T U F F P

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Holden Promoted to Associate Professor Rank with Tenure

We are proud and happy to announce that, recently, after the lengthy rigorous academic evaluation process, Dr. Hong-quan (Holden) Zhang has been promoted to the rank of Associate Professor with tenure with unanimous recommendations from both department and college tenure and promotion committees. Please join us in congratulating Holden for this milestone.

Holden has been with TU for 10 years, 5 years as a research associate for TUFFP and TUPDP and 5 years as a tenure track faculty member at the department of Petroleum Engineering. Currently, Dr. Zhang serves as the Associate Director for TUFFP and Principal Investigator for the Tulsa University High-Viscosity Oil Projects (TUHOP). He has proven himself as an effective teacher, an excellent researcher and an invaluable asset to the department.

Dr. Polat Abduvayt Joins TUFFP as Post-Doctoral Research Associate

Dr. Abdel Salam Al-Sarkhi, the lead research associate for TUFFP for 1 ½ years resigned his position effective August 26, 2008 due to family obligations in Jordan. He has

contributed significantly to TUFFP during his short stay with us. His position has recently been filled.

We are very pleased to introduce Dr. Polat Abduvayt, a Chinese National, as our newest TUFFP Post Doctoral Research Associate. He has BS degree in Petroleum Geology from University of Petroleum in China, and MS and Ph.D. degrees in Petroleum Engineering from Waseda University in Japan.

Before joining TUFFP, Dr. Abduvayt was a Senior Petroleum Engineer with Japan Oil Engineering Company and conducted extensive studies on fluid flow characteristics in wellbores and pipelines and in development of pressure drop and heat transfer prediction models as part of his duties. Before joining Japan Oil Engineering Company, he was a research associate in Waseda University in Japan. During his tenure with Waseda University, he worked as Research Engineer conducting several experimental and theoretical multiphase flow studies for JOGMEC (formerly JNOC).

Visiting Professors to Spend Their Sabbatical with TUFFP

Dr. Eissa Al-safran

We are pleased to announce that Drs. Eissa Al-safran and Yuxing Li are currently with TUFFP as Visiting Professors conducting TUFFP research.

Dr. Eissa Al-safran, an Assistant Professor of Petroleum Engineering in Kuwait University, has started his sabbatical research activities with TUFFP in Fall 2008. Dr. Al-safran is working on Slug Length Characteristics of High Viscosity Oil and Gas Flow based on the data acquired by Dr. Bahadir Gokcal.

Dr. Al-safran has received BS, MS and Ph.D. degrees in Petroleum Engineering from the University of Tulsa. He studied two-phase slug flow in hilly terrain pipelines in TUFFP as part of his MS and Ph.D. degrees. He has become an Assistant Professor of Petroleum Engineering in 2003 in Kuwait University. In 2006, he founded Kuwait University Production Research Centre (KUPRC). He is presently the director of KUPRC. He has published 23 papers in journals and conference proceedings. He is active in multiphase flow community. He currently serves as an international member of the Technical Advisory Committee of both BHRg's European and North American Multiphase Conferences.

Dr. Yuxing Li

Dr. Yuxing Li, a Professor of Petroleum Engineering in University of Petroleum (East China), came to TUFFP to spend his six months sabbatical leave starting February 2009. Dr. Li will be working on Three-phase Low Liquid Loading project in TUFFP.

Dr. Li's research activities focuses on the various subjects of multiphase flow in pipelines, such as slug flow, transient flow simulation crude oil/water/gas flow and metering. He has published 22 papers in journals and conference proceedings.

New Research Assistant Arrived

Kiran Gawas

Mr. Kiran Gawas has joined TUFFP team as a research assistant to pursue his Ph.D. degree in petroleum engineering. Mr. Gawas has a BS degree in Chemical Engineering from University of Mumbai, Institute of Chemical Technology and a Master of Technology degree from Indian Institute of Technology (IITB). Kiran will be assigned a project in up-scaling studies.

Bahadir Gokcal

Congratulation to Our Recent Graduate

Dr. Bahadir Gokcal has successfully completed his Ph.D. degree requirements. Dr. Gokcal is currently working for Technip USA as Staff Specialist in the Flow Assurance Group. We wish Dr. Gokcal the best in his future endeavors.

TUFFP Membership and Support

We have lost Tenaris as a member for 2009. The current membership of TUFFP stands at 16 industrial members and Mineral Management Services of Department of Interior (MMS). SPT has joined TUFFP for 2009. We thank our members for their continued support. We are continuing our efforts to increase the TUFFP membership.

Recent Publications and Presentations

Since the last Advisory Board meeting, the following publications and presentations are made.

Atmaca, S., Alsarkhi, A., Zhang, H. Q. and Sarica, C.: "Characterization of Oil Water Flows in Inclined Pipes," SPE 115485, Presented at 2008th SPE Annual Technical Conference and Exhibition, Denver, CO, September 21-24, 2008.

Gokcal, B., Alsarkhi, A. and Sarica, C.: "Effects of High Viscosity on Drift Velocity for Inclined Pipes," Accepted for Publication in *SPE Projects, Facilities & Construction Journal,* 2009

Al-Safran, E. Kappos, L. and Sarica, C. "Experimental and Numerical Investigation of Separator Pressure Fluctuation Effect on Terrain Slugging in a Hilly-Terrain Two-phase Flow Pipeline," *Journal of Energy Resources Technology* September 2008.

Vielma, M., Atmaca, S., Zhang, H. Q., and Sarica, C.: "Characterization of Oil/Water Flows in Horizontal Pipes," SPE 109591, *SPE Projects, Facilities & Construction Journal,* December 2008.

Website Update

James Miller has returned to us after serving one year in Iraq. He has begun a major overhaul of the TUFFP website, as well as continuing to serve as the Computer Manager. The website is scheduled to be completed by March 1st, 2009. We are hopeful that the University of Tulsa will finish their licensing agreement with Microsoft to purchase MS SharePoint. This will allow our customers to interface with one another via a chat board, and share blogs about research projects. More can be read about this software at: http://www.microsoft.com/sharepoint/capabilities/default.mspx. It is our hope that this purchase will be completed sometime during 2009 or early 2010. Any critiques or comments can be sent to James by clicking the comments box at the bottom of the website.

Meetings/Conferences

Spring 2009 Advisory Board Meetings

Plans have been finalized for the Spring 2009 Advisory Board meetings. The TUFFP, TUPDP and TUHOP Advisory Board meetings and both receptions will be held on the University of Tulsa Campus. The TUHOP Advisory Board meeting will be held on Tuesday, March 24th in the Gallery Room at ACAC Breakfast will be served at 8:00 a.m. with the meeting beginning at 8:30 a.m. Following the TUHOP meeting, there will be a TUFFP workshop also in the Gallery Room. There will be a TUHOP/TUFFP reception at 6:00 p.m. in the Faculty Study in McFarlin Library. The TUFFP Advisory Board meeting will be held on Wednesday, March 25th in the Gallery Room. Breakfast will be served at 8:00 a.m. with the meeting beginning at 8:30 a.m. and will adjourn at approximately 5:00 p.m. There will be a TUFFP/TUPDP reception following the TUFFP meeting at 5:30 p.m. in the Faculty Study in McFarlin Library. The TUPDP Advisory Board Meeting will be held on Thursday, March 26th also in the Gallery Room in ACAC. Breakfast will be served at 8:30 a.m. with the meeting beginning at 9:00 a.m. and adjourning after lunch. The Request for Information form will soon be available on the website. All persons from your company that plan to attend the Advisory Board meetings, should complete and return this 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. 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 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 Workshop

The purpose of this workshop is to bring together the researchers, exchange experiences, discuss problems and share new ideas among the member companies. It will be also beneficial to TU by exposing our students and staff to the "real" life problems and helping us to identify future research projects. The first two workshops were a tremendous success and very well received by the membership. The next TUFFP workshop is scheduled for March 24th at 1:00 p.m. in the Gallery room in ACAC.

For those who are interested in giving a presentation for the workshop, abstracts of NO more than 500 words

should be sent to Dr. Michelle LI by via email: michelle-li@utulsa.edu.

The workshop agenda will be arranged according to the submitted abstracts. All the submitted abstracts will be confidential. To promote open discussion, No printed or electronic records will be distributed to anybody.

BHR Group Conference on Multiphase Technology

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. This conference has become one of the premier international event providing delegates with opportunities to discuss new research and developments, to consider innovative solutions in multiphase production area.

14th International Conference on Multiphase Technology, supported by IFP, Technology Initiatives and TUFFP, will be held 17-19 of June 2009 in Cannes, France. The conference 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 which 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 scope of the conference includes variety of subjects pertinent to Multiphase Production in both technology development and applications of the existing technologies. The theme of the conference is *"Bigger, Deeper, Longer".* The detailed information about the conference can be found in BHRg's (www.brhgroup.com).

Fluid Flow Short Course

The 34th TUFFP "Two-Phase Flow in Pipes" short course offering is scheduled for May 18-22, 2009 in Tulsa, Oklahoma. For this short course to be self sustaining, at least 10 enrollees are needed. We urge our members to let us know soon if they plan to enroll people in the short course. The detailed registration information can be found at http:// www.cese.utulsa.edu/programdetail.php?ID=134.

Progress Updates

Slug Flow Evolution in Three-Phase Gas-Oil-Water Flow in Hilly-Terrain Pipelines

Gizem Ersoy

A hilly-terrain pipeline is considered as a pipeline consisting of horizontal, upward inclined, and downward inclined sections. Hilly terrain pipelines are common in both onshore and offshore production and transportation systems. Understanding the characteristics of slug flow in hilly-terrain pipelines will help to prevent or reduce the operational problems, flooding of downstream facilities, severe pipe corrosion, and structural instability of the pipeline, as well as production loss.

The general objectives of this project are to investigate and develop models for the slug flow characteristics in three-phase gas-oil-water flow in hilly-terrain pipelines. These will require an extensive analysis on the distribution of the phases, slug dissipation, generation and growth with changing water cuts.

The gas-oil-water facility of TUFFP was modified for the experimental part of this study. This test facility was used previously by Atmaca (2007) for characterization of oil-water flows in inclined pipes. The facility consists of a closed circuit loop with progressive cavity pumps, heat exchangers, metering sections, filters, test section, separator and storage tanks. The test section consists of 69-m (226.4-ft) long transparent pipes with 50.8-mm (2-inch) diameter. Capacitance and laser sensors were tested for three-phase slug flow conditions. Their limitations were determined within the test matrix. A total of 110 tests were conducted for water cuts of 20%, 40%, 60% and 80% for inclination angle of 5° for the valley configuration. Six cameras were also used to visualize the flow and measure slug flow characteristics. A new high-speed data acquisition program was developed for pressure transducers, laser and capacitance sensors. Data analysis will be conducted by analyzing both pressure drop and change in slug characteristics with water cuts from the outputs of pressure transducers, laser and capacitance sensors and videos. Data analysis and modeling studies for transient three-phase slug flow will be completed by May 2009.

Kyle Magrini

Liquid Entrainment in Annular Two-Phase Flow in Inclined Pipes

Annular flow usually occurs at high gas velocities and low to medium liquid velocities. The liquid flows as a film along the wall of the pipe and as droplets entrained in the gas core. The interface between the gas core and liquid film is usually very wavy, causing atomization and deposition of liquid droplets. Under equilibrium conditions, the rate at which the droplets atomize and deposit becomes equal, resulting in a steady fraction of the liquid being entrained as droplets, F_E. This critical parameter is crucial to understand and model the behavior of annular flow.

The need to obtain for entrainment fraction data at larger pipe diameters and inclination angles has been identified and is the main goal of this project. The TUFFP 76.2-mm (3-in.) severe slugging facility has been modified with an entrainment measurement test section to obtain this data. Experiments for entrainment fraction will be conducted at inclination angles 0^o, 10^o, 20^o, 45^o, 75^o, and 90^o from horizontal. Iso-kinetic sampling and liquid film removal will be used to calculate the entrainment fraction. Quick-closing valves have been installed on the facility to measure the local liquid holdup of the flow.

Currently over 75 of the proposed 150 experiments have been completed, which include results at inclination angles 0^o, 10^o, and 20^o from horizontal. In early spring 2009, the remaining experimental results will be obtained for inclination angles 45^o, 75^o, and 90^o from horizontal. Once all data is obtained, the results will be compared and validated with the current model correlations for entrainment fraction. If necessary, a new correlation will be developed.

Anoop Sharma

Modeling of Hydrodynamics and Dispersions in Oil-Water Pipe Flow

Accurate prediction of oil-water flow characteristics, such as flow pattern, water holdup and pressure gradient is important in many engineering applications. However, despite their importance, liquid-liquid flow has not been explored to the same extent as gas-liquid flow. The objectives of this study are first to develop better model for oil-water flow which captures the physics behind the process, especially for transitions and between two flow patterns, and then to validate the model using available present experimental data.

A model has been developed to predict flow pattern and pressure gradient by considering the fact that each segregated layer (dispersed or single phase) in the pipe system has unique fluid properties and velocities. The system stabilizes to its minimized total energy and always satisfies combine momentum equation. If turbulence is not enough to cause any dispersion, the flow pattern will remain segregated. When any layer thickness falls below 1% of diameter, the thinner phase can be neglected leaving one phase dispersed fully in the other. In between, either partial dispersion flow pattern or dual dispersion flow pattern will exist. Two-fluid model will be used to calculate the pressure gradient, except for full dispersion, where homogeneous model will be used.

A preliminary code is already been written for the model. Currently, the model is being analyzed by comparing the results obtained by the code with the already present experimental data from previous TUFFP studies. After that, all necessary changes will be made in the code or model for better predictions.

Tingting Yu

Multiphase Flow in an Annulus

Upward vertical two-phase flow in annuli was previously studies in TUFFP experimentally and theoretically by Caetano (1986). A mechanistic model was proposed. In light of the new developments in mechanistic modeling, multiphase flow in annuli has been re-investigated.

A new mechanistic model has been developed to predict liquid holdup, pressure gradient and the flow pattern transition. The unified model idea was successfully applied in the modeling of annulus. Caetano's (1986) experimental data were used to evaluate the mechanistic and flow pattern transition models and the results are compared with the modified unified model results. The comparison shows that the predictions from the flow pattern transition models agree well with the experimental observations. For the hydrodynamic model, the average absolute errors for pressure gradient and liquid holdup predictions are within 10% for slug flow and churn flow. However, these errors become larger for annular flow. The results are analyzed to identify the reasons for the large errors in annular flow. A further study is recommended to improve the annular flow model.

Ceyda Kora

Effects of High Viscosity Oil on Slug Liquid Holdup

Effects of high viscosity oil on multiphase flow behavior have been experimentally studied by Bahadir Gokcal (2005&2008). This is a continuation study of the high oil viscosity effect on flow behaviour, and is assigned to Ceyda Kora, a graduate student who joined TUFFP in fall 2008. In recent years, because of the increased consumption of hydrocarbon resources and decline in discoveries of low viscosity oils, the importance of the high viscosity oil has increased. Gokcal (2005) observed the slug flow as the dominated flow pattern for the two phase flow with high viscosity oil. Moreover, Gokcal reported significant differences in slug charactersitics of high viscosity oils when compared with those of low viscosity oils. Gokcal (2005) has already shown that the liquid slug holdup is crucial for the calculation of pressure drop, and thus, it is very important for the design of production and transportation systems. Therefore, the main objective of the present study is to investigate the liquid slug holdup for high viscosity oil and gas flows and develop a better liquid slug holdup closure relationship.

Significant effort has spent on the literature review since the last Advisory Board meeting. One of the challenges of this project is to acquire accurate liquid slug holdup data. Currently, different measurement techniques are being investigated. The capacitance sensor developed in -house has been tested. Unfortunately, the response of the current capacitance sensor was not satisfactory. A detailed report will be provided at Spring 2009 Advisory Board meeting. Next, the feasibility ofdifferential pressure drop measurement across the cross section of the pipe will be tested for liquid holdup measurement. Moreover, we are in communication with IFE for the construction of a fast responding gamma-densitometer for this project.

Low Liquid Loading Gas-Oil-Water Flow in Horizontal and Near Horizontal Pipes

Low liquid loading exists widely in wet gas pipelines. These pipelines often contain water and hydrocarbon condensates. Small amounts of liquids can lead to a significant increase in pressure loss along a pipeline. Moreover, existence of water can significantly contribute to the problem of corrosion and hydrate formation problems. Therefore, understanding of flow characteristics of low liquid loading gas-oil-water flow is of great importance in transportation of wet gas.

Large amount of data were already collected on various flow parameters such as flow patterns, phase distribution, onset of droplet entrainment, entrainment fraction, and film velocity. The results revealed a new flow phenomenon.

Due to insufficient performance of the research assistant, the project was put on temporary hold last fall. A new graduate student was identified to take over the project January 2009 to pursue her Ph.D. degree. She decided to accept a job offer and put her Ph.D. aspirations on hold. Currently, we are searching for a new graduate student for the project. On the other hand, Dr. Yuxing Li, a visiting professor from China, will specifically be working on this project starting February 2009. We hope that Dr. Li's involvement will accelerate the pace of this project.

Update on 6 in. High Pressure Flow Loop

One of the most important issues that we face in multiphase flow technology development is scaling up of small diameter and low pressure results to large diameter and high pressure conditions. Studies with a large diameter facility would significantly improve our understanding of flow characteristics in actual field conditions. Therefore, our main objective in this study is to investigate the effect of pipe diameter and pressures on flow behavior using a larger diameter flow loop.

The design of a high pressure (500 psi operating pressures) and large diameter (6 in. ID) facility was completed before the last Advisory Board meeting. During this period the facility P&ID drawings and the civil and structural engineering work were completed. In Mid-December, we applied for all the applicable building permits that we need from the City of Tulsa and are awaiting approval at this time. We are currently in the process of securing bids for both the concrete work and the structural steel fabrication. Our goal is to have all the concrete work done by the end of February and begin assembling the structural steel in March. The flow-loop itself will probably be constructed during the summer of 2009.

The Sundyne Gas compressor is on location as well as the 500KVA diesel generator that will be providing the electricity for the compressor and liquid pumps. Equipment that still needs to be purchased is as follows: Separation System, Pumps, Liquid Tanks, Surge tank for gas, Flow-Meters, and Instrumentation.

Tulsa University Fluid Flow Prediction Tools (TUFFPT)

TUFFP has created a computer program platform named Tulsa University Fluid Flow Prediction Tools (TUFFPT). The objective of this creation is to streamline the process from experimental data analysis to model development (or improvement) and to convenient applications of the models in multiphase flow calculations. The TUFFP unified model and the previous models are integrated under an Excel VBA interface with unified inputs and outputs. There are four features of this software including Flow Pattern, Case Study, Contour Plot, and Well and Pipeline. In the Flow Pattern module, user can select between Taitel-Dukler, Barnea and TUFFP Unified models for gas-liquid flow pattern prediction. The flow pattern map is automatically generated after the calculation. The Case Study module can be used to predict the detailed multiphase flow behaviors under different flow conditions. It also provides an easy way to compare model predictions with experimental or field data. The Contour Plot module allows the user to generate contour plots of parameters which reflect the flow behaviors across a 2-D plane of gas flow rate versus liquid flow rate. The Well and Pipeline module can be used to do multiphase flow hydrodynamic and heat transfer calculations for a single flowline with changing inclination angles. The TUFFPT is available for the members at www.tuffp.utulsa.edu.

Investigation of Heavy Oil Two-Phase Slug Length in Horizontal Pipe Flow

The significance of the average slug length and slug length distribution in pipelines is related to pipeline design and deliverability and the design of downstream separation facilities. Although several slug length empirical and probabilistic models are available in the literature for light crude oil, there is no such model exist for heavy crude oil. The recently acquired heavy oil slug length data in horizontal pipes in TUFFP (Gokcal, 2008) will be intensively evaluated and analyzed in this study.

The objective of this study is to experimentally and theoretically investigate the average slug length and slug length distribution of heavy oil two-phase flow in horizontal pipes. A comparison of heavy oil and light oil average slug length, slug length distribution and maximum slug length will be carried out to study the effect of viscosity on these slug length parameters. Extensive comparisons will be conducted in this study between the commonly used slug length probabilistic distribution functions, namely Log-Normal and Inverse Gaussian to investigate their suitability to fit the heavy oil slug length distribution. Furthermore, the existing empirical correlations and models' predictions will be validated against the heavy oil experimental data to identify their discrepancy and propose modifications to those models.

Upcoming 2009 ABM's

March 24	TUHOP Advisory Board Meeting TUFFP Spring Workshop TUHOP/TUFFP Reception Tulsa, Oklahoma
March 25	TUFFP Advisory Board Meeting TUFFP/TUPDP Reception Tulsa, Oklahoma
March 26	TUPDP Advisory Board Meeting Tulsa, Oklahoma
September 29	TUHOP Advisory Board Meeting TUFFP Fall Workshop TUHOP/TUFFP Reception Tulsa, Oklahoma
September 30	TUFFP Advisory Board Meeting TUFFP/TUPDP Reception Tulsa, Oklahoma
October 1	TUPDP Advisory Board Meeting

2009 TUFFP Members

Baker Atlas
BP
Chevron
ConocoPhillips
ExxonMobil
JOGMEC
Kuwait Oil Company
Marathon Oil Co.
Minerals Management Services
Pemex
Petrobras
Petronas
Rosneft Oil Co.
SPT (Scandpower)
Schlumberger
Shell
TOTAL

Calendar of Events

March 24	TUHOP Advisory Board Meeting, Tulsa, Oklahoma
	TUFFP Spring Workshop, Tulsa, Oklahoma
March 25	TUFFP Spring Advisory Board meeting, Tulsa, Oklahoma
March 26	TUPDP Spring Advisory Board meeting, Tulsa, Oklahoma
April 4 - 8	SPE Production and Operations Symposium, Oklahoma City, Oklahoma
May 4 - 7	Offshore Technology Conference, Houston, Texas
May 18 - 22	TUFFP Short Course, Tulsa, Oklahoma
June 17 - 19	BHRg's Multiphase Technology 2009, Cannes, France
September 29	TUHOP Advisory Board Meeting, Tulsa, Oklahoma
	TUFFP Fall Workshop, Tulsa, Oklahoma
September 30	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
October 1	TUPDP Advisory Board Meeting, Tulsa, Oklahoma
October 4 - 7	SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana
December 7 - 9	International Petroleum Technology Conference, Doha, Qatar