1 Problem Statement

Outline the problem statement (5), the mathematical model (5), and the computational model parameters (5). In your report, provide the geometry of the simulation domain, governing equations, and mathematical formulation of boundary and initial conditions. In computational model section, present the mesh of the simulation domain (only one mesh out of five), the values of boundary and initial conditions, convergence criteria is set for RMS of momentum at 10^{-5}*, provide the name and order of the scheme used for convective term discretization (should be second order accurate). Use the coupled solver. In a table, list all the models that you selected in "Methods" tab of the software, as well as the details of the solver under "General".*

1.1 Objective

The problem objective is to calculate the drag coefficient C_d of a square object at a Reynolds number of 20 and estimate the length of a vortex that forms behind the object.

Secondary objectives include learning about mesh refinement and mesh convergence. The problem will be solved numerically in ANSYS Fluent for five systematically refined meshes. The first (coarsest) mesh should contain in the order of 2000-3000 cells or control volumes with a cell size of 5.0 mm. The rest of the meshes are generated by reducing the size of each cell by two in both directions, i.e. increasing the total number of cells by four. The topology of the mesh remains the same as the mesh is refined. During the simulation, it is necessary to monitor the drag force F_d as a function of iteration.

1.2 Mathematical Model

put NS in here put BC in here put IC in here

1.3 Computational Model Parameters

First U_∞ needs to be determined. The Reynolds number is given from the problem statement as $Re = 20$. Then,

$$\begin{aligned} \mathrm{Re} &= \frac{U_\infty \rho D}{\mu} \\ \implies U_\infty &= \frac{\mathrm{Re}\mu}{\rho D} \end{aligned}$$

The properties of air are given as $\rho = 1.0$ kg/m^3 and $\mu = 2.0 \times 10^{-5}$ kg/m·s. The side length of the square object is $D = 0.01$ m. Thus,

$$U_\infty = \frac{20 \times 2.0 \times 10^{-5}}{1.0 \times 0.01} = 0.04 \text{ m/s}$$

The mesh element size will be 5.0 mm for the first mesh. The mesh will be refined by reducing the mesh element size by 2, resulting in a total of 4 times the number of cells. The mesh will be refined 5 times. The convergence criteria is set for the RMS of momentum at 10^{-5}. The scheme used for convective term discretization is second order accurate. The coupled solver will be used.

5 inflation layers, growth rate of 1.2, default transition ratio 0.272

use viscous laminar model

describe the BC i guess idk what they want

Table 1: General Solver Details

Type	Pressure Based
Velocity Formation	Absolute
Time	Steady
2D Space	Planar

method: coupled Gradient: least squares cell based Pressure: Second order Momentum: Second order upwind

start point (0.001, 0.005) end point (0.20005, 0.005) max iterations 1000

mesh 1: 2390 elements mesh 2: element size 0.0025, 9390 elements mesh 3: element size 0.00125, 37870 elements mesh 4: element size 0.000625, 152044 elements mesh 5: element size 0.0003125, 613378 elements

2

Approximate the convective term of the obtained equation using the upwind scheme. For upwind scheme with east as positive flow direction,

$$\hat{T}_w = \hat{T}_W$$
$$\hat{T}_e = \hat{T}_P$$

Then, the convective term becomes,

$$\begin{aligned}\text{Convective} &= \hat{T}_e - \hat{T}_w \\ &= \boxed{\hat{T}_P - \hat{T}_W}\end{aligned}$$

3

Approximate the diffusive term of the equation using the central difference scheme.

For central difference scheme,

$$\left[\frac{d\hat{T}}{dx}\right]_e = \frac{\hat{T}_E - \hat{T}_P}{\Delta x}$$
$$\left[\frac{d\hat{T}}{dx}\right]_w = \frac{\hat{T}_P - \hat{T}_W}{\Delta x}$$

Then, the diffusive term becomes,

$$\begin{aligned}
\text{Diffusive} &= \frac{1}{\text{Pe}}\left[\frac{d\hat{T}}{dx}\right]_e - \frac{1}{\text{Pe}}\left[\frac{d\hat{T}}{dx}\right]_w \\
&= \frac{1}{\text{Pe}}\left(\frac{\hat{T}_E - \hat{T}_P}{\Delta x}\right) - \frac{1}{\text{Pe}}\left(\frac{\hat{T}_P - \hat{T}_W}{\Delta x}\right) \\
&= \boxed{\frac{1}{\text{Pe}}\left(\frac{\hat{T}_E - 2\hat{T}_P + \hat{T}_W}{\Delta x}\right)}
\end{aligned}$$