The University of Tulsa

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

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Editorial by Cem Sarica

We enter 2003 with no net loss of membership inspite of the fact that the consolidation of our industry continues. I am happy to say that TotalFinaElf and Saudi Aramco have rejoined TUFFP. BG International and JNOC terminated their membership for 2003 due to financial shortfalls. Both companies are still very much interested in TUFFP and hope to rejoin in the near future. Efforts are underway to increase the membership. We hope to gain one or two more members during 2003.

The Tulsa University Severe Slugging JIP was successfully completed in August 2002. All JIP members are also current members of TUFFP. The JIP members indicated the need to continue with severe slugging studies. Several other TUFFP members have also indicated interest in the project. Therefore, future severe slugging studies are being considered for migration to TUFFP.

Our family keeps growing. I would like to welcome Dr. Harvey Hensley and Dr. Mengjiao Yu, the newest additions to our research team. Dr. Hensley, a retiree of ConocoPhillips and former Phillips Petroleum Company representative to TUFFP and TUPDP, volunteers as a part time senior research associate. Dr. Yu, the newest addition to the Petroleum Engineering faculty, is serving as a co-investigator in the TUCoRE (a ChevronTexaco Initiative) Offshore Heavy Oil (OHO) project. I am happy to announce that we have also added two new M.S. students to our family. Carlos Beltran from Venezuela will be assigned to a TUFFP project. Mohammad Hossain from Bangladesh has been assigned to the OHO project in TUCoRE.

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

Several improvements have been made to the TUFFP unified hydrodynamic model. The modified Blasius friction factor correlation for turbulent flow has been replaced by the Haaland correlation to incorporate the effect of pipe wall roughness. The computational stability has been improved.

Revisions to the Manabe mechanistic model to predict multiphase flow local heat transfer phenomena for different flow patterns in wells and pipelines have been completed and will be made available on the web. A newly

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Web Sites

www.tuffp.utulsa.edu
www.tupdp.utulsa.edu
www.tuhfp.utulsa.edu

developed unified mechanistic model for multiphase heat transfer is currently being evaluated against experimental and field data.

Eissa Al-Safran completed his studies on two-phase flow in hilly-terrain pipelines. The final report and experimental data will be made available to members before the next Advisory Board meeting. This project will be continued to integrate the models developed in this study into the TUFFP slug-tracking model and to improve its predictions of slug flow characteristics variation along a hilly-terrain pipeline.

Efforts continue with modifications to the 6-in. flow loop and to modeling studies in the low liquid loading gas-liquid flow in near-horizontal pipes project. A new screw type air compressor with twice the capacity of the current Joy compressor was purchased to cover a wider range of flow rates in the stratified flow pattern. The compressor will also be used to provide air to all TUFFP facilities, increasing our operating conditions.

The assessment study for three-phase flow technology continues to identify the gaps and weaknesses in our models and resulted in development of a preliminary model. The TUFFP oil-water flow facility has been upgraded to a three-phase gas-oil-water facility to experimentally investigate gas-oil-water flow in horizontal and slightly inclined pipes. Current activities are focused on finalizing the instrumentation. Testing is expected to start before the Spring 2003 Advisory Board meeting.

The TUFFP pipeline field databank development is an on-going project. AGA (1988) gas-liquid pipeline data are included in the databank. The Prudhoe Bay data are being analyzed and will be added to the databank.

As part of our up-scaling studies, Sulphur Hexaflouride (SF6) is being considered as the gas phase to investigate pressure effects without operating under high-pressure conditions the in 6-in. ID flow loop. The required modifications include a high capacity gas compressor or a multiphase pump to circulate SF6 in the loop. A cost analysis revealed the necessity of significant capital investment which can not be covered with the current TUFFP revenue through annual membership fees.

PETROLEUM ENGINEERING POSITIONS FILLED

New Chairman

In November 2002, Dr. Mohan Kelkar became Chairman of Petroleum Engineering at The University of Tulsa.

Dr. Kelkar joined The University of Tulsa as an Assistant Professor of Petroleum Engineering in 1983 after completing his M.S. and Ph.D. degrees at the University of Pittsburgh. He became Professor of Petroleum Engineering in 1995. Dr. Kelkar's major area of research interest is reservoir characterization. His research is funded by many domestic and international oil companies, as well as the U.S. Department of Energy. In 2002, Dr. Kelkar co-authored a book titled "Applied Geostatistics for Reservoir Characterization," which was published by the Society of Petroleum Engineers. As the department Chairman, his main goals are to increase the enrollment of undergraduate students, improve contacts with alumni, and enhance the visibility of the University.

New Faculty

Dr. Mengjiao Yu joined the Petroleum Engineering Department in 2002 as an assistant professor of Petroleum Engineering. He serves as co-investigator in the TuCore Offshore Heavy Oil project.

Dr. Yu received his Ph.D. degree in Petroleum Engineering and his M.S. degree in Electrical & Computer Engineering from the University of Texas at Austin. He also holds a Masters degree in Chemical Engineering and a BS degree in Chemistry. His current research interests are in drilling fluids, cuttings transport, wellbore stability, rheology of fluids, and petroleum chemistry.

RESEARCH TEAM GROWS

Senior Research Associate

Greetings! I'm the "new kid on the block". You might think a retiree is not a kid, but I'm having as much fun as a kid in my new position as a volunteer Senior Research Associate in the Petroleum Engineering Department. I've been asked to introduce myself and outline some of my initial goals in this article, so if you know me, you may wish to skip the next paragraph.

I majored in ChE, obtaining a B. S. at Kansas State U. and a Ph. D. at the U. of Texas. My first engineering job was with the duPont Engineering Department. While at duPont, I had positions in bench research, plant technical assistance, and large scale process modeling. The latter included both steady-state and dynamic models. After nine years with duPont, my wife, Susan, and I yearned to be closer to family in the Midwest. I found a challenging position in the Research Department of Phillips Petroleum in Bartlesville. Initial assignments involved conceptual process design and economics, but the work evolved to include the setup of a laboratory to obtain reaction kinetics, reactor model development, and computational fluid dynamics. The latter led to multiphase pipeline simulation using OLGA which in turn led to involvement in flow assurance technology. I eventually chaired the Flow Assurance Committee in the DeepStar consortium for a few years before retiring last Fall from the new ConocoPhillips.

During my career, I had several opportunities to do both formal and informal teaching. I enjoyed those experiences. In addition, I see that we are not finished with the wax deposition modeling. So it was natural to wish to continue working with the TUPDP research team and the consortium. I believe that my background in kinetics, reactor modeling, experimental design and fluid flow will be a good basis for mentoring the students. I am working on a way of categorizing the multiphase flow project literature, TUFFP output, and current objectives.

Why do this without pay? The reward is seeing students gain confidence as they tackle areas of technology that are completely new to them, and eventually they master the existing technology and improve it. The ultimate goal is the production of graduates with confidence that, given a reasonable amount of time, they can tackle the broad range of technical problems that will arise in their career.

New Masters Students

Carlos Andres Beltran Romero received his B.S. degree in Chemical Engineering from Simon Bolivar University in Caracas, Venezuela (November 1999). His thesis project involved the study of energetic properties of refrigerants based on cubic equations of state with variations in the cohesion parameter and modeling the TADiP equations for refrigerants.

He did his internship in a pharmaceutical company in Caracas, where he made evaluations, optimizations and validations of the different machineries of the plant. He stayed with the company working as a Maintenance Engineer.

Now, Carlos is pursuing his MS degree in Petroleum Engineering at The University of Tulsa, working as a Research Assistant in the Tulsa University Fluid Flow Projects.

Mohammad Sohrab Hossain joined the TUCoRE Project in January 2003 as a Research Assistant and is pursuing his MS Degree in Petroleum Engineering at The University of Tulsa.

Mohammad received his BS Degree in Chemical Engineering in July 1997 from Bangladesh University of Engineering And Technology (BUET) Dhaka, Bangladesh. After graduation he served three years in the Sangu Gas Field operated by Halliburton as a Production Engineer.

At present, he is working with our team on Heavy Oil Rheology to develop or modify a correlation to predict offshore heavy oil properties at low temperature.

TUFFP Graduate Seminars

Cem Sarica is serving as the Petroleum Engineering Graduate Seminars Coordinator for Spring 2003. The graduate seminars are intended to be part of the education of our graduate students. Seminars are open to the public. You are welcome to attend any of the seminars. They are held on Fridays starting at 3:30 PM. The graduate seminar program is given below.

Date	Speaker	Presentation Title
January 17, 2003	Probjot Singh, ConocoPhillips	"Science of Wax Deposition"
January 24, 2003	Michael Levitan, BP	Application of Water Injection/Falloff Tests for Reservoir Appraisal: New Analytical Solution Method for Two-Phase Variable Rate Problems.
January 31, 2003	Randy Rodifier, ConocoPhillips	Coalbed Methane Parametric Study - What's Really Important to Production and When?
February 6, 2003	Erdal Ozkan, Colorado School of Mines	Optimization of Plunger-Lift Performance in Stripper Gas Wells
February 21, 2003	Ron Thomas	High Temperature Sandstone Acidizing of the Jauf Reservoir in Saudi Arabia
March 7, 2003	Mustafa Onur Istanbul Technical University	Permeability Estimation from Multi-Probe and Packer-Probe Wireline Formation Tester Pressure Data
March 14, 2003	Robello Samuel Landmark Graphics	Accelerating Technology for Drilling - Changing Paradigm
April 4, 2003	Gary Sams, Natco	Optimizing Separator Designs for FPSO Operation
April 18, 2003	Norm McMullen, BP	Flow Assurance Challenges in Deepwater: A BP Perspective

TUFFP Membership

TUFFP 2003 membership stands at 12 companies. We lost one member due to the ConocoPhillips merger for 2003. BG International (through Advantica) and JNOC terminated their membership for 2003. Both companies have indicated their desire to come back after the completion of their internal restructuring. I am pleased to announce that TotalFinaElf and Saudi Aramco have rejoined TUFFP for 2003.

Efforts are underway to increase TUFFP membership. We have initiated communications with past and possible new members in an effort to expand our membership. Yukos Oil, the second largest Oil&Gas Company in Russia, has recently indicated their intention to join TUFFP. We have recently had a positive meeting with PetroChina for possible collaboration and membership in TUFFP. Several other companies have been contacted and communications continue towards their involvement in TUFFP

We submitted a proposal in July 2002 in response to DOE's PRIME Solicitation to significantly leverage TUFFP industry funding. DOE has yet to make an announcement with respect to their decision on PRIME Solicitation.

TUFFP Financial Status

TUFFP's financial status remains stable for 2003. We entered 2003 with approximately $320,000 in our reserve fund. Our 2003 income will be $420,000 for 12 members. Our total expenditures for 2003 are estimated to be $550,000. The imbalance between the income and 2002 expenditures will be compensated from the reserve account lowering the balance to $165,000 at the end of 2003.

Pipesim™ Training

Mack Shippen of Schlumberger gave a Pipesim™ workshop on January 18, 2003 at The University of Tulsa. Schlumberger provided a network license of Pipesim™ to the University for Academic Use. The software is being used in undergraduate and graduate production engineering and capstone design courses.

Remodeling

A dedicated flow assurance laboratory is currently being set-up to house all of the flow assurance related laboratory devices such as a DSC, viscometers, oil-water separation, a hydrate cell, a cold-finger apparatus, etc. The laboratory is located on the upper floor of The University of Tulsa Model Lab building. The TUFFP horizontal well facility, which was idle for four years, has been dismantled to make space for the Flow Assurance Lab.

Research activities in our various projects have recently increased significantly, resulting in more demand for office space for graduate students. Office space for 3 to 4 additional research personnel has been created through remodeling of our offices in the lower floor of the Drill Building at the North Campus. As part of the remodeling, the Periodical Library was combined with the TUFFP Library. Also, DB 106 (Copy room) and DB107 (Suzette Blankenship's Office) have been combined to house both of our project assistants, Suzette Blankenship and Linda Jones. The office Linda Jones vacated (DB 103) is now assigned to TUCoRE project research assistants.

Meetings and Conferences

Spring 2003 Advisory Board Meetings

Final plans have now been made for the Spring 2003 Advisory Board meetings. A tour of test facilities will be held on Monday, April 14 at 3 p.m. Following the tour, there will be a joint TUFFP and TUPDP BBQ between 5:00 - 7:00 p.m. The TUFFP Advisory Board meeting will begin at 8:30 a.m. on Tuesday, April 15 and will adjourn at 5:00 p.m. Following the meeting, there will be a joint TUFFP and TUPDP reception at the Doubletree Hotel at Warren Place from 6:00-9:00 p.m. On April 16, 2002, the TUPDP Advisory Board meeting will be held. The meeting will start at 8:00 a.m. and will adjourn at 5:00 p.m. The Hydrate Flow Performance JIP Advisory Board meeting will be held in the Allen Chapman Activity Center in the President's Lounge at the University of Tulsa on April 17, 2003 from 8:00 a.m. to 4:30 p.m.

The Request for Information form and the Doubletree Hotel at Warren Place Reservation form will be placed on the TUFFP web page in early March. All persons from your company that plan to attend the Advisory Board meetings should complete and return these forms 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 www.tuffp.utulsa.edu/ABM/index.html. You can then follow the links for the Request for Information form. The hotel reservation form is a word document for downloading and faxing to the hotel.

Tentative dates and locations for the Fall 2003 Advisory Board meetings are yet to be determined.

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 TUFFP web site at www.tuffp.utulsa.edu 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.

TUFFP Short Course

The 28th annual TUFFP Short Course on Two-Phase Flow in Pipes will be taught May 19-23, 2003 by Drs. Sarica and Brill at the Tulsa Marriott Southern Hills Hotel.

Based on the most current, up-to-date-research done at the Tulsa University Fluid Flow Projects (TUFFP) and Tulsa University Paraffin Deposition Projects (TUPDP), this five-day course focuses on the fundamentals of two-phase flow in piping systems encountered in the production and transportation of oil and gas. Completed and current research projects permit teaching the latest techniques for designing multiphase flow systems. This course will provide an improved understanding of multiphase flow in wells, flow lines and risers, and paraffin deposition for single and multiphase flows.

The registration fee schedule for the short course is given below:

TUFFP and TUPDP Member Companies	
Per Person	$1,395
Group Discount - Per Person	$1,195
Non-Member Companies	
Per Person	$1,995
Group Discount - Per Person	$1,795

A brochure advertising the course will soon be mailed to TUFFP and TUPDP members and an electronic copy will be available through the TUFFP web page at www.tuffp.utulsa.edu. Interested persons are urged to enroll as soon as possible to help us plan the course.

BHR Group's Multiphase '03 Conference

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 Multiphase '03 Conference will be held June 11-13, 2003 in the beautiful resort of San Remo, Italy. The opening address of the conference will be given by Dr. James P. Brill. The title of his address will be "Multiphase Technology - Past, Present and Future, the World According to Brill". Moreover, Dr. Jarl Tengesdal and Ms. Oris Hernandez will be presenting two technical papers based on research conducted in the severe slugging and paraffin deposition projects, respectively. It is expected that Multiphase '03 will benefit anyone engaged in the application, development and research of multiphase technology for the oil and gas industry.

Calendar of Events

2003

March 22 - 25, 2003	SPE Production Operations Symposium- Oklahoma City, Oklahoma, USA
March 30 - April 3, 2003	AIChE Spring National Meeting and Petrochemical and Refining Exposition - New Orleans, Louisiana, USA
May 5 - 8, 2003	Offshore Technology Conference - Houston, Texas, USA
May 12 - 14, 2003	ATW - Deepwater Subsea Well Flowbacks - Houston, Texas, USA
May 18 - 23, 2003	Forum Series - Production Optimisation - Phuket, Thailand
June 8 - 13, 2003	22nd International Conference on Offshore Mechanics and Arctic Engineering - Cancun, Mexico
June 11 - 13, 2003	BHR Group 11th International Conference on Multiphase Technology - San Remo, Italy
June 23 - 26, 2003	4th International Conference on Petroleum Phase Behavior and Fouling - Trondheim, Norway
July 6 - 10, 2003	4th ASME/JSME Joint Fluids Engineering Conference - Sheraton Hotel-Waikiki, Honolulu, Hawaii
July 13 - 17, 2003	ATW - Development of Marginal Offshore Fields - Ho Chi Minh City, Vietnam
August 11 - 12, 2003	ATW - Subsea Facilities Management - Houston, Texas, USA
August 19 - 22, 2003	ATW - Deepwater Technology - Kota Kinabalu, Sabah, Malaysia
August 25 - 29, 2003	Applied Statistical Physics - Molecular Engineering International Conference - Puerto Vallarta, Jalisco, Mexico
Aug. 31 - Sept. 5, 2003	2003 Forum Series - Multiphase Capabilities in Frontier Environments - Ste. Maxime, France
September 2 - 5, 2003	Offshore Europe - Aberdeen, Scotland
October 5 - 8, 2003	SPE Annual Technical Conference and Exhibition - Denver, Colorado, USA
October 22 - 24, 2003	Rio Pipeline Conference and Exposition - Hotel Inter-Continental Rio-Rio de Janeiro, Brazil

2004

May 3 - 6, 2004	Offshore Technology Conference - Houston, Texas, USA
September 26 - 29, 2004	SPE Annual Technical Conference and Exhibition - Houston, Texas, USA

Two Phase Flow in a Hilly-Terrain Pipeline

A hilly-terrain pipeline consists of interconnected horizontal, uphill, and downhill sections. The characteristics of liquid slugs will change when the pipe inclination angle is reduced or increased. Long slugs often cause operational problems, flooding of downstream facilities, severe pipe corrosion, and structural instability of the pipeline, as well as production loss and poor reservoir management.

The objectives of this project are to: 1) investigate, experimentally and theoretically, slug initiation at the bottom elbow, 2) develop closure relationships for slug tracking models, and 3) generate data to evaluate the developed models.

A 420-m (1378-ft) long, 50.8-mm (2-in.) diameter, horizontal steel pipeline was used to conduct the experimental tests. The test section, made of a 2-in. diameter transparent acrylic pipe, simulates a single hilly-terrain unit of 70-ft uphill (downhill) and 70-ft downhill (uphill) sections. The test section included four measurement stations to monitor the change in slug flow characteristics along the test section. A total of 105 tests were conducted with hill and valley configurations (with inclination angles of +1°, +2°). The superficial liquid and gas velocities ranged from 0.2 to 4 ft/s and from 2 to 15 ft/s, respectively.

Slug initiation at the dip of the hilly-terrain section was investigated. It revealed that two types of initiation mechanisms can exist, namely wave growth, and wave coalescence. The wave growth mechanism is characterized by flow reversal of the liquid downstream of the elbow. As the liquid level increases, a new slug will be generated by Kelvin Helmholtz instability. The wave coalescence initiation mechanism is a different phenomenon where small amplitude waves are generated at the dip, move downstream, and eventually coalesce to form a large wave that becomes a slug under K-H instability.

Two-phase flow mechanistic-probabilistic-empirical models have been developed to predict initiated slug length distribution at the bottom elbow, and slug length distribution at the hilly-terrain pipeline entrance has been modeled. A log-normal probability model was found to fit the experimental slug length distribution better than an inverse Gaussian probability model. The log-normal probability model was then correlated empirically with mechanistic, operational and geometrical parameters of slug flow. Validation studies were carried out that showed a satisfactory match between the model prediction and experimental data.

Eissa Al-safran successfully defended his PhD dissertation in September 2002. The dissertation will soon be posted on the TUFFP website (www.tuffp.utulsa.edu) for the TUFFP members. The future plan for this project is to integrate the models developed in this study into the TUFFP slug-tracking model to improve its predictions of slug flow characteristics variation along a hilly-terrain pipeline.

Mechanistic Modeling of Multiphase Heat Transfer in Wells and Pipelines

Estimating heat transfer for gas-liquid pipe flow is required to model the thermal behavior of petroleum multiphase systems. However, heat transfer in crude oil-natural gas pipe flow is not well understood. A robust prediction method for all possible operating conditions does not exist.

The objectives of this project are to: 1) acquire experimental data on average convective heat transfer coefficients for high-pressure, gas-liquid (natural gas-crude oil) flow in horizontal, inclined and vertical pipes; 2) develop a comprehensive mechanistic heat transfer model; and 3) validate the proposed model with experimental data.

Manabe (2001) developed a comprehensive mechanistic model for heat transfer in gas-liquid pipe flow. The model overall performance is better than previous correlations when compared with experimental results. Manabe's model was then improved by Wang and the results were reported at the 2002 TUFFP Fall Advisory Board meeting. The final report of the revised model, computer programs and experimental data will be released and made downloadable from the TUFFP web site (www.tuffp.utulsa.edu) for members.

Multiphase heat transfer is interrelated with multiphase hydrodynamics. A good multiphase hydrodynamic model is crucial for the modeling of multiphase heat transfer. The newly developed TUFFP unified hydrodynamic model performs better than previous mechanistic models in predicting flow pattern transitions and hydrodynamic flow behavior. Based on the unified hydrodynamic model, a unified model for multiphase heat transfer has now been developed by Zhang for different flow patterns of gas-liquid pipe flow at different inclination angles from -90 to 90 deg (reported at the 2002 TUFFP Fall Advisory Board meeting). The model predictions have been compared with experimental measurements for a crude oil/natural gas system, and good agreement was observed.

Gas-Oil-Water Pipe Flow

Three-phase gas-oil-water flow is a common occurrence in the petroleum industry. However, only a limited amount of experimental data and modeling results can be found in the literature. The ultimate objective of TUFFP for gas-oil-water studies is to develop a mechanistic model based on theoretical analysis and experimental results. There are two parallel studies underway in TUFFP for gas-oil-water pipe flow. The first study focuses on assessing current three-phase flow technology, identifying technology gaps and weaknesses, and developing a modeling framework. The second study is to investigate, by experiments and modeling, gas-oil-water flows in horizontal and slightly inclined pipes, starting with the investigation of flow patterns.

The objectives of the assessment study are to: 1) assemble previous experimental data and review theoretical models for gas-oil-water pipe flow from the open literature, 2) evaluate existing models with experimental data, 3) identify limitations and shortcomings of the models, 4) suggest modifications and new developments for future studies, and 5) develop a preliminary three-phase flow model. The major parts of assembling data and literature review are completed. Existing models found in the open literature will be evaluated by comparison with the collected experimental data.

The experimental work will be conducted on the existing TUFFP facility for oil-water flow. A gas metering run was constructed and new Micro-Motion mass flow meters were installed for the measurement of air flow rate. The existing test section was modified by building a new mixing tee. Aluminum nets were constructed around the test section for protection against explosion. Wiring of the flow loop and test section was completed. For the measurement of phase fractions and flow characteristics, fiber optic conductance probes and a gamma densitometer were considered. The testing program for the experiments was determined. A number of emulsion and separation experiments were performed using a Tulco Tech 80 oil sample. 2500 gallons of Tulco Tech 80 oil will be used in testing. The oil tank, separator and pipes were cleaned and existing equipment such as pumps, heat exchangers, flow meters, separator and storage tanks were checked and made operational.

Currently, efforts are focused on determination of a method to obtain droplet size distribution of water-in-oil dispersions. Calibration of the instruments and updating the data acquisition program will soon be started. Testing is expected to begin before the Spring 2003 Advisory Board Meeting.

Pipeline Data Bank Development

TUFFP has worked on multiphase flow for 30 years. During this time, a large quantity of laboratory and field data has been collected. The objective of this project is to develop a pipeline data bank, which contains the maximum possible amount of quality multiphase flow data for pipelines. The data bank can be used for validation of newly developed mechanistic models and for improvements in previous models. The data bank will also be distributed to TUFFP members for them to evaluate simulation abilities of different software.

A primary pipeline data bank for laboratory measurements has been developed. Seven laboratory data sets are included. The total number of tests is 1361. New data will continuously be added to the data bank.

The AGA (1988) gas-liquid pipeline data are included in the data bank as one of the field data sets. The Prudhoe Bay data are being examined for inclusion in the data bank.

Unified Model for Gas-Liquid Flow in Wells and Pipelines

During oil and gas production, fluids are transported upwards from vertical or deviated wells, through hilly-terrain pipelines to downstream processing facilities. Steam, water and gas injection are often used to boost production rate. Therefore, gas-liquid two-phase flows at all inclination angles from vertical downward to vertical upward are frequently encountered in the oil and gas industry. A unified model is required which can accurately predict two-phase flow behavior at all inclination angles.

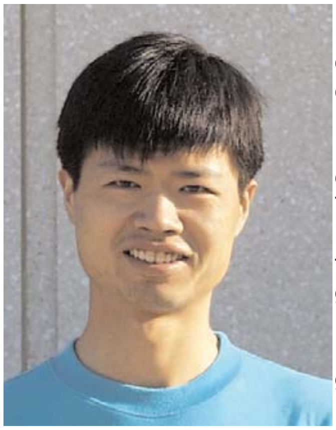
The TUFFP unified hydrodynamic model has been developed for predictions of flow pattern transitions, pressure gradient, liquid holdup and slug characteristics in gas-liquid pipe flow at different inclination angles from -90 to 90 deg. The model is based on the dynamics of slug flow. The equations of slug flow are used not only to calculate the slug characteristics, but also to predict transitions from slug flow to other flow patterns.

The new 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. Good agreement was observed in every aspect of two-phase pipe flow. Further validations and modifications will be made when new experimental results are available and new closure relationships are developed.

Recently, several improvements have been made to the unified hydrodynamic model. The modified Blasius friction factor correlation for turbulent flow has been replaced by the Haaland correlation to incorporate the effect of pipe wall roughness. The computational stability has also been improved by dissipating the overshooting of flow parameters such as liquid holdup in the iterations.

A publication based on the new unified model will appear in the ASME Journal of Energy Resources Technology later in 2003.

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



A more accurate prediction of liquid holdup and pressure drop in near-horizontal, wet-gas pipelines is needed in order 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 diameter, 19-m long flow loop is being 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.

Modification of the 152.4-mm (6-in) flow loop is underway to investigate low liquid loading stratified flow. Gas velocities of 5-15 m/s with liquid loading changing between 50 and 1200 m3/MMm3 will be investigated. The measured parameters will include gas flow rate, liquid flow rate, pressure drop, temperature, liquid holdup, liquid film velocity and the thickness of the liquid film at the bottom of the pipe.

A model based on the double circle assumption is being developed to predict the wetted perimeter, liquid thickness at the bottom and the length of the gas-liquid interface in low liquid loading stratified flow.

2003 Fluid Flow Projects Membership

- Baker Atlas
- BP Exploration
- ChevronTexaco
- ConocoPhillips, Inc.
- Marathon Oil Company
- Minerals Management Service
- PDVSA - Intevep
- Pemex
- Petronas
- Saudi Aramco
- Schlumberger
- TotalFinaElf

Related Projects

Severe Slugging JIP

The Tulsa University Severe Slugging JIP was successfully completed in August 2002. All JIP members are also current members of TUFFP. The JIP members indicated the need to continue with the severe slugging studies. Several other TUFFP members have also indicated an interest in the project. Therefore, severe slugging studies are being considered for migration to TUFFP. The initial studies will focus on improvement of existing models for the self-lifting concept, three-phase gas-oil-water severe slugging occurrence, and elimination with self lifting.

TUFFP members who were not member of the Severe Slugging JIP will be asked to pay a nominal information fee to receive the deliverables of the JIP. They will be fully entitled to the results of the project conducted under TUFFP auspices.

TUCoRE Activities

Several of our research personnel are involved in ChevronTexaco's TUCoRE initiative. Currently, offshore heavy oils and emulsions are being investigated.

Future Advisory Board Meetings Schedule

April 14, 2003

TUFFP/TUPDP/TUHFP JIP
Tour of Test Facilities
University of Tulsa North Campus - Tulsa, OK
3:00 - 5:00 p.m.

TUFFP/TUPDP/TUHFP JIP
Barbeque
University of Tulsa North Campus - Tulsa, OK
5:00 - 7:00 p.m.

April 15, 2003

Tulsa University Fluid Flow Projects (TUFFP)
Advisory Board Meeting
Doubletree Hotel at Warren Place - Tulsa, OK
8:30 a.m. - 5:00 p.m.

TUFFP/TUPDP/TUHFP
Reception
Doubletree Hotel at Warren Place - Tulsa, OK
6:00 - 9:00 p.m.

April 16, 2003

Tulsa University Paraffin Deposition Projects (TUPDP)
Advisory Board Meeting
Doubletree Hotel at Warren Place - Tulsa, OK
8:00 a.m. - 5:00 p.m.

April 17, 2003

Tulsa University Hydrate Flow Performance JIP (TUHFP)
Advisory Board Meeting
Allen Chapman Activity Center - Tulsa University
President's Formal Lounge
8:00 a.m. - 4:30 p.m.

Tulsa University Hydrate Flow Performance Joint Industry Project (TUHFP)

Hydrates are ice-like solids that form when a sufficient amount of water is present, a hydrate former is present, and the right combination of temperature or pressure is encountered (hydrate formation is favored by low temperature and high pressure). Hydrates are also notorious for forming at conditions where a solid would not otherwise be expected. Under the right conditions, hydrates can form anytime and anywhere hydrocarbons and water are present. In wells, downhole separators, flowlines and meter discharges, accumulation and agglomeration of hydrates can form plugs that act as a hindrance to hydrocarbon flow. Shut-in and startup are primary times when hydrates form. On shut-in, the line temperature cools very rapidly to that of the ocean floor (40°F for depths greater than 2000 ft) so that the system is almost always in the hydrate region if the line is not depressurized. At that condition, multiple hydrate plugs can form. An understanding of how hydrates form deposits and how this leads to hydrate plug formation in subsea satellite wells, flowlines and risers is important to avoid plugging in deepwater production operations.

Figure 1 - Flow Assurance Loop Facility

The overall project objective of this Joint Industry Project (JIP) is to conduct experimental flow studies using four live crudes to quantify the amount of hydrates that could form in a pipeline and determine whether the hydrates formed would block a pipeline. Dissociation times for any blockages will be studied as will the use of inhibitors to prevent the blockage. Hydrate formation, transport and dissociation models will be developed and validated. These studies will answer the following basic questions and be useful in model development: What combination of operating conditions result in the flash formation of hydrates? What are the kinetics of the formation process? How do fluid and flow characteristics affect hydrate particle growth and the nature of the deposit? What factors control the agglomeration of the flowing particles? How does the deposition on pipe walls occur? What volume fraction of hydrate particles in the flowing stream represents plugging potential in either vertical or horizontal pipes? How can we start to model the formation and deposition process? What is the mechanism of natural plug inhibition? Can this natural inhibition performance be quantified?

Large quantities of data will be gathered with this facility to better understand hydrate formation kinetics in live oil-water-gas systems. Two oils will have low water cut plugging tendencies (form hydrate blockages at water cuts < 10 - 20%) and two will have high water cut plugging tendencies (form hydrate blockages when water cut is in excess of 50 to 70%). The JIP will focus on different hydrate production issues with the intent of providing valuable information to oil producers for a more economical approach to deep-water developments. These issues can be grouped into three categories: producing in the hydrate domain, shut-down and restart of production systems, and preventing hydrate formation. A kinetic model will be developed and validated to predict transient (shutdown - startup) conditions.

This JIP will lead to both economic and health, safety and environmental impacts, such as:

1. Reduced risk of hydrates interfering with hydrocarbon production, minimizing losses of production and remediation costs that could be in the millions of dollars.
2. Potential reduction of capital costs for insulation, heated bundles, etc. for hydrate mitigation prevention.
3. Millions of dollars of operating cost reduction as a result of not having to overtreat with chemicals.
4. Minimize or eliminate instances of line rupture, sometimes associated with loss of life, attributed to the formation of hydrate plugs.
5. Reduce the amount of flammable hazardous materials that need to be stored on offshore facilities.

Current project members include BP, BHP, Champion Technologies, Marathon, and the MMS. Funds to tear down and move the flow loop from Littleton, Colorado were made available by the U.S. DOE and funds to reconstruct the facility were obtained from The University of Tulsa. Efforts to solicit additional members are ongoing. For additional information contact Michael Volk at 918-631-5127 or by email at michael-volk@utulsa.edu.

Please complete and send in your Request for Information form and make hotel reservations for the upcoming Advisory Board meetings as soon as possible.

NEWS ABOUT PARAFFIN DEPOSITION FACILITIES

Flow Assurance Laboratory

A dedicated flow assurance laboratory is currently being set-up to house all of the flow assurance related laboratory devices such as a DSC, viscometers, oil-water separation, hydrate cell, cold-finger apparatus, etc. The laboratory is located in the upper floor of The University of Tulsa Model Lab building. The TUFFP horizontal well facility, which was idle for four years, has been dismantled to make space for the Flow Assurance Lab.

Single Phase Paraffin Deposition Studies

The studies continue with CBI oil tests.

Jose Alana
Single-Phase Paraffin Deposition Studies

The objective of this study is to continue investigation of paraffin deposition phenomena during single-phase oil flow. Experimental data are being gathered from a 164-ft long horizontal test facility. Data processing and measuring are the main activities during data acquisition. For simulation purposes, two models, a kinetic model and a diffusion model have been developed to predict wax deposit thickness in pipes.

Multiphase Paraffin Deposition Studies

The studies continue with Garden Banks' fluids. Several intermittent tests are currently underway.

Nilifur Kincer
Multiphase Flow

My research area is investigating multiphase flow paraffin deposition phenomena. This research includes conducting multiphase flow deposition tests in different flow patterns and modeling the experimental results. The deposition tests are run for both vertical and horizontal flow on a test section of 2-in diameter and 20-ft long.

Three-Phase Paraffin Deposition Studies

On the multiphase loop, all the main equipment necessary for the installation of the water phase system have been received, including the oil-water separator. Installation of this equipment on site will take place in January. Piping and instrumentation installation will begin shortly after the main equipment is positioned.

Additional oil-water separation tests are being conducted to assess the separation difficulties.

Guilherme Couto
Three-Phase Flow Paraffin Deposition Project

The objective of this project is to investigate paraffin deposition in pipelines with high pressure tests flowing oil, water and gas. Cold finger type experiments with oil and water are ongoing before the beginning of tests in the multiphase flow loop.

Small-scale flow facility

The small-scale flow loop was commissioned. Initial shakedown tests have been conducted. This facility is designed to operate for extended periods of time with no attendance, except for startup and shutdown procedures. The first oil to be tested in the small-scale loop will be South Pelto oil. Testing with South Pelto is underway.

Charlie Gao
Small Scale Loop

The objective of my project is to run long-term paraffin deposition tests on the new small scale loop, which can achieve unmanned operation. These long-term tests will yield important data for modeling aging and shear stripping.

Pigging tests will also be conducted on this facility to obtain data in 1.5-in pipe with real field pigs.

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