

Introduction

To design our constructions the best inspiration comes often from the nature itself. The evolution has permitted some animals to become very efficient, using as less as possible energy with very high speed for instance. During the thesis a literature study was performed to investigate the state of the art knowledge about fish swimming and a study was done on a static NACA0012 foil which gave satisfying results compared to the literature. The final study uses the NACA0012 foil to simulate the motion of a subcarangiform swimmer in order to observe the formation of reversed Karman vortex street.

Method

Openfoam was used to investigate the fish-like locomotion. The first stage was to simulate a static NACA0012 foil in a free flow and calculate the forces acting on the foil and compare them to the literature in order to validate the model in Openfoam. The method used in Openfoam is overset grid, one grid works as a background grid whereas a body-fitted grid was made in ICEM for the foil. The final study has the objective to make the foil heave and pitch to imitate the swimming of a subcarangiform fish in order to find out which parameters of swimming give reversed Karman vortex street and thus thrust.

Conclusion

The simulation of a static NACA0012 foil has shown good results with use of an overset grid composed of two grids. A convergence study was conducted to choose the best grid for the simulation of a fish-like motion. The final results are not yet available but the first test simulation of a subcarangiform motion seems to show a Karman street vortex. The integration of the forces at the outlet should prove if thrust or drag is created with these conditions. Other simulations will be done to find out which parameters give thrust or drag. These investigations could be used for instance for underwater robots using a fish-like locomotion. Further work should also be done with a flexible body in order to be as like as possible a fish.

References

[1] Streitlien K. Barrett D. Triantafyllou M. Anderson, J. Oscillating foils of high propulsive efficiency. *Journal of Fluid Mechanics*, 360:41–72, 1997.

[2] Dimitrios Koubogiannis Nikolaos Lampropoulos and Kostas Belibassakis. Numerical simulation of flapping foil propulsion. 2016.

[3] Christophe Eloy. Optimal strouhal number for swimming animals. *Journal of Fluids and Structures*, 30:205–218, 2012.

[4] Dilek Funda Kurtulus. On the unsteady behavior of the flow around naca 0012 airfoil with steady external conditions at re=1000. *International journal of micro air vehicles*, Volume: 7 issue: 3:301–326, 2015.

Acknowledgements

I would like to thank my supervisor Professor Marilena Greco and my co-supervisor, Adjunct Professor Claudio Lugni for their advices during this semester and Phd-students Hui-li Xu and Mohd Atif Sidiqqi for their precious help.

Parameters for the fish-like motion

Parameters	Value
ω	25 rad s ⁻¹
y_0	0.75 m
ψ	1.57 rad
θ_0	0.82 rad

Table 1: Parameters of a subcarangiform swimmer [3]
[1]

To make the foil imitate the motion of a subcarangiform fish the equation for the rigid body motion with the foil is divided into an equation representing the heaving and an equation for the pitch. [2] [1]

Heaving is described by

$$y(t) = y_0 \sin(\omega t) \tag{1}$$

Pitching is described by:

$$\theta(t) = \theta_0 \sin(\omega t + \psi) \tag{2}$$

ω represents the angular frequency here equal to 4, y_0 the heaving amplitude, θ_0 the amplitude and ψ the phase lag between pitching and heaving.

Preliminary results

Figure 1 left shows the NACA0012 foil at AOA = 15° and Re = 1000 in Paraview after having simulated it in Openfoam. The pressure coefficient was then plotted and compared against results from [4] and Bardazzi, Lugni (personal communication). The Cp can be seen in figure 1 right. The pressure coefficient corresponds well to the literature results.

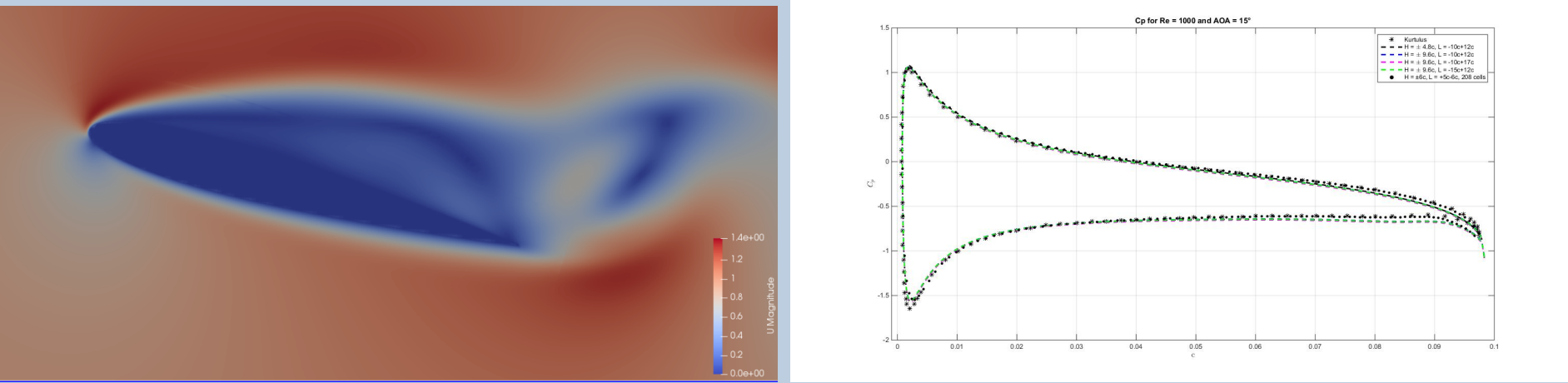


Figure 1: Figure caption 1 (left); Figure caption 2 (right)

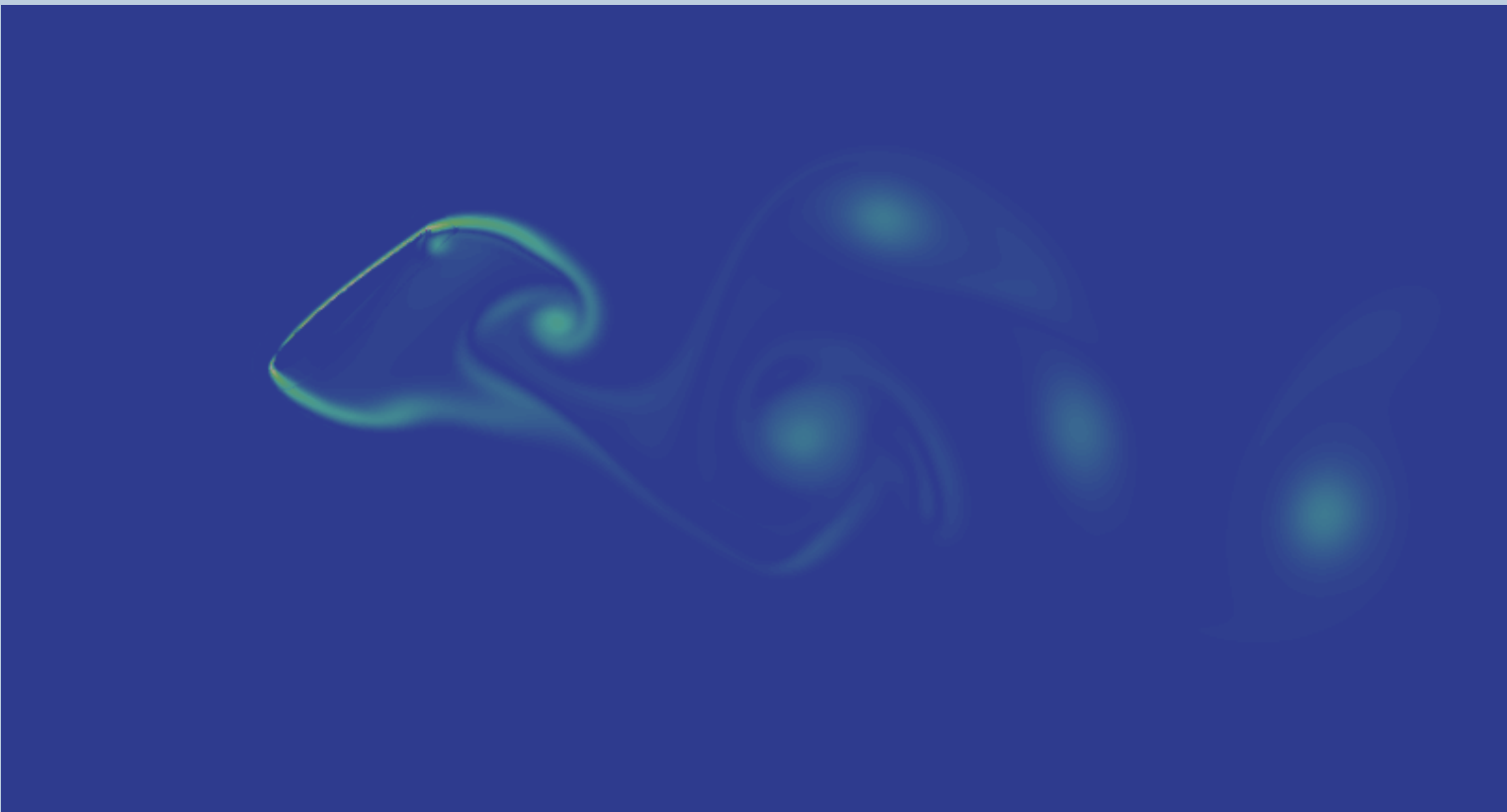


Figure 2: Vorticity

Figure 2 shows a snapshot of the simulation of the motion of the foil. The simulation is currently still under analysis but from figure 2 it seems that the motion produces a Karman vortex street which means drag. To verify if the motion is producing thrust or drag, mass conservation can be calculated using the following formula:

$$T = \rho \int_a^b u(y)(u(y) - U)dy \tag{3}$$

Where U represents the inlet velocity and $u(y)$ the velocity along the outlet. Positive T means thrust, negative means drag.