Numerical Methods in Thermo-Fluid Dynamics II

Summer Semester 2023

DELIVERABLE TASK I:

Numerical Investigations on flow over a circular cylinder

Hand in: Monday, 24/04/2023
Deadline: Monday 22/05/2023

Chair of Fluid Mechanics

Department of Chemical and Bio Engineering,
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The Deliverable Task I should contain the case folder of OpenFOAM and a written report describing the following results primarily for Reynolds number **Re = 3900: (unless stated otherwise)**

Based on Re, design case studies and identify domain size and distances to inlet, outlet from the cylinder wall as discussed in **NMTFD-1**. Generate appropriate grids for the problem based on blockMesh, snappyHexMesh or import .msh files with appropriate sizing and refinements. Comment on the meshing and refinement strategy. *(Hint: Refine after cylinder or Adaptive Mesh Refinement to capture vortex streets accurately)*

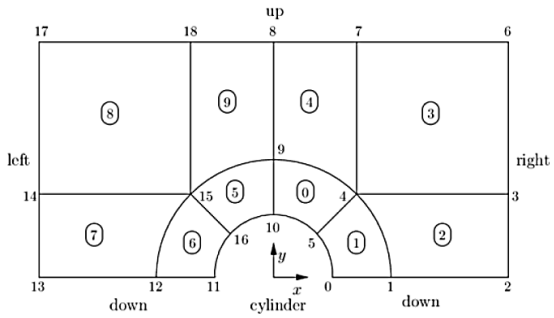

Figure 1Example of Block Mesh Setup in OpenFOAM

Comment on the boundary and initial conditions used to run the simulations at different walls, inlet, outlet and domain. Explain the modelling approach used to model the flow (Hint: RANS, LES etc)

Grid convergence study (GCI)/ Mesh Independence Study: Consider a reasonable output (eg: drag averaged over iterations, recirculation length) as determining factor for GCI.

- In a single figure, plot number of grid points/mesh count vs. property of interest to show its convergent behaviour. Based on the plot, comment on the mesh to be chosen to run further investigations.
- Using the **checkMesh** command identify the mesh quality and report key parameters like skewness, cell quality and orthogonality. Comment on the ideal requirements for a good quality mesh.

pimpleFoam: Using the mesh chosen above, adjust the relaxation factor of pressure and velocities to improve convergence and induce stability.

- Generate a table regarding the number of outer iterations vs different relaxation factor pairs. The case folder with the optimal relaxation factor should be submitted. (Test a maximum of 3-4 pairs)

- Check for optimal Courant number as discussed in NMTFD 1 and comment.

What is **vortex shedding** and how does it occur?
Comment on impact of flow at various Reynolds number (Re) vs flow characteristics. (Hint: Creeping flows, Stable vortices, Laminar Vortex Street (Von Karman Street), Transitions and Turbulent vortex street)

Simulate 3 different Reynolds numbers {3900,x,y} scenarios with different flow characteristics.

For Re = 3900 and two other Reynolds Number chosen, plot the following reports and graphs. Comment briefly on their significance:

- Velocity contour plot on the complete domain (midplane slices).
- Velocity vectors on the complete domain.
- Velocity component in x (u) and corresponding y-component (v) along the centerline behind the cylinder and give explanation.
- Velocity(instantaneous) streamline for the complete domain.
- Wall shear stress (τ_w) along the cylinder wall.
- Pressure coefficient $C_p = \frac{1}{2}\frac{(P-P_\infty)}{\rho U_\infty^2}$ along the cylinder wall.
- Friction coefficient $C_p = \frac{1}{2}\frac{(\tau_w)}{\rho U_\infty^2}$ along the cylinder wall.
- Lift coefficient $C_l = \frac{1}{2}\frac{(F_l)}{\rho A U_\infty^2}$
- Drag coefficient $C_d = \frac{1}{2}\frac{(F_d)}{\rho A U_\infty^2}$

RANS approach to be used with preferably k-epsilon model before moving to LES.

Submit a well drafted scientific report in a .zip/.rar file with the openFOAM case setup (without solution files) via email before the above specified and agreed upon deadline to suharto.saha@fau.de