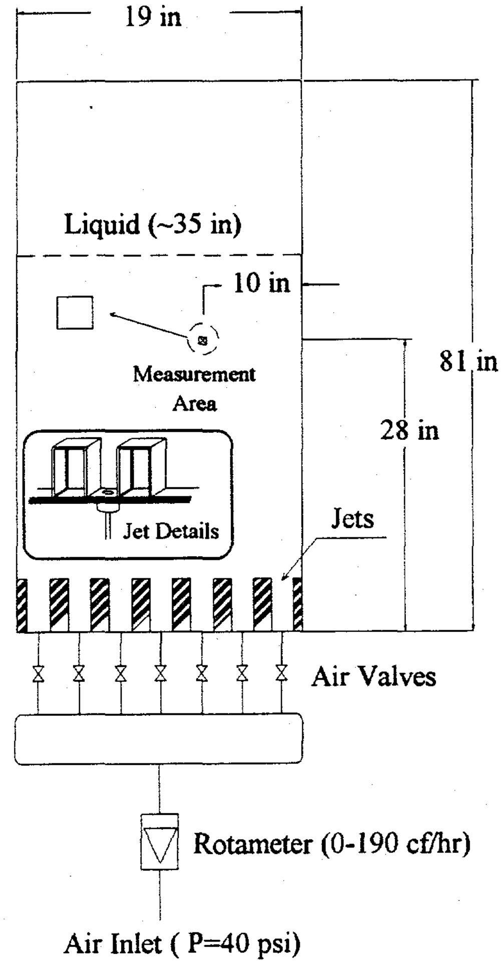

Fig A - The Measurement area location
with respect to the liquid height and bed dimensions

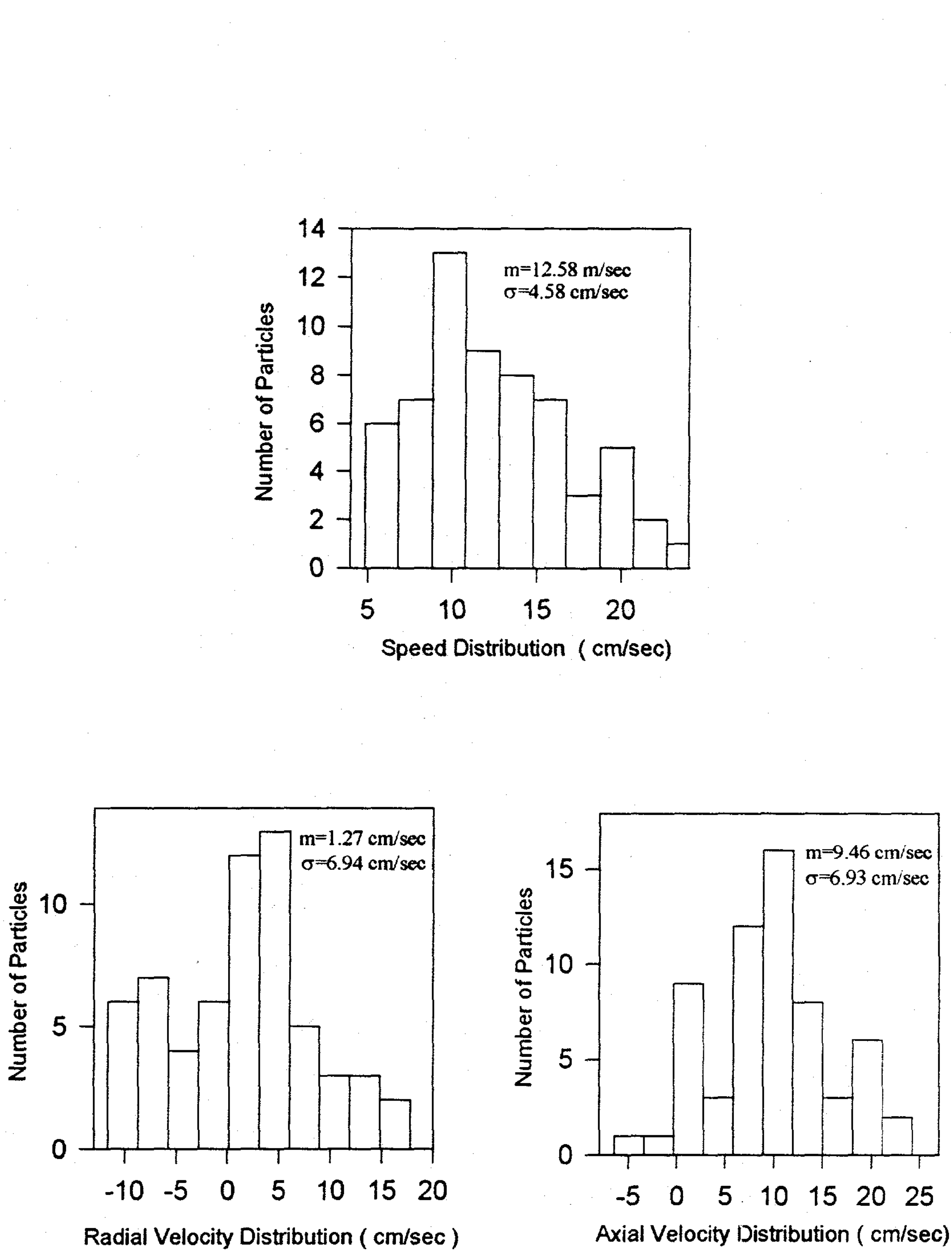

Fig B - Particles speed , radial and axial velocity distribution at $\varepsilon_S = 0.07$

(m = mean , σ = standard deviation)

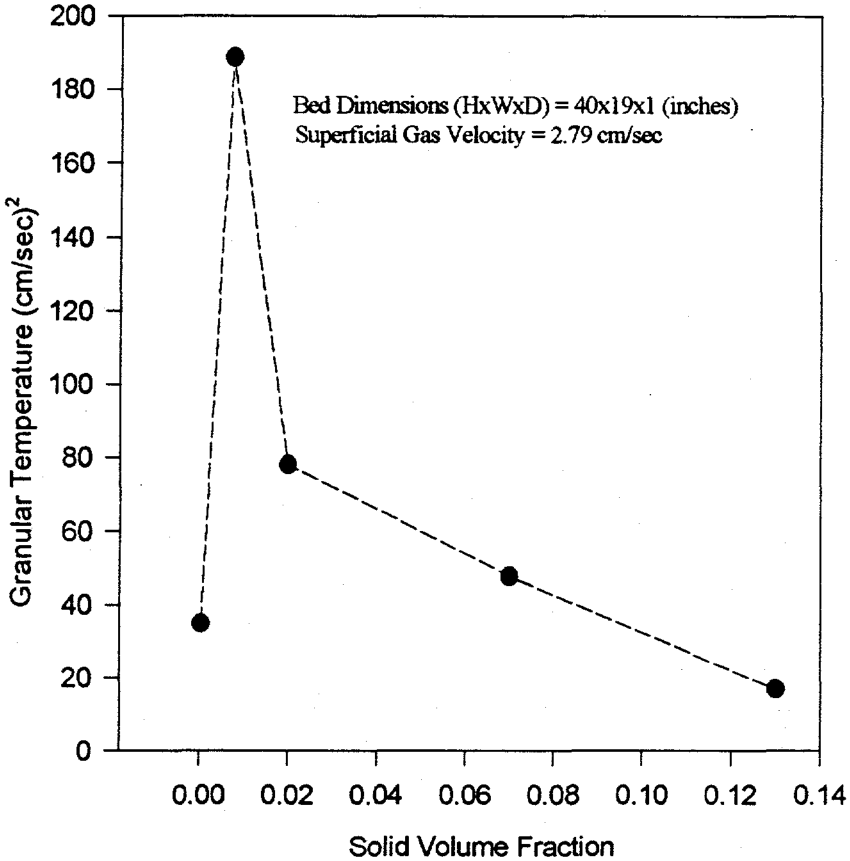

Fig C - Variation of Solid Granular Temperature with Solid Concentration