T U F F P

Tulsa University Fluid Flow Projects

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From the director's desk:

Time passes quickly. It is already February 2008. TUFFP has reached to another milestone. This year is the 35th year TUFFP service to its members. I will take this opportunity to thank our membership for their continued and unwavering support.

Since the last Advisory Board meeting everybody at TUFFP has been quite busy. In this newsletter, you will find a short progress report on each of the projects currently underway. I would like to look back and highlight some of the TUFFP activities and accomplishments in 2007.

- Two of the Research assistants graduated with MS degrees and hired by two service companies even before their graduation.
- One of our research associates was hired by a service company.
- Four new research assistants started their studies.
- Two new research associates, Drs. Al-Sarkhi and Li, were hired. They have been excellent additions to our team.
- Director Emeritus, Dr. James P. Brill, has been inducted to Oklahoma Higher Education Hall of Fame.
- Associate Director, Dr. Holden Zhang received Zelimir Schmidt Outstanding Researcher Award.
- TUFFP membership rose from 16 to 18. The largest amongst the TU Consortia.
- Two research projects were completed and four new projects were started.
- Two-phase version of TUFFP Unified Model has been incorporated in one of the widely used all purpose software developed and maintained by one of our members.
- Three refereed publications and two conference papers were produced from the past TUFFP research projects.
- TUFFP low-pressure 6 in. ID flow loop has been re-commissioned and the first TUFFP project using the facility has been completed.
- TUFFP embarked on construction of a high pressure—large diameter multiphase flow facility. When completed, the facility will be utilized for various up-scaling projects.

Best regards,

Cem Sarica

Computer Manager Serving in Iraq

James Miller has worked as the TUFFP Computer Manager since July 2006. James was also serving as a flow loop operator for TUPDP. James was called up for military service in November 2007 and deployed to Iraq in January 2008. This is his second tour of duty. We hope James will be back with us in October or November of 2008.

At the present time, we are looking for a part-time temporary person to fill his position until he returns.

Recent Publications and Presentations

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

Keskin, C., Zhang, H. Q., and Sarica, C.: "Identification and Classification of New Three-Phase Gas/Oil/Water Flow Patterns," SPE 110221, Presented at SPE 2007 Annual Technical Conference and Exhibition, Anaheim, CA, Nov. 11-14, 2007.

Vielma, M., Atmaca, S., Zhang, H. Q., and Sarica, C.: "Characterization of Oil/Water Flows in Horizontal Pipes," SPE 109591, Presented at SPE 2007 Annual Technical Conference and Exhibition, Anaheim, CA, Nov. 11-14, 2007.

Gokcal, B., Wang, Q., Zhang, H. Q., and Sarica, C.: "Effects of High Oil Viscosity on Oil-Gas Flow Behavior in Horizontal Pipes," SPE 102727, Accepted for Publication in SPE Projects, Facilities & Construction Journal, 2008.

TUFFP Membership and Support

We lost Landmark Graphics as a member for 2008. The current membership of TUFFP stands at 16 industrial members and Mineral Management Services of Department of Interior (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.

We thank our members for their continued support. DOE funding that has supported our research activities in oil-water-gas project is ending in 2008. This means a loss of about $145,000/year income. To be able to continue at the same capacity and pace, the membership fee is increased to $48,000/year effective 2008.

Current TUFFP Members

Baker Atlas	**Pemex**
BP	**Petrobras**
Chevron	**Petronas**
ConocoPhillips	**Rosneft Oil Co.**
ExxonMobil	**Schlumberger**
JOGMEC	**Shell**
Kuwait Oil Company	**TENARIS**
Marathon Oil Co.	**TOTAL**
Minerals Management Services	

Upcoming 2008 ABM's

March 5	TUHFP Advisory Board Meeting Houston, Texas
April 14	TUHOP Advisory Board Meeting TUFFP Spring Workshop TUHOP/TUFFP Reception Tulsa, Oklahoma
April 15	TUFFP Advisory Board Meeting TUFFP/TUPDP Reception Tulsa, Oklahoma
April 16	TUPDP Advisory Board Meeting Tulsa, Oklahoma
September 16	TUHFP Advisory Board Meeting TUHOP Advisory Board Meeting TUFFP Fall Workshop TUHFP/TUHOP/TUFFP Reception Tulsa, Oklahoma
September 17	TUFFP Advisory Board Meeting TUFFP/TUPDP Reception Tulsa, Oklahoma
September 18	TUPDP Advisory Board Meeting

Meetings/Conferences

Spring 2008 Advisory Board Meetings

Plans have been finalized for the Spring 2008 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 Monday, April 14th in the Gallery Room at ACAC Breakfast will be served at 8:30 a.m. with the meeting beginning at 9:00 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 President's Suite in the Reynolds Center. The TUFFP Advisory Board meeting will be held on Tuesday, April 15th 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 6:00 p.m. in the President's Suite in the Reynolds Center. The TUPDP Advisory Board Meeting will be held on Wednesday, April 16th also in the Gallery Room in ACAC. Breakfast will be served at 9:00 a.m. with the meeting beginning at 9:30 a.m. and adjourning at approximately 3:00 p.m. The Request for Information form and hotel information will soon be available on the website. 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. 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

Following to the discussions at the Advisory Board Meeting (ABM) in November 2007, TUFFP is initiating a workshop program. The length of the workshop will be ½ day. The first workshop is scheduled right before the upcoming TUFFP ABM in April.

The purpose of the 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.

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.

BHRg's 2008 Multiphase Production Technology 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. 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.

6th North American Conference on Multiphase Technology, supported by Neotechnology Consultants of Calgary, Canada, New Technology Magazine, SPT Group and TUFFP, is scheduled to be held 4-6 of June 2008 in Banff, Canada. 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 conference brings together experts from across the American Continents and Worldwide.

The scope of the conference includes variety of subjects pertinent to Multiphase Production in both technology development and applications of the existing technologies. Over 30 papers will be presented at the conference. The detailed information about the conference can be found in BHRg's (www.brhgroup.com).

Fluid Flow Short Course

The 33nd TUFFP "Two-Phase Flow in Pipes" short course offering is scheduled May 12-16, 2008. For this short course to be self sustaining, at least 10 enrollees are needed. We urge our TUFFP and TUPDP members to let us know soon if they plan to enroll people in the short course.

Progress Updates

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 10000 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. Multiphase flows are expected to exhibit significantly different behavior for higher viscosity oils.

Gokcal in his previous work at TUFFP observed slug flow to be the dominant flow pattern for the high viscosity oil and gas flows. It was found that increasing oil viscosity had a significant effect on flow behaviors. The knowledge of the slug flow characteristics is crucial to design pipelines and process equipments. In order to improve the accuracy of slug characteristics for high viscosity oils, accurate closure models for slug flow are needed.

The objectives of this study are to:

- Acquire experimental data on characteristics of slug flow for high viscosity oil.
- Develop closure models on slug flow for high viscosity oils in horizontal and near-horizontal pipes.
- Validate proposed models with experimental results.

TUFFP High Viscosity Facility (2-in. ID) has been modified. New visualization box is installed on the acrylic pipe to observe and record flow patterns in details. Laser beams and sensors are installed on the test section to measure slug flow characteristics. Temperature transducers and lasers sensors are calibrated. New pipe section is added to the test facility to measure drift velocity as a part of translational velocity closure relationship. The inclination angle can be changed from 0° to 90°. Drift velocity experiments are conducted at different temperatures for the whole range of inclination angles. Experiments on slug flow characteristics for horizontal and near horizontal pipe will be conducted in Spring 2008.

Gas-Oil-Water Flow in Hilly-Terrain Pipelines

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.

Gizem Ersoy

The general objectives of this project are to investigate and develop models for the slug flow 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 and inclination.

The gas-oil-water facility of TUFFP is under modification 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 will consist of 69-m (226.4-ft) long transparent pipes with 50.8-mm (2-inch) diameter. The inclination angles will be ±1°, ±2° from horizontal for the valley and hill configurations. High speed video system will be used to identify the flow patterns and determine the oil-water mixing status. Conductance probes, quick closing valves, laser sensors, pressure and differential pressure transducers are planned to be installed on the facility. Testing is expected to start by May 2008.

Lagrangian-Eulerian Transient Two-Phase Flow Model

Kwon Il Choi

Description of the transient multiphase flow in a wellbore-flowline-riser system is one of the most complex problems in the petroleum production. A new approach for transient computational model for two-phase flow is introduced. In this model, gas mass tracking technique will be applied in order to get around the numeric diffusion which is a persisting problem for the transient multiphase flow programs based on Eulerian grid. TUFFP mechanistic Unified model is coupled as a closure model in a proxy table form for holdup calculation and frictional pressure drop. Currently, the model can simulate transient two-phase flow phenomena as:

- Production startup and shut-in
- Gas lift, gas injection at subsea wellhead or bottom of the riser
- Severe slugging, gas lift instability and production fluctuations

The validation of the model against small scale experimental data remains to be concluded during the spring of 2008.

Multiphase Flow in an Annulus

Tingting Yu

Upward vertical two-phase flow in an annulus was previously studied in TUFFP experimentally and theoretically by Caetano (1984 and 1985). A mechanistic model was proposed. In light of the new developments in mechanistic modeling, multiphase flow in an annulus will be investigated.

Ms. Yu serves Teaching Assistant in Petroleum Engineering Department. She is pursuing this project as her MS thesis. She is currently reviewing the literature.

Feng Xiao

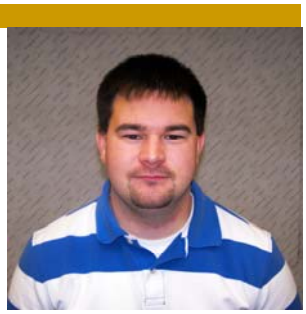
Low-Liquid Loading Gas-Oil-Water Flow in Inclined Pipes

Since the last Advisor Board meeting, Mr. Feng Xiao has taken over the research work on Low Liquid Loading Three Phase Flow. This study consists of both experimental and theoretical parts, aiming at evaluation and improvement of existing models and establishing new model specifically for this case. The experimental part of the research is conducted on a large scale 152.4-mm ID (6-in) and 120 m length loop.

The initial Low Liquid-loading Three-phase Horizontal Flow tests have been completed by Mr. Hongkun Dong, former MSc student. A total of 156 data points were acquired and many valuable recommendations were given.

Currently, a more careful analysis of the horizontal flow results is being made by comparing with Fan (2005) and Unified Three Phase Models and identifying the gaps in the data to develop better closure relationships. After completion of the data analysis, additional horizontal flow tests will be conducted as identified. Moreover, Mr. Xiao is working on the facility and instrumentation modification for the Low Liquid Loading Three Phase Inclined Flow testing, which involves -2° and +2° inclined angles.

Liquid Entrainment in Annular Two-phase Flow in Inclined Pipes



Kyle Magrini

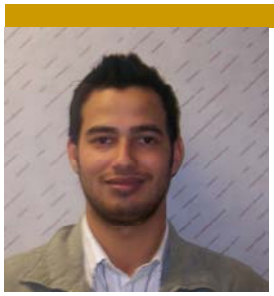
Dr. Abdel Al-Sarkhi presented “Droplet-Homophase Interaction: Effect of Pipe Inclination on Entrainment Fraction” at the November 2007 advisory board meeting. In his presentation, Dr. Al-Sarkhi identified the need for more entrainment fraction data at larger pipe diameters and inclination angles. To obtain more experimental data, the TUFFP 76.2-mm (3-in.) severe slugging facility will be modified with an entrainment measurement test section. The results of this study will be compared with existing models to determine application range and accuracy.

Preliminary tests have already begun on the 50.8-mm ID (2-in.) TUFFP gas-oil-water facility. This facility was modified with a porous test section that, under annular

flow conditions, will strip the liquid film leaving only the entrained liquid droplet flow in the pipe. From this liquid film flow rate, the droplet entrainment fraction will be calculated. The objectives of these preliminary tests are to:

- Establish a procedure to accurately obtain droplet entrainment fraction from liquid film flow rate.
- Test performance of the test section under varying flow rates and inclination angles, and
- If necessary, suggest modifications and new development for the test section.

Currently, the literature review is under way. Modifications for the 76.2-mm ID (3-in.) severe slugging facility will be concluded by late spring with experimental data collection to begin immediately following completion.



A Study on Oil-Water Flow Closure Relationships

Anoop Sharma

The occurrence of oil-water flow is common in many industries and areas especially in transportation of oil-water through pipeline. Therefore, understanding the physics of oil-water flow is essential but not much work has been done in oil-water flow in comparison to gas-liquid flow.

Several oil-water studies have been completed through TUFFP and other research programs. These studies resulted in significant amount of data. The main objective of the present work is to further our understanding of the oil-water flow utilizing the existing data, thereby modifying the present models through the development of better closure relationships or if necessary, propose a new model.

Currently, the existing data are being used to better identify the shortcomings of the existing models.

Upscaling Studies of Multiphase Flow

Abdel Al-Sarkhi

Scaling up of small diameter and low pressure results to the large diameter and high pressure conditions is very important in multiphase flow research. Studies with a large diameter facility would significantly improve our understanding (and modeling) of flow characteristics in actual field conditions. Therefore, our main objective in this project is to be able to investigate the effect of pipe diameter and pressures on flow behavior using a large diameter and high pressure flow loop. The facility is designed for gas-oil-water three-phase flow. The operating pressure will be 500 psig. The length of the flow loop will be approximately 523 ft, and the pipe diameter will be 6 in. The last section of the flow loop will be 3^o upward and 3^o downward inclinable. The facilities, equipment and instrumentation are designed to work with either natural gas (The Tulsa City Natural gas) or nitrogen. At the operating condition, the natural gas density will be 24 kg/m^3 and the nitrogen density will be 38 kg/m^3. The engineering design has already been completed, and the quotations for most of the equipment have been received and analyzed. Purchasing orders of the biggest ticket items are placed. The construction will start this summer.

Gas-Oil-Water Three Phase Flow Modeling

Michelle Li

Three-phase gas-oil-water flow is a common occurrence in the petroleum industry during the production and transportation of produced fluids. Three-phase flow behaviour such as liquid holdups and pressure gradient may be very different from those of two-phase flow. These can have significant impact on design and many flow assurance issues including hydrate formation, emulsion, wax deposition and corrosion. Therefore, a reliable and general model needs to be developed for prediction of gas-oil-water pipe flow behaviors under different flow conditions.

A unified model and software package to predict the gas-oil-water three phase flow characteristics has been developed. The software package was tested by comparing the prediction results with the available experimental data. The comparison was generally good, except in some cases where the prediction gives fairly large error. The comparison results will be further analysed and the model will be further improved according to the comparison results.

Calendar of Events

March 5	TUHFP Advisory Board Meeting, Houston, TX
April 14	TUHOP Advisory Board Meeting, Tulsa, OK TUFFP Spring Workshop, Tulsa, OK
April 15	TUFFP Spring Advisory Board meeting, Tulsa, OK
April 16	TUPDP Spring Advisory Board meeting, Tulsa, OK
May 5 – 8	Offshore Technology Conference, Houston, Texas
May 11 – 16	Deepwater – The Way Forward, Phuket, Thailand
May 12 – 16	TUFFP Short Course
June 4 – 6 2008	BHRg's Multiphase Technology 2008, Banff, Canada
August 10 – 14	8th International Symposium on Numerical Methods for Multiphase Flows – 2008 ASME Fluids Engineering Conference, Jacksonville, Florida
September 4 – 7	Offshore Europe, Aberdeen, Scotland
September 16	TUHFP Advisory Board Meeting, Tulsa, OK TUHOP Advisory Board Meeting, Tulsa, OK TUFFP Fall Workshop, Tulsa, OK
September 17	TUFFP Advisory Board Meeting, Tulsa, OK
September 18	TUPDP Advisory Board Meeting, Tulsa, OK
September 21 – 24	SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA
December 3 – 5	International Petroleum Technology Conference, Kuala Lumpur, Malaysia