Separating the Streams

Multiphase simulation can improve performance of oil and gas separation equipment.

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Separators are used throughout the oil and gas industry to split production fluids into components of oil, gas and water (as well as contaminants). On an offshore facility, the equipment is found in many parts of the overall process. The initial separator, usually referred to as first-stage, separates the initial stream into distinct gas, oil and water streams. These streams are then individually processed. Poor separation performance can hinder overall production; in some cases, platforms produce only 50 percent of design capacity due to poor separation.

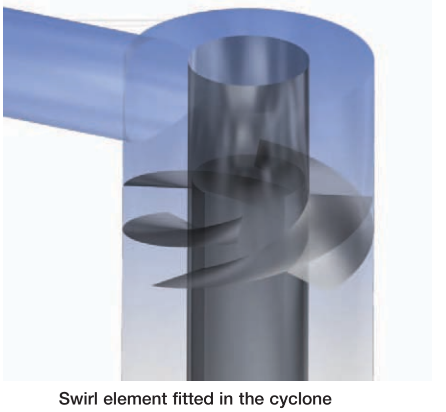
The industry has used computational fluid dynamics (CFD) extensively to troubleshoot separation equipment performance with different methodologies. Most common is segregated single-phase simulation, in which gas and liquid phases are analyzed separately. Multiphase volume of fluids (VOF) simulations are useful in analyzing liquid sloshing behavior in separators secured to moving platforms. This sloshing analysis is usually carried out in combination with a user-defined function that adjusts gravity and applies three inertial forces: Coriolis, Euler and centrifugal. Historically, fluids neither enter nor leave the vessel.

Benefits of Multiphase Simulation

As new separation equipment becomes smaller and flow rates exceed the design capacity of existing equipment, end users are questioning the accuracy of both the segregated single-phase approach and VOF for sloshing. Extended use of multiphase simulation is now possible as a result of enhancements to computer power and ANSYS FLUENT capabilities. Software improvements have led to reduced run times; multiphase and turbulence models have a greater ability to handle primary and secondary phases. The multiphase method overcomes the limitations of segregated single-phase and VOF approaches. It also allows for detailed analysis of interphase interactions, providing more realistic results. Swift Technology Group has studied two types of separation devices that use the multiphase method. The company is a technology-driven organization that offers complete end-to-end product development for the aircraft, marine, automotive, oil and gas, and renewable energies industries.

Simulation of a vertical cyclone vessel designed to remove bulk liquid from the feed stream. Pathlines of primary gas phase show where the liquid has a concentration of more than 25 percent.

Droplet separation is fundamental to good separation. The most common equipment for droplet separation is vertical or horizontal vessels that use gravity as the driving force. More-compact separation equipment often uses cyclones. By spinning the flow, employing a standard tangential inlet, or using more-elaborate swirl elements, cyclones can generate accelerations many times that of gravity to potentially provide more efficient separation in a smaller amount of space. However, many other considerations must be investigated. Traditionally, cyclonic equipment required exhaustive prototyping and testing to ensure that the many negative consequences were designed out of the final product — a lengthy and costly exercise. In a recent R&D program for cyclone development, Swift researchers found that the time for each design change cycle was approximately eight weeks at a cost of around £45,000 (approximately $73,000 U.S.) per cycle, with



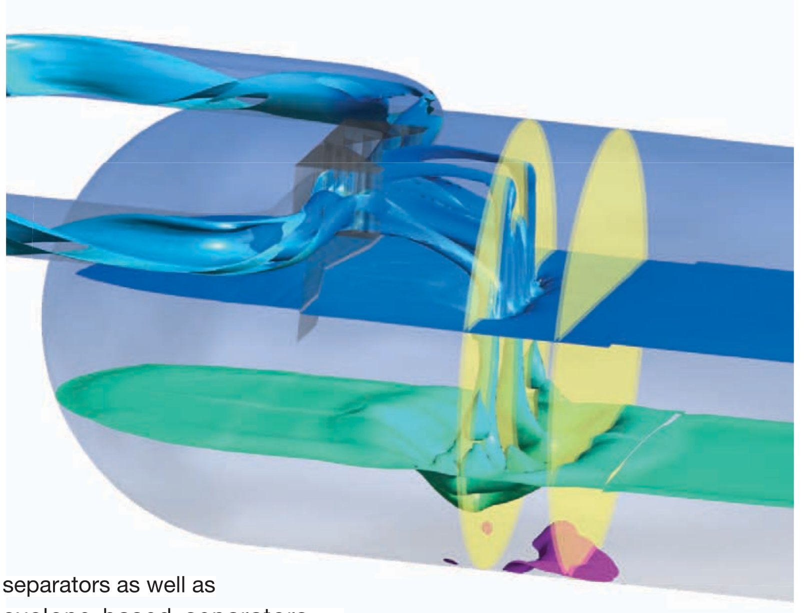
Swirl element fitted in the cyclone

seven changes required. By using CFD, each change can be modeled in two weeks, requiring only one actual test — saving a total of more than £300,000 (approximately $485,000 U.S.). Note, however, that it is difficult to quantify the exact benefits of simulation in every case.

Simulation of Separation Equipment

There are many examples in which the mixture multiphase model has been used to analyze separation within cyclonic equipment. The model is applicable for dilute-to-moderately dense volume loading, for low-to-moderate particulate loading, and for cases in which the Stokes number is less than 1. The simplified model can be used for hydrocyclones — equipment whose main function is to separate final oil droplets from water prior to disposal at sea. The comprehensive Eulerian multiphase model is applicable to the complex flows that are found in the most common types of separation equipment designed to remove bulk phases as well as re-entrained droplets. Users can enhance their analysis of cyclonic flows by applying the Reynolds stress turbulence model without limitation for all primary and secondary phases.

One important part of separator analysis is commonly overlooked: the impact of upstream piping. This system has a large effect on the distribution of fluids within the vessel. The simulation examples provided — horizontal and vertical gravity-driven separators as well as cyclone-based separators — incorporate the impact of upstream piping.

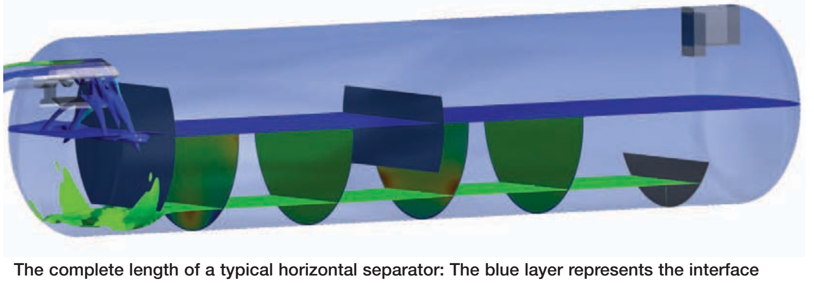


Multiphase simulation within a horizontal three-phase separator with inlet piping, a vane-type inlet device and full-diameter perforated baffles. The lower layer of fluid is water; above that is the oil phase with the inlet device in the gas phase of the vessel. The pink area at the bottom of the vessel shows where sand entrained in the water phase will initially settle.

It is difficult to accurately validate the simulation results of the installed vertical cyclone and separator. Simulation has been shown to accurately capture both flow field and separation performance in lab and pilot test rigs. [See references.] Using these modeling strategies as well as exhaustive testing performed over many years, all the critical aspects of the flow are correctly resolved and indicate the key performance characteristics. As a result, Swift is changing out the internal components of many vessels based upon simulation results.

The main function of a horizontal three-phase separator is to split a feed stream into discrete gas, oil and water streams. Normally, gas is the primary phase, and the two liquid phases are secondary. These liquid phases form droplets that are entrained in the gas phase, and they produce a film on the pipe walls leading to the separator. The first component in the separator is the inlet device, whose primary function is to provide a coarse separation of gas and liquid phases. The gas phase continues along the top of the vessel, while the liquids drop to the bottom of the separator. At the bottom of the vessel, the two liquid phases separate, with the water at the bottom and the oil forming a layer between the water and gas phases.

In most cases, perforated baffles are used along the length of the horizontal vessel to control liquid phase flows and to distribute them evenly across the available cross-sectional area of the vessel, minimizing axial velocity and maximizing separation. The Eulerian model is required in this



The complete length of a typical horizontal separator: The blue layer represents the interface between gas and oil phases, and the green layer represents the interface between oil and water. The vertical blue areas represent part diameter perforated baffles. Along the length of the vessel, four contours show velocity distribution in both oil and water phases.

Analysis of a vertical production separator with a vane-type inlet device shows that the inlet pipe keeps much of the liquid on one side of the vessel — leading to non-optimal separation.

type of simulation because of the number of fluid regime changes.

In a vertical production separator with a vane-type inlet device example, gas and liquid are introduced at the start of the pipe run to the separator vessel. The pipe routing causes the liquid to be biased to one side of the vessel — which does not produce optimal separation and, in some cases, can lead to the gross carryover of liquid though the vessel's gas outlet.

In conclusion, Swift researchers have found that ANSYS FLUENT software can model — to a high degree of accuracy — many combinations and permutations of separators available within the industry. ■

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