Perth Hydro

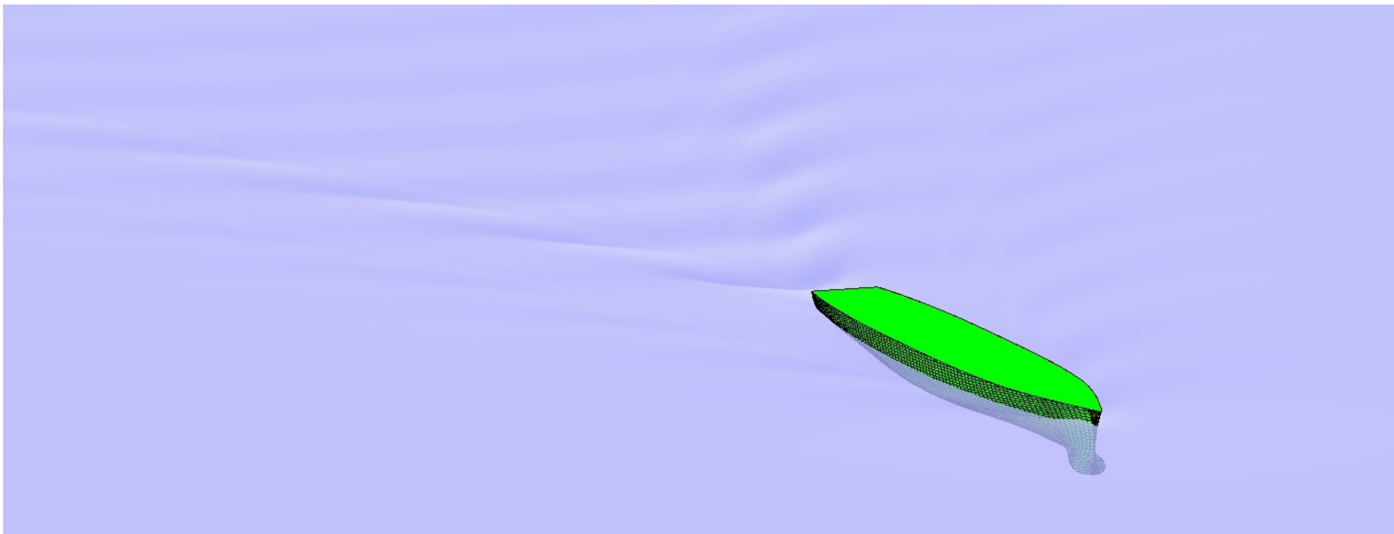
Level 29, 221 St Georges Tce
Perth, WA 6000

Contact: Dr Tim Gourlay
+61 416 328883
tim@perthhydro.com

phFlow Wavemaking Calculations for the DTMB 5415 Hull

Tim Gourlay

Perth Hydro Research Report R2019-07



Document History	
16 December 2019	Report published

CONTENTS

1. Introduction

The mathematical equations used in phFlow are described in Gourlay (2019), together with a validation study for the KRISO Container Ship, which has a transom above the still water level. In this article we undertake a similar validation for a deep-transom hull, the DTMB 5415 (Lindenmuth et al. 1991). This is a high-speed, destroyer-type hull with a sonar dome.

2. DTMB 5415 hull

Particulars of the DTMB 5415 hull are shown in Table 1.

Length between perpendiculars (L_{PP})	142.0 m
Length waterline	142.0 m
Beam waterline	18.9 m
Beam overall	20.5 m
Draft (to keel line)	6.16 m
Sonar dome depth beneath keel line	3.03 m
Displacement	8,425.4 m^3

Table 1: DTMB 5415 particulars at full scale

Test case conditions are as used in Lindenmuth et al. (1991, Table A1) and shown in Table 2.

Speed (knots)	18.1 knots	30.0 knots
Speed (m/s)	9.33 m/s	15.43 m/s
Froude number	0.25	0.41
Water depth	Deep	Deep
Ship vertical position fixed at measured sinkage:	0.25 m (FP); 0.03 m (AP)	-0.06 m (FP); 1.04 m (AP)

Table 2: Test conditions used in this report. Values given at full scale.

3. Ship mesh

The DTMB 5415 has been meshed as follows:

- Read publicly-available IGES file into DELFTship
- Export OCTOPUS hull file
- Generate surface mesh using OCTOPUS 3D mesher

The stern is cut off vertically, with no panels used on the transom. The resulting ship surface mesh is shown in Figure 1.

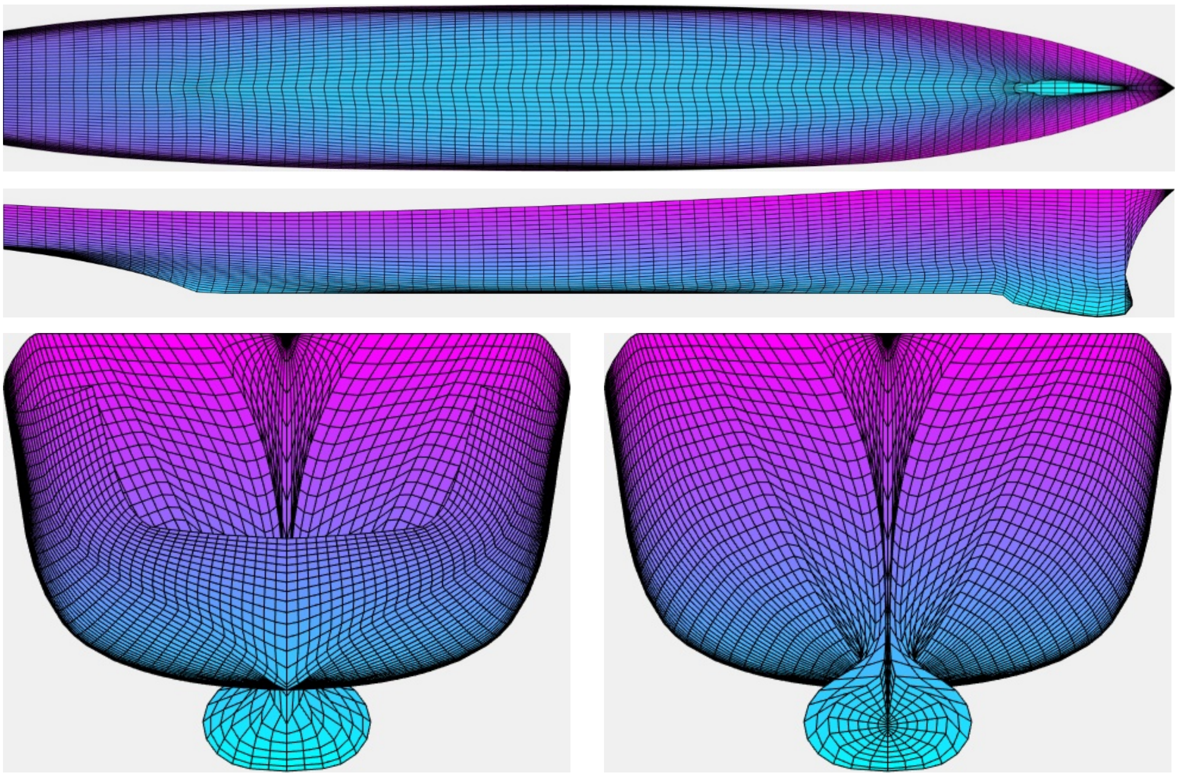


Figure 1: DTMB 5415 surface mesh, up to 13.0 m above keel line. (Top) plan view; (Middle) profile view; (Bottom left) stern view; (Bottom right) bow view.

4. Raised free surface mesh

Raised free surface panels are set on a horizontal grid. Panel lengths in the x-direction are constant along the length of the ship, and uniformly increased at a constant expansion ratio astern of and ahead of the ship. Panel widths in the y-direction are constant in the inner region; in the outer region, panel widths are uniformly increased at a constant expansion ratio.

Free surface collocation points are chosen as ¼ of the way aft on each free surface panel.

Raised free surface mesh details for the test case are shown in Table 3.

	18.1 knots	**30.0 knots**
Panel length (minimum)	1.20 m	2.00 m
Panel width (minimum)	1.20 m	2.00 m
Aft limit of mesh	$x = -2.6L_{PP}$	$x = -5.6L_{PP}$
Forward limit of mesh	$x = 2.0L_{PP}$	$x = 2.0L_{PP}$
Transverse limit of mesh	$y = 1.9L_{PP}$	$y = 3.9L_{PP}$
Number of panels in x-direction	327	280
Number of panels in y-direction	52	53

Table 3: Raised free surface mesh characteristics for DTMB 5415 test case

5. Combined ship and free surface mesh

The combined ship and free surface mesh is developed as described in Gourlay (2019).

Views of the combined mesh, for the fully-converged flow, are shown in Figure 2 to Figure 6.

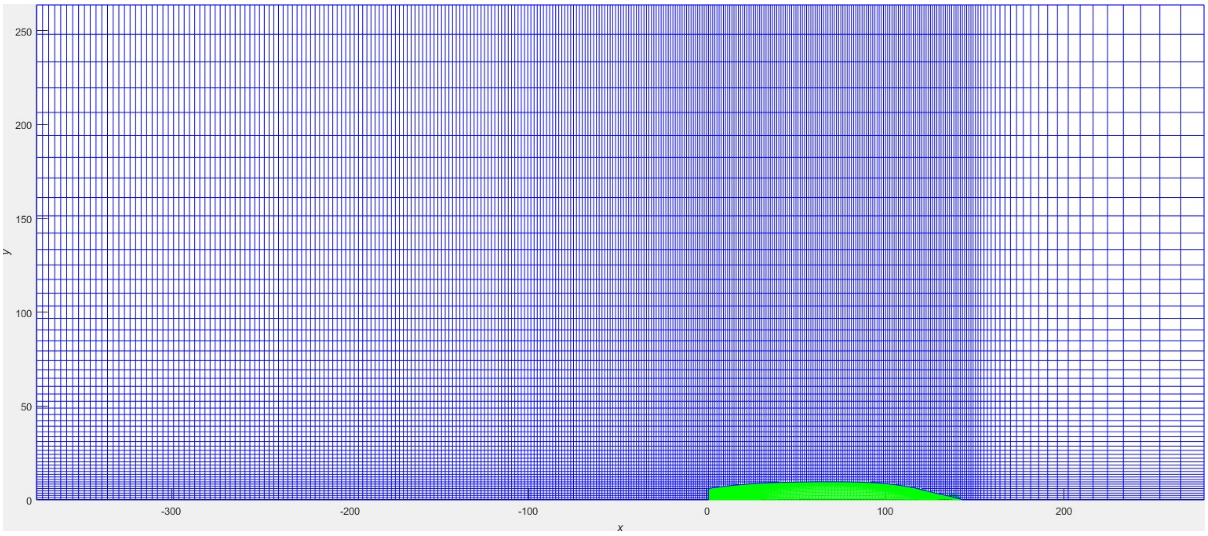


Figure 2: Hull panels (green) and raised free surface panels (blue) for DTMB 5415 hull at 18.1 knots

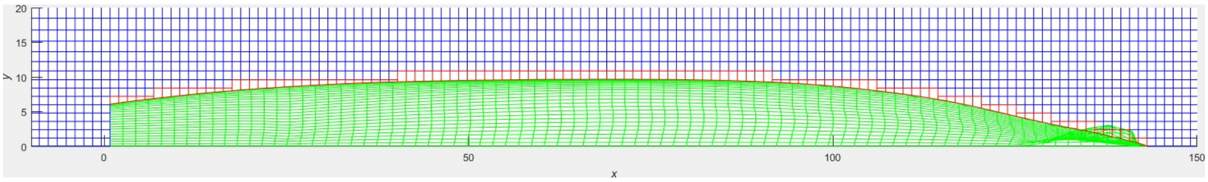


Figure 3: Close-up of free surface panels around hull at 18.1 knots, showing regular panels in blue, and infill panels in red

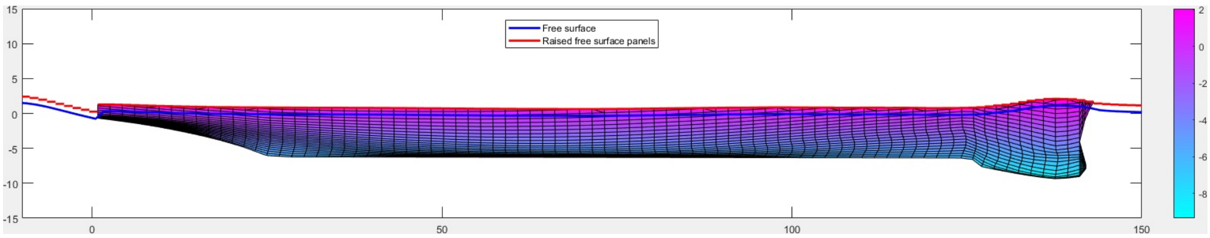


Figure 4: Profile view of wetted hull panels and raised free surface panels for fully-converged flow at 18.1 knots

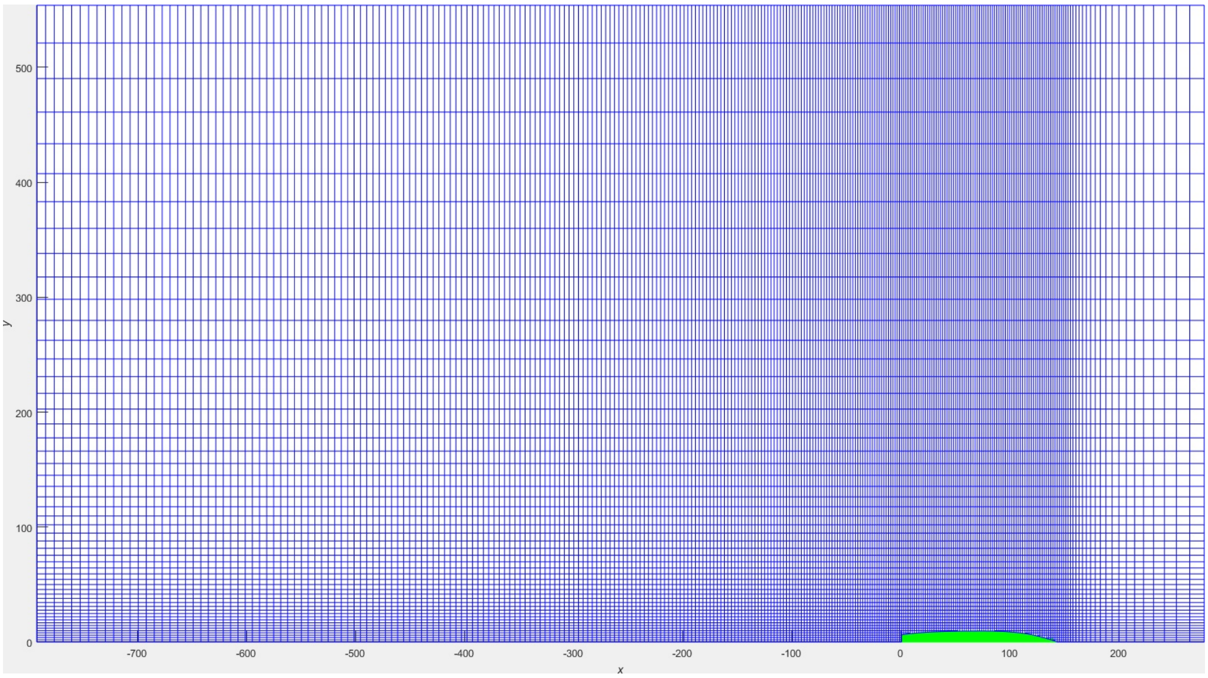


Figure 5: Plan view of hull panels (green) and raised free surface panels (blue) for DTMB 5415 hull at 30.0 knots

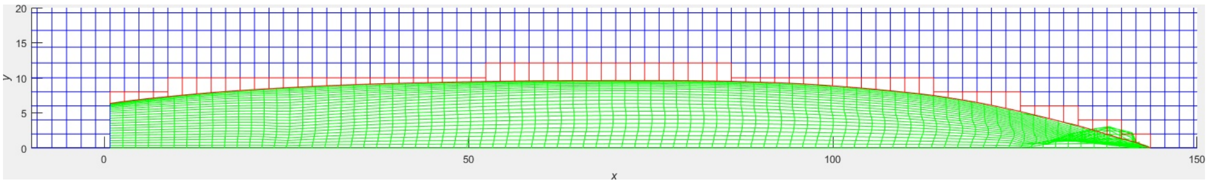


Figure 6: Close-up plan view of raised free surface panels around hull at 30.0 knots, showing regular panels in blue, and infill panels in red

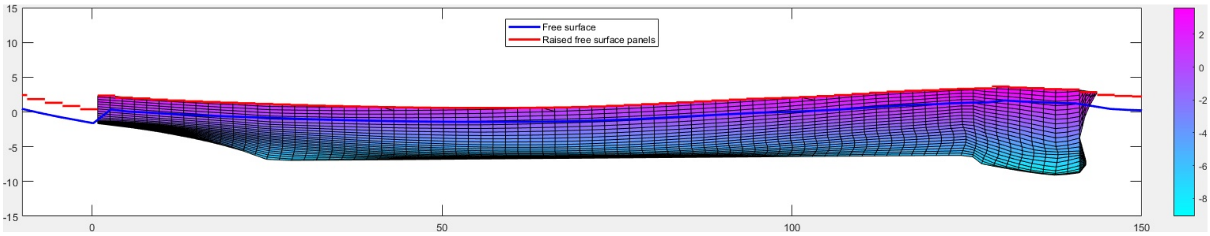


Figure 7: Profile view of wetted hull panels and raised free surface panels for fully-converged flow at 30.0 knots

Combined mesh details are given in Table 4. Port/starboard symmetry is assumed, so only panels on the port side are considered as unknowns.

	18.1 knots	30.0 knots
Number of hull panels	1996	2068
Number of raised free surface panels	16241	11715
Total number of panels	18237	13783

Table 4: Number of panels on port side of combined mesh, for fully-converged flow

6. Wavemaking results for 18.1 knots ship speed

Convergence was reached after 8 iterations. Wave profiles are shown below.

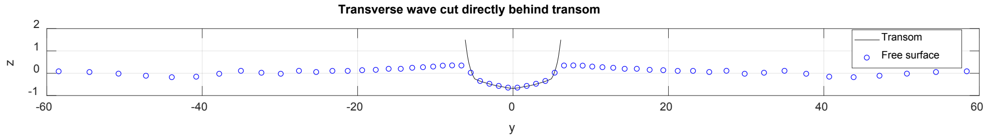


Figure 8: Transverse free surface profile directly behind the transom, as calculated with phFlow

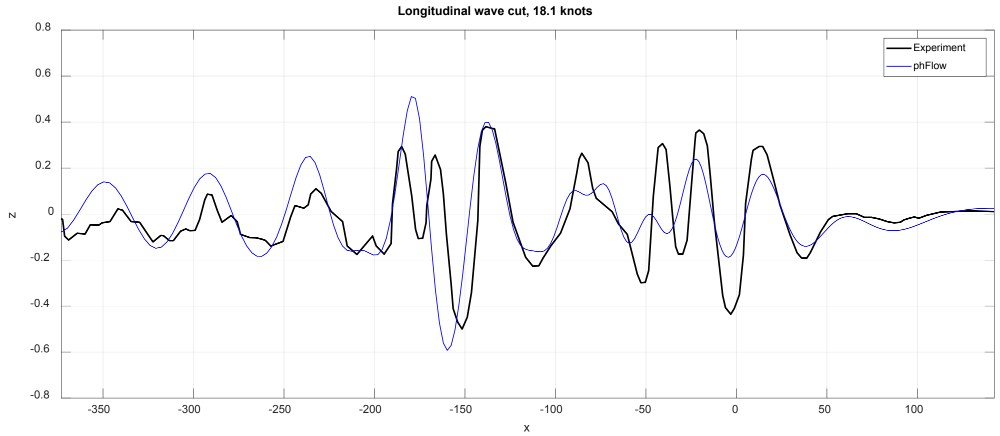


Figure 9: Longitudinal wave cut at $y/L_{PP} = 0.324$. Experimental results from Lindenmuth et al. (1991, Fig. B2).

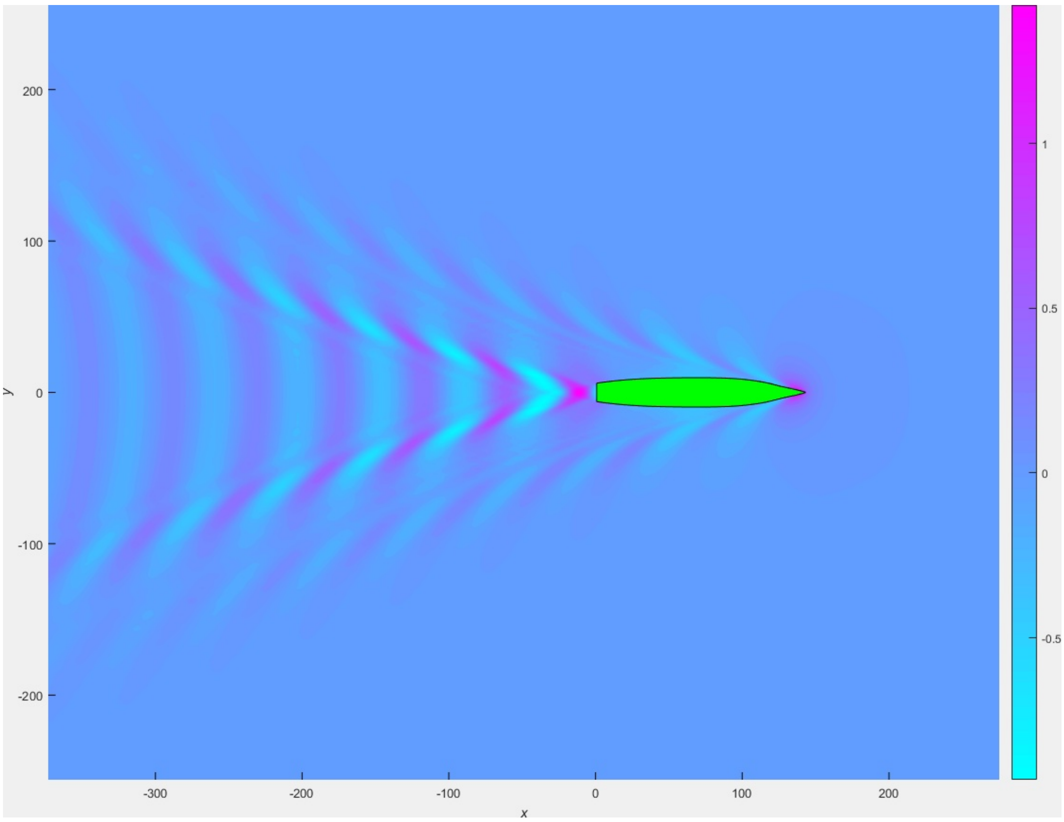


Figure 10: Free surface height contour plot, as calculated using phFlow. Colours show free surface elevation in metres.

7. Wavemaking results for 30.0 knots ship speed

Convergence was reached after 8 iterations. Wave profiles are shown below.

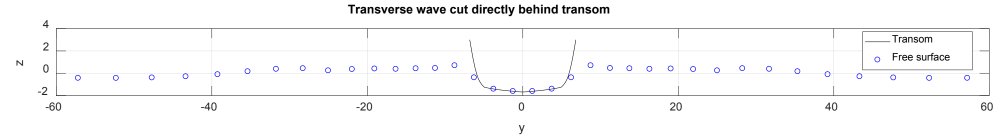


Figure 11: Transverse free surface profile directly behind the transom, as calculated with phFlow

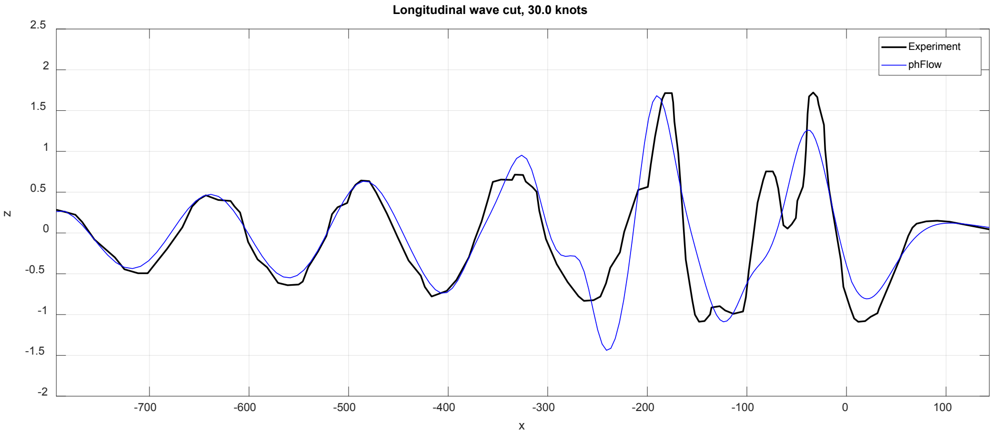


Figure 12: Longitudinal wave cut at $y/L_{PP} = 0.324$. Experimental results from Lindenmuth et al. (1991, Fig. B8).

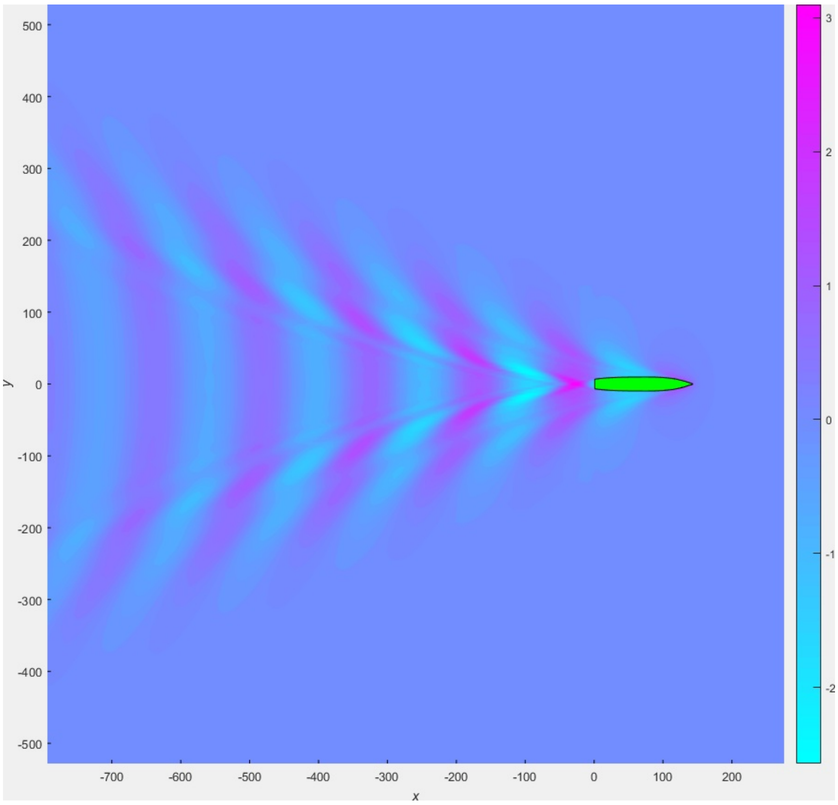


Figure 13: Free surface height contour plot, as calculated using phFlow. Colours show free surface elevation in metres.

8. Wave pattern resistance

Calculated and experimental wave resistance coefficients (based on wetted surface area 2,995 m^2) are shown in Table 5.

	18.1 knots	30.0 knots
Experiment	0.00037	0.00240
phFlow	0.00128	0.00355

Table 5: Wave resistance coefficient. Experimental results from Lindenmuth et al. (1991, Table 5).

9. Acknowledgement

The author acknowledges valuable discussions on ship wavemaking with Dr Hoyte Raven and Dr Leo Lazauskas.

10. References

Gourlay, T.P. 2019 phFlow wavemaking calculations for the KRISO Container Ship. Perth Hydro Research Report R2019-05, December 2019.

Lindenmuth, W.T., Ratcliffe, T.J., Reed, A.M. 1991 Comparative accuracy of numerical Kelvin wake code predictions – 'Wake-Off'. Report DTRC-91/004, David Taylor Model Basin, Sept. 1991.