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Full Scale Trials - An Important Element in the Research on High Speed Ship Performance in Following Seas.

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Summary

Studies of stability problems in following waves for high speed monohulls will be carried out as a joint Finnish and Swedish research program sponsored by the Navies in the two countries. The program will be started by extensive full scale studies where the behaviour in following waves will be characterised by oscillation tests.
It is proposed to use some test procedures originally used to characterise calm water manoeuvring performance of ships. The procedures will be slightly modified and it is anticipated that the results might be used as the measure of the ability of the ships to stay on course in following waves and thereby avoiding the risk for broaching.
The test results will also be used for validation of mathematical models being developed for theoretical studies of the behaviour described.

Introduction

Work on research and development on broaching and other undesired behaviour of ships in following seas are often focused towards the risk for capsize. However ship behaviour in following seas can be dangerously detoriated without having a direct risk for capsize. Especially the reduced maneouvring performance for a ship entering a harbor or a narrow passage into an archipilago when approaching from the open sea in following waves is of great concern to many operators.

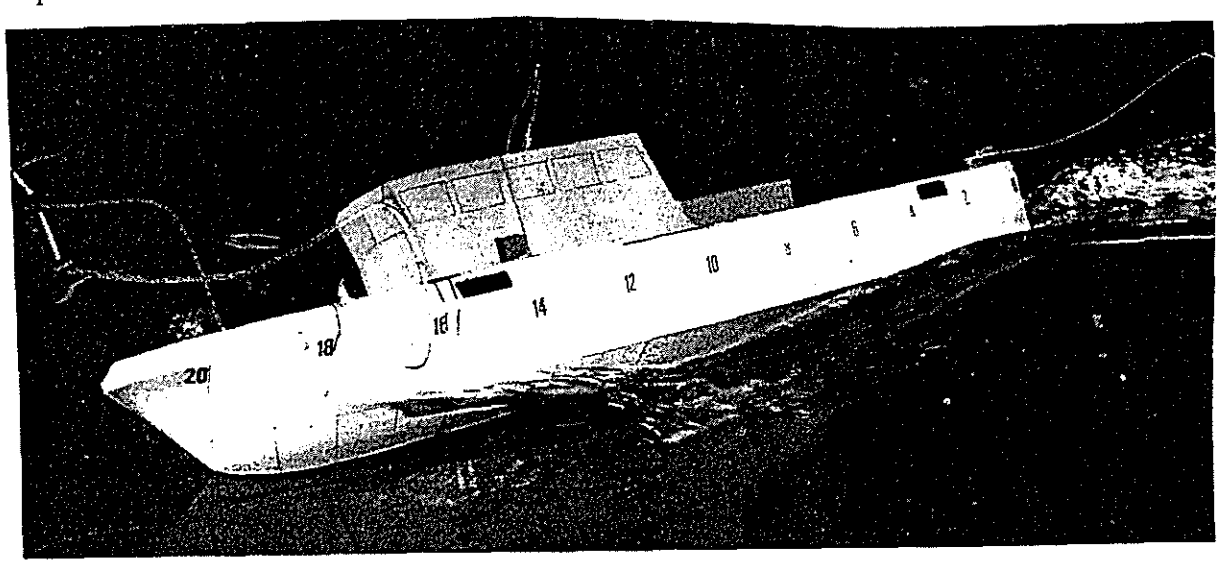

Figure 1. Model of patrol craft broaching in stern quartering waves.
(From Rutgersson and Ottosson 1987)

In the Baltic Sea, high-speed monohulls with planing and semiplaning hulls are frequently used by the Coast Guards and the Navies in the area. The major seakeeping problems experienced with these vessels are broaching to or resonant rolling phenomena in stern quartering seas. Usually the behaviour is developed as a combined rolling-yawing oscillation which is very unpleasant and which can turn into a situation where the vessel is out of control.

Attempts to develop mathematical tools and experimental techniques to study the risk for broaching is an ongoing international process reported in earlier Stability Workshops and Conferences (Renilson 1982, Umeda 1996 and Vassolos 1997). In the Nordic countries earlier work have been carried out by SSPA in cooperation with the Swedish Navy (Rutgersson and Ottosson 1987).

A new research project is now initiated in Finland and Sweden. The aim is to develop practical operational and design oriented criteria and tools for studies of high-speed monohulls in following sea conditions. The work will be joinly sponsored by the Finnish and the Swedish Navies and carried out by SSPA and KTH in Sweden and VTT in Finland. The project will start with an extensive fullscale trials program. The reasons for this are threefold:

* the practical experience of the operators when handling these vessels in following sea conditions can then be included in the study.
* attempts will be made to develop a trial technique in fullscale where the margin against resonant rolling and broaching to phenomena, may be determined by oscillation tests in fullscale.
* the test results will be used to define problems to be studied in the more theoretical part of the project. Access to test results for validation of the developed tools is of course also important.

An interesting part in the present project is that two major types of vessels will be studied. The first vessel is the somewhat larger "coastal corvette" type where the major problem is the classical broaching to phenomenon in open sea. The other and smaller type of vessels more often experience the resonant rolling phenomenon in stern quartering seas (Hua 1997).

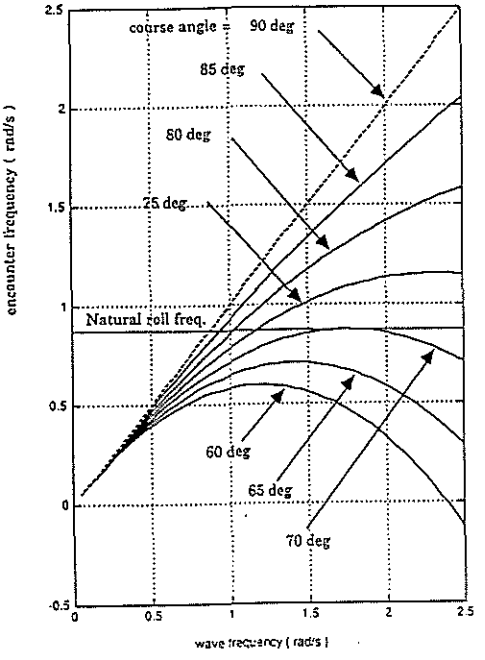

Figure 2. Focusing effect exciting resonant rolling on ships in quartering waves. (Hua 1997)

At the full scale tests it is intended to use procedures to actively oscillate the ships in waves and thereby having the possibility to receive more information than is usually done from normal straight course tests. The test procedures will be presented and discussed.

Proposed Tests.

In the test program ships with potentially good and bad behaviour in following waves will be used. Portable measduring systems using a Saetex MRU-6 sensor giving motions in all six degrees of freedom will be used together with a GPS registration of the track, a measurement of the rudder angle and probably a wave bouy registration of the wave environment.

Test procedures for three different "broaching tests" have been worked out:

* straight course test
* zigzag test
* reversed spiral test

Straight course test.

The test is a simulation of realistic conditions where the helmsman (or autopilot) tries to keep the ship on course at a desired speed and heading in following waves. From the time signals the variations in heading angle, roll angle and speed can be recorded at different wave -heights, -lengths, ship speeds and heading for the typical rudder action used on board. From practical point of view condensation of these data will form valuable information for the master of expected behaviour of the ship in following seas.

It is not anticipated that real broaching situations where the ship cannot be brought back on course will occur during the limited time span for these tests. These tests therefore probably cannot give very reliable information on the real risk for broaching.

Zigzag test.

The zigzag tests represents a popular calass of tets where the ships manouevring characteristics are determined on free running models or in full scale in oscillation manoeuvres simulating the behaviour of a ship trying to stay on course inspite of external disturbancies. It is thertefore believed to be a suitable test for characterising the risk for broaching on ships in following waves. The procedure of the test is: from a steady course and speed condition starboard rudder to a predetermined angle is given, when the course change up to an also predetermined angle is reached a counteraction with port rudder is given. An oscillatory motion is then going on as long as counteracting rudder motions are given. A typical view of a zigzag test and the measured parameters are given in Fig 3 from Brix 1993. Overshoot angle and timelag are two parameters representative of the manoeuvring capacity of the ship.

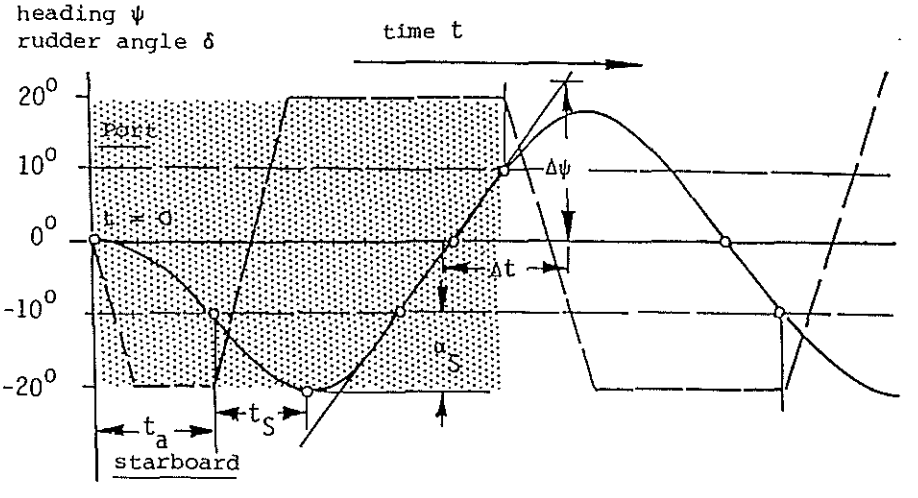

Figure 3. Zigzag test and typical parameters. (Brix 1993)

Carrying out zigzag tests in calm water the period of the oscillations will be determined by the period of the ship in yawing motion. When carrying out the same tests in following waves the ship based period will be influenced by the encounter period of the waves and in conditions close to broaching the wave encountering period will be driving the motions.

In conditions in following waves the helmsman will probably use fairly large rudder angles. It is therefore suggested to use large rudder angles also for the zig zag tests. On the other hand it might be dangerous to use large angles of course changes before giving counter active rudder angles. A typical suggested zigzag test therefore would be a 20 / 10 degrees test.

The phase lag between the ship motions and the waves will be imporatant for the exact ship response to the exiting rudder action. It is therefore proposed to run these tests for as many wave encounters as possible. The tests will be run in different shipspeeds and wave conditions from calm water up to waves where the proposed rudder angle is no longer enough to keep the ship on course.

The results can be given as overshoot angles and time lags for different wave conditions and operating conditions for the ship. The combination of conditions where the used rudder angle are not enough to stay on course is one indication where the risk for broaching might be large. It is also anticipated that analysis of the over shoot angles and time lags can be used to determine some kind of margin against broaching for different operational conditions.

Reversed spiral test.

As the zigzag test is believed to simulate the initial conditions in a broach, another test is also needed where the ability to stop a broach is better simulatied. It is suggested that a type of reversed spiral test might simulate this. In a reversed spiral test in calm water the helmsman (or autopilot) tries to keep the ship at a steady turning rate by actively work with the rudder. The results are then prsented as a graph of turning rate as a function of the mean rudder angles. A typical result for an unstable ship is given in Figure 4 from Brix 1993. The width of the unstable area is then a measure of the course keeping ability of the ship in the conditions tested.

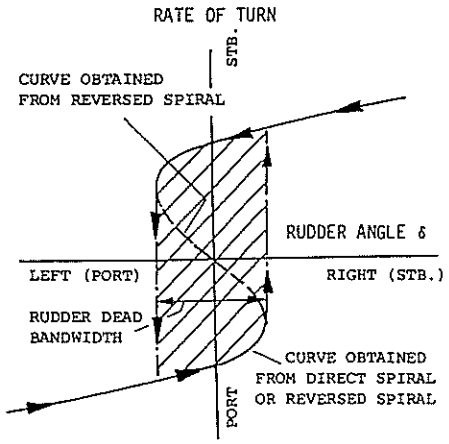

Figure 4. Results from spiral tests for an unstable ship. (Brix 1993)

The proposed spiral tests in following waves will be carried out always starting with zero degrees heading. Starting for instans on a wave crest a starboard turn with constant radius will be initiated and proceeded until 90 degrees heading angle is reached (beam seas). After reaching steady turning conditions in beam seas a port turn at the same turning rate will be carried through until the heading angle zero degrees is reached again. These tests will be repeated with initial turn using starboard and port rudder for as many wave encounters as possible and for different wave and speed conditions covering calm water to waves where dagerous respons is anticipated.

It is believed that the spiral tests will simulate the rolling bahaviour of a broching ship in a more realistic way than the zigzag test and therefore also gives a more realistic view of the possibilities to interupt an initiated broach tha the zigzag test. Comparison of the width of the unsteady rudder area for different wave- and speed conditions probably also will give information about the margin against broaching. With a width close to the maximum possible rudder angle the risk for a real broach must be very large.

Concluding remarks.

As a Nordic continuation of studies of stability problems in following waves for high speed monohulls of the planing and semi planing type an extensive program for full scale tests will be carried out.

It is proposed to use some test procedures originally used to characterise calm water manoeuvring performance of ships. The procedures will be slightly modified and it is anticipated that the results might be used as the measure of the ability of the ships to stay on course in following waves and thereby avoiding the risk for broaching.

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