EXPERIMENTAL INVESTIGATION OF THE FLOW PATTERN BEHIND CYLINDER

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Abstract

Investigation of the flow behind bluff bodies, especially for cylinder, is one of the highly topical research topics in the fluid mechanics. Nevertheless, mainly because of its complexity, this topic is still an open problem. This article discusses the running project at the Czech Technical University in Prague, Faculty of Mechanical Engineering and it deal with the implementation of a methodology for measuring the cylinder wake in a wind tunnel and also recapitulates the partial results obtained measurements.

Key words: *wind tunnel, measuring CTA, wake, PSD, frequency*

1 INTRODUCTION

Bodies in a flow can be divided into streamlined and bluff bodies. When the pressure force on a body dominates, we speak about bluff bodies. When the frictional force on a body dominates, we speak about streamlined bodies. A cylinder placed in a flow belongs to bluff bodies.

Investigation of a flow behind bluff bodies is one of the main topics of fluid dynamics. The knowledge of formation, interaction and decay of turbulent structures in a bluff body wakes makes it possible to predict flow stability and consequently influence and control wake behind these bodies.

The knowledge gained from the study of processes behind bluff bodies can be applied in the construction and development in almost all industrial applications. Wake shedding and shedding frequencies have an effect for example on noise, body drag and other phenomena associated with it.

Although the investigation of unsteady flow behind the cylinder, study of its wake and identification of its vortex structures is relatively frequent subject of research, it is still very current. With the continuous development of technology, measurement methods and computer simulations still improve and that is why it is possible to understand better the processes occurring in the bluff bodies wake.

The topicality and not yet fully clear understanding of this problem has led to the fact that currently there is an intensive research of the cylinder wake for the project SGS (student grant competition) at the Institute of Fluid Mechanics and Thermodynamics at the Faculty of Mechanical Engineering Czech Technical University in Prague.

2 EXPERIMENTAL STAND AND MEASURING METHODS

2.1 Experimental stand

A stand for measuring and visualization of the phenomena in the cylinder wake was built for the wind tunnel in the laboratories of the Institute of Fluid Mechanics and Thermodynamics. The wind tunnel is a closed circuit with open test section, driven by an axial fan. The fan is controlled by a frequency inverter, which regulates the flow speed. It is possible to adjust the flow speed in the range of 0.5 to 42 m/s. The nozzle on the outlet has a width 360 mm and a height 200 mm. The nozzle has an octagonal shape, which inhibits vortex formations in corners. The length of the test section of this tunnel is 395 mm.
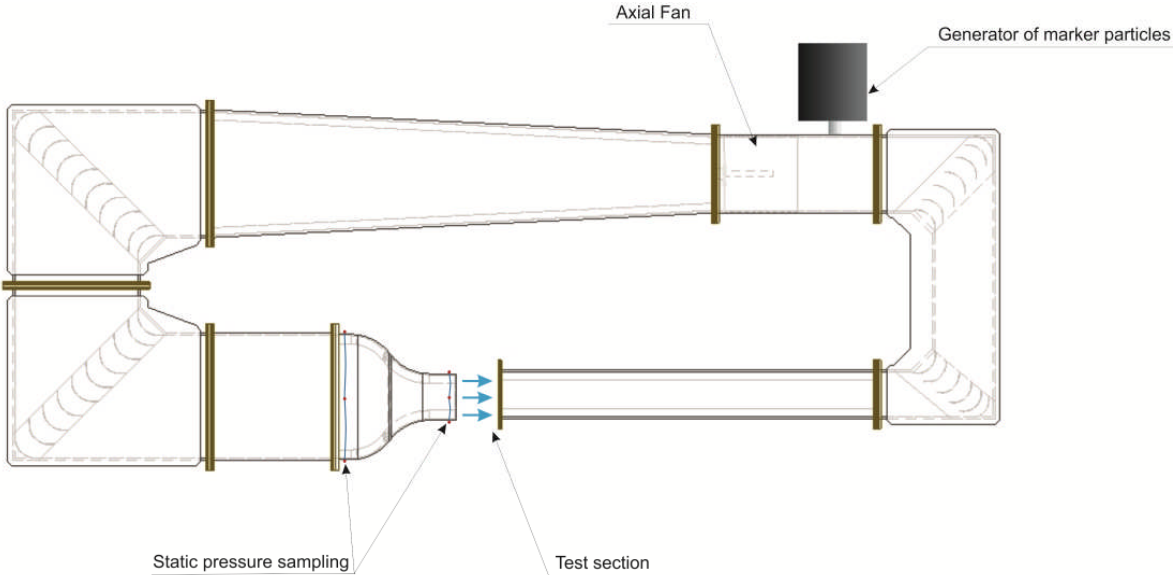

Fig. 1.: Scheme of the wind tunnel utilized for the measurement
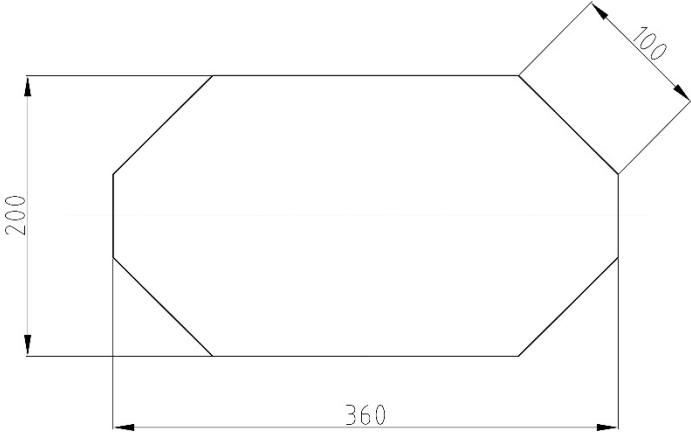

Fig. 2.: Dimensions and shape of the nozzle at the inlet to the measuring space

The air flow threads up across a measuring cylinder (figure 3). The distance between cylinder's rotation axis and outlet of nozzle is 140 mm. The wake was observed behind three cylinders. The first cylinder has a diameter of 3.89 mm, the second cylinder has a diameter of

9.84 mm and the third cylinder has a diameter of 20.88 mm. The diameters of these cylinders were selected based on requirements for values of Reynolds numbers.
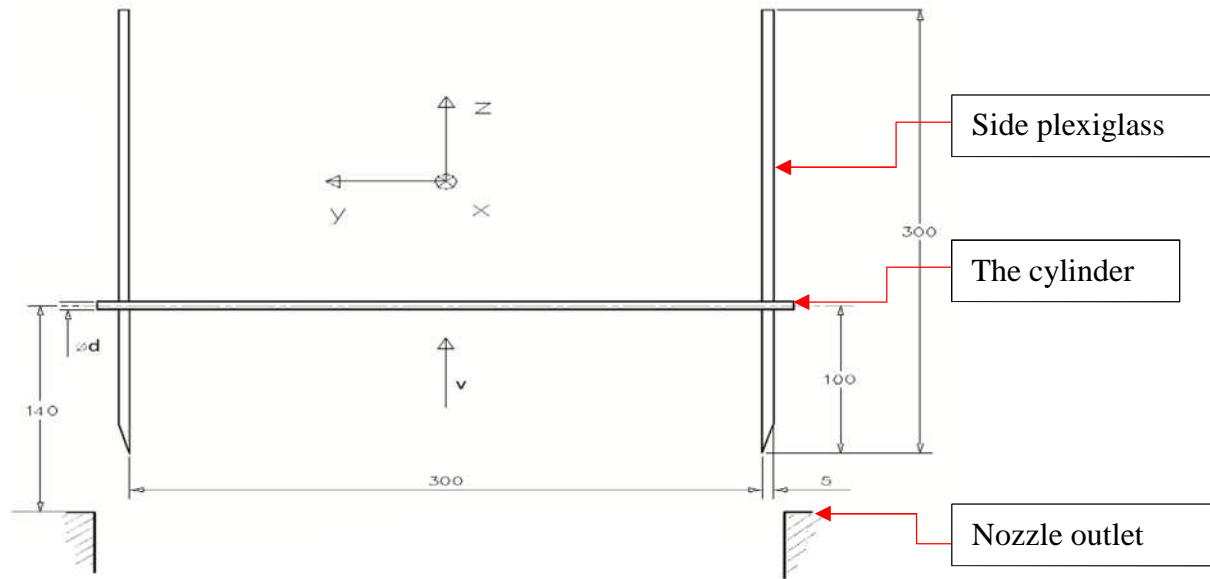

*Fig. 3.: Scheme measurement, where the **v** is direction of the running flow and **d** is the diameter of the cylinder*

For investigation of cylinder wake were applied the CTA method with hot wire and visualizations methods: the simply visualization of flow and TR PIV (time resolved particle image velocimetry).

2.2 Measuring CTA

For measuring the fluctuation of the speed is used measuring system for preheating anemometry with constant temperature probe (HWA). The measurement system includes a computer with a PCI card, measuring software created in LabVIEW, the device MiniCTA, a stabilized power supply and the hot wire probe. Because measurements are performed for the low speed, the working temperature of the probe is set to 250 ° C. Within the measurement the probe is positioned on a single carrier with manual traverse. Measuring and recording software provides preview processing of measured data in real time and store them in a text file with a defined data structure. The software allows setting the sampling frequency and the number of stored samples. From the measured and stored data by this software is able to immediately evaluate the mean velocity and turbulence intensity. During measurement this software evaluates immediately the mean of speed and turbulence intensity. It is thus possible to quickly identify possible adverse effects and verify the quality of the collected data, in particular the presence of electrical interference and noise caused by the presence of frequency converters in the surrounding power network. It's necessary for these conditions to adjust the settings of frequency filters in the unit MiniCTA, set the low pass filter 10 kHz.
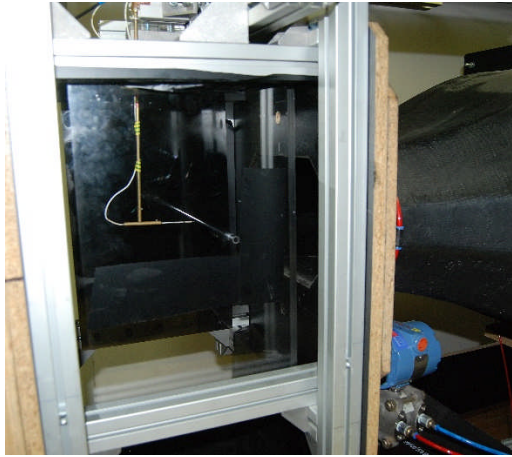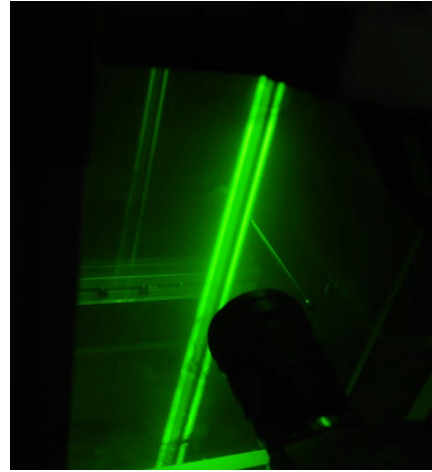
Fig. 4.: Measuring with the hot wire probe

Fig. 5.: Visualization

2.3 Visualization and TR PIV

Visualization and TR PIV is implemented using a high-speed camera system with camera Olympus i-SPEED 3, the laser module with TTL laser beam, which has a wavelength of 532 nm, and smoky particle generator SAFEX. The camera has options to capture up to 150,000 frames per second, but this setting degrades image resolution. For PIV is commonly used the value of 1000 - 3000 frames per second, for flow visualization is lower frame rate, around 300-750 frames per second. Used objective is an objective Nikon 85 mm with 36 mm extension tube.

3 MEASURING

In this section is given attention primarily by measuring the CTA.

3.1 The intensity of turbulence in the tunnel

Before the start of measurement it was necessary to measure the intensity of the turbulence in the test section of the wind tunnel. Turbulence intensity was measured for 6 points on the axis for 20 modes of flow velocity in the tunnel and one speed mode was measured grid of 6 points in a plane perpendicular to the flow direction.
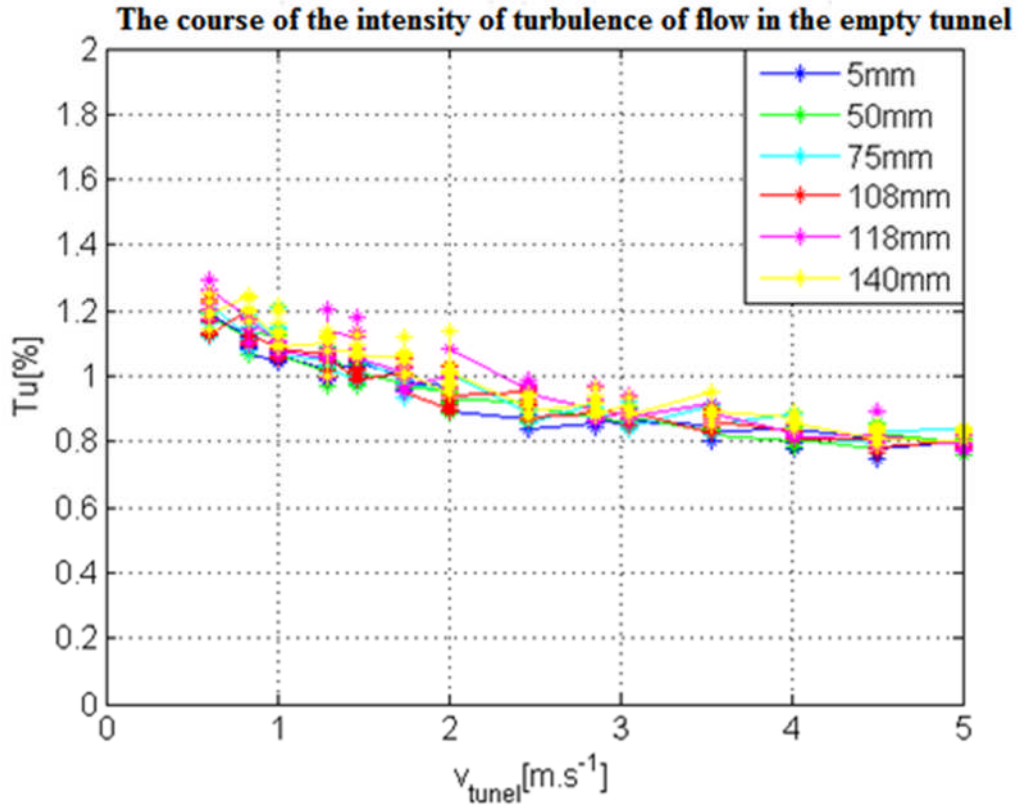
Fig. 6.: The course of the intensity of turbulence of flow in the empty tunnel

As seen from the graph in Figure 5, intensity of the turbulence is relatively low. It starts at around 1.2% and with increasing speed decreases to a value of about 0.8%.

3.2 Frequency Signal Analysis of the wake behind a cylinder

For each cylinder were measured field with 15 points for the 21 modes of Reynolds numbers (Re). The Reynolds number is defined as the ratio of inertial forces to viscous forces

$$Re = \frac{ud}{v} , \tag{3.1}$$

where u is the mean velocity of the fluid, d is the characteristic size (diameter), v is the kinematic viscosity of the flowing fluid.

The main point of this measurement was to obtain and verify (according to literature) the dominant frequency of vortex shedding in the wake. Therefore, the data calculated from the measured power spectral density (Power Spectral Density - PSD), which it define the distribution of signal power versus frequency. The equation for calculating the power spectral density S_{xx} is

$$S_{xx}(f) = \lim_{T_M \to \infty} \frac{1}{T_M} |X_{TM}(f)|^2, \tag{3.2} [1]$$

where T_M is the measuring time, X_{TM} is the frequency spectrum, f is the frequency.

From these data were obtained dominant frequencies in the wake. The key for the desired measurement modes were low Re. Given the potential for wind tunnel were achieved the lowest values Re for cylinders with a diameter of 3.89 mm, namely Re = 147, at the cylinder

with a diameter of 9.84 mm was the lowest measured Re = 334 and the cylinder with a diameter of 20.88 mm was achieved Re = 737.
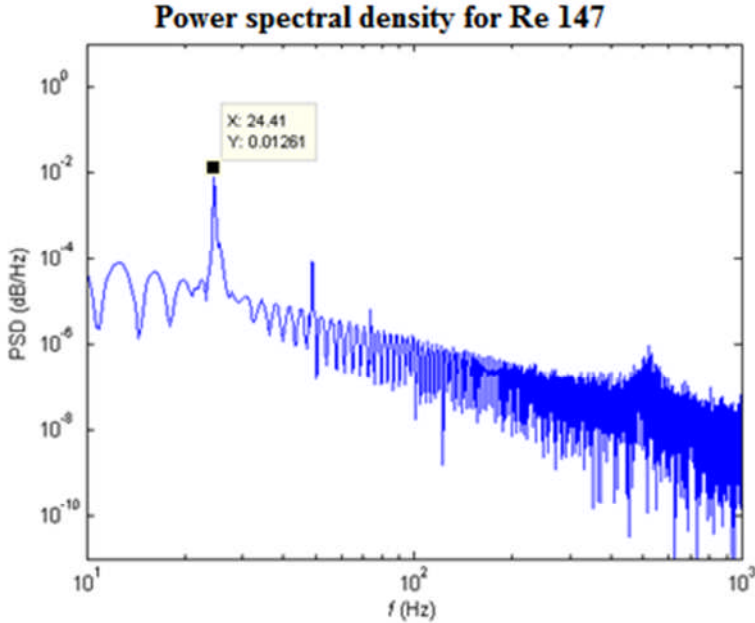
Power spectral density for Re 147

Fig. 7.: Power spectral density for the cylinder with a diameter of 3.89 mm with an enhanced dominant frequencies Re = 147
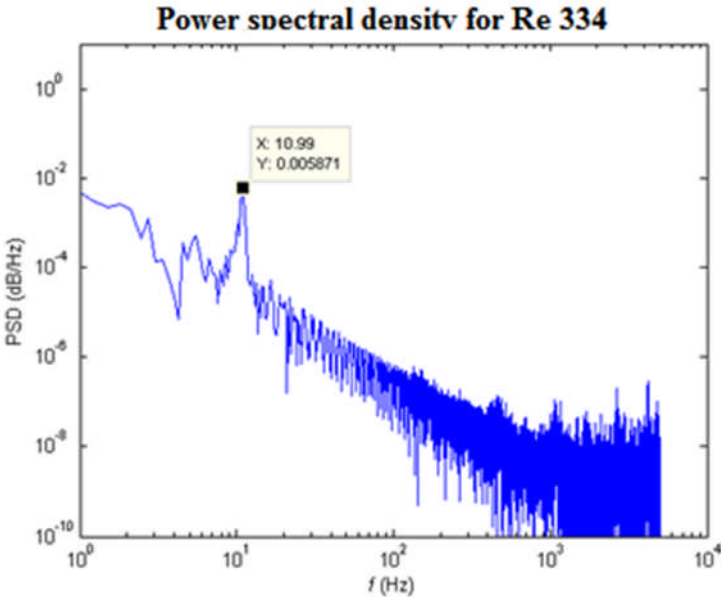
Power spectral density for Re 334

Fig. 8.: Power spectral density for the cylinder with a diameter of 9.84 mm with an enhanced dominant frequencies Re = 334

Furthermore, from the data calculated Strouhal's numbers (St). Figure No. 9 shows the dependence of the Re number for the cylinder with a diameter of 3.89 mm.
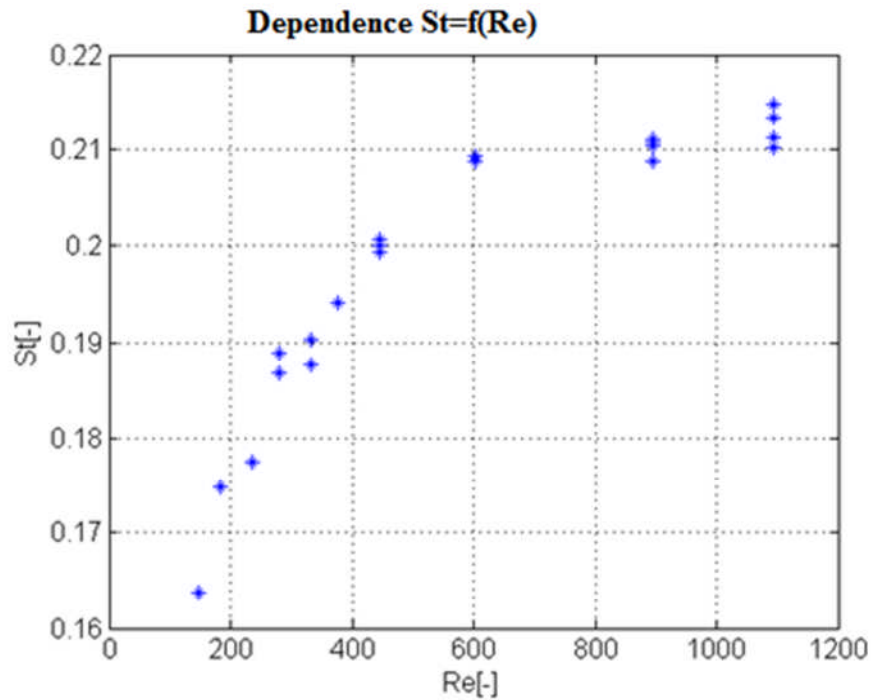
Fig. 9.: Dependence Strouhal number on Reynolds number for the cylinder with a diameter of 3.89 mm

3.3 Visualization and TR PIV

Visualization and TR PIV were measured for low values of the speed in the tunnel (approximately up to 1.5m / s), because the possibilities of the camera scanning the wake behind the cylinder are limited for higher velocities. Measurements were carried out for three different sizes of cylinders, therefore, to be measured for Re data from 147 to about 800.
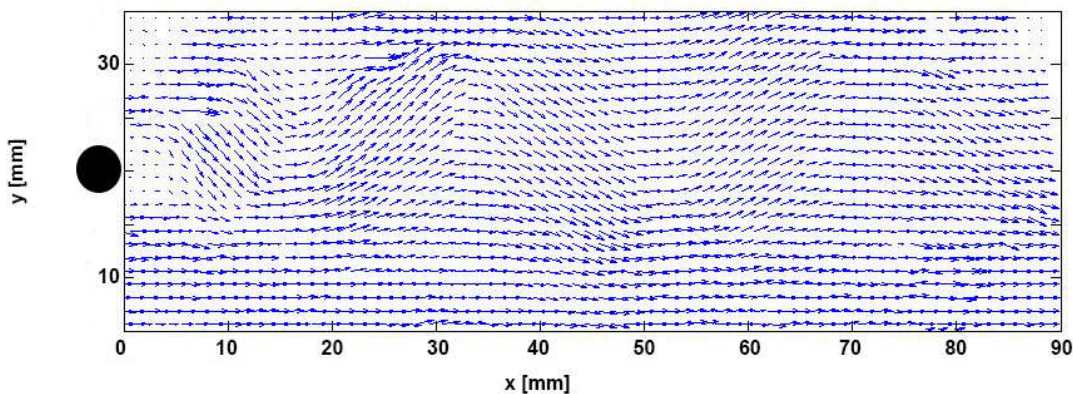

Fig. 10.: Velocity vectors in the wake behind the cylinder with a diameter of 3.89 mm at Re 147

On the figure 10 is to see a vector map of velocity in the wake behind the cylinder. On the picture is clearly visible vortex flow structure. In order to obtain this data, the camera was set to capture 2000 frames per second. (These data, as well as examples of the other images were taken just beyond the edge of the measured cylinder and the flow is from left to right.)
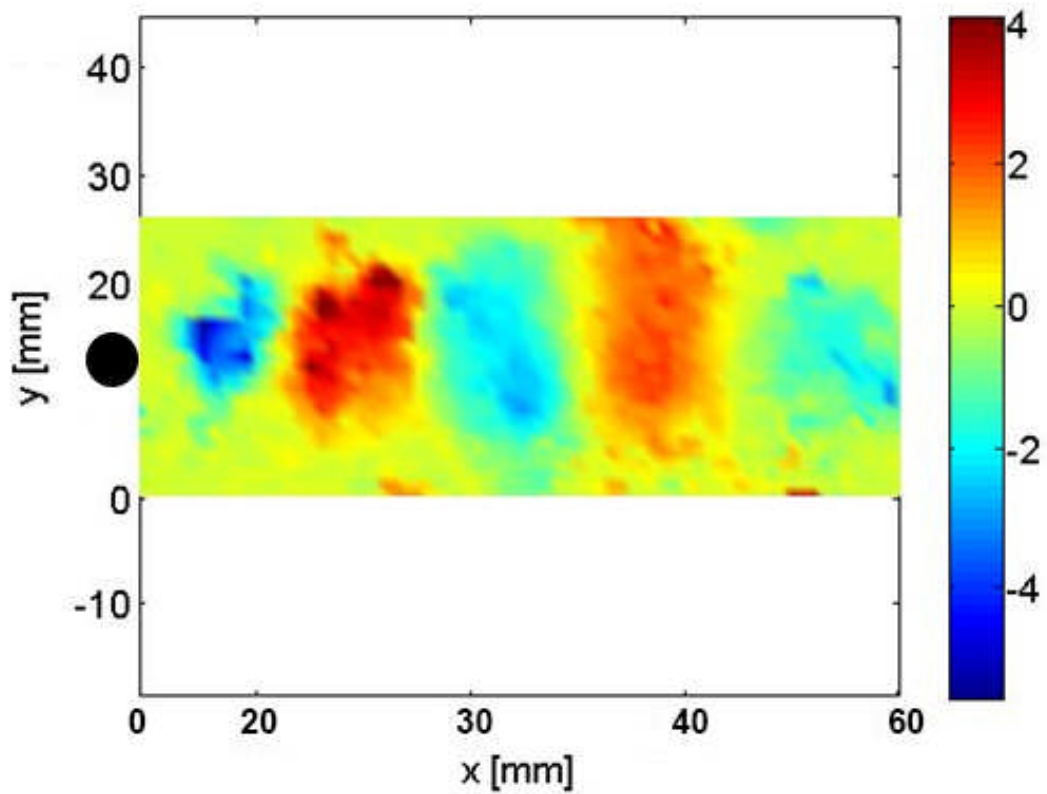
Fig. 11.: Velocity field behind the cylinder with a diameter of 3.89 mm at Re 147

The figure 11 shows the velocity field in the y direction. Here it is again clearly visible vortex structures. Visualization of the flow is in the following figure 12.
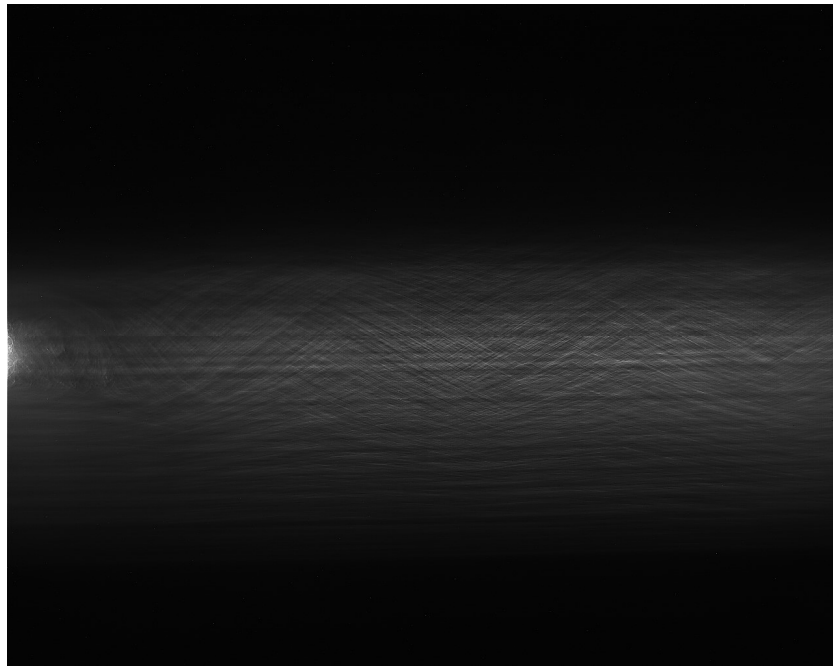

Fig. 12.: Visualization of flow behind the cylinder of diameter 3.89 mm at 147 Re

4 CONCLUSION

In this study the data were presented and the results of measurements of unsteady flow in the wake behind a cylinder. The dominant frequencies in the wake were found for measured cylinders and were taken a series of PIV data and visualization. In addition, intensity of turbulence in a flow was measured in the test section of the wind tunnel using hot wire probe. The aim of this project isn't to introduce something new, but experimentally verify the correctness of the chosen method of measurement, which becomes the default tool for other solution phenomena taking place in the wake. These include passive control of cylinder wake.

List of symbols

d	diameter of the cylinder	(mm)
v, u	velocity	(m/s)
v	kinematic viscosity	(m^2/s)
S_{xx}	power spectral density	(dB/Hz)
T_M	measuring time	(s)
X_{TM}	spectrum of frequency	(dB)
f	frequency	(Hz)

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