DYNAMIC SINKAGE AND TRIM OF SHIPS ON SHALLOW WATER

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Dynamic sinkage and trim of ships on shallow water are of interest not only because of possib grounding. Forward trim usually encountered on shallow water can reduce yaw stability so severel that ships may loose their abilitity to keep course. The flow around a container ship with transo stern was investigated using a modification of Jensen's method /1/. As this method has bee described on the last workshop, details will not be presented again.

A symmetrical ship advances with speed U through smooth water of constant finite depth. Viscosit is neglected and potential flow assumed. The local disturbance in the velocity field is represente by a distribution of Rankine sources on the following surfaces:

1. On the wetted ship surface
2. On the ship surface above the waterline. In this case up to a plane parallel to the still wate plane and 2.5 m above it. Thus the dynamic locally increased sinkage of the ship is take into account
3. On a mirror image of this surfaces on the above mentioned plane 2.5 m above the still wate line
4. On a horizontal plane 4 to 8 m above the still water line in a sufficiently large area aroun the ship hull
5. On the mirror images of the surfaces 1 to 4 on the sea bottom. Thus the no penetration condition at the sea bottom is taken into account
6. On the mirror images of all above surfaces on the starboard side

The source strength of the mirror images of surfaces 3, 5 and 6 is equal to the source strength o the original surfaces. Thus only the strength of the sources on the surfaces 1, 2 and 4 on the port side remains to be determined by meeting the corresponding boundary conditions:

- no penetration condition on the hull for 1 and 2 except for the transom stern
- The transom stern is assumed to be fully emerged. A longitudinal velocity through the stern is determined such that the hydrodynamic pressure at the rim of the transom stern i atmospheric pressure. For parts of the transom stern above the stagnation pressure height this longitudinal velocity is set to be zero.
- no penetration condition and dynamic condition (hydrodynamic pressure = atmospheri pressure) on the free water surface

In an iteration both the non-linear water surface boundary condition and the final position o the ship (sinkage and trim) are determined. In each step static and dynamic vertical force an trimming moment are determined. In addition small corrections for the trimming moment c to frictional resistance and propelling or towing force are applied. An estimated linear relati between resultant force and moment on the one hand and sinkage and trim on the other gives t new correction of the ship's position. For high depth Froude numbers this relation correspor to the customary formulas for determination of small sinkages and trims which are based on assumption of hydrostatic pressure distribution on the ship's hull. For depth Froude numbers clc to 1 the ship reacts far more sensitively on remaining forces and moments as compared to t static case.

For a given container ship non-dimensional results for sinkage and trim are given in fig. 1. F realistic length Froude numbers the ship has ground contact before reaching depth Froude numb $F_{nh} = 1$ (dotting lines in fig. 1). Depth Froude numbers around 1 could only be investigated f unrealistically high length Froude numbers. Here strong changes both in the wave pattern ar sinkage and trim occurred, a tendency well known from experiments.

Supporting experiments for this case are in the stage of preparation but not yet conducted. Cor putational results were compared with approximate formulas according to Barras /2/ (regressic analysis for model and real ships) and Tuck /3/ (analytical method). Agreement is not bad. Hov ever, we expect our method to be more accurate at least for higher length Froude numbers as we as for depth Froude numbers close to 1.

Error estimates of the numerical method can be performed by comparing results using differer panel grids. For $F_n = 0.15$ results appear to be doubtful. Unacceptable discretization errors ar due to limitations in the available computer (VAX 8550). For higher length Froude numbers th corresponding waves can be resolved properly and grid variation gives no significant changes (abou 2%) in the results for sinkage and trim. This indicates that error due to unsufficient discretizatio are unlikely.

The formal correctness of the program code has been checked in many trial computations. A points both inside the fluid domain and on its boundaries these computations show that continuit and boundary conditions are met with good accuracy.

Typical CPU-time requirements on the VAX 8550 were 4 resp. 23 minutes for 500 resp. 100 collocation points (unknowns) for each iteration step. The number of necessary iteration step depends largely on the corretion of sinkage and trim. On water of great depth typically 2, on wate of small depth up to 5 iteration steps were necessary to determine sinkage at the perpendicular within an accuracy of 1 cm.

/1/ JENSEN, G.
Numerical Solution of the Nonlinear Ship Wave Resistance Problem
3rd International Workshop on Water Waves and Floating Bodies, 1987
/2/ BARRASS, C.B.
A Unified Approach to "Squat" Calculations for Ships
Bulletin of the PIANC 1, No. 32, 1979
/3/ TUCK, E.O.
Shallow-water Flow past Slender Bodies
J. Fluid Mech. 26 Part 1, pp. 81-95, 1966

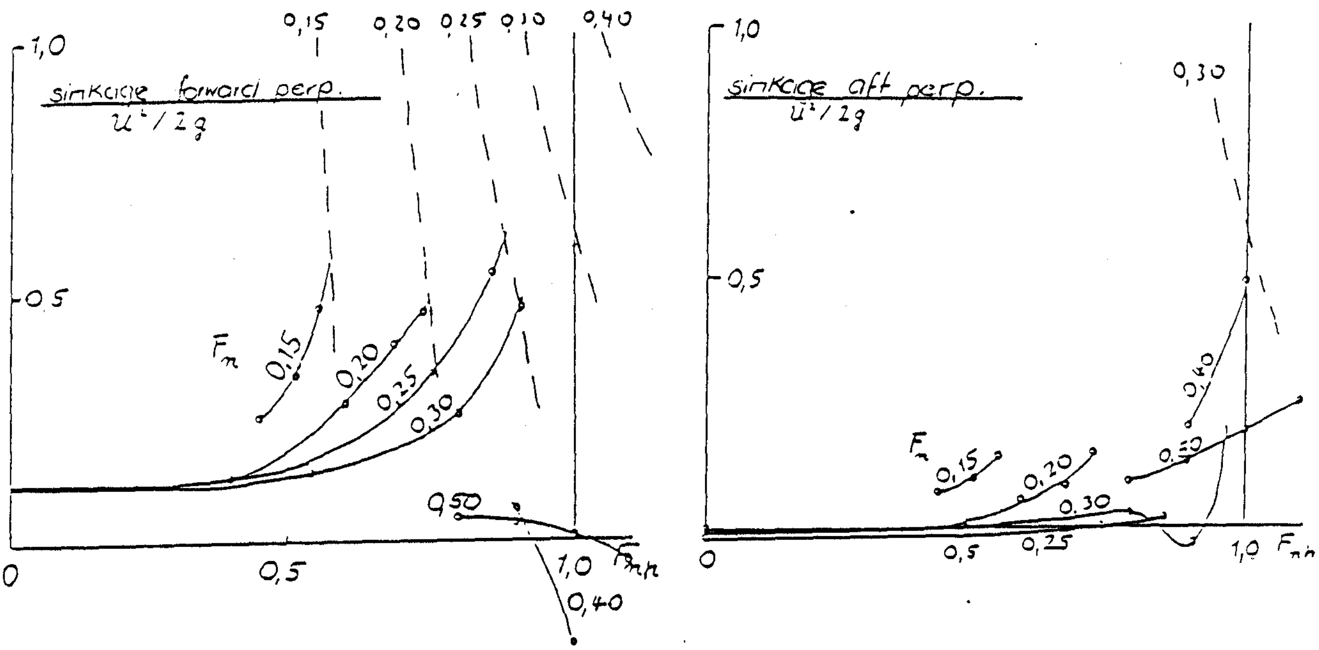

Fig. 1: Sinkage at forward and aft perpendicular in non-dimensional form
Dotted lines indicate limits at which ship touches ground

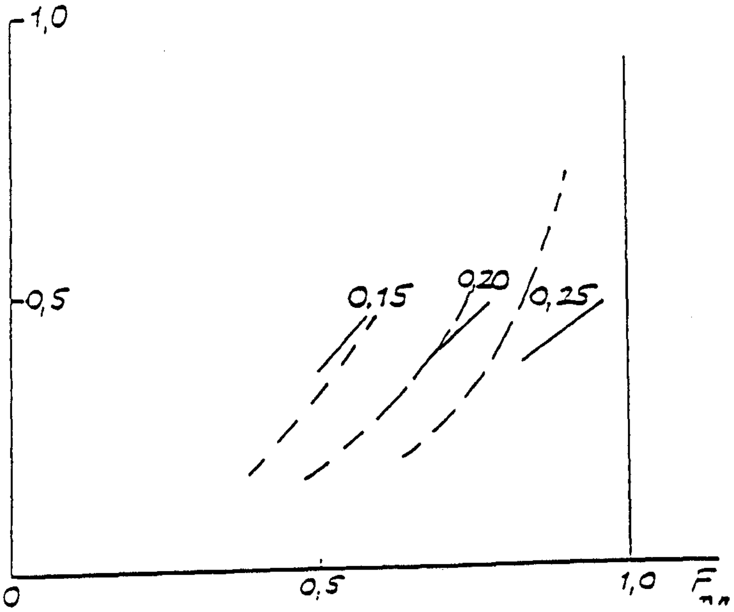

Fig. 2: Sinkage at forward perpendicular in non-dimensional form
— Barass /2/
- - - Tuck /3/

DISCUSSION

Raven: Did you always achieve complete convergence of the iteration for the free surface form, also for Fn=1? In that case, could you show us some calculated work resistance results?

Söding & Bertram: We stopped iterations when the nondimensional errors in the free surface conditions were less than 10^{-3} at every collocation point and if squat corrections were less than 1 cm. That was achieved in all cases for this ship. Unfortunately, wave resistance results have not been stored.

Yeung: For similar results using a slender-body theory applicable to the nonlinear transcritical regime of Fn=1·0, the works of Lea & Feldman 8th symp. on Naval Hydrod., 1972 and C.C. Mei (J.Fluid Mech. 77 (1976) pp.737-751) could serve well for the purpose of comparison.

Söding & Bertram: Thank you for the very valuable references.

Cao: Could you explain why you distribute the source over the ship surface rather than put some concentrated sources inside the ship hull as you do for the free surface?

Söding & Bertram: We do that because singularities inside the body work only for smooth surfaces without knuckles. For ships, especially at the bow and stern this condition is not satisfied.