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RESEARCH OF LOCAL VALUES OF HEAT TRANSFER COEFFICIENTS IN THE AREA OF HEATED CURVED WALL

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Abstract: *The paper focuses on determination of local values of the heat transfer coefficient during the flow around heated curved wall by mortise air flow. In the paper there are presented the pictures of temperature fields, which were used to determine temperature profiles and consequently the distribution of local values of heat transfer coefficient. During experiments we used the regime of natural air convection and we compared the distribution of local values of the heat transfer coefficient during forced convection. Raising the speed of streaming led to the change of local values of the heat transfer coefficient as it is illustrated in the figure 2. To visualize temperature fields and consequently the analysis of local values of the heat transfer coefficient we used the method of holographic interferometry.*
Key words: *temperature, cylinder, velocity, interferometry.*

1. INTRODUCTION

Streaming of fluids (most often the air) around heated curved walls can be encountered in many technical appliances e.g. heat exchangers, combustion chambers, heating appliances, cooling appliances, at curved surfaces of engines, machines and various other technological appliances.

The paper describes the investigation of the distribution of the local values of the heat transfer coefficient in the area of curved walls for streaming of the air from a mortise located above the upper part of cylinder surface (Fig. 2). The aim of this research is especially the analysis of temperature fields and temperature profiles necessary to determine the distribution of local values of the heat transfer coefficient inevitable for gaining the knowledge to optimalize the construction disposition of some technological appliances from the viewpoint of efficient thermal performances. The convection part of heat transfer has a significant influence on effective and optimal disposition of tubular heat exchangers. The information about temperature distribution in boundary layers enables us to determine more effectively surface temperature gradients which are necessary to calculate heat transfer.

To visualize the temperature field we used the method of holographic interferometry. This optical method allowes to visualize transparent inhomogeneity in the whole observed space (Pavelek, 2001), which enables us to achieve a complex picture of the observed object even without a direct contact with the object it means without interference of stream profile.

While carrying out literature retrieval we found several studies which dealt with the topic. The research of heat transfer for natural air convection in the compositions of heated vertical plates with constant temperatures is described by Pavelek (2001). Heat transfer by natural convection of the air on vertical plates and in mortises was investigated on a model by the interferometric method. The analysis of temperature fields above horizontally laid objects using holographic interferometry was dealt by Pivarčiová (2009).

Two-dimensional flow along an inclined plane wall and the impact of Coanda effect on the flow character is described also in the paper of Allery et al. (2004). He dealt there with an experimental investigation and numerical simulation of the flow along one and also two symmetrically inclined planar walls. The research of local heat transfer in heat exchangers by holographic interferometry was also elaborated by Fehle at al. (1995). He tested two types of geometries and as a testing medium used the air. The tested part of the experimental facility was heated by warm water so that to ensure even temperature of the surface. To visualize temperature fields he applied holographic interferometry.

Naylor (2003) elaborated the comparison of traditional and holographic interferometry which are used in the research of convection heat transfer. He also dealt with the analysis of knowledge for investigation of multidimensional temperature fields.

2. CALCULATION OF HEAT TRANSFER FROM TEMPERATURE DERIVATIONS

During circumfluence of block surface by fluid with the temperature T_∞ different from the surface temperature T_{wx} in the spot *x*, the local heat transfer between the surface and the fluid occurs in this spot.

The value of the local heat transfer coefficient α_x depends on many factors, e.g. the kind of flowing fluid, the flow velocity, the shape of the circumfluent surface, the position of the researched spot and on the difference of temperature between the surface and fluid.

Local value of the heat transfer coefficient can be calculated from the equation (Pavelek & Janotková, 2007):

$$\alpha_x = -\lambda_v \left(\frac{dT}{dy}\right)_{wx} \frac{1}{T_{wx} - T_\infty}, \tag{1}$$

where λ_v is the coefficient of the thermal conductivity (stated for the temperature of surface), T_{wx} is the surface temperature, T_∞ is the fluid temperature (the surrounding).

Based on measured or calculated shape of temperature profile we can express the temperature difference $(T_{wx} - T_\infty)$ and derivation of the temperature using an angle β_x, which is created by a tangent line towards the temperature profile in the place of surface and with an *y* axis.

For derivation of temperature at surface in the right direction towards the surface it applies:

$$\left(\frac{dT}{dy}\right)_{wx} = tg(\beta_x)\cdot \tag{2}$$

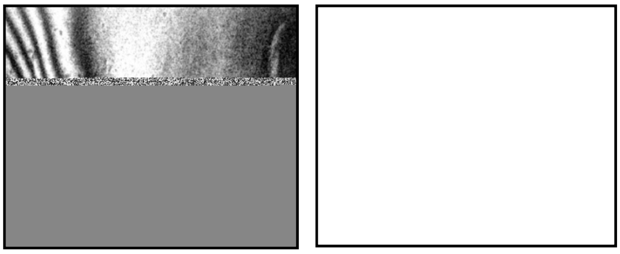
Installing this equation into the equation (1) will produce the relation to calculate the local value of the heat transfer coefficient:

$$\alpha_x = -\lambda_v \cdot tg(\beta_x)\cdot \frac{1}{T_{wx} - T_\infty}\cdot \tag{3}$$

Such a method of calculation of the heat transfer coefficient from temperature derivations can be advantageously applied in the interferometric research of heat transfer because interferograms can be used to state detailed distribution of fluid temperatures (Pavelek, 2007).

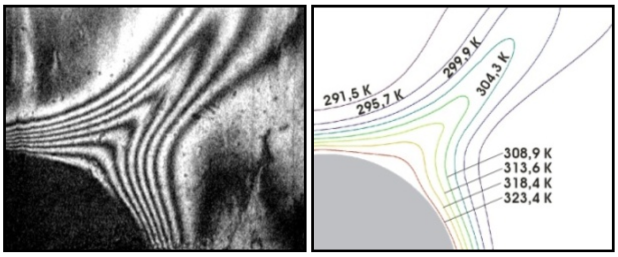
3. MEASUREMENTS

To analyse temperature fields in the area of inclined wall the temperature fields were observed around a cylinder with 50 mm diameter. The air flew from 10 mm – wide mortise. The schematic layout of the air outlet towards the inclined wall is pictured in the Fig. 2 left. The experiments were carried out at surface temperature $T_w = 323{,}5$ K, at free air convection and as well at forced convection for the velocities of fair flow $u_{b1} = 0{,}16$ m.s^{-1} and $u_{b2} = 0{,}3$ m.s^{-1}. Samples of pictures of holographic interferograms of temperature fields around the cylinder and their quantitative analysis are in the Fig. 1.



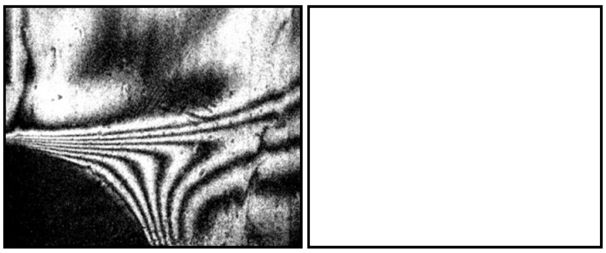
holographic interferogram quantitative analysis

a) free air convection



holographic interferogram quantitative analysis

b) forced air convection, $u_b = 0{,}16$ m.s^{-1}



holographic interferogram quantitative analysis

c) forced air convection, $u_b = 0{,}3$ m.s^{-1}

Fig. 1 Temperature fields around the cylinder ($T_w = 323{,}5$ K, $T_\infty = 291{,}5$ K, d = 50 mm, b = 10 mm)

4. RESULTS AND DISCUSSION

In the figure 1a there is shown the temperature field around the cylinder with the surface temperature 323,5 K at free air convection. The air flows in the boundary layer in the direction upwards and the boundary layer gradually widens, however, the parameters of heat transfer are declining. The distribution and shape of the boundary layer can be influenced by the change of air flow form the mortise which affects also the parameters of heat transfer. In the figure 1b we can see temperature fields around the cylinder at the same surface temperature but the air flow velocity from the mortise is 0,16 m.s^{-1}. In the figure 1c is there the temperature field at the air flow velocity from the mortise of 0,3 m.s^{-1}. The temperature profiles were determined from the measured values and out of them (temperature profiles) we determined heat transfer coefficients. Distribution of local values of heat transfer coefficients and the scheme of a part of the experimental facility is given in the figure 2.

Fig. 2 Distribution of local values of heat transfer coefficients

5. CONCLUSION

The results of interferometric visualisation of temperature fields in transparent objects are the pictures of interferograms which can be assessed in a qualitative way as well as a quantitative way. In the qualitative assessment of interferograms of two-dimensional temperature fields and at setting the interferometer at an infinite width of fringes in the reference area, interferential fringes present isotherms of temperature fields. Qualitative assessment of interferogram pictures enables us to uncover the shape of temperature fields, their mutual interactions and their impact on local parameters of heat transfer.

These findings were achieved by the method of holographic interferometry. Optical errors were automatically compensated by the Interferometric Method, which provided accurate, detailed and useful information. Obtained interferograms gave detailed view of a temperature boundary layer, from which heat transfer coefficients can by determined. Pictures achieved by holographic interferometry gave us an idea about physical processes and better adaptability to physical reality.

6. ACKNOWLEDGEMENTS

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