MAE560/460 Applied CFD, Fall 2020, Project 1 discussion

Task 1

See reference solutions for detailed contour plots and line plots. The contour plots and outlet temperature given in the solutions are robust (see statistics below). An extreme outlier with respect to those solutions is an indication of possible errors in the setup.

With a stronger gravity in Task 1a, the “cool waterfall” drops much sooner (closer to the left wall) compared to its counterpart in Task 1b. From the statistics of all submissions, the outlet temperature for Task 1a is concentrated in 298°K ± 0.5°K, and that for Task 1b is shifted about 1.7°K lower.

Task 1a

Outlet temperature, in °K, # of answers from the class

< 297.0 * 1
297.0-297.4 **** 4
297.4-297.8 ************************ 24
297.8-298.2 ************************************** 38
298.2-298.6 ******** 8
298.6-299.0 ***** 5
> 299.0 **** 4

Task 1b

Outlet temperature, # of answers from the class

< 295.6 * 1
295.6-296.0 ******** 8
296.0-296.4 *** 43
296.4-296.8 ****************** 18
296.8-297.2 ********* 9
> 297.2 **** 4

Except for the expected initial fluctuation, the line plot of outlet temperature vs. # of iteration should generally be smooth for Task 1a. (An isolated slight jump or transient fluctuation may occur in the middle of the iterative process, for example see Reference solution #3.) For Task 1b, the plot also exhibits this smooth structure for the majority of submissions. Nevertheless, in about a quarter of submissions the curve exhibits a slight but persistent oscillation. It is possible that this case is located close to the boundary of “steady” and “oscillatory” flow regimes, and the detail in the setup (for example, mesh resolution) influences which way the numerical solution asymptotes to. We did not foresee this situation when designing the task, as the simulations performed by instructor did not exhibit the oscillatory behavior. In grading Task 1b, the requirement on the convergence criterion was slightly relaxed, and most of the solutions with the oscillation (as long as it is not too strong) still receive full credit.

Task 2

Reference solution #2 includes a back-of-the-envelope calculation of heat budget with some idealization as discussed in class. The values of ΔT obtained show the same trend as those from numerical simulation using Ansys Fluent. Namely, both show that ΔT is approximately proportional to 1/u where u is the inlet velocity.

Task 3

For this task, a reasonable choice of time step size is somewhere in the neighborhood of 0.1 s (for example, 0.125s, 0.1s, 0.05s). In general, with a decreasing time step size, the outlet velocity at t = 5s increases, then saturates at around 0.025 m/s. This also depends on mesh resolution, and the number of iterations per time step. For this task, we apply a relatively loose standard that a wide range of values (of outlet velocity at 5s), from 0.005 – 0.03 m/s, are accepted. With a very small time step size, the outlet velocity begins to exhibit oscillatory behavior, although the maximum is still capped at around 0.035 m/s. Full credit is still given for those results (although there is no clear physical justification that the oscillation is real). See previous lectures for more discussions on the subtlety of choosing an appropriate time step size.

In a few submissions, the outlet velocity at t = 5s is extremely small (for example, less than 0.003 m/s). This is very likely because the time step size is too large. In that case, a minor deduction is assessed on it.

In deliverable (iii), the fractional variation of density for Task 3 is in the range of 13-14 %. For Task 1, given the thermal expansion coefficient as β = 0.000366 (1/°K), the fractional variation of density is essentially $\beta*(T_{max} - T_{min}) = \beta*(55 - 20) = 1.28\%$. This is smaller than its counterpart in Task 3 but not negligible.

Task 4

The result from the simulation using the “quarter geometry” is generally close to that obtained by using the full system. Due to various overheads, it is not easy (or expected) to fully reduce the computational time to a quarter. Nevertheless, the reduction of computational cost is very significant in this case.