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T U F F P

Tulsa University Fluid Flow Projects

July 2004 **Volume 18, Issue 2**

Editorial by Cem Sarica

Dr. Lawless, President of The University of Tulsa, decided to retire effective July 1, 2004 after many years of exemplary service. Dr. Stedman Upham has recently been announced as the new President. A press release on Dr. Upham is reprinted in this newsletter.

Two new Research Associates, Dr. Hong Chen and Dr. Xianghui (Paul) Chen, have been hired as a result of our increased research activities. Dr. Hong Chen will be concentrating his efforts toward the Tulsa University Paraffin Deposition Projects (TUPDP) while Dr. Paul Chen will be involved in both TUFFP and TUCoRE activities.

Our efforts are continuing in the improvement of software deliverables to our members. The objective of this effort is to improve and increase the use of the developed multiphase technology by our membership. Microsoft's Excel platform has been selected as the interface, regardless of the scientific programming language such as FORTRAN, C++, etc. A beta-version of the pressure gradient and holdup prediction software has recently been delivered to our membership.

TUPDP started its second three-year phase on April 1, 2004. This phase of the project focuses on model and software development, supported by experimental studies. Experimental studies will include high pressure oil-water hydrodynamic studies using Garden Banks Condensate and Tulsa City Water. The results of this study will be made available to TUFFP membership as part of collaboration between TUFFP and TUPDP.

Progress on each TUFFP research project is given later in this Newsletter. A brief summary of the activities is given below.

Modifications to the 6-in. flow loop have been completed and data acquisition has been begun for the low-liquid loading project. Modeling studies are underway for the low liquid loading gas-liquid flow in near-horizontal pipes. A two-fluid model based on the double-circle assumption has been developed to predict the pressure gradient, liquid holdup, wetted perimeters, and liquid film thickness at the bottom in low liquid loading stratified flow for given operation conditions, liquid properties and pipeline orientation.

An assessment study on three-phase flow technology identified the gaps and weaknesses in current models. Gas-oil-water experimental studies are currently underway. A new non-intrusive optical probe is being designed and constructed. This device will be used first in the gas-oil-water flow project. TUFFP has purchased a High Speed Video Camera to be used in various projects to observe and make measurements of multiphase flow behavior. This device will be used first in the gas-oil-water flow project.

Oils with viscosities as high as 10,000 cp are produced from many fields around the world. Current multiphase flow models are largely

based on experimental data with low viscosity fluids. Thus, the gap between actual lab data and field data may be three orders of magnitude or more. Currently, a newly designed facility is being set-up in the Model Lab for the experimental part of this study. The facility will consist of a 64.0-ft long pipe with a 27.0-ft visualization section. Testing is expected to begin after the Fall 2004 Advisory Board meeting.

Three-phase gas-oil-water severe slugging facility modifications have been completed and data acquisition has begun. Preliminary results will be presented at the Fall 2004 Advisory Board meeting.

In multiphase flows, there are many cases where droplets are entrained from or coalesced into a continuous homo-phase. For example in annular mist flow, the liquid droplets are in dynamic equilibrium with the film on the walls, experiencing both entrainment and coalescence. Similarly, in oil-water flows, the observed mixing and/or separation involve both entrainment and coalescence. Very few mechanistic models exist for entrainment rate and coalescence rate. Understanding the basic physics of these phenomena is essential to model situations of practical interest to the industry, such as separator designs or chemical injection ports for corrosion control. A new TUFFP project has recently been initiated to investigate droplet-homophase interaction.

New TU President Announced

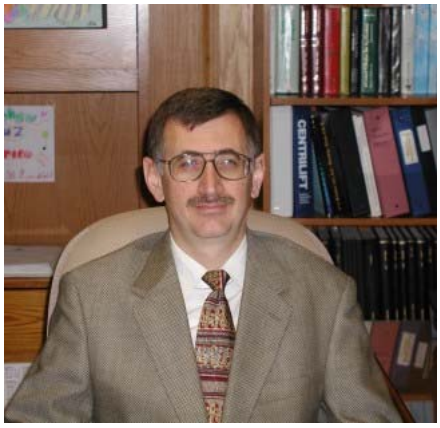
The University just announced an appointment of a new president who would be joining the University in October 2004. Steadman Upham, currently president of Claremont Graduate University in Claremont, California will be TU's seventeenth President.

Prior to his presidency at Claremont, Upham served as vice provost for research and dean of the Graduate School at the University of Oregon from 1990 to 1998 where his responsibilities included the academic and administrative functions for the university's 21 research centers and institutes. He also was a professor in the anthropology department.

Upham, 55, earned a Ph.D. in anthropology from Arizona State University in 1980, where he also earned a M.A. in the same field. He has a B.A. from the University of Redlands, Redlands, Calif. where his major areas of study were English literature and Spanish.

Before his presidency at Claremont and his positions at the University of Oregon, he held numerous positions at New Mexico State University, including Associate Dean of the Graduate School, professor of archaeology, assistant professor of archaeology and chief archaeologist of the Cultural Resources Management Division.

His professional service and accomplishments are extensive and include commissioner of the Western Association of Schools and Colleges, chairman of the Board of Directors of the Council of Graduate Schools; president, National Physical Science Consortium; director of The American Mutual Funds, The Capital Group Companies; Trustee for the Educational Foundation for African Americans, and trustee for the University of Redlands, Claremont Graduate University and the Thomas Rivera Policy Institute. For more on Dr. Upham, please check www.utulsa.edu.



Cem Sarica Promoted to Full Professorship

Effective Fall 2004 semester, Cem Sarica has been promoted to Professor of Petroleum Engineering.

Cem graduated with BS (1982) and MS (1984) degrees from Istanbul Technical University (ITU) in Turkey. Cem received a Ph.D. degree in petroleum engineering from The University of Tulsa (TU) in 1990. After his graduation, he worked for ITU as an Assistant Professor of Petroleum Engineering. In October 1992, he returned to TU as a Post Doctoral Research Associate in the Tulsa University Fluid Flow Projects (TUFFP). After serving 4 years as a Research Associate, he became Associate Director of TUFFP. He served in that position for two years. Later, he joined the faculty of Petroleum and Natural Gas Engineering at The Pennsylvania State University. Cem served as Associate Professor of Petroleum and Natural Gas Engineering at the Energy and Geo-Environmental Engineering

Department until June 2001. He, once again, returned to TU in June of 2001 as an Associate Professor of Petroleum Engineering. Cem currently serves as the director of two consortia, TUFFP and TUPDP and Principal Investigator of the High Viscosity Multiphase Flow TUCoRE project.

Cem was one of the recipients of the 1999 ASME Jacobson Best Paper Award. He is a member of the Society of Petroleum Engineers (SPE) and the American Society of Mechanical Engineers (ASME). He served as one of the Associate Editors of Journal of Energy Resources Technology (JERT) ASME between 1997 and 2004. He is a member of SPE Facilities and Construction Standing Committee. He is currently serving as the chair of SPE Facilities and Construction Award Committee. He is a member of *SPE Journal* Editorial Board. He was one of the recipients of SPE's Outstanding Editor Award in 2000. He is a member of ITU Petroleum and Natural Gas Industry Advisory Board. In addition to his SPE and ASME activities, he currently serves as a Technical Advisory Committee Member of BHRg's Multiphase Technology Conferences.

Scott Graham

New Electronics Technician Hired

After Tony Butler's retirement, Mr. Scott Graham was hired as the new electronics technician to serve primarily TUFPP and TUPDP consortia. Scott has an Associates Degree in Electronics and Instrumentation and study towards a BS degree in Instrumentation and Automation from Oklahoma State University.

Scott was the Electrical/Electronics Team Lead for the Engineering Technologies Division at OSU-Okmulgee before joining TU. Scott began his career working as a roustabout for Conoco NGP in Carlsbad, New Mexico. Later as an instrument technician Scott designed and installed automation systems for gas processing plants. He also performed new electrical construction and assisted in putting together electrical/instrumentation classes for Conoco's associate engineer program in New Mexico and West Texas.

In 1992 after working for Conoco and gaining experience elsewhere, Scott's career lead him to operate his own company based in Broken Arrow. Through Panel-Tek Inc., Scott designed, manufactured, and marketed chemical injection equipment, electronics controls for the oil and gas industry. The products produced included such items temperature and pressure measurement devices, flow computers, and data acquisition equipment. In 1997 Emerson Electric purchased Panel-Tek.

Scott enjoys working with students to help them to develop and master their technical skills that will provide the same opportunities he has been able to enjoy in life.

Project Coordinator Hired

Wendy Fusselman

Wendy Fusselman holds a Masters Degree in College Teaching/Student-Personnel Services from Northeastern State University in Oklahoma. Her previous experiences include working as a trading analyst for Williams Energy Marketing and Trading, where she was responsible for accounting, associated with traders daily market positions. She has also held various collegiate positions, including being staffed by the Texas State University, Dean of Students Office, as well as adjunct staff for Tulsa Technology Center and Northeastern State University.

Wendy's primary responsibility includes the financials related to all research accounts and coordination among various projects.

New Post-Doctoral Research Associates

Drs. Hong Chen and Xianghui (Paul) Chen are recent additions to our team. Dr. Hong Chen is currently devoting all of his time to the Tulsa University Paraffin Deposition Projects (TUPDP) while Dr. Paul Chen is involved in both the Fluid Flow Projects and the TUCoRE activities.

Hong Chen

Dr. Hong Chen received his Ph. D degree in Mechanical Engineering from the University of Saskatchewan in Canada in 2000. The subject of his Ph. D study was numerical modeling and simulation of frost growth on heat exchanger surfaces which is close to the wax deposition problem. Before he joined TUPDP project, he had been a post doctoral research associate in Mechanical Engineering Department in the University of Saskatchewan for about 3 years. In Canada, he was working on experimental and numerical investigations on heat and mass transfer

through potash fertilizer products sponsored by the world largest potash fertilizer company, the Potash Corporation of Saskatchewan. In TUPDP, he will be responsible for the development of wax deposition model and the improvement of TUWAX.

Dr. Xianghui (Paul) Chen holds B.S. (1997) and M.S. (2000) degrees in Thermal Energy Engineering from Chongqing University and a Ph.D. (2004) degree in Mechanical Engineering from The University of Tulsa. His dissertation is dedicated to the investigations of sand erosion in elbows and plugged tees in single-phase and multiphase flow systems using the Computational Fluid Dynamics (CFD) approach.

Paul joined TUFFP and TUCoRE in June 2004 and serves as a Research Associate. He participates in multiple multiphase flow research projects undergoing in TUFFP and TUCoRE.

Xianghui (Paul) Chen

Two New Research Assistants Expected

Maria Vielma Paredes

Ms. Maria (Nina) Vielma Paredes and Mr. Antonio Bruno, both from Venezuela, will join our team in the Fall 2004 to pursue their MS degrees in Petroleum Engineering. Nina received her BS degree in Chemical Engineering from University of Los Andes (U.L.A.) in Venezuela in 2003. Nina has arrived on campus and has been assigned to the gas-oil-water flow projects in TUFFP.

Antonio received his BS degree in Petroleum Engineering from The University of Tulsa in 2001 and graduated Magna Cum Laude. Antonio received the Thomas C. Frick Award for Outstanding Academic Achievement in Petroleum Engineering in April 2001 and was consistently on the Dean's and President's Honor Rolls. Upon arrival, Antonio will be assigned to the oil-water studies in the Paraffin Deposition Projects.

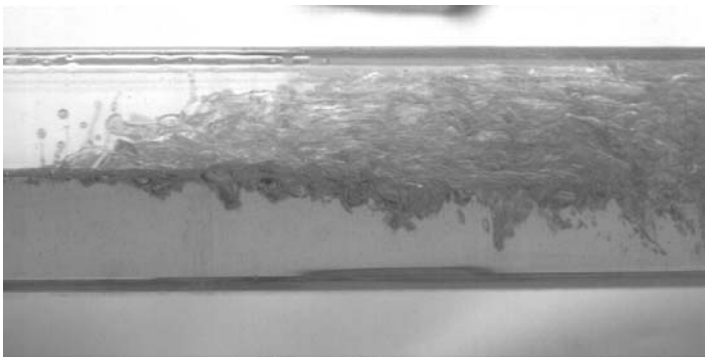
New Computer Manager Hired

Ted Chapman

Edward (Ted) Chapman has been hired as the new computer manager. Ted's degrees include a BS and a MS in Mathematics and he is currently working on another degree in Computer Science. He is helping students, staff, and faculty in their computing needs and to ensure that our computers are properly maintained.

TUFFP Buys a High Speed Video Camera

TUFFP is purchasing a high-speed digital video camera from Motion Engineering, Inc. The camera is a color digital APX camera with a maximum shutter speed of 100,000 frames per second and a maximum resolution of 1280 x 740. The camera will initially be used for three-phase flow patterns identification as well as flow dynamics in general. Below is a picture of a slug front with a gas-oil system from the APX camera realized on the severe slugging facility. This tool will give the Fluid Flow projects the opportunity obtain new insights on flow dynamics.



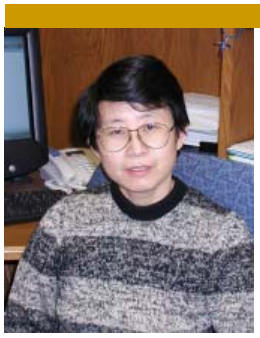
Scott Graham Develops New Optical Multiphase Flow Measurement Device

Our in-house efforts to develop optical probes have been critically reviewed and some design deficiencies that can result in unreliable data have been identified. Therefore, we have made a philosophical shift towards utilizing commercially available sensing products. Currently, two different approaches, intrusive and non-intrusive, are being investigated simultaneously.

The insertion type probe, similar to the previous probe, provides localized flow information. The current probe is now very reliable in sensing the difference between liquid and gas. The challenge with this probe has been the

coating of the probe tip with the oil henceforth preventing the detection the difference between the oil and water. The current probe is made of quartz. Quartz will soon be replaced with Teflon in hopes of addressing the problem.

We are developing a non-intrusive optical device consisting of arrays of optical probes covering the entire cross section of the pipe. A technical presentation describing the device will be made at the Fall 2004 Advisory Board meeting.



Qian Wang

Software Improvement

A major effort is underway to improve the software deliverables to our members. The objective of this effort is to improve and increase the use of the developed multiphase technology by our membership. Microsoft's Excel platform was selected as the interface, regardless of the scientific programming language such as FORTRAN, C++, etc. After completion of a pilot project involving TUFFP's Flow Pattern Prediction Software, user friendly interfaces were developed for the Unified Model Program and the TUFFP Core Program, which contains eleven pressure drop and liquid holdup prediction methods. This has recently been distributed to the members. Efforts are underway to enhance the software for the temperature predictions.

Web Site News

As all of you probably know, our hosting company for tufpc.org website was hit with a worm virus earlier this spring and was unable to provide a recent backup of our website. We have reverted back to our old websites—for fluid flow—www.tuffp.utulsa.edu—and for paraffin—www.tupdp.utulsa.edu. All past reports are currently available through the research section. Reports, data and software are currently being uploaded to the Deliverables section. We anticipate reports to be uploaded by the end of August.

The previous data and software are on a variety of media (floppies, jazz, zip, dat tapes, etc) requiring a major undertaking. The process of retrieving all useable archived data and software is underway and will be an ongoing project. As the data and software are recovered, they will be made available through the web or DVD when necessary.

TUFFP Membership and Support

TUFFP 2004 membership currently stands at 13, 12 industrial companies and MMS. DOE supports TUFFP in the development of new generation multiphase flow predictive tools for three-phase flow research. DOE's support translates into the equivalent 4 additional members for five years, effective July 2003.

Efforts are underway to increase TUFFP membership. Landmark Graphics have recently indicated their intention to join TUFFP for 2005.

TUFFP Financial Status

We entered 2004 with approximately $188,000 in our reserve funds. Our 2004 industrial membership income is $430,000 from 12 members. DOE and MMS incomes total $195,385. The total income is expected to be $625,385. The total expenditures are estimated to be $679,159. This will lower the total of our reserve balance by $53,774 to $134,226. More than half of our reserve funds are depleted due to our increased activities and reduction in our income due to further mergers in our industry within last four years. Moreover, no increase in membership fees has been implemented in the last four consecutive years. Therefore, the membership fees will be increased from $35,000 to $40,000 effective 2005.

2004 Fluid Flow Projects Membership

Baker Atlas

BP

ChevronTexaco

ConocoPhillips, Inc.

Marathon Oil Company

Minerals Management Service

PDVSA - Intevep

Pemex

Petronas

Saudi Aramco

Schlumberger

TOTAL

YUKOS

Meetings/Conferences

Fall 2004 Advisory Board Meetings

Plans have now been finalized for the Fall 2004 Advisory Board meetings. Previously, both TUFFP/TUPDP Advisory Board meetings were scheduled for September 22 and 23, 2004 in Tulsa, OK. Recently, the Flow Assurance Forum organized by Penn Well is scheduled for the same dates. A significant percentage of our combined membership requested that we change the dates of our Advisory Board meetings. Therefore, the Fall 2004 Advisory Board meetings have been rescheduled and will be held on September 30 and October 1 in Houston Texas.

The Advisory Board meetings will begin with the TUPDP meeting on September 30th at the ChevronTexaco Heritage Plaza. The address is 1111 Bagby and we will be in Room 4652. The meeting will begin at 9:00 a.m. and will adjourn at approximately 4:00 p.m. Following the TUPDP Advisory Board meeting, there will be a joint TUFFP/TUPDP reception from 5:00—8:00 p.m. at the DoubleTree Hotel—Allen Center. The Doubletree Hotel is directly across the street from the ChevronTexaco Heritage Plaza. The TUFFP Advisory Board meeting will be held also at the ChevronTexaco Heritage Plaza in Room 4652 on October 1st. The meeting will begin at 8:30 a.m. and will adjourn at approximately 5:00 p.m.

Request for Information form will be placed on the web page soon. All persons from your company that plan to attend the Advisory Board meetings, should complete and return this form as soon as possible to help us plan the meetings. Information on the Advisory Board meetings can also be found on our web site at http://www.tuffp.utulsa.edu/abminfo.htm. You can then follow the links for the Request for Information form. TUFFP Advisory Board meeting brochures will be available for members at the meeting and a concerted effort will again be made to have the combined brochure and slide copy available for downloading from the web site at www.tuffp.utulsa.edu/abmbrochures.htm shortly before the meeting. The brochure will contain sufficient information to help each attendee actively participate in discussions on current and future research projects, financial matters, and operating procedures.

BHRg's Multiphase Production Technology 05 to Be Held in Barcelona, Spain

BHR Group's Conference on Multiphase Production Technology '05 is scheduled to be held between 25-27 of May 2005 in Barcelona, Spain. Multiphase Production Technology '05 will benefit anyone engaged in the application, development and research of multiphase technology for the oil and gas industry. Applications in the oil and gas industry will also be of interest to engineers from other industries for whom multiphase technology offers a novel solution to their problems. The conference will also be of particular value to designers, facility and operations engineers, consultants and researchers from operating, contracting, consultancy and technology companies.

The conference is being structured into themes that will be introduced by one or more Review Papers that describe aspects of: "*Today's Technology*". These will be followed by the traditional accepted technical papers that feature new developments, new applications and hitherto unpublished work: "*Tomorrow's Technology*". Finally, throughout the Conference, delegates will be invited to post their views on a notice board as a contribution to the debate on the technology gaps and the needs for the future: "*Next Week's Technology*". These will be discussed during the Closing Technology Review. There will be five themes in the Multiphase Production Technology Conference: 1. Laboratory and Field Measurement 2. Process, Measurement and Control Equipment and Analysis 3. Production Chemistry 4. Modeling and Simulation 5. Thermal Management.

Deadline for receipt of abstracts is September 3, 2004. The detailed information about the conference can be found in BHRg's (www.brhgroup.com) and TUFFP's (www.tuffp.utulsa.edu) web sites.

Upcoming ABM's

September 30, 2004

Tulsa University Paraffin Deposition Projects
Advisory Board Meeting
ChevronTexaco Heritage Plaza - Houston, Texas
1111 Bagby, Room 4652
8:30 a.m. - 4:00 p.m.

TUFFP/TUPDP
Reception
Doubletree Hotel—Allen Center– Houston, Texas
5:00 - 8:00 p.m.

October 1, 2004

Tulsa University Fluid Flow Projects
Advisory Board Meeting
ChevronTexaco Heritage Plaza - Houston, Texas
1111 Bagby, Room 4652
8:00 a.m. - 5:00 p.m.

BHR Group 4th North American Conference on Multiphase Technology—A Success

Since 1991, TUFFP has participated as a co-sponsor of BHR Group Conferences on Multiphase Production. TUFFP personnel participate in reviewing papers, serving as session chairs, and advertising the conference to our members.

BHR Group's 4th North American Conference on Multiphase Technology was held June 3-4, 2004 in Banff, Canada. Twenty Two excellent papers on various subjects covering multiphase flow in pipes, flow assurance, multiphase pumping and metering were presented. Mr. Yongqian (Richard) Fan and Dr. Cem Sarica presented two technical papers based on TUFFP research.

SPE 2004 Annual Meeting

SPE 2004 Annual Technical Conference and Exhibition will be held in Houston, Texas on September 26—29, 2004. In the Production Modeling and Assessment Session on Monday, September 27th at 3:00 p.m., Dr. Holden Zhang will present a paper titled “Unified Model of Heat Transfer in Gas-Liquid Pipe Flow, SPE 90459”

TUFFP Short Course

The 29th annual TUFFP Short Course on Two-Phase Flow in Pipes was taught May 17 - 21, 2004. The course covered the most current, up-to-date-research performed at the Tulsa University Fluid Flow Projects (TUFFP) and Tulsa University Paraffin Deposition Projects (TUPDP). This five-day course focused on the fundamentals of two-phase flow in piping systems encountered in the production and transportation of oil and gas. The enrollment was 7 consisting of 4 and 3 participants from member companies and non-member companies, respectively.

Progress Updates

Cengizhan Keskin

Experiments and Modeling of Gas-Oil-Water Flow in Horizontal Pipes

The ultimate goal of TUFFP for gas-oil-water studies is to develop a mechanistic model based on theoretical analysis and experimental results for the prediction of flow behavior during production and transportation of gas-oil-water in pipes. This study will be the first of a series of gas-oil-water studies. The objective of this study is to investigate three-phase flow of gas-oil-water in horizontal pipes.

The experimental work is being conducted using the TUFFP facility for gas-oil-water flow located at The University of Tulsa North Campus Research Complex. The facility consists of a closed circuit loop with the following components: pumps, heat exchangers, metering sections, filters, test section, separator and storage tanks.

The current test section is composed of two 69.3-ft (21.1-m) long straight transparent pipes, connected by a 4.0-ft (1.2-m) long PVC bend. The pipeline has a 2.0-in. internal diameter. The transparent pipes are instrumented to permit continuous monitoring of the temperature, pressure, differential pressure, holdup, inclination angle and spatial distribution of the phases. Quick-closing valves, fiber optic and conductance probes, capacitance sensors and a gamma densitometer are used to measure phase fractions and flow characteristics. In addition, High Speed Video system will be used to investigate the three-phase flow patterns in detail and to get the droplet size distribution in liquid-liquid dispersions if possible.

The three-phase tests are being conducted for various gas, oil and water flow rates and for various water fractions. Three-phase testing will continue until the freeze in November.

Modeling study of three-phase gas-oil-water flow is underway. The basic equations for the three-phase unified model were presented at the last TUFFP ABM Meeting on March 31, 2004. Current efforts are focused on the development of required closure relationships.

Richard Fan

Low Liquid Loading Gas-Liquid Flow in Near-Horizontal Pipes

A more accurate prediction of pressure gradient and liquid holdup in near-horizontal, wet-gas pipelines is needed to better size pipelines and downstream processing facilities. The objective of this study is to investigate, experimentally and theoretically, low liquid loading gas-liquid two-phase flow in near-horizontal pipes, and to develop improved design models for wet-gas pipelines.

A 50.8-mm (2-in) diameter, 19-m long acrylic flow loop was used for this study. Both air-oil and air-water low liquid loading two-phase flow experiments have been finished, with the inclination angle changing from -2˚ to 2˚ from horizontal. The measured parameters include gas flow rate, liquid flow rate, pressure, differential pressure, temperature, liquid holdup, liquid film flow rate and liquid entrainment fraction. The tests on the 149.6-mm diameter PVC pipe have been finished for horizontal flows, with the gas superficial velocity changing from 7.5 to 13.5 m/s and liquid superficial velocity from 0.00075 to 0.05 m/s. Now the facility is being modified to 2˚ inclined and the second test section is being constructed. After it is finished, the upward flow and downward flow can be investigated simultaneously. More data will be acquired during the summer time.

A two-fluid model with new closure relationships of wetted wall fraction, liquid-wall friction factor and interfacial friction factor has been developed to predict pressure gradient, liquid holdup, wetted perimeter under the given operation conditions, fluid properties and pipeline geometry.

Effect of High Viscosity on Multiphase Flow Behavior

Bahadir Gokcal

High viscosity oils are produced from many oil fields around the world. Oil production systems are currently flowing oils with viscosities as high as 10,000 cp. Current multiphase flow models are largely based on experimental data with low viscosity liquids. Commonly used laboratory liquids have viscosities less than 20 cp. Thus, the gap between actual laboratory data and field data is three orders of magnitude or more.

Almost all flow models have viscosity as an intrinsic variable. Multiphase flows are expected to exhibit significantly different behavior for high viscosity oils. Many flow variables will be affected by a high viscosity liquid, including droplet formation, surface waves, bubble entrainment, slug mixing zones, and even three-phase stratified flow. The flow pattern transitions and pressure drop predictions need to be experimentally determined and models must be modified to account for any discrepancies. Furthermore, the impact of low Reynolds number oil flows in combination with high Reynolds number gas and water flows may yield new flow regimes and concomitant pressure drop behaviors.

The objectives of this study are:

1. Investigating experimentally the effect of high liquid viscosity on multiphase flow behavior by identifying the differences from low viscosity oils;

2. Modifying existing models or developing a new model for multiphase flow of high viscosity liquid.

A new 2-in. ID high viscosity indoor facility is being constructed at The University of Tulsa North Campus Research Complex. The indoor test facility consists of a 62-ft long, steel pipe section and a 27-ft long transparent acrylic pipe section. The inclination angle can be changed from -2° to 2° from horizontal. Flow patterns will be identified, and pressure gradient and liquid hold-up will be measured during the tests.

The candidate oil should be physically stable, Newtonian, immiscible with water, easily discernible in acrylic pipe, safe to handle and reasonable in price. Under these considerations, Citgo Sentry 220 was selected as the test liquid phase. Its viscosity changes from 100 cp to 1000 cp when temperature changes from 120^{o}F to 58^{o}F.

All equipment and accessories have been purchased and the test facility is being constructed. Data acquisition system will be completed and the instruments will be calibrated. Once the constructions are completed, preliminary testing will be conducted during Fall 2004.

Carlos Beltran

Investigation of Occurrence and Elimination of Severe Slugging for Gas-Oil-Water Flow in Pipeline-Riser Systems

Severe slugging can occur in multiphase pipeline-riser systems, which are typical in deep water petroleum production. Severe slugging can cause periods of no liquid and gas production in the separator, followed by very high liquid and gas flow rates. This phenomenon is very undesirable due to large pressure and flow rate fluctuations.

The main objective of this study is to investigate severe slugging occurrence, prediction and elimination for gas-oil-water flow.

The TUFFP severe slugging test facility has been modified to operate with three-phase flow. The modified facility consists of a 65-ft pipeline followed by a 40-ft riser, and the inner diameter of the transparent R-4000 PVC pipe is 3 in. The liquid and gas flow rates are varied in the ranges of 0.1 – 2.0 m/s and 0.1 – 3.0 m/s, respectively. Different water cuts (0, 20, 40, 60, 80 and 100%) in the liquid phase are being tested to study the effects of water in the severe slugging occurrence. The riser is attached to the available tower and the downward pipeline before the riser is mounted on the boom. The boom is inclinable and it permits the investigations at different pipeline inclination angles (-1°, -3° and -5°).

During the summer, data have been collected at downward inclination angles of –1°, –3° and –5°, and different water cuts. The severe slugging envelopes have been generated. The experimental results will be processed and analyzed. The modeling part will be considered after gathering all the data. Previously developed models will be evaluated and modified, if necessary, for the three-phase severe slugging prediction.

Xianghui (Paul) Chen

Closure Laws for Droplet-Homophase Interaction

In multiphase flows, there are many cases where droplets are entrained from or coalesced into a continuous homo-phase. For example, in annular mist flow the liquid droplets are in dynamic equilibrium with the film on the walls, experiencing both entrainment and coalescence. Similarly, in oil-water flows, the observed mixing and/or separation involve both entrainment and coalescence.

Very few mechanistic models exist for entrainment rate and coalescence rate. Understanding the basic physics of these phenomena are essential to being able to model situations of practical interest to the industry, such as separator designs or chemical injection ports for corrosion control. There are no good models for film thickness or flow rates due to the mass and momentum exchanges between the mist and the film. A good understanding of the physics of these phenomena will also help us understand the basis of many of the pressure drop and holdup correlations used in current pipeline simulators.

This project has been initiated with literature search and review. It would start with an existing computation fluid dynamics model (CFD) to simulate the physics and would refine that model based on directed experiments. The experiments would gather three-dimensional information such as mist versus film mass flow rates, droplet distributions, 3D velocity fields, drop size measurements, etc. New instrumentation, test sections, and methodologies will be required to obtain the desired information. Different experimental methods such as high-speed video recording are examined for possible application to this study.

Unified Model for Gas-Liquid Flow in Wells and Pipelines

The TUFFP unified hydrodynamic model has been developed for predictions of flow pattern transitions, pressure gradient, liquid holdup and slug characteristics in gas-liquid pipe flow at different inclination angles from -90 to 90 deg. The model has been validated with extensive experimental data acquired with different pipe diameters, inclination angles, fluid physical properties, gas-liquid flow rates and flow patterns. The Fortran computer program for the unified model has been integrated with an Excel interface to make it more user friendly.

This is an ongoing project. Further validations and modifications will be made when new experimental results are available and new closure relationships are developed.

The unified model is being expanded to include the unified multiphase heat transfer model recently developed at TUFFP. Further expansion will be carried out to a unified model of gas-oil-water three-phase pipe flow.

Related Research

Several related projects are underway. The related projects involve sharing of facilities and personnel with TUFFP.

Holden Zhang

Two TU-CoRE Seed Projects Started

With Dr. Holden Zhang as the principal investigator from The University of Tulsa and Dr. Lee Rhyne as the Champion from ChevronTexaco, two seed projects have been approved by the TU-CoRE Decision Review Board. The first seed project is “Droplet Dynamics in Multiphase Flow.” The purpose of this project is to understand droplet dynamics in multiphase flows. Droplets are formed from films, break off of the waves, fly about in the gas phase, collide with other droplets, breakup and coalesce, impact the films forming droplets or coalescing with the films. Knowledge of droplet dynamics provides the basis of predicting pressure drops, holdups, drop sizes, turbulence fields, droplet spatial distributions. For gas-liquid flows, this project directly addresses particles size predictions and interfacial phenomena.

The second seed project is “Measurements of 3-D Multiphase Flow Structures Using NMR.” The objective of this project is to investigate the feasibility of using Nuclear Magnetic Resonance (NMR) for measurements of three-dimensional droplet/bubble size and distribution, interfacial structure, phase fraction and velocity profile in multiphase flow. These measurements are critical for development and validation of mechanistic models and CFD simulations, understanding the physics of various flow assurance issues such as hydrate formation kinetics and prevention, wax deposition, colloidal structure, emulsion rheology, etc, and improving design of efficient and reliable production and separation systems.

These seed projects are the planning stage for a full research project on Droplet Dynamics in Multiphase Flow which involves CFD simulations and measurements of 3-D multiphase flow structures. Researchers and graduate students from ChevronTexaco, the TU Petroleum Engineering Department (TUFFP and TUSTP) and the TU Physics Department are involved in these seed projects. Collaborations with other institutions and funding from other companies and government will be explored in the full project proposal.

Paraffin Deposition Projects

TUPDP started its second three years phase on March 31, 2004 with 15 members. The studies will continue in three areas namely, single phase deposition, multiphase deposition and pigging. This phase of the project focuses on model and software development, supported by experimental studies. Experimental studies will include high pressure oil-water hydrodynamic studies using Garden Banks Condensate and Tulsa City Water. The results of this study will be made available to TUFFP membership as part of collaboration between TUFFP and TUPDP.

Currently, Mr. Guilherme Couto and Ms. Gladys Sucre are working towards their MS degrees studying water effects on deposition and assessment of current single-phase deposition models and development of better models, respectively. Mr. Antonio Bruno will be our newest research assistant. He will be focusing on oil-water flow loop studies.

TUCoRE High Viscosity Multiphase Flow (HVMP) Studies

The Center of Research Excellence (TUCoRE) initiated by ChevronTexaco at The University of Tulsa funds several research projects on flow assurance topics. TUFFP researchers are involved in TUCoRE activities through conducting the HVMF studies. Two students, Ms. Gizem Ersoy and Mr. Mohammad Hossain are working towards their MS degrees. The studies are currently focusing on the development of improved viscosity and inversion point (for oil-water mixtures) prediction tools.

Calendar of Events

2004

September 8	Hydrate Flow Performance JIP Advisory Board Meeting-BP Westlake-Houston, Texas
September 21—23	Flow Assurance 2004-Galveston, Texas
September 26—29	SPE Annual Technical Conference and Exhibition-Houston, Texas
September 30	Paraffin Deposition Projects Advisory Board Meeting-ChevronTexaco Heritage Plaza-Houston, Texas
	Fluid Flow Projects/Paraffin Deposition Project Reception-Doubletree Hotel-Allen Center-Houston, Texas
October 1	Fluid Flow Projects Advisory Board Meeting-ChevronTexaco Heritage Plaza-Houston, Texas
October 4—8	ASME International Pipeline Conference (IPC 2004)-Calgary, Alberta, Canada
October 18—20	Asia Pacific Oil and Gas Conference and Exhibition-Perth, Australia
November 14—18	International Conference on Heavy Organic Deposition (HOD), Presidente Intercontinental Hotel-San Jose del Cabo, BCS, Mexico

2005

April 3—7	NACE Corrosion 2005-George R. Brown Convention Center-Houston, Texas
April 10-14	AIChE 2005 Spring National Meeting-Hyatt Regency-Atlanta, Georgia
April 17—19	SPE Production and Operations Symposium-Oklahoma City, Oklahoma
May 2—5	Offshore Technology Conference-Houston, Texas
May 25—27	Multiphase Production Technology ‘05-Barcelona, Spain
July 17—22	ASME Heat Transfer Conference ‘05-Westin St. Francis Hotel-San Francisco, California
September 6—9	Offshore Europe 2005-Aberdeen, United Kingdom