Advanced Computation in Fluid Mechanics Project

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Unicorn provides a G2 solver for the incompressible Navier-Stokes equations. Use Unicorn to solve problems 1-5 below, to be presented in a report of 5 pages, one page per problem. The solution of each problem should be presented using a mix of plots from the computations, together with text explaining the results. The report should be submitted individually (even if the computations are carried out in a group) by each student as one single pdf-file.

Problem 1: Use Unicorn to compute the drag coefficient c_D for a cylinder in a uniform velocity field, with

$$c_D = \frac{F_D}{\rho \frac{1}{2} U_\infty^2 A} \tag{1}$$

where F_D is the drag force (saved in file `drag_file.m`), A is the area of the cross-section of the cylinder (length times diameter), and U_∞ is the inflow velocity. Starting from the initial mesh `mesh.xml`, refine the mesh using adaptive mesh refinement with respect to the error in drag. Comment on the results. Can you get close to the experimental value of $c_D \approx 1.0$? Use an inflow velocity $U_\infty = 1$, and set the viscosity so that the Reynolds number $Re = UD/\nu$ based on D the diameter of the cylinder is $Re = 10^4$. To simulate a no slip boundary condition choose the boundary friction parameter large ($\beta = 1$).

Problem 2: Describe the velocity field and the pressure, separation and turbulent wake, as you refine the mesh. How is it changing? Also, test different viscosities (Reynolds numbers), how does the results change?

Problem 3: Consider the dual solution. Describe the dual solution, where is it large/small, can you motivate why?

We now study flow separation with respect to different boundary conditions.

Problem 4: Use Unicorn to compute the flow past the cylinder using skin friction boundary conditions, for friction parameters $\beta = 0.1, 0.01, 0.001, 0$. Describe the dependence of separation on the friction parameter. Use the finest mesh from Problem 3, and set $\nu = 0$.

For $\beta = 0$ we have a pure slip boundary condition without any friction. Use this model to simulate the flow past a NACA wing profile at take-off by increasing the angle of the incoming velocity. Set $\nu = 0$.

> **Problem 5**: Use Unicorn to compute the flow past a NACA airfoil `mesh-naca0012.xml` under increasing angle of attack $\alpha = (0, 30°)$. Compute lift and drag as a function of α, comment on the result.