In-depth study of shallow water

A number of studies have cast a new light on ship resistance in shallow water. While previously, tests in shallow-water basins were essentially analysed in the same way as those in deep water, it is now understood that there are important differences. A more complete understanding of shallow water ship hydrodynamics has been gained, and new procedures have been developed.

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A first step we introduced in 2011, was to correct for the effect of the limited width of the model basin. While the Shallow Water Basin has a substantial width of 16 m, this still affects the measurements far more than in deep water. No method was available to correct for this, i.e. to translate the model resistance in the tank to that in a waterway of unlimited width and equal depth.
By analysing the flow field from several computations, the nature of the tank wall effect was established, and a new theoretical method developed [1]. It requires making a single potential-flow computation; evaluation of some fluxes from the result, and the solution of an algebraic equation to obtain corrected model speeds. Thus the measured resistance points are shifted to a slightly higher speed by an amount that depends on water depth, speed and hull form. It then appears that the limited tank width exaggerated the apparent water depth dependence: after the correction, the true water depth effect appears to be a lot smaller. The second figure, an example of older model tests for a ferry, illustrates the significance of the correction.

Viscous resistance increase But there is another important aspect. Model tests are 'extrapolated' to full scale to derive a ship performance prediction. The straightforward application of common model-to-ship extrapolation methods would include the shallow-water resistance increase entirely in the 'wave' or 'residual' resistance component, which is assumed equal for model and ship. But much of the resistance increase in shallow water is actually viscous resistance. Computational studies [2] have indicated that this viscous resistance increase is in most cases a similar percentage for model and ship, and should be included in an increase of the form factor. This is the method now applied at MARIN, and also this reduces the assumed water-depth dependence of the ship resistance. Both steps have substantially improved the power predictions for ships in shallow water.

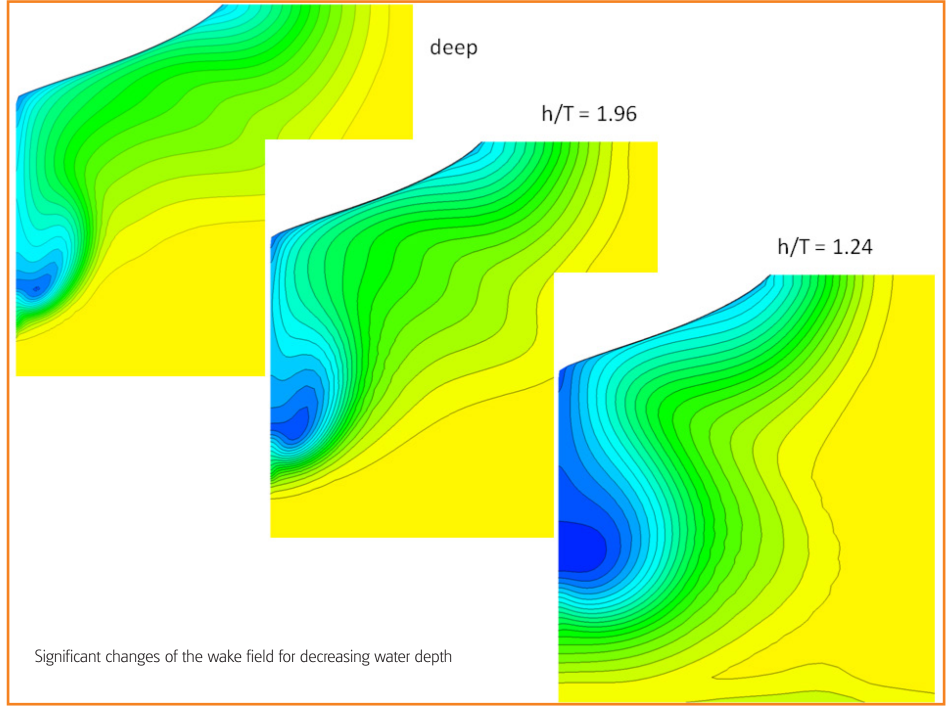
Speed trials Incipient shallow-water effects may also occur in ship speed trials. Usually, a contract speed at a given power is specified for deep water. But for large or fast ships, the actual water depth at the trials location may be such that a small speed loss is incurred. The measured trial speed may then be augmented by a speed correction, and the prescribed way so far was by a formula from Lackenby (1963). However, this formula was often found inadequate.

A new trial correction procedure has now been proposed [3]. From the main dimensions and block coefficient, the viscous resistance of the ship and its increase in shallow water are estimated. The wave resistance is supposed unaffected as long as the depth Froude number is limited; but an additional correction for the effect of the increased dynamic sinkage is applied. The procedure thus estimates the power increase in shallow water at equal speed; for which the trial measurement may be corrected.

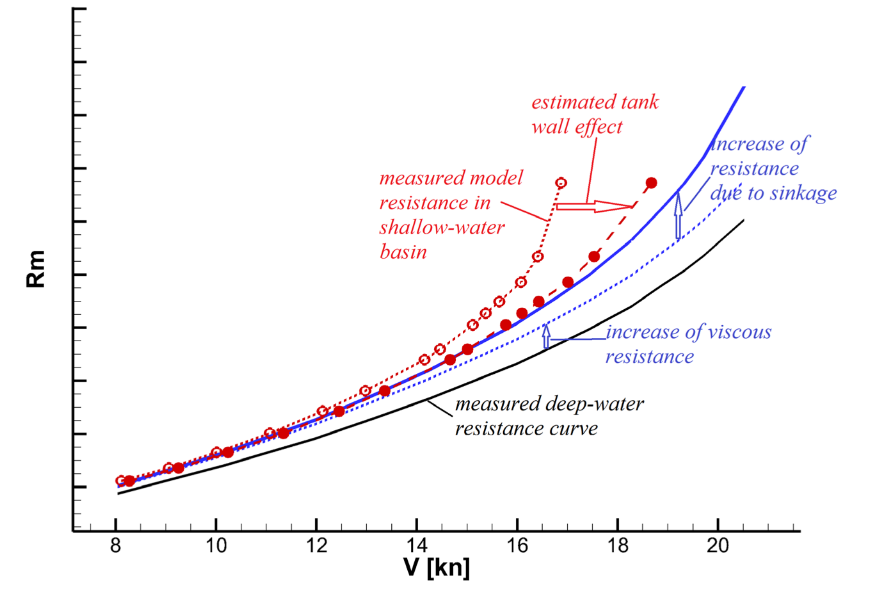
ITTC procedure With the support of the 'Sea Trial Analysis' (STA) Group, speed trials have been done for three ships at full scale in several water depths. Invariably the new procedure estimated the shallow-water speed loss much better than Lackenby's method. It is now being considered by the ITTC for general acceptance [4].

With all these steps, a much better understanding has been obtained of what happens in shallow water [5]. For the same model tests, the figure shows how we can explain the large difference between the measured model resistance in deep and shallow water. We added the two empirical contributions from the shallow-water correction method to the deep-water resistance curve: the increase of the viscous resistance, and the increase of resistance due to the additional dynamic sinkage. Thus we come quite close to the actual measurements in the Shallow Water Basin, corrected for the tank wall effect; the remaining discrepancy being the shallow-water increase of the wave resistance.

While a decade ago these model test results just had to be taken for granted, now we understand precisely what is going on. An understanding reflected in improved and consistent solutions for the long-standing problem of the power and speed of ships in shallow water.



Significant changes of the wake field for decreasing water depth



Measured model resistance in deep and shallow water, and decomposition of the difference

[1] Raven, H.C., A method to correct shallow-water model tests for tank wall effects. Jnl Marine Science Techn., Vol.24-2, June 2019.
[2] Raven, H.C., A computational study of shallow-water effects on ship viscous resistance. 29th Symp. Naval Hydrodynamics, Gothenburg, Sweden, 2012.
[3] Raven, H.C., A new correction procedure for shallow-water effects in ship speed trials, PRADS 2016 Symposium, Copenhagen, Denmark, 2016.
[4] ITTC Recommended Procedures and Guidelines, Preparation, Conduct and Analysis of Speed/Power Trials, Procedure 7.5-04-01-01.1, 2017.
[5] Raven, H.C., Shallow-water effects in ship model testing and at full scale, 5th MASHCON conference, Oostende, Belgium, 2019; to appear in Ocean Engineering.