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A projekt a Nemzeti Kutatási és Technológiai Hivatal támogatásával valósult meg.
TEMPERATURE FIELD VISUALIZATION AROUND A HEATED CIRCULAR CYLINDER BY SCHLIEREN TECHNIQUE

Péter Bencs¹, Szilárd Szabó²
¹PhD student, ²Professor
Department of Fluid and Heat Engineering, University of Miskolc, Hungary

1. INTRODUCTION

Prismatic bodies placed in a flow often have different temperature compared to that of the surroundings such as electrical transmission lines, cartridge heaters, pipes of heat exchangers, factory chimneys and so on. The structure of the flow, developing around prismatic bodies has been already examined for a long time. The evolving Kármán vortex street was and is examined by numerous researchers both experimentally and numerically. Schlieren measurement technique has also been investigated by many researchers [1-3]. For example, such a Schlieren system can be used for visualization of shockwave in a supersonic tunnel [4-7]. The system is basically adapted for 2D measurements; there are many problems with 3D measurements [4]. The experimental tests were carried out at low Reynolds numbers (Re<200), thus the flow field was approximately two dimensional (same flow in every normal planes of a heated circular cylinder). The method has also been used for general visualization of heat transport processes [4]. In this work the adaptability of a Schlieren system is investigated, which should be ultimately applicable in a wind-tunnel in order to investigate forced convection flows. An electrically heated circular cylinder was placed perpendicular to the flow in a wind tunnel. The first objective of this work is to determine the structure of the instantaneous temperature field. The results show, that the system will be good for quantitative measurements. Image processing will be the next important part of this project.

2. PRINCIPLE OF SCHLIEREN MEASUREMENT TECHNIQUE

The basic optical Schlieren system uses light from a single collimated source shining on, or from behind, a target object. Variations in refractive index caused by density gradients in the fluid distort the collimated light beam. The collimated light is focused with a lens, and a knife-edge is placed at the focal point, positioned to block about half the light. In flow of uniform density this will simply make the photograph half as bright. However in flow with density variations the distorted beam focuses imperfectly and parts which have focused in an area covered by the knife-edge are blocked. The result is a set of lighter and darker patches corresponding to positive and negative fluid density gradients in the direction normal to the knife-edge. When a knife-edge is used, the system is generally referred to as a Schlieren system, which measures the first derivative of density in the direction of the knife-edge. Temperature is determined from density (refractive index) [4]. Principle of that is shown in Figure 1.
3. EXPERIENCES OF Z-TYPE SCHLIEREN SYSTEM

First z-type Schlieren system was built up in wind tunnel (Laboratory of Fluid Dynamics and Technical Flows, University of Magdeburg "Otto von Guericke").

First setup can be seen in Figure 2. and the first results are shown in Figure 3:

Figure 3.
First results of Schlieren measurements at 0.3 m/s. Cylinder temperature was 100, 200, 300°C respectively (from left to right).

The measurement results presented in this work confirm that the z-type Schlieren system is in principle suitable to visualize and qualitatively analyze the temperature field in a wind tunnel. However, considerable improvements (such as stable frame for the complete system, digital camera, or knife edge with fine adjustment screws) are still required in the existing system to make more precise and really accurate measurements. In order to analyze the images in a further step, the recording quality must be increased to get more meaningful images.

4. APPLICATION OF THE SCHLIEREN SYSTEM IN THE WIND TUNNEL

General recommendation for the applications of a z-type Schlieren system according to Settles [4]:

- According to an old rule, the mirror thickness ought to be 12-17% of the mirror diameter for stability.
- To achieve good quality, the ratio of the mirror surface smoothness should be between $A/8$-$A/10$, where $A$ is the wavelength of the light and the ratio gives the deflection of the wave front, caused by the surface roughness of the mirror.
- A minimum distance between the field mirrors of about $2f$, is required to provide enough space for the test area, where $f$ is the mirror focal length.
- The recommended process to minimize both astigmatism and coma is to limit the offset angles $\theta$ to their minimum practical values. Furthermore, mirrors with $f/n$ with $n$ equal to 6 or greater are strongly recommended. The mirror power in z-type Schlieren systems is usually between $f/6$ and $f/12$, where $f/n$ expresses the ratio of the focal length and mirror or lens diameter.

Table 1.
Properties of the applied components in the z-type Schlieren system

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror thickness</td>
<td>25% of the diameter</td>
</tr>
<tr>
<td>Optical quality of the mirror</td>
<td>$A/8$</td>
</tr>
<tr>
<td>Offset angle</td>
<td>$\theta=3.81^\circ$</td>
</tr>
<tr>
<td>Power of lens</td>
<td>$f/10$</td>
</tr>
<tr>
<td>Distance between the mirrors</td>
<td>$L=4500$ mm</td>
</tr>
</tbody>
</table>
The Schlieren system is applied here to qualitatively describe the temperature distribution in a flow around a heated cylinder. The measurement system has been adapted according to the available place around the test section of the wind tunnel. The properties of the applied components are detailed in Table 1. New setup can be seen in Figure 4 and Figure 5. Complete Schlieren System (mirrors, camera, light source) is built up on a stable body (steel frame). Colour filter was applied instead of knife edge. Different type of colour filters can be seen in Figure 6. Best result was visualized by circle colour filter (Figure 6/1).

5. RESULTS

The temperature distribution has been investigated in the wake of a heated cylinder. Temperature of the cylinder has been set to 300°C respectively. The range of air flow velocity in the wind tunnel has been set to 0-0.3 m/s. First results for different velocities are shown by the Schlieren images in Figure 9. The principle usability of our z-type Schlieren system was confirmed by these results, as with increasing velocities, the temperature distribution was changing as well. Free convection and forced convection is introduced in Figure 9. (convection change by velocity changing). Now it will be necessary to fine tune the Schlieren system, in order to get more contrasted and fine structured images, by adjusting the light intensity and position, the colour filter.

Figure 1.
First results of Schlieren measurements at 0-0.3 m/s. Cylinder temperature was 300°C respectively (from left to right).
6. CONCLUSIONS

The measurement results presented in this work confirm that the z-type colour Schlieren system is in principle suitable to visualize and qualitatively analyze the temperature field in a wind tunnel. However, considerable improvements (such as precisions colour filters) are still required in the existing system to make more precise and really accurate measurements. In order to analyze the images in a further step, the recording quality must be increased to get more meaningful images.

7. ACKNOWLEDGEMENTS

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REFERENCES


EXPERIMENTAL STUDY ON EFFECT OF VIBRATION ON THERMAL CONVECTION

David Jesch
Research engineer

Department of Applied Mechanics, Budapest University of Technology and Economics

Abstract - World's economies are experiencing substantial challenges from newly evolving long term forces. Therefore there is an increasing pressure to manage fossil fuel consumption and hence emissions in a more suitable manner. In order to achieve this goal there are several approaches in car industry to use waste heat to produce electricity in order to supply power for different actuators. One method is to plant packed thermoelectric modules near the exhaustive pipe. In this way the modules are exposed to vibration. Certain studies and numerical simulations show, that vibration can change the parameters of thermal convection. At certain resonance frequencies the Nusselt-number can change significantly due to vibration-enhanced flow in the enclosure. The details of the process are still not perfectly understood. In this paper the background of this phenomena is summarized including the theoretical approaches and the results of the numerical simulations. In addition an experimental setup is introduced in order to determine the magnitude of the effect at a special case.

INTRODUCTION

The transportation industry worldwide meets new challenges recently such as reducing fossil fuel consumption and emissions (including green house gases) while providing recyclable and cost competitive products. Therefore several new methods are investigated to simplify the electrification process. There is a tendency of reducing fuel consumption by replacing a significant portion of the alternator produced electric power with electric power produced from waste heat conversion to electricity in a Thermoelectric Generator Module (TGM) [1-3]. According to studies, approximately one third of the energy is lost through engine cooling system and an other one third through exhaust heat. Nowadays waste heat recovery systems are planned to use this exhaust gas waste heat (Figure 1).

Figure 1: Exhaust gas waste heat recovery system block diagram [1]
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