Performance in Ice-Covered Waters Committee

Committee Chair: Mr. K. Riska
Session Chair: Dr. H. Kitagawa

I DISCUSSIONS

Contribution to the Committee on Performance in Ice Covered Water

by Neil Bose

In section 6, the Committee discusses tests on a propeller model during ice milling. These tests are potentially very valuable for work on propeller-ice interaction aimed at design standards for these propellers. The report mentions several phases of this work, of which only part of phase I has been completed. In addition, the results that are reported, for example in figure 6-5 (page 251) show large uncertainty in the results. While this may have been expected for the tests in ice, it is not acceptable for the open water tests reported in figure 6-13 (page 263).

Is it intended to complete this work, in particular by conducting the planned similar tests at different institutions? If so, it is suggested that a careful uncertainty analysis is done for these experiments and that the results from this are published alongside the experimental results.

Discussion on the Performance in Ice-Covered Waters Committee Report.

by K. Izumiyama,
Ship Research Institute, Japan

First of all I would like to congratulate the members of Ice Committee for their excellent work. It is even amazing to write a report of this high quality by that small number of people. I would like to appreciate the efforts by Dr. Riska and other Committee members. I have some comments and discussions on the report.

1) On the elasticity measurements by the plate deflection method.
This is a comment on the plastic limit of ice sheet. As noted in the report, there should be some limitation to the weight used in the plate deflection method not to cause plastic deformation of ice sheet. At our ice tank we performed a series of elasticity measurements by plate deflection method. In the test, the ice sheet was loaded by a wide range of weight. The purpose of the test was to know the plastic limit of ice sheet. As a result we reached a conclusion that non-linear displacement of ice sheet occurred when the displacement of ice is larger than 1/10 of ice thickness. This is a result for a limited range of thickness and strength of ice. But this may give some index for the limiting weight for the plate deflection method.

2) On the measurement of specific weight of model ice
Importance of specific weight of model ice is well recognized. It is known that the specific weight of model ice is higher than that of sea ice, and this is the reason for the development of the Controllable Density Ice, CD-ice.

The Committee proposed a new method to measure the specific weight of model ice, "the free board method" and compared it with the method proposed by the previous Committee, "the submersion method". I wonder if the Committee estimated the error involved with the two methods. Taking the accuracy of ultra-sonic displacement sensor and surface roughness of ice sheet into consideration, I have a feeling that the measurement uncertainty is higher for "the free board method" than "the submersion method".

3) On the resistance in pre-sawn ice

We recently performed resistance tests in pre-sawn ice. In some tests we measured unreasonably high resistance. This high resistance was always accompanied with large side force and unsymmetrical flow of ice pieces. And this phenomenon occurred to a particular model. I'm still wondering why. It might be due to imperfect coincidence of center lines of pre-sawn ice and model.

4) On the turning test.

As shown in Fig. 3-12, the larger the turning angle is, the smaller the error in the estimation of turning diameter will be. However, the size of ice tank is limited. Most of the ice tanks are shorter than 50 m and less than 10 m wide. Then the typical turning circle obtained in these ice tanks would be less than 30 degrees as long as the model has usual propulsor and rudder. The recommended turning angle of 135 degrees doesn't seem to be very practical value.

Propulsion Test of a Model Ship in Ice Thrust Deduction, Wake Fraction and Ice Effect Factor

by K.Koyama,
Ship Research Institute, Japan

The Performance in Ice-Covered Waters Committee presents an extensive review of the procedure for propulsion test in ice in section 3.4 of the Report. With reference to the procedure an analysis of propulsion test of model ship in ice tank is presented in this discussion in which the problems and improvement are shown and a new analysis method is proposed.

Towed propulsion test was performed in level ice in an ice tank and in ice free condition in an ordinary tank. Towed propulsion test in ice free condition corresponds to overloaded test. The ship is small Japanese patrol icebreaker "Teshio" which recently started the operation in the Sea of Okhotsk. The ship has twin ducted propellers. The model tests were carried out in the ice model basin and the towing tank of Ship Research Institute. (Ref. 1, 2)

Thrust deduction 1-t was derived from the gradient of the F-T diagram of the towed propulsion test. Where F indicates tow force and T indicates thrust. The thrust deduction obtained is shown in Fig.1. Thrust deduction of the model in level ice is nearly equal to the limiting value of that of the model in overloaded test. And the thrust deduction values are not so scattered as the case of free running test.

Wake fraction 1-w based on thrust identity method is shown in Fig.2. Wake fraction value for the test in ice free condition is reasonable while that value in level ice becomes extremely large as the advance coefficient becomes small. The large value is beyond the reasonable value as the meaning of the wake fraction. It may be an easy method that the large wake fraction value from the test in level ice is accepted as a superficial technique. But more reasonable method should be found.

The large value of wake fraction is caused by smaller KT of ice condition than that of POT due to the effect of ice. Here I propose the new method using both level ice test and ice free overloaded test. In the proposed method the expression for propulsive efficiency in ice is composed of data of towed propulsion test in ice condition and POT data as the usual method. Furthermore the data of towed propulsion test in ice free condition are inserted in the proposed expression. The proposed expression is as follows.

$$\eta = \frac{EHP}{DHP} = \frac{R_I V_I}{2\pi n_I Q_I}$$

$$= \frac{T_O V_O}{2\pi n_O Q_O} \bullet \frac{T_L/T_O}{Q_L/Q_O} \bullet \frac{1}{n_L/n_O} \bullet \frac{R_L/T_L}{V_O/V_L} \bullet \frac{R_I/R_L}{Q_I/Q_L} \bullet \frac{V_I/V_L}{n_I/n_L}$$

$$= \eta_O \bullet \eta_r \bullet \eta_h \bullet \eta_i$$

$$\eta_O = \frac{T_O V_O}{2\pi n_O Q_O}$$

$$\eta_r = \frac{T_L/T_O}{Q_L/Q_O} \bullet \frac{1}{n_L/n_O} = \frac{T_L/T_O}{Q_L/Q_O}$$

$$\eta_h = \frac{R_L/T_L}{V_O/V_L} = \frac{(1-t)_L}{(1-w)_L}$$

$$\eta_i = \frac{R_I/R_L}{Q_I/Q_L} \bullet \frac{V_I/V_L}{n_I/n_L} = \frac{1}{Q_I/Q_L} \bullet (R_I/R_L) \bullet (J_I/J_L)$$

Where

η : Propulsive Efficiency
EHP: Effective Horse Power
DHP: Delivered Horse Power(=E H P/η)
R : Resistance of ship
V : Velocity
T : Thrust of Propeller
Q : Torque of Propeller
n : Number of revolution of Propeller
t : Thrust Deduction Fraction
w : Wake Fraction

And suffix O, L, and I indicates POT, overloaded and ice condition respectively. η_o, η_r, η_h are the values from the overloaded test in the ice free condition. Only η_i corresponds to the factor relating to ice effect. In the factor the concept of thrust deduction and wake fraction is not used. J indicates advance coefficient based on ship speed. How can we determine the corresponding condition of the overloaded test? There is a choice for the condition.

$$J_I = J_L$$

or

$$R_I = R_L$$

In conclusion towed propulsion test in ice supplies reasonable data for thrust deduction. Proposed new expression for propulsive performance will yield reasonable value for wake fraction and ice effect factor. In the proposed method overloaded test in ice free condition is necessary as well as the test in level ice.

References
1) K. Koyama et al. "Model Tests of a Small Icebreaking Patrol Ship",66 General Meeting of Ship Research Institute, November 1995
2) S. Kishi et al. "Performance of the Patrol Icebreaker "TESHIO" in Ice-Covered Waters---Model vs. Full-Scale Comparison of Propulsive Performance in Ice ---", J. Society of Naval Architects of Japan, Vol.180, 1996

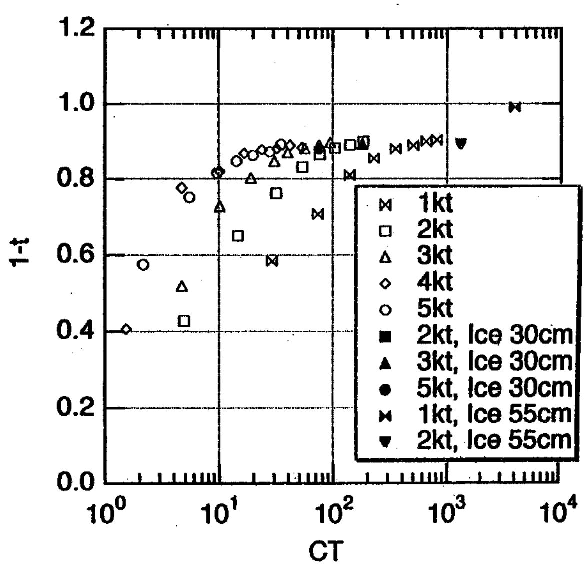

Fig.1 Thrust Deduction Factor

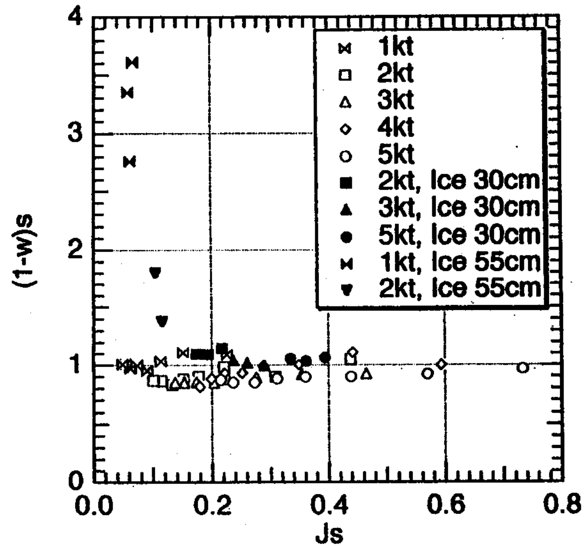

Fig.2 Wake Fraction, Starboard

Comments to the report

from John Murray,
Institute for Marine Dynamics ,
National Research Council Canada

My comments are in relation to ice - structure interaction with particular application to the offshore industry.

As the offshore industry moves into ice-infested waters such as the Canadian east coast and regions off Japan, Russia and possibly Norway, they will have to contend with ice forces on fixed an floating structures.

These forces can be divided in to two issues:

- mooring forces in broken sea ice or pack ice,
- collisions with glacial ice in the form of small to medium size icebergs.

1. Pack ice forces in ice concentrations greater than 50% coverage will induce slow drift oscillations similar to the slow drift response to hydrodynamic forces. These loads can however be higher than those related to the design hydrodynamic forces.

2. The second issue is a model of structure collisions with floating glacial ice. Apart from the mechanical aspects of the energy exchange between the ice and structure, there are the hydrodynamic aspects to consider. The motions of small ice masses are very sensitive to wave and current forces, including wave scatter and diffraction from the structure. At present approximate methods treat both the ice and the structure as rigid bodies and do not account for the hydrodynamic effects of the interaction. Consequently the impact loads can have a wide margin of error. The model should include the properties of the ice and the hydrodynamics.

I ask that the committee consider these issues when planning future programs.

Thank You.

II REPLIES

Response to Prof. Neil Bose

So far the ice milling tests have only been done at one laboratory, and it is not certain at this time if other laboratories wish to conduct similar tests. Regarding the apparent scatter in the results for the open water tests, we believe this is mainly due to deliberately using the same equipment for the open water tests as was used for the ice tests. The equipment is designed for the relatively high forces involved in milling ice, rather than for open water tests. This means that the equipment is not sufficiently sensitive to make good measurements in open water. It would be better in future to use a more sensitive dynamometer for the open water tests, and then we would expect the results to be more reproducible. We agree that it is always important to do an uncertainty analysis on the results.

Response to Mr. Izumiyama

1. Plate deflection method to determine elastic modulus of an ice sheet.

The Ice Committee would like to appreciate Mr. Izumiyama for his contribution. As Mr. Izumiyama pointed out, it is quite important to avoid sensing any plastic deformation in a measured deformation in performing the plate deflection method. The Ice Committee did recognize this vital limitation, however in the report, the Committee only qualitatively described a limit of weight to put on. Mr. Izumiyama suggests one promising way to determine quantitatively the limit of weight to put on.

The Ice Committee would like to request

Mr. Izumiyama to inform his data to the next Ice Committee. The Ice Committee is quite sure that the information would help a lot to standardize the plate deflection method to determine elastic modulus of an ice sheet.

2. Specific weight measurement of model ice.

The Ice Committee recognized that a detailed error estimation has to be done on both the submersion method and the free board method. However, we could not deduce the error associated with the irregularity of ice surface using an ultra-sonic method.

Originally, the free board method was proposed in order to have a method which is quicker and easier than the submersion method. The Committee believes that the free board method is also accurate but also differences in one ice tank between the methods have been observed. Overall, the Committee recommends that the free board method is to be examined in other tanks. And the Committee also believes that the detailed error estimation has to be done on both methods before making a final recommendation.

3. Tests in presawn ice.

The presawn ice tests are done in order to correct for small deviations from the target ice strength and thickness. The correction method is based on division of ice resistance into components and the dependency of these components on ice parameters. Some organizations correct, however, directly the total ice resistance.

The presawing is done in order to be able to disregard the breaking part of the resistance. Always, however, some breaking/crushing occurs and thus no presawn patterns are correct. This is particularly so as the patterns used consist usually of one or at most two row patterns. The row pattern has been overall questioned based on the observed chaotic nature of the pattern. Here could be some reasons for the observed unsymmetric flow of ice pieces. Overall, the committee finds the repeatability of tests in presawn ice quite satisfactory as the Figure 3-6 shows.

4. The turning tests in ice

The recommendation of turning at least 135^0 is only an indication of the error sources involved. If the error in sampling is reduced to, say, 1 % then already a turn of 45^0 gives a good accuracy. Also, if sampling includes more points than 3 and eq. (3-26) is used then also the resulting error is reduced. The committee wanted to draw the attention of researchers to this problem and is awaiting for new results in this field

Response to Dr. Koyama

The Ice Committee would like to congratulate Dr. Koyama for his contribution. Dr. Koyama presents a new idea of propulsion test in ice, which can help us to understand thrust deduction, wake fraction and ice effect factor better than the existing methods. Those are important knowledge to clarify ship performance in ice. Though the Committee have not fully understood the method proposed by Dr. Koyama, the Committee recognizes it is promising in order to understand thrust deduction, wake fraction and ice effect factor.

The contribution presented here is too brief for us to understand. The Committee would like to request Dr. Koyama to publish a more detailed paper to public domain, which would allow people to examine his proposed method.

The Committee would like to add one practical request. Usually, a test in ice can not be performed right on a target ice condition, commonly ice thickness and ice flexural strength. There must be some deviation from the target ice condition. We generally have to correct test data to meet the target by a certain technique. Though it is important for ice tank practice to establish a methodology to correct the deviation from the target, the Committee do not see how to establish such methodology from the contribution here. Thus the Committee also would like to request Dr. Koyama to present a method to perform such correction.

Again, the method proposed by Dr. Koyama is considered to be promising toward better understanding of ship performance in ice. The Ice Committee should appreciate if Dr. Koyama could present his proposal in detail to people who are interested in ship performance in ice.

Response to Dr. Murray.

The question Dr. Murray presented is most topical as the demand for tests assessing the operational limits of various offshore systems are increasing at the moment. Recent systems tested have included FPSU's, loading terminals and jacket type of platforms.

The Ice Committee started 9 years ago the comparative programme in this field of ice forces on offshore structures. The topic selected was loads on a narrow vertical (and inclined) cylinder in level ice. This problem includes solely one force component - one which is most difficult to model theoretically or physically in model scale of all forces present, viz. the crushing force. Model ice is more tuned to bending type of failure. This has resulted in many difficulties in interpreting the various results as the present ice committee has also noticed.

It is the opinion of the present committee that the next ice committee should focus their attention to other types of offshore structures than those with vertical sides. For example the upward breaking conical caisson could be taken as a basic case. Also other ice conditions than only level ice should be considered.

Both the proposals of Dr. Murray are very interesting: the pack ice problem and the icebergs in waves. The former has been investigated in CRREL and HUT while the action of waves and ice drift together have been investigated in Japan and in HUT. All these investigations are preliminary and no reporting is done, yet, but they show that the discusser puts his finger on active topics. The next committee should bear this discussion in mind.