Comparative study of ADV and LDA measuring techniques

Zdenek Chara[1*] and Vaclav Matousek[2]
[1] Institute of Hydrodynamics ASCR, v. v. i., Pod Patankou 5, 166 12 Prague 6, Czech Republic
(*Corresponding author, e-mail: chara@ih.cas.cz).
[2] Czech Technical University, Faculty of Civil Engineering, Prague, Czech Republic, Thakurova 7,
166 29 Prague, Czech Republic

The contribution compares measurements of local velocities for water flows of different configurations carried out with the help of the ADV (Acoustic Doppler Velocimeter) and LDA (Laser Doppler Anemometry) measuring techniques. Three different geometrical configurations were tested – open channel flow, flow behind a rectangular cylinder and flow behind a hole in a plate.

Keywords: Flow measurements, turbulent flow, LDA, ADV.

1 INTRODUCTION

Nowadays a lot of experimental techniques exist to measure flow characteristics of complex free surface flows as HWA (Hot-Wire Anemometry), LDA, PIV (Particle Image Velocimetry) , UVP (Ultrasonic Velocity Profiler), ADV. However for 3D measurements in a non purely transparent flow a number of suitable experimental methods is limited. An acoustic doppler method represents one of such techniques. This contribution presents a comparison of two measuring techniques - LDA and ADV. Similar study was published in [1] for near-bottom comparison of LDA and ADV; study the mean velocities measured by the ADV techniques were always lower compared to the LDA data. On the other hand the ADV velocity fluctuations were higher than those measured by the LDA.

2 EXPERIMENTAL DETAILS

The measurements were carried out in a hydraulic flume length of which attains 6 m and rectangular cross section 0.25 x 0.25 m. The LDA system consisted of a Dantec two-component system with two BSA processors. The ADV system used was a Nortek 3D side-looking probe (two sensors were oriented parallel with the channel bottom).

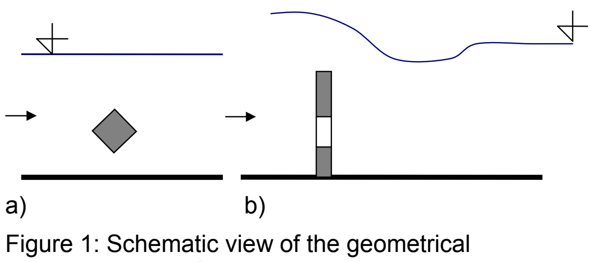

Figure 1: Schematic view of the geometrical arrangements, a) flow behind a rectangular cylinder, b) flow behind a hole in a plate.

Three different configurations were tested, the first one was a pure flow in the hydraulic flume, the flow depth was 110 mm and flow discharge 4.8 l/s. The second one was the free surface flow behind a rectangular cylinder of the cross section 30x30 mm symmetrically tilted (see Fig. 1, left) where lower edge was 30 mm above the channel bottom. Finally, the third configuration was the free surface flow behind the plate of 80 mm height with a rectangular hole 30x30 mm (see Fig. 1, right). The lower rim of the hole was 20 mm above the bottom. Working frequency of the ADV system was 25 Hz.

3 RESULTS AND DISCUSSION

Fig. 2 depicts velocity profiles of the longitudinal velocity component measured by the both experimental techniques in the open channel. The measuring volume of the ADV system was set to 6 mm and the velocity range was 30 cm/s. As can be seen in Fig, 2 the ADV data compared with the LDA data underestimated the velocity values. The deviation seems to be more or less constant and if the ADV data are multiplied by a factor 1.07 the results fit very well the LDA data. RMS (Root-Mean-Square) values of the horizontal as well as vertical velocity fluctuations are shown in Fig. 3. The RMS values of the horizontal velocity component measured by the ADV method are about 12% lower compared to the LDA data.

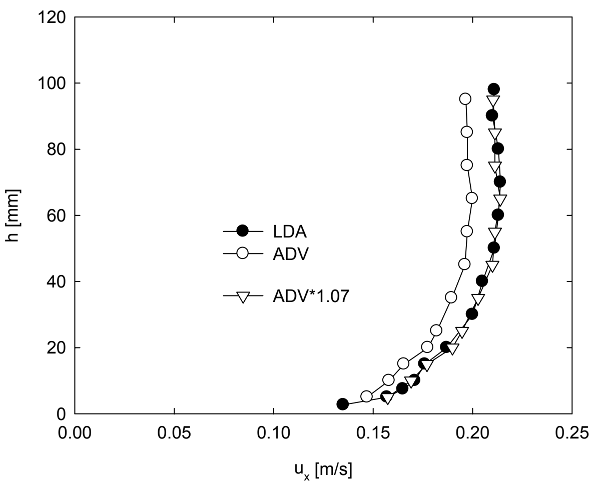

Figure 2: Profiles of the longitudinal mean velocities

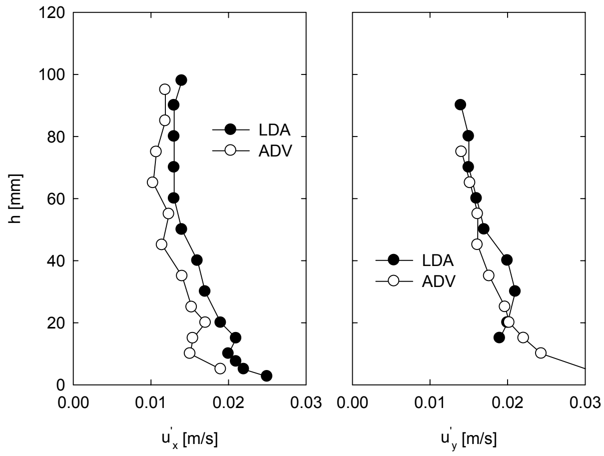

Figure 3: RMS data of horizontal (left) and vertical (right) velocity component

In the upper part of the flow the RMS data of the vertical velocity component measured by the both methods are practically the same, close to the channel bottom the ADV data systematically increased.

The second flow configuration was represented by flow behind the rectangular cylinder. In this case the flow measurements were performed at a distance 40 mm behind the cylinder. ADV velocity range was set to 100 cm/s and a size of the measuring area attained 6 mm. Profiles of the mean velocities in the longitudinal direction are presented in Fig. 4 where a vertical axis shows distances from the channel bottom. A similar tendency as in the previous case was observed - the ADV velocity data are lower compared to the LDA data, but the differences are higher - about 20%.

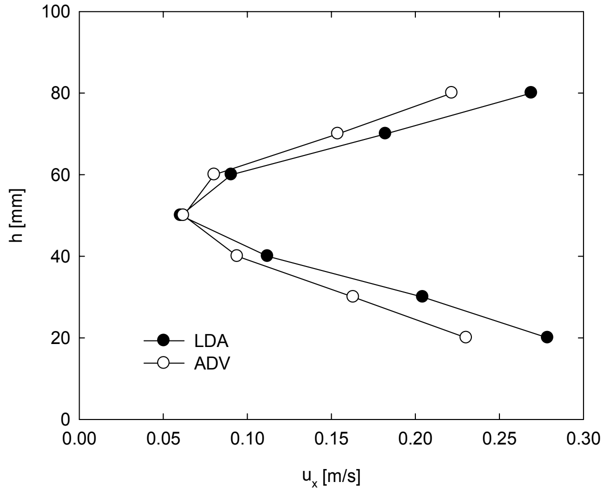

Figure 4: Flow behind the cylinder - mean velocity profiles in the longitudinal direction

Mean velocity profiles in the vertical direction are shown in Fig. 5. Also in this case the ADV data are lower but the discrepancy between the both methods is higher. The RMS values of longitudinal as well as vertical directions are shown in Fig. 6. In the longitudinal direction the RMS

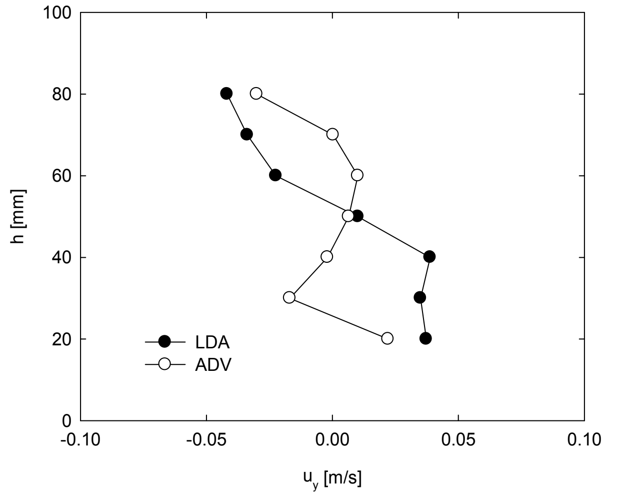

Figure 5: Flow behind the cylinder - mean velocity profiles in the vertical direction

values measured by the ADV are always lower, in the vertical direction the values are lower behind the cylinder, close to the cylinder edges the values are higher.

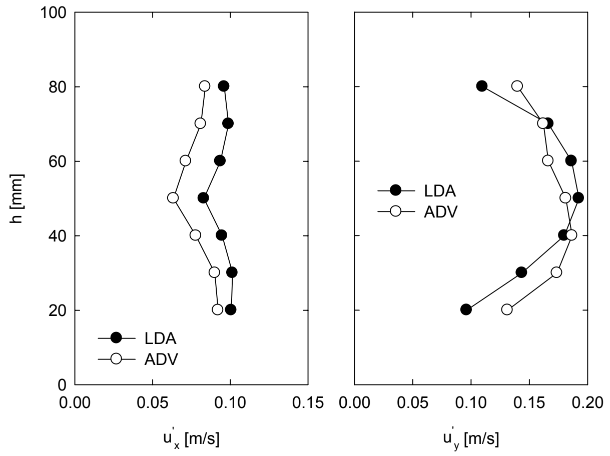

Figure 6: Flow behind the cylinder - RMS data of horizontal (left) and vertical (right) velocity component

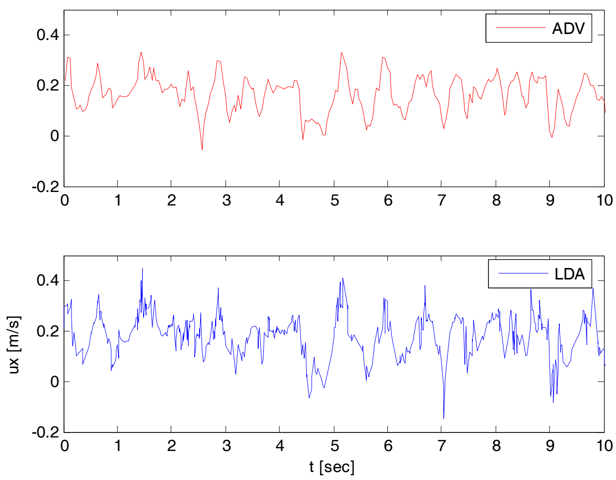

Figure 7: Flow behind the cylinder - time series of the longitudinal velocity component, h = 70 mm

Fig. 7 depicts the parts of the time series of the longitudinal velocity component measured simultaneously at a distance 70 mm above the channel bottom where a periodical vortex shedding was observed. As can be expected due to the relatively large measuring volume and low data rate (25 Hz) the ADV method is able to follow quite well only low velocity frequencies. This expectation was confirmed by our measurements. From the time series a FFT analysis was performed and the results are plotted in Fig. 8. The both methods practically indicate the same dominant peak frequency corresponding with the vortex shedding, f=1.378 (ADV), f=1.366 (LDA).

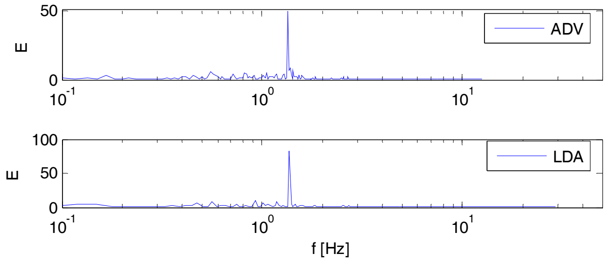

Figure 8: Flow behind the cylinder - FFT analysis of the longitudinal velocity component, h = 70 mm

The third experimental run represented flow behind the rectangular hole in the plate. This arrangement was chosen for a comparison of both methods in a region characterized by higher velocities and higher turbulent intensities. The measurements were performed at a distance 45 mm behind and along the vertical axis of the hole. The setting of the ADV measurements was as follows: size of the measuring volume - 6 mm, velocity range - 250 mm/s.

Mean velocity profiles in the longitudinal direction are plotted in Fig. 9. The origin of the vertical axis is placed at the lower rim of the hole. The velocities measured by the ADV are again lower but the ratio of the values of LDA and ADV velocities is no more constant as it was observed in the free surface flow. The ratio is

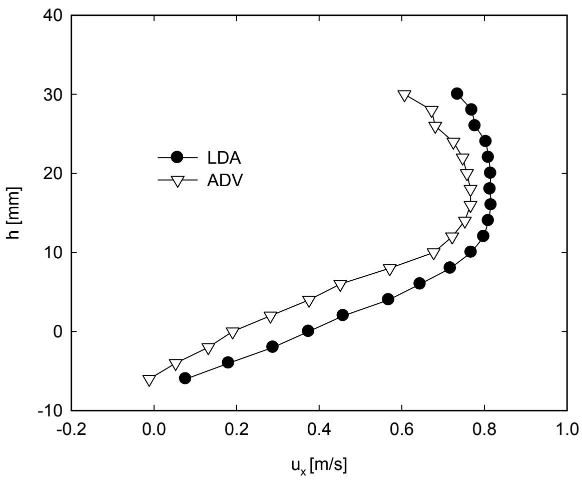

Figure 9: Flow behind the hole - mean velocity profiles in the longitudinal direction

plotted in Fig. 10. In the central part of the hole the velocity ratio is about 1.07 which coincides with the free surface flow but close to the hole rim the ratio is continuously increasing. An example of the time series of longitudinal velocities measured simultaneously at the level of lower rim is shown in Fig. 11. Due to the low data rate of the ADV probe and large measuring volume the ADV technique is unable to measure correctly in an area where a large turbulence level occurs. In such area the ADV has a tendency to smooth the velocity fluctuations as can be seen in Fig. 11. Such inaccuracy was also observed on RMS profiles of the longitudinal velocity component depicted in Fig. 12. At the centre of the hole the RMS values of the ADV probe correspond to the LDA data, but at a distance 7 mm above the hole rim ($u'_x \sim 0.20$ m/s) the ADV data are suddenly decreasing.

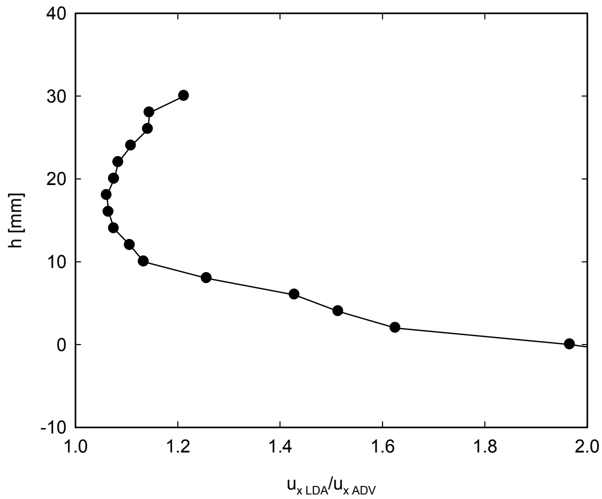

Figure 10: Flow behind the hole - ratio of the LDA mean longitudinal velocities to ADV mean velocities

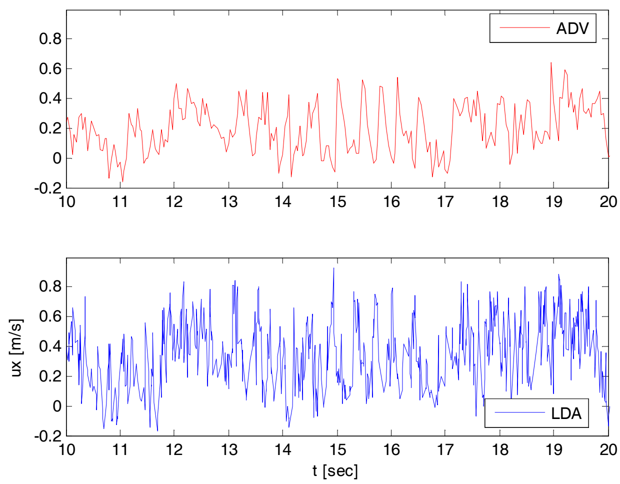

Figure 11: Flow behind the hole - part of the time series of the longitudinal velocities, h=0 mm

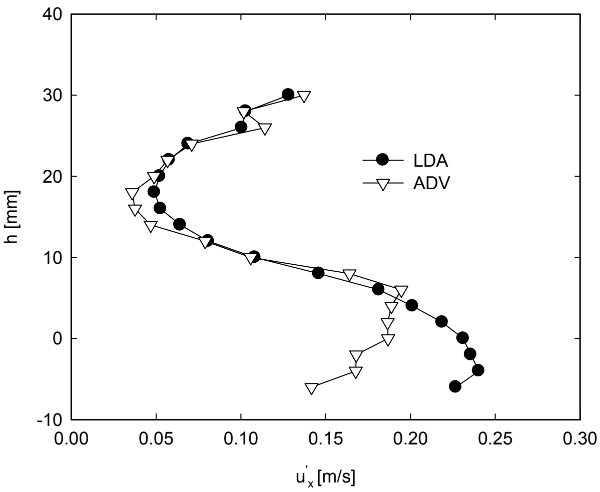

Figure 12: Flow behind the hole - RMS data of the longitudinal velocities

Mean velocity profiles in the vertical direction are shown in Fig. 13. While in the centre of the hole the ADV velocities correspond to the LDA data, close to the hole rim the deviation is strongly increasing. At the lower hole rim the ADV velocities are several times higher than the LDA data. Similar behavior can be seen in Fig. 14 where RMS profiles of the vertical velocity component are plotted.

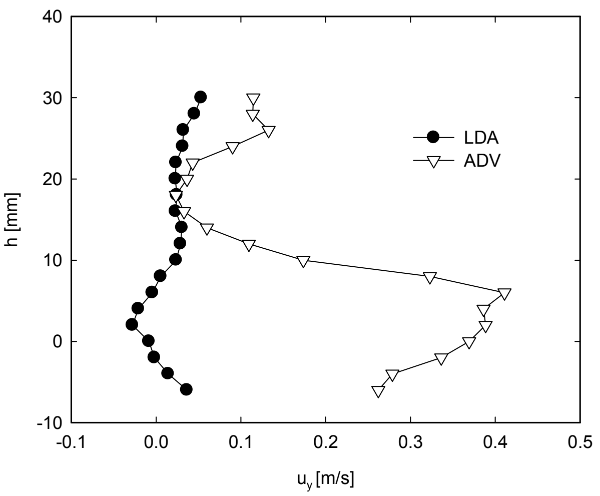

Figure 13: Flow behind the hole - mean velocity profiles in the vertical direction

5 CONCLUSIONS

In this study the comparative study of the ADV and LDA measuring techniques was performed for three different geometrical arrangements of free surface flows. In all tested cases the ADV method underestimated the mean velocities in the longitudinal direction. The deviation attains about 7% for relative simple flow geometry without large disturbances as open channel flow. This conclusion

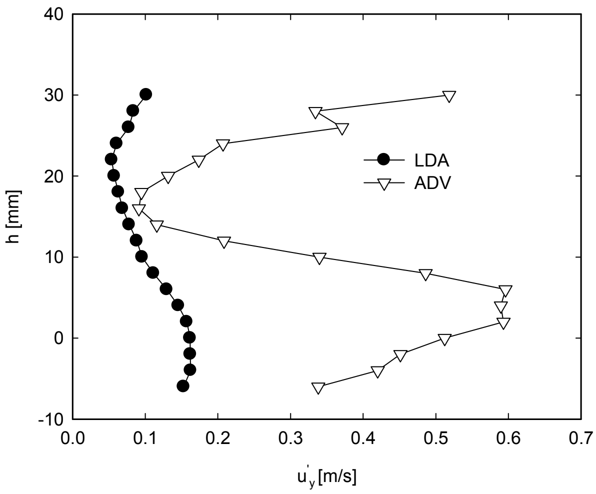

Figure 14: Flow behind the hole - RMS data of the vertical velocities

is consistent with the results published in [1]. But for increasing turbulence level is increasing the deviation between both techniques is also increasing. Mean velocity profiles in the vertical direction were measured for flows behind the rectangular cylinder and behind the hole. In both cases the deviation was larger in comparison to the longitudinal direction and for flow behind the hole the ADV method measured even higher mean velocities. We suppose that the measurement in the vertical direction is affected by one of the ADV probe which seems to be more sensitive.

ADV technique tested is suitable for flow conditions with relatively low turbulence level. In the case of higher turbulence the results have to be carefully analyzed.

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