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# NUMERICAL SIMULATIONS OF RECOVERY HEAT EXCHANGERS

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**Abstract:** *This paper is focused on evaluation and comparison of air-air heat exchangers of plate type used for retrieving the heat from the waste air. The first part of this paper shows how it is possible to evaluate and compare each exchanger with another one. Process and procedure of numerical simulation is described in the main part. The procedure involves selecting an appropriate geometry of the exchanger, computational mesh generating, defining boundary conditions and the choice of a viscous flow model. Three geometrical types of heat transfer surface were compared in this work. Results of numerical simulations were compared with experimental measurement.*

**Keywords:** ***Recovery heat exchangers, heat recovery, numerical simulations, Fluent.***

## 1. Introduction

Saving every kind of energy is an important requirement. Thermal energy is the most important in environmental technology. For that reason equipment for heat recovery from waste air is supplied to system of power ventilation. This part of ventilation unit can take back heat (or cold in summertime) from a waste outlet air and transfer it to a fresh inlet air. This work deals with recovery heat exchangers which have air flows separated by a solid wall. Specially shaped aluminum foil is used for a parallel heat transfer surface. Heat exchangers have a cross-contra flow set of air flow. Heat transfer plates are implanted to the body of exchanger.

Production of a stamping tool is the most expensive operation when designing and optimizing the heat transfer surface. For this reason author of this paper tried to solve this problem by numerical simulation of the flow between heat transfer plates.

## 2. A way of evaluation of a recuperative heat exchanger for heat recovery

### 2.1. Experiment

Results of measurements must be comparable with results of numerical simulations. The experiment respected some principles of European norm ČSN EN 308. Mass flow rates of inlet and outlet side were the same. Each exchanger was measured at five different volume flows from 100 up to 500 $m^3 \cdot hod^{-1}$. Waste air stayed at 25°C and its air humidity stayed above the condensation level of heat transfer surface (wet bulb temperature c. 14°C), so it could meet cold fresh air with 5°C. In this case, dry air was taken as flow medium in numerical simulation.

### 2.2.1. Pressure loss of a recovery heat exchanger

Pressure loss $\Delta p_{rek}$ of a recovery heat exchanger is a very important parameter in determining the quality of exchanger. The loss increases a total pressure loss in air distribution. In our case the loss only depends on air mass flow. Intensive heat transfer on surface by convection is desired as well as lowering the pressure loss. High pressure loss will increase operational costs for electric gear of radial ventilator.

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### 2.2.2. Recuperation efficiency of recovery heat exchangers

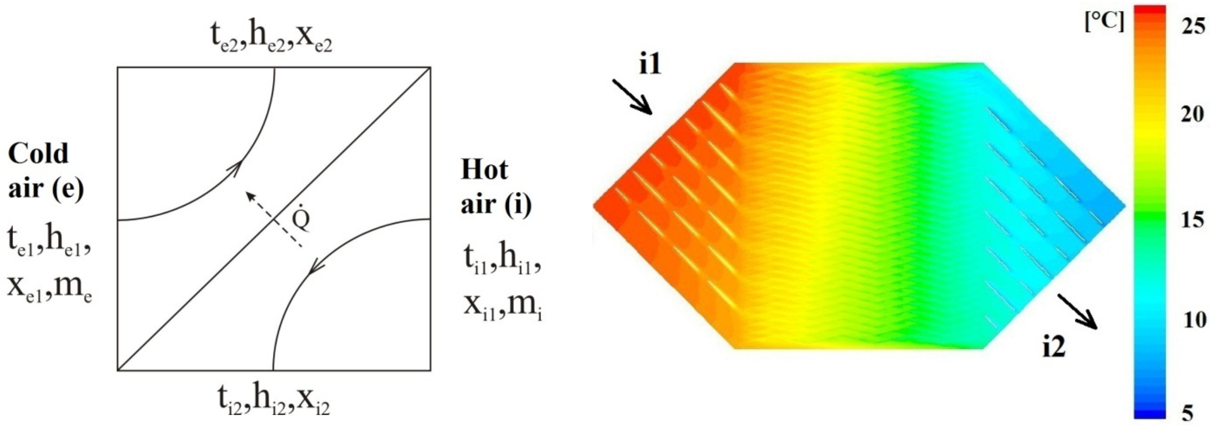


*Fig. 1: Scheme of recuperative heat exchangers and a sample of the heat transfer surface (temperature field).*

Heat fluxes that vent through a plate are equal in a heat insulated system. One of the main characteristics is heat recuperate efficiency $\eta_{ZZT}$. It is defined as:

$$\eta_{ZZT} = \frac{\dot{m}_i \cdot (h_{i1} - h_{i2})}{\dot{m}_i \cdot h_{i1} - \dot{m}_e \cdot h_{e1}} = \frac{\dot{m}_e \cdot (h_{e2} - h_{e1})}{\dot{m}_i \cdot h_{i1} - \dot{m}_e \cdot h_{e1}} \tag{1}$$

where $\dot{m}$ is mass flow rate and $h$ is specific enthalpy of air. If condensation doesn't come and mass flow rates are the same, the relation is:

$$\eta_0 = \frac{t_{e2} - t_{e1}}{t_{i1} - t_{e1}} \tag{2}$$

This means ratio of warmed-up air temperature increment and difference between air inlet temperatures. Recuperation efficiency depends on many parameters, but in our case it only depends on volume flow rate of fresh air.

### 2.3. Numerical simulation

First of all geometry of a model must be defined. Because an exchanger is large (c. 500 x 300 x 200 mm), a model was chosen as only a small part of the whole exchanger. A model consists of one layer between plates, which represents a warm outlet air. A layer was between half layers of a cold inlet air as a sandwich (Fig. 2). All models are 3D and consist of hexahedrons mainly. Numerical mesh was made in MSC Marc Mentat software and boundary conditions were supplied in Gambit 6.3.26. Numbers of elements in a model were from 1.2 up to 2 million. Creating a computation model consumes most of the time. Spacing between plates in exchangers was 2.0, 2.2 and 2.6 mm. Thickness of a plate was 0.1 mm, but it was neglected in a model. It was published in the diploma work Recovery heat exchangers by Petr Novotný (2010).

Important part of producing the computation model is setting of suitable boundary conditions (Fig. 2). Boundary condition of upper parallel surfaces was set as *periodic*, heat transfer surface was set as *wall* with a possibility of heat flux. Every contact surface was set as *interface* (cross and contra-flow parts were made separately).

Computations of simulation were done in Fluent 6.3.26 software by Ansys Fluent Inc., where *pressure inlet* boundary conditions (temperature and pressure) on inlets of air surface were defined. Heat transfer surfaces created small gaps between each other, which allowed us to approximately calculate Reynolds number. In this case maximum Reynolds number was 1500 which is under critical value (without considering next shanking). Viscous models of turbulence *k-ε*, *k-ω* and viscous *laminar* model were tested by author. Results from numerical simulations show their applicability for this type of problems.

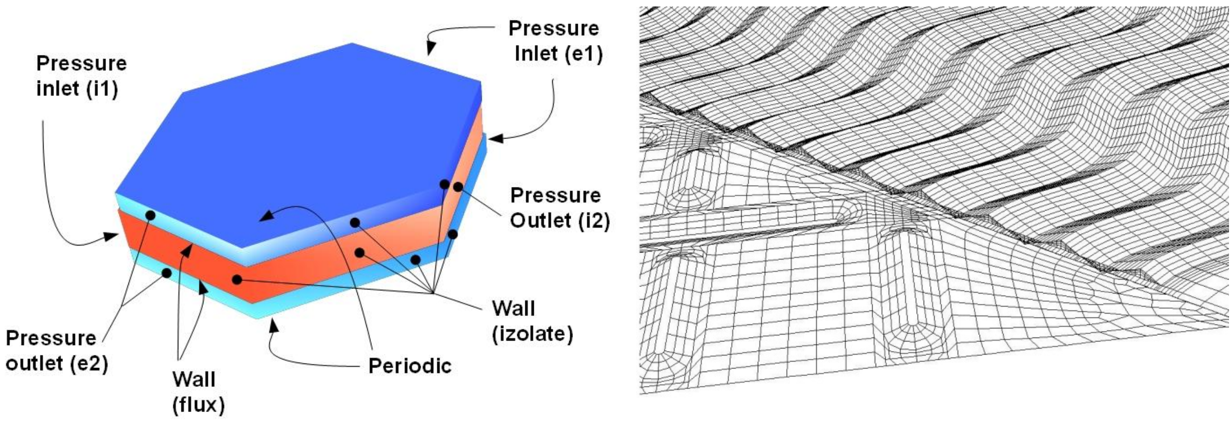


*Fig. 2: Boundary conditions and a sample of computational mesh.*

Air was considered an ideal gas in numerical simulations during a steady mode. Useful values were detected in important sections and surfaces. The most important values are average outlet temperatures, pressure loss between inlet and outlet of exchangers and heat flow through the heat transfer surface.

### 2.4. Comparison of experiment and numerical simulation

Values of boundary conditions were set on the basis of measurement results for objective comparing simulation and experiment. All characteristics depend on fresh air volume flow. Efficiency of heat recuperator$\eta_0$can be determined by equation No. 2.

Heat recuperate efficiency and pressure loss with viscous turbulence model *k-ε* were preferable than in experiment. A viscous turbulence model *k-ε* is more suitable for developed turbulent flow (in this case Re number was from 500 up to 1500 in inlet of exchanger's gap). For this reason *k-ε* model isn't suitable for numerical simulations of plate exchangers.

A model *k-ω* respects areas near wall during turbulence flow better. In this case values of thermal efficiency and pressure loss were closer to experiment results. This viscous model is more suitable for flow between parallel formed plates.

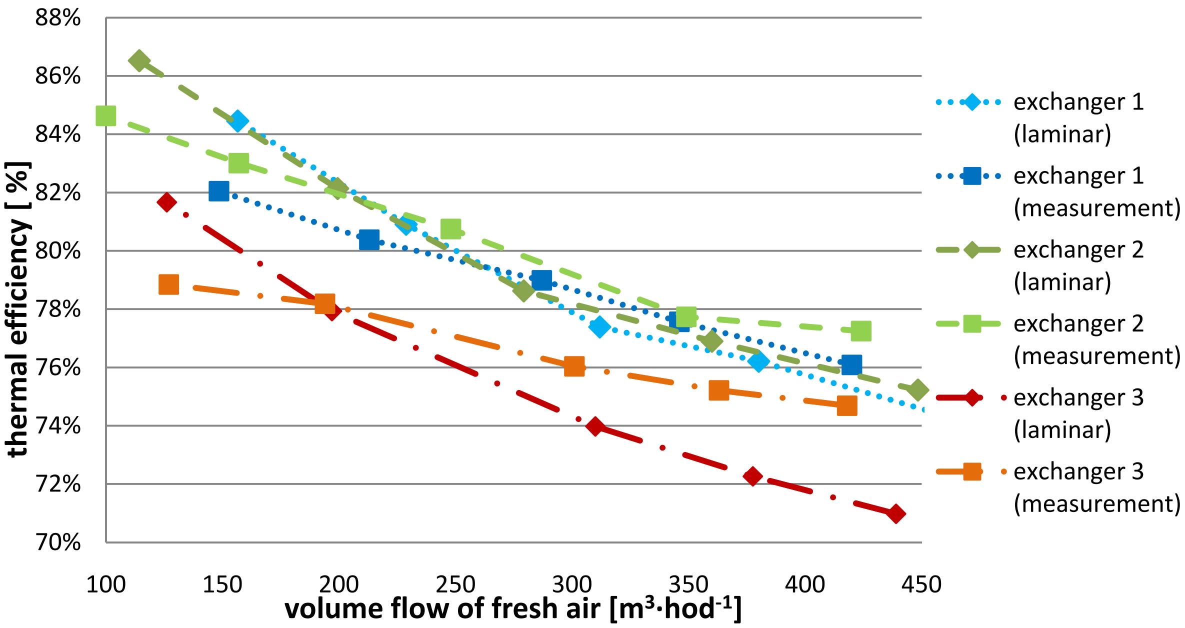


*Fig. 3: Comparison of thermal efficiency from measurement and simulation with viscous laminar model.*

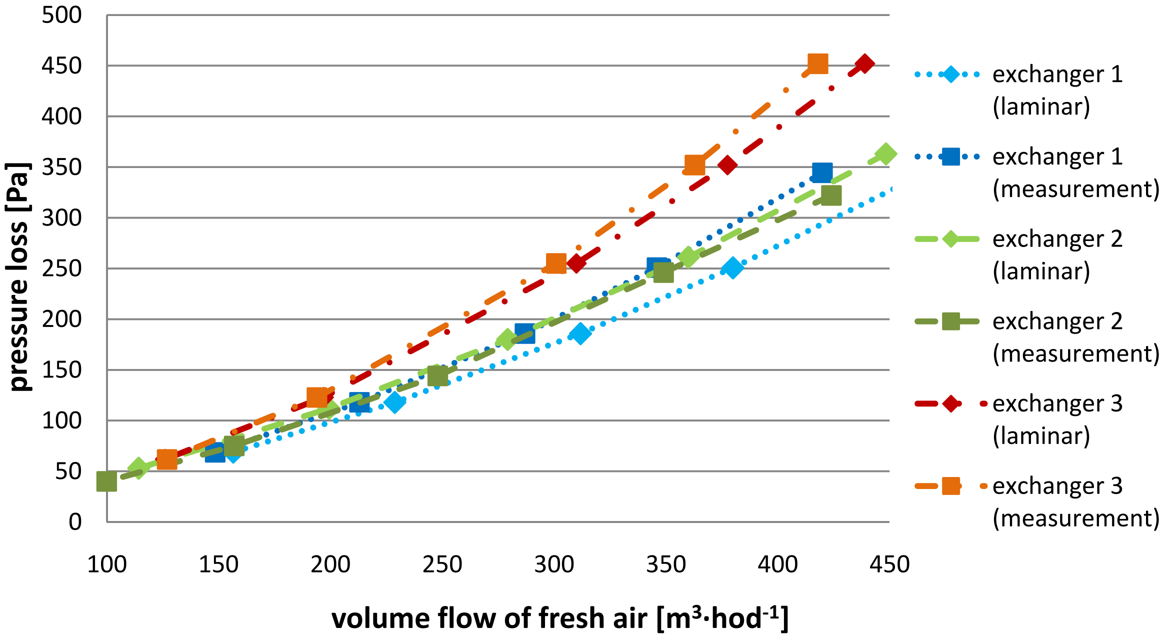


*Fig. 4: Comparison of pressure loss from measurement and simulation with laminar model.*

In the last part of this work the *laminar* viscous model of flow was set at Fluent. A laminar model results respected measurement much more. We can see comparison of thermal efficiency (Fig. 3) and pressure loss (Fig. 4). Bigger difference of results is expected at greater volume flows, because there might develop a turbulence of the flow. *Laminar* viscous model should be the most suitable one for a development of recuperative heat exchangers with parallel heat transfer surface.

## 3. Conclusions

We could look into some interesting areas in an unsteady flow simulation in the next step of the research. Considering a condensation of air humidity on the heat transfer surface in numerical simulations would be beneficial. Another aim is to develop a heat transfer surface that can transport air humidity (without phase change).

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