Raising the Standards

Fluid-mechanical simulation can help prevent offshore disasters by supporting development of more effective structural standards.

By Richard Grant, President, Grantec Engineering Consultants Inc., Halifax, Canada

The critical nature of offshore structures has been tragically demonstrated by incidents such as the Piper Alpha explosion in the North Sea in 1988, which took 167 lives, and the Deepwater Horizon fire in 2010 in the Gulf of Mexico, which caused both loss of life and environmental damage. Every offshore disaster provides an opportunity to understand its causes and to ensure that future structures are designed to avoid its recurrence. Computer simulation can play an important role by helping to diagnose real-life or potential disasters and evaluate the effectiveness of alternate remediation methods.

Offshore oil and gas production in Canada started in the late 1980s with the development of the Cohasset and Panuke fields (first oil in 1992) off the coast of Nova Scotia, followed by the Hibernia field (first oil in 1997) off Newfoundland. Atlantic Canada's offshore presents one of the harshest weather environments in the world. Oil-related tragedies already have occurred in this area, such as the 1982 sinking of the Ocean Ranger mobile offshore drilling unit, with complete loss of life at the Hibernia field.

AVOIDING REPEAT MISTAKES

Many of the offshore disasters that occurred throughout the world could have been prevented if only the best practices

Richard Grant has worked on developing structural standards for offshore platforms since 1997, when he became a founding member of the Canadian Advisory Committee (CAC) on Offshore Structures Standards under the Standards Council of Canada (SCC). His involvement with the CAC began with providing input into the offshore structural standards then being developed by the International Organization for Standardization (ISO). Shortly afterward, while working on a Canadian offshore project, Grant noted serious shortcomings in Canadian regulations and standards pertaining to fire and explosion safety. He has since been instrumental in correcting deficiencies in Canadian offshore standards through his work with the Canadian Standards Association (CSA). He was subsequently called upon by the international community to assist with the related work being performed under ISO.

Simulation can play an important role by helping to diagnose real-life or potential disasters and evaluate the effectiveness of alternate remediation methods.

available at the time had been followed. During development of the Sable and Terra Nova offshore projects in Atlantic Canada, it was recognized that Canada's CSA offshore standards needed to be reviewed and, where necessary, updated. It was also recognized that Canada's efforts in this area would be better served through direct participation in developing the new offshore structures standards being established under ISO. International standardization of industry best practices helps ensure that lessons learned are captured, and past mistakes are not repeated.

The offshore environment's nature means that realistic physical testing is often too expensive or dangerous and, in many cases, is simply impossible. Simulation plays a crucial role by enabling those involved in developing standards, as well as those designing offshore structures, to evaluate potential disaster scenarios and determine the impact of implementing requirements to help improve the safety of workers and the environment.

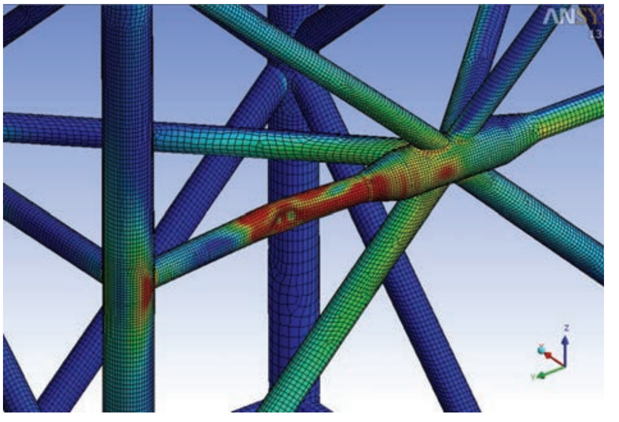
SHIP-TO-PLATFORM COLLISION

ANSYS Mechanical structural simulation has been used to gain a better understanding of one of the more dangerous offshore scenarios: a ship-to-platform collision. The 2005 incident at Bombay (Mumbai) High North, off the coast of India, is a good example for illustrating this situation. A vessel was called to the platform to transport an injured person to shore for medical attention. The vessel came too close to the platform, and it hit and ruptured risers carrying gas to the platform. The subsequent fire destroyed the platform and resulted in many fatalities.

To avoid such catastrophes, offshore structures are required to safely protect critical components such as risers and to absorb energy during a collision. This collision energy is dependent on the vessels permitted within the safety zone around the platform. In performing a simulation of this type, a structure is typically modeled using shell elements with nonlinear material properties and large displacements to accurately represent the resistance of the structure. Collision causes tubular denting, leading to large plastic strains. The structure absorbs energy as its tubular members are crushed by the impact of the vessel. Analysis can accurately capture the amount of energy that the structure can absorb. This type of simulation is invaluable to assess the safety of offshore platforms and can be used to assure that they can withstand certain types of collisions without catastrophic failure, as required by the standards.

PROCESS PRESSURE VESSEL INTEGRITY

Grantec is performing research pertaining to the integrity of process vessels subjected to external hydrocarbon gas explosions. This research is aimed at better understanding the



Analysis is used to confirm that the structure can absorb sufficient energy to withstand impact from ships permitted within the safety zone.

Progress in Canada's Offshore Standards

Canada's own offshore standards were significantly improved in the area of fire and explosion safety through new provisions in the CSA Offshore Structure Standards (2004). With Canadian input, similar provisions were developed for the ISO 19901-3 Topsides offshore structures standard. The ISO standards will improve safety in offshore structures around the world. Canada also holds leadership positions in ice loading and concrete construction requirements for offshore structures; the country's experts have provided significant input in these areas of the ISO standards.

Lessons learned from the international community and from Canadian projects have been considered in the rewrite of the Canadian offshore structures welding requirements, contained in the CSA W59-13 welding standard, which is referenced by the ISO 19902 standard for Fixed Steel Structures. Canada's participation with international standards bodies benefits Canada by ensuring that the country's standards reflect the advances made by the international community; it also helps to ensure that advancements made in Canada are reflected in international standards. Many of the new ISO offshore structures standards have been adopted as National Standards of Canada, replacing the CSA S47x Canadian offshore structures standards.

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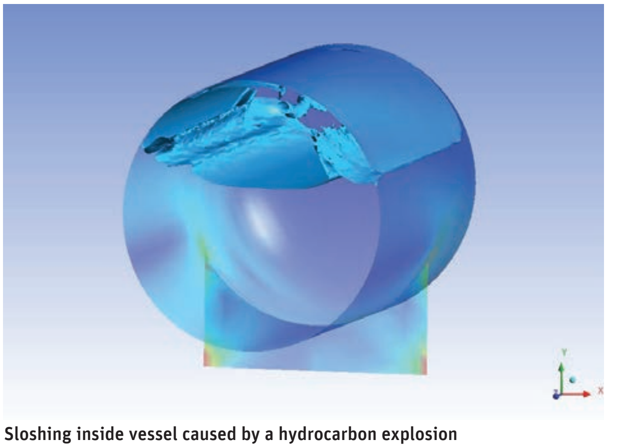
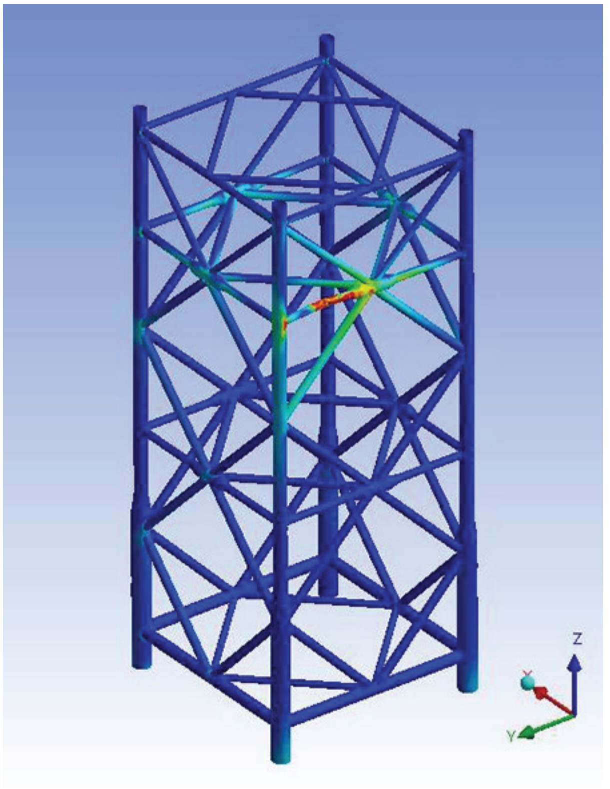


Sloshing inside vessel caused by a hydrocarbon explosion

dynamic response of the process vessel shell (pressure envelope), including effects due to internal fluids and the support structure, such as saddles, process skids and decks. Rupture of the pressure envelope of a hydrocarbon process vessel, or the failure of vessel supports, during a hydrocarbon explosion can cause the event to escalate. In the case of a rupture, more hydrocarbons are released to fuel a fire, and, in the case of support failure, the vessel could become a projectile impacting and impairing other safety-critical systems. In the Piper Alpha disaster, failure of hydrocarbon process piping and equipment resulted in the escalation of the fire onboard the platform. In this incident, a loose blind flange on piping resulted in a gas leak that, in turn, produced an explosion that tore loose a bulkhead. The explosion launched the bulkhead, which then ruptured process piping and equipment, resulting in a fire that continued to escalate and destroy the platform with significant loss of life.



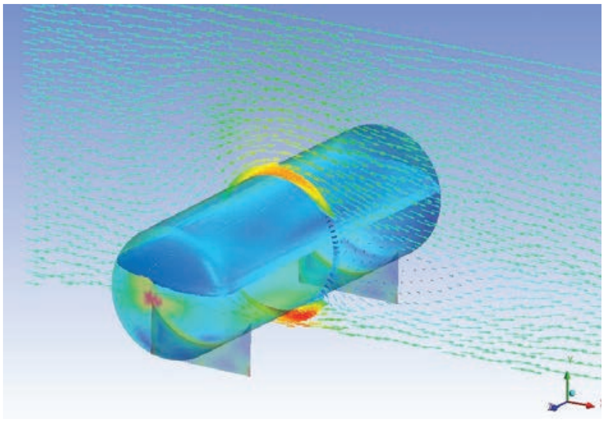
Simulation of accidental ship collision with wellhead platform

Process vessel integrity research at Grantec is being performed using multiphysics simulation software from ANSYS. The simulation is a fully coupled transient fluid–structure interaction (FSI) analysis that uses ANSYS Mechanical for the structural simulation and ANSYS CFX for the computational fluid dynamics (CFD) analysis. The vessel shell and saddle supports are modeled with shell elements, and the support structure is modeled using beam elements to simulate deck flexibility. Nonlinear material properties and large deflections are also incorporated. A fluid domain outside the vessel is used for simulating the transient explosion acting on the external surface of the vessel, and an internal fluid domain is used for the fluids (liquid and gas) in the vessel. The time history of the explosion is applied at the inlet of the fluid domain upstream of the vessel. The explosion, advancing rapidly through the domain, results in high transient drag loading on the vessel, causing it to move. The movement of the vessel causes the internal liquid to undergo sloshing, generating additional loads on the shell of the vessel.

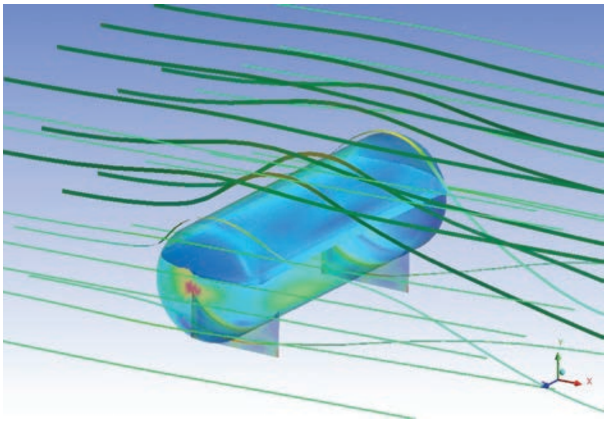
Grantec engineers leverage the ANSYS HPC (high-performance computing) multi-processor option to significantly speed up the computationally demanding analysis. The company migrated from two HPC licenses to the HPC Pack license, which resulted in a four-times speed improvement for multiphysics simulations on an HP Z820 workstation. The team is looking at ways to further improve turn-around on multiphysics simulations — such as using GPU capabilities, additional hardware and other methods.

The results of the research conducted will be used to assess and guide future standards requirements.

International cooperation between standards-making bodies helps to substantially improve offshore platform standards in the areas of structural integrity, control and mitigation of accidents, and protection of safety-critical systems. Simulation enables engineers to understand and diagnose many potential accidents and evaluate the effects of possible design standards in protecting human life and the environment.



Fluid–structure interaction simulates an explosion that induces load on pressure vessel. Image shows instantaneous velocity vectors of air moving as a result of explosion.



Time slice shows streamlines of explosion flow over pressure vessel.

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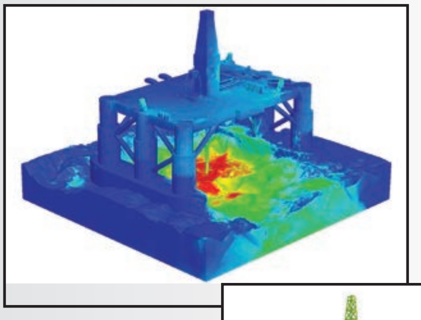

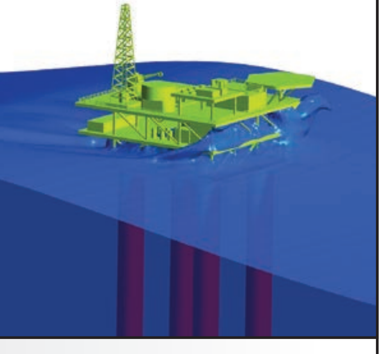

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