

LPT and DA CASE 01

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1. Physical situation

This test case considers the square duct DNS simulations of Pirozzoli et al. (2018), to study a fully developed turbulent flow. Figure 1 illustrates the simulation results, conducted at a bulk Reynolds number of $Re_b = \frac{2hu_b}{\nu} = 40,000$ and a friction Reynolds number $Re_\tau \approx 1,000$, where h denotes the duct half-width, u_b is the bulk velocity and ν the fluid's kinematic viscosity.

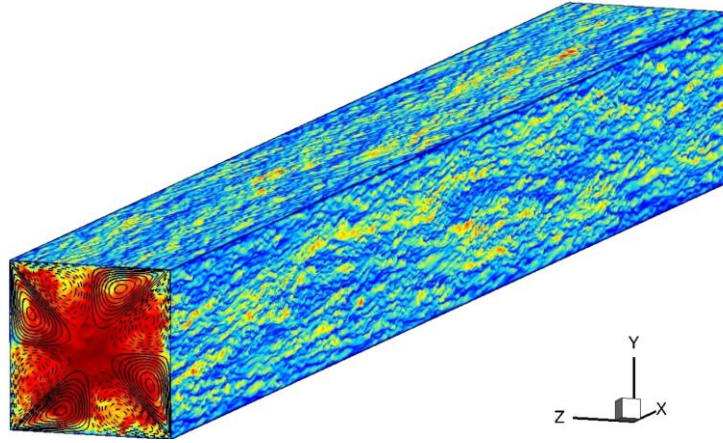


Figure 1: visualization of the square duct flow DNS simulations from Pirozzoli et al. (2018)

For the challenge, a domain of $h \times h \times h$ is considered, where x denotes the streamwise direction, and $y = 0$ and $z = 0$ are the duct walls. A virtual experiment is conducted in water ($\rho = 1000 \frac{\text{Kg}}{\text{m}^3}$, $\nu = 1 \cdot 10^{-6} \text{ m}^2/\text{s}$), with $h = 100 \text{ mm}$ and $u_b = 0.2 \text{ m/s}$. The experimental setup is sketched in Figure 2, including the four-camera arrangement for the LPT challenge.

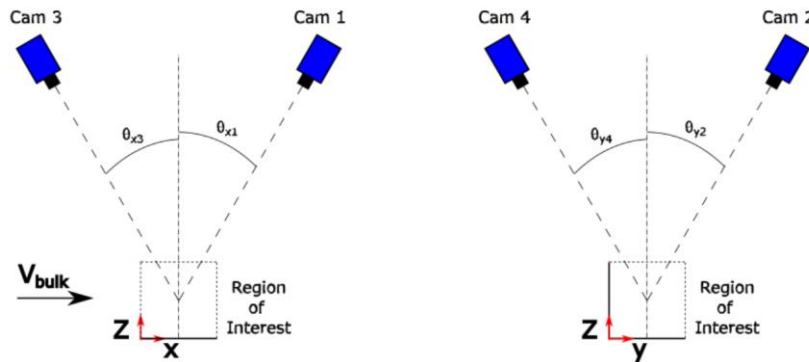


Figure 2: schematic of the measurement region, together with the definition of the coordinate system

This test case is considered for both the DA and LPT challenges independently. A cloud of virtual particles, hypothesized as fully passive tracers, has been propagated within the DNS simulation.

References

Pirozzoli, S., Modesti, D., Orlandi, P., & Grasso, F. (2018). Turbulence and secondary motions in square duct flow. *Journal of Fluid Mechanics*, 840, 631–655. doi:10.1017/jfm.2018.66

2. LPT challenge

This test case of the LPT challenge considers four cameras viewing the fully-illuminated measurement region of 100×100×100 mm. The cameras view the measurement volume mainly from above (z -direction) onto the xy -planes. The cameras (1,024×1,024 pixels, 10 μm pitch) are located at a height of about $z = 1\text{ m}$ with a viewing angle of $\theta = \pm 30^\circ$ relative to the z axis. Equipped with $f = 105\text{ mm}$ objectives and aiming at the centre of the measurement domain, the full volume is not entirely in view by each camera.

Camera calibration

Camera calibration can be performed by downloading the ASCII file [LPT_CASE01_CalibPoints.txt](#). Each line of this file contains the coordinates of a point in the domain together with its projections on the four cameras:

X Y Z x1 y1 x2 y2 x3 y3 x4 y4

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 comprises three different situations, with varying particle displacements in the bulk. The time separation between frames is set to 5.916, 8.283 and 10.649 ms for each case, such that particles at the bulk velocity displace approximately 10, 15 and 20 pixels respectively. For every condition, the seeding density is kept constant at 0.1 ppp. Some typical camera noise is added to the images. A constant particle image size (PSF or OTF) is used. A sequence of 100 frames (starting at frame 0) is provided for each situation, and the images are stored in 16-bit tiff compressed format.

The images are named in the following format:

[LPT_CASE01_TR_dtT_IBBBB_C.tif](#), with:

T: dt value (1, 2 or 3), corresponding to the approximate bulk displacement of 10, 15 and 20 px respectively

BBBB: snapshot number, starting from 0000

C: camera number, from 0 to 3

Requested output and file format

The flow field for time step 49 (from the sequence starting at 0) needs to be supplied for each processed bulk displacement situation 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 .

Naming of the files, after compression into .zip files, should follow:

[ZZZZ_LPT_CASE01_TR_dtT_PartField49.zip](#), with:

ZZZZ: participant identification name, with free number of characters

T: dt value (1, 2 or 3), corresponding to the approximate bulk displacement of 10, 15 and 20 px respectively

3. DA challenge

This test case of the DA challenge consists of the reconstruction of the velocity and pressure fields from scattered positions of particles. Simulated results from time-resolved (TR) acquisitions, four-pulse (FP) recordings and two-pulse (TP) recordings are considered. For each, seeding density is varied over 0.001ppp, 0.01 ppp, 0.05 ppp and 0.2 ppp.

Input files

The particles' positions in 3D space and the particles' IDs are given in ASCII files. The first three columns of the data files correspond to the instantaneous X, Y, Z particle coordinates respectively (given in mm). The particles within the same track are identified with the particles/track ID (4th column). The data files have a header composed by three lines:

1. Title = Snapshot #
2. Variables = X Y Z PartID
3. Zone I= , F=POINT

The parameter I indicates the number of particles present in Snapshot #n.

TR cases

A sequence of 50 consecutive frames (starting at 0) is provided for each seeding density case. The time separation between snapshots is 5.916 ms. The file naming follows the convention:

[DA_CASE01_TR_ppp_0_AAA_PartFile_BBBB.dat](#)

where AAA is the fractional value of the seeding density in ppp (e.g. 010 for 0.01 ppp images), and BBBB is the snapshot number (from 0000 to 0049).

FP cases

The particles belonging to each of the four pulses of the sequence are provided for every seeding density case. The timing template of the four-pulse acquisition is 2-1-2, with the unitary separation of 5.916 ms. This means that the time separation between the first and second pulse is 11.832 ms, the separation between the second and third pulses is 5.916 ms, and finally between the third and fourth pulses is again 11.832 ms. The file naming follows the convention:

[DA_CASE01_FP_ppp_0_AAA_PartFile_BBBB.dat](#)

where AAA is the fractional value of the seeding density in ppp (e.g. 001 for 0.001 ppp images), and BBBB is the pulse number (from 0000 to 0003).

TP cases

The particles belonging to each of the two pulses of the sequence are provided for every seeding density case. The time separation between pulses is 5.916 ms. The file naming follows the convention:

[DA_CASE01_TP_ppp_0_AAA_PartFile_BBBB.dat](#)

where AAA is the fractional value of the seeding density in ppp (e.g. 200 for 0.2 ppp images), and BBBB is the pulse number (from 0000 to 0001).

Requested output and file format

The results need to be prescribed on a Cartesian grid with constant spacing of 1 mm in each direction. The following ranges are requested:

- X: 101 grid points, from $x = 0$ to $x = 100$ mm
- Y: 100 grid points, from $y = 0.1$ to $y = 99.1$ mm
- Z: 100 grid points, from $z = 0.1$ to $z = 99.1$ mm

corresponding to a total number of 1,010,000 grid points.

The output variables required on this grid are the following (total of 16 variables):

- Grid nodes: X, Y, Z in mm
- Velocity components: VX, VY, VZ in m/s
- Velocity gradient components: dVXdX, dVXdY, dVXdZ, dVYdX, dVYdY, dVYdZ, dVZdX, dVZdY, dVZdZ in 1/s
- Static pressure: p in Pa

where the pressure variable refers to the relative pressure with respect to the point (X,Y,Z) = (0,0.1,0.1) mm.

In order to ease file transfer, output files are requested in HDF5 format. In order to avoid confusion, the space coordinates are expected to vary in the order: X, Y and then Z, i.e. X corresponding to the innermost loop and Z to the outermost loop. Example Matlab ([Generate_DA_output.m](#)) and Python scripts ([Generate_DA_output.py](#)) generating such hdf5 files are available on the challenge portal.

TR cases

The flow field at timestep 24 (from the sequence starting at 0) needs to be supplied for each seeding density situation. Providing the output also at timestep 2 is optional. The file name has to follow:

[ZZZZ_DA_CASE01_TR_ppp_0_AAA_PartFile_BBBB.h5](#)

where ZZZZ identifies the name of the participant (free number of characters), AAA is the fractional value of the seeding density in ppp (e.g. 001 for 0.001 ppp images) and BBBB is the snapshot number (e.g. 0002 or 0024).

FP cases

The flow field at the time in the middle of the second and third pulses (centre of the sequence) needs to be supplied for each seeding density situation. The file name has to follow:

[ZZZZ_DA_CASE01_FP_ppp_0_AAA.h5](#)

where ZZZZ identifies the name of the participant (free number of characters), AAA is the fractional value of the seeding density in ppp (e.g. 001 for 0.001 ppp images).

TP cases

The flow field at the time in the middle of the two pulses needs to be supplied for each seeding density situation. The file name has to follow:

[ZZZZ_DA_CASE01_TP_ppp_0_AAA.h5](#)

where ZZZZ identifies the name of the participant (free number of characters), AAA is the fractional value of the seeding density in ppp (e.g. 001 for 0.001 ppp images).