ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Manoeuvring Tests in Ice

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Disclaimer

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Manoeuvring Tests in Ice

1. PURPOSE OF PROCEDURE

Definition of standards for performing manoeuvring tests in model ice. While manoeuvring test is a common name for all those tests in which the rudder is turned or the turning forces and moments are obtained by other means e.g. azimuthing thrusters, tunnel thrusters in bow. This procedure covers the most common manoeuvring tests for which standard methods exist in the different ice basins.

2. MANOEUVRING TESTS IN ICE

Manoeuvring test is a common name for all those tests in which the rudder is turned or the turning forces and moments are obtained by other means e.g. azimuthing thrusters, tunnel thrusters in bow, different rpms at twin propellers etc. The primary purpose of manoeuvring tests is to investigate the effectiveness of the hull in making turns, changing course or leaving a broken ice channel. The other primary purpose is to investigate the effectiveness of the turning devices like rudders, thrusters or azimuthing propulsors. Manoeuvring tests are also used to investigate the flow of ice floes around the hull in various ship operations other than straight ahead or astern.

The scaling of results of manoeuvring tests should follow the ITTC Guideline 7.5-02 -04-01 General Guidance and Introduction to Ice Model Testing.

Typical manoeuvring tests include turning circle tests, star manoeuvres and breaking out of channel. The model tests are often performed with a free model under its own propulsion.

Sometimes, maneuvering tests can be performed with a captive mode using x-y carriage or PMM (Planar Motion Mechanism). This allows force measurements and it is mainly ad-hoc approach for certain cases. Data to be reported from manoeuvring tests are mainly the same as in the case of propulsion tests with a free model. In section 4.1 and 4.2 the quantities to be measured or recorded are listed. The underwater photography or videos are important in manoeuvring tests to record the track of ice pieces around the hull.

The testing conditions of the model should be measured and documented similar as defined for Recommended Procedure for Free Running Model Tests 7.5-02-06-01. The loading condition of the model (draft fore/aft and *GM*) should be checked and documented. The *GM* should be as close as possible to the specified target value. If no value is specified the actual value should be determined and reported. This value should at least be adjusted in a realistic range as full scale tests have revealed that the heeling angle of the ship has a large influence on the turning capability. For manoeuvring test with larger models at relatively low speed (e.g. turning circle) the correct adjustment of GM value is of lower relevance.

2.1 Turning circle test.

The purpose of the turning circle test is to find out how much area is needed to turn the ship. In practice, the result of this kind of test may look as shown in Figure 1.

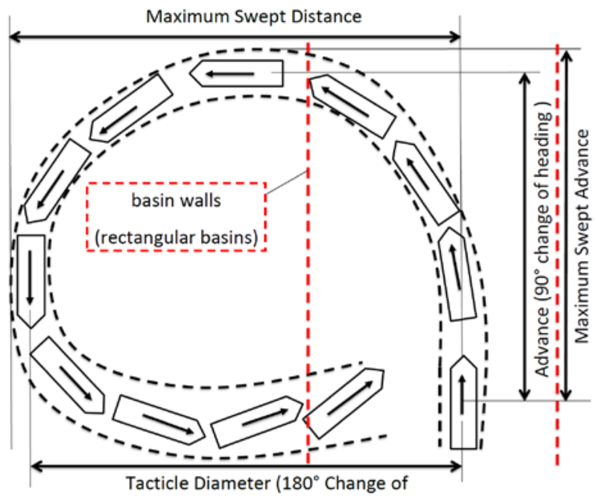

Figure 1. Definition of quantities used in turning circle tests

The test is started by proceeding the model straight ahead / astern at a certain speed into ice for at least one ship length. Thereafter a turning is induced by control of the rudder or thruster angles. The turning is continued until the maximum possible turning angle (with respect to basin restrictions) is achieved.

If the turning diameter, *Dc*, or radius, *Rc*, is determined, the method by which it was obtained should be described. The turning circle may be not a perfect circle, but a spiral.

There is a vast difference in results, if the measurement of *Dc* is based on the outer edge of the broken channel or if it is based on the track of the centre of gravity of the model. Both values can be measured and it is therefore recommended to use the following definitions:

Dc Tactical diameter of the turn, determined from the path of the centre of gravity of the vessel (see Fig.2-1)
D_{out} Outer diameter of the broken channel
D_{inn} Inner diameter of the broken channel

The radius R_C of a circle can be approximately determined if co-ordinates of three points on the circle $\{(x_1, y_1), (x_2, y_2)$ and $(x_3, y_3)\}$ are known The radius is then

$$R_C = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2} \qquad (2.1)$$

and the centre of the circle is

$$x_0 = k_2 - n_2 y_0, \quad y_0 = \frac{k_2 - k_1}{n_2 - n_1} \qquad (2.2)$$

where the intermediate results are

$$k_1 = \frac{1}{2}[(x_1 + x_2) + n_1(y_1 + y_2)] \qquad (2.3)$$

$$k_2 = \frac{1}{2}[(x_1 + x_3) + n_2(y_1 + y_3)] \qquad (2.4)$$

$$n_1 = \frac{y_1 - y_2}{x_1 - x_2}, \qquad n_2 = \frac{y_1 - y_3}{x_1 - x_3}$$

Using at least three measured points (*x*- and *y* - co-ordinates) from the path of the model and some averaging or smoothing procedure, if necessary, it is possible to determine the diameter of the circle. By this method the radius of a circle can be determined also from less than 180° turn.

It should be noted that there are several error sources (e.g. channel width variation) when determining the turning radius based on a limited number of measured points and limited turning angle. The relative error of turning radius clearly decreases for higher achieved turning angles. The main reason is the aforementioned asymmetry of the turning track.

Considerable errors may appear, if the determination of D_C or R_C is based on a too small turn. Figure 2 presents an example of the broken track left after a turning circle test. To illustrate the possible maximum error in diameter D_{inn}, when determined based on few points on the inner circle, as a function of the turning angle.

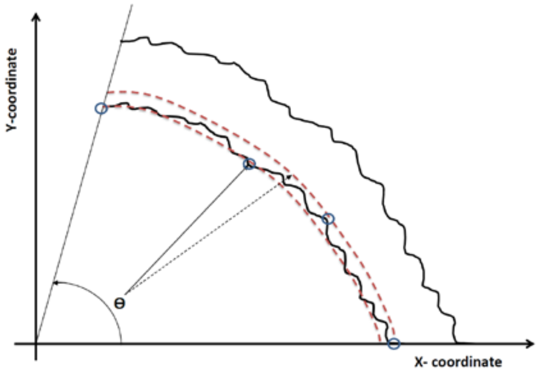

Figure 2. Broken channel of turning test

In many cases motion capture data can be used to alternatively derive the turning radius from the time series of models change of heading.

2.2 Breaking out of channel test.

Breaking out of channel is a test which can be performed from zero speed or some other specified speed. The model is typically accelerated to a certain speed or power in the channel and thereafter the rudder / azimuth thrusters are turned. The model will change heading and the fore or aft shoulders will break ice from the channel edges. After achieving a certain yaw angle the model will be able to enter the surrounding ice sheet (Figure 3).

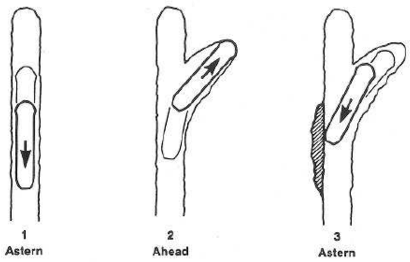

Figure 3. Sketch Break Out Manoevre, Quinton, Lau (2006)

The test is concluded by leaving the channel completely (or at a specified yaw angle). The success of breaking out of channel manoeuvre is significantly affected by the width of the broken channel (in relation to model width).

The most relevant parameters that should be determined and reported are required distance in the channel (starting / end point), number of required attempts and time consumption.

2.3 Star Manoeuvre (Captain's Turn)

The Captain's turn is typically used when space and / or manoeuvring space is limited: The vessel turns around 180 deg by performing a series of channel breakouts fore and aft (Figure 4).

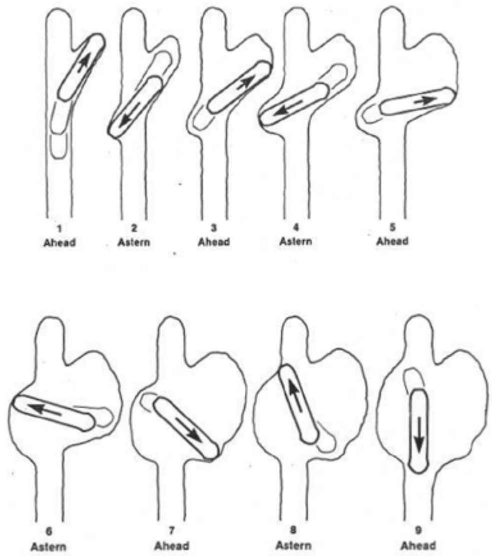

Figure 4. Sketch Star Manoevre, Quinton, Lau (2006)

Results to be obtained and reported for the star manoeuvre (captain's turn) are similar to those of break out tests.

3. ADDITIONAL COMMENTS

It should be noted that typically the behaviour of the model propulsion and manoeuvring / steering units does not exactly reflect the capability of the ships propulsion and manoeuvring systems. The reason is that stiffness and dynamic response of the model propulsion trains are not adjusted according to scaling similarities.

Further effects on manoeuvring tests resulting from restricted basin dimensions should be avoided.

As the results of manoeuvring tests are subject to the actual operating of manoeuvring systems the procedure for each manoeuvre should always be clearly documented and influence from operator should be limited to a minimum extent.

4. PARAMETERS

4.1 Parameters to be Measured

Parameter	Priority
RPM, torque and thrust (each thruster)	1
Rudder (or thruster) angle	1
Yaw angle	1
Ship’s track	1
Ship's heading	1
Roll angle	1
Pitch angle	1
Rudder forces in x- and y-direction	2
Rudder torque	2
Roll angle	2
Velocity of the model on the curved path	2

4.2 Parameters of the Model Ice to be Measured

Parameter	Priority
Ice thickness	1
Broken channel width	1
Piece size, breaking pattern	1
Model ice type	1
Flexural strength	1
Compressive strength	1
Ice Concentration	1
Underwater photography	1
Ice density	2
Elastic modulus	2
Piece size, breaking pattern	2

5. VALIDATION

5.1 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 Offshore Model Structure (19th 1990 pp.534-540)
7. Repeatability Tests for Quality Control (20th 1993 pp.488-490)
8. Model Propulsion Tests in Ice (21st 1996 pp.252-263)

6. REFERENCES

Quinton, B; Lau, M, 2006, “Manoeuvring in Ice – Test/Trial Database”, NRC Publication Archive (NPArC)