

Stereo-Micro PIV measurements of the three-dimensional separated flow in the wake of a backward facing step

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A new PIV-system which measures all three velocity-components (3C) instantaneously in a microscopic two-dimensional plane is used to investigate the flow behind a backward facing step in microscopic length scales. It is the first application of a system which combines the principles of stereo microscopy and PIV to investigate unsteady three dimensional flows.

The new measuring system has been developed for a wide range of applications, e.g. in the medical technology (stent flow), in biological systems (flow induced by micro organisms) or in MEMS structures (lab on a chip), where the knowledge about the instantaneous three-dimensional flow structures and mixture conditions are essential.

1. Method

The Stereo-PIV setup comprises two PIV-cameras, the filter box, the stereo-microscope and a lens. The cameras are Dantec Hi-Sense cameras with 1280 pixel x 1024 pixel CCD. They are placed on the camera output on the stereo head of a Zeiss Stemi 11 microscope. The lens is a leica planapo lens with a short focal length of 15 mm. It allows a view angle of 25° for each of the optical paths. The two CCD cameras generate a double frame image pair. These images are cross correlated with an interrogation area size of 32 pixel x 32 pixel. The third velocity-component (out-of-plane component) is obtained from the usual stereo PIV vector processing. The setup allows the measurement of flow fields in an observation area down to 500 μm x 600 μm , with interrogation area sizes down to 12 μm x 12 μm .

The test object is a micro channel with a cross section of 200 μm x 200 μm and an optional step of 100 μm length and height which has been manufactured in transparent polystyrol by Greiner BioOne. The length of the channel is 200 times the width. The wall roughness of the channels is below 0.05 μm . The channels are closed by a transparent polystyrol plate which is chemically bonded to achieve complete water tightness.

2. Results

In figure the vertical velocity (w -component) is presented as colour plots from the experimental result (top) and the numerical solution (bottom) for the plane $z = 50 \mu\text{m}$. Additionally velocity vectors of the in-plane components (u,v) are shown. Now the two regions mentioned above are clearly recognized as the centers of vertical motion. Upstream of the step in a close distance to the edge of the step the motion is oriented upwards, in the wake of the step downward motion is detected with a significant distance to the backward edge of the step, thus forming a well defined wake flow region. While the irregularities in the experimental results

show that there is considerable noise in the measurement process, it should be mentioned that the overall position, general shape and the maximum values are correctly represented in the experimental velocity field in comparison to the numerical solution.

The experimental results show a good agreement with results from numerical simulation using a solver for the Reynolds-averaged Navier Stokes equations (see figure). The representation of the third velocity component (out of plane components) matches the flow topology as well as the in-plane components (see figure). The flow fields allow a quantitative study of the wake, particularly the 3D flow field and also concerning the unsteady behavior since the instantaneous velocity fields are available with this stereo-micro PIV method.

In the next step of development the stereo-micro PIV system will receive stronger illumination equipment. Currently several measurement projects are scheduled including the investigation of the flow around bionic micro sensors, the flow near micro-organisms and the flow in micro-medical applications.

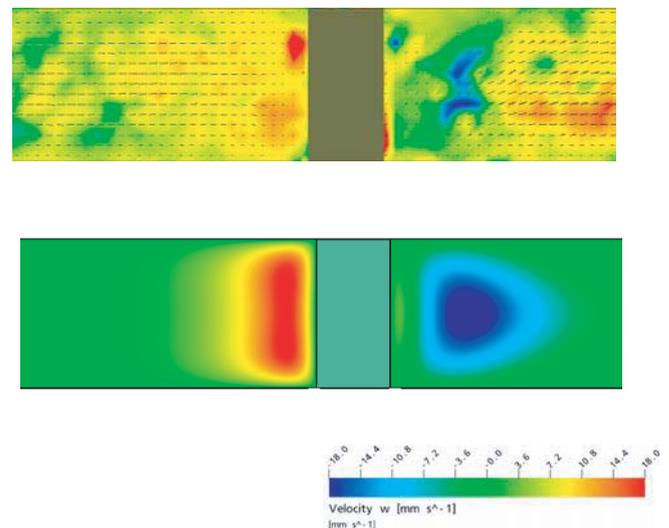


Fig. 1 Experimental (top) and numerical (bottom) results of the flow in the channel from fig. 7, plane $z = 50 \mu\text{m}$, colour: velocity component w , top: Stereo- μ PIV result (averaged field), bottom: numerical simulation with ANSYS cfx 10