T U F F P

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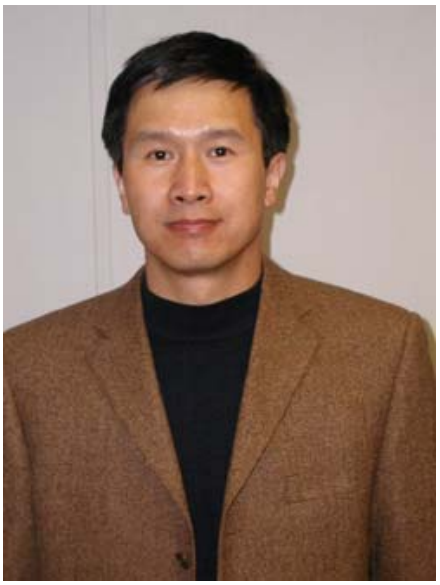


Dr. Shejiao Du Joins TUFFP / TUCoRE

We are very pleased to introduce Dr. Shejiao Du as our newest Post Doctoral Research Associate. Before joining TUFFP, Dr. Sheijiao Du, was a Research Associate of State Key Laboratory of Multiphase Flow, Xian Jiaotong University, Xian, Shaanxi, China. Dr. Du has conducted extensive experimental and theoretical research on Reflux Flooding Phenomena in Vertical Pipes, and Convective Boiling Heat Transfer during High-Pressure Steam-Water Two-Phase Flow in Vertical Pipes. He is currently spending his time primarily on TUFFP and TUCoRE HVMPF project.

New Post Doctoral Research Associate Offered Position

Due to increase in our activities, an additional post-doctoral research associate position is created and Dr. Abdel Salam Al-Sarkhi, a Jordanian-Canadian National, is offered and accepted the position after lengthy search process. Currently, he is waiting on the issuance of his H1B visa. Abdel Salam has received a Ph.D. in Mechanical Engineering from Oklahoma State University in 1999. Then, he spent two years as post-doctoral research associate at University of Illinois at Urbana-Champaign under Professor Thomas J. Hanratty. He has been a faculty of Mechanical Engineering Department at Hashemite University in Jordan since fall 2001. He has conducted several research projects and published several peer reviewed papers on multiphase flow in pipes in respected Journals.

Scott Graham Promoted

Effective January 2, 2007, Mr. Scott Graham, Senior Electronics Technician has been promoted to Project Engineer position. With this promotion, Scott oversees all of the facility operations and continues to be the senior electronics technician for TUFFP and TUPDP consortia and related projects.

Computer Manager and Web Administrator Positions are Combined

After the resignation of Ms. Jessica Kurtz as Web Administrator, Mr. James Miller, Computer Manager, has assumed the duties of TUFFP/ TUPDP Web Administrator. His original part-time position is converted to full time due to increase in his work load.

Congratulations to Our Recent Graduates

Mr. Antonio Bruno of TUPDP and Ms. Maria (Nina) Vielma of TUFFP have successfully completed their MS degree requirements. Antonio is currently working for Chevron and Nina is working for Schlumberger Information Solutions. We wish Antonio and Nina the best in their future endeavors.

TUFFP Membership and Support

We have lost Saudi Aramco as a member for 2007. The current membership of TUFFP stands at 15 industrial members and Mineral Management Services of Department of Interior (MMS). We expect ExxonMobil, Invensys and JOGMEC to join TUFFP in 2007. BHP has shown an interest in joining TUFFP.

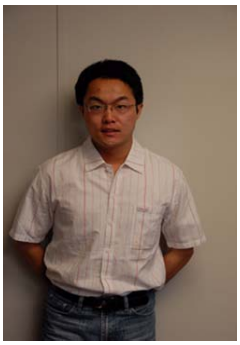
DOE supports TUFFP in the development of new generation multiphase flow predictive tools for three-phase flow research. DOE's support translates into the equivalent 4 additional members for five years, effective July 2003.

New Research Assistants Arrived

Mr. Yitie Han

Two new MS students joined TUFFP/ TUPDP. Mr. Feng Xiao, from Peoples Republic of China, received a BS degree in Petroleum Engineering from China University of Geosciences with a distinction of ranking first in his graduating class. Mr. Xiao joined us in January 2007 and will be assigned a project in TUFFP soon.

Mr. Yitie Han, also from Peoples Republic of China, received a BS degree in Mechanics-Electronics from Hebei University of Technology, China. He was employed by China National Offshore Oil Corporation, Tianjin as an engineer and as deputy project manager for China Petroleum Technology & Development Corporation, SUDAN Branch. Mr. Han joined TUPDP in January 2007 as a research assistant.



Mr. Feng Xiao

Current TUFFP Members

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

Recent Publications and Presentations

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

Fan Y., Wang, Q., Zhang, H. Q., Sarica, C., and Danielson, T.: "A Model To Predict Liquid Holdup and Pressure Gradient of Near-Horizontal Wet-Gas Pipelines," SPE 95674, Accepted to be Published in *SPE Projects, Facilities & Construction Journal*.

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, Presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, TX, September 24 – 27, 2006.

Al-Safran, E. Sarica, C. Zhang, H. Q., and Brill, J.P: "Mechanistic/Probabilistic Modeling of Slug Initiation in a Lower Elbow of a Hilly Terrain Pipeline," SPE 102254, Presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, TX, September 24 – 27, 2006.

Upcoming ABM's

November 5, 2007	TUFFP/TUPDP/TUHFP Facilities Tour The University of Tulsa North Campus 2450 East Marshall Tulsa, Oklahoma 3:00 - 5:00 p.m.
	TUFFP/TUPDP/TUHFP Barbeque The University of Tulsa North Campus 2450 East Marshall Tulsa, Oklahoma 5:00 - 7:00 p.m.
November 6, 2007	TUFFP Advisory Board Meeting The University of Tulsa Allen Chapman Activity Center Tulsa, Oklahoma 8:00 a.m. - 4:00 p.m.
	TUFFP/TUPDP Reception The University of Tulsa Allen Chapman Activity Center Tulsa, Oklahoma 5:30 - 3:00 p.m.
November 7, 2007	TUPDP Advisory Board Meeting The University of Tulsa Allen Chapman Activity Center Tulsa, Oklahoma 8:00 a.m. - 4:00 p.m.
	TUHFP Reception The University of Tulsa Allen Chapman Activity Center Tulsa, Oklahoma 5:30 - 8:00 p.m.
November 8, 2007	Hydrate JIP Advisory Board Meeting Location to be determined Tulsa, Oklahoma 8:00 a.m. - 2:45 p.m.

Meetings/Conferences

Spring 2007 Advisory Board Meetings

Plans have been finalized for the Spring 2007 Advisory Board meetings. The TUFFP, TUPDP and TUHFP Advisory Board meetings and both receptions will be held on the University of Tulsa Campus in the Allan Chapman Activity Center. The TUFFP Advisory Board meeting will be held on Tuesday, April 24th in the Gallery Room. Breakfast will be served at 8:00 a.m. with the meeting beginning at 8:45 a.m. and will adjourn at approximately 4:00 p.m. The Request for Information form and hotel information are now 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. A reception will be held following the TUFFP meeting in the President's Formal Lounge beginning at 5:30 p.m. The TUPDP Advisory Board Meeting will be held on Wednesday, April 25th. 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. There will also be a facility tour of the North Campus on Wednesday at 3:15 p.m. A reception will follow the facility tour in the President's Formal Lounge beginning at 6:00 p.m. The TU Hydrate JIP (TUHFP) Advisory Board meeting will be held on Thursday, April 26th. Breakfast will be served at 7:45 a.m. with the meeting beginning at 8:30 a.m. in the Gallery Room and will adjourn at approximately 3:00 p.m.

BHR Group's 2007 Multiphase Production Technology Conference

BHR Group's 2007 Multiphase Production Technology is scheduled to be held between June 13 and 15, 2007 in Edinburgh, UK. This conference is co-sponsored by BP, Bornemann Pumps, IFP, SPT Group Technology Initiatives, and TUFFP. It brings together experts Worldwide. 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 whom multiphase technology offers a novel solution to their problems. The conference will also be of particular value to designers, facility and operations engineers, consultants and researchers from operating, contracting, consultancy and technology companies.

Over 30 papers in various multiphase flow and flow assurance subjects will be presented at this conference. The detailed information about the conference can be found on BHRg's web site www.brhgroup.com.

TUFFP Short Course

The 32nd TUFFP "Two-Phase Flow in Pipes" short course is scheduled to be taught May 7-11, 2007 in Tulsa by Dr. Sarica and Dr. Brill. The course covers the most current, up-to-date-research performed at the Tulsa University Fluid Flow Projects (TUFFP) and Tulsa University Paraffin Deposition Projects (TUPDP). This five-day course is focused on the fundamentals of two-phase flow in piping systems encountered in the production and transportation of oil and gas. The short course will include a half-day session on paraffin deposition in pipes. 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. Information regarding the short course can be found at www.cese.utulsa.edu/coursedetail.jsp?db=1&id=53.

Progress Updates

Three-Phase Redistribution in Subsea Flowline-Riser System after Shut-in

Kwon Il Choi

Modeling transient three-phase segregation phenomena in the flowline-riser system will support the prediction of hydrate formation following the cool-down of the fluids and high pressure surge during the extended shut-in. The first stage of the study will be qualitative identification of different transient flow patterns during shut-in to define the scope of the components of the computational model. Then, a transient three-phase flow model will be formulated using the "moving numerical discretization grid" concept which is intended to minimize the numerical diffusion problem. This becomes very important for tracking the precise locations of water, oil and gas along the flow line and riser.

The computational model will be validated with experimental measurements and observations on the TUFFP severe slugging facility consisting of a 65-ft pipeline followed by a 48-ft riser. The main part of the experimental study will be measuring the holdup values of oil, water and gas in the mixture trapped in 7 vertical sections of the riser divided by quick closing valves in a series of different time lapses after closing the top valve. The horizontal part of the pipeline may also require similar experimental measurements. The same operation will be simulated by the computational model and compared to the experimental data.

The following modifications to the facility have been done for the preliminary part of the experimental research:

- Installation of a quick closing valve at the top of the riser to simulate shut-in.
- Installation of automatic closing system for gas input at the bottom of the riser and the top quick closing valve.
- Rearrangement of the data acquisition system.

Currently the numerical model is being adapted to work with time steps as small as 0.1 second. Moreover, the experimental work has been conducted in two-phase flow using oil and air. The initial results are being evaluated to help determine the future testing program.

Effect of High Viscosity on Multiphase Flow Behavior

Bahadir Gokcal

High viscosity oils are discovered and produced all around the world. There are fields that are currently producing oils with viscosities as high as 10,000 cp. High viscosity or "heavy oil" has become one of the most important future hydrocarbon resources with the ever increasing world energy demand and the depletion of conventional oils. Commonly used laboratory liquids have viscosities less than 20 cp. Thus, the gap between actual laboratory data and field data is three orders of magnitude or more. Therefore, existing mechanistic models need to be verified with higher liquid viscosity experimental results.

The objectives of this study are:

- To perform two-phase high viscous oil-air flow experiments in 2-in ID flow loop
- To analyze experimental data and flow behaviors, and
- To develop a better prediction model focusing on closure relationships.

The first phase of the study was completed. The details of the study were reported in Gokcal's MS thesis[1]. The facility is being revised according to the findings from the study. The separation system will be improved. A new cooling system will be designed to control temperature more precisely. A new capacitance sensor has been designed and tested. It will be fabricated and installed to the facility to measure liquid holdup and slug characteristics.

1. Gokcal, B.: "Effects of High Oil Viscosity on Two-Phase Oil-Gas Flow Behavior in Horizontal Pipes," M.S. Thesis, The University of Tulsa, Tulsa, OK (2005).

Gizem Ersoy

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.

The general objectives of this project are to thoroughly investigate, compare existing models and develop closure relationships and predictive models for three-phase flow of gas-oil-water in hilly-terrain pipelines. These will require both experimental tests and model development.

An existing two-phase flow facility of TUFFP will be modified for this study. This test facility was used previously by Al-Safran (2003) for two-phase flow in hilly terrain pipeline. The facility is a 420-m (1378-ft) long, 76.2-mm (3-in.) diameter, horizontal steel pipelines. The facility is planned to be modified to include water phase. The instrumentation will be redesigned based on the experiences from the recent studies. The test facility modifications are expected to be finished by July 2007.

Characterization of Oil-Water Flow in Horizontal Pipes

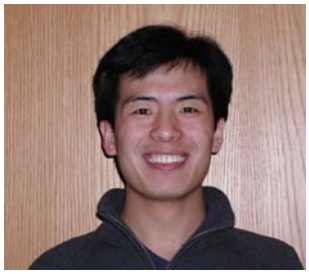
Maria Vielma

The flow of oil and water was experimentally investigated. The flow characterization was accomplished through the acquisition and analysis of experimental data of pressure drop, water holdup, phase distributions and droplet sizes. The experiments were conducted at the gas-oil-water experimental facility. A new data acquisition program was developed using LabVIEWä Express 7.1. All of the instruments were calibrated, and the data were acquired following a careful testing procedure. An uncertainty analysis including random, systematic and combined uncertainties was conducted on the measured parameters.

A total of 159 tests were conducted for the water and oil superficial velocities ranging from 0.025 m/s to 1.75 m/s. A high speed video camera was used to identify flow patterns. A comparison of experimental data points with Trallero's experimental and theoretical transition boundaries was performed. Pressure drop and water holdup data were acquired for each test, and the data was analyzed to understand the flowing characteristics of oil and water. Ten conductivity probes across the pipe diameter were used for each flowing condition in order to obtain the phase distribution. Log-normal droplet size distributions were obtained for fully dispersed flow patterns and the droplet size data obtained were used to evaluate existing models including Hinze (1955), Kubie and Garner (1977), Angeli and Hewitt (2000) and Kouba (2003). Droplet size variation across the pipe cross section was analyzed for dispersions of oil in water over a water layer. From this analysis, an empirical correlation that predicts the Sauter

Mean Diameter (SMD) profile of droplets was developed giving average percentage relative error ranges from 2% to 108% for different oil superficial velocities.

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



Hongkun Dong

Gas-oil-water three phase flow exists in the production and transportation of hydrocarbons. A more accurate prediction of pressure gradient and liquid holdup in near horizontal, wet-gas pipelines is needed to better size pipelines and downstream processing facilities. Moreover, the delivery of the various inhibitors is a strong function of the flow of the fluids and their distribution in pipelines. The objective of this study is to investigate experimentally and theoretically low liquid loading three-phase flow in near horizontal pipes, and to develop improved design models for wet-gas pipelines.

Low liquid loading gas-liquid two-phase flow has been studied both experimentally and theoretically on the flow loops of 50.8-mm ID (2-in.) and 152.4-mm ID (6-in.) by Richard Fan (2005) at TUFFP. A mechanistic two-fluid model with new closure relationships was developed to better predict low liquid loading gas-liquid two-phase flow characteristics.

In this study, the 152.4-mm (6-in.) ID, 54.9-m (180-ft) long flow loop is under modifications for low liquid loading three-phase flow investigation. The PVC pipes have been replaced with steel pipes to alleviate the ageing problem. An oil tank, a new water tank, a preliminary separator, a three-phase separators, two new pumps have been purchased or manufactured and will be added to the system for three-phase flow study. A new metering section for oil and water flow rate measurements will be installed. A new three-phase mixing tee has been developed. A new iso-kinetic probe for liquid entrainment measurement is in development and will be first tested in the experiments. A new cross-sectional viewing and imaging system has been developed and will be applied in the experiments. Laser reflection for film thickness measurement is another new technique developed for this study. Besides these new techniques, a new digital data acquisition system (Delta V) has been installed to the system, and will be tested.

The modification of the flow loop will be completed by the end of February 2007 and the experiments will be conducted thereafter. The measured parameters will include pressure gradients, holdups of the three phases, wetted wall fractions by oil and water, phase distributions and flow pattern transition. The superficial velocities of gas, oil and water will be set in the ranges of 5-25 m/s, 0.00025-0.03 m/s and 0.00025-0.03 m/s, respectively. The inclination angles include -2^o, 0 and 2^o. The experimental results will be compared with low liquid loading two-phase model developed by Richard Fan (2005) at TUFFP, the unified model gas-oil-water pipe flow model of TUFFP and the Taitel and Dukler two-phase flow model. Suggestions will be given for the improvements of these models, and new model will be proposed if necessary.

An Experimental Study of Oil-Water Flow in Inclined Pipes

Serdar Atmaca

Two-phase liquid pipe flow may be defined as the simultaneous flow of two immiscible liquids in pipes. One of the common occurrences in the petroleum industry during transportation and production is oil-water flow in pipes. Moreover, two-phase liquid-liquid flow is so common in process and petrochemical industry where the oil-water flows together in production wells and in sub-sea pipelines. Perhaps, the most relevant and important application is transportation of oil-water through pipelines. Although the accurate prediction of oil-water flow is so essential, oil-water flow in pipes have not been explored as much as gas-liquid flow.

The experimental work will be conducted on the TUFFP's for gas-oil-water flow facility. The facility consists of pumps, heat exchangers, metering sections, filters, test section, separator and storage tanks. One of the most important and new devices we will use to determine the flow behavior is the new optical multiphase flow measurement probes. The automated motor will be mounted to the probe section in order to determine the phase distribution around the pipe section. The new probes will be used to measure liquid holdup and slug behaviors. Also, high speed video camera system will be used to determine the flow behavior. The test section is attached to a boom whose angle can be changed with a cable system and a vertical tower. By changing the angle of test section, we will be able to conduct oil-water flow experiment at different inclined angles. $\pm 5^o$, $\pm 1^o$ and horizontal tests are planned to be conducted. Hot film anemometer will be tested, calibrated and mounted to the test section in order to determine the phase velocities individually.

The literature review is almost completed. The required modifications will be done in the late winter and early spring. Experimental data collection is tentatively scheduled to start in April 2007.

Upscaling Studies of Multiphase Flow

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, a new facility with large pipe diameter and high pressure are proposed at the Fall 2006 TUFFP ABM. With this facility, the effects of pipe diameter and pressure on two-phase flow behaviors can be investigated. Experimental data from this facility can be used to verify existing model predictions.

The pre-engineering design of the facility has been complete. The operating pressure will be 500 psig. Test section will be a 4-in. or 6-in. ID, 380-ft long steel pipe. The operating range of the facility will cover flow patterns as many as possible depending on the gas compressor capacity. As the first step, the facility will be designed for gas oil two-phase flow. Facility can be extended to run gas-oil-water three-phase flow at a late date. The engineering design will be completed in the Summer 2007 and soon after the construction will start.

TUFFP Unified Model for Gas-Oil-Water Pipe Flow

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 behavior 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 has been developed for the prediction of flow behavior during production and transportation of gas, oil and water through wellbores and pipelines. The phase distributions and hydrodynamics are described based on two criteria: gas-liquid flow pattern and oil-water mixing status. The three-phase flow is treated as gas-liquid two-phase flow if the two liquids are fully mixed or as a three-layer stratified flow at low flow rates in horizontal or slightly inclined pipes. Most three-phase flows fall between these two extremes: partially mixed with slippage between the two liquid phases. Closure relationships describing the distribution between the liquid phases, namely mixing and inversion have been proposed. Preliminary validation has been done with experimental results.

A beta version of the unified model for gas-oil-water three-phase pipe flow will be released to TUFFP members at the 2007 Spring Advisory Board meeting. Schlumberger Information Solutions plans to integrate the model into PIPESIM software.

Calendar of Events

March 31-April 3	Production Operations Symposium, Oklahoma City, Oklahoma
April 15-18	Latin American and Caribbean Petroleum Engineering Conference, Buenos Aires, Argentina
April 24	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
April 25	TUPDP Advisory Board Meeting, Tulsa, Oklahoma
April 26	TUHFP Advisory Board Meeting, Tulsa, Oklahoma
April 30-May 3	Offshore Technology Conference, Houston, Texas
May 11	Fluid Flow Projects—Two-Phase Flow in Pipes Short Course, Tulsa, Oklahoma
September 4-7	Offshore Europe, Aberdeen, Scotland
November 6	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
November 7	TUPDP Advisory Board Meeting, Tulsa, Oklahoma
November 8	TUHFP Advisory Board Meeting, Tulsa, Oklahoma
November 10-14	SPE Annual Technical Conference and Exhibition, Anaheim, California