ACFD 2019 Project 4 discussion

Task 1

See reference solutions (which adopted Option 1) for detail. The simulation of the oscillation is somewhat sensitive to the setup of time step size and mesh resolution. The reference solutions represent the range of the most robust results. The amplitude of oscillation is the highest for the case with an ellipse elongated in y-direction, followed by the case with a circular cylinder. The case with an ellipse elongated in x-direction has the smallest amplitude. The order of the period is the opposite; The case with y-elongated ellipse has the longest period. This is consistent with the video we showed in class. For the two cases with elliptic cylinders, under some settings the temporal behavior could become quasi-periodic (i.e., the time series has more than one periods).

Task 2

The two contour plots should reflect the setup of the parabolic profile of velocity at inlet. The drag force increases monotonically with the tilt angle. The behavior of the lift force is more subtle. It peaks at θ = 30°, then decreases with a further increase of θ. The drop of lift for the θ = 45° case resembles the situation of "stalling".

Depending on the detail of initialization, it can take a significant number of iterations for the value of lift or drag to reach a steady level (or a level with steady running average). Too few iterations could lead to a significant error.

Task 3

As is typical for a flow over an obstacle, we see high pressure on the upstream side of the building and a "wind shadow" of low velocity (even reverse flow) on the downstream side of the building. There is also notable acceleration over the rooftop above the leading edge (facing the incoming flow) of the building.

The total drag (that the fluid exerts on the building) is higher for the case in Task 3(b). The reference solutions represent the range of most robust results for the drag and its two components. In both systems in Task 3(a) and 3(b), pressure term overwhelms viscous term in their contribution to the total drag. As explained in class, the balance in the momentum equation for a steady flow (or a general flow after some time averaging) can be written as

0 = (inertial term) + (pressure gradient force) + (viscous term) .

For an incompressible flow, PGF balances with the greater of the inertial and viscous terms. As Reynolds number represents the ratio of (inertial term)/(viscous term), the primary balance is (inertial term) $\approx$ PGF for a high Reynolds number flow, and PGF $\approx$ (viscous term) for a low Reynolds number flow. Also recall that the "pressure" and "viscous" components of the drag come from the integrals of the PGF and viscous terms, respectively. At high Reynolds number (as is the case for the systems in Task 3), since PGF $\approx$ (inertial term) >> (viscous term), we have PGF >> (viscous term), thus the pressure component overwhelms viscous component of the drag.

Task 4

See some examples in reference solutions.