ACFD 2020 Project 3 discussion

Task 1

The amplitude and period of oscillation are slightly sensitive to 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 experiments in the video shown in class.

For the case with x-elongated ellipse, some students find a quasi-periodic behavior in their simulation; The amplitude of oscillation varies instead of holding constant. (This is acceptable if the overall amplitude remains the smallest, and period the shortest, of the 3 cases.) This behavior is likely transient. If the simulation is extended beyond 3 minutes, eventually the oscillation will become more "regular" with a uniform amplitude.

Task 2

The contour plots of velocity should demonstrate a correct setup of the parabolic profile of velocity at the inlet. The drag force increases monotonically with the tilt angle. (A major factor is that the cross-sectional area increases tilt angle.) The behavior of the lift force is more subtle. It increases from $\theta = 0°$ to $\theta = 20°$, then decreases as θ is further increased to 40°. At a large tilt angle, the case begins to resemble the situation of "stalling".

The 500K limit on the number of elements does not allow us to thoroughly push for grid convergence. Using approximately 500K elements to cover the 3-D domain, the values of lift and drag can still vary slightly depending on the detail of mesh. The reference solutions represent the range of robust results under the constraint of element number.

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. The total drag is higher for the case in Task 3(b). This is likely because the cross-sectional area of the "front" of building (that directly blocks the impending flow) is larger in Case (b).

The values of total drag and its two components vary with the detail of mesh. The reference solutions represent the range of robust results. 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. When Reynolds number is much greater than 1 (as is the case for the system 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.