

# The Specialist Committee on Ice

## Final Report and Recommendations to the 23rd ITTC

### 1. MEMBERSHIP AND MEETINGS

The 23rd ITTC Specialist Committee on Ice consists of:

- Dr. Hajime Yamaguchi (Chairperson)
- Dr. Ahmed A. Derradji (Secretary)
- Mr. Koh Izumiyama
- Mr. Göran Wilkman

The committee met four (4) times:

- May 4, 2000 (Houston, TX, USA)
- September 15, 2000 (Helsinki, Finland)
- August 10, 2001 (Ottawa, ON, Canada)
- March 4, 2002 (Tokyo, Japan)

### 2. CONCLUSIONS OF THE 23RD ITTC COMMITTEE

#### ITTC procedure 4.9-03-03-04.1

This procedure provides the general guidelines for ice model testing. Its purpose is to assist in making the test results from different test series and different laboratories more consistent. The Ice Committee has reviewed the pre-

vious ITTC Ice Committee report (20th ITTC, in 1993) and presented an up to date collection of recent methods developed for ice model testing. The effect of the size of the test facility (ice tank itself) and the effect of ice conditions (such as patterns in the presawn ice sheet) were discussed. Two lists for the required parameters (for both ship and model ice) were given. A reference list for benchmark tests was provided.

#### ITTC procedure 4.9-03-03-04.2.1

This procedure deals with resistance tests in level ice. The basic reason for these tests is to determine the effectiveness of the hull form in breaking ice and in progressing through ice. The Ice Committee has reviewed the existing procedure and provided the update methodology and the corresponding equations for the calculation of the resistance in level ice. The updated procedure includes, also, a description of the current experimental practices for conducting ice resistance tests. The parameters needed for reporting (for both ship and ice) are listed and a reference list for benchmarks tests was given.

#### ITTC procedure 4.9-03-03-04.2

This procedure is for measuring the mechanical properties of model ice. The Ice Committee updated the existing procedure. The committee specified the following test meth-

ods: the flexural strength of model ice is determined using the in-situ beam test method; the modulus of elasticity is determined using the infinite plate test method; the compressive strength of model ice is determined using indentation tests; the submerged ice-piece test is used to measure the specific weight of the ice. The equations for each test method are given, and the parameters that need to be reported are listed in this updated procedure.

### **Experimental Uncertainty Analysis**

A report containing examples for precision uncertainty calculation in ice tank tests for a typical ice tank experiment is completed.

### **New developments and an up-to-date bibliography in ice model testing**

A review of new developments in ice model testing and to prepare an up-to-date bibliogra-

phy of the relevant technical papers and reports is completed.

### **Statement for Iceberg Impact Experiments**

The committee issued a statement concerning the use of ice tanks for impact experiments of small icebergs with ships and offshore structures.

## **3. RECOMMENDATIONS TO THE CONFERENCE**

Adopt the amended procedure “Guidelines for ice model testing” 4.9-03-03-04.1.

Adopt the amended procedure “Ice resistance test in level ice” 4.9-03-03-04.2.1.

Adopt the amended procedure “Test methods for model ice properties” 4.9-03-03-.04.2.1.

## APPENDIX A. UNCERTAINTY ASSESSMENT OF SHIP MODEL TEST IN ICE

### A.1. Error sources in test in ice

The first step of uncertainty analysis is to identify error sources or elementary errors to be taken into account in the analysis. Error levels (bias and precision limits) are calculated and/or estimated for each source. Error sources involved in model test in ice may be classified into the following four categories.

Errors in measurements. Model testing in ice is composed of various measurements. They include those related to ship performance in ice such as resistance, speed, propeller thrust and torque, etc. Properties of model ice in which the test is performed are also measured. None of the measurements can be free from error and the measured results and values calculated based on measurements have some uncertainty. Uncertainty in this category may be termed as the “measurement uncertainty” in a narrow sense.

Error due to model ship and test set-up. Although great efforts are given in model manufacturing, no model geometry can be free from error. Wooden models are most frequently used in ice model basins. They may be deformed during long time use. Misalignment in test set-up will also cause error. Ice-hull friction is one of important resistance components in ice. Effect of ice friction on resistance was discussed in past ITTC Ice Committees. Model surface is treated so that it gives a target value of friction coefficient. Actual friction coefficient, however, may differ from the target.

Errors due to test facility and model ice. Model testing is performed in a model ice basin that has limited width and length. Test result may be affected by existence of tank wall, if the test is made in ice too close to it. Length of a test run is also limited compared to that in open water tank. Thickness and mechanical properties of model ice are adjusted to the target val-

ues. It is inevitable, however, there is some scatter in ice properties within an ice sheet. This will mean that ice properties measured at a location of the ice sheet may differ from the ones in the area of ice where the test is made.

Errors in extrapolation to full-scale conditions. Final objective of model testing is to estimate ship performance at full scale. Test results are scaled-up to calculate full-scale values. It is inevitable, however, that there exist scale-effects in any model testing. Model testing for ships in water has a long history. There have been various studies done on the scale-effects to establish methodologies for model-ship correlations. For the model testing in ice efforts have been made to develop model ice with properly scaled properties. More works are required, however, on other aspects of scale-effects of model testing in ice.

Many of error sources in the first and second categories are also taken in uncertainty analysis for tests in open water conditions, although some of them are peculiar to ice test. There are items that are taken in open water cases but can be ignored in ice test. Water temperature is such an example. It is an important item to be taken in the analysis as shown in the 22nd ITTC Quality Manual procedure 4.9-03-02-02. In ice model basin, however, water temperature is very constant and uniform at the freezing point.

Little is known on the uncertainty in the fourth category. Each ice model basin has its own way of model-ship correlation. No study and/or data are published, however, on its uncertainty. It seems that the largest problem for this is lack of full-scale data.

An example of uncertainty analysis of resistance test in ice is given in the next section. The analysis takes into account the uncertainty due to special scattering of ice properties, which is described in the third category. These error sources are peculiar to model testing in ice.

## A.2. Example: uncertainty analysis of resistance test in ice

Kitagawa et al. made an uncertainty analysis of resistance test in level ice (Kitagawa, 1991). They made the analysis for the results of resistance tests for a model of an icebreaking tanker. In the following outline of their analysis is given as an example of uncertainty analysis of test in ice. The analysis takes into account the uncertainty due to special scattering of ice properties. Tests were carried out for wide ranges of thickness and flexural strength of ice. Uncertainty range was calculated for each test case.

Items analyzed: Analysis was made for uncertainty levels of resistance of the model ship,  $R$ , flexural strength,  $\sigma_F$ , and thickness,  $h$ , of the ice. The following expressions are used here;

$X_I$ : item on which uncertainty level is calculated

$B_I$ : bias limit of  $X_I$

$S_I$ : precision index of  $X_I$

$U_I$ : uncertainty level of  $X_I$

In this analysis,

$X_1$ : resistance of the model ship,  $R$ ,

$X_2$ : flexural strength of ice,  $\sigma_F$ ,

$X_3$ : ice thickness,  $h$ .

Elementary error sources. Uncertainty of above-mentioned items is given by summing up elementary errors included in each item.

Resistance of the model ship,  $X_1$

This item is composed of elementary error in resistance measurement.

Flexural strength of ice,  $X_2$

Flexural strength of ice is given by the bending test of cantilever beams of ice. It is calculated by the following equation

$$\sigma_F = \frac{6Pl}{bh^2}, \quad (1)$$

where,  $P$  is the load to break the ice beam,  $l$  is the beam length between loaded point and ice

failure,  $b$  is the width of the beam and  $h$  is the thickness of the beam, namely ice thickness. This item is composed of elementary errors in measurements of above-mentioned values.

Ice thickness,  $X_3$

This item is composed of elementary error in ice thickness measurement.

Spatial scatterings of ice properties

Although ice sheets are formed as uniform as possible, it is inevitable that there are scatters in ice properties within an ice sheet. Ice properties measured at a location of the ice sheet may differ from the ones in the area of ice where the test is made. To take into account this effect not only errors involved in measurements, errors due to spatial distribution of ice properties are considered. This results in additional elementary errors for items  $X_2$  and  $X_3$ .

For the elementary errors, the following expressions are used:

$X_{JI}$ :  $J$ -th elementary error source of item  $X_I$

$B_{JI}$ : bias limit of  $X_{JI}$

$S_{JI}$ : precision index of  $X_{JI}$

Elementary errors used in the analysis are;

$X_{11}$ : error in measurement of  $R$ ,

$X_{12}$ : error in measurement of  $P$ ,

$X_{22}$ : error in measurement of  $h$ ,

$X_{32}$ : error in measurement of  $b$ ,

$X_{42}$ : error in measurement of  $l$ ,

$X_{52}$ : error due to spatial distribution of  $\sigma_F$ ,

$X_{13}$ : error in measurement of  $h$ , and

$X_{23}$ : error due to spatial distribution of  $h$ .

Bias and Precision Limits. Error levels are estimated for each elementary error. Bias limits are given by the measurement accuracy of the devices used for the measurement. Precision errors for the dynamometers used for resistance measurement and ice bending test are calculated using data of calibration tests. For manual measurements like ice thickness measurement, precision errors are assumed to be 3% of meas-

ured values. To calculate precision error due to spatial distribution of ice properties, statistical data from extensive measurements are used. Bias limits and precision errors are summarized below.

$B_{11}=1.0$ N,	$S_{11}=2.6$ N
$B_{12}=0.01$ N,	$S_{11}=0.008$ N
$B_{22}=0.1$ mm,	$S_{22}/h=0.03$
$B_{32}=0.1$ mm,	$S_{32}/b=0.03$
$B_{42}=1.0$ mm,	$S_{42}/l=0.03$
$B_{52}/\sigma_F=0.0$ ,	$S_{52}/\sigma_F=0.2$
$B_{13}=0.1$ mm	$S_{13}/h=0.03$
$B_{23}/h=0.0$	$S_{23}/h=0.015$

Sensitivity. To define the effect of each error on the final uncertainty sensitivity,  $\theta_{JI}$  is calculated.

$$\theta_{JI} = \frac{\partial X_I / X_I}{\partial X_{JI} / X_{JI}} \quad (2)$$

Items of resistance and ice thickness are composed of a single measurement. Then naturally,

$$\theta_{11} = \theta_{13} = 1.0$$

For the flexural strength of ice equation (1) is used. From equation (1) relative sensitivities of flexural strength on  $P$ ,  $h$ ,  $b$  and  $l$  are given as follows, respectively.

$$\begin{aligned} \theta_{12} &= \frac{6l}{bh^2} \frac{P}{\sigma_F} = 1.0 \\ \theta_{22} &= -2 \frac{6Pl}{bh^3} \frac{h}{\sigma_F} = -2.0 \\ \theta_{32} &= -\frac{6Pl}{b^2h^2} \frac{h}{\sigma_F} = -1.0 \\ \theta_{42} &= -\frac{6P}{bh^2} \frac{l}{\sigma_F} = 1.0 \end{aligned} \quad (3)$$

Calculation of uncertainty range. Uncertainty range for a 95-percent confidential level was calculated. Bias limit,  $B_I$ , and precision index,  $S_I$ , of item  $X_I$  are given as

$$\begin{aligned} B_I / X_I &= \left[ \sum_I (\theta_{JI} B_{JI} / X_I)^2 \right]^{1/2} \\ S_I / X_I &= \left[ \sum_I (\theta_{JI} S_{JI} / X_I)^2 \right]^{1/2} \end{aligned}$$

Uncertainty range,  $U_I$ , is given as

$$U_I = \left[ (B_I^2 + S_I^2) / X_I^2 \right]^{1/2}.$$

Uncertainty ranges for resistance, flexural strength and thickness of ice are shown in Figures 1, 2 and 3, respectively. Although uncertainty range for the resistance widely distribute, most of the data fall within 0–5 %. On the other hand, uncertainty ranges for flexural strength and thickness of ice don't differ much between tests.

Combined uncertainty of resistance. Uncertainty ranges for resistance, flexural strength and thickness of the ice are calculated separately. Resistance of a ship in ice, however, is a function of ice properties. Uncertainties in ice properties will affect that of resistance. Combined uncertainty range of resistance that takes into account the uncertainty of ice properties as well as that of resistance measurement is calculated. To calculate this the following formula is assumed for the resistance in ice.

$$R = R_{BR} + R_G + R_{IN}, \quad (4)$$

where

$$\begin{aligned} R_{BR} &= C_1 \sigma_F h^2 \\ R_G &= C_2 h^2, \\ R_{IN} &= C_3 h \end{aligned} \quad (5)$$

In equation (4)  $R_{BR}$ ,  $R_G$  and  $R_{IN}$  are breaking, gravity and inertia components of ice resistance, respectively. It should be noted equations (4) and (5) are given here not as universal formulae but the ones empirically obtained for the particular model used in the present test. Relative sensitivities of resistance to flexural strength of ice,  $\theta_2$ , and to ice thickness,  $\theta_3$ , are calculated as follows.

$$\theta_2 = C_1 h^2 \frac{\sigma_F}{R} = \frac{R_{BR}}{R} \tag{6}$$

$$\theta_3 = 2 - \frac{R_{IN}}{R}$$

Using results in resistance tests in pre-sawn ice, the authors assumed the following values.

$$\theta_2 \approx 0.7$$

$$1.7 \leq \theta_3 \leq 2.0 \tag{7}$$

Combined uncertainty range of resistance will be given by

$$U = \left[ U_1^2 + (\theta_2 U_2)^2 + (\theta_3 U_3)^2 \right]^{1/2} \tag{8}$$

Results of calculation are shown in Figures 4 and 5. In the calculation  $\theta_3 = 2.0$  was assumed. Combined uncertainty range of resistance increases by about 5%. Correlation of combined and single uncertainty ranges of resistance shows that the increase in uncertainty is large for low region of uncertainty range and small for the high uncertainty region.

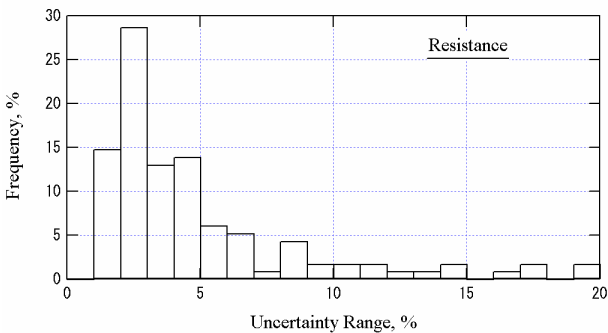


Figure A.1 Uncertainty Range for Resistance.

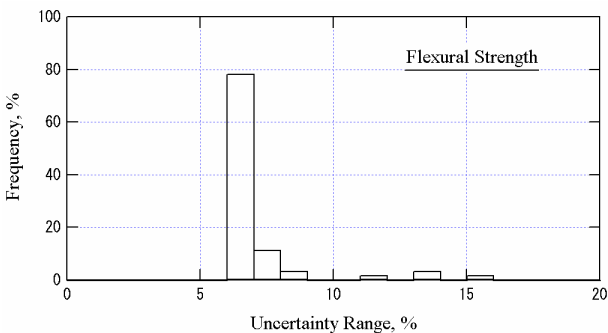


Figure A.2 Uncertainty Range for Flexural Strength.

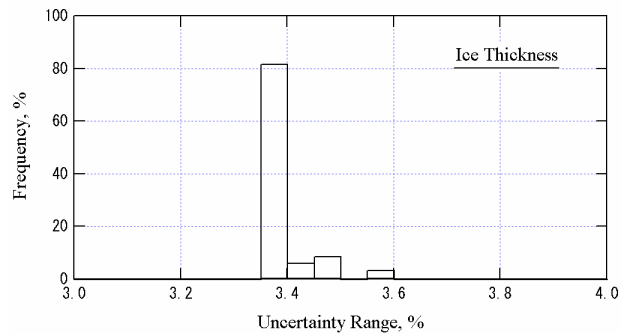


Figure A.3 Uncertainty Range for Ice Thickness.

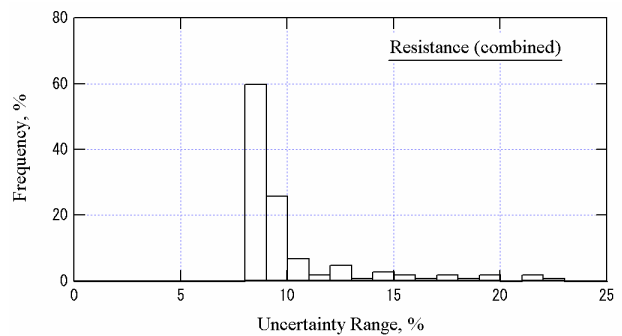


Figure A.4 Combined uncertainty range of resistance.

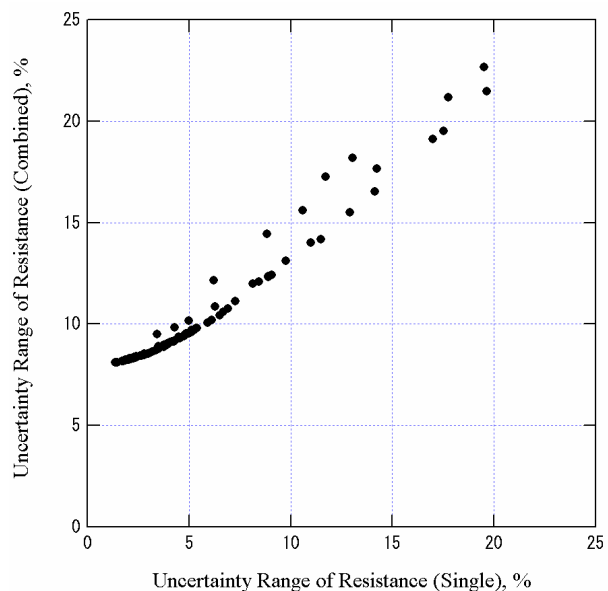


Figure A.5 Correlation of Uncertainty Ranges of Resistance.

## APPENDIX B. NEW DEVELOPMENTS AND AN UP-TO-DATE BIBLIOGRAPHY IN ICE MODEL TESTING

### <Ice-propeller interaction test>

Searle, S., Veitch, B., and Bose, N., 1999, “Experimental Investigation of Highly Skewed Propeller in Ice”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John’s, NF, Canada, OMAE99/P&A-1130.

Tamura, K., and Kato, H., 1999, “Experimental Study on Interaction between Nozzle Propeller and Ice”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John’s, NF, Canada, OMAE99/P&A-1103.

### <New test procedure for earthquakes against a structure in ice>

Hyodo, M., Fujii, T., Yamamoto, Y., Yoshimoto, N., Ito, S., Kamesaki, K., and Yamauchi, Y., 2001, “On-line seismic response test on gravity offshore structure based on sand seabed subjected to ice load”, Proceedings of the 16th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 130-133.

Hyodo, M., Yoshimoto, N., Hyde, A.F.L., Yamane, Y., Fujii, T., Kamesaki, K., and Yamauchi, Y., 2001, “Behaviour of Offshore Structure Based on Sand Seabed Subjected to Ice and Seismic Loads by On-Line Dynamic Response Test”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 597-606.

Kiyakawa, T., Ishikawa, S., Nishigaki, M., and

Kurokawa, A., 1999, “Analysis of Hydrodynamic Forces Acting on Offshore Structures Surrounded by Ice Sheet During Earthquakes”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John’s, NF, Canada, OMAE99/P&A-1142.

Toyama, Y., Kato, K., Kamesaki, K., Yamauchi, Y., and Kurokawa, A., 2001, “Ice and Earthquake Loads on a Structure in Offshore Sakhalin”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 597-606.

### <Ridges and ridge/structure interaction>

Jensen, A., Loset, S., Hoyland, K.V., Liferov, P., Heinonen, J., Evers, K.-U., and Maattanen, M., 2001, “Physical Modeling of First-Year Ridges – Part II: Mechanical Properties”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 3, pp. 1493-1502.

Hoyland, K.V., Jensen, A., Liferov, P., Heinonen, J., Evers, K.-U., Loset, S., and Maattanen, M., 2001, “Physical Modeling of First-Year Ridges – Part I: Production, Consolidation and Physical Properties”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 3, pp. 1483-1492.

Tuhkuri, J., and Lensu, M., 2001, “Energy Balance of Laboratory Scale Ridging and Rafting Processes”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 3, pp. 1473-1482.

Yamauchi, Y., and Kamesaki, K., 2001, “First Year Ridge Acting on a Vertical Sided

Structure Placed in Shallow Water”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 577-586.

Yasunaga, Y., Kioka, S., Matsuo, Y., and Saeki, H., 2001, “Tests on Strength of Consolidated Parts of Hummock Ice Model”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 3, pp. 1503-1511.

#### <Oil spill test>

Izumiyama, K., Konno, A., and Sakai, S., 2002, “Laboratory Test on Spreading of Oil under Ice Covers”, Proceedings of the 17th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 267-273.

Narita, S., 2001, “Tests of a New Oil Recovery Device – Icecleaner #1”, Proceedings of the 16th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 87-92.

Ogiwara, K., Otsuka, N., Kanaami, K., Takahashi, S., Maida, K., and Saeki, H., 2002, “Experimental Study on Spreading of Oil under Uneven Icesheets”, Proceedings of the 17th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 290-297.

#### <Ice pressure around ship hull>

Izumiyama, K., Wako, D., and Uto, S., 2001, “Ice Pressure Acting Over a Model Ship Hull”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 793-802.

Valanto, P., 2001, “On the Cause and Distribu-

tion of Resistance Forces on Ship Hulls Moving in Level Ice”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 803-813.

#### <Various ice tank tests and hull form design>

Derradji-Aouat A., Moores, C., and Stuckless, S., 2002, “Terry Fox Resistance Tests – Phase 1: The ITTC Experimental Uncertainty Analysis Initiative”. IMD report # TR2002-01.

Ha, M.-K., Kim, H.-S., Ahn, D., Williams, F.M., and Molyneux, W.D., 1999, “Development of an Arctic Tanker”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John’s, NF, Canada, OMAE99/P&A-1136.

Juurmaa, K., Mattsson, T., and Wilkman, G., 2001, “The Development of the New Double Acting Ships for Ice Operation”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 719-726.

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Rupp, K.H., Schutle, G., and Gehl, S., 2001, “(Double) Acting in Ice”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 759-768.

Yamaguchi, H., Suzuki, Y., Uemura, O., Kato, H., and Izmiyama, K., 1999, “Influence of Bow Shape on Icebreaking in High Speed Range”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John's, NF, Canada, OMAE99/P&A-1104.

#### <Others>

Arpiainen, M., Backstrom, M., Suojanen, R.-A., Wilkman, G., Kostiaainen, K., and Holm, O., 2001, “Winter Transportation Possibilities through the Inland Water Ways in Finland”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 839-848.

Azarnejad, A., Frederking, R., and Brown, T.G., 1999, “Ice Rubble Strength from Plane Strain Punch Tests”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John's, NF, Canada, OMAE99/P&A-1168.

Brette, P.D., Phillips, R., McKenna, R.F., Jones, S.J., and Crocker, G., 1999, “Interaction between Level Ice and a Conical Structure: Centrifuge Simulations”, CD-ROM Proceedings of the 18th International Conference on Offshore Mechanics and Arctic Engineering, ASME, St. John's, NF, Canada, OMAE99/P&A-1148.

Comfort, G., Singh, S., and Spencer, D., 2001, “Moored Vessel Station-Keeping in Ice-Infested Waters: an Assessment of Model Test Data for Various Structures and Ship

Shapes”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 541-552.

Evers, K.-U., Spring, W., Foulkers, J., Kuehnlein, W., and Jockmann, P., 2001, “Ice Model Testing of an Exploration Platform for Shallow Waters in the North Caspian Sea”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 1, pp. 255-264.

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Leiviska, T., Tuhkuri, J., and Riska, K., 2001, “Model Tests on Resistance in Ice-Free Ice Channels”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 881-890.

Moores, C., Veitch, B., Bose, N., Jones, S.J., and Bugden, A., 2001, “Effects of Strain Rate and Temperature on the Uniaxial Compressive Strength of EG/AD/S CD Model Ice”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 3, pp. 1423-1432.

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New Bow Form for Operation in Brash Ice Channels”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 2, pp. 867-876.

Sato, K., Yashima, N., and Nakanishi, M., and Adachi, H., 2002, “Study on the Seismic Response Characteristics of Offshore Structures in Ice Covered Seas (Comparison between Seismic Response Analytic Results and Pseudo Response Test Results on the Conical Structures)”, Proceedings of the 17th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 319-328.

Surkov, G., 2001, “Loads on Cylindrical Support Structures due to First-Year Hum-

mocks”, Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, ON, Canada, Vol. 1, pp. 441-450.

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Yasunaga, Y., Kioka, S., Matsuo, Y., and Saeki, H., 2002, “Compressive Strength of Consolidated Layer Model of Ice Ridge”, Proceedings of the 17th International Symposium on Okhotsk Sea & Sea Ice, Mombetsu, Japan, pp. 343-349.

## APPENDIX C. STATEMENT FOR ICEBERG IMPACT EXPERIMENT

The potential for catastrophic damage, loss of life and environmental pollution are serious considerations for vessels travelling through iceberg infested waters. A historical investigation indicates that, over the last two hundred years, an average of two major collisions of ships with icebergs were reported each year (Hill, 1999). Today, large icebergs can be detected and avoided. However, small icebergs (known as bergybits and growlers) cannot be easily detected. They still pose a major risk to the naval transportation in the North Atlantic. This risk become more pronounced with the recent increase of the offshore oil and gas activities and the plans for hydrocarbon transportation off the coast of Newfoundland and Labrador, Canada.

The United States Coast Guard, International Ice Patrol, gave definitions, approximate sizes and shapes of various existing icebergs, see the following web site:

<http://www.uscg.mil/lantarea/iip/home.html>.

Recent reports indicate that bergybits and growlers collide with ships at relatively high

strain rates. Sielbeck (1999), of the International Ice Patrol, listed four different collisions of merchant ships with small icebergs (collisions occurred during the period of 1989-1993). All of these collisions resulted in significant damage to ship hulls, and posed serious threats to humans and environment. He reported that all collisions took place at full sea service speeds (about = 12 knots  $\approx$  22 km/h).

The initial impact strain rate in ice can be calculated using the traditional ice indentation equations (such as the equation given by Michel and Toussaint, 1977). Assuming a range of bergybit-ship contact width between 3 and 20 m, and ship cruising speed of 22 km/h, the resulting initial impact strain rate in ice ranges between  $7 \times 10^{-2} \text{ s}^{-1}$  to  $2 \text{ s}^{-1}$ . This is a high strain rate range.

It should be pointed out that the committee recognizes that, up to now, there is no standard testing procedure for bergybit-ship impact experiments. If the need for such experiments continues, the present committee will recommend the development for an iceberg-ship impact testing produce to future committees.

# The Specialist Committee on Ice

Committee Chair: Prof. Hajime Yamaguchi (University of Tokyo)

Session Chair: Dr. Georges Thiery (Bassin d'Essais des Carènes)

## I. DISCUSSIONS

### I.1. Discussion on the Report of the 23rd ITTC Specialist Committee on Ice: Error in equation (1)

By: David Clarke, University of Newcastle-upon-Tyne, United Kingdom

I would like to point and that there seems to be an error in the equation (1) of the committee Report.

If the equation is that for the maximum stress in a cantilever beam, then the number 6 should be in the numerator and not in the denominator of equation (1). This will give

$$\frac{6Pl}{bh^2}$$

### I.2. Discussion on the Report of the 23rd ITTC Specialist Committee on Ice: Full-scale data for validation

By: Harri Soininen, VTT, Finland

The committee has to be thanked for the work that they have done especially regarding the uncertainty analysis.

You mention briefly in the proceedings the lack of full scale data for validation. Could you elaborate that a little?

You mentioned the minimum clearance between the model and basin wall. Have you defined a minimum also between parallel runs?

## II. COMMITTEE REPLIES

### II.1. Reply of the 23rd ITTC Specialist Committee on Ice to David Clarke

The Committee would like to thank Dr. Clarke for his valuable finding. That was a typological error.

### II.2. Reply of the 23rd ITTC Specialist Committee on Ice to Harri Soininen

The Committee thanks for the discussion by Dr. Soininen. There are two questions on our report.

As a part of its activities, the Ice Committee for the 22nd ITTC sent questionnaires to ice model basins in the world to ask several questions. One of the questions was "What is the largest problem in performing ice research?" Many basins replied that it was the lack of reliable full-scale data. Chances for field tests in ice-covered waters are much limited compared with those in open water conditions. The Committee hopes that model-ship correlation in ice will be studied in the future ITTCs.



Regarding the minimum clearance between the model and basin wall, the Committee would like to briefly explain a study made at National Maritime Research Institute, Japan. In the study they performed plate tests at various spots in the ice sheet at different length from a basin wall. From the test results they concluded that the length between the basin wall and the loading spot should be larger than four times of the characteristic length of the ice sheet to avoid the effects of basin wall on the flexural

behaviour of ice. The Committee feels that this criterion may also be applicable to cases of parallel runs. It should be also mentioned, however, that the result of above-mentioned study is applicable only to conditions where flexure is the dominant deformation mode of the ice sheet. Further studies are required on the effects of a basin wall or parallel runs for other deformation mode of ice such as compression or shearing.