30. Setkání kateder mechaniky tekutin a termomechaniky

HYDRO TERMO

22.-24.6. 2011

Špindlerův Mlýn

Jednotlivý příspěvek ze sborníku

TECHNICKÁ UNIVERZITA V LIBERCI

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

The influence of geometry changes to the flow in the floor heating convector

František LEMFELD[1], Karel FRAŇA[2]

[1] Ing. František Lemfeld, Technical University of Liberec, Studentská 2, Liberec 1, frantisek.lemfeld@tul.cz
[2] doc., Ing. Karel Fraňa, Ph.D., Technical University of Liberec, Studentská 2, Liberec 1 karel.frana@tul.cz

Abstract: *This article deals with the numerical simulation of the floor heating convector in 2D. Presented convector can operate in two modes – cooling mode and heating mode. This initial numerical simulation is focused on the changes of the geometry of the floor heating convector and its influence to cooling power of the convector. The modification of the geometry consists of rotating and shorting of the metal plates for regulation of an ingoing and outgoing air.*

1. Introduction

The heat convector systems have many construction variations. One of them is installation of the convector to the floor. This is the type of examined convector.
Heating convector consists of the outer container. Inside the container is the water-air exchanger with axial radiator fan. The exchanger has system of pipes equipped with the fins. The pipes are separated to two independent sets, one for the cooling and the other for the heating mode.

The temperature difference of the outer air and heating water in the heating mode is considerably higher, then the temperature difference in the cooling mode (surrounding air to coolant). That is why the set for the cooling has more pipes then the set for the heating (figure 1). The outer container is covered by the aluminium grid coinciding at the floor level.

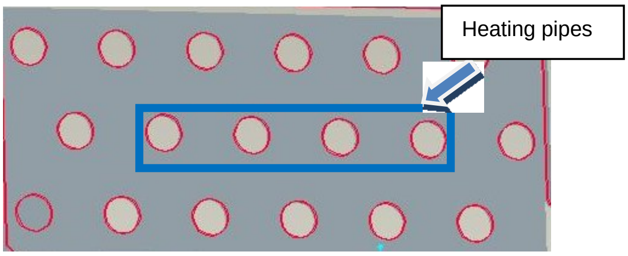

Figure 1 – fin of the heat exchanger

The object of the work was to examine the influence of the modified geometry to the air flow. The original geometry was compared with several cases of modified set up. The metal plate over the fin points the air away from the intake place of the floor convector, but it also increase the pressure loss of the convector. That is why the influence of the length of this plate was examined by the numerical simulation. Another option was rotation of this metal plate. At the lower level of the convector is another metal plate designed to aim the inlet air flow directly to the pipes. The effect of this plate was examined as well.

2. Numerical simulation

For the numerical simulation was used commercial software Fluent. Model geometry was created in the Pro Engineer. The flow is solved as an unsteady by the DNS model because of the low Reynolds number. All simulations were made in cooling mode, where was temperature of the pipes set to 9 °C. Room temperature of ingoing air is 22 °C. Inlet velocity is 3,5 m/s. The calculations were made to the time of 1 second, then 0,6 second for time average values, all with the time step 0,001 second.
The configuration of the boundary condition is on figure 2.

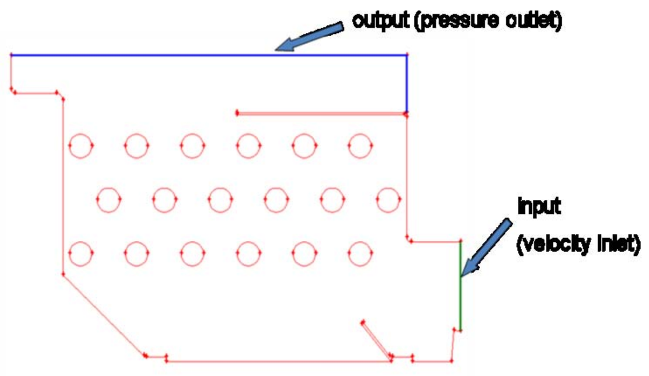

Figure 2 – configuration of the boundary conditions

3. The geometry variation

Several different geometry cases were examined with intention to observe the influence of the metal plates to the flow and heat transfer from the pipes to the air. The first case is trimming of the upper metal plate. There were made 3 models with reduced metal plate (10, 20 and 30 mm), as we can see on the figure 3 (the first is the initial model).

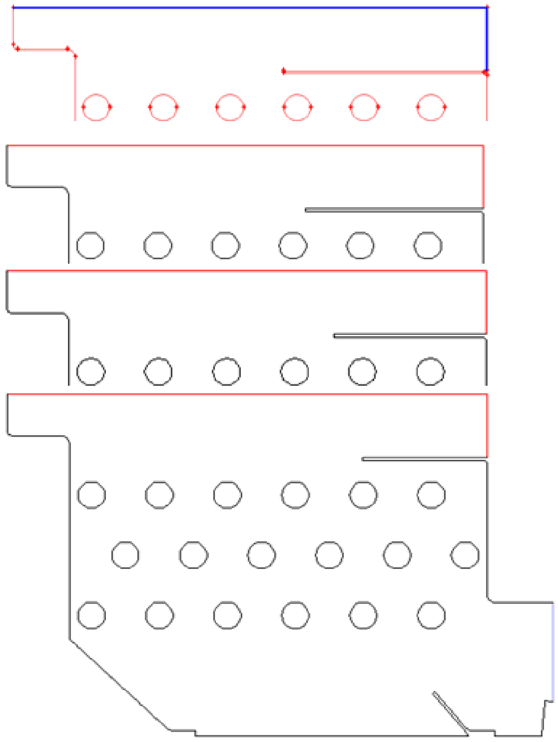

Figure 3 – trimming of the upper metal plate

The second case is the rotation of the upper metal plate, as we can see on the figure 4.

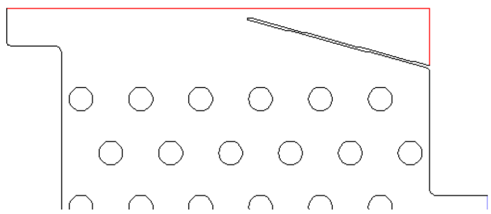

Figure 4 – rotation of the metal plate

The last case was focused on examination of influence of the metal plate beneath the fin (figure 5). The model without plate was compared with the initial geometry.

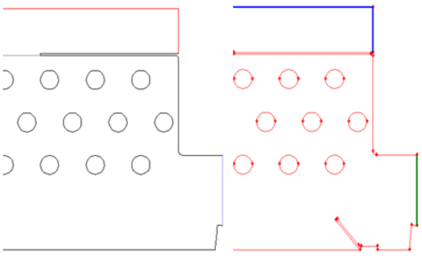

Figure 5 – models with and without bottom metal plate

4. Results

Trimming of the metal plate - the simulation was made for 4 different lengths of the plate.

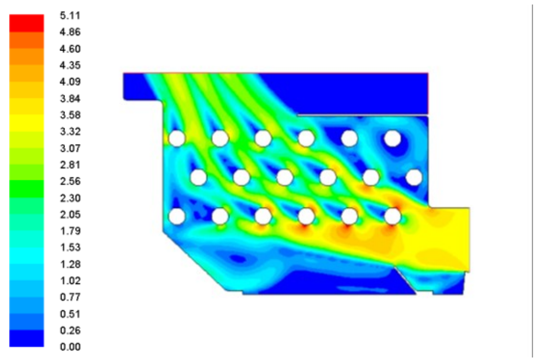

Figure 6 – initial state

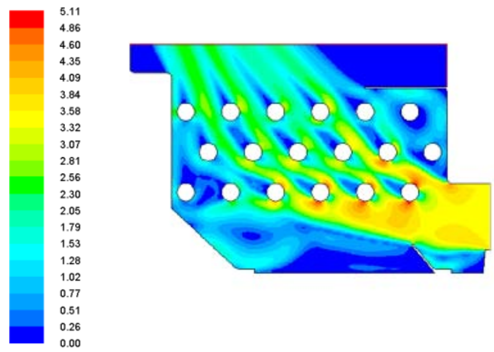

Figure 7 – trimming 30 mm

On the figure 6 a 7 we can see contours of time averaged velocity for initial state and for the maximal trimming of the metal plate. The main purpose of the metal plate is to isolate the outgoing air from the intake place of the ventilator. Separation is ensured by directing of the flow with sufficient velocity to the room. The intake place of the fan is on the right side over the velocity inlet boundary condition (it's not the part of the model). As we can see from the figure 6, pipes at the right upper corner are not properly flowed. Situation is getting better on figure 7, except of the middle right pipe.

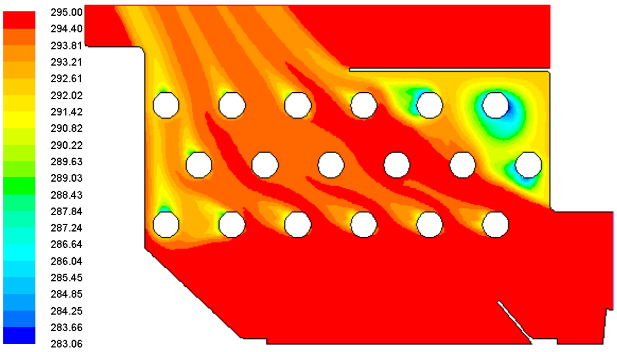

Figure 8 – initial state

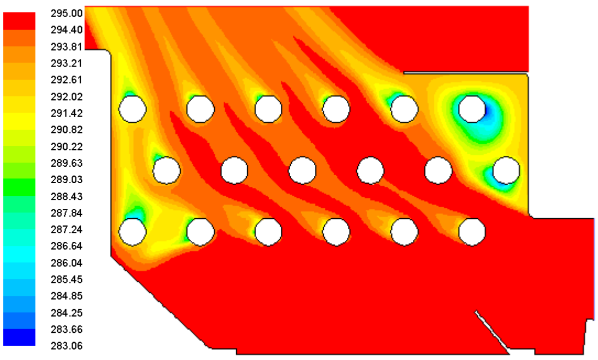

Figure 9 – trimming 30 mm

If we look at contours of the time average static temperature at the initial state and at the maximal trimming (figure 8 a 9), we can observe the change in the temperature field at the upper line of heat exchanger pipes. 4 pipes in the centre are used for heating, the rest in the cooling mode.

The better flow around pipes at the maximal trimming leads to increased specific cooling output according to initial state, as we can see at the table 1.

Case	Inlet velocity(m/s)	Outlet velocity(m/s)	Q_j (W/m)
Initial	3,50	2,16	233,21
-10 mm	3,50	1,89	235,00
-20 mm	3,50	1,67	237,40
-30 mm	3,50	1,56	246,93

Table 1 – specific output for trimming of the metal plate

The specific output Q_j increases with higher trimming of the metal plate, but the outlet velocity decreases, so the main function of the metal plate could be reduced.

Instead of trimming of the metal plate we can change the angle between the plate and heat exchanger fin.

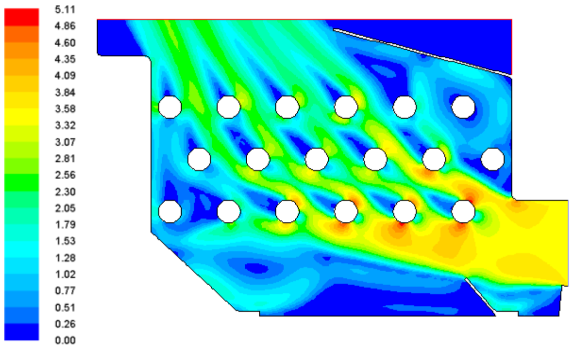

Figure 10 – rotated upper metal plate

On figure 10 are presented contours of time averaged velocity for the rotated upper metal plate. If we compare results, pipes at the upper right corner are slightly better flowed then in the initial state (fig. 6), but the velocity is still decreasing to 1,88 m/s.

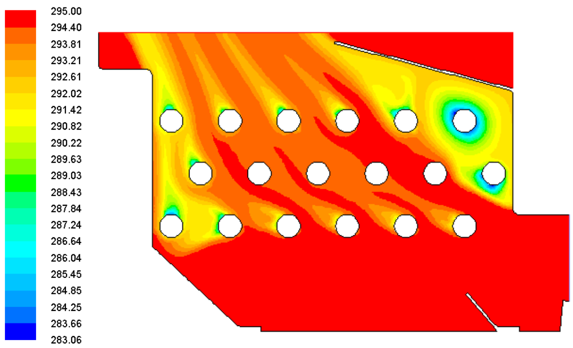

Figure 11 – temperature field of the rotated metal plate

The contours of time averaged temperature shows the influence of metal plate rotation to the temperature field at the heat exchanger.

The improved flow around pipes is cancelled by the influence of the decreased output velocity.

The last case of the work was focused on the metal plate beneath the fin. Primary purpose of the metal plate is to aim air flow to the pipes.

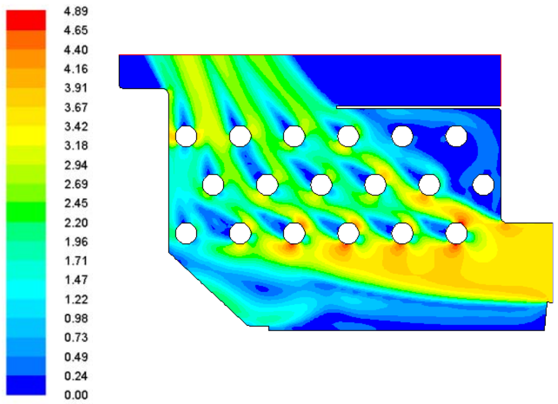

Figure 12 – velocity field without the lower metal plate

On the figure 12 we can observe contours of time averaged velocity. Maximal velocity at the exchanger decreased to 4,89 m/s. Removing the metal plate leads to reduction of flow around the pipes in the upper right corner (with comparison to fig.6). Unblocking of the stream in the x direction leads to better flow around pipes on the left side of the heat exchanger.

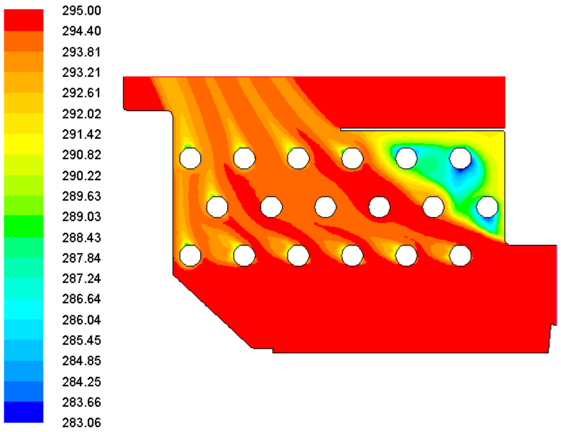

Figure 13 – temperature field without the lower metal plate

Contours of the time average temperature shows the area on the right side with low temperature. It's caused by insufficient flows in this region. The temperature field around the pipes on the left side responds with to the increased velocity in this area.

5. Conclusion

Several models of floor heating convector were examined. The trimming of the upper metal plate positively effects the specific cooling output, but decreases velocity of outgoing air. This can lead to the backflow into the ventilator. The rotation of the upper metal plate partially eliminates the velocity reduction. Removing the lower metal plate leads to decreasing of the maximal velocity and slightly reduces the cooling power of the floor heating convector.

6. References

[1] INCROPERA, F. P.; DEWITT, D. P.: INTRODUCTION TO HEAT TRANSFER, 5TH EDITION, JOHN WILEY & SONS, 2007, ISBN: 978-0-471-45727-5

[2] WILCOX, D. C.: BASIC FLUID MECHANICS, DCW INDUSTRIES, 2003

[3] CENGEL Y. A.; BOLES M. A.: THERMODYNAMICS AN ENGINEERING APPROACH, CHINA, MC GRAW HILL, 2008

Acknowledgements

This work was financially supported from the project of the Technology Agency of the Czech Republic 01020231 and from the European Grant CZ.1.07/2.4.00/12.0001 financially supported by the European Union and Ministry of Education of the Czech Republic.