Measurement methods developed for model brash ice

Aker Arctic is leading a research project with the aim to ensure that brash ice model tests in all model testing facilities correspond to real life in the best manner. The ultimate goal is to give ship designers reliable guidelines for building safe vessels that correctly fulfil the ice class requirements.

Last year, a series of full-scale channel tests were performed in the Bay of Bothnia (see issue 16). Then, a series of model tests were performed in the model test basin in Helsinki for comparison. The model-scale tests in the brash ice channels were prepared to fulfil the Finnish-Swedish Ice Class Rules (FSICR).

Test results vary

The Finnish-Swedish Ice Class Rules define the minimum engine power required for safe operations in certain conditions. The rules present an equation for required engine power, but a vessel with less engine power can be approved if the engine power is sufficient according to ice model tests.

Recently, variations in model-scale channel test results have been observed, especially when the new EEDI- type tankers have been tested. These inconsistent results occur even though the channels in which the ships have been tested fulfil the test performance requirements of the FSICR.

"In the FSICR, a model brash ice channel is defined only by its thickness and its width," Riikka Matala, Research Engineer at Aker Arctic, explains. "Ice coverage is a requirement, but does not need to be verified."

Different model test results indicated that the channel resistance depends on parameters, which are not defined by the guidelines.

Five parameters identified

Test equipment to measure different brash ice parameters was built and used with three different brash ice types. The difference between the materials was the target crushing strength of the ice pieces. Two of the materials were fine-grained, salt-doped model ice (FGX-ice) with crushing strengths 29 kPa and 57 kPa, which were manually cut into small pieces. The third brash ice channel consisted of fresh water ice cubes (crushing strength about 3 MPa).

To be able to compare the brash ice types, some basic parameters were measured from the parental ice: flexural strength, compressive strength, ice density, and friction between ice and model.

Matala presented her research at the POAC-conference in Delft in June 2019. Photo: Toni Skogström

The research team then identified five parameters, which could potentially explain the different results and developed measurement methods for the following: porosity, piece size distribution, angle of repose, angle of internal friction (or shear strength) and compressibility.

Porosity

Porosity of the brash ice was measured according to ITTC recommendations by submerging a known amount of brash ice and measuring the ice mass buoyancy. An instrumented box was completely submerged through the brash ice channel and held steady until the buoyancy force was constant.

The force was measured with a force transducer and the ice channel porosity was calculated according to Archimedes' principle.

Piece size distribution

In soil mechanics, grain size is useful as a distinguishing property of materials. However, the same grain-sized materials can have different mechanical properties.

Piece shape also affects the mechanical properties. For example, material consisting of round particles has lower shear strength than a material consisting of particles with sharp edges. Therefore, the distribution of the size of pieces is as important as the actual grain size.

Piece size distribution was defined by pouring a known volume of brash ice on a plate, on which an indicative grid was drawn. The plate was photographed and the picture analysed using Matlab so that the program defined the area of each individual ice piece and produced a distribution chart from the observations.

Angle of repose

The angle of repose is defined as the steepest slope of the unconfined material measured from the horizontal plane, on which material can be heaped without collapsing.

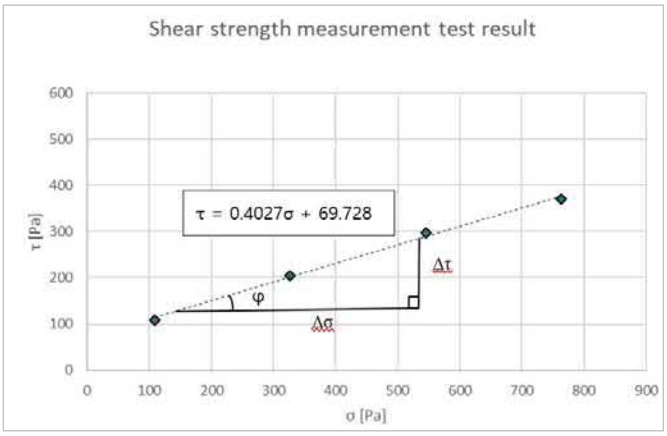
Angle of repose below water was defined with a container made of plexiglass. The container was set just below the surface level and filled with brash ice. The angle of repose was defined visually under water, using an underwater camera and then measured from the picture.

The angle of repose above the water was defined by piling ice brash gently on a horizontal plane. A picture was then taken and the angle measured from the picture in the same way as under water.

Brash Ice Angle of Internal Friction and Shear Strength

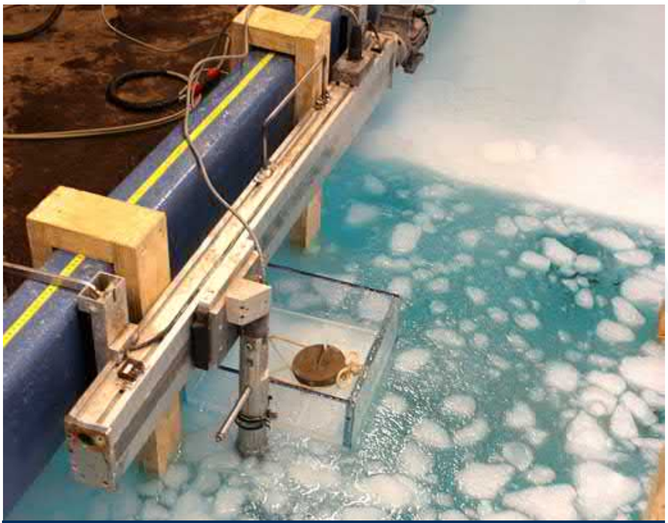
The shear strength measurement was arranged by building a plexiglass box, which consisted of two separate halves. The box was filled with brash ice and a weight was positioned on top of the upper box to cause a normal load. The upper part was slightly relocated and the required force was measured using a force transducer.

The results were plotted in a chart and a line was fitted to the data points. The slope of the line represents the internal friction angle, φ. An example of test results is presented below.

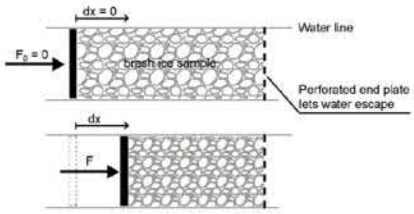


Compressibility

The compressibility is defined as the change in volume as a function of external pressure. The compressibility of brash ice was defined using a measuring device made of low-friction plexiglass. The end plate of the box was made of a perforated plate allowing water to escape. The front plate was attached to a piston, which moved forward when a weight was added in the wire system.



A double-box device was developed for studying shear strength and internal friction angle of brash ice.



Compressibility measurement in theory and practice.

Going forward

The objectives of developing new devices and practices for measuring brash ice properties are to enable comparison between different brash ice types. The comparison, in turn, is relevant when studying the brash ice channel behaviour in vessel's ice model tests.

The devices functioned well in general so that the comparison between the materials could be done, and the results were reasonable. However, the most relevant question for channel testing is to understand the physics behind the behaviour of the brash ice mass in the ice channel. Based on that, reliable models can be developed to estimate the resistance of ships in channel ice. Furthermore, reliable testing methods in model scale can be developed when the physics of brash ice behaviour is well studied.

"Our next step is to compare the full-scale tests with the model tests and see which model test corresponds better with the full-scale test," Matala says. "We also want to investigate which of the measured parameters could explain why a certain model test would correspond better. Our aim is to repeat the full-scale tests, hopefully next winter, in order to get more results to compare with so that the impact of the hull form could be studied." ■