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On 3D dynamical structure of the wake behind circular cylinder

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The wake behind a cylinder with circular cross-section will be explored experimentally using Stereo PIV time-resolved method. Dynamics of the wake is to be analysed using the OPD method. Variation of the flow-field in spanwise direction are to be studied in detail. Presence of streamwise vorticity in the wake is to be shown in instantaneous snapshots, however absent completely in the time-mean flow-field.

Both external and internal flows could be characterized by 2D boundary conditions in practical cases very often. Typical example could be the case of cross-flow around a prismatic body. In spite of inherent dynamical nature of the flow-field, this case could be considered as a plane flow, invariant along the body (excluding the ends). Such a case is also mathematically modelled as a 2D flow very often, taking into account only a single section, supposing the same flow picture for any other cross-section along the body.

The case of circular cylinder in cross-flow belongs to so called canonical cases. We could find extensive information on this case in literature – theoretical, experimental and numerical studies. Most of available studies treat the prismatic cylinder as forced 2D case, no 3D structures are detected, of course. The 3D structure of the wake behind a body of 2D geometry has been already addressed e.g. in [2]. The paper [1] deals with the d'Alembert paradox (zero forces) for inviscid flow and shows that this paradox is due to forcing 2D stationary flow pattern. In the real 3D nonstationary flow the forces are generated even in the inviscid case and the the d'Alembert paradox is thus resolved.

It is known that the wake behind circular cylinder exhibits several types of flow patterns: steady, unsteady periodical and chaotic, the control parameter is Reynolds number. Description of the wake topology including its dynamics could be find in any good book on fluid mechanics, more information on the details are in numerous papers, see e.g. [4].

In the presented paper flow-fields in the cylinder wake are to be shown. The cylinder is placed in the low turbulent regular flow, Reynolds number is about 5 thousands. The measurements are performed in the plane perpendicular to the flow and parallel to the cylinder axis in the distance 8 cylinder diameters. Time resolved PIV stereo technique is used evaluating all 3 velocity components within the plane of measurement with repetition frequency 1 kHz.

The figures are to be presented in dimensionless form, references are cylinder diameter for lengths and incoming velocity for velocities.

The mean velocity field is shown in Fig. 1. The variations of the mean velocity along the cylinder axis are due to perspective view of the cameras, which are placed symmetrically in x direction. The in-plane velocity field is shown by vectors with vector lines, the third out-of-plane velocity component W is represented by colour.

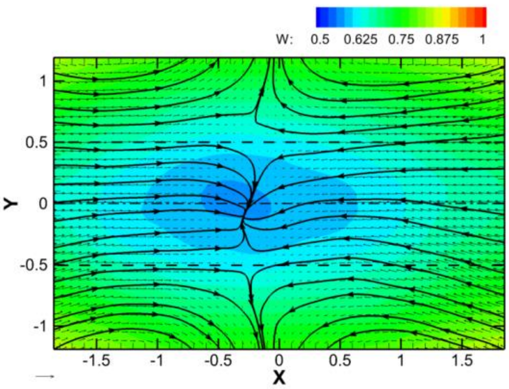

Fig. 1. Mean velocity field

To study the dynamical properties of the flow-field the Oscillation Pattern Decomposition method (OPD) was adopted resulting in series of OPD modes. Each OPD mode is characterized by its topology in complex form (consisting of real and imaginary parts), frequency and attenuation of the pseudo-periodic (oscillating) behaviour. The details on OPD method could be found in [3].

For presentation the dominant oscillating mode has been chosen corresponding to the vortex shedding process.

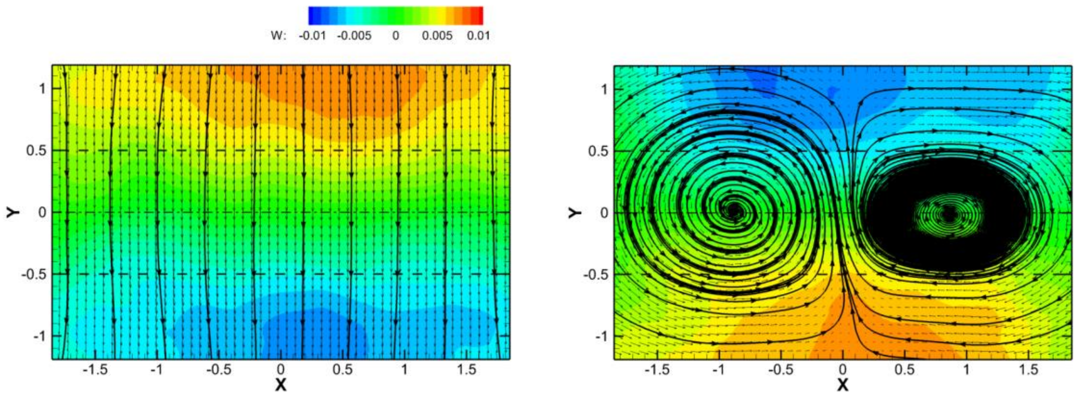

Fig. 2. The vortex shedding OPD mode, real part left, imaginary part right

The real part of the OPD mode is shown in left part of Fig. 2 and documents 2D structure of the fluctuation flow-field. On the other hand the imaginary part in the right Fig. 2 part contains a contra-rotating pair of streamwise vortices with spacing 2 cylinder diameters.

Acknowledgements

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