ON STRUCTURE OF RECIRCULATION ZONE BEHIND BACKWARD-FACING STEP IN A NARROW CHANNEL

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Introduction

The backward facing step flow has been established as a benchmark configuration for separated flow studies in fluid mechanics, one of so called canonical cases. The presented paper deals with 3D backward-facing step at high Reynolds numbers.

However the flow over a backward-facing step is very simple as to its geometry and boundary conditions, but the resulting flow structure is extremely complex. It occurs in many engineering applications ranging from various fluidic elements, cooling of turbine blades, air-conditioning pipelines to many other devices.

The flow-field in the recirculation region downstream the backward-facing step in a narrow channel is described in [1]. The acquired data suggests that a couple of nearly stable contra-rotating corner vortices in the channel input near sidewalls are passing towards the plane of symmetry, they are pushed downwards in the same time. Then, they form a kidney-shaped common footprint on the bottom wall behind the step (confirmed by wall visualization). Finally, the vortices rebound from the wall pointing up and turning downstream being pressed to the centre of the channel. This scenario is subjected to revision in the presented paper.

Experimental setup

The existing blow-down test rig was modified for experiments with the separated flow in a narrow channel with a backward facing step.

The area of the test section input is 0.25 x 0.1 m^2. Reynolds number based on the hydraulic diameter of the inlet channel and volume velocity was about 5 10^4, velocity of air was about 20 m/s in the channel upstream the step. Conventional thickness of boundary layer at the step tip was approximately 0.003 m. The natural turbulence level was about 0.1% in the working section input. The channel downstream the backward facing step was 1 m in length, and the ratio of the input channel width to the step height was 4.

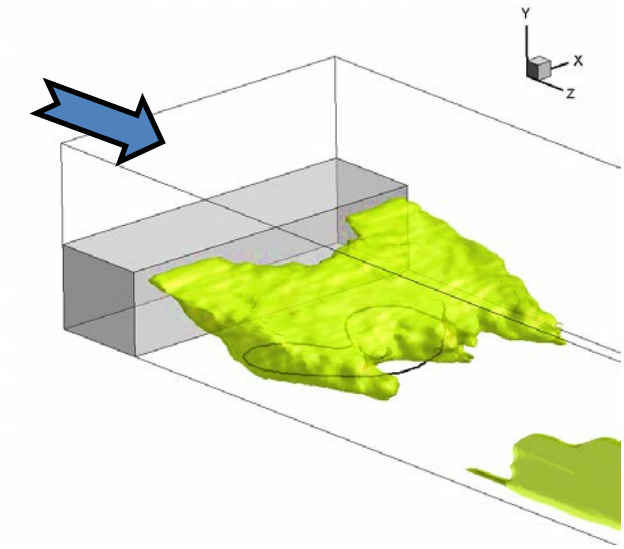
The stereo time-resolved PIV method was used for the experiments. The measuring system DANTEC consists of laser with cylindrical optics and two CCD cameras with Scheimpflug correction. For the presented measurements the frequency 50 Hz and 400 double-snaps in sequence corresponding to 8 s of record for mean evaluation was acquired in each measuring plane to obtain data for time-mean structure evaluation.

The experimental setup and instrumentation is described in details in [3].

Results

The velocity field was interpolated within the measuring zone and analyzed in details. Special attention has been paid to the recirculation zone with kidney-shaped footprint coming from the wall visualization, see [1], where hypothesis of presence of a counter-

rotating vortex pair is presented. Surprisingly, no distinct vortical structures have been detected in the mean velocity field within that region in the obtained velocity data, distinct rising flow region was detected in the recirculation zone instead. In Figure the isosurface of mean vertical velocity component (0.4 m/s) is shown.



The high positive vertical velocity component region in trident shape was studied in details. As the maximal value of the vertical velocity is about 0.6 m/s. The structure originates in corners on the top of the step forming two elongated structures, the third elongated structure arises in the middle of the channel.

The rising flow provokes a low-pressure region close to the wall below the structure, which form the kidney shape detected earlier. The area of low pressure is of very sharp and distinct contour.

Conclusions

The time mean structure of the flow behind a step in a narrow channel was shown. The footprint behind the step is not connected with vortical structures, as formulated in older studies, but the low pressure generation close to the channel bottom in the recirculation region seems to be more relevant.

Acknowledgement

This work was supported by the Grant Agency of the Czech Republic, projects Nos. 101/08/1112 and P101/10/1230.

References

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