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D szekció: Áramlás- és hőtechnika
Section D: Fluid and Heat Engineering
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DESIGN OF SUCTION PIPE FOR A WIND-TUNNEL

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1. INTRODUCTION

An open circuit wind-tunnel for flow measurements was designed in 2009. The size of the test section is 500x500x800 mm [1, 2]. The prismatic bodies placed in the test section of the wind-tunnel and the flow around the prismatic bodies is investigated by LDA (Laser Doppler Anemometry), PIV (Particle Image Velocimetry), CTA (Constant Temperature Anemometry) [3-5]. The temperature field is determined by special probe of CTA system, Z-type Schlieren system and BOS (Background Oriented Schlieren) system [6]. The properties of the wind-tunnel: blow-down wind-tunnel, with the test section placed near the end of the wind tunnel. Environment air is blown into the wind-tunnel by axial fan. Oil fog is required for PIV and LDA measurements and a suction pipe is needed for the disposal of the oil fog from the test area. The first objective of this work is to design the optimal suction pipe for the wind-tunnel system. The range of suction speed: c=0.3-5 m/s. The suction pipe has two functions; in the first case oil fog is sucked by the suction pipe. In the second case low speed (c=0.3-1 m/s) is created by only the suction pipe. Uniform velocity distribution is required in the second case; it is the main goal of this work. Vanes are placed into the suction pipe bend. The lengths and positions of the vanes are determined by set goal. Numerical simulation is made by Ansys-FLUENT software. Velocity distribution in the suction pipe is controlled by 3D numerical simulations.

2. WIND-TUNNEL

The wind-tunnel is shown in Figure 1. The suction pipe is designed for this wind-tunnel (to remove the oil fog).
The influence of friction can be seen in Figure 7. The hydraulic loss of the suction pipe with three vanes increases because of the extra frictional surfaces (three vanes). The change of hydraulic loss is compensated by the uniform velocity distribution (see Figure 6). The selection of the roof fan and frequency changer is assisted by the findings shown in Figure 7.

5. CONCLUSIONS

The results presented in this work confirm that the suction pipe is suitable for creating uniform velocity distribution in the whole velocity range. The influence of vanes is presented in this work. The required parameters of the roof fan and frequency changer are selected from the hydraulic loss diagram. The suction pipe is suitable for setting the suction volume flow rate (to remove of the oil fog).

6. ACKNOWLEDGEMENTS

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REFERENCES


DEVELOPMENT OF A PIV-BOS TECHNIQUE FOR SIMULTANEOUS MEASUREMENT OF VELOCITY AND TEMPERATURE FIELD

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1. INTRODUCTION

Bluff bodies placed in a flow, such as electrical transmission lines, cartridge heaters, pipes of heat exchangers, factory chimneys and so on, often have a different temperature compared to that of the surroundings. The structure of the flow developing around bluff bodies has been already examined for a long time [1, 2]. The evolving Kármán vortex street was and is examined by numerous researchers, both experimentally and numerically. Nevertheless, the question arises, how this vortex street is modified by a heated cylindrical body. What is the influence of heating on the frequency of the detaching vortices, the structure of the vortices and the location of the detachment? Many of these questions already have been answered by the help of numerical simulation and of measured velocity distributions using Particle Image Velocimetry (PIV) and vortex distributions obtained from these [3]. A further question is the heat loss caused by the vortex structure and forced convection. To tackle this question, the Background Oriented Schlieren (BOS) method described below has been applied. At the same time, the first steps have been taken towards determining the temperature and vortex distributions in real time, which are introduced in this paper.

The objective of this work was to carry out non-intrusive measurements of the temperature and flow fields by means of BOS and PIV respectively, using the experience from previous research [5-9]. The flow was examined behind a heated cylinder, mounted in a Göttingen-type (closed-loop) wind-tunnel with suitable conditions. Future intention is to validate existing numerical calculations.

2. EXPERIMENTAL SETUP

The experimental set-up is mounted in a closed-loop wind tunnel (Fig. 1). The cross-section of the test area had the dimensions of 500x600 mm. The mean velocity was set to 0.5 m/s, since this was the minimum stable velocity of the wind-tunnel in this configuration. This led to a flow Reynolds number in the wind-tunnel of Re=11000, calculated from the mean flow velocity in the test section, the hydraulic diameter and the viscosity of the air at ambient temperature. Two transparent windows were mounted on both sides of the measurement section, with a hole in the middle, used to mount the heated cylinder perpendicular to the main flow direction (see Figure 1). The cylinder with a diameter of 10 mm was electrically heated by an adjustable transformer. The mean temperature of the cylinder was measured by a
thermocouple and the power of the transformer was adjusted according to the desired value. The cylinder Reynolds number was \( Re_{cy} = 200 \).

Figure 1. Schematics of the experimental setup

3. PIV/BOS SYSTEM

The system used for the present measurement was a regular 2D-PIV system, consisting of the components listed in Table 1.

Table 1. Description of the PIV/BOS system

<table>
<thead>
<tr>
<th>Component</th>
<th>Remarks</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double frame CCD camera</td>
<td>Flow Sense 2M/E with 8 bit resolution, recording frequency: 15 Hz</td>
<td>Dantec Dynamics</td>
</tr>
<tr>
<td>Objective</td>
<td>Manual Focus Nikkor 180 mm; f-number: 11 focus set to ( \sim 4 m )</td>
<td>Nikon</td>
</tr>
<tr>
<td>Double pulse Nd-YAG laser</td>
<td>Power: 2x300 mJ at 532 nm, max. frequency: 15 Hz</td>
<td>Litron</td>
</tr>
<tr>
<td>High-energy mirrors</td>
<td>for a wavelength of 532 nm</td>
<td>CVI Melles Griot</td>
</tr>
<tr>
<td>Laser sheet-optics</td>
<td>( f = -10 )</td>
<td>LaVision</td>
</tr>
<tr>
<td>Timer box</td>
<td>TTL logical electronic unit to change the laser light and LED lights</td>
<td>Self-produced</td>
</tr>
<tr>
<td>PC with a frame grabber card and PIV software</td>
<td>For image data acquisition and for the processing of the acquired data</td>
<td>Dantec Dynamics</td>
</tr>
</tbody>
</table>

The applied software for the acquisition and evaluation was a commercial PIV software (Dynamics Studio 3.0 from the co. Dantec Dynamics), used both for PIV and BOS measurements. The PIV measurements are only briefly discussed here, since there are numerous publications describing the principals of PIV (e.g., [4]). Camera alignment was the same for both PIV and BOS measurements. The camera was calibrated by the help of a calibration plate to set the pix/mm factor and to eliminate possible distortion. The camera optics was focused on the calibration plate and the \( f \)-number (the focal length of the lens divided by the “effective” aperture diameter) was set to 11.

3.1. Timer Box

The timing diagram of the synchronization method assuring that the temperature and velocity information were synchronized is shown in Figure 2. The PIV and BOS pictures were made in the same recording (order of recording is shown in Figure 2). The measurement area was lit by the laser (at PIV recording). The background (for the BOS measurement) was lit by LEDs (shown in Figure 3).

Figure 2. Timing diagram

LEDs were placed between the wind-tunnel and the background plane (Figure 1).

Figure 3. Experimental LEDs setup
This timer box (with timer electronics) was especially developed for the PIV/BOS measurements. A block diagram of the timer box is shown in Figure 4.

![Block diagram of the timer box](image)

Figure 4. Schematics of the timer box setup

3.2. PIV Measurements

For the PIV measurements the background was not illuminated and the TTL electronics turn on the laser light. Oil droplets of 3 μm diameter were added to the flow as tracer particles and the measurement plane was lit by a doubled Nd:YAG double pulse laser through the light sheet optics with 300 mJ/pulse. The velocity field was calculated from the scaled images using a cross-correlation with a 64x64 pixel interrogation area, with 75% overlap. The resulting vector maps were then exported to ASCII files for later visualization using Matlab®.

3.3. BOS Measurements

For the Schlieren measurements a background with white noise was printed and placed 0.5185 m behind the plane of focus. The background was illuminated homogeneously with LEDs (in every second double frame), such that the same f-number could be applied as in case of the PIV measurements. The Schlieren recordings were carried out in double frame mode, (where only the second frame was used). The time between two double frames, was \( B=1500 \) μs (see Figure 2), was important for the calculation of the deflection from the exported correlation information. The cross-correlation was carried out with an interrogation area of 32x32 pixels and an overlap of 75%. The results were also exported into an ASCII file for later post processing and visualization in Matlab®.

4. RESULTS

The raw PIV (laser lighting) and BOS (LEDs lighting and background) recordings are shown in Figure 5. The vortex shed can be seen in the PIV picture (left image). The diffraction, caused by the air density change near the heated cylinder, can slightly be seen in the BOS picture.

![PIV and BOS raw picture](image)

Figure 5. PIV and BOS raw picture (573 K)

The resulting velocity field (PIV method) and temperature field (BOS method) are shown in Figure 6. More details about PIV and BOS method can be found in chapter 3 and [8, 9]. The periodicity of the vortex and temperature detachment can be seen in Figure 6 (velocity and temperature contour plot).

![Velocity and Temperature field](image)

Figure 6. Velocity field and Temperature field (cylinder temperature: \(~573 K\) )

5. CONCLUSIONS

The measurement results presented in this work confirm that the BOS system is suitable to visualize and quantify the temperature field of the vortex street behind a heated cylinder in a wind tunnel. A Matlab® script was successfully applied to the calculation of the temperature field from the measured deflection, resulting from the density variations in the flow. Thank to the employed timer box, the temperature and velocity measurements could be reasonably synchronized. However, considerable improvements (especially concerning timing method and optics (convex lens to parallel light rays)) are still required in the existing system to make more reliable and comparable measurements. In order to analyze the images in a
further step, the recording quality must be increased to get more meaningful images (high speed camera (decrease the time between two recordings)). A further validation possibility should also be found to check the measured temperature values in the aim to detect the differences in vortex shedding due to the temperature of the cylinder.

6. ACKNOWLEDGEMENTS

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REFERENCES


EFFECT OF GAP GEOMETRY ON FLOW LOSSES

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1. INTRODUCTION

During the design of hydraulic reducing elements, it is important to determine the relationship between the pressure differential and the volume flow rate through a reducing gap. The flow coefficient (Kv) as a gap resistance factor is determined by the previous data. The main objective of this study is to determine the relationship between the volume flow rate, flow coefficient (Kv), and gap geometry (gap cross-section of 9 mm²). Numerical simulation and experiments were carried out for the following gap shapes: square, circle and triangle. Another objective of this study is to use measurements to validate computational results for one case (gap length of L=15 mm) in order to be able to predict numerical results for further cases. The range of the pressure difference between the two ends of the gap is Δp=10-80 bar. Numerical simulation is carried out using the Ansys Fluent software package.

2. GAP SHAPE AND EXPERIMENTAL CASES

Reducing elements with a center hole (L=15 mm) are made from cylindrical body (Ø62). Reducing elements are shown in Figure 1. The three differential gap shapes (A_ba,=9 mm²) and sizes are shown in Figure 2. The test section and pressure measurement points (50 mm from the reducing element) are shown in Figure 3. Outlet pressure is set to p2=30 bar (to avoid cavitation). The pressure difference between the inlet and outlet is Δp=10-80 bar (given by measurement system).

Figure 1. Reducing elements
Figure 2. Size of gap shapes

MOL Hydro HM 46 hydraulic oil is used as the flow medium. Its temperature-dependent properties (density, viscosity, specific heat, heat conduction) are used in computations and the measurement process [1].

Figure 3. Size of pressure measurement points