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NOVEL TECHNIQUES FOR SLURRY BUBBLE COLUMN HYDRODYNAMICS

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Novel Techniquees for Slurry Bubble Column Hydrodynamics

First Annual Report for
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July 1, 1995 - June 30, 1996

ABSTRACT

The objective of this cooperativee research effort between Washington University, Ohio State University and Exxon Research a and Engineering Company is to improve the basis for scale-up and operation of slurry bubble columnn reactors for syngas conversion and other coal conversion processes by increased reliance c on experimentally verified hydrodynamic models. The first year of this three year program was spennt on developing and tuning the experimental tools that can provide accurate measurement of pertinenent hydrodynamic quantities, such as velocity field and holdup distribution, for validation of hydrodynamic models. Advances made in preparing the unique Computer Automated Radioactivive Particle Tracking (CARPT) technique for use in high pressure systems are described in this repport. The work done on developing a reliable heat transfer coefficient measurement probe a at operating conditions of interest is also described. Finally, the work done in preparing the Exxcon pilot plant facilities for high pressure runs and pertinent hydrodynamic measurements is o outlined together with preliminary studies of matching the fluid dynamics program predictions anand data in a two dimensional column.

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DE FG 22-95 PC 95212

JOINT UNIVERSITY/INDUSTRY PROJECT

July 1, 1995 - June 30, 1998

First Annual Report

July 1, 1995 - June 30, 1996

TABLE OF CONTENTS

NOVEL TECHNIQUES FFOR SLURRY BUBBLE COLUMN HYDRODYNAMICS

FFIRST ANNUAL REPORT FOR DE FG 22 - 95 PC 95212

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EXECUTIVE SUMMARY

The objective of this cooperativve research effort between Washington University, Ohio State University and Exxon Research h and Engineering Company is to improve the basis for scale-up and operation of slurry bubble columnn reactors for syngas conversion and other coal conversion processes by increased reliance e on experimentally verified hydrodynamic models. The emphasis during this first year of this threee year project was placed on developing the experimental techniques that are capable of pproviding accurate measurements of hydrodynamic quantities such a velocities and holdup distributiion at operating conditions of interest. Research progress has been made in the following areas:

At Washington University (WUJ) the unique Computer Aided Radioactive Particle Tracking (CARPT) technique was modifiied and improved. The technique is capable of providing solids (or liquid) velocities at high gas or s solids holdup where all other methods fail. Wavelet filtering of particle position versus time datata was implemented, and this improved by an order of magnitude the accuracy of the turbulence pparameters that the technique can provide. A Monte Carlo based simulation was implemented forr calculation of detector responses for any position of the tracer particle. Three dimensional mapps for the inversion problem will be completed during the next phase of the project. This will a allow accurate calibration and use of CARPT in high pressure systems. Data obtained with CARPT were compared to other techniques.

At Ohio State University (OSU)) the limitations of the most powerful Particle Image Velocimetry (PIV) technique were explored a and it was found that the technique has the potential of providing the full velocity and holdup fieldd up to a 4" diameter column at high gas superficial velocity and holdup. Experiments are currenntly underway to compare PIV results in such a column to the previously obtained CARPT datata. A new and useful heat transfer coefficient probe was developed at OSU and its capabilities are ddescribed in this report.

At Exxon Research and Engineeering preparations were made for making the high pressure 6" diameter bubble column availablble for CARPT and other measurements. Necessary modifications to the column are being made. J Jointly with WU needed tracer particle strength was determined and a device for calibration was desisigned. In addition, CFDLIB codes for hydrodynamic modeling have been installed and a prelimminary case study of a two dimensional column was conducted. It is shown that experimental time avveraged velocity profiles can be matched by the model with proper selection of closure parameters.

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DE-FG22-95-PC 95212

I. REVIEW OF OBJECCTIVES

The overall objective of this cooperative university (Washington University and Ohio State University) - Industry (Exxon RResearch and Engineering) research is to improve the basis for scale-up and operation of slurry y bubble column reactors (SBCRs) by an increased reliance on phenomenologically or fundamentally based hydrodynamic models which are experimentally verified. This research complements the work in progress related to the LaPorte Advanced Fuels Demonstration Unit (AFDU) opperated by Air Products with Department of Energy funding. The research under the present grant it focuses at providing experimental tools for measurement of important fluid dynamic quantities at high pressure, high temperature operation.

Specifically the following goals s have been set for this three year project.

Task 1. Develop computerized mathematical procedure (based on physics of radiation and Monte Carlo calculations) for calibration of the Computer Automated Radioactive Particle Tracking Technique (CARPT) that will eliminate the currently lengthy in-situ calibration and allow the technique to be used in the field on high pressure units. Specifically, plan the use of CARPT on a high pressure bubble column at Exxon Florham Park pilot plant facility.

Task 2. Improve the accuracy of the CARPT technique and compare the velocities obtained by CARRPT in certain region of the column to those determined by the Heat Transfer Probe and Particle Image Velocimetry (PIV).

Task 3. Develop local probes for assessing velocities, holdups and heat transfer coefficients in commercial bubble column reactors.

Task 4. Collect velocity a and voidage profile data in gas-liquid and gas-liquid-solid systems at different solids loadings and at close to atmospheric pressure.

Task 5. Use state-of-the-art hydrodynamic models and codes to predict velocity and holdup fields under conditions studied experimentally. Search for most suitable constitutive forms (e.g., lift, drag, turbulence closure models, etc.) to reach agreement between calculated and experimentally observed values. Try to assess the effect of elevated operating pressure on various constitutive forms.

Task 6. Collect the data in a high pressure 6" diameter bubble column at Exxon Research and Engineering and compare to model predictions. Also collect high pressure PIV data in slurry systems at Ohio State University. Refine models if needed.

II. SUMMARY OF RESSEARCH ACCOMPLISHMENTS

Here we briefly summarize the a activities conducted as part of this project at Washington University, Ohio State Universitity and Exxon Research and Engineering. In the subsequent sections a more detailed report is is provided from each of the above three organizations, which are involved in this cooperative resesearch effort, only for the work that has been completed. Work in progress will be reported on in d detail upon completion.

The activities at Washington Uniniversity were on improving the accuracy of the CARPT technique (Task 2) and developing a mathenematical Monte Carlo method for CARPT calibration (Task 1). In Section III of this report we shoow that CARPT accuracy for obtaining turbulence data has been remarkably improved via wavelelet filtering of the particle position - time data. Now CARPT provides not only accurate ensemmble averaged quantities but also fluctuating quantities. Preliminary comparison of CARRPT data with other techniques is also shown. Data has been collected in air-water system (Tatask 3) in different columns and 4" diameter column data has been selected for comparison with PIIV. These PIV experiments are now in progress at OSU.

The activities at Ohio State Univiversity included making PIV operable in 3 dimensional columns and testing the upper limits on columnmn diameter for which the technique is still reliable. A set of gas superficial velocities studied by y CARPT in a 4" column are now being investigated by PIV at OSU. Section IV of this report it is focused on the successful development of a heat transfer probe to be used in the pilot plant and c commercial reactor.

The activities at Exxon Researchh and Engineering involved the preparations for high pressure measurements in a pilot plant 6" ," diameter column and computational fluid dynamics.

The 6" diameter, high pressure, :, slurry bubble column is being prepared at Exxon for the experimental program to obtain a detailed hydrodynamic measurement. The unit is equipped with basic measurements, such as diflfferential pressure along the column, sampling ports and optical windows. Additional measuremments, such as, void fraction, liquid velocity, and tracer testing are planned along with the CARPT i' measurement to cross check all measurement techniques under representative pilot plant reactor ir conditions.

A heat-pulsed-anemometer manmufactured by Professor Lubbert of Hannover University and purchased by Exxon was sent too the Ohio State University to test against PIV technique under low gas holdup (< 15%) conditions f for velocity and local mixing of the liquid phase. Three gas holdup measurement probes and one heeat transfer probe which will be suitable for our 6" unit use are under construction by the Ohio S State University. These probes will be tested against PIV measurements with or without tthe presence of solid. An Extrel MS250 mass spectrometry was purchased and will be used for b both gas and liquid tracer experiment.

The mechanical drawing of the h high pressure 6" diameter slurry bubble column was sent by Exxon to Washington University for reveview to prepare it for the CARPT experiment. The nozzles and flange on the unit could potentialally affect the accuracy of the CARPT data. It will be evaluated by Washington University if any mmodifications are necessary.

Jointly with Washington Universrsity a device for calibrating the Exxon column for CARPT was designed, and source strength foor the CARPT particle was estimated and radioactive safety procedures established (see Sectiction V).

In the area of computational fluiuid dynamic modeling work was pursued jointly between Exxon and Washington University. The Los Alamos CFDLIB code was installed on the Exxon SGI server. A case study from two dimensisional column (described in Section V) was computed.