Multiphase flow gets closer to reality

A transient multiphase simulator improves accuracy for temperature calculations and prediction of slug behavior.

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With the need to produce from deeper, colder and less accessible fields, production systems are becoming more complex, and the risk of flow assurance problems is becoming proportionally higher. Through game-changing technology and extensive testing, a new breed of simulator brings multiphase flow calculations even closer to reality.

Emergence of multiphase flow research

Multiphase flow research in the oil and gas industry has been driven over the past 30 years by two Norwegian institutes, SINTEF and IFE. These institutes developed a technology that made it possible to transport oil and gas in a single pipeline over long distances, which became known as multiphase transport. Transportation of the multiphase fluid stream over long distances is extremely complicated, and before operators could invest in long subsea pipelines they needed to understand these challenges and reasonably predict any flow assurance problems such as slugging and hydrate formation.

New discoveries in the Norwegian Continental Shelf at greater water depths (50 m to 70 m or 164 ft to 230 ft) and sharply increasing costs in the 1980s were the drivers to develop a multiphase flow simulation tool that could facilitate these types of projects. The first transient engineering tool for design, operational support and simulation of multiphase pipelines was developed, enabling the application in smaller fields and subsea-to-beach transfer.

Since then, long-distance multiphase transport has been firmly on the agenda for oil and gas companies as field developments have moved into deeper water (850 m to 1,500 m or 2,789 ft to 4,921 ft) and with longer step-offs (up to 550 km or 342 miles).

Aware of these subsea challenges and the need for improved accuracy predicting flow conditions, ConocoPhillips and SINTEF teamed up to develop a new multiphase flow tool. Total E&P soon came on board along with Kongsberg Oil & Gas, and the integrated tool known as LedaFlow was born. For more than a decade LedaFlow has continued to keep pace with the maturing of the digital oil field.

Dynamics of multiphase behavior

The LedaFlow multiphase transient simulator is a tool that models the dynamics of multiple fluid phases within well and pipe networks. Understanding the dynamics of multiphase behavior assures safe and reliable operation of complex production systems while uncertainties in predictions can result in serious operational problems. Improved prediction accuracy of transient multiphase flow allows the design of longer multiphase pipelines, therefore reducing the amount of processing required offshore and increasing the operational safety margins.

Adding value across the life cycle

LedaFlow is used throughout field development in feasibility studies, conceptual studies, FEED and detailed designs, and operation of the field.

Transient simulation is needed to address more detailed design and operability considerations. The fundamental driver to model the dynamics of multiphase flow in wells and pipelines is to understand and thereby manage the liquids, both within the system and as they leave the pipelines and enter the first stages of processing.

A transient multiphase simulator must accurately determine the locations for liquid accumulation due to local differences in phase velocity (slip). Some typical flow assurance applications for LedaFlow include determining system/component warm-up and cooldown times, blowdown fluid rates and temperatures, slugging behavior (rate change, hydrodynamic and more severe terrain-induced slugging), liquid inventory during pigging and rate changes, prediction of liquid holdup in low-rate gas/condensate systems, gas lift impact on flow conditions, inhibitor tracking and hydrate risk assessment, and thermal design of flowlines.

Two key features that provide increased operability stability are:

- The LedaFlow Buried Pipe Model that provides increased accuracy and resolution for temperature calculations, reducing uncertainty and leading toward optimal design. Relevant applications include blow down, top-of-line corrosion, material selection, pipe thermal stress, wax deposition and hydrate risk; and
- The LedaFlow Slug Capturing module, the first commercial implementation of technology that predicts

hydrodynamic slugs. Previously, it was possible to approximately replicate field observations by imposing user-controlled slug seeds and tuning them to match the observed results as closely as possible. However, this approach did not capture the interaction of hydrodynamic and terrain slugging, and that meant that the limits of stable operation were not properly understood. This could lead to significant operational difficulties avoided with the LedaFlow Slug Capturing module.

Validated against lab, field data

LedaFlow has been extensively validated against laboratory and field data to confirm the primary objectives of accurately estimating liquid holdup that causes pressure to drop within pipelines.

Testing included comparison with experimental data (more than 12,000 experimental points) and field data (pipelines and wells, from wet gas to oil) as well as comparisons to other commercially available software. Another part of the testing was focused on typical flow assurance user cases; transient simulations such as turn-down, shutdown, startup and depressurization were run for a number of realistic field geometries.

Development of the tool has been based on both existing and new large-scale experimental data from the Tiller loop. Data were acquired for holdup, pressure gradient and flow regime. These data are exclusively available for the development of LedaFlow and fill in data gaps in the existing SINTEF database.

The LedaFlow partners provide field data from various types of fields in operation around the world. A joint industry project called LedaFlow Improvements to Flow Technology or LIFT is a three-year project to compare LedaFlow against field data provided by the operator partners and identify areas of improvement in the models used. There is a focus on areas where LedaFlow provides particular strength such as the solution of three energy equations to resolve temperatures with greater accuracy, the prediction of slug behavior and the flexibility of the solution to allow users to impose their own physical models. All of the operators involved share relevant field data from various fields around the world.

The LedaFlow partners have installed more than 90 solutions across the globe, and it is now a proven alternative to legacy solutions.

The transient three-phase 1-D simulator offers new modeling capabilities as it is based on a model concept conserving mass for nine fields (bubbles, droplets and continuous fluids), using three momentum equations and solving for the enthalpy and temperature of the three individual fluid zones. The multifluid, multiphase approach is unique to LedaFlow in that no other multiphase flow tool on the market today solves as many equations. The additional number of mass and energy equations provides increased results and insight into fluid changes on a first-principle level.

LedaFlow was developed to improve the overall design and operation of multiphase pipelines. (Source: Kongsberg Oil and Gas Technologies)

Future of multiphase operations

Improving accuracy and reliability on the existing multiphase flow tools that are out there is important as challenges in multiphase flow increase and evolve. Improved accuracy will result in confidence in designing pipelines with reduced safety margins.

There have been many attempts at developing an alternative multiphase flow tool, but they have not achieved the level of success or market share desired. What makes LedaFlow different includes the industry involvement from the start, early market input from a commercialization partner with a strong background in this domain, an agile and experienced development team, and access to one of the world's largest experimental databases.

With strong support from key major oil companies, LedaFlow has proven itself a viable alternative to the existing commercial tools and will continue to improve the overall design and the operation of multiphase pipelines. E&P