ITTC Quality System Manual

Recommended Procedures and Guidelines

Guideline

General Guidance and Introduction to Ice Model Testing

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Updated / Edited by	Approved
Specialist Committee on Ice of the 29th ITTC	29th ITTC 2021
Date: 04/2020	Date: 06/2021

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General Guidance and Introduction to Ice Model Testing

1. PURPOSE OF THE GUIDELINE

The purpose of this guideline is to assist in making the test results from different test series and different laboratories more consistent. The ice committee has reviewed the earlier ITTC ice committee reports; this section represents a collection of methods developed during the past years. The following test types are discussed:

- Ship resistance in level ice
- Ship propulsion in level ice
- Manoeuvring of ships in level ice
- Ship tests in deformed ice
- Tests with offshore structures
- Modeling and testing in complex ice environments

Some important information is common to all of the above test types.

2. GENERAL GUIDELINES

2.1 Facilities, Ice Conditions and Ship Model

Differences in the dimensions and layout of the facility may have some influence on the tests. An important factor is the effect of the basin size on the number of tests that can be run in one ice sheet. The test length, in linear tests, limits this number. This test length should be such that the transients due to entering the testing ice have disappeared.

Thus, if the model comes to level ice from open water, the stem must be in the level ice part before the actual test run can start. In this case, the ship should proceed in ice at least two ship lengths (see 15th ITTC). The other factor, which may restrict the test program, is the vicinity of the basin walls. The level ice sheet may be considered to have infinite extent if the shortest distance from the point of application of any loads to the nearest tank wall is more than three characteristic lengths. The characteristic length is defined as:

$$l_c = [Eh_i^3 / 12\,(1-\nu^2) / \rho_w g]^{1/4} \quad (1)$$

where E is Young's modulus of ice, h_i is the ice thickness, ν is Poisson's ratio of ice (ν = 0.3 - 0.33), ρ_w is the density of water and g is the acceleration of gravity (see also Test Methods for Model Ice Properties, 7.5-02-04-02). In resistance tests with the basin width D and the bean of the vessel B the requirement is (subscript "M" refers to model scale):

$$l_{cM} < (D - B_M) / 6 \quad (2)$$

It is useful to present a layout of the test facility in the model test report. This layout should be used to report how the ice sheet was used in the tests and where ice properties measurements were carried out. It must be noted that model ice might behave elastic-plastic (e.g. von Bock und Polach, 2015) which limits the accuracy of Equation 1 and 2. Additional specific information is found in the particular guidelines of 7.5-02-04 Ice Testing.

2.2 Model Ice Production

Different methods and procedures are used in the various ice tank facilities to produce model ice and to adjust its properties (see Test Methods for Model Ice Properties, 7.5-02 -04-

02). Table 1 provides an overview of grain structure and chemical composition of the model ice in operating facilities.

Today's modelling practice favours the use of laboratory ice with weakening additives (dopants). Doped ice was developed originally for modelling ice forces on structures and icebreaker vessels. In difference to testing in open water, in ice model testing also scaling similarities for the ice properties must be met (e.g. *Schwarz, 1977).*

2.2.1 Model Ice Production Methods

In the model ice production generally two methods are distinguished: spraying and seeding. *Spraying* means that several layers of ice crystals are sprayed onto the cold tank surface a fine-grained ice structure is build upwards layer by layer. *Seeding* means that only one layer of ice crystal seeds in sprayed onto the surface, from which columnar structures ice grows into the tank. Each facility has its own customized chemical composition of spraying or seeding water and tank water (Table 1). Note: Tank water is always used for spraying except in some facilities some layers of fresh water are sprayed in between. For seeding some facilities use fresh water and others tank water.

Table 1: Ice sheet production methods in various refrigerated ice tank facilities

Ice tank facility	**Grain structure**	**Chemical composition**
Aalto University, Finland	fine grained	ethanol
Aker Arctic Technology inc, Finland	fine grained	sodium chloride
Japan Marine United (former Universal Shipbuilding Corporation) (former NKK), Japan	fine grained	urea
Krylov State Research Center (KSRC), Russia	columnar and fine grained	sodium chloride
National Research Council Canada, Ocean, Coastal and River Engineering (NRC-OCRE, formerly the Institute for Ocean Technology and Canadian Hydraulic Laboratory), Canada	columnar	EG/AD/S [*)]
Maritime Ocean Engineering Research Institute (KRISO), Korea	columnar	EG/AD [*)]
National Maritime Research Institute of Japan (NMRI), Japan	columnar	polypropylene glycol
The Hamburg Ship Model Basin (HSVA), Germany	columnar	sodium chloride
Tianjin University, China	columnar	urea

[*)] EG = ethylene glycol, AD = aliphatic detergent, S = sugar

2.2.1.1 Seeding Method

The preparation of the ice sheet is started by a seeding procedure (Figure 1). For this purpose, water is sprayed into the cold air of the ice tank. The droplets freeze in the air forming small ice crystals which settle on the water surface. By this method the growth of a fine-grained ice of primarily columnar crystal structure is initiated.

By using a sufficiently cold temperature, both water and dopant are frozen in solution together forming an ice sheet. This impure ice sheet is inherently softer than pure-water ice but may be harder than the scaled target strength. Once a desired thickness is achieved, the air temperature is raised to a tempering temperature.

Figure 1: Water is sprayed under high pressure into the air of the pre-cooled ice tank forming crystal nuclides which settle down on the water surface

Prior to model testing the relevant ice properties (e.g. ice strength, ice density and ice thickness) are measured along the ice tank at locations in accordance with the test run sections see Test Methods for Model Ice Properties, 7.5-02-04-02).

2.2.1.2 Spraying Method

In the spraying method a dense water fog is sprayed onto the ice. Unlike natural ice the model ice produced is growing upwards and not downwards. Compared to the seeding method the ice texture is fine granular (FG-ice and FGX-ice) instead of columnar (*Nortala-Hoikkanen, 1990*).

Basin water is sprayed into the cold air and the water droplets will somewhat freeze before reaching the water surface. In some cases, the basin water is mixed with or replaced by fresh water. This might vary from layer to layer. Each spraying pass produces a layer of soft granular white ice slush. The process is repeated until the required thickness is obtained. Thereafter the strength properties are adjusted by the cooling process. Figure 2 illustrates the spraying process.

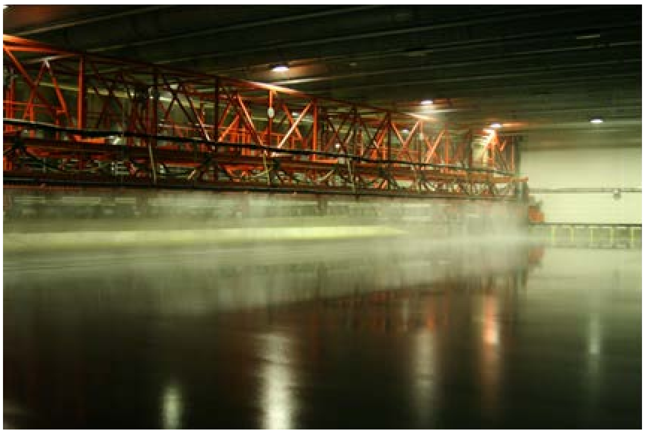

Figure 2: The spraying process

Furthermore, it must be acknowledged that non-standard tests may require different procedures. Lau et al (2007) have reviewed and summarized the ice modeling techniques used in different ice modeling facilities worldwide.

2.3 Scaling

This section presents only the traditional scaling approach which found its origin in the scaling of ships breaking ice. In ice model testing geometrical scaling is applied with the scaling factor, λ. In order to satisfy dynamic similarities both Froude and Cauchy similarity are maintained. The Froude similarity postulates to maintain the ratio of gravity and inertia forces in both scales. Cauchy similitude reflects the ratio of inertia and elastic forces. The elastic reaction forces refer to the elasticity of ice. More detailed information is found in (Vance, 1975; Schwarz, 1977; Zufelt & Ettema, 1996.

2.4 Modellig of different ice conditions

The origin of most modeled ice conditions is the level ice field. The manufacturing methods of different ice conditions or scenarios may be facility specific. In this section some general information are presented on a high level. Additional information is found in the guidelines on Ice Property Testing 7.5-02-04-02.

2.4.1 Level Ice

Level ice is a homogeneous ice sheet unaffected by deformation with consistent ice thickness.

Figure 3: Cutting pattern of pre-sawn ice

2.4.2 Presawn Ice

Presawn ice is level ice in which the approximate breaking pattern of the tested model is cut prior to testing. The measured resistance force does not contain the ice breaking component. The force difference in level ice resistance tests and pre-sawn ice resistance tests equals the ice-breaking resistance (see Resistance Guideline 7.5-02-04-02.1 for more details). Figure 3 shows a typical pattern of pre-sawn ice.

2.4.3 Modelling of ice floes

Ice floes in nature are defined as a flat piece of ice 2 m or more across. The floes are subdivided according to size and horizontal extent as summarized in Table 2. As in nature the processes and methods for ice breaking and floe generation can be of various origins such as ice broken by ships or waves. In model ice testing ice can be cut by other devices such as saws. Additional information is found in the ITTC Guidelines 7.5-02-04-03 Model Tests in Complex Environments.

Figure 4 shows ice floes in nature and scaled for model tests in an ice model basin.

Table 2: Types of ice floes

Type of ice floe	Ice floe size
Very small	2 – 20 m across
Small	20 – 100 m across
Medium	100 – 500 m across
Big	500 – 2000 m across
Vast	2 km – 10 km across
Giant	> 10 km across

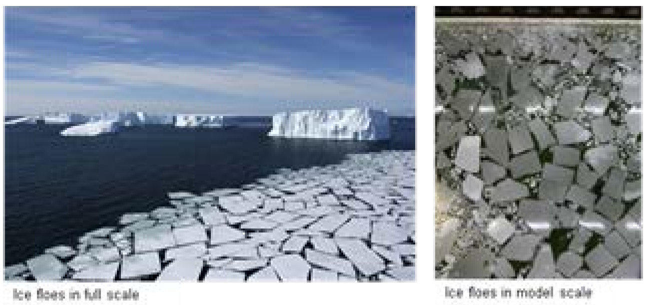

Figure 4: Floe ice in full (left) and model scale (right)

When modeling ice floes or broken ice conditions a pre-defined parental level ice sheet is prepared first and then cut into pieces corresponding to the required size and shape which can be of regular or irregular distribution. The ice pieces are dispersed on the water surface to achieve the required ice concentration.

2.4.4 Modeling of managed ice

Managed ice in this context represents ice broken by icebreakers to reduce loads on offshore structures and station keeping vessels. An example of a managed ice sheet with ice floes of different sizes and parts of brash ice in between is shown in Figure 5. More information is found in 7.5-02-07-03 Modeling of Complex Ice Environments.

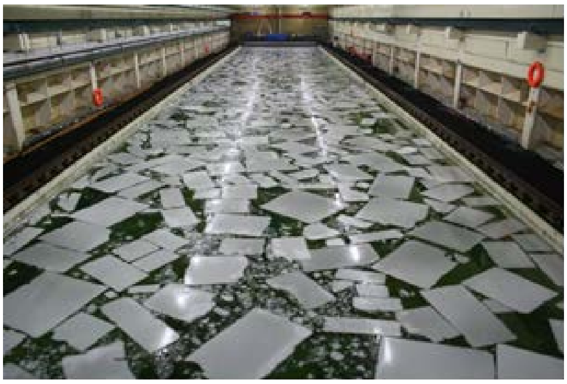

Figure 5: Managed Ice in a model test basin

2.4.5 Brash ice channel

A brash ice channel is modeled by accumulating small ice pieces in a shipping channel. In nature brash ice channels have a thinner brash accumulation in the middle which thickens towards the edges. The Finnish-Swedish Ice class rules provide guidelines for the conduction of brash ice tests for ice class certification (Trarficom & Swedish Transport Agency, 2011). More information is found in 7.5-02-04-03 Modeling and Testing in Complex Ice Environments.

2.4.6 First year ridges

In nature an ice ridge is a line or wall of broken ice forced up by pressure due to wind drag forces or current. It may be fresh or weathered. The submerged volume of broken ice under a ridge is termed ridge keel while the part forced upwards is termed ridge sail. When a ridge is formed, consolidation of the upper portion starts by freezing the void volumes inside and below the waterline of the ridge. First-year ridges usually have a triangular or trapezoidal shape below water.

The preparation of the ridge, and the definition and adjustment of the characteristic parameters of the ridge depend on the facility specific procedures and processes. More information is found in 7.5-02-04-03 Modeling of Complex Ice Environments.

2.4.7 Rubble ice fields

Rubble ice is a jumble of ice fragments or small pieces of ice that covers a larger area without any particular order to it.

Ice rubble fields can be prepared from former used level ice sheet by breaking it into small pieces and compacting it to target thickness. An example of an unconsolidated rubble ice field in the ice tank is shown in Figure 6.

It is common practice to continue the cooling process after a rubble ice field is formed in order to achieve a certain degree of rubble ice consolidation.

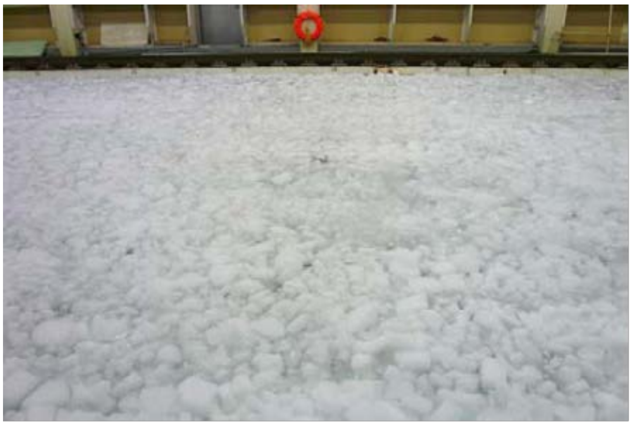

Figure 6: Example of an unconsolidated ice rubble field

2.5 The ship model parameters

The parameters of significance in ice are similar to those in open water as described in the guidelines 7.5-01-01-01 Ship Models. In ice model testing turbulence stimulators are not used.

In addition to the parameters stated in 7.5-01 -01-01 Ship Models the friction between model ice and ship model is of significance as it can impact the performance. The friction coefficient can have values between 0.05 and 0.15 depending on the modeled scenario (such as wet or dry contact, new or old hull). The friction coefficient is a function of the model surface and the model ice type. The friction can have a significant impact on the resistance.

It is important to document the ship (or structure) model particulars and the propulsion system data in detail. This information should be provided as drawings and tables and photographs of the model from various view angles should also be presented. Hull lines plan should be provided containing the required geometrical information for model production.

It must be accounted that in ice model testing the forces are significantly larger than in open water. Therefore, sufficient strength of the model is to be ensured.

3. BENCHMARK TESTS

In the 18th ITTC (Final Report 1987) a benchmark test with a R-class icebreaker had been conducted to compare the impact of different model ice types of ice basins on the measured resistance. Similar benchmark tests are nowadays conducted on the basis of commercial projects between various model ice basins.

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