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ON TURBULENT BOUNDARY LAYER DYNAMICS

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Abstract: *Results of experiments on fully developed turbulent boundary layer are presented. The boundary layer was generated on a smooth flat wall forming one side of the channel of rectangular cross section.*

Keywords: ***Turbulent boundary layer, dynamics, time resolved PIV.***

1. Introduction

The stereo PIV method applied to the plains parallel to the wall has been used for study of the transitional boundary layer structure. This method was suggested for the first time in Longmire et al. (2003). They demonstrated the method in which the flow structure is described by planar fields of three-dimensional velocity vectors and can be effectively visualized in a single plot. In addition to local velocity values, the fields also contain information on in-plane velocity gradients. For the turbulent boundary layer examined, vorticity, swirl strength, instantaneous Reynolds shear stress, and streamwise velocity were considered as useful quantities to visualize. In combination they can be used to identify and characterize packets of hairpin vortices as shown recently in Volino et al. (2007).

2. Experimental setup

Experiments have been carried out on the blow-down facility in channel of cross section 250 x 100 mm^2 and 3 m in length. The inner surface of the channel with dimension 250 mm have been used as a wall for development the boundary layer. The Cartesian coordinate system have been introduced with *x* axis in the channel axis, *y* perpendicular to the wall and *z* direction parallel to the wall and perpendicular to the channel axis. Mean velocity in the channel core of about 4.5 m/s have been set and the boundary layer on the smooth wall in distance 2000 mm from the channel inlet, where the boundary layer starts its development. The Reynolds number based on *x* distance was about 6.10^5.

The flow-field measurements were acquired using time-resolved PIV technique. Streamwise-wall normal (*x*, *y*) plane were acquired at the spanwise centerline of the test section to evaluate the boundary layer characteristics. The main experiments were performed in streamwise-spanwise (*x*, *z*) planes were acquired at *y* equal approx. 2 mm, this corresponds to approximately 0.08 of the boundary layer conventional thickness.

The time-resolved PIV method was used to resolve the instantaneous velocity fields. The measuring system DANTEC consists of laser with cylindrical optics and CMOS camera. Laser New Wave Pegasus Nd:YLF, double head, wavelength 527 nm, maximal frequency 10 kHz, a shot energy is 10 mJ for 1 kHz (corresponding power 2 x 10 W). Camera NanoSense MkIII, maximal resolution 1280 x 1024 pixels and corresponding maximal frequency 500 double-snaps per second. The camera internal memory 4 GB represents 1635 full resolution double-snaps. The maximal working frequency of the camera is limited by data rate, so it could be augmented by reducing its resolution. In the experiments we used reduced resolution with maximal possible frequency, 1600 consecutive snaps were acquired and evaluated representing 3.2 s in real time. As tracing particles the SAFEX smoke was applied. The software Dynamics Studio ver.3 was used for both data acquisition and velocity-fields evaluation by application of the adaptive correlation method.

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3. Results

The boundary layer was of well-developed turbulent structure. The profiles of mean longitudinal velocity component U and variances of both velocity varU and varV components are shown in Fig. 1. The mean velocity profile shows well developed logarithmic part. Please note that the points close to the wall are of informative meaning, because the size of the interrogation area (i.e. measuring point) was about 1 mm.

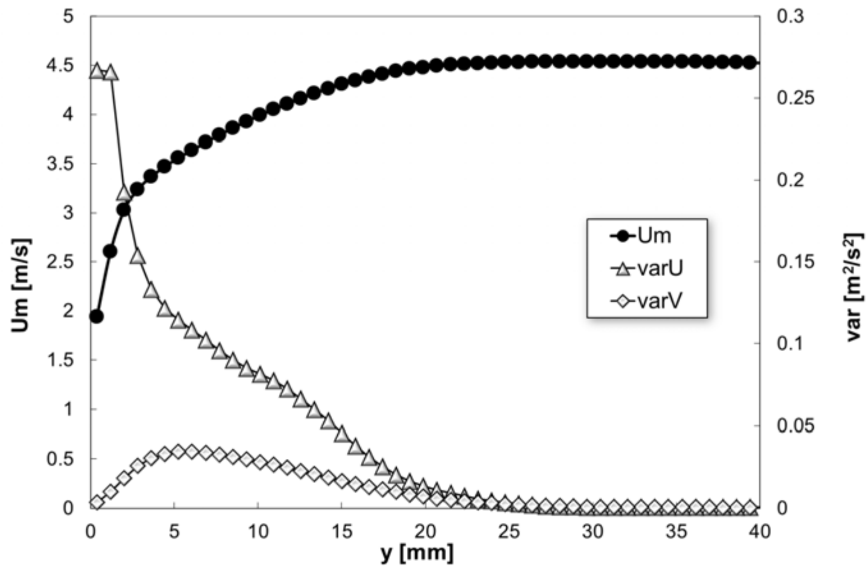

Fig. 1: Boundary layer mean velocity profile and variances of both velocity components.

The boundary layer thickness has been estimated to approx. 25 mm. The distance of measuring plane (x, z) in y was approx. 2 mm, this corresponds to 0.08 of the boundary layer conventional thickness. The mean velocity was about 2.9 m/s and was approximately constant in the measuring plane with dimension 82 mm streamwise and 65 mm spanwise.

The mean velocity was subtracted from all instantaneous vector fields. The flow-field in the snap number 110 has been chosen in a random way and its vector field is shown in Fig. 2. The typical structure of the in-plane velocity vector components is visible. The vortices are moving in the mean flow direction and the structure is subjected to changes. However the character is not changing significantly.

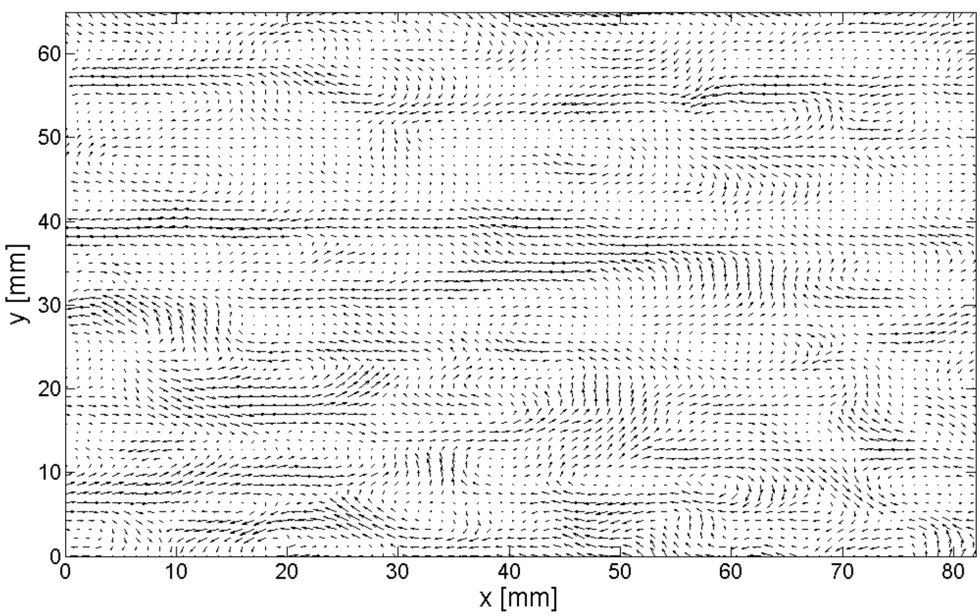

Fig. 2: Distribution of instantaneous velocity vectors.

In Fig. 3 distribution of instantaneous streamwise velocity fluctuations is depicted. The low velocity streaks can be identified in the flow-field and in Fig. 3 are represented by dark color.

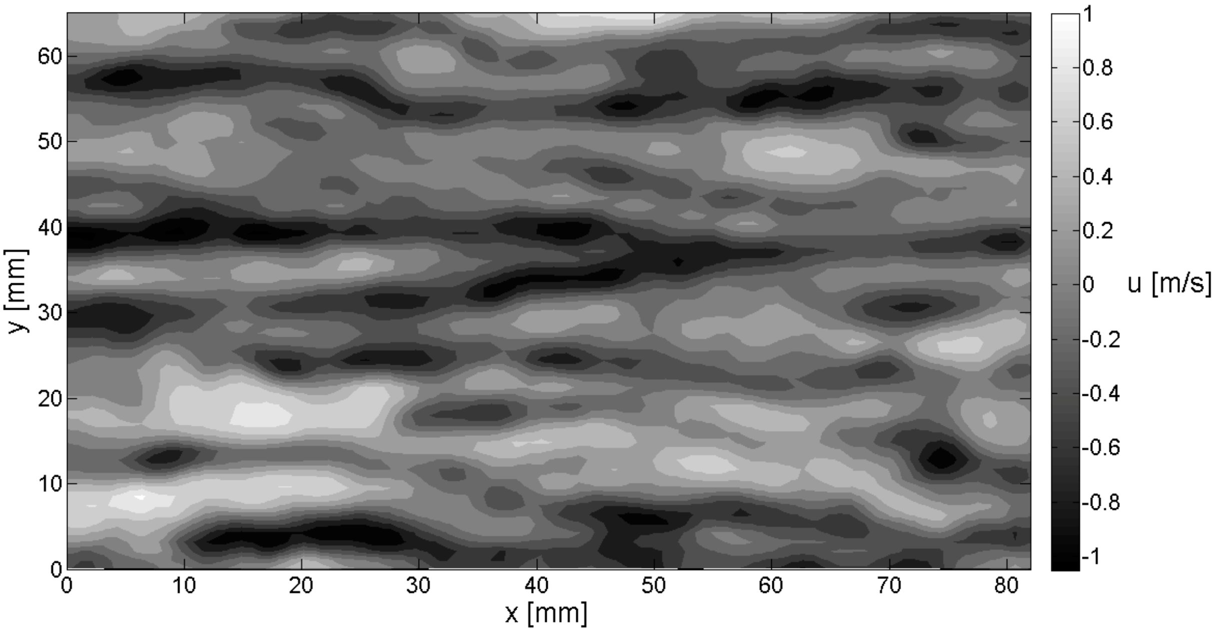

Fig. 3: Distribution of instantaneous longitudinal velocity component.

Distribution of vorticity component perpendicular to the measuring plane is shown in Fig. 4. Light parts represent positive vorticity (anticlockwise direction) while dark parts indicate negative vorticity (clockwise direction).

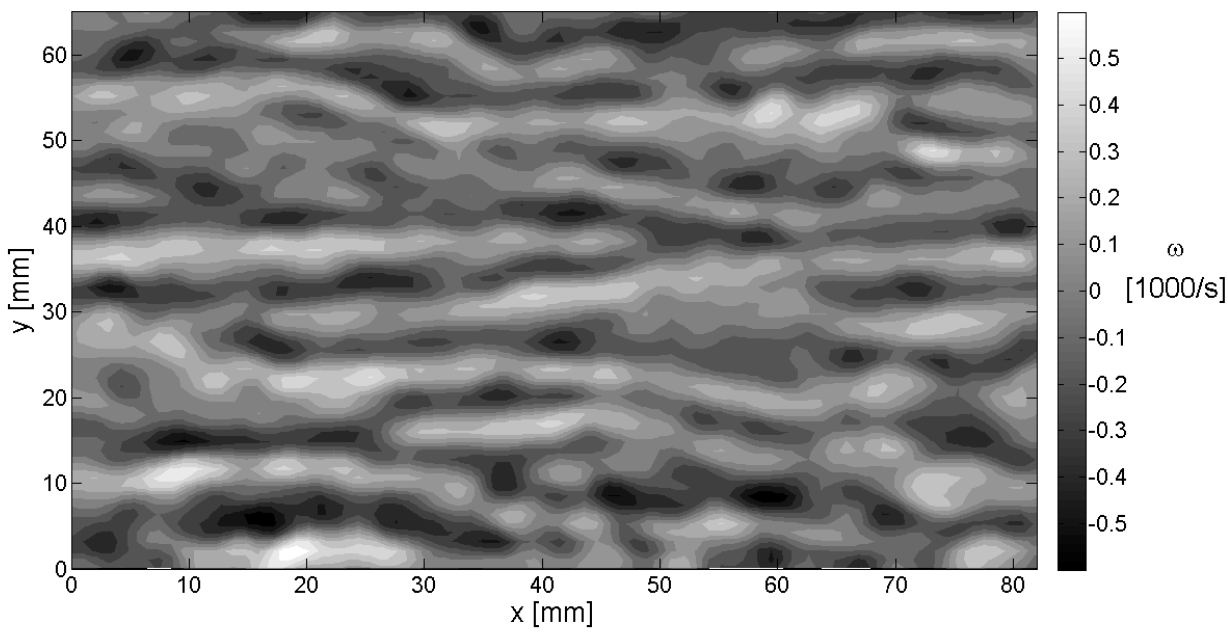

Fig. 4: Distribution of instantaneous vorticity.

4. Conclusions

The fully developed turbulent boundary layer was subjected to experiments using time-resolved PIV technique. The profiles of mean longitudinal velocity of this boundary layer were evaluated from acquired set of data. The velocity fields in plane parallel to the wall close to it were evaluated in time sequences. The time evolution of the vector fields will be subjected to further analysis.

Acknowledgement

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