27th ITTC Spcialist Committee on Ice Report

Presented at: IDA, Copenhagen, September 2, 2014
Presented by: ITTC Specialtist Committee on Ice

Presentation Outline

- General overview - Michael Lau
- Test methods for model ice properties & tank survey - Rudiger von Bock und Polach
- Resistance test in ice – data correction procedures - Topi Leiviskä
- Survey of numerical modeling of ice-structure interactions - Akihisa Konno
- Recommendations - Michael Lau

General Overview

Presented by Michael Lau (Secretary), National Research Council of Canada

Membership and Meeting

- Mr. Peter Jochmann (Chairman), HSVA, Germany (resigned 2013)
- Dr. Michael Lau (Secretary), National Research Council of Canada, Canada
- Mr. Johannes Huffmeier, SSPA, Sweden (replaced 2013)
- Prof. Akihisa Konno, Kogakuin University, Japan
- Mr. Topi Leiviskä, Aker Arctic, Finland
- Mr. Rudiger von Bock und Polach, Aalto University, Finland
- Dr. Kirill Sazonov, Krylov, Russia
- Mr. J. Römeling, FORCE, Denmark (passed away 2012)
- Mr. Victor Westerberg, SSPA, Sweden (started 2013)
- Prof. Qianjing Yue, Dalian University of Technology, China (inactive)
- Dr. Rod Sampson, Newcastle University, United Kingdom (resigned 2013)

- Five physical & six online committee meetings were held

Terms of Reference

- Define which existing ice related procedures need to be checked and if new ones need to be developed
- Review ice properties modeling (full scale and model scale) considering various conditions, ridges, and pressurized ice for both offshore structures and ships
- Review the existing numerical methods for offshore structures and ships
- Look into operational conditions in frozen seas relevant to modeling (in view of the climate change)

Brief Description of the Task Execution

- Review of existing *Recommendations and Guidelines*
  - *General Guidelines (1999) - 7.5-02-04-01 – in progress*
  - *Model Ice Properties (2002) - 7.5-02-04-02 - accepted*
  - *Tests in Deformed Ice (1999) - 7.5-02-04-02.4 – obsolete*
  - *Resistance Test in Level Ice (2002) - 7.5-02-04-02.1 – in progress*
  - *Maneuvering Tests In Ice (1999) - 7.5-02-04-02.3* – in progress
- Preparation of an inventory list of ice tanks
  - By developing and distributing a questionnaire
- Compilation of existing publications regarding numerical simulations
  - Ice resistance of vessels, ice loads on structures, and Maneuvering and DP in ice

Test Methods for Model Ice Properties & Tank Survey

Revision, Extension and Modification of guidelines in related to *Model Ice Properties (2002) - 7.5-02-04-02*

Presented by Rudiger von Bock und Polach, Aalto University

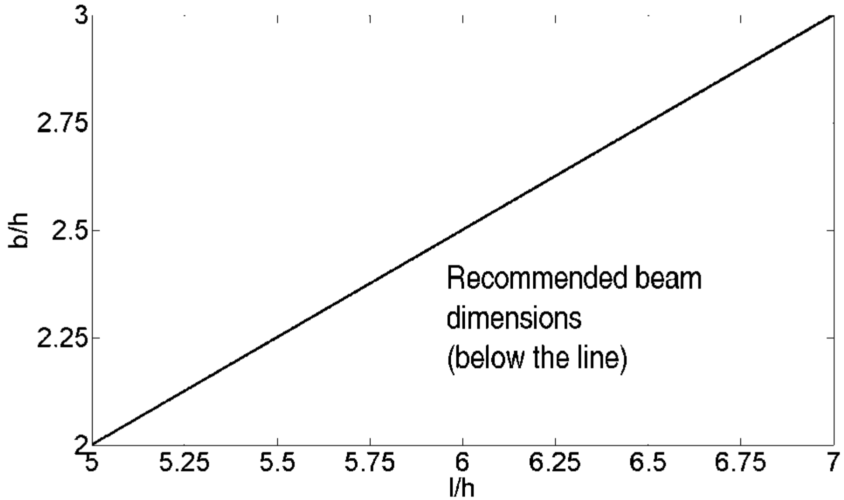
General

- Existing test guidelines have been extended with additional testing options
- The stated options for testing methods are discussed in terms of applicability and boundary conditions
- Methods added reflect the state of the art in testing basins
- Added test procedures:
  - Compressive strength
  - Ice-model friction coefficient
  - Shear strength
  - Ice thickness
  - Ridge tests

Flexural Strength

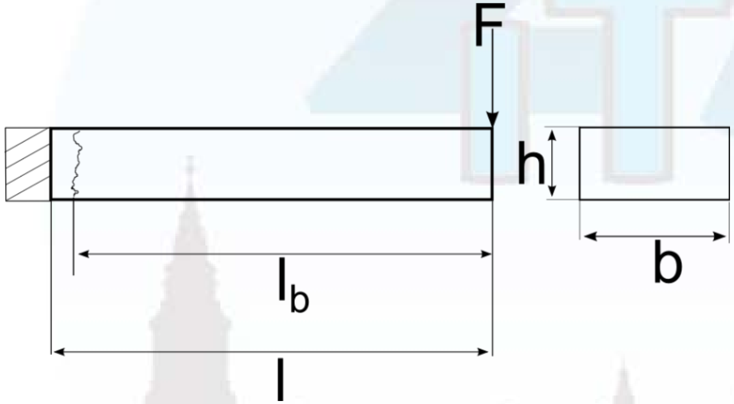
- Flexural strength and ice thickness as most significant parameters

- Previous: L = (5-7) x h, B = (2-3) x h
- New: Clarification on Dimensions to main-tain validity of beam theory

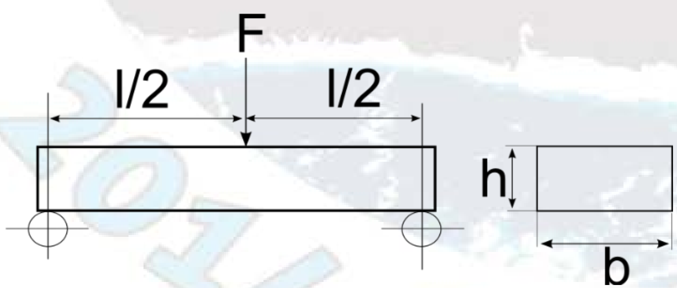


Flexural strength

- Cantilever beam testing as standard

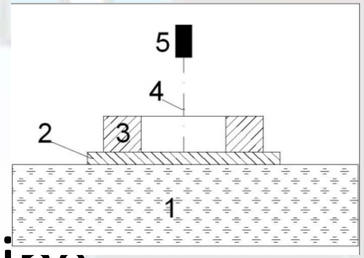


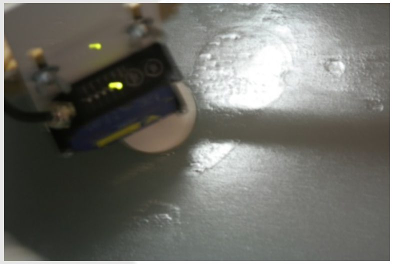
- 3-point bending added as test method

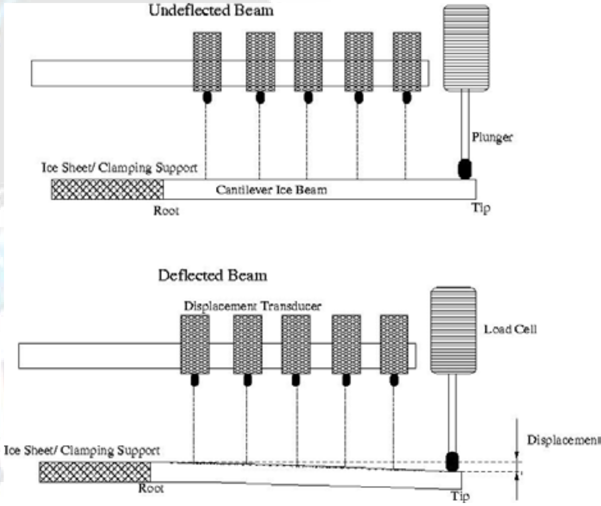


Strain modulus of Elasticity

- State of the art: Infinite plate deflection of elastic plate on elastic foundation
- New:
  - Calculation method for and offset between loading and displacement measurement location (more practical)
  - Measurement of elastic modulus by cantilever beam tests



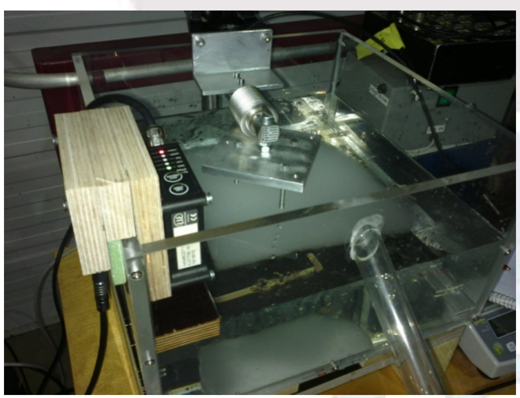




Density measurements

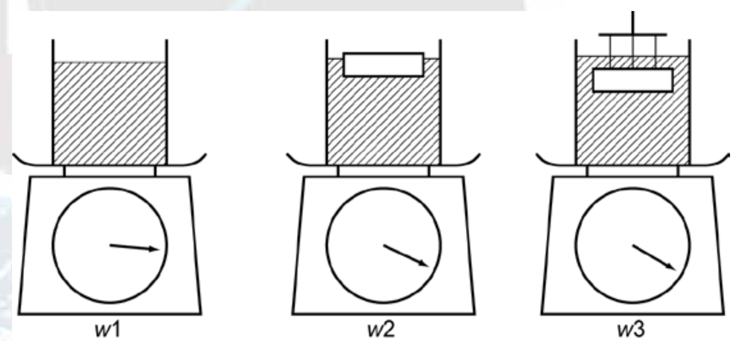
- Three methods

Displaced water



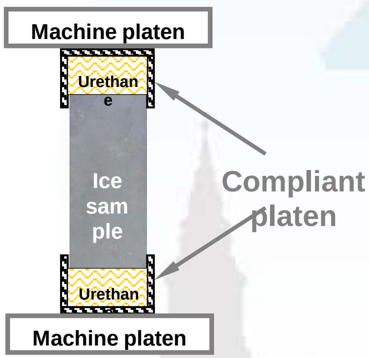
Surface elevation

Scale loading (Japanese method)

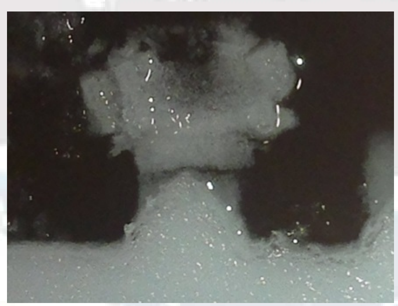


Compressive strength

- Ex-situ method (incl. Recomended dimensions)



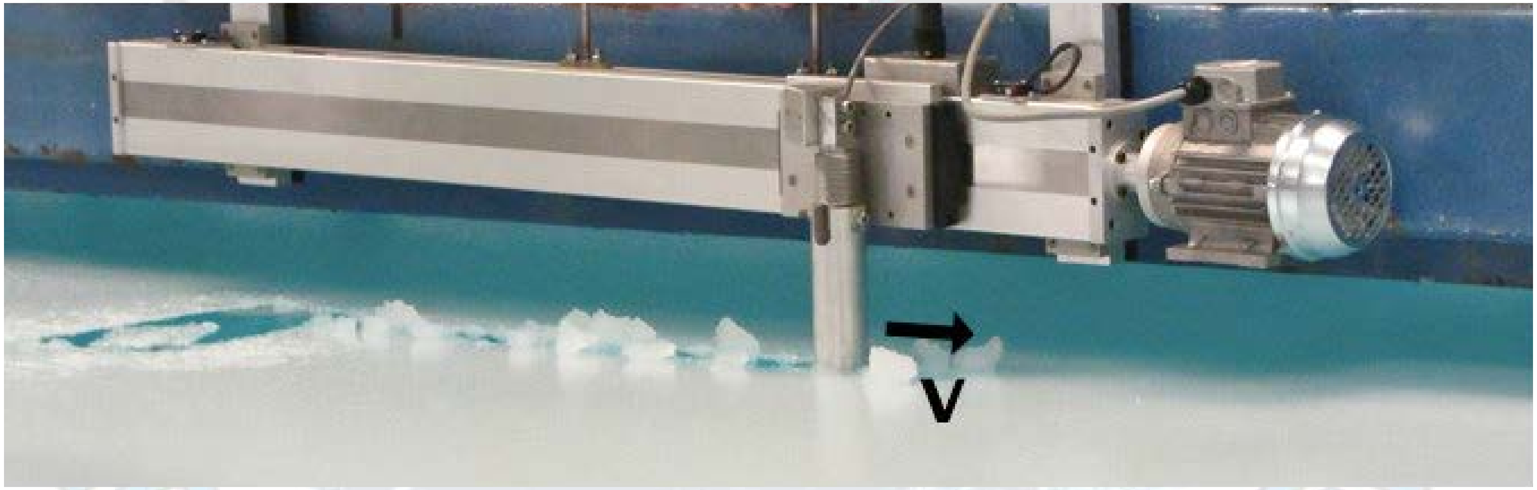
- In-situ



- This guideline still requires further work

Indenter Tests

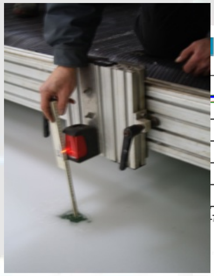
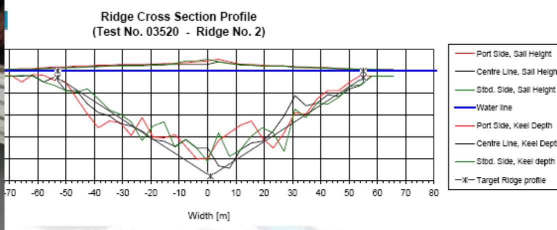
- In the version of 2002 indenter tests have been named compressive tests
  - Indenter tests



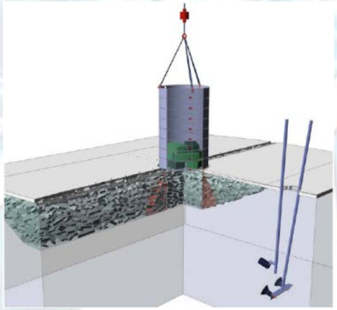
New guidelines


- Thickness
  Accuracy and intervall
- Friction
  Distinction between static and dynamic friction
- Shear strength
- Ridge Profiling



- Rubble shear strength



Tank Survey

- Aalto University
- Aker Arctic Technology Inc.
- Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA)
- Japan Marine United Corp. (JMUC)
- Krylov State Research Center new ice tank (KSRC)
- Krylov State Research Center old ice tank (KSRC)
- National Maritime Research Institute (NMRI)
- National Research Council / Ocean, Coastal and River Engineering (NRC/OCRE)

General Conclusions on Ice Properties

- Ice model testing technology has developed to its maturity in the last four decades.
- Individual ice tanks have developed their own ice productions and characterization techniques, which have been compiled, unified and evaluated.
- The recommended methods perform well within appropriate boundary conditions.
- Testing methods require continuous updating and development, based on the needs of society

Resistance Test in Ice

Revision, Extension and Modification of guidelines in related to *Resistance Test in Level Ice (2002) - 7.5-02-04-02.1*

Presented by Topi Leiviskä, Aker Arctic

Resistance Test in Ice

- Determination of ice resistance for ships is one of the main tasks to be resolved by the ice model basins.
- Previous edition of ITTC “Resistance Test in Level Ice” procedure was issued in 2002.
- Revision of the guideline is prepared and proposed by the current Ice Committee, but is incomplete. We present the modified part of the guideline in this presentation.

Resistance Test in Ice

Purpose of revision:

- updating of experimental procedure
- preparing basis for the offshore facilities guidelines

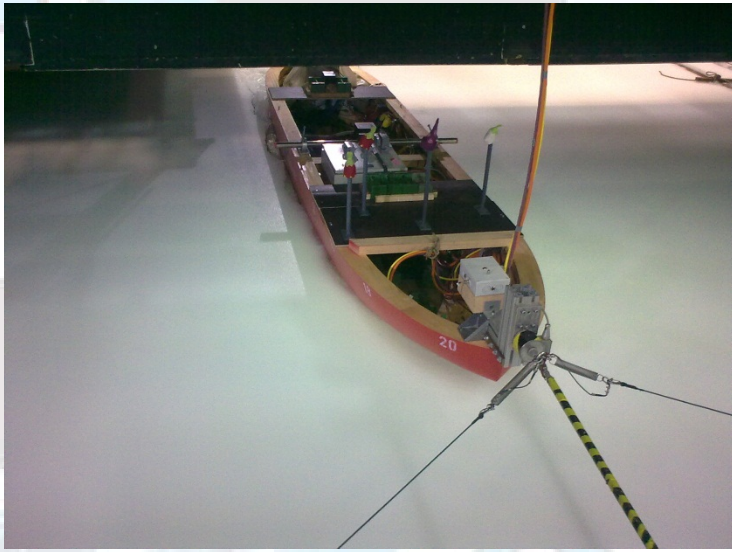
Resistance Test in Ice

- Towing tests in the ice basin have some special features compared with open-water tests.
- Ice model is to be developed. Ice properties are to be controlled.
- Towing test procedures
- Ways to extrapolate test data to specified conditions

Resistance Test in Ice

- Presently there are two methods to conduct the towing tests

Model directly under the carriage



Model towed by carriage using rigid pole.
This method was not described
in the previous procedure

Resistance Test in Ice

- We propose to extend Procedure of 2002 to the towing tests in other ice conditions but for the level ice:

Floe ice

Resistance Test in Ice

Pressure Ridges

Broken channels
(incl. brash ice)

Broken ice

Resistance Test in Ice

- Recommendations for test data corrections have been summarized to take into account all ice conditions.
- Procedure presents general approaches practiced in all ice basins.
- The final report surveys ice basins specific methods.

Resistance Test in Ice

- Correction of minor deviations in ice thickness

$$R_I = R_{I,meas} \left(\frac{H_{I,target}}{H_{I,meas}} \right)^x \qquad 1.0 \le x \le 2.0$$

$$x = \frac{\ln\left(\frac{R_{I1}}{R_{I2}}\right)}{\ln\left(\frac{H_{I1}}{H_{I2}}\right)}$$

Resistance Test in Ice

- Correction for ice strength

$$R_I = R_R + \frac{\sigma_{f,t\arg et}}{\sigma_{f,meas}} R_B$$

General formula

- Modified formulas

$$R_{I,corr} = aR_{I,meas} + b\frac{\sigma_{f,t\arg et}}{\sigma_{f,meas}} R_{I,meas}$$

KSRC, Aker Artic

$$R_{I,corr} = \boldsymbol{R_{I,meas}} \frac{1+\left(\frac{\boldsymbol{\lambda\sigma_{f,targer}}}{500}-1\right)/\boldsymbol{C}}{1+\left(\frac{\boldsymbol{\lambda\sigma_{f,meas}}}{500}-1\right)/\boldsymbol{C}}$$

HSVA

Resistance Test in Ice

- Correction for friction

$$R_{I,corr} = C_{if} R_I$$

General formula

- Modified formulas for level ice

$$C_{if} = \frac{1}{0.6 + 4 f_{ID}}$$

HSVA

$$C_{if} = \frac{0.61 + 1.34 f_{ID,target} + 5.9 f_{ID,target}^2}{0.61 + 1.34 f_{ID,meas} + 5.9 f_{ID,meas}^2}$$

KSRC

Resistance Test in Ice

- Instead of defining ships ice resistance by resistance tests, it can also be defined by self propulsion tests with some open water calibration tests. It was decided to describe this procedure in the future revision of Propulsion Test in Ice - 7.5-02-04-02.2

Survey of Numerical Methods for offshore structures and ships

Ice loads on ships and structures
Manouevring and DP in Ice

Presented by Akihisa Konno, Kogakuin University or Victor Westerberg, SSPA

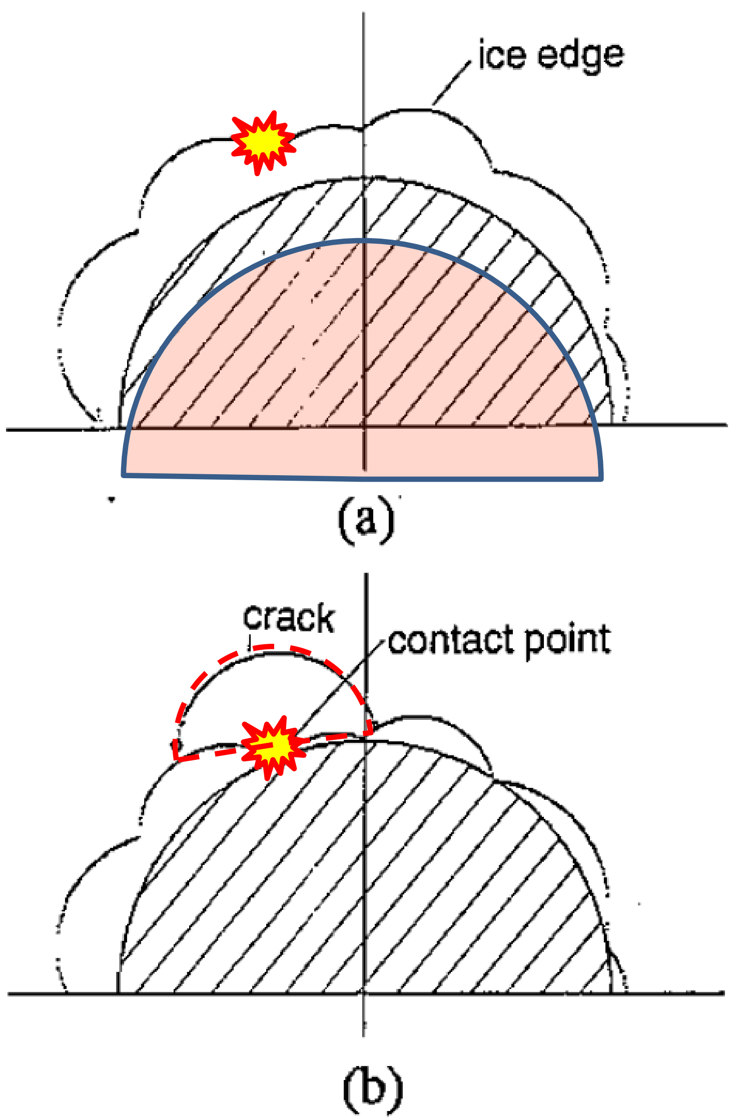
Applications of interest

– Ice-hull resistance
– Ice loads on ships hulls and offshore structures
– Design tool
– Operational training and planning
– Ice management operations and DP-systems

Loads on ships and structures

- Investigation of loads on structures in ice using numerical simulation is not a new topic, however old methods are improved and new methods are developed.
- Focus on commercial ice operations such as NSR and Arctic exploration has increased lately.

Earlier study



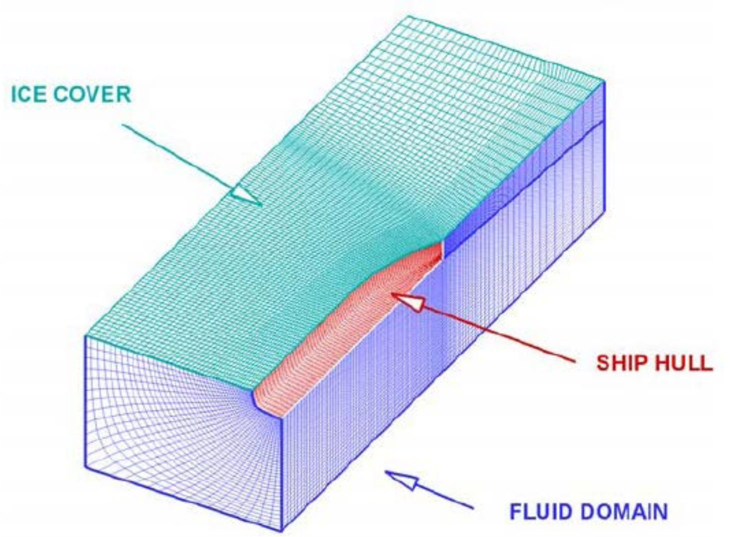
- Method of Crack Pattern Simulation for Ice-Cone interaction (Izumiyama, 1992)
- Beam theory, crack pattern approximation and ice force calculation are combined to estimate ice load on a conical structure

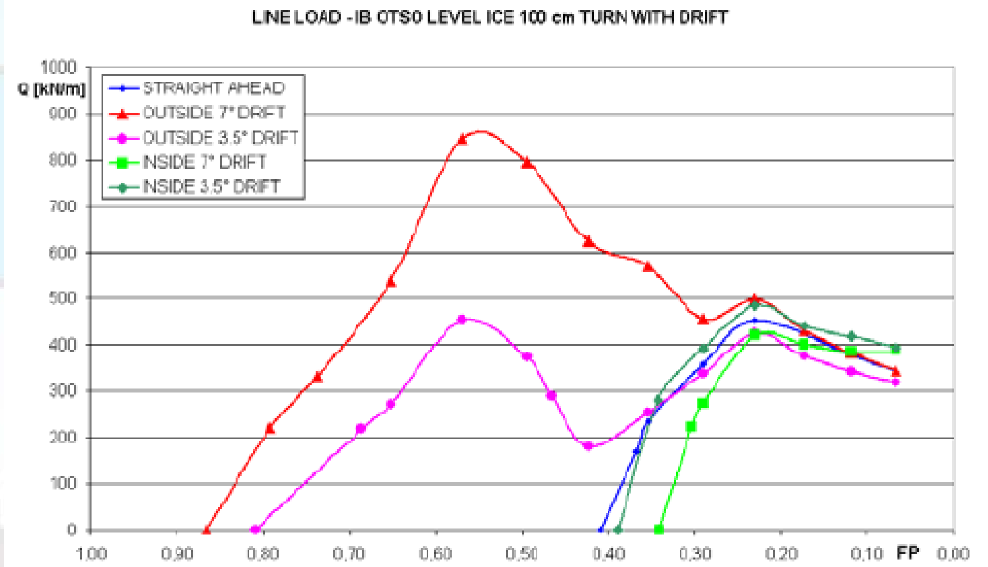
Recent studies

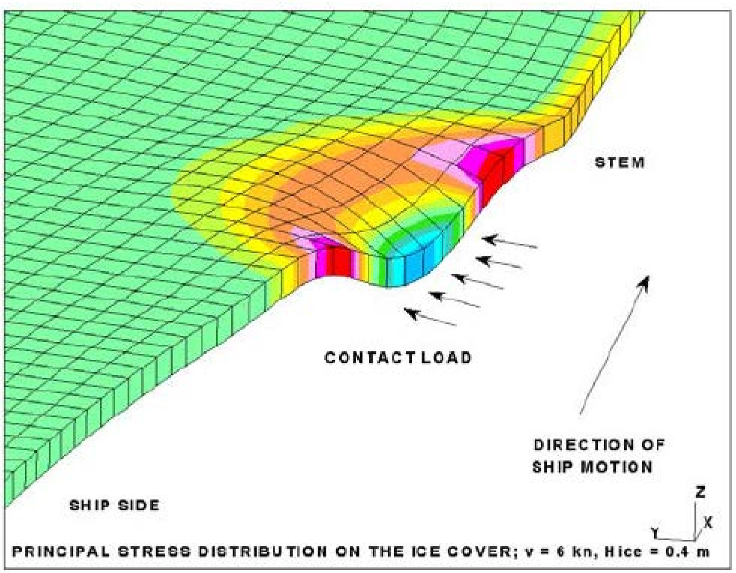
Use of advanced numerical methods such as:

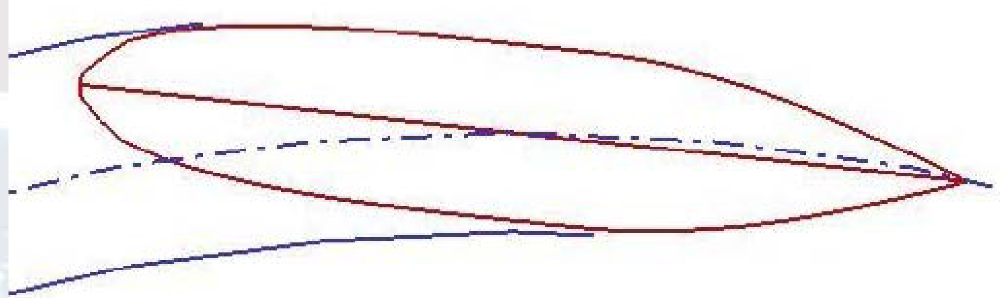
- FEM simulations are often conducted using commercial software packages such as Abaqus/Explicit and LS-DYNA.
- Many researchers use DEM simulations with their own codes, e.g., DECICE.
- Physically based modeling

Ice Load Simulation for Ships (FEM)



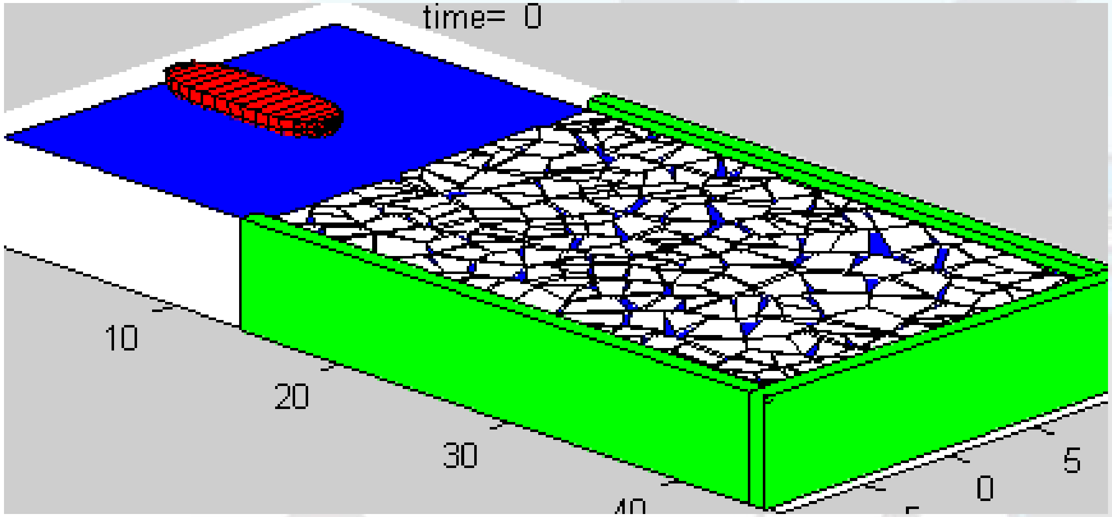




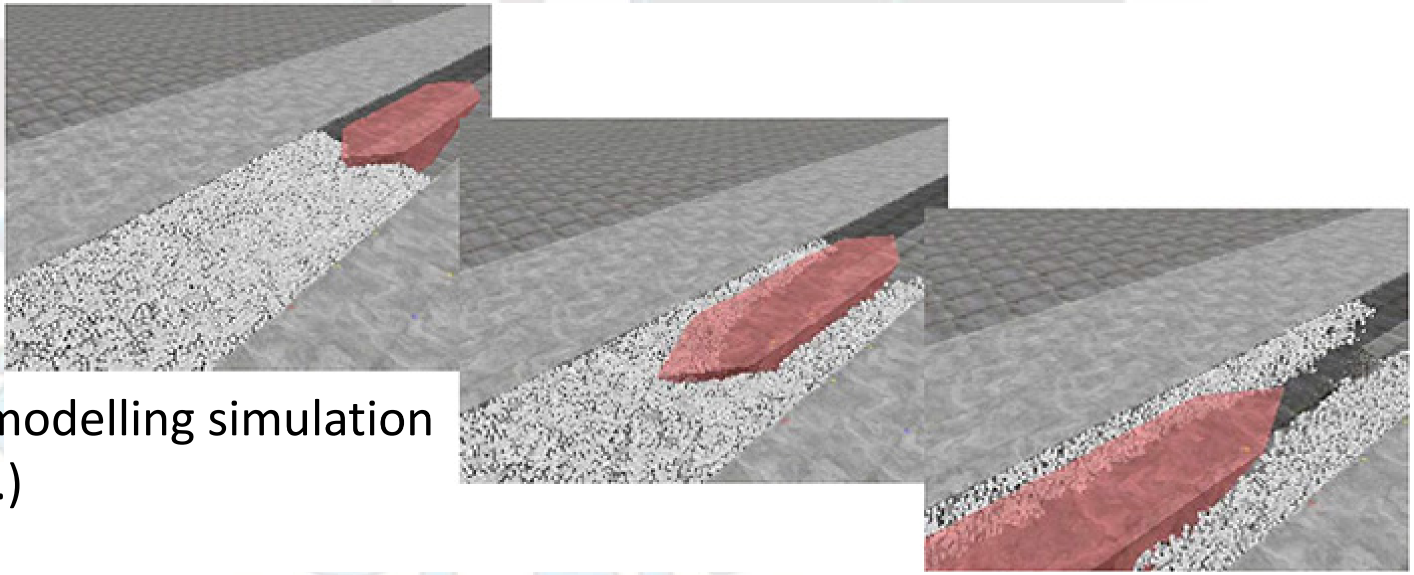


Valanto, POAC09-60
HSVA's code *Venice*

Ship simulations (DEM)



DECICE simulation
(Lau et al, 2011, etc.)



Physically-based modelling simulation
(Konno, 2009, etc.)

Ship simulations (DEM)

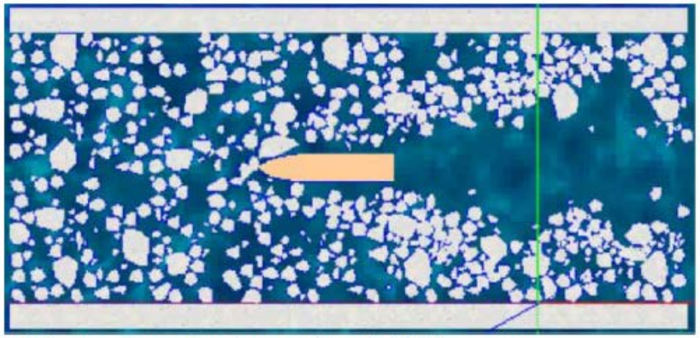
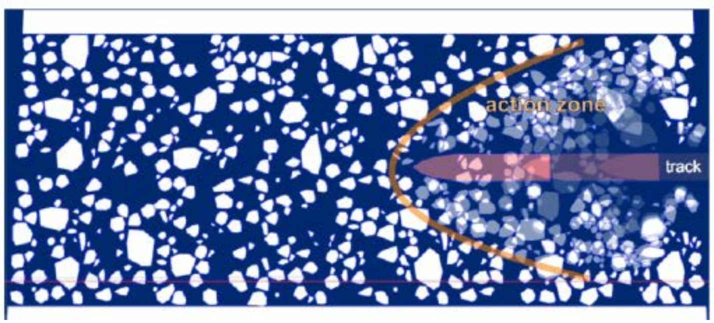
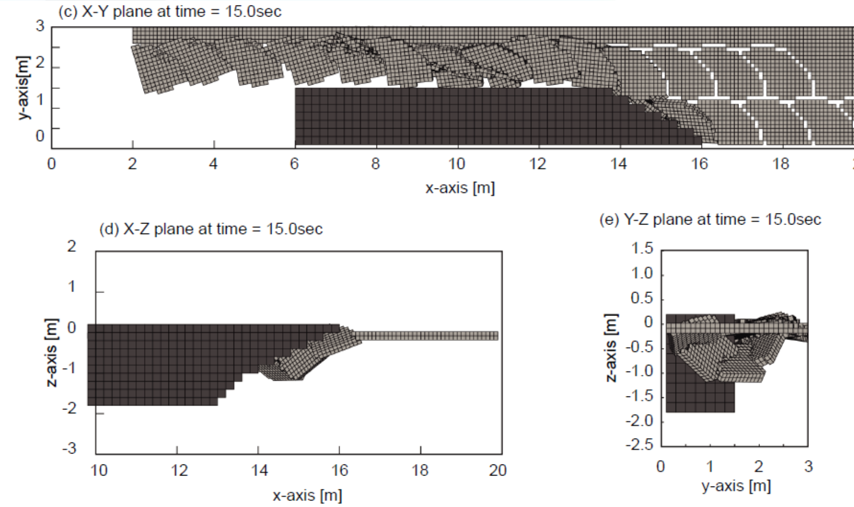


Figure 9. Image from simulation video in 35% coverage

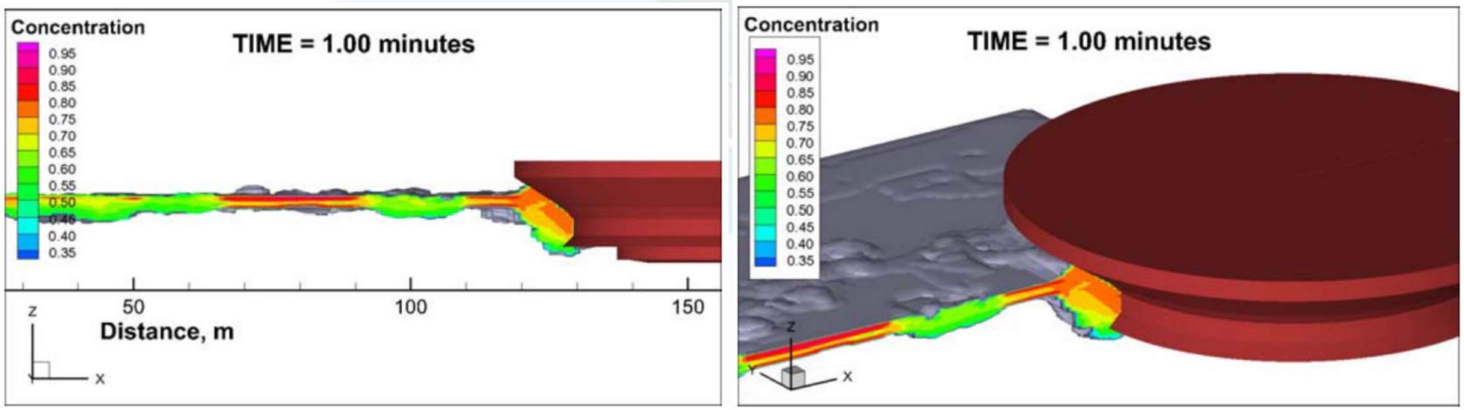


Delay et al, ICETECH12-109-RF
GPGPU simulation for real-time use

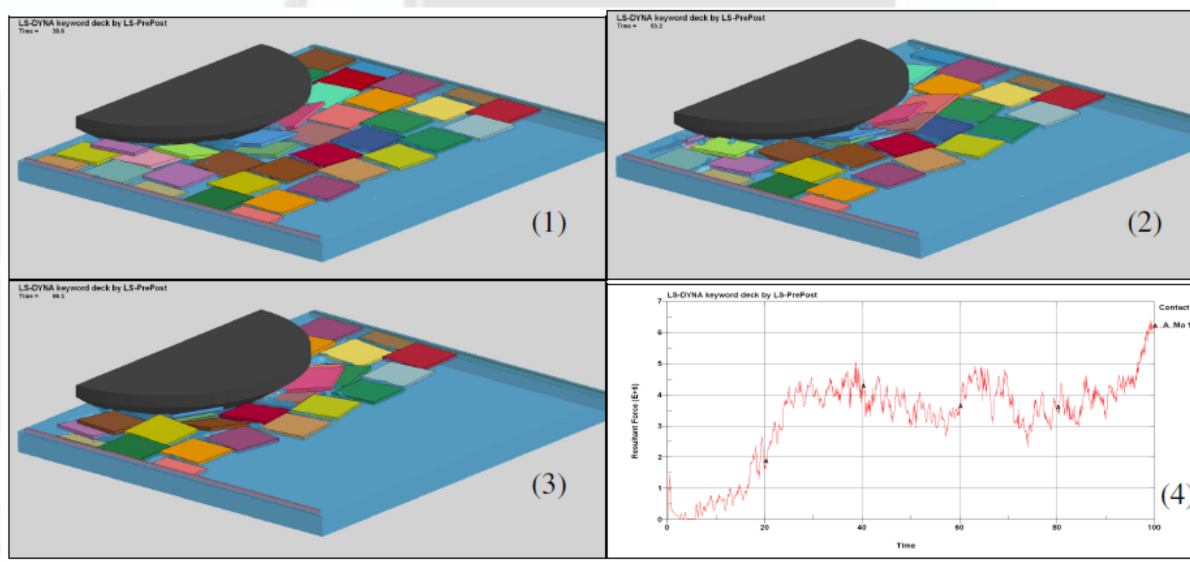


Sawamura, IAHR Symp. Ice 2012
DEM-type simulation w/FEM-based database for cracking pattern and reacting force

Ice-structure interactions



Sayed et al, ICETECH12-129-RF

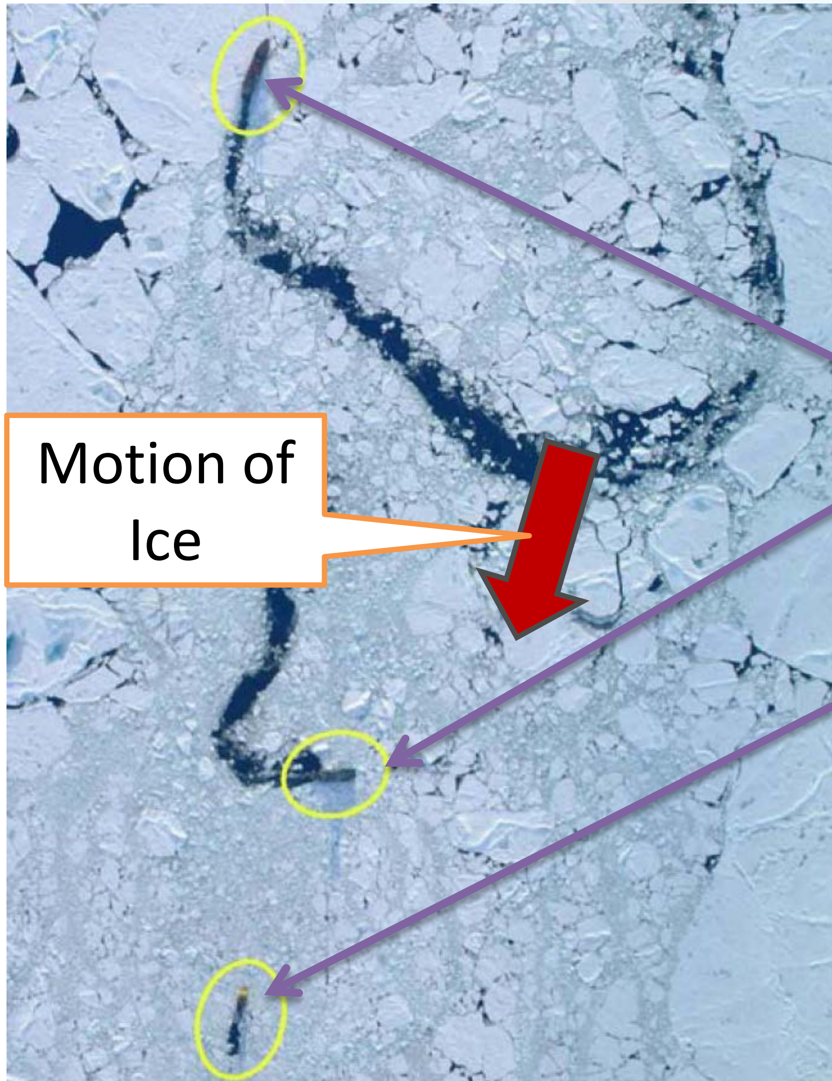


Wang, A. Derradji-Aouat, POAC11-172
FEM-DEM simulation incl. fluid analysis

Maneuvering and Dynamic Positioning in ice

- Maneuvering in ice:
  Turning in level ice or in (densely-) packed ice field
- Dynamic positioning in ice:
  Drillship in *managed* ice or level ice

Ice management and DP in ice

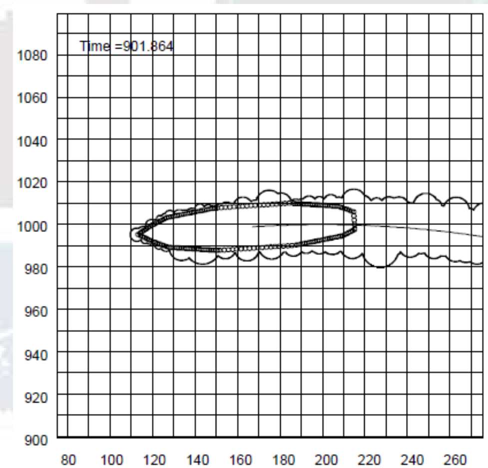


Moran, K., et al., 2006. Proc. IODP, 302

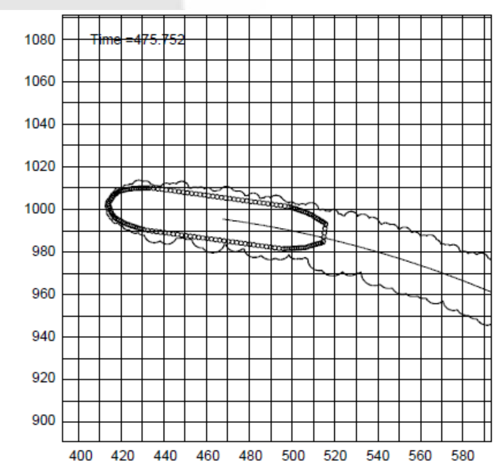
Numerical simulation of maneuvering and DP

Maneuvering in level ice
Sawamura et al, POAC11-35
DEM-type simulation w/FEM-based database for cracking pattern and reacting force

DP in level ice
Metrikin et al, 2013
DEM-type simulation (physically-based modelling)

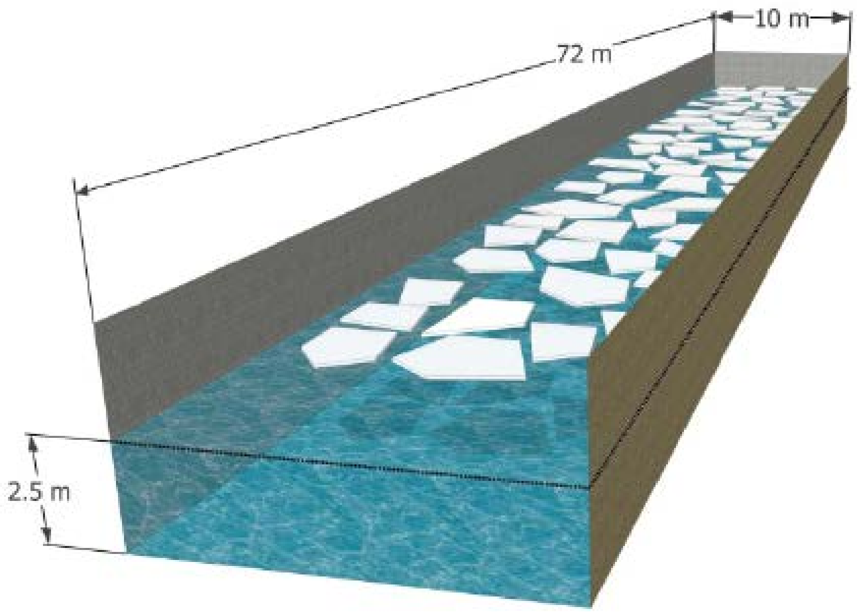


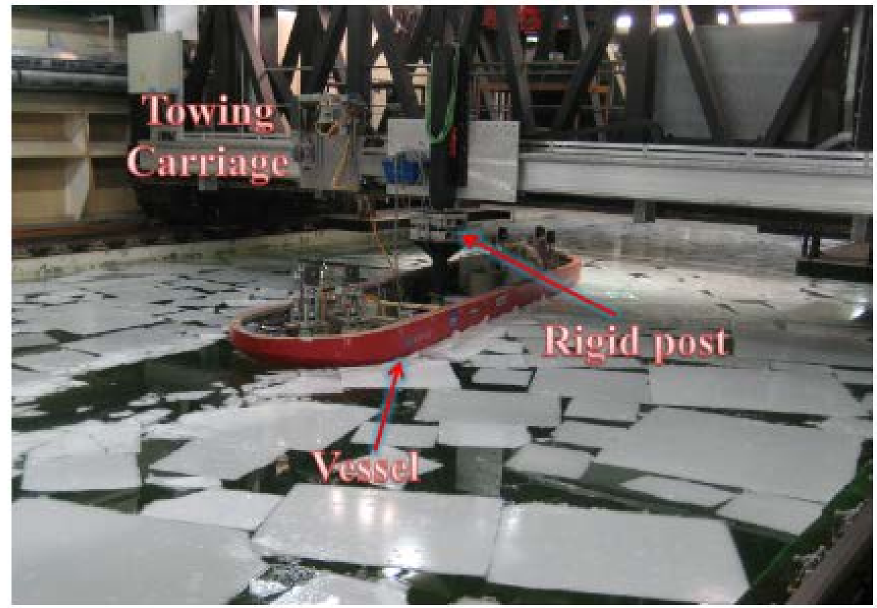
(a-3) Ice breaking channle with R=500m, v=2.0m/s, Thickness=0.8m (time=901s. rotate=183deg.)



(b-3) Ice breaking channle with R=500m, v=4.0m/s, Thickness=0.8m (time=475s, rotate=172deg.)

Simulation and experiment of DP in managed ice





Metrikin and Løset, POAC13_051
Experiments were conducted in HSVA.

Numerical methods - Conclusions

- Main issues/difficulties
  - The discontinuous nature of ice,
    rapidly changing ice conditions e.g. drifting ice field, growlers etc. Especially for DP.
  - For some applications; Real time capability (computational cost) vs. accuracy.
  - Fluid effect on ice

- Validation and benchmarking of developed methods against measurements are of high importance.
  - Ice tank tests
  - Full scale measurements

Recommendations

Recommendations to the Full Conference

- Adopt the revised procedure *7.5-02-04-02 Test Methods for Model Ice Properties*
- Remove procedure *7.5-02-04-02.4 Tests in Deformed Ice*

Recommendations for Future Works

The committee recommends that the ITTC completes:

- Review of existing Recommendations and Guidelines
  - Resistance Test in Ice - 7.5-02-04-02.1
  - Maneuvering Tests in Ice - 7.5-02-04-02.3
  - Propulsion Test in Ice - 7.5-02-04-02.2
  - Ship Trials in Ice - 7.5-04-03-01
  - Experimental Uncertainty Analysis for Ship Resistance in Ice Tank Testing - 7.5-02-04-02.5

Recommendations for Future Works

- Preparation of new Recommendations and Guidelines
  - Bash ice channel tests
  - Dynamic position in ice
  - Scalability of model test data
  - Offshore structures (fixed and floating)
- Review of numerical and prediction methods
- Establish a joint research project on maneuvering testing methods