CFD analysis of the flow around a Vikingship rudder

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Objective:
During a test voyage of a replica of the Oseberg ship, the crew experienced that they lost steering over the ship when turning to starboard. It was believed that he rudder was at fault and it were modified in terms of length and thickness. This rudder proved better when turning to starboard, but not as good as when turning to port. Additionally, it were recorded to vibrate in certain conditions. It was therefore of interest to see if CFD might reveal the cause of these problems.

Model:
- The modified Oseberg rudder were examined with three different rudder rake angles, β= 20, 25 and 30 degrees.
- Reynolds number of 250 and 1000 were chosen
- Both Reynolds numbers a rudder rake angles were tested at incoming flow angle of attack α= -10, -5, 0, 5 and 0 degrees.
- Final structured mesh consists of 3.7 mill. cells.

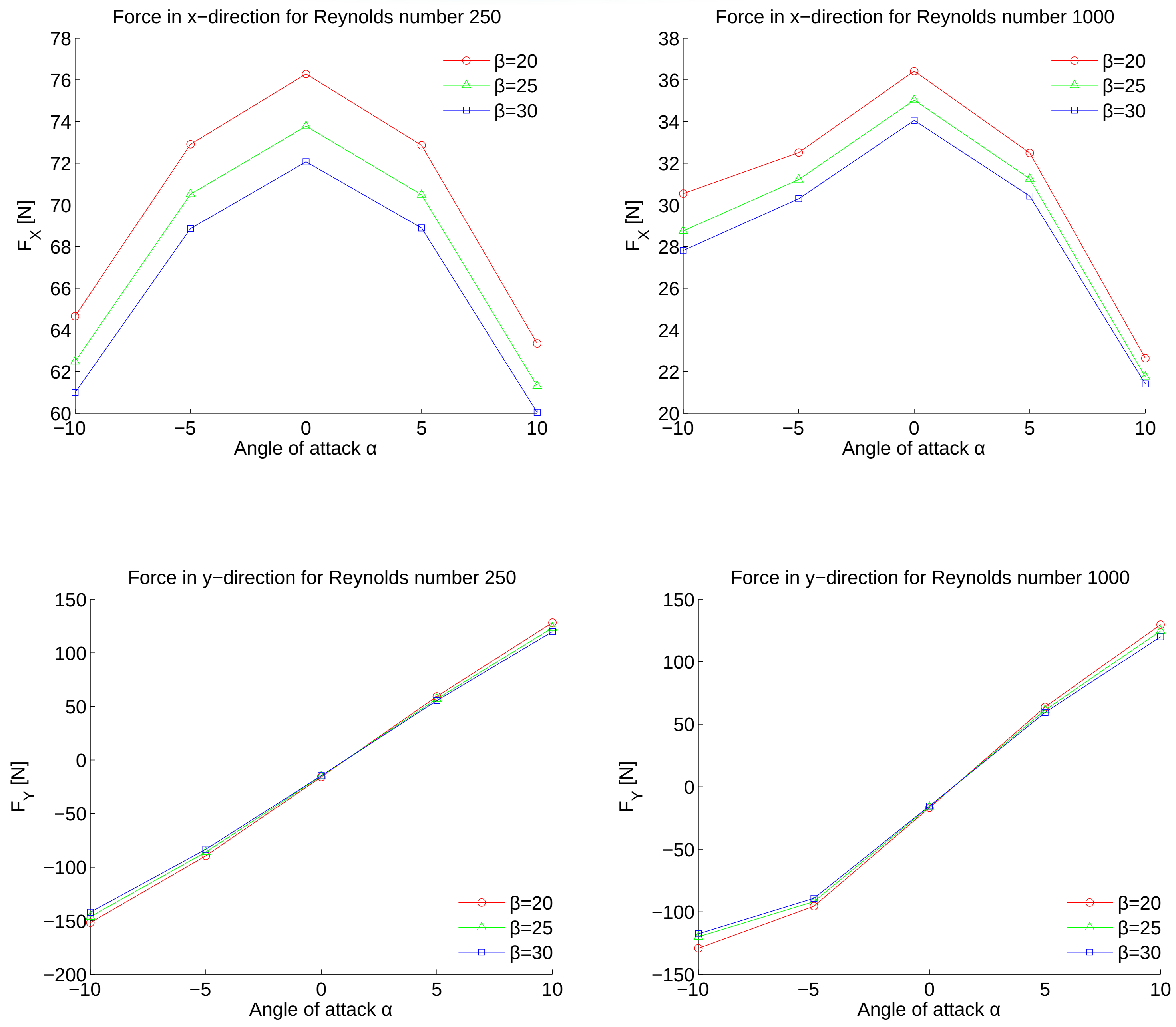

Figure 1: The resulting resistance (x-direction) and lift (y-direction) force experienced by the rudder at two different Reynolds numbers.

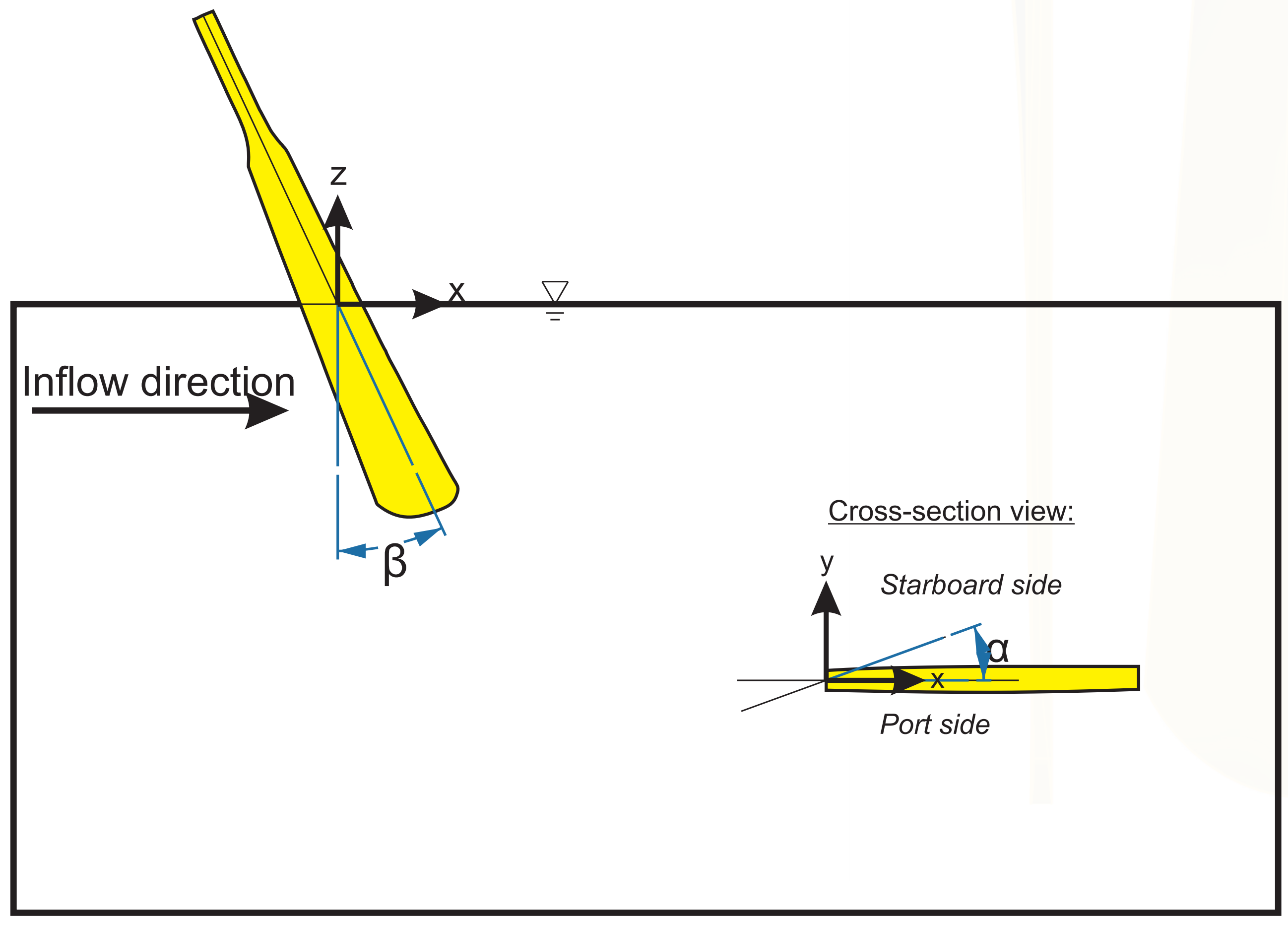

Figure 2: Computational domain and angle definitions

Results:
Figure 1 illustrates the resulting forces from the analysis. The resistance decreased as Reynolds number increased, mainly due to a reduction in viscous resistance.
At Re=1000 and α= -10 the rudder experienced vortex shedding, as illustrated in figure 4 and 5. The shedded vortices caused the resulting lift and drag to oscillate with the following frequencies:

- Rudder rake angles
  - **20:** Drag: 1.166 Hz, Lift: 1.166 Hz
  - **25:** Drag: 1.103 Hz, Lift: 1.103 Hz
    Drag: 0.260 Hz, Lift: 0.238 Hz
  - **30:** Drag: 0.373 Hz, Lift: 0.041 Hz

The vortex shedding will cause a larger mean resistance experienced by the rudder at this angle of attack in comparison with α= 10 degrees. At rudder rake angle β= 25 degrees the vortex shedding will have two significant periods, signifying a transition between two shedding frequencies here.

Conclusion:
The vortex shedding appears when the ship is steering to starboard. Increased resistance, vibrations induced by the oscillating lift and drag force due to vortex shedding will cause loss of steering power. The shedding frequencies indicates that it would be advantageous to use a 30 degree rudder rake angle to reduce the resistance experienced by the rudder. At this rake angle the vortex shedding are more slowly-varying, resulting in a more stable lift and drag force on the rudder.

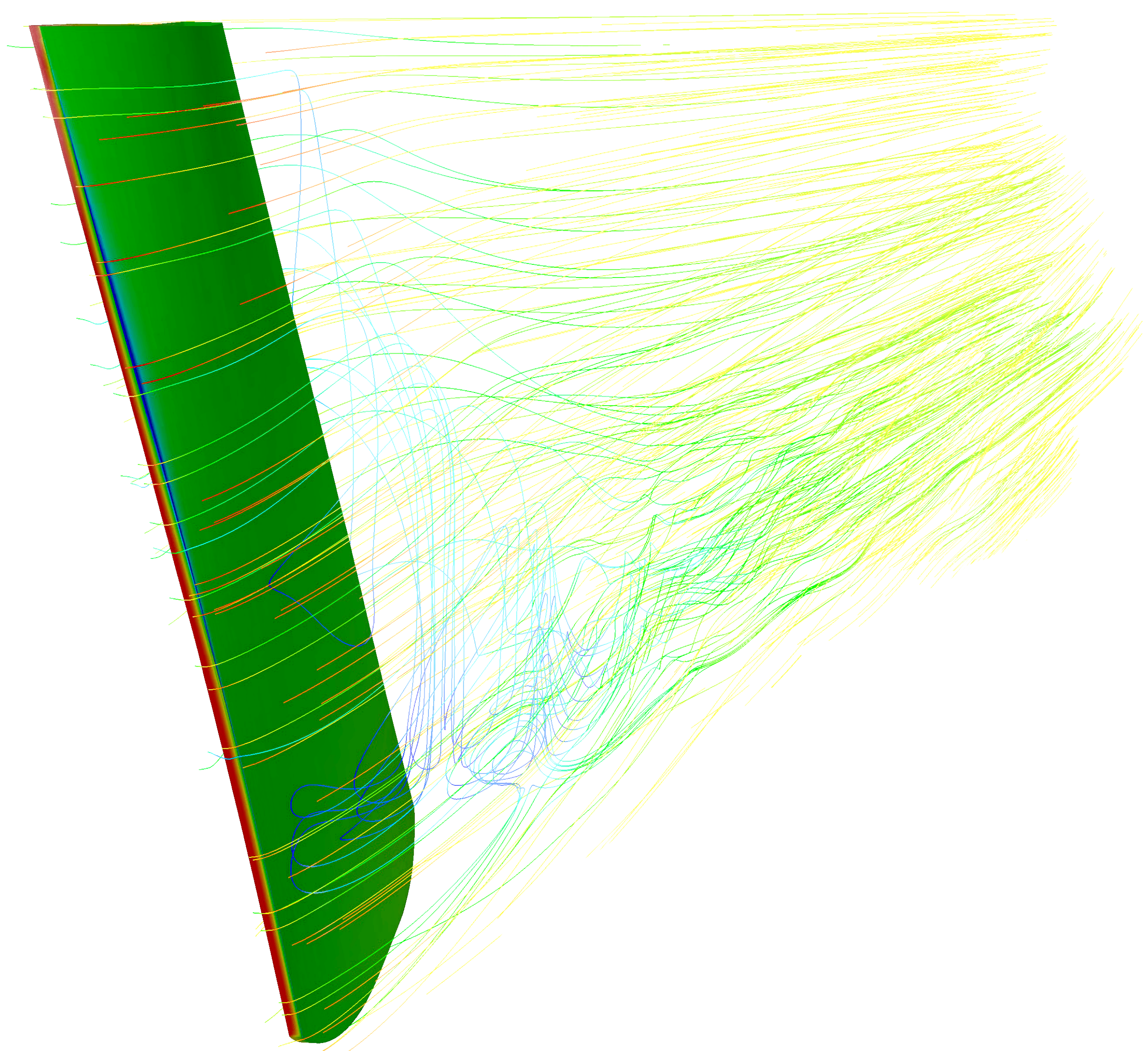

Figure 3: Streamlines at Re=1000. The rudder has a rake angle β=25 and the incoming flow has an angle of attack α=-10 degrees.

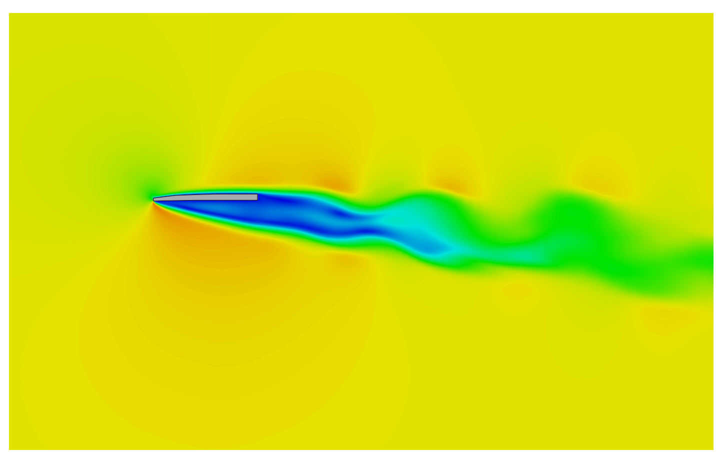

Figure 4: The instantaneous velocity field at t=30 U/c at Reynolds nr 1000. U=inflow velocity, c=average cord length

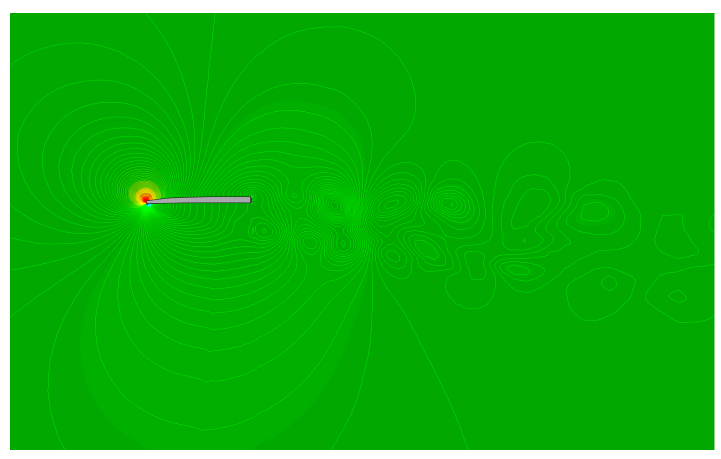

Figure 5: Pressure contours at Re=1000, rake angle β=25 and incoming flow angle of attack α=-10 degrees.