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IMPACT OF LOWER HEAT EXCHANGE PLATE's GEOMETRY ON HEAT TRANSFER IN HORIZONTAL CHANNEL.

CERNECKY, J[ozef]; KONIAR, J[an] & BRODNIANSKA, Z[uzana]

Abstract: *The contribution describes the impact of geometry of heat exchange areas on heat transfer intensity during a forced convection in a horizontal experimental channel. Visualisation of temperature fields in the vicinity of heated surfaces was carried out using the method of holographic interferometry. The obtained holographic interferogram images of temperature fields were used to determine the local values of heat transfer coefficients for a heat exchange area without protrusions and were compared with the results for a heat exchange area with triangular protrusions*

Key words: *heat transfer, heat exchange area, holographic interferometry*

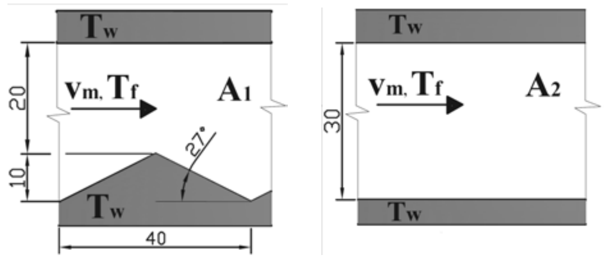
1. INTRODUCTION

Nowadays, the study and intensification of heat transfer in thermal processes of various technical and technological equipments represent up-to-date discussion topics not only in terms of maximum energy utilisation and consequently also time and finance savings, but also in terms of environmental protection. Heat exchange areas of various shapes are used in practice e.g. as heat transfer surfaces of plate heat exchangers, heating objects, cooling and heating equipment or cooling parts within electrical engineering.

The issue of heat transfer intensification in case of various profiled heat exchange surfaces is addressed by scientists in different countries around the world. The authors (Herman & Mayinger, 1992) were experimentally examining heat transfer by convection in a channel with rectangular grooves located on a wall heated by a water circuit. The authors (Herman & Kang, 2002) were attempting to intensify the heat transfer by adding curved blades over the brims of the electrically heated rectangular grooves. In his contribution, (Naphon, 2007) presents the characteristics of heat transfer and pressure losses in a channel with protrusions in the shape of a triangle on the lower and upper plates. (Elshafei et al., 2010) were dealing with an experimental research of characteristics of heat transfer by convection at a flow in a channel with triangular grooves.

2. EXPERIMENT

For observation of the characteristics of heat transfer in case of forced convection, we used a channel, in which the lower plate had triangular protrusions (Fig. 1a). The upper plate was flat and both plates were being heated by a water circuit. Analogically, we made a visualisation of temperature fields between flat protrusion-free plates (Fig. 1b). The air was flown in between the plates (transported) by a ventilator. Temperature of the inflowing air was T_f = 292.75 K and temperature of the plate surface was T_w = 323.35 K. Visualisation of temperature fields was primarily aimed at temperature boundary layers between both plates. We monitored the impact of the flowing air core's shift to the temperature boundary layer below the upper plate and how the temperature boundary layer would shift towards the upper plate wall during a forced convection in a horizontal channel.



a) b)

Fig. 1. Scheme of Heat Exchange Profiles in an Experimental Channel
a) with protrusions, b) without protrusions
v_m – flowing air medium speed, T_f – flowing air temperature, T_w – plate surface temperature, A_1 – inner surface of channel with protrusions, A_2 – inner surface of channel without protrusions.

3. CALCULATION OF LOCAL HEAT TRANSFER COEFFICIENTS

The difference in temperatures of heated surface and flowing air creates a temperature boundary layer near the plate surface, where the temperature changes in a direction vertical to the surface. With the boundary layer's increasing width along the surface, at a laminar flowing mode, the heat transfer coefficient α is dropping, since the boundary layer works as insulation against the remaining part of the flowing air. Due to this reason, it is necessary to interfere in the boundary layer by various protrusions (Cernecky & Koniar, 2010).

The local heat transfer coefficient was determined from temperature derivations (Pavelek, 2001):

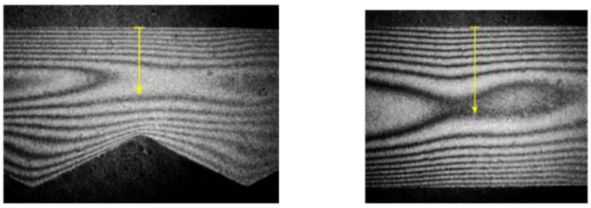
$$\alpha = -\lambda_f \, . \, tg\beta \cdot \frac{1}{T_w - T_f} \qquad (1)$$

where, λ_f – coefficient of air's thermal conductivity [$W.m^{-1}.K^{-1}$], tgβ [-] – angle created by the tangent to the temperature profile in the point of surface, T_w – surface temperature [K], T_f – flowing air temperature [K].

4. RESULTS AND DISCUSSION

The measurement was conducted on a holographic alternative of the Mach - Zehnder's interferometer in real time. Fig. 2a shows the holographic interferogram of the temperature field in case of forced convection in a channel with a heat exchange area with triangular protrusions.

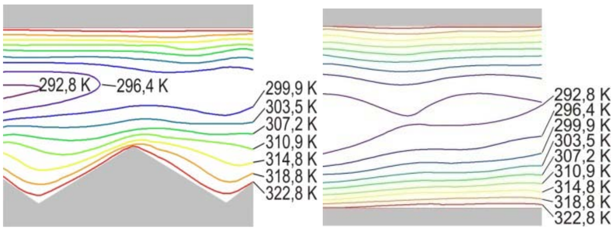
Similarly, we also created an interferogram for flat protrusion-free heat exchange areas located in the channel also in a forced convection. The temperature gradient was determined from the cut marked with an arrow (Fig. 2).



a) b)

Fig. 2 Holographic Interferograms at Forced Convection in a Channel
a) with Protrusions, b) without Protrusions

Fig. 3a,b displays temperatures corresponding to interference stripes. Graphic dependence of temperature on the distance from heat exchange surface, for a channel with protrusions and without protrusions, is shown in Fig. 4.



a) b)

Fig. 3 Temperature Fields at Forced Convection in a Channel
a) with Protrusions, b) without Protrusions

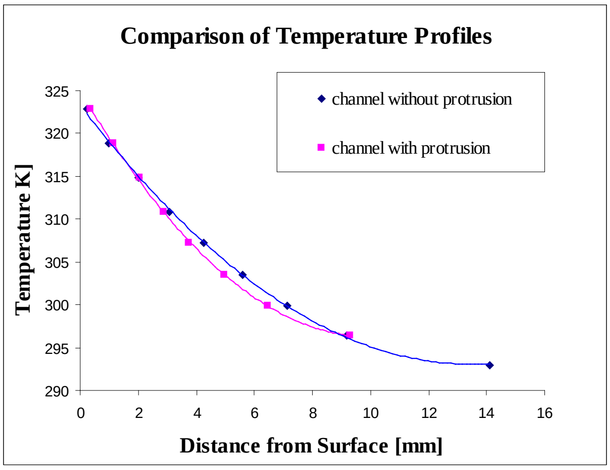


Fig. 4 Temperature's Dependence on Distance from Upper Plate's Surface

5. DISCUSSION

During the flowing of air between two flat plates, the temperature boundary layer is expanded from the leading edge separation point. Along with an expanding boundary layer, the heat transfer coefficient is dropping, and therefore the effort is to interfere in this boundary layer by means of various routing elements or reduce the channel's diameter by building in various protrusions. The situation changed, when the lower flat plate was replaced by a plate with triangular protrusions.

As protrusions on the lower layer caused a reduction of the channel's diameter and shifting of the core of flow towards the upper plate, subsequently also the width of the temperature boundary layer was reduced.

This resulted also in an increased temperature gradient in the boundary layer near the wall and the heat transfer coefficient α was increasing as well. The increased gradient, and thus also a higher steepness of the curve against the heat exchange wall is shown in Fig. 4. This was reflected in an increased heat transfer coefficient, which was calculated according to the ratio (1).

For the channel without protrusions, the heat transfer coefficient value was $\alpha = 2.88\ W.m^{-2}.K^{-1}$. For the channel with the lower plate with protrusions and the upper plate without protrusions, the heat transfer coefficient value was $\alpha = 4.2\ W.m^{-2}.K^{-1}$.

6. CONCLUSION

In our contribution, we were dealing with intensification of heat transfer in a forced convection in a horizontal experimental channel. At high Reynolds number values, the heat resistance may be reduced by means of turbulence with the streaming medium disrupting the boundary layer also near the wall. Nevertheless, this method requires expending of a bigger amount of energy to make the streaming medium move, which translates into a higher noisiness of the equipment.

In our contribution, we were examining the impact of a heat exchange area's geometry on heat transfer intensity coefficients at low Reynolds number values. The qualitative and quantitative analysis showed that as a result of using a heat exchange area with protrusions, the temperature gradient increased as opposed to the situation, when the exchange areas had no protrusions, which was also reflected in the increased heat transfer coefficient α. In the future, we would like to examine what is the maximum Reynolds number value up to which the holographic interferometry method can be used for visualisation. We would also like to optimise the geometry of the heat exchange areas using various routing objects.

7. ACKNOWLEDGEMENTS

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