SIMULATION OF RECUPERATING PROCESS

Igor Polák, Ján Cigánek, Stanislav Števo

Institute of Control and Industrial Informatics
Faculty of Electrical Engineering and Information Technology
Slovak University of Technology
Ilkovičova 3, 812 19 Bratislava, Slovak Republic
Tel.: +421 2 60291111 Fax: +421 2 60291111
e-mail: igor.polak@atlas.sk, stanislav.stevo@stuba.sk

Abstract

The article discuss about recuperation (regaining) heat from draffy air. Main goal is to verify ability of Comsol as a simulation software, to set up the nearly real conditions for calculation of heat convection and conduction in recuperation unit. Experiments showed that the air humidity, in mentioned temperature range, makes an unimportant difference in point of efficiency. On the other side, airflow speed greatly influenced into efficiency of recuperation process. The results were changing in reciprocal ration with speed of air streaming along the divider. This is the reason why is needed to consider the size (dependent on volume) of recuperation unit in bigger buildings, because higher volume of recuperated air in same recuperation unit means higher airflow speed.

Key words: Recuperation, Comsol Multiphysics, modeling, simulation

Introduction

The sense of simulations using roots in their ability to provide information about process results without the creation of specific real conditions. That is the way how to lower costs of research and optimization. User can anyhow change particle conditions influencing simulations results. The main advantage of mentioned approach is possibility of finding of phenomenon behaving in environment of our examination without time and money investing into creation of device and specific conditions which are needed to examine experiment. The problem comprises also the hardness of specific conditions. *(The exact moisture, extremely low or super high temperatures, etc.)*

Heat recuperation falls into basic attributes of low-energy houses and intelligent buildings. Well implemented recuperation system can markedly save amount of expenses needed to heating of building. Manufacturers and constructors most of times face the problems with high costs in research and testing of their devices. Possibilities of using virtual reality for testing and modeling are presented right in this article.

Energy balance

Energy balance is one of the buildings quality categories which shows us consumed and produced energy rate. The goal is to lower energy loses, mostly by improving isolation, and to lower its energy depending on external sources. The last one is in most cases practiced by replacing conventional sources by using relatively new technologies like solar thermal power stations and heat recuperation.

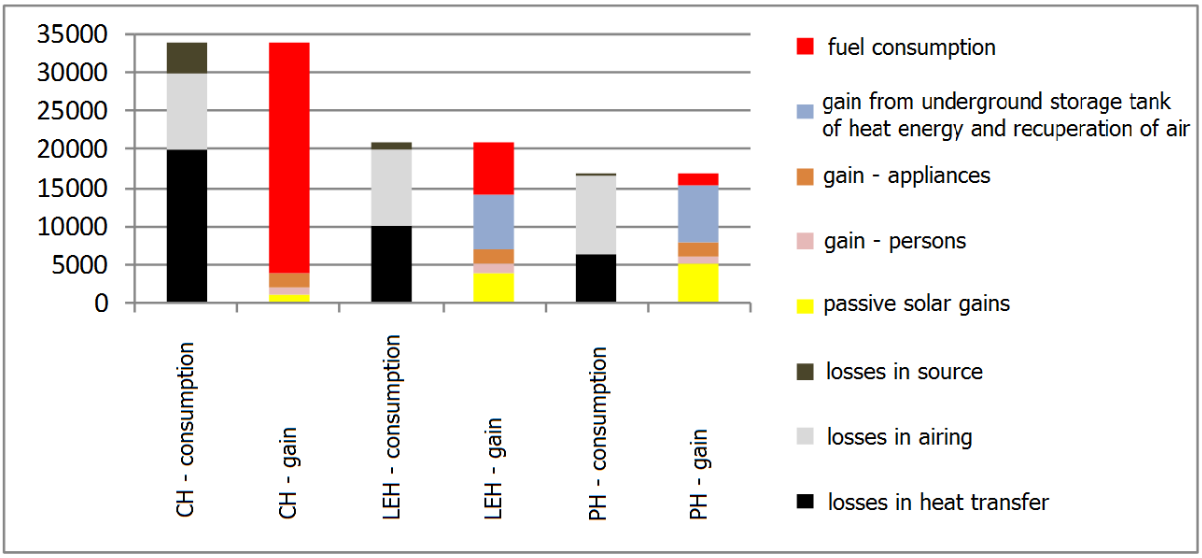

Figure 1: Energy house types and their energy balances [1]
(CH – common house, LEH – low energy house, PH – passive house)

As is shown in figure above, heat recuperation itself represents about third of energy gains in low-energy houses and almost half of them in case of net-zero houses.

Air-conditioning with heat recuperation

Air-condition is usually designed in order to achieve intensity of air refreshing about 0.3 to 0.5 h^{-1} (rooms air is fully replaced in every 2-3 hours), another way how to pass minimum air supply demand is to provide 30-50 m^3/h of fresh air per person. If we don't look at conduction losses and ordinary cooling down, it means, also in cold year periods, that is needful to completely re-heat whole air in room every 2 or 3 hours. The difference between outer and inner air temperature determines the extent of mentioned losses.

Air recuperation works in principle that wasted air depleted from inner room, on its way out, is passing along a divider. It is the place where is heat conduction between wasted (warm) air and divider. This process is followed by warming of fresh (cold) air running along the divider from the other side in opposite direction. Plastic and metal (mostly aluminum) dividers are usually used in units of this kind. [1]

There are three common basic construction types in practice. The cross flow recuperator, the counterflow recuperator and the rotational one. In the first two cases, the difference is only air-flow direction between numerous parallel dividers. Rotational recuperator is designed to capture of humidity of waste (moist) air in paper lamella rotating inside in unit and to return it to the fresh air alternately running through lamella into the room. This ability makes rotational recuperator less efficient in heat recuperation itself and overall unwanted particulates can be returned to fresh air too. [2]

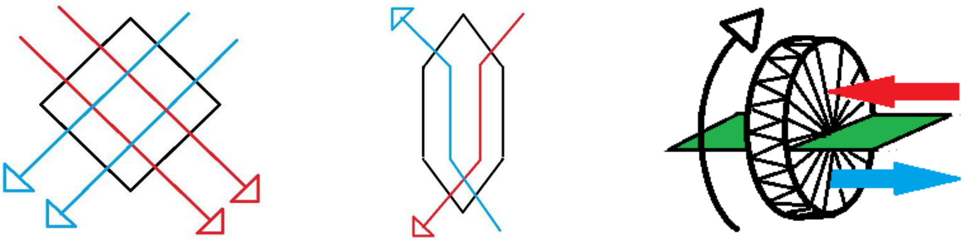

Figure 2: Examples of three types of recuperation units. From right: crosflow, counterflow and rotational

Software environment for simulation

COMSOL multiphysics was used in order to create model and to simulate one part of recuperation unit. Authors of mentioned tool belong into graduates of professor Germund Dahlquist from Royal Institute of Technology in Stokholm, Sweeden. COMSOL is a finite element analysis solver and simulation software for various physics and engineering applications, especially coupled phenomena, or multiphysics. COMSOL also offers an extensive interface to MATLAB and its toolboxes for a large variety of programming, processing and postprocessing possibilities. The Packages are cross-platform (Windows, Mac, Linux, Unix). [3]

Model set up process

At first is needed to choose a correct module solving intentioned problem, the one which can solve combination of our specific coupled phenomena. The operative parameters of recuperation are flow directions, air temperature and speed of air flow (for dynamic interactions). In this case is Heat Transfer Module an ideal choice (Fluid-Thermal Interaction mode for Non-Isothermal Flow).

Firstly (in Draw mode) an 2D sketch of cross-section along the part of recuperator was done. In the sketch are 2 layers of flowing air, 1mm thick, isolated by aluminium layer with 0.083 millimeters thicknes. Whole model length is 245 mm. For next processing, an aluminium divider was taken as subdomain n. 2. The other ones were air filled.

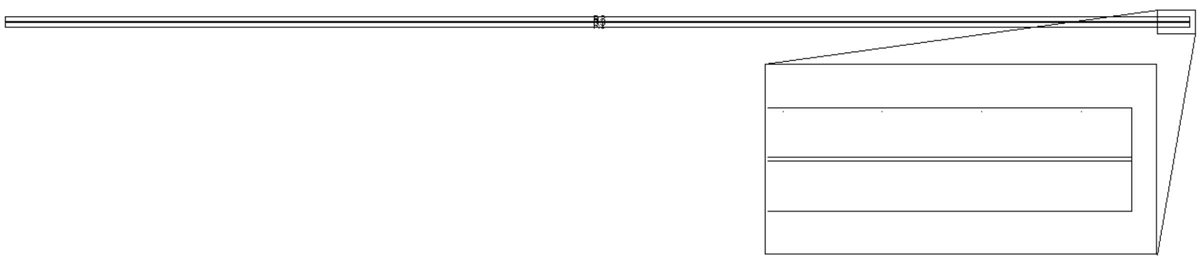

Figure 3: Model of cross-section along the middle part of recuperation unit

Non-Isothermal flow module includes two parts: General Heat Transfer and Weakly Compressible Navier-Stokes. In both cases, it’s possible to take advantage of Material library, where all needed parameters of used materials are expressed as a function (depending of operative parameter) and are able to import in the model.

Simulation

The first starting condition was set as 0.5m/s air-flow speed, equal to 18.36m^3/h volume of exchanged air. Outside air temperature was set to 0°C (273 K), and heated to inner temperature of 20°C (293 K). *Solving* started with generating FEM structure (net) with desired number of elements. Solver stops when get desired small error in tolerated. It determines state, when temperature all-through model became semi-stable. In our case it happened when outer air had been heated from starting 0°C (273 K), to final temperature of 17.49°C (290.49 K), which means that recuperation had been successful for 87.47% in total. (cold air was heated from 0°C (273 K) to 87% of 20°C (293 K)).

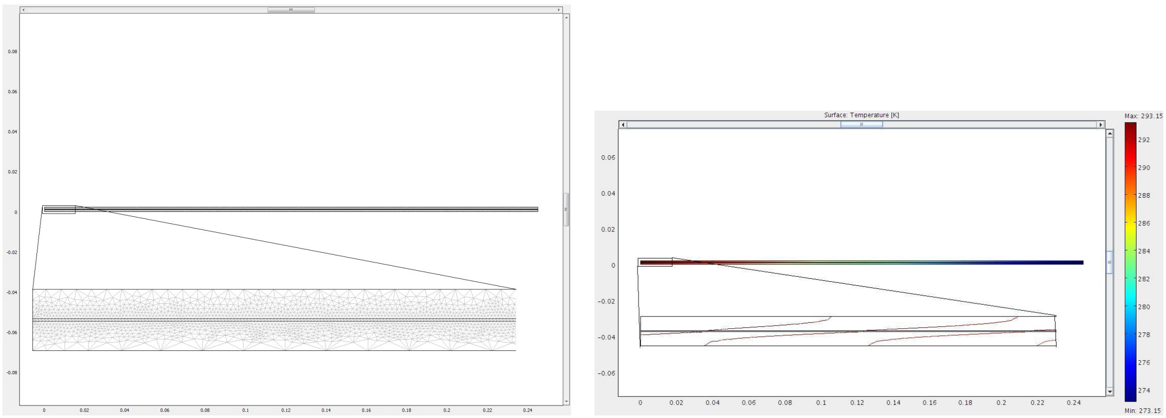

*Figure 4: Generated FEM net (**F**inite **E**lement **M**ethod) – on left, Heat zone described in color scale by Surface feature and threshold temperatures described by Isosurface feature in case of outer air temperature as 0°C (273 K)– on right*

In following simulations, real-like values were used. e.g. 100 m^3/h, which is considered as desired volume of exchanged air for 2-3 persons in room. Recuperation mode for number of 3 to 5 person is set to 155m^3/h.

Air volume [m^3/h]	Speed of airflow [m/s]	Outer Temperature [°C]			Average success rate [%]
		-3 (270 K)	-4 (269 K)	-10 (263 K)	
100	**9.26**	44.9	45.7	46.3	45.6
155	**14.26**	35.2	36.0	36.6	35.9

Table 1: Efficiency rate of recuperation process expressed in percentage (Various outer temperature and airflow speed were considered)

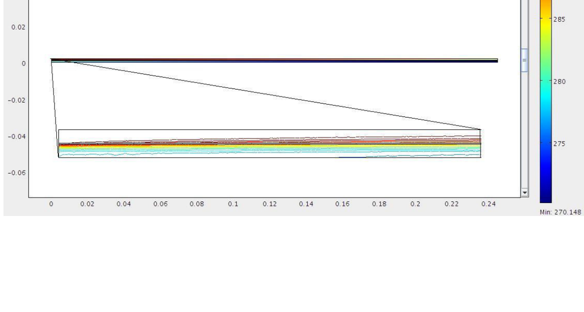

Figure 5: Heat zone described in color scale by Surface feature and threshold temperatures described by Isosurface feature in case of outer air temperature as 0°C (273 K)

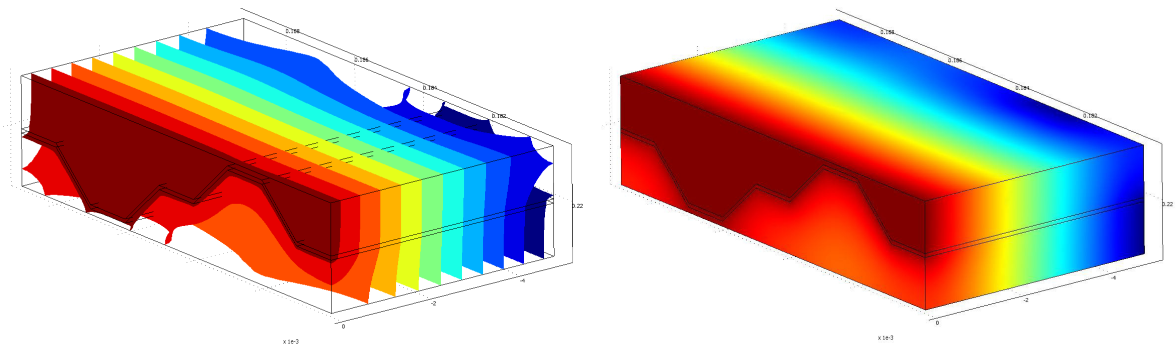

Figure 6: Example of more complex simulation. 3D cross-section of middle part of recuperation unit postprocessed (2x9x5mm)

Conclusion

The first result of described experiment is dynamopathic model, which reflects very correctly correlation between reality (measured data by producer) and simulation results. COMSOL Multiphysics proved its capability of simulating coupled phenomena and multiphysics. This fact can be used in desired designing, testing and improving process of selected problem. Temperature difference between outer and inner air appeared as minor factor in scope of efficiency. *(with considering of middle values in temperate climate areas with temperature range down to -10°C (263 K) in winter).* Experiments also proved that air humidity in mentioned temperature range makes an unimportant difference in results (efficiency) because air thermal conductivity is insignificantly changed by its humidity [4]. On the other side, airflow speed greatly influenced successfulness (efficiency) of recuperation. The results were changing in reciprocal ration with speed of air streaming along the divider. That means higher costs for additional heating. Because higher volume of recuperated air in same recuperation unit means higher airflow speed, it is important to consider the size (dependent on volume) of recuperation unit in bigger buildings,.

References

[1] Energeticky soběstačný dům, realita či fikce. 2. Aktualizované vydání - Karel Srdečný

[2] www.centrum-rekuperacie.sk

[3] http://en.wikipedia.org/wiki/COMSOL_Multiphysics

[4] http://www.electronics-cooling.com/2003/11/the-thermal-conductivity-of-moistair/