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Tests in Deformed Ice

1. PURPOSE OF PROCEDURE

- Definition of standards for performing ice tests in deformed ice
- Ensure standard procedure follows a defined structure and format

2. TESTS IN DEFORMED ICE

Resistance and propulsion tests can be performed also in deformed ice. Two types of deformed ice has been used in the tests: Rubble fields and pressure ridges. A rubble field is formed by a layer of small ice pieces. This layer has an uniform thickness and is much thicker than the pieces constituting the rubble. The propulsion or resistance tests in this rubble field are carried out in a similar fashion than these tests in level ice. The emphasis on tests in rubble ice stem from the fact that normal merchant vessels do not navigate in level ice much compared to time spent in old channels which are typical rubble fields.

The model ice parameters which should be measured in tests in rubble ice and also in ice ridges are presented in the below table of parameters.

When a rubble field or a ridge is made, it starts to consolidate. Consolidation occurs by freezing the void volumes inside and below the waterline of the ridge. This consolidated layer influences the ice resistance of a vessel in a rubble field. Thus, if the measurement of the degree of consolidation is not practical the temperature history of the rubble field or the ridge should be presented. Ridge strength measurements are described e.g. in Coon & al. (1995).

The pressure ridges in nature consist of a triangular sail above water and a similar triangular keel below water. The ridges are characterized usually with six quantities shown in Fig. 2-1.

When performing ridge tests these quantities should be measured and the shape of the ridge should be made as close as possible the ones found in nature where the sail and keel angles are about 25°.

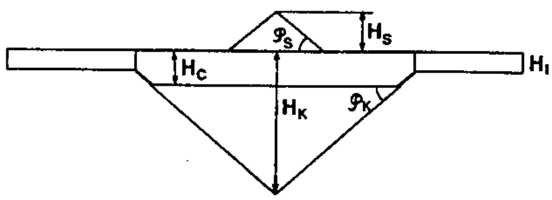

Fig. 2-1. -The six quantities determining the size and shape of a pressure ridge.

The thickness of a ridge is not constant. Thus the ridge resistance differs from the rubble field resistance in that it is not a single number but varies when a ship penetrates a ridge. This is illustrated in Fig. 2-2 where the measured resistance when penetrating a ridge is shown. One possibility to define the ridge resistance, RR, is shown in this figure. The definition uses the similarity of defining the level ice resistance from the integral of towing force.

Many times the merchant vessels do not penetrate ridges in a continuous fashion but have to ram a ridge several times. The ridge penetration by ramming is accomplished by consuming the inertia of the vessel in entering the ridge. Thus the definition based on energy gives also the energy, E_R, required to penetrate the ridge. When carrying out ramming tests in ridges or, similarly, in thick level ice, record must be kept of the additional penetration made in each ram and also the time consumed by each ramming cycle should be noted.

The scaling of ridge or rubble field resistance is again straightforward if all the parameters are scaled properly. There do not exist many data about the strength and cohesion of ridge material. It can be assumed that the ridge material strength is not solely dependent on the strength of the ice the rubble field is made of. This could involve a scale distortion. Another problem with ridges is caused by the consolidated layer thickness. This thickness is determined by (Leppäranta 1993)

$$H_0 = \sqrt{2\frac{\kappa_1}{\rho_1 L}}\frac{1}{\sqrt{1-p}}\sqrt{\int_0^t [T_\mathrm{f} - T(t)]dt} \qquad (2.1)$$

where L is latent heat of fusion of ice, κ_i, is heat conductivity of ice, T_f freezing point of ice and T prevailing temperature. The heat properties are the same for model ice and natural ice. Further, the porosity p can be assumed the same for model and prototype ridges. If the prevailing temperature is constant, this leads to the conclusion that the consolidation times should be scaled with λ^2. A rubble field which is left to consolidate for two days in nature must consolidate only for 7 min in the same temperature if the scale is 1:20.

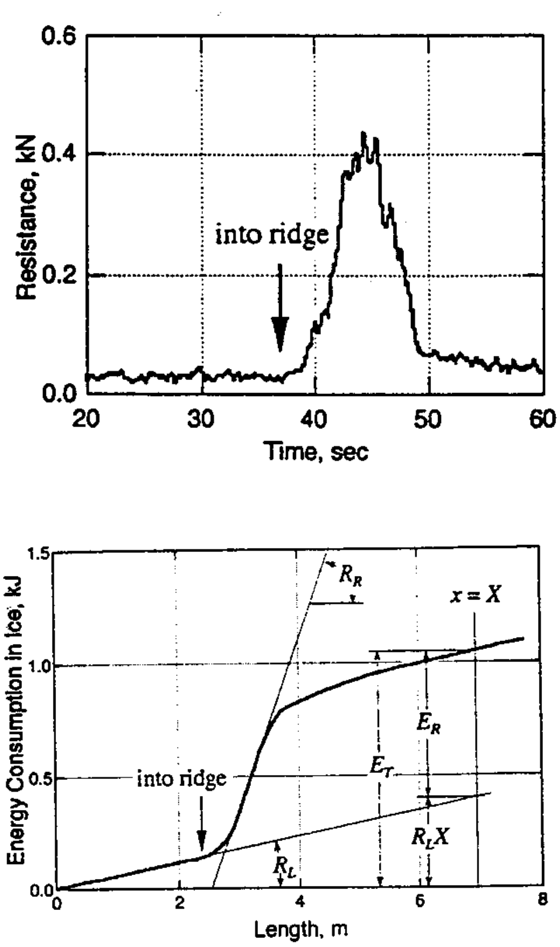

Fig. 2-2. The measured ridge resistance and the definition of ridge resistance based on the energy integral (Izumiyama & Uto 1995)

3. PARAMETERS

3.1 Parameters to be Measured

Parameter	Priority
Rubble field thickness	1
Ridge sail height	1
Ridge keel depth	1
Ridge transverse profile	1
Rubble field profiles, transverse and	1
longitudinal	1
Degree and depth of consolidation	1
Porosity	2
Description of ridge cohesion or strength	2

4. VALIDATION

4.1 Uncertainty Analysis

None

4.2 Benchmark Tests

1) Report of Committee on Ships in Ice-Covered Water (16th 1981 pp. 363-372)
   g) Catalogue of Available Model and Full Scale Test Data (16th 1981 pp. 370-371)

2) Standard Model Tests(Ice) (17th 1984 pp.591-601)
   (1) Model Tests with R-Class Icebreaker
   (2) Propulsion Tests
   (3) Full Scale Prediction

3) Reanalysis of Full Scale R-Class Icebreaker Trial Results (18th 1987 pp.528-531) To Get Reliable Full-Scale R-Class Data CCGS "Pierre Radisson“ and CCGS “Franklin“

4) Retest of R-Class Icebreaker Model at a Different Friction Level (18th 1987 pp.532-543)
   (1) Resistance Tests (18th 1987 pp.532-540)
   (2) Self Propulsion Test (18th 1987 pp.540-543)

5) Comparative Test Program with R-Class Model (19th 1990 pp.526-531))

6) Comparative Test Program with Basic Off-shore Model Structure(19th 1990 pp.534-540)

7).Basic Cylinder Tests (20th 1993 pp.470-481)

8) Repeatability Tests for Quality Control (20th 1993 pp.488-490)

9) Analysis of the Cylinder Tests (21st 1996 pp.245-252)

10) Model Propulsion Tests in Ice (21st 1996 pp.252-263)