LPT Case 02

Physical situation

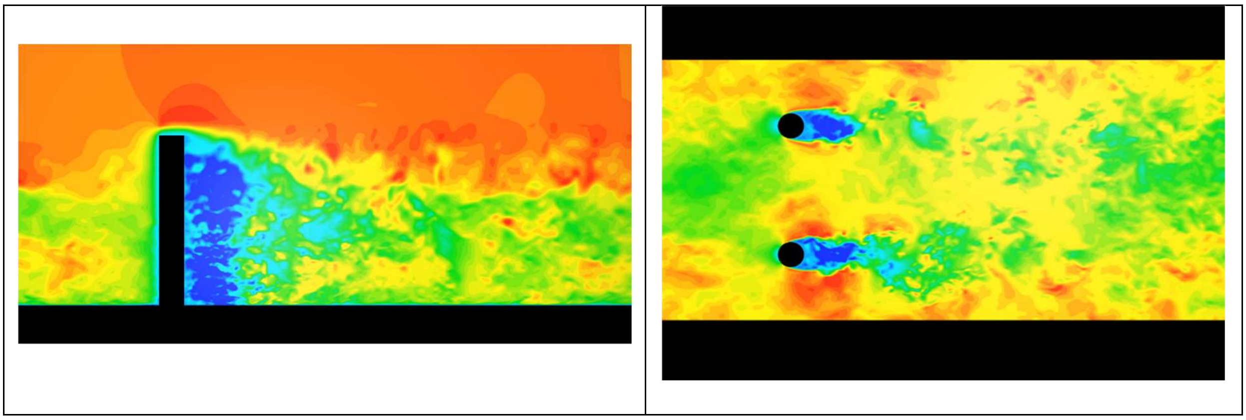

Figure 1 – Axial velocity snapshots of the flow (left: vertical plane passing through one of the cylinders centre, right: horizontal plane at 20 mm from the lower wall)

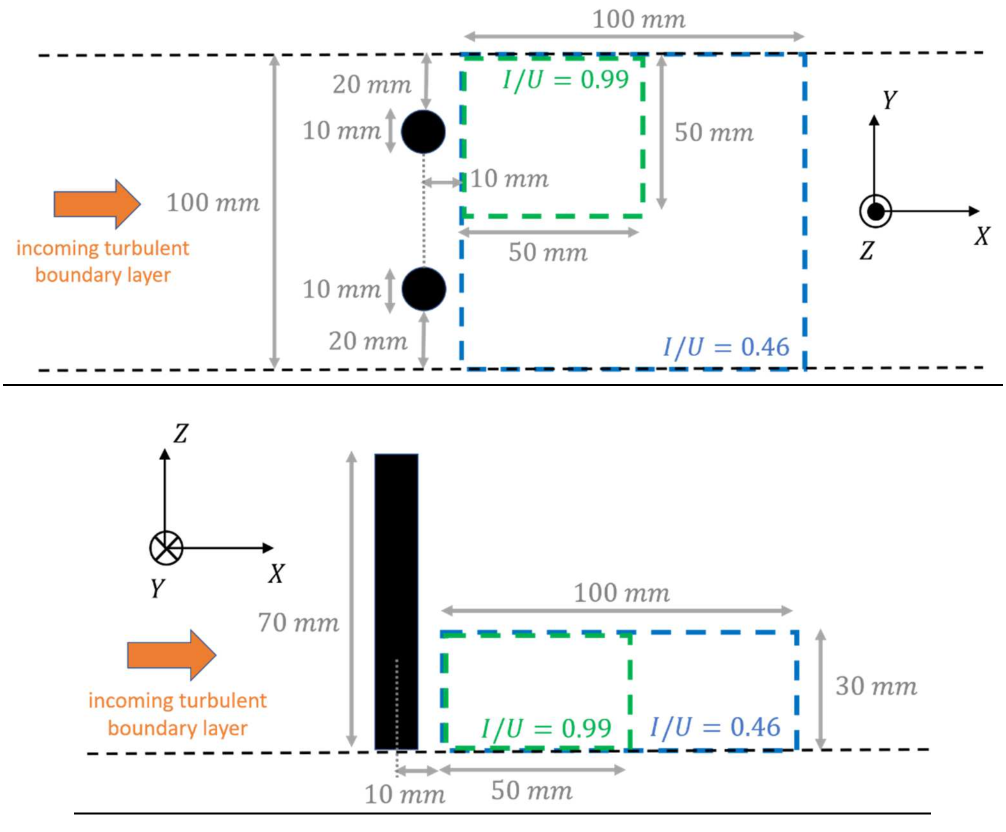

Figure 2 – Schematics of the physical situation. Top: view from above, bottom: lateral view.

The physical situation is that of the wake caused by two cylindrical pillars placed in a turbulent boundary layer. The flow medium is air, and its bulk velocity outside the boundary layer is equal to $10\ m.s^{-1}$. At the streamwise position of the cylinders, the boundary layer is approximately $60\ mm$ thick, with a momentum Reynolds thickness $Re_{\theta} \approx 4{,}150$. Numerical simulation is performed using Monotone Integrated LES, wherein embedded propagation of virtual particles, hypothesized as fully passive tracers, is included.

Axes X, Y and Z respectively correspond to the streamwise, spanwise and wall-normal directions (see Figure 2). Simulation is performed over an extension of $100\ mm$ in Y, with spanwise periodic boundary conditions. Cylinders have a diameter of $10\ mm$ and their centres are located $25\ mm$ from the simulation spanwise edges. For the challenge, different domains of $30\ mm$ thickness (Z direction), starting $10\ mm$ downstream from the cylinder centres, have been selected.

The optical setup consists of four virtual cameras which view these domains mainly from above (Z direction), onto the XY plane. They are located at the base of a square pyramid, at a height of around $0.45\ m$ (Z direction). Edges of this base are along the X and Y axes and the edge size is equal to $0.6\ m$. All cameras have a 2048×2048 sensor with $10\ \mu m$ pixel pitch, and are equipped with an $f = 200\ mm$ lens.

Among the varying parameters in this case is the ratio I/U between the volume of the *intersection* of the cameras' fields of view (denoted by I) and of their *union* (denoted by U). Value of this parameter determines whether all of the illuminated domain (and particles) are viewed by all cameras ($I/U = 1$), or if parts of the domain/particles are viewed only by a subset of them ($I/U < 1$). As depicted in Figure 2, the domain extensions in X and Y directions change depending on the I/U value: the domain is largest for $I/U = 0.46$, and smallest for $I/U = 0.99$, which are respectively the smallest and largest values for the I/U parameters in the dataset. The origin O of the coordinate system changes accordingly, as it is always supposed to be located at the centre of the domain in the X and Y directions, and at the wall (Z direction). As the camera system also adapts to the different domains, i.e. always has the same location relatively to the origin O, this allows to consider the same calibration for all cases. Note also that, in order to obtain the desired I/U values, illumination had to be cut artificially in both the X and Y directions (for all $I/U > 0.46$). In a sense, this amounts to using a slab for cutting in X, and to consider wind-tunnels of different spans for cutting in Y.

Camera calibration

Camera calibration can be performed by using the ASCII file LPT_CASE02_CalibPoints.txt. Each line of this file contains the coordinate of a point in the domain together with its projection on the four cameras:

$X\ Y\ Z\ x1\ y1\ x2\ y2\ x3\ y3\ x4\ z4$

where (X, Y, Z) are the point coordinates in units of mm and (xi, yi) the coordinates of its projection on camera i in units of pixel. Pixel position $(0,0)$ corresponds to the centre of the pixel located at the top left corner of an image.

Cases and images

This test case contains both two-pulse (TP) and time-resolved (TR) image sequences. The inter-frame time is fixed at $40\ \mu s$. A constant particle image size (PSF/OTF) is used, and some typical camera noise is added on the images. Parameters explored are the seeding density, the I/U value and Mie scattering ($Mie = 1$ if accounted for, $Mie = 0$ if not). Note that Mie scattering coefficients correspond in fact to different observation angles than that of the present setup. Indeed, the current setup would either lead to having a pair of cameras in forward scattering and the second in backward scattering, which is a situation that one would seek to avoid in practice (case of light in the X or Y direction), or to having all cameras with the same scattering conditions (case of light in the Z direction). Instead, equivalent camera positions have been picked corresponding to different angles in the forward scattering domain (close to 30° and 45° relative to incident light).

For both acquisition types TP and TR, the parameter sweep is the same:

- $I/U = 0.99$, $Mie = 0$: variation of seeding density: $0.025, 0.05, 0.08, 0.12, 0.16, 0.20$ and 0.25 particles per pixel (ppp)
- 0.08 ppp, $Mie = 0$: exploration in I/U, with values $0.46, 0.59, 0.72, 0.85$ (and 0.99, included within the ppp variation)
- Influence of Mie scattering at 0.08 ppp: cases with $Mie = 1$ at $I/U = 0.99$ and 0.46 (to be compared with the same with $Mie = 0$)

Images are named in the following format:

LPT_CASE02_YY_ppp_0_AAA_IU_BBB_Mie_D_IEEEE_C.tif, with:

YY: acquisition strategy (TR or TP)

AAA: fractional ppp value

BBB: value of I/U multiplied by 100

D: Mie accounted for (D=1) or not (D=0)

EEEE: snapshot number, starting from 0000

C: camera number, from 0 to 3.

In the TR case, sequences contain 50 images for ppp ≤ 0.16, and 100 images for ppp ≥ 0.2.

Note that for participation to this case to be valid, whatever the acquisition strategy chosen (TP or TR), submission of all cases corresponding to ppp ≤ 0.12 (including those with varying I/U and with Mie scattering) is mandatory. Submitting higher densities as well is of course encouraged.

Requested output and file format

For TP, the single computed flow field needs to be supplied for each processed seeding density in the following format:

ASCII-file with first line

X0 Y0 Z0 X1 Y1 Z1

followed by one line for each particle with the two measured particle positions $X0, Y0, Z0$ and $X1, Y1, Z1$ in mm for time steps $t0$ and $t1$.

For TR, the tracked particles for time step 25 (images ‘_I0024’, ppp ≤ 0.16) or 50 (images ‘_I0049’, ppp ≥ 0.2) need to be supplied for each processed seeding density in the following format:

ASCII-file with first line

X Y Z Xfit Yfit Zfit VX VY VZ AX AY AZ

followed by one line for each particle track with raw position X, Y, Z in mm, fitted position (i.e. associated to the estimation of velocity and acceleration) Xfit, Yfit, Zfit in mm, the velocity VX, VY, VZ in m/s, and the acceleration AX, AY, AZ in m/s^2, all calculated at time step 25 or 50 depending on the seeding density of the case. In their accompanying description, participants should describe how fitted position, as well as velocity and acceleration, are computed.

Naming of the files should follow the convention (applies to both TP and TR):

ZZZZ_LPT_CASE02_YY_ppp_0_AAA_IU_BBB_Mie_D_PartFieldNN.zip, with:

ZZZZ: participant identification name (free number of characters)

YY: acquisition strategy (TR or TP)

AAA: fractional ppp value

BBB: value of I/U multiplied by 100

D: Mie accounted for (D=1) or not (D=0)

NN: time-step index (24 or 49 depending on ppp for TR, 00 for TP).

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