JOURNAL ARTICLE

Fluid Structure Interaction Helps Design Water Quality Monitor Float

While developing a water quality monitoring float designed to carry a sensor for capturing environmental data, the engineering team at Grantec Engineering Consultants Inc. encountered some interesting challenges. The goal was to minimize drag and ensure stability of the float as well as to develop specifications for the mooring system and structure.

Grantec leveraged the ANSYS fluid structure interaction (FSI) solution to model the float and sensor under a wide range of water current and wave conditions. ANSYS tools provided integrated bi-directional FSI, offering the ability to evaluate the marine performance of numerous float shapes. The Grantec engineering team determined that the bow of the original design would have been driven below water, primarily due to a moment generated by current loading on the sensor. They developed a new hinged sensor mount that solved this problem. The company also reduced the drag of the float, which in turn reduced the cost of the mooring system.

Grantec, based in Nova Scotia, Canada, helps customers in the defense, offshore, marine, manufacturing, energy and aquaculture fields advance new designs and systems. In particular, Grantec has done extensive work in the finite element analysis (FEA) and computational fluid dynamics (CFD) fields.

IMPORTANCE OF FSI

"Many of our engineering projects involve both fluid dynamics and structural analysis," said Richard Grant, founder of the company. "In the past, we primarily had to separately analyze the fluid and structural portions of the engineering problem. When the interaction between fluids and structure was critical, we manually entered the results from the fluids software into the structures software and vice versa. In a few cases we wrote software that moved the results between the programs, but this worked at only a very basic level."

When engineering analysis software companies introduced FSI products designed to integrate fluid dynamics and structural analysis, Grantec rigorously evaluated the leading products in this area. "We approached one company, a firm rooted in multidisciplinary analysis, with several of our problems, and they told us that their software was unable to address them. We talked to a CFD leader that offered an integrated solution to discover that their solution requires buying CFD from one company, FEA from another, and software to tie it all together from a third company. I was concerned that the individual companies would shun responsibility if problems arose," said Grant. "In contrast, ANSYS offers a solution that integrates several of the most powerful and mature CFD and FEA packages. The company provides and supports the complete solution, so there are no questions about who to call if a problem occurs."

The FSI solution from ANSYS is an integrated part of its multiphysics technology, in which the ANSYS Multi-field solver is used to create a true bi-directional FSI capability for time-transient or steady-state analysis with moving or deforming geometry. The structural part of the analysis is solved using the well-established full-capability ANSYS structural mechanics and fluid mechanics solvers. The solutions can run simultaneously on the same or different machines, thus accommodating larger models more efficiently than a multi-field solver using a single machine environment.

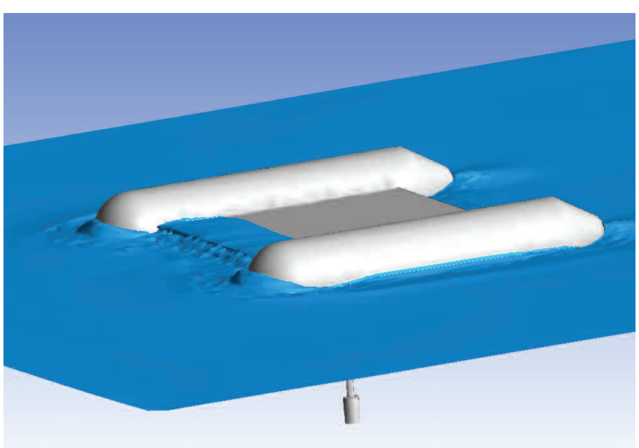
WATER QUALITY MONITORING FLOAT

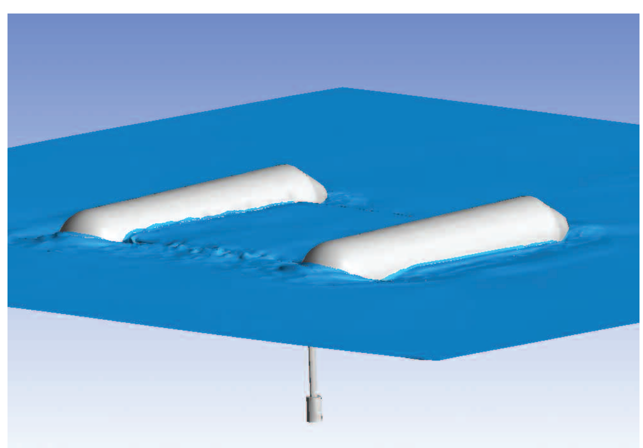
The Grantec engineering team used the ANSYS FSI solution on a water quality monitoring float fixed in position by an anchor, a project commissioned by Environment Canada. The float is constrained by the mooring line, which leaves it free to move in any direction as long as it does not exceed the distance of the length of the mooring line from the anchor. The engineer modeled the initial concept design in ANSYS® Multiphysics™ software. In the original design, the sensor was fixed to the float by a boom and extended vertically into the water. The float and sensor were modeled as a flow obstruction in the CFD mesh. The CFD mesh takes into account current and wave loading on the float as well as buoyancy forces.

The float plays a role roughly similar to and looks somewhat like a catamaran boat. It is designed to be moored rather than driven by an engine or sails. In addition, the hydrodynamic effects of the sensor extend into the water. The ANSYS software simulates the development of bow and stern waves that result from the resistance of the hull to fluid flow, just as with the hull of a ship. The software duplicates the heaving (or vertical motion) and pitching (or angular motion) of the float in response to different wave and current conditions. The model also solves for the stresses and deformations on the float. The simulation showed small deformations of the float and larger deformations of the boom that together had a significant impact on fluid flow. FSI made it possible to optimize the design of the hull to a much higher level than would have otherwise been possible.

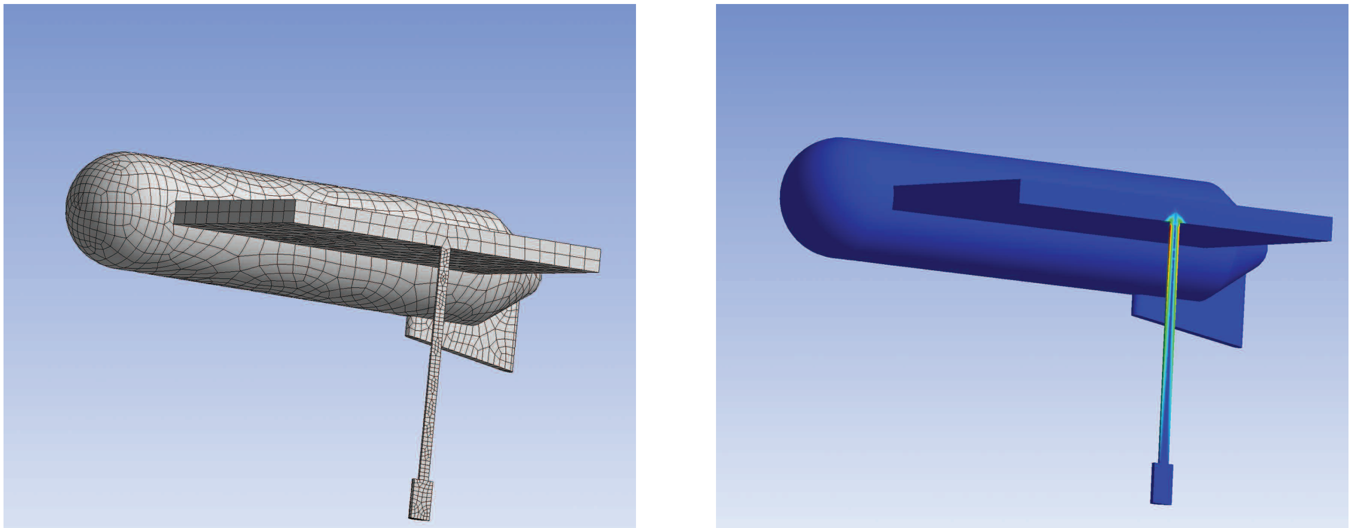
Using FSI, Grantec engineering was able to evaluate the performance of a wide range of hull profiles and mass distributions under different flow conditions. In the initial series of designs, the sensor was fixed to the stern of the float and extended vertically into the water. As the speed of the current increases, the waves increase in size and the magnitude of the force exerted on the float also increases. The FSI results for these designs showed that the force exerted by wave currents on the sensor combined with the bow wave tends to push the bow of the float underwater in faster currents. Considering the scope of the project, it would not have been practical to solve this problem by simply changing the hull design, so Grantec tried a hinged connection between the sensor and the float that reduces the load transmitted from the sensor to the float. The hinged sensor greatly increases the complexity of the analytical challenge.

Grantec engineers decided to simulate the float with the sensor fixed in different hinge positions using the immersed pipe element in ANSYS Multiphysics software. This





Sensor float fluid structure interaction (FSI) transient response to current flow (left); sensor float bow nosing down due to flow on sensor below float, deck awash (right)



FSI analysis was performed not to look at the stress in the hull but rather the effect of a fixed boom (flexible) on the float. Mesh (left) and the stress plott (right)

immersed pipe element provides a fast and simple way to perform FSI analysis by enabling the user to apply wave and current loading to a structural model without the computational load involved in coupling the model to a full fluid dynamics analysis. The immersed pipe element uses Morrison's equation to calculate drag coefficients and fluid forces acting on the structure with minimal computational resources. This simplified FSI approach also provides the ideal method for performing detailed design of the structure by making it possible to evaluate the performance of a large number of designs in a short period of time. In future studies, it will be possible to perform more-complete FSI analysis including moving mesh and other CFD capabilities that will evaluate the motion of the hinge in response to hydrodynamic forces.

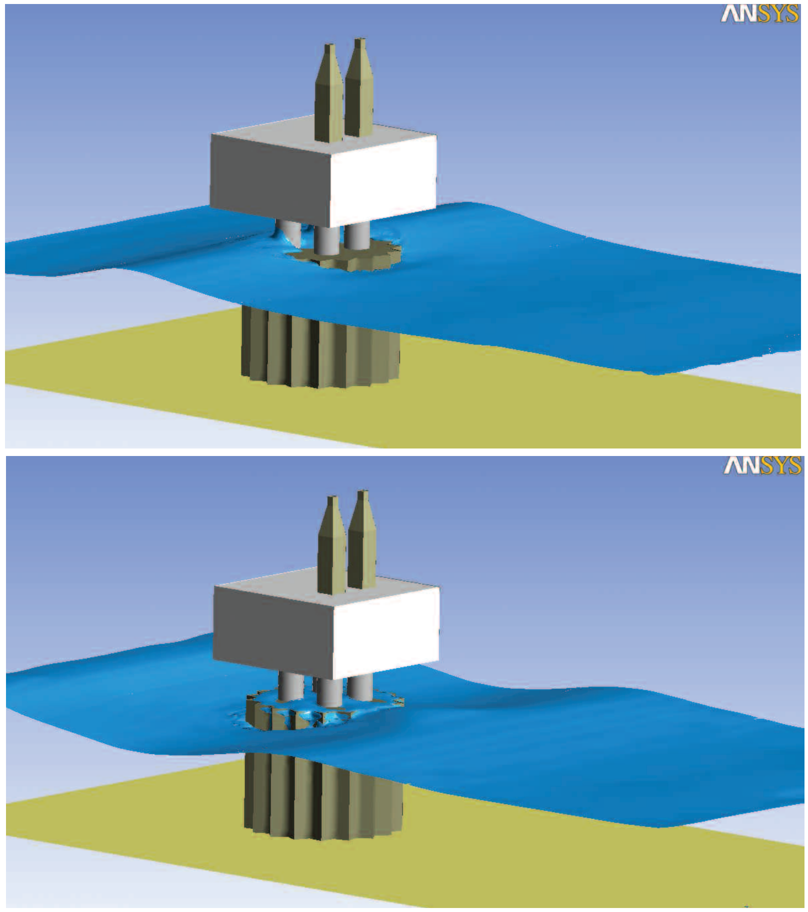
OTHER FSI APPLICATIONS

One of Grantec's specialties is analyzing and evaluating the response of structures and systems to time-varying loads, such as explosions, earthquakes, ocean waves and strong vibrations.

Grantec has used the ANSYS FSI solution to assess gravity-based structures (GBSs) used to protect offshore oil drilling and production platforms from icebergs. GBSs rely on weight to secure them to the seabed, which eliminates the need for piling in hard seabeds. Concrete GBSs are typically built with huge ballast tanks so they can be floated to the site and, once in position, sunk by filling the tanks with water. Engineering simulation results show the effect of wave loading on GBSs and the effect of green water coming over the top.

Marine risers, used in offshore drilling and production, are used as conduits from underwater drilling equipment to platforms on the surface. The Grantec team uses the ANSYS immersed element to simulate the effects of different currents at different water depths. Most important for this application, the ANSYS immersed pipe element provides the ability to model advanced nonlinear waves, including Stokes fifth-order waves and Dean's stream function.

Grant believes that his company's investment in FSI has made a significant addition to their already impressive analytical capabilities. "Companies seek us out because they know we perform advanced engineering and can solve very complex problems," he said. "FSI solutions from ANSYS put another full capability tool in our toolbox that makes it easy to address design challenges that just a few years ago would have been much more difficult. The ability to solve these specific and specialized FSI problems could have profound ramifications for industry and society."



Waves washing over top of gravity-based structure of an offshore platform
(waves traveling to the right)

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