Investigation of the Influence of Wavefoils on Wave Pattern Resistance of a Ship - Using CFD

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Problem

Hydrofoils mounted in the bow region of a conventional displacement ship hull provides thrust when the ship moves forward in waves. Such foils can be called wavefoils. However, in calm water conditions there will be an interaction between the steady wave patterns of the ship hull and wavefoils. This interaction effect can cause the total wave-making resistance to increase or decrease, depending on the placement of the wavefoils, thus affecting the total resistance of the ship. The effect of the wavefoils is therefore similar to a bulb.

Objective

The effect of wavefoils on the steady wave pattern of a ship is investigated by means of computational fluid dynamics (CFD). Positioning of the wavefoils is adjusted in order to see if an optimum position can be found. Further, the work focuses on one particular case, while a general understanding of the importance of the wavefoils on the ship wave resistance is sought.

Method

-The open source CFD software **OpenFOAM** is used for the analyses.
-The computational grid is created using the OpenFOAM native meshers **blockMesh** and **snappyHexMesh**.
-Turbulence is modelled using the **k-ω SST** model [1].
-**Logarithmic wall functions** are used in the boundary layer for the turbulence, such that the non-dimensional distance from the ship wall for the first cell, y^+, is located in the logarithmic region of the boundary layer.
-The two phase solver **interFoam** is used to investigate the steady wave pattern.
-**Volume of fluid** (VOF) method is used to model the two phases water and air, thus modelling a free surface. The VOF method uses a phase fraction in order to represent the phases, where 1 = water and 0 = air.
-**The Duisburg test case hull** (DTC hull), [3], is used for the analyses in order to obtain validation data.

Acknowledgements

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References

[1] F. R. Menter, M. Kuntz and R. Langtry: *Ten Years of Industrial Experience with the SST Turbulence Model*, Turbulence, Heat and Mass Transfer 4(1), pp 625-632 (2003)

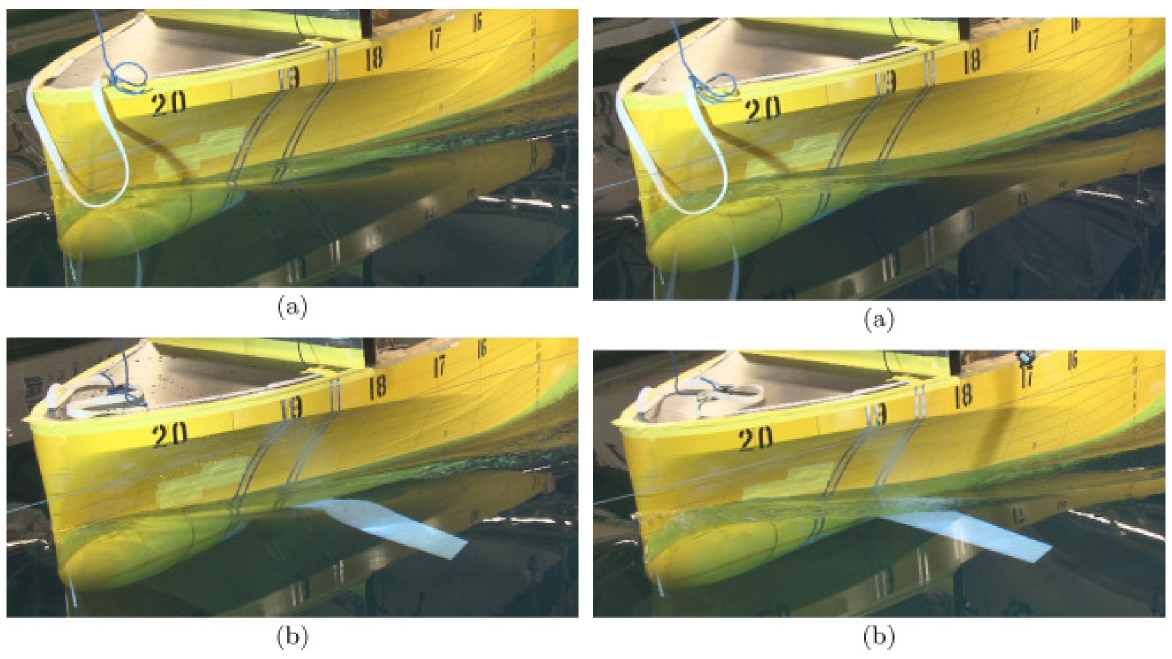
[2] E. Bøckmann and S. Steen: *Model test and simulation of a ship with wavefoils*, Applied Ocean Research, vol. 57, pp 8-18 (2016)

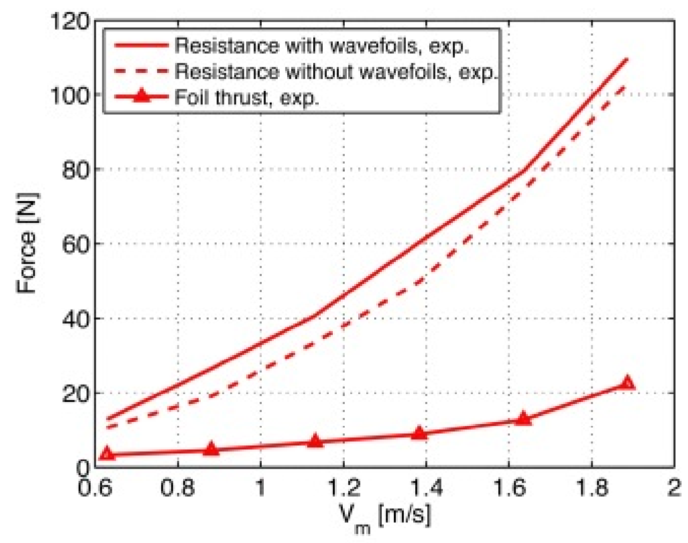
[3] O. el Moctar, Vladimir Shigunov and Tobias Zorn: *Duisburg Test Case: Post-Panamax Container Ship for Benchmarking*, Ship Technology Research, vol. 59:3, pp 50-64 (2012)

Experimental Results by Bøckmann and Steen

Experiments by Bøckmann and Steen (2016) [2], show that the wavefoils produce a significant thrust force in calm water conditions. However, they found an increase in the total resistance in their experiments, which is illustrated in the force plot to the lower right. This may be explained by the figures to the left and in the middle. The left figure illustrates the wave pattern in the bow region with and without wavefoils for a model speed of 1.64 m/s. The middle illustrates the same, but with a model speed of 1.89 m/s. From the figures it can be seen that the water level is slightly higher above the bulb with wavefoils. In addition, for the highest model speed, the wave crest above the bulb is amplified. These figures supports the assumption that the wavefoils interact with the ship hull, and thus modify the wave-making resistance.

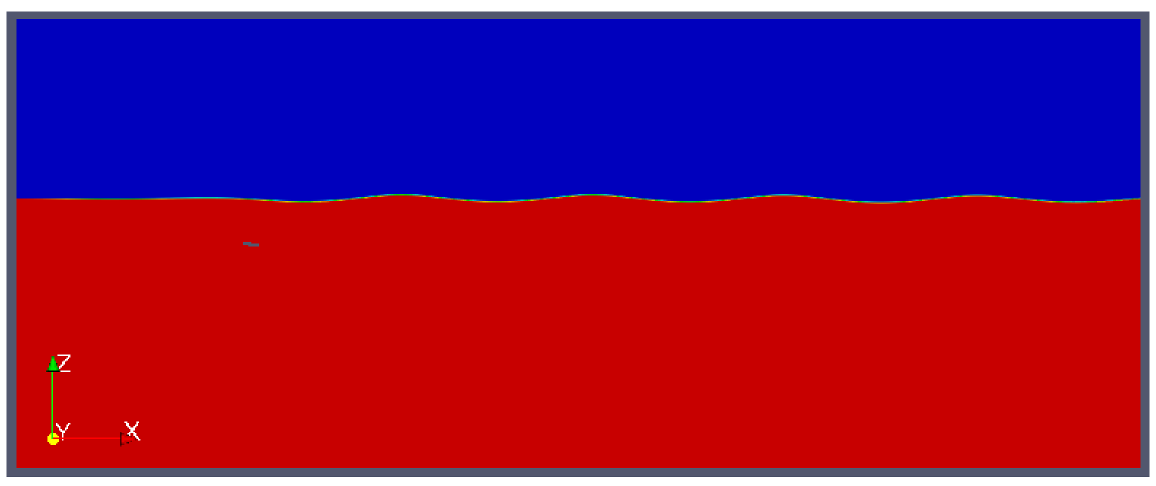
All figures and presented work in this section are taken from [2], and do not represent the work of the author.

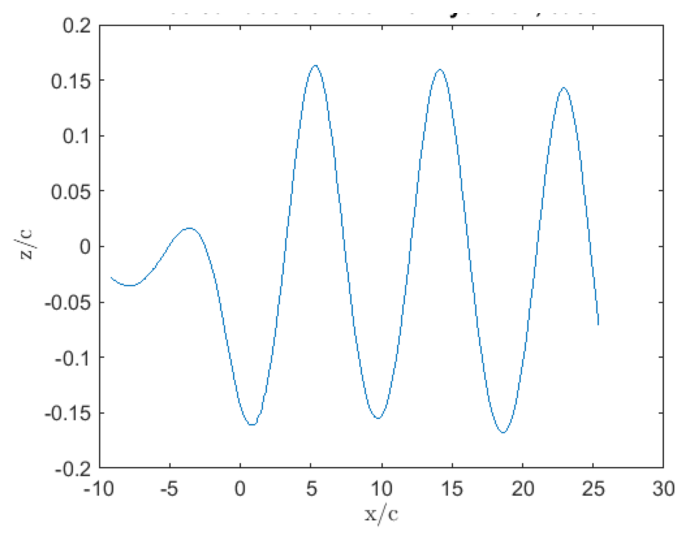




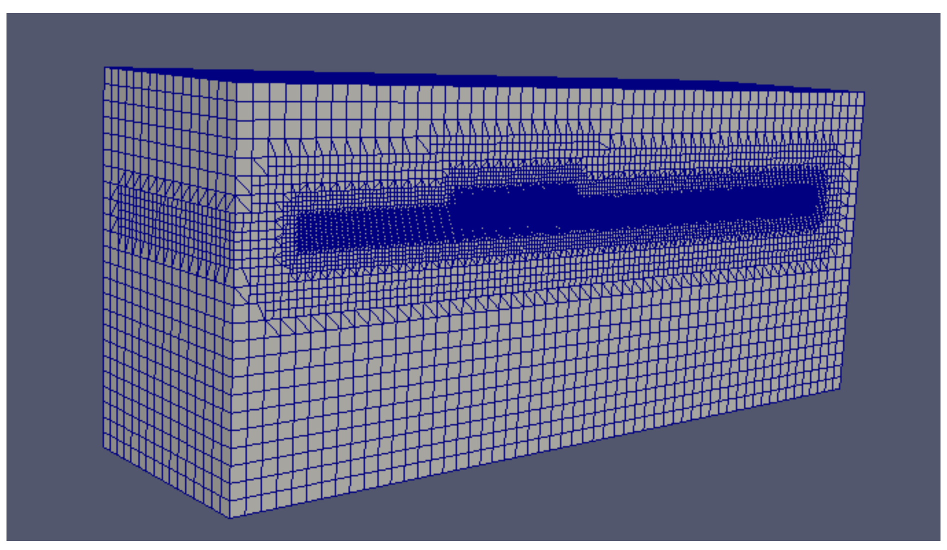
Preliminary Results

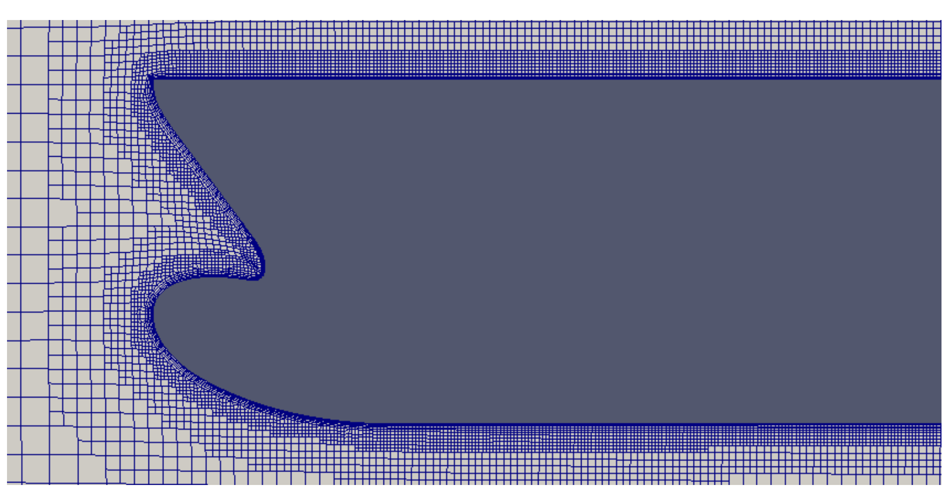
Elevation of the free surface for a NACA0015 foil profile with chord length 0.193 metres and submergence-chord length ratio 2 can be seen below, with the parameters chosen with respect to the experiments of Bøckmann and Steen (2016) [2]. The free surface analysis is performed in 2D and the foil has an angle of attack of 5°, and was a part of the project thesis work during the autumn semester 2017. A clear disturbance of the free surface is observed, indicating that that wavefoils can indeed modify the wave-making resistance of a ship.





The computational domain for free surface analysis of a ship can be seen below to the left. This is only a preliminary computational grid, as the free surface needs further refinement in order to capture the wave pattern created by the ship. The figure to the right shows the computational grid around the bow section of the Duisburg Test Case hull [3]. Care is taken to resolve the boundary layer with prismatic cells - surface layers. As turbulence is modelled and wall functions in use, the cell size closest to the ship hull is modelled such that y^+ values are in the range of 55-70, i.e. in the middle of the logarithmic region.





Final conclusions are not made, as further results are still to be produced. However, based on the experiments by Bøckmann and Steen (2016) [2] and the 2D foil analysis, it is most likely that the wavefoils modify the wave pattern of the ship and so the wave-making resistance.