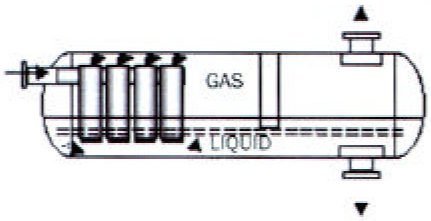
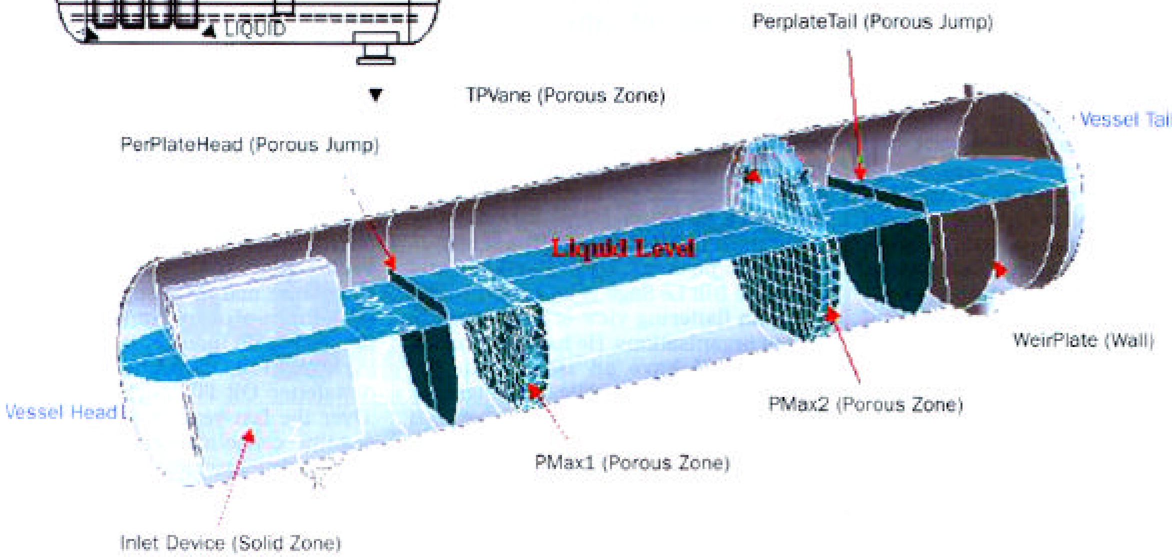


A baffled free water knockout (FWKO) separator.



Simulation software helps reduce offshore separator size

Using computational fluid dynamics (CFD), Natco engineers, led by Dr Chang-Ming Lee, have redesigned the configuration of internals in two phase and three phase, gas-oil-water, separators to optimize them for service on floating platforms.

The result is a reduced separator size that permits a corresponding reduction in the size of an offshore production platform, potentially saving millions in construction and operating costs. Separating oil, water and gas is particularly difficult on floating platforms since wave motion tends to mix the three phases.

Natco previously had to rely on costly physical testing to evaluate separator designs, but this did not let them visualize the liquid phase movement inside the real full-scaled vessel. By using computational fluid dynamics (CFD) software to study the hydrodynamics inside a separator, Natco engineers were able to see what was happening to the gas, oil and water during even the most complicated wave motion induced sloshing conditions. They learned that a horizontal baffle configuration that is often used in separators was ineffective and that conventional porous baffles had too much porosity to dampen the liquid motions.

New internal baffle designs were developed to sharply reduce sloshing motion within a vessel and to prevent short-circuiting of liquids flowing through the separator. Momentum waves can develop within a separator that makes oil-water separation particularly difficult. CFD studies led to the development of special baffle configurations for dampening these waves. CFD also demonstrated that how fluid is introduced into or removed from a separator affects the separation efficiency (*see diagram above*).

Questions also arise as to where level controls should be placed within a vessel that is experiencing a significant amount of wave motion. Even three to four inches of fluid height variation due to wave motion effect can impact level controls. By observing animated simulation results of the fluid movement and interface levels within a separator as it moves in response to sea waves, a designer can select the best position for placement of level controls. The vessel dimensions and wave motion characteristics affect the harmonics that develop between baffles. Thus the spacing of baffles within a separator should be determined based upon an understanding of these harmonics. Taking all these considerations together, the separators can be made smaller and more efficient, 'which is what our customers are demanding,' explains Dr Ted Frankiewicz, vice president at Natco Liquid Process Solutions.

Offshore separators affected by sea states

Much oil production is now done on offshore platforms that float, such as semi-submersibles, tension leg platforms (TLP), and floating, production, storage, and offloading (FPSO) systems. Separating the oil and water from gas is done in a stand-alone device called a three-phase separator that occupies part of the production platform.

Offshore exploration and production companies would like to make their floating platforms as small as possible to minimize both the initial construction cost as well as the on-going operating expenses. Reducing the weight of the platform by just one pound, for instance, is estimated to save $5 to $8 in construction costs. As oil companies strive to reduce the size of the platforms, manufacturers of oil-gas separators, such as Natco, are forced to shrink the size of their products as well.

However, this has become a difficult challenge because of the wave motion experienced by floating platforms. 'Weather conditions are normally calm, but sometimes they are stormy,' explains Dr Frankiewicz. 'The platform can experience six degrees of wave motion:

heave, surge, sway, pitch, roll, and yaw. This has a natural mixing effect on the oil, water and gas.' The mixing effect increases the time it takes to separate the fluids. Since separation occurs as the liquids and gas flow through the vessel, the longer it takes to separate the three phases, the larger the vessel must be.

Gas-liquid separators employ an arrangement of internal baffles in an attempt to dampen wave motion. 'The design of the baffles is a critical issue because the more effective they can be, the more they can suppress sloshing, which directly affects separation time,' says Frankiewicz. Baffles can be placed in different orientations, horizontal or vertical, and at different locations within a separator.

As mentioned previously, the interaction of the sea wave period and the vessel fluid motion harmonics must be considered when placing baffles. Baffles can be made of different materials, and the amount of porosity can vary from low to a high percentage.

Finding the optimal combination of all these variables is an important design goal. In the past, engineers built scale models to determine how well certain baffle designs performed.

The testing was very expensive, however, due to the cost of building the model and running the test program. Also, the information obtained from such testing was limited. One reason was that tests were done on scale models and it wasn't known for certain how accurately the results would be applied to a full size vessel. In addition, even when the model was made of Plexiglas, it was still somewhat difficult to visualize and interpret the sloshing or the fluid flow patterns.

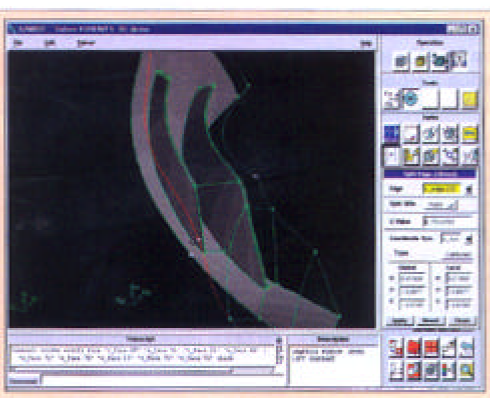
The search for an alternative to scale model testing led Natco engineers to applying CFD. 'With CFD, we can simulate the full size vessel and actually see the details of liquid motion,' says Frankiewicz. A CFD simulation provides fluid velocity and pressure values throughout the solution domain for time-dependent problems with complex geometries and detailed boundary conditions.

As part of the analysis, a designer may change the geometry of the system or the boundary conditions such as the inlet fluid velocity, or the inlet nozzle geometry and view the effect on fluid flow patterns. CFD is an efficient and effective tool for conducting detailed parametric studies, significantly reducing the amount of experimentation necessary to develop a device. Natco chose Fluent CFD software from Fluent Inc, of Lebanon, New Hampshire, because it is one of the few solvers capable of solving sophisticated multiphase flow problems, a requirement for this application since it deals with oil, water and gas flows. Natco also prefers this CFD program to others because of the user-friendly nature of its interface and because the vendor provides very strong and satisfying technical support.

Experience with previous baffle designs

Natco's first experience in applying CFD to separator design was to model an existing separator in the analysis software. The geometry was created directly from Fluent's preprocessor, Gambit. This module also automatically generated the geometry meshing. Dr Chang-Ming Lee, the Natco engineer who performs the CFD analyses, took advantage of the software's ability to produce both unstructured and structured meshes. He placed an unstructured mesh consisting of tetrahedral and hybrid elements at both ends of the separator, scaling the unstructured mesh to account for differences in the size of the components being analyzed.

In the central portion of the device, Lee placed a structured mesh consisting of all hexahedral elements. He tried both fine and coarse meshes. The fine mesh had about 126,000 cells while the coarse mesh had approximately 40,000. To represent the wave motion of the processing platform, Lee created a user-defined function with assistance from Fluent's technical support based on known environmental data. He used Fluent's Volume of Fluid (VOF) model to track the free surface and liquid-liquid interface in the vessel, and used the standard k-e model for turbulence simulation.



OPENING GAMBIT: Fluent recently released version 2.0 of Gambit, its general-purpose preprocessor for CFD analysis, and G/Turbo, an integral part of Gambit 2.0 designed specifically for meshing turbomachinery applications. 'Gambit 2.0 continues to allow engineers easier access into the CFD world,' says Fluent's Erling Eklund. 'With improved CAD integration and enhanced meshing tools, Gambit 2.0's features set new industry standards in meshing software.'

The first separator that Lee analyzed had no internal baffles. An animated presentation of the results, created with Fluent's post-processor, made it easy to see the severe sloshing inside the vessel. Next he modeled the separator with internal baffles, which were specified as porous media, in the vertical orientation, using different baffle materials, shapes, and degrees of porosity.

Lee ran multiple CFD analyses to find the most effective combination of the design variables. One of the interesting findings in this set of analyses was that conventional perforated baffles had too much open area to provide sufficient damping. By using CFD, Lee was able to evaluate varying amounts of open area to obtain more effective damping. To assess the different designs, he compared the amplitude of the fluctuating drag coefficient on the end wall of the unit, derived from the liquid sloshing motion. A preliminary design that used less open area had a drag coefficient that was 56% of the original value, for a vessel without baffles.

With subsequent modifications to the design, Lee was able to reduce that to about 38% of the original value.

Natco has since used the CFD tool to design a three-phase separator that completes oil, water and gas separation in three to four minutes of retention time, which is half the volume of previous designed devices. The design uses the new, optimized baffle design and placement that Lee developed based upon his earlier analyses.

Natco took advantage of CFD analysis to find the best location for these baffles within that particular separator. 'Since we had the specifications about where exactly that separator would be located on the platform, we are able to include that information into the simulation model,' Lee explains. Those results, combined with using more effective baffles, resulted in a separator that worked more efficiently. Because separation time was significantly shortened, the size of separator could be reduced as well. 'The analyses we ran to optimize baffle placement were specific to that particular separator's location on the platform,' Frankiewicz adds. 'But now that we have a CFD model, we have the ability to optimize baffle placement in any new offshore separators we supply.'

By applying CFD analysis to the problem of gas-oil-water separator design, Natco has been able to minimize wave motion within the device, thus reducing the time needed to separate oil from gas and water. This, in turn, enables the company to build smaller separators and meet the oil companies' demands.

'By letting us visualize the effectiveness of baffle designs and their placement in the vessel, CFD assists us get a level of wave suppression we couldn't achieve in the past, 'says Frankiewicz. 'CFD is key to properly designing our separators.' ■