4th International PIV Challenge

Test case A: µ-PIV

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1. Introduction

Micro dispersion systems are very important in the field of process engineering. These systems have certain advantages if driven with high pressures. The basic geometry consists of a straight micro channel with a sudden decrease in cross section and a sudden expansion thereafter as can be seen in Fig. 1. Due to this sudden change in width (500 µm to 80 µm) the velocity changes significantly by about 230 m/s within the field of view. The strong normal and shear forces are necessary to generate a homogeneous multi-phase dispersion. The flow includes cavitation, particle-wall and particle-particle interaction, and strong gradients.
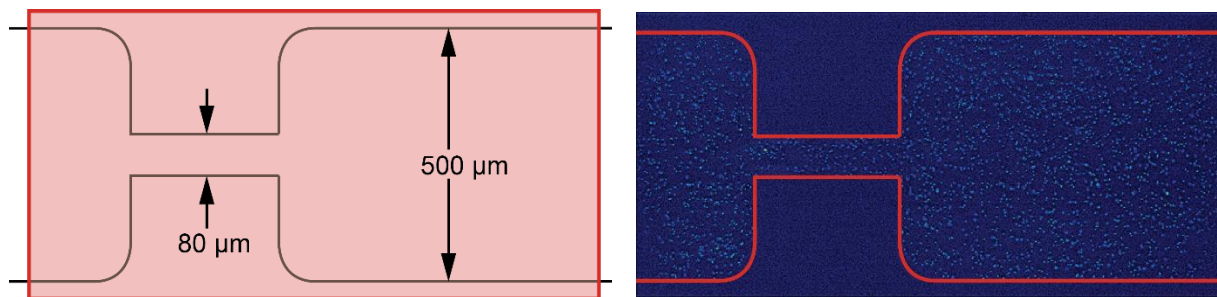

Figure 1: Sketch of the micro channel (left) and recorded image (right)

2. Technical Information

To characterize the basic single-phase flow, a µPIV experiment was performed at the Bundeswehr University Munich within the DFG research group FOR 856. The channel was driven by 200 bar of pressure. Fluorescent polystyrene particles with a diameter of 1 µm were added to the flow and imaged by a Zeiss Axio Observer microscope with a 20x magnification lens. To capture the flow, a sCMOS camera with an interframing time of 120 ns was used. The particles were illuminated using a Litron Nano-PIV double pulse Nd:YAG laser with 4 ns pulse length. 600 double-frame images were recorded. The field of view covers approximately 1400 x 600 µm^2 on 2560 x 1230 pixels.

Besides the strong gradients and the high dynamic velocity range, the main technical challenges are caused by the depth of correlation, optical aberrations due to the thick window used to hold the pressure and low signal-to-noise ratio.

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Camera: PCO.edge sCMOS
Laser: Litron double-pulse Nd:YAG
Laser pulse duration: ~ 4ns
Particles: fluorescent polystyrene particles (1 μm)
Number of double-frames: 600
Frame size: 2560 x 1230 pixels
Driving pressure: 200 bar
Frame rate: 10 Hz

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

The double frame images are provided in uncompressed b/w 16 bit TIF format. They have a resolution of 2560 x 1230 pixels each and they are named A_00001_a.tif, A_00001_b.tif, A_00002_a.tif, A_00002_b.tif, …, A_00600_a.tif, A_00600_b.tif. "_a" is the first frame of the image, "_b" is the second frame.

To allow for a comparison between all different methods (ensemble correlation, window correlation and tracking approaches) the data has to be provided as specified in the following sections.

3.1 Data format and vector grid

The evaluated data must be provided in the following data format. If the format deviates from this format (e.g. different number of vectors, additional variables) the file cannot be included in the challenge. Data sets with wrong data format will not be considered!
The data files must be provided in ASCII-Tecplot format.

3.1.1 Example for all evaluation methods

The following example shows a file as it has to be provided by the participants for the **mean displacement** field.

```
TITLE = "[Specific Name]"
VARIABLES = "x", "y", "Vx", "Vy", "Flag"
24.0    24.0    5.45732   6.78354 1
26.0    24.0    5.14894   5.97568 1
  :       :       :         :    :
2536.0  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
  :       :       :         :    :
2536.0  26.0    6.52546   7.57974 1
  :       :       :         :    :
24.0    1206.0  3.51546   6.47674 1
  :       :       :         :    :
2536.0  1206.0  5.51846   4.27974 1
```

The separation of the numbers must be done with a white space.

The convention for "Flag" is as follows:
    "0" Not valid
    "1" Valid
    "2" Interpolated

The participants must provide the results on the following grid:

Vector grid: The locations of the vector grid points in pixel are:
               X = 24 to 2536   with a grid distance of Δx = 2 px $\rightarrow$ 1257 nodes
               Y = 24 to 1206   with a grid distance of Δy = 2 px $\rightarrow$ 592 nodes

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

RMS fields are to be provided in a similar way on the same grid:

```
TITLE = "[Specific Name]"
VARIABLES = "x", "y", "RMS_Vx", "RMS_Vy", "Flag"
24.0    24.0    5.45732    6.78354 1
26.0    24.0    5.14894    5.97568 1
  :       :        :          :     :
```

Instead of the mean values of Vx and Vy, RMS_Vx and RMS_Vy should be provided.

3.1.2 Example for PTV approaches

In addition to the fields specified in section 3.1.1, teams who apply PTV must provide files which contain individual particle locations (xp, yp) and the corresponding displacements, as follows:

```
TITLE = "[Specific Name]"
VARIABLES = "xp", "yp", " Vx", " Vy", "Flag"
5.674   9.4873  5.45732    6.78354 1
32.983  11.983  5.14894    5.97568 1
  :       :        :          :     :
```

3.2 Desired Quantities and Name Convention

3.2.1 Displacement fields, evaluation 1 [eval1]

This evaluation is performed by teams who apply spatial correlation such as conventional window cross correlation or sum-of-correlation by means of window correlation.

The evaluation must be performed at a final interrogation window size of 32 x 32 px. Multipass, window-weighting, image deformation, etc are allowed. It is NOT allowed to perform the evaluation with e.g. 16 x

16 px windows and only to provide the vectors on the specified locations. The participants are free to apply masks.

Mandatory file for Case A, eval1:

```
A_eval1_[TeamName]_mean.dat
```

Additional file for Case A, eval1:

```
A_eval1_[TeamName]_rms.dat
```

Data format and grid are specified in section 3.1.1.

A short description of the methods used and algorithms applied must be provided by each participant in a pdf document named "Documentation_A_eval1_[TeamName].pdf".

3.2.2 Displacement fields, evaluation 2 [eval2]

This evaluation is performed by teams who apply spatial correlation such as conventional window cross correlation or sum-of-correlation by means of window correlation as well as all other teams.

The teams are completely free to choose the interrogation window sizes or other parameters. However, the vector grid is specified in section 3.1.1. The data must be provided by all teams exactly as specified in this section. When PTV evaluation is performed, the displacements must be obtained by interpolation on this grid by the participants. PTV teams must provide, additionally, the files specified in section 3.1.2.

Mandatory file for Case A, eval2, for all Teams:

```
A_eval2_[TeamName]_mean.dat
```

Additional file for Case A, eval2, for all teams. Shear stresses may be obtained by e.g. the approach from Scharnowski et al. (2012) if ensemble correlation is applied for the evaluation:

```
A_eval2_[TeamName]_rms.dat
```

Mandatory file for Case A, eval2, for PTV approaches:

```
A_eval2_[TeamName]_%05i.dat        with %05i = 00001 … 00600
```

For each double frame image, a dat-file is provided with the detected particle positions and the corresponding displacements.

A short description of the methods used and the applied algorithms (including interpolation for PTV) must be provided by each participant in a pdf document named "Documentation_A_eval2_[TeamName].pdf".

4. References

Scharnowski S, Hain R, Kähler CJ (2012) Reynolds stress estimation up to single-pixel resolution using PIV-measurements. Exp Fluids 52:985-1002