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TUSTP COMPLETES SUCCESSFULLY FIRST-PHASE OF JIP ON COMPACT SEPARATORS

BACKGROUND

Multiphase separation technology has advanced slowly and incrementally for many years. A new look and infusion of novel ideas and concepts are now needed to develop breakthrough technologies in this area for the 21st century. In the past, the petroleum industry has relied mainly on conventional, vessel-type separators to process wellhead production of oil-water-gas flow. For land based oil fields this does not pose a significant problem because of availability of ample space. However, economic and operational pressures continue to force the petroleum industry to seek less expensive and more efficient separation alternatives in the form of compact separators. This is specially significant for offshore applications where availability of space and weight-carrying-capacity of platforms become critical and expensive. As compared to the bulky, heavy and expensive vessel-type separators, compact separators are simple, low-cost, low-weight, require little maintenance and are easy to install and operate. However, a lack of understanding of the complex multiphase hydrodynamic flow behavior in compact separators inhibits complete confidence in their design and necessitates additional research and development. The Tulsa University Separation Technology Projects (TUSTP) was established in 1994 as a Joint Industry Project (JIP) to fulfill this objective. TUSTP is supported by 17 companies, including leading national and international oil companies and vendors.

MISSION

The mission of TUSTP is to advance the state-of-the-art of compact separation technology for gas/oil/water flows. Emphasis is placed on the measurement and understanding of the hydrodynamic flow behavior in compact separators and the development of design tools for the industry. Long-term cooperation with the industry is envisioned in conducting projects to better understand, analyze and design compact separators and compact separation systems.

INITIAL-PHASE (1994/97)

In the initial phase, the foundation study of the JIP was established, focusing on the design and performance of the Gas Liquid Cylindrical Cyclone (GLCC) compact separator for multiphase production facilities. The GLCC is simple, inexpensive, efficient, requires little maintenance and is easy to install and operate, and has a wide range of applications, from only partial separation to full separation. The aim of the project is to make the GLCC more predictable, reliable and viable for the Petroleum Industry. Following is a summary of the activities and results of the first-phase of the JIP.

ACHIEVEMENTS

- Detailed experimental investigations were conducted for single-inlet, dual-inlet and passive level control GLCC prototypes, utilizing different fluid properties, to establish the operational envelope corresponding to the onset of liquid carry-over and measure % liquid carry-over beyond it.
- A Mechanistic model was developed for prediction of the hydrodynamic flow behavior in the GLCC, including the equilibrium liquid level, vortex shape, operational envelope for liquid carry-over and bubble trajectory analysis.
- A dedicated CFD code for the GLCC was developed and CFD simulations were carried out, using a commercial code, both aimed at shedding more light on the complex multiphase flow behavior in the GLCC. The simulations results are being incorporated into the mechanistic model.
- TUSTP has helped member companies to design GLCC separators for their operations. Chevron, Texaco, Intevep, Schlumberger and Petrobras are several of TUSTP member companies that already utilize, or, are in the process of utilizing GLCCs in their operations. Krebs Petroleum is now offering a commercial GLCC separator in their product line, designed based on the technology developed by TUSTP.

DELIVERABLES

The deliverables of TUSTP to the supporting member companies include:

- New GLCC experimental data and design criteria.

- A user-friendly Visual Basic interface computer code which is the state-of-the-art for design of GLCC separators.
- Technical help for designing GLCC separators in field applications.
- A dedicated, stand alone, PC version CFD code (TUCFD) for the simulation of multiphase flow behavior in GLCCs.
- 2-D and 3-D CFD models simulated with the commercial code CFX for the prediction of the detailed flow behavior in the GLCC.
- A third generation GLCC prototype incorporating an improved inlet configuration design based on the laboratory experimental results, field operation feedback and modeling and simulation results.

SUCCESSFUL APPLICATIONS

TUSTP research is aimed at technology transfer and rapid deployment of GLCCs in the field. The recently developed technology has been implemented successfully by the member companies within the USA and overseas, as detailed below, demonstrating the great potential of the GLCC for the Petroleum Industry.

- *Multiphase Metering Loop*: In this application, the GLCC is used as an integral feature of a multiphase metering loop. This type of measurement loop configuration affords several advantages over either conventional separation and single-phase measurement or nonseparating multiphase meters. The compactness of the GLCC allows the measurement loop to weigh less, occupy less space, and maintain less hydrocarbon inventory than a conventional test separator. Furthermore, complete or even partial gas-liquid separation can improve the accuracy of each phase rate measurement in a multiphase metering system. More than two dozen GLCC multiphase metering loops are being operated by Chevron in Oklahoma and other locations. Texaco tested the GLCC in its multiphase meter under field conditions in the Humble facility in Houston and installed one unit in the Eugene Island 354 platform. Intevep/Maraven, Venezuela is in the process of installing a multiphase meter on a Lake Maracaibo platform.
- *Partial Separation:* A compact GLCC is often very appropriate for applications where only partial separation of gas from liquid is required. One such application is the partial

separation of raw gas from high pressure wells to use for gas lift of low pressure wells. The GLCC is a central feature in the design for raw gas lift system operated by Chevron in Okan, Nigeria. The use of GLCC eliminated gas compressors and pipelines to and from the wells. Separating a significant portion of the gas will reduce fluctuations in the liquid flow and may result in improved performance and smaller units of other downstream separation devices. Krebs Petroleum Technologies has conducted field studies on the use of a GLCC in series with other compact separation devices such as a wellhead desanding hydrocyclone in order to reduce the required size of the desander and improve its performance.

- *Enhancing existing separators*: As an added apparatus upstream to an existing separator, the GLCC can enhance the performance of the separator and increase its throughput capacity. Petrobras, Brazil has designed an added GLCC separator in one of its fields. Also Schlumberger, Etudes et Productions, France, is evaluating the possibility of incorporating GLCCs upstream of their test separators.
- *Compact Separation Systems*: Compact separation systems are a key element in reducing cost of production operations. Several member companies are looking into utilizing the GLCC in a compact separation system, for example to improve the performance of a free water knock out hydrocyclone (Chevron).
- *Commercial GLCC Products*: Krebs Petroleum has incorporated the GLCC into its compact separators product line. Accuflow incorporated the GLCC into their commercial multiphase metering system.

STUDENTS INVOLVEMENT IN TUSTP RESEARCH

Six graduate students have completed their studies in TUSTP in the past 3 years. Following are the names of the students and their thesis/dissertation titles. The completed studies served as reports to the participating member companies:

- Mauricio Prado: "A Block Implicit Numerical Solution Technique for Two-Phase Multidimensional Steady-State Flow" (Ph.D., PE, 1995).
- Inta Arpandi: "A Mechanistic Model for Two-Phase Flow in Gas-Liquid Cylindrical Cyclone Separators" (MS, PE, 1995).

- Ashoutosh Joshi : "Two-Phase Flow in Gas-Liquid Cylindrical Cyclone Separators - Experiments and Modeling" (MS, PE, 1995).
- Ferhat Erdal: "CFD Simulations of Single-Phase and Two-Phase Flow in Gas-Liquid Cylindrical Cyclone Separators" (MS, ME, 1996)
- Brenno Motta: "Rotational Two-Phase Flow in Gas-Liquid Cylindrical Cyclone Separators" (Ph.D., PE, 1997).
- Shaya Movafaghian "The Effects of Geometry, Fluid Properties and Pressure on the Flow Hydrodynamics in Gas-Liquid Cylindrical Cyclone Separators" (MS, PE, 1997).

Six Students are currently pursuing graduate degrees at TUSTP on the following topics:

- Williams Chirinos: "Liquid Carry-over in Gas-Liquid Cylindrical Cyclone Separators" (MS, PE).
- Ferhat Erdal: "Local Measurements and CFD Simulation of Two-Phase Flow in Gas-Liquid Cylindrical Cyclone Separators" (Ph.D., ME).
- Luis Gomez: "Gas Carry-under in Gas-Liquid Cylindrical Cyclone Separators" (MS/Ph.D., PE).
- Ivan Mantilla: "Comparison between CFD Simulations and Mechanistic Modeling of GLCC Separators" (MS, PE).
- Carlos Oropeza-Vasquez: "Three Phase-Flow in Gas-Liquid Cylindrical Cyclone Separators" (Ph.D., PE).
- Shoubo Wang: "Passive and Active Control of Gas-Liquid Cylindrical Cyclone Separators" (MS/Ph.D., PE).

Currently, three faculty members are involved in TUSTP research, namely, Drs. Ovadia Shoham (PE), Siamack Shirazi (ME) and Ram Mohan (ME).

PUBLICATIONS

The research conducted at TUSTP during the past three years have resulted in six publications. One was presented at the 7th international BHR Group meeting on "Multiphase Production" (Cannes, France, June 1995), the second was presented at the 1995 Annual SPE Meeting

(Dallas, October 1995), and was published in the SPE Journal in December 1996. Two other publications were presented at international conferences in England: "Hydrocyclone 96" (Cambridge, UK, April 1996) and “Production Separation Systems” (Aberdeen, UK, April 1996). A fifth paper, presented at the 1996 Annual SPE Meeting in Denver, will be published in the SPE Journal in September 1997. Finally, a sixth paper was presented at the ASME FED summer meeting (Vancouver, Canada, June 1997).

Several papers are under preparation for the International Journal of Multiphase Flow, IBC Production Separation Systems Forum (Houston, November 1997) and the Journal of Petroleum Technology.

LEVERAGE OF FUNDING

A cooperative effort is being pursued between The University of Tulsa (TUSTP) and the Louisiana State University (LSU) in the area of compact separation technology. The principal investigator at LSU is Dr. Stuart Scott. The complementary nature of the research facilities and expertise of these institutions are expected to provide maximum leverage of research dollars for participating companies. LSU will provide field-scale, high pressure testing capabilities with real crudes and application oriented research geared for deepwater and subsea multiphase production systems, which is a JIP under way in LSU directed by Dr. Scott.

In an effort to leverage TUSTP funding and to expand the JIP activities, TUSTP has submitted a proposal to DOE. The proposal is aimed at the extension of the JIP research to three-phase gas/oil/water flow. TUSTP wishes to thank Ms. Rhonda Lindsey from the DOE National Petroleum Technology Office in Tulsa for her guidance and support of the proposal. In Phase-I of this proposal, the existing two-phase GLCC facility will be expanded to three-phase flow, data will be acquired and a mechanistic model and CFD simulations will be conducted. Phase-II will include high pressure testing of the GLCC at LSU. The total budget is $766,000 for 5 years.

Another proposal has been submitted by TUSTP to the Oklahoma Center for Advancement of Science and Technology (OCAST) for conducting research on GLCC design improvement through local measurements of the hydrodynamic flow behavior and development of an active control system for the GLCC. The total budget of this proposal is $250,000 for 3 years.

LONG TERM PROJECTS

Possible future long term projects of compact separators include the study of other compact separator configurations such as tee junctions, auger, vortex tube, etc., enhancement of convective heat transfer, down-hole configurations, variable inlet area, modern control systems, compact separation systems, field testing, handling foam and emulsion, and sand handling capabilities and the effect of solids in erosion of compact separators.

We are not limited to the GLCC. Our mission is, however, COMPACT separators, and compact separation systems.

Other compact separator configurations that we might study in the future are tee junctions, auger, vortex tube, down-hole configurations and variable inlet area separators. We would like to test compact separation systems, including several separation units in series, such as a GLCC with a hydrocyclone etc.

We are also interested in the following topics: enhancement of connective heat transfer, modern control systems, high pressure/field testing, handling foam and emulsion, and sand handling capabilities and the effect of solids in erosion of compact separators.

At the present time we are moving to GLCC separators with 3 phase flow. We will check if the GLCC can separate roughly the free water (not complete separation) from the oil. We got a contract from DOE to do it and this will be shared with the members of TUSTP.