Dr. Claude Daley and the large double-pendulum test units in Memorial University, St. John's structures lab

The Sawyer Glacier, Alaska overwhelms observers in a Zodiac inflatable boat. Icebergs and ice are powerful natural forces, which need to be understood

ICE-CRUSHING RESEARCH

Developing design tools that can accurately model ship-ice and ice-structure interactions under Arctic conditions is the focus of a five-year research project at Memorial University in St. John's, Newfoundland and Labrador, writes Andrew Safer, St John's

Now in its third year, the Sustainable Technology of Polar Ships and Structures (STePS2) project is focused on gaining a better understanding of the dynamics of these interactions and developing new numerical modeling processes.

"If the risks are unknown," says Dr. Claude Daley, principal investigator and professor of Ocean and Naval Architectural Engineering at Memorial University in St. John's, Newfoundland and Labrador, "the level of conservatism is through the roof. Technology enables the costs to be understood and, usually, lowered."

The $7.2 million STePS2 project is supported by a group of oil companies, service companies and contractors including Husky Energy; ABS; Samsung Heavy Industries; Rolls-Royce Marine, and BMT Fleet Technology in the private sector, and the Atlantic Canada Opportunities Agency, Research & Development Corporation of Newfoundland and Labrador, key technical partner National Research Council of Canada-St. John's, Memorial University, and the research funding agencies Natural Sciences and Engineering Research Council of Canada and Mitacs.

The ice-crushing experiments conducted in the structures lab at the Faculty of Engineering and Applied Science are generating the data for Dr. Daley's team to model. For the past 12 months, they have been modeling a ship transiting in pack ice. Tests to date have involved crushing 10- and 25 cm ice cones against a small steel frame, 25 cm to 1 metre cones against a large steel frame, and 25 cm cones in a small double-pendulum apparatus at impact load levels up to 500,000 pounds. They are using artificial multi-year ice in most of the experiments, and will be using glacial ice harvested from iceberg fragments in at least one of the large double-pendulum experiments.

> Things that wouldn't have caused any difference in theoretical results, like a fairly small feature of the ice's shape, are causing big differences in measured results. New models are definitely needed

Ice event mechanics

Using powerful, parallel computer processing capacity boosted with Graphics Processing Units (GPU) researchers are able to develop 'ice event mechanics modeling', which models all of the discrete events that occur during the ice-breaking process—hundreds of ice-ship events and thousands of ice-ice events, including the numerous ice floes that are impacted by the initial event. They plan to translate this simulation into the ability to model, for example, all of the operations of a set of icebreakers managing ice to protect offshore structures in the Beaufort Sea. These calculations, which used to take months, are now completed in hours.

In the 1980s, impacts were measured during major ice-loading events on platforms in the Beaufort Sea, north

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When ice collides at a glancing angle, compared to striking the surface head on, the structure is further weakened. This tangential movement can also score the surface. "This would have occurred on the Titanic".

St John's developing centre for upstream Arctic expertise

of Alaska but the high-pressure zones were not recorded due to the low spatial resolution technology that was available at the time. In STePS2, Dr. Daley's team is using an advanced-technology impact module that can withstand the loads and photograph the pressure distributions at high resolution. This specialized piece of equipment consists of a high spatial resolution array of pressure sensors covered by a thin metal sheet, against which the force is applied. These patented sensors rest on an 18-inch-thick block of clear acrylic that has a high-speed camera mounted behind it to capture the pressure data. The impact module was designed by Dr. Bob Gagnon, a principal researcher in STePS2 and physicist at the National Research Council of Canada-St. John's, located close by the Memorial University's Ocean and Naval Architectural Engineering structures lab.

Design point

In experiments scheduled for the fall, the large double-pendulum apparatus (4.5 m by 6.5 m; approximately 18 tons) will measure the force and pressure distribution when one five-ton steel pendulum collides with another equally massive one that has a 1-metre diameter ice sample attached to it, at forces up to four mega-Newtons and at speeds up to 15 knots—close to full-scale ship-ice impacts. In May, the research team will be doing full-scale tests on the structural grillage (side shell of the hull) of a 10,000-ton PC 6 ice class ship.

The 6-metre by 2-metre section will consist of nine frames plus the plating and stringers. During the quasi-static tests, a hydraulic ram will slowly push ice into the grillage. The tests will overload the design limit of 40,000 pounds by a factor of ten times. "We're going way beyond the design point so we'll damage the structure," says Dr. Daley. "The object is to assess the damage tolerance, reserve capacity, and failure mechanisms so we can understand where the risk is."

Significant effects

Asked what his researchers have discovered to date, Dr. Daley says, "We're surprised that the speed effects on ice are as significant as they are. Not only do the values change between low-, medium-, and high-speed tests, the nature of the pressures and the loads, and the failure process, change very dramatically between very low and high speeds." He adds that in pressured pack ice, loading on an offshore structure or the mid-body of a ship develops slowly, whereas in a collision scenario, it develops very rapidly. Another significant finding is that the initial shape of the ice is much more important than previously thought (for example, the nose of the ice being flattened off for a few inches). "Things that wouldn't have caused any difference in theoretical results, like a fairly small feature of the ice's shape, " he says, "are causing big differences in measured results. New models are definitely needed." He adds that the research team is learning how to set dozens of inputs for various values. "Lots of students are getting very skilled at numerical modeling and experimental modeling," Dr. Daley says. "Some very good educational results are occurring." By the time STEPS2 is completed in June 2014, 32 co-op students, 24 graduate students, nine international exchange students, two post-doctoral fellows, six faculty, three staff, and three principal researchers from the National Research Council of Canada-St. John's will have been involved in the project.

Another key finding, says Dr. Daley, is that when ice collides at a glancing angle, compared to striking the surface head on, the structure is further weakened. This tangential movement can also score the surface. "This would have occurred on the Titanic," he says. "All real collisions are glancing." This finding points to the need for additional research that is beyond the scope of STePS2 .

When the project concludes in 2014, the deliverable will be a design tool that enables Arctic ship and offshore structure designers, operators and engineers to model a range of scenarios involving ship-ice and ice-structure interactions to specify design parameters. FE

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