8th Assignment – Simulation of the flow around a square cylinder using the Finite Elements Method

The objective of this simulation is to verify the Strouhal number of the laminar flow around a square-section body of side h. The body is located at the position (0,0) within a rectangular domain that extends in the x direction between -10h and 20h, and in the y direction between -10h and 10h (Fig. 1). The Reynolds number of the flow is $Re_h$=200.

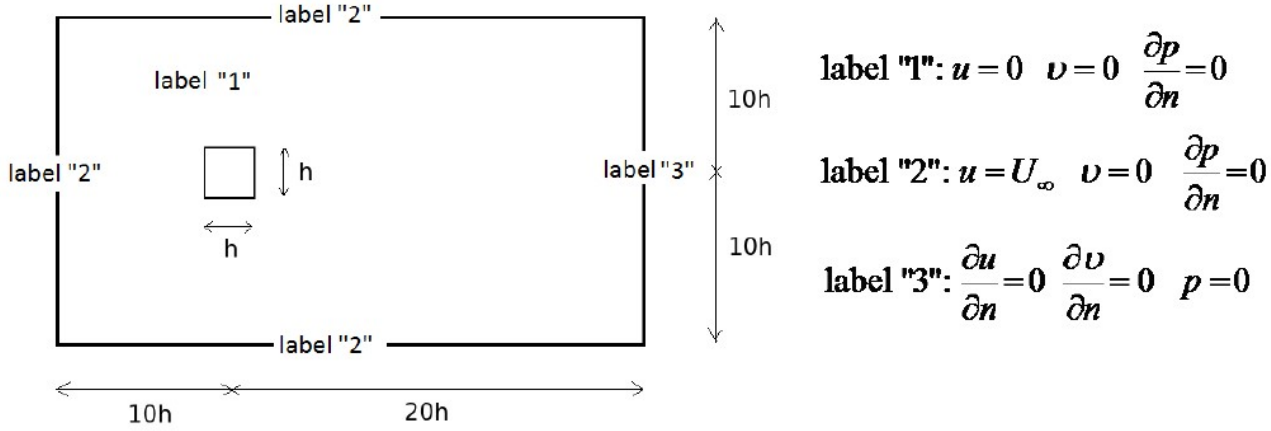


Fig. 1) Flow domain and boundary conditions.

To do so, you must download the file "bluffBody.edp" from the course website and replace the a0 edge, which defines the wall of a circular cylinder, by the four edges which will define the wall of the square cylinder. These four new edges will be labeled “1” as can be seen in Figure 1.

When running the program, the transient flow will be solved over Ndt=4000 time steps, with a time step dt=0.025. Drag and lift forces will be recorded in the “forces.dat” file, which is a text file with three columns. The first column indicates the time, the second column indicates the drag coefficient of and the third column indicates the lift coefficient. This file can be imported into excel and allows plotting the coefficients over time. The time history of the lift force allows you to calculate the Strouhal number, which for $Re_h$=200 must be around $St$=0.15-0.16. The mean drag coefficient is $C_{D_{mean}}$ =1.45 – 1.60 for $Re_h$ = 200.

You should carry out four simulations: (a) using 16 elements along each side h of the object, with P2 elements for velocity and P1 elements for pressure; (b) using 8 elements along each side h of the object, P2 elements for velocity and P1 elements for pressure; (c) using 4 elements along each side h of the object, P2 elements for velocity and P1 elements for pressure; and (d) using 4 elements along each side h of the object, P3 elements for velocity and P2 elements for pressure. Compare your results for $St$ and $C_{D_{mean}}$ with the values given above. Write a short report in .pdf explaining the changes made to the “bluffBody.edp” file and presenting the results and conclusions obtained from the simulations.

Check that the flow reaches a regime where the amplitude and frequency of the lift force are constant. Eventually it may be necessary to increase the number of time steps.

Eventually, it may be that the time step used in the simulation of the flow around a circular cylinder, dt=0.025, proves to be too high for the simulation of the square cylinder. If stability problems occur, the time step should be reduced.

After installing FreeFem++ on Windows, to run the program just open a prompt, go to the directory where the .edp file is located and type “FreeFem++” at the prompt followed by a blank space and the filename (eg “FreeFem++ bluffBody.edp”).

The .edp file can be edited with notepad, wordpad or other similar program like notepad++. To plot the figures in .eps format, you can use the eps Viewer (download from epsviewer.org).