4th International PIV Challenge

Test case B: Time resolved PIV

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1. Introduction

The turbulent flow over periodic hills is a common test case to validate numerical flow simulations (see ERCOFTAC test case Nr. 81). The geometry of the channel flow features a flat upper wall and a lower wall with smooth periodic hills of height *h*, see Fig. 1. At the top of the hill, the velocity reaches its maximum as a consequence of the contraction of the channel. Afterwards, the turbulent flow begins to detach from the hill and multiple new coherent structures evolve from the shear layer. Due to the smooth geometry, the separation and reattachment are not fixed either in time or in space. The flow is characterized by a great amount of turbulent scales with strong shear and vorticity.

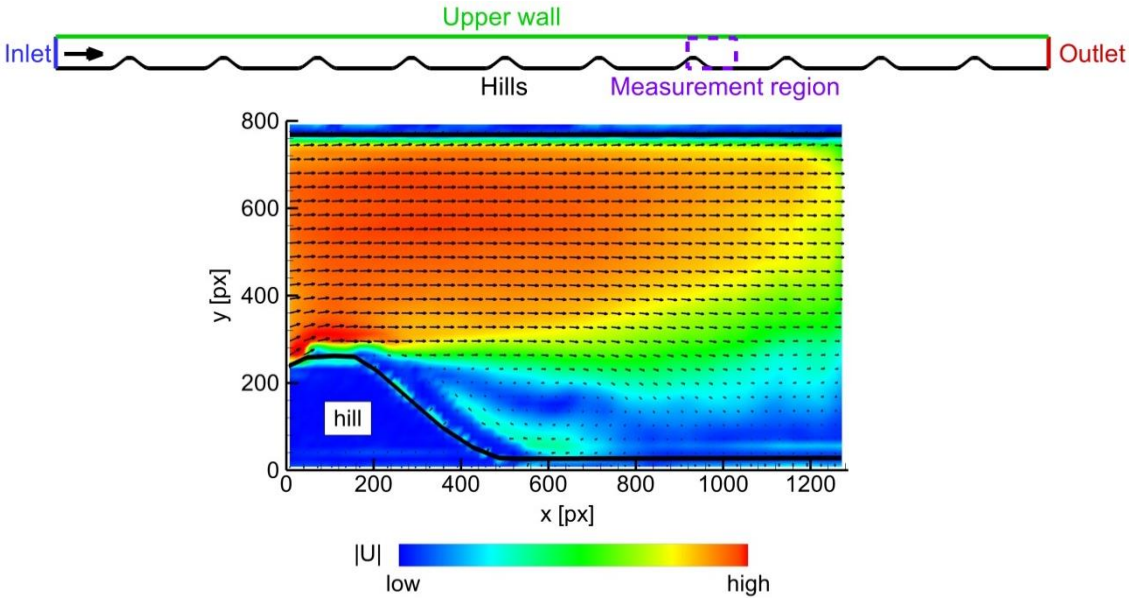

Figure 1: Sketch of the experiment and the mean velocity / displacement field (not every vector shown)

2. Technical Information

To characterize the periodic hill flow, time resolved PIV experiments were performed by the Bundeswehr University at the TU Munich (Cierpka et al, 2013) within the FP7 EU project AFDAR (Advanced Flow Diagnostics for Aeronautical Research). The data set contains single frame particle images acquired in the central plane of the channel. Hollow glass spheres with a mean diameter of d = 10 µm were illuminated with a 5W Nd:YAG cw-laser and recorded by means of a Phantom v12 camera. The acquisition frequency was 2000 Hz and the exposure time 200 µs. More than 5000 images were recorded

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but only 1044 will be given to the participants. The large dynamic velocity range, out-of-plane effects and small particle images caused by the large pixel size of the high-speed camera are the main challenges of test case B.

Camera:	Phantom v12
Laser:	Spectra Physics 5 W cw-Nd:YAG
Particles:	Glass hollow spheres (mean diameter d = 10 µm)
Number of single-frames:	1044
Frame size:	1280 x 800 pixels
Frame rate:	2000 Hz

3. Data Format, Vector grid, Desired Quantities and Name Convention

The single frame images are provided in uncompressed b/w 16 bit TIF format. They have a resolution of 1280 x 800 pixel each and they are named B_00001.tif, B_00002.tif, …, B_01044.tif.

3.1 Data format and vector grid

The data files must be provided in ASCII-Tecplot format. Specific examples are given in section 3.2. The evaluated data must be provided exactly in this data format. If the format deviates from this format (e.g. different number of vectors or additional variables) the file will not be included in the challenge. Data sets with the wrong data format will not be considered!

A common example should read as follows:

```
TITLE = "[FileName]"
VARIABLES = "x", "y", "Vx", "Vy", "Flag"
ZONE, I=617, J=377, F=POINT
24.0    24.0   5.45732   6.78354 1
26.0    24.0   5.14894   5.97568 1
  :       :       :         :    :
1256.0  24.0   4.51546   6.57674 1
24.0    26.0   6.56494   6.63287 1
26.0    26.0   5.47537   5.75648 1
  :       :       :         :    :
1256.0  26.0   6.52546   7.57974 1
  :       :       :         :    :
24.0    776.0  3.51546   6.47674 1
  :       :       :         :    :
1256.0  776.0  5.51846   4.27974 1
```

The separation of the numbers must be done with a white space. The number after “I=” is the number of vectors in the x-direction and the number after “J=” is the number of vectors in the y-direction. These numbers are fixed.

The convention for "Flag" is as follows:

"0" Not valid
"1" Valid
"2" Interpolated

The data must be provided exactly on the following grid:

Vector grid: The locations of the vector grid points in pixel are:
X = 24 to 1256 with a grid distance of Δx = 2 px → 617 nodes
Y = 24 to 776 with a grid distance of Δy = 2 px → 377 nodes

Origin: The origin (0,0) of the grid is in the upper left corner of the raw images, according to Fig. 1. Thus the center of the upper left pixel is located at (0.5,0.5).

When Particle Tracking Velocimetry (PTV) is used for data evaluation, the displacement information must be interpolated on the grids specified above. The participants are free to choose the interpolation scheme. The Flag for PTV may only be "0" or "1". In regions where no particles are identified, a displacement of 0 and a Flag "0" may be specified.

3.2 Desired Quantities and Name Convention

3.2.1 Velocity fields, evaluation 1 [eval1]

The evaluation must be performed by correlating the following image pairs:

"B_00010.tif" with "B_00012.tif"	→	Result (displacement vectors [px] divided by 2) is stored in "B_eval1_[TeamName]_00011.dat"
"B_00011.tif" with "B_00013.tif"	→	Result (displacement vectors [px] divided by 2) is stored in "B_eval1_[TeamName]_00012.dat"
: :		:
"B_ [%05i-1].tif" with "B_[%05i+1].tif"	→	Result (displacement vectors [px] divided by 2) is stored in "B_eval1_[TeamName]_[%05i].dat"
: :		:
"B_01033.tif" with "B_01035.tif"	→	Result (displacement vectors [px] divided by 2) is stored in "B_eval1_[TeamName]_01034.dat"

The final interrogation window size is 32 x 32 px with 93.75% overlap (multipass, window-weighting, image deformation, … is allowed) resulting in the vector grid specified in section 3.1.

It is NOT allowed to perform the evaluation with e.g. 16 x 16 px windows and a high overlap and only to provide the vectors on the specified locations. The participants are free to apply masks.

In total, 1024 dat-files should be obtained.

When PTV evaluation is performed, the particle displacements are determined from the same images as specified for the PIV evaluation. Displacements are interpolated to the grid specified in section 3.1.

The participants must provide a file “Documentation_B_eval1_[TeamName].pdf” which outlines the parameters / methods which have been used for the evaluation.

3.2.2 Velocity fields, evaluation 2 [eval2]

For this evaluation, the velocity fields at time steps 11 to 1034 are to be determined. The participants are free to choose how to obtain these fields and which interrogation window sizes and overlaps should be applied. Masking of reflections, window overlap, window weighting, and other evaluation parameters can be freely chosen as well. However, the data must be provided exactly on the grid specified in section 3.1.

The following files are to be delivered:

“B_eval2_[TeamName]_00011.dat”
“B_eval2_[TeamName]_00012.dat”
“B_eval2_[TeamName]_00013.dat”
:
“B_eval2_[TeamName]_[%05i].dat”
:
“B_eval2_[TeamName]_01033.dat”
“B_eval2_[TeamName]_01034.dat”

The velocity (displacement) field at time step 11 can e.g. be obtained by correlating “B_00009.tif” with “B_00013.tif” and dividing the determined displacements by a factor of 4. The participants are encouraged to apply more sophisticated evaluation methods to get more accurate results, e.g. by taking more images into account, see Hain and Kähler (2007). A total of 1024 dat-files are obtained in this procedure.

The participants must provide a file “Documentation_B_eval2_[TeamName].pdf” which outlines the parameters / methods which have been used for the evaluation.

4. References

Cierpka C, Scharnowski S, Kähler CJ, Manhart M: *Characterization of the flow over periodic hills with advanced measurement and evaluation techniques*. 8th International Symposium on turbulence and shear flow phenomena (TSFP-8), Poitiers, France, August 28-30, 2013

Hain R, Kähler CJ: *Fundamentals of multiframe particle image velocimetry (PIV).* Exp Fluids 42:575-587, 2007