DRAFT RISK SIMULATION IN A ROOM WITH AIR TRANSFER DEVICE

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ABSTRACT

The article describes the influence of the supply air devices that are part of hybrid ventilation system which is being developed within a EU funded project RESHYVENT as a part of this project, on thermal comfort in living-room of a three-bedroom apartment. The supply air radiator and the supply air convector are compared. The fresh air is sucked through a supply air convector and supply air radiator respectively and the air leakage through the facade is assumed too. 2 variants, which cover different outdoor temperature and supply air temperature for each device, have been solved. The main difference between them is the direction of the incoming air. Supply air radiator is like a classical radiator, outdoor air comes through the radiator, warms up and enters the room vertically. Supply air convector is stand-alone device with heat exchanger to preheat the entering air and with a back draft damper and a wind damper. In this case the outdoor air enters the room horizontally. The CFD model of the room was created and solved using the commercial code STAR-CD. Based on temperature and velocity fields, draft risk was calculated according prEN 13799:2003_01 in the occupation zone as a parameter for thermal comfort specification.

KEYWORDS

ventilation, CFD, thermal comfort, draft risk

INTRODUCTION

More and more people suffer from allergy and asthma due to the bad indoor air. The problem is especially big in schools, offices and other working places. But with increasing time people spend at home, the problem concerns also residential buildings. The rooms where we spend long hours must have a well working ventilation system, which is effective also after being used for many years and which doesn’t gather dust and germs. Air supply convectors, also called outdoor air transfer devices (ATD) are part of such a system. Supply air devices takes in the outdoor air through a wall of the room and uses the heat exchanger connected to the radiator heat system to preheat the supply air. It’s also possible to have an individual hot water system for supply air devices. These devices are also equipped with a back flow damper and wind damper to prevent back-draughts and with a filter which clear the supply air. The best ventilation effect is achieved when the ATD device is placed low down, since the outlet air vents are mostly positioned opposite and at a high level.

ATD devices that have been used in this case are Supply Air Convector (designed by Thermopanel, Sweden, Fig 1.) and Supply Air Radiator (designed by Purmo, Sweden, Fig. 2.). Supply Air Convector is a stand alone device with heat exchanger and thermostat system so it's easy to control the temperature of supply air. The plume from supply air convector has a horizontal direction. Supply Air Radiator is improved standard radiator (see Fig. 2.) The supply air comes through the wall to the radiator and warms up. The plume from supply air radiator has vertical direction. Temperature of the supply air depends on a thermal load of the radiator and can't be controlled exactly.

Fig 1. Supply Air Convector

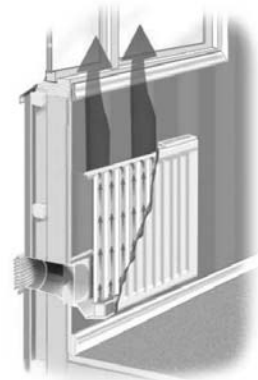

Fig 2. Suply Air Radiator

DESCRIPTION OF THE ROOM WITH SUPPLY AIR DEVICE AND SOLUTION PROCEDURE

The room in which the air flow was studied is a living room in a three-bed room – see the outside 3D view (Fig. 3.). Floor area of this room is 29,4m^2. Bedrooms, bathroom, closet and WC weren't considered in the model. The room contains kitchen unit with cooker and cooker hood. Cooker hood wasn't considered in the model because of its irregular work. Main exhaust outlet which was the only outlet in the model is pos. 8 in Fig. 3. Exhaust outlets in WC, closet and bath room were ignored too. The outdoor air enters the living room through a Supply Air Convector, model TK35 or a Supply Air Radiator. Air leakage is assumed too. Air leakage is assumed to occur in the joint between the exterior wall (walls where windows pos. 1, 3, 6 in Fig. 3. are situated) and floor, the joint between the exterior wall and ceiling and the windows (pos 1,3,6 in Fig. 3.). Pos. 7 in Fig. 3. is balcony door. The convector Thermopanel TK-35 (supply air radiator) is situated under the window (see Fig. 3. pos. 4).Supply Air Radiator has the same position as the TK-35. Positions 2 and 5 indicate standard flat radiators.

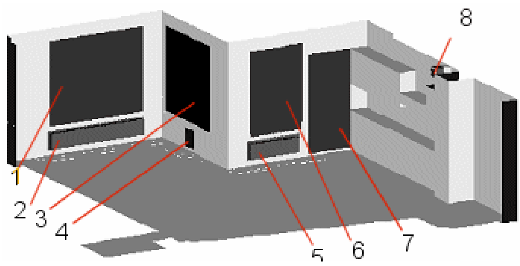

Fig. 3. 3D view of the room

The following U-values were assumed for the room:

- Exterior walls 0.25W/m²K
- Windows 1.8 W/m²K

There are no heat losses or gains to the neighbouring apartments. The heating system is a low temperature system with nominal setting at 60/40 °C. However, the thermal load of radiators has been adjusted according to scenario in order to keep the room air temperature

at the desired value. For each supply air device 2 combinations of outdoor temperatures were studied.
Next Tables 1 and 2, show the summary of solved variants.

TABLE 1
Boundary conditions for 2 variants when supply air convector is installed

Variant	Te	Ti	Tc	vk	vi	q
1	-10	22	18	16.2	6	650
2	0	22	18	16.2	6	510

TABLE 2
Boundary conditions for 2 variants when supply air radiator is installed

Variant	Te	Ti	Tsar	vk	vi	q
1r	-10	22	0	16.2	6	770
2r	0	22	8	16.2	6	585

Te –outdoor temperature (° C)
Ti – indoor temperature (° C)
Tc – temperature of preheated air from convector (° C)
Tsar – temperature of preheated air from radiator (°C)
vk –air volume flow through the convector and radiator, respectively ($l.s^{-1}$)
vi – air volume flow through the façade ($l.s^{-1}$)
q – specific thermal load of radiators ($W.m^{-2}$)

The problem was solved using a set of equations for incompressible, transient turbulent 3D flow with standard *k-ε* model of turbulence. The equation for a general variable ϕ has the well-known form:

$$\frac{\partial}{\partial t}(\rho\varphi)+\frac{\partial}{\partial x_i}(\rho u_i\varphi)=\frac{\partial}{\partial x_i}\left(\Gamma\frac{\partial\varphi}{\partial x_i}\right)+S_\varphi \qquad (1)$$

where the variable ϕ substitutes velocity components *u, v, w*, temperature *T* and kinetic energy of turbulence *k* and its rate of dissipation *ε*. The set of equations was solved using the control volume method and CFD code StarCD. Solution domain contains in total 450000 control volumes.

RESULTS AND THEIR DISCUSSION

Results of the modeling are presented in the form of draft risk DR, which corresponds with percentage of dissatisfied persons PPD. Draft risk is one of the several criteria, with which thermal comfort is evaluated. A well-accepted method to evaluate the predicted PPD concerning draft is the following equation, according to prEN 13799:2003_01

$$DR=(34-T_i).(v-0.05)^{0.62}.(3.14+0.37v.Tu) \qquad (2)$$

where T_i is local temperature, *v* is local air velocity, *Tu* is intensity of turbulence. Draft risk determined with eq.(2) gives a percentage of dissatisfied persons on the basis of an insulation value of clothes clo=0.75 and an activity met=1.2. Intensity of turbulence was assumed 0.4. Velocity and temperature were taken from the appropriate predicted fields in the locations of interest. Results of simulation are presented in vertical plane and horizontal plane (0,1 m above the floor), see Fig 4.

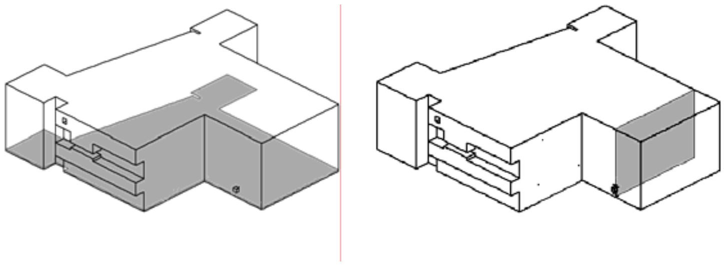

Fig. 4. Planes where PPD is discussed

Variants with different supply air device have been solved (supply air convector-SAC, and supply air radiator SAR). Supply air temperatures are 0°C, 8°C respectively when the SAR is installed. These temperatures was calculated assuming that radiator which works as a supply air device gives 25% of its thermal load to the incoming air which flows through. These low temperatures have a significant influence on DR nearby the supply air radiator. Infiltration also affects the DR distribution negatively. The air leakage is assumed to occur in the joint between the exterior wall and the floor, the joint between the exterior wall and the ceiling and the windows, 1/3 evenly distributed at each location.

Outdoor temperature: -10°C 0°C
Supply air temperature: 0 °C 8 °C
Variant 1r Variant 2r

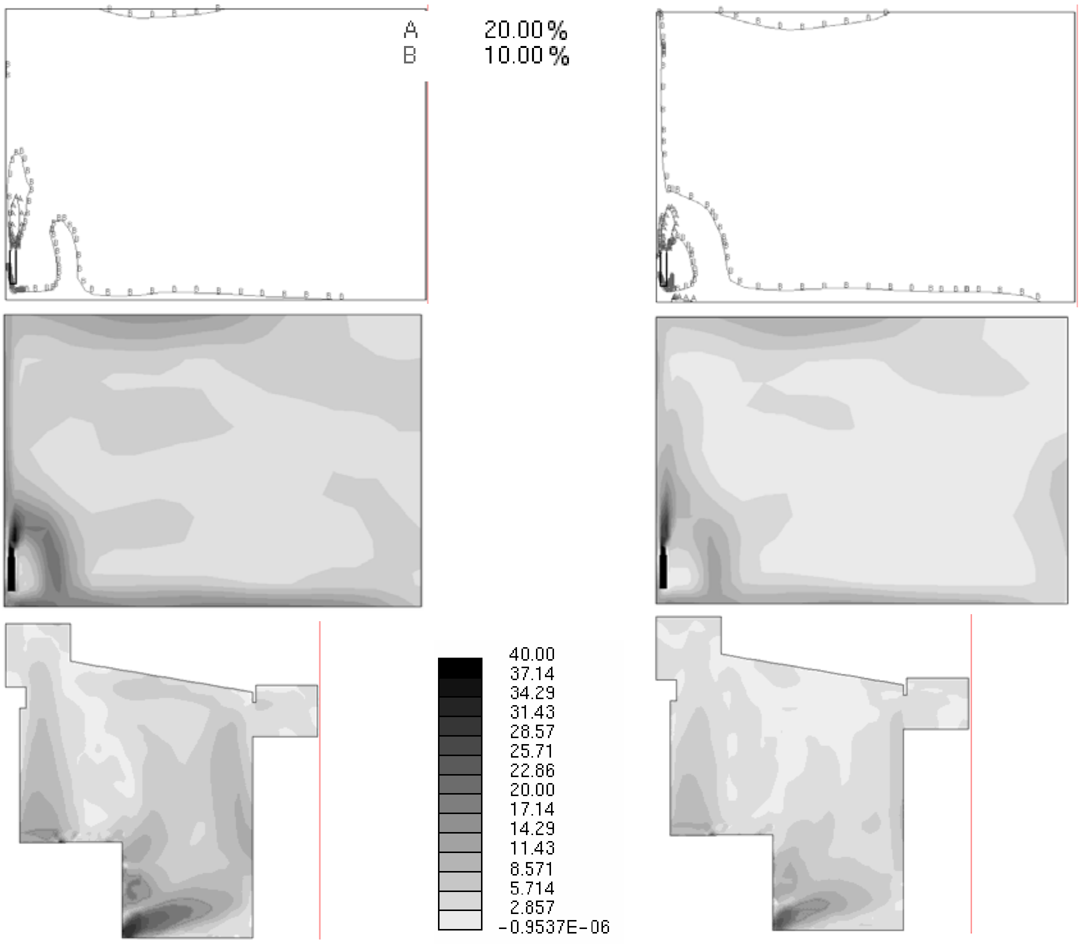

Fig.5 PPD values for variants with Supply Air Radiator

Simulations show that there are very high PPD values nearby the supply air radiator. The cold air turns down to the floor, so the PPD values exceed recommended value of 10 % in this area (see Fig. 5). When supply air convector is installed (see Fig. 6), there is different distribution of PPD in front of the device. As we can see the highest PPD are cumulating in the zones between floor and the distance 0.1m above the floor and under the ceiling (these zones are due to infiltration through air leakage which brings in a very cold air at the temperature of –10°C) and along window. Above the level of 0.1m from the floor, PPD are below 10%, in most cases below 5%. We clearly see that other cold area is located in front of the balcony door and in the small space between wall with convector and the opposite partition between living room and bedrooms. The highest PPD can be found just in this space where values of PPD reach up to25% We can expect that if a table is placed in this space, people could feel a cold draft close to the floor. In case of the balcony door, the value of PPD 10% extends along the kitchen unit and we can expect certain dissatisfaction of those who cook. The higher values of PPD along the kitchen unit can be observed in all cases that were modeled.

Outdoor temperature: -10°C 0°C
Supply air temperature: 18 °C 18 °C

Variant 1 Variant 2

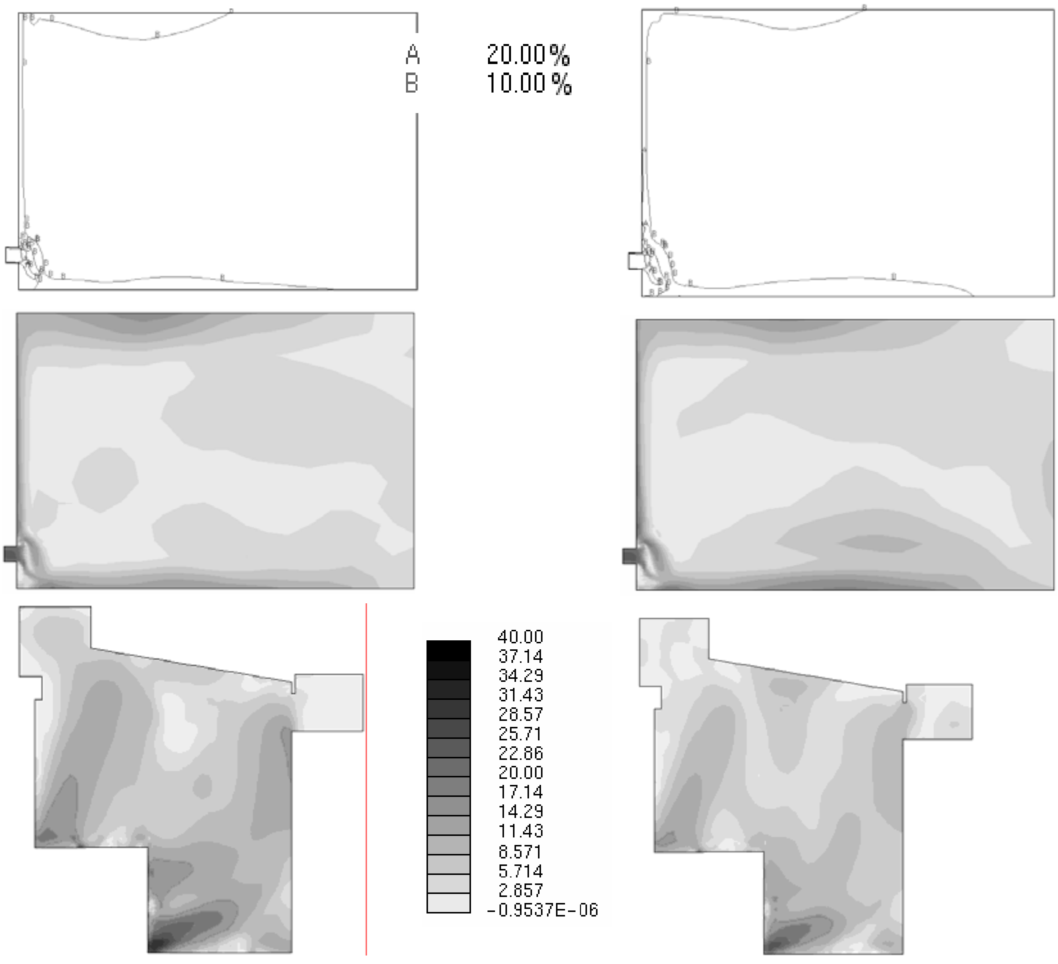

Fig.6 PPD values for variants with Supply Air Convector

CONCLUSIONS

Draft risk was evaluated based on CFD modeling of velocity and temperature fields in a living room of a 3 bedroom apartment in a multifamily house. Results of modeling show that supply air radiator doesn't have sufficient thermal load to heat up outdoor air to a satisfactory temperature in light of PPD (in case of low outdoor temperatures). Outdoor air comes through and turns down to the floor so the PPD values rises up to 20% in front of the radiator. When supply air convector is installed, PPD values are affected by infiltration. Close to the floor, the PPD values are higher just due to air leakage in both variants of supply air device. The PPD values of up to 20% can be met in the area of a cavity formed with exterior walls (walls where windows 1 and 3 are located - Fig 3) and namely in front of the balcony door along the kitchen unit.

To lower PPD values in critical areas, air leakage should be avoided, convector should direct the preheated air partly downward and the supply air radiator should be more powerful.

ACKNOWLEDGMENT

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