Newsletter Shallow Water

Knowledge Centre Manoeuvring in Shallow and Confined Water

Flanders Hydraulics | Flanders State of the Art | GHENT UNIVERSITY

October 2023

This is the 55th newsletter of the Knowledge Centre Manoeuvring in Shallow and Confined Water, which aims to consolidate, extend and disseminate knowledge on the behaviour of ships in shallow and confined water. In this newsletter, we present a CFD study on propeller - rudder interaction in off design conditions.

CFD study on propeller - rudder interaction

Most ships today use propellers to advance through water and rudders to steer the ship. Theoretical methods generally treat the propeller and the rudder separately. One aspect that is understood far less, is the interaction between the propeller and the rudder. The presence of a rudder in the flow field interferes with the pressure field in which the propeller is operating, thus affecting the thrust and torque developed by the propeller. In return, the acceleration of the flow by the propeller alters the incidence and speed of the flow arriving at the rudder and affects the forces and moments developed by the rudder. Propeller – rudder interaction has received increased attention with the advent of powerful computing resources, but the modelling of the rudder behaviour behind the propeller in four-quadrant wake fields has rarely been done.

A study is being carried out on the hydrodynamic performance of a NACA 0018 semi-balanced rudder behind a KP505 propeller rotating ahead and astern, i.e. in the first and the second quadrant. CFD calculations were carried out with OpenFOAM using a transient solver for incompressible flow of Newtonian fluids on a moving mesh using the PIMPLE algorithm. The k-ω SST turbulence model was applied to close the Reynolds-averaged Navier Stokes equations.

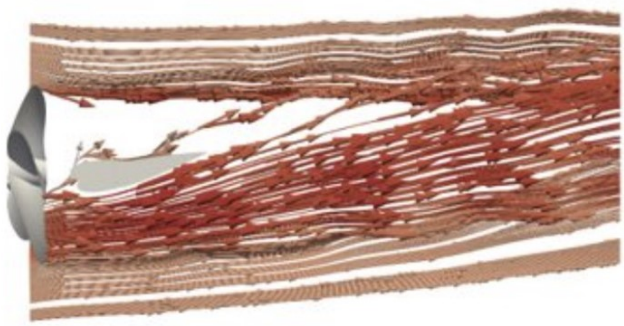


Figure 1. First quadrant – propeller running ahead (advance J = 0.5, rudder angle a = 15°, t = 1s) – streamline distributions.

Figure 1 shows 3D streamlines around the propeller-rudder system for an ahead running propeller and shows that the uniform flow passing through the propeller disk is accelerating, flowing straightforward to the rudder.

Figure 2 and Figure 3 show an astern rotating propeller. Instead of being accelerated, the flow enters a recirculation zone. Due to the propeller's pumping effect, the strong reverse flow significantly decreases the inflow velocity to the rudder. Figure 2 shows that an advance coefficient J = -0.5 leads to larger reverse flow motions than when J = -0.7, shown in Figure 3.

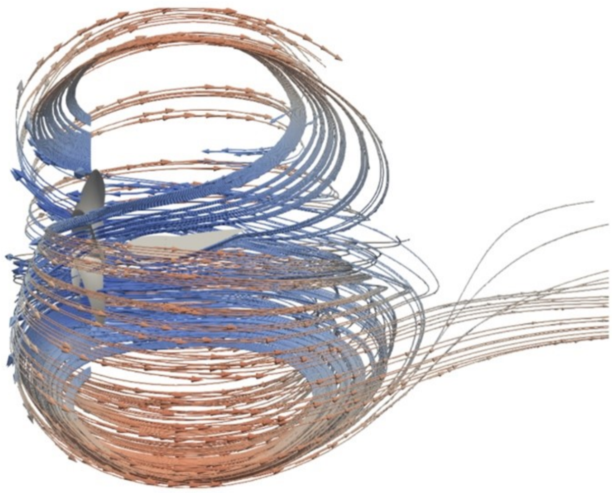


Figure 2. Second quadrant – propeller running astern (J = -0.5, a = 15°, t = 8s) – streamline distributions.

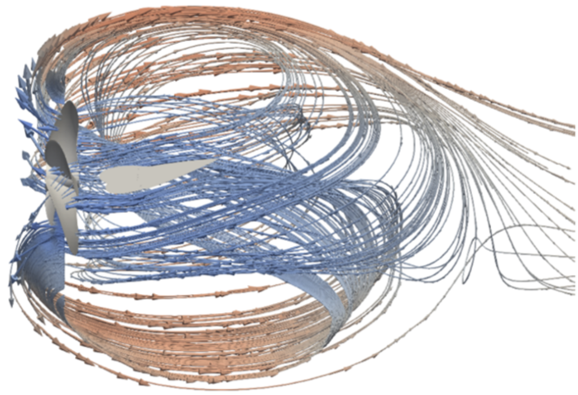


Figure 3. Second quadrant – propeller running astern (J = -0.7, a = 15°, t = 8s) – streamline distributions.

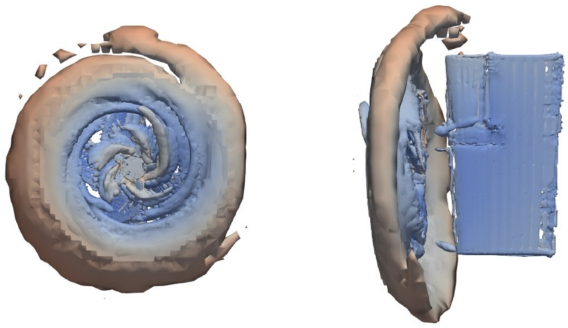


Figure 4. Second quadrant – propeller running astern (J = -0.7, a = 15°, t = 8s) – visualized vortex structures: front view (left) and side view (right).

Figure 4 shows a visualization of the vortex structures for the situation shown in Figure 3. The highly unsteady vortex ring is captured and the trend of the vortex ring to move forward is blocked by the incoming flow.

The axial velocity distributions of the rudder inflow in ahead and astern conditions were also studied. In ahead conditions, the far ahead inflow is accelerated within an approximately circular region of the propeller diameter, except for the flow shed from the propeller hub. In the second quadrant condition, however, the rudder experiences reverse axial velocities for the whole rudder span length, and heavier loadings make the reverse flow more violent inside a larger recirculation zone.

This research gives a preliminary qualitative description of rudder hydrodynamics behind a propeller in the first and the second quadrant, and studies in four quadrants will be performed in the future. A better understanding of propeller – rudder interaction will ultimately lead to improved prediction of the manoeuvring behaviour of ships and offers scope for improvements in detailed rudder design.

Researchers associated with the Knowledge centre recently published:

He, H.; Lataire, E.; Van Zwijnsvoorde, T.; Delefortrie, G. (2023). A Ship Manoeuvring Desktop Simulator for Developing and Validating Automatic Control Algorithms. *TransNav, Int. J. Mar. Navig. Saf. Sea Transp. 17*(*3*): 607–616.

Lu, S.; Boucetta, D.; Van Hoydonck, W.; Lataire, E.; Delefortrie, G. (2023). Rudder hydrodynamics behind a propeller rotating ahead and astern. *IOP Conf. Ser. Mater. Sci. Eng. 1288*(*1*): 012057.

Pribadi, A.B.K.; Mansuy, M.; Lataire, E. (2023). Force measurement analysis of a full scale offshore seaweed cultivation system, ***in***: (2023). *Aquaculture Europe 2023*: Vienna, Austria. pp.1148–1149

Sotelo, M.S.; Boucetta, D.; Van Hoydonck, W.; Doddugollu, P.; Vantorre, M.; Toorman, E.; Delefortrie, G. (2023). Hydrodynamic Forces Acting on a Cylinder Towed in Muddy Environments. *J. Waterw. Port, Coastal, Ocean Eng. 149*(*6*): 04023016.

Van Zwijnsvoorde, T.; Verhagen, B.; Delefortrie, G. (2023). A state-of-the-art free running system in the Towing Tank for Manoeuvres in Shallow Water, in: *7th International Conference on Advanced Model Measurement Technology for The Maritime Industry*. Istanbul, Turkey.

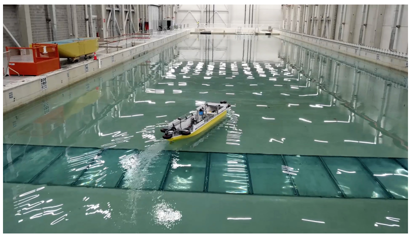
Activities

Katrien Eloot attended the third SIMMAN workshop, which was held in Songdo from 17 to 19 July 2023. She was invited as non-committee member to take the lead in an independent evaluation and critique on the contributions related to “Shallow water”.

Suli Lu presented “Rudder hydrodynamics behind a propeller rotating ahead and astern” at the 12th International Workshop on Ship and Marine Hydrodynamics, which was held in Aalto from 28 August to 1 September.

Ajie Brama Krishna Pribadi presented “Force measurement analysis of a full scale offshore seaweed cultivation system” at Aquaculture Europe 2023, which was held in Vienna from 18 to 21 September.

Marc Mansuy attended the Belgian Hydraulic Days in Châtelet on 2 October and presented “Turning basins for inland waterways: optimized design”.



Thibaut Van Zwijnsvoorde presented “A state-of-the-art free running system in the Towing Tank for Manoeuvres in Shallow Water” at the AMT’23 Conference, which was held in Istanbul from 24 to 26 October.

Knowledge Centre Manoeuvring in Shallow and Confined Water
Berchemlei 115
2140 Antwerp
Belgium
T. +32 3 224 60 35

Flanders Hydraulics | Flanders State of the Art | GHENT UNIVERSITY