PERFORMANCES OF DAHT CONNECTED TO BUILDING AIRTIGHTNESS AND INDOOR HYGRO-THERMAL CLIMATE

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ABSTRACT

As building insulation level increases, the coupling of ventilation systems with building enveloppe airtightness becomes an important issue in order to improve buildings energy performances. A building ventilation model can be built on a set of resistances and generators in order to handle infiltration, natural ventilation as well as fan driven air flows. The model is able to assess the indoor air humidity level and the building energy balance.

Double flow ventilation can be handled through decentralized air handling terminals (DAHT), integrated in window ledges. A model of DAHT can be combined with the model of a whole building envelope, including infiltrations as well as dynamic behaviour, allowing comparisons with classical ventilation systems, such as natural or hybrid systems, or with centralized double flow systems. Results regarding energy consumptions, air humidity levels and superficial condensation risks can be analysed. Fresh air flow can be calibrated in order to meet air quality standards related to indoor humidity level and CO2 concentration.

The modelization of buiding indoor hygro-thermal climate allows a complete assessment of the seasonal heat exchanger efficiency, including heat recovery through the condensation of indoor air humidity when it flows through the exchanger.

KEYWORDS

Building ventilation, building infiltrations, heat recovery, fan models, indoor air quality.

INTRODUCTION

Double flow ventilation can be handled through Decentralized Air Handling Terminals, integrated in walls or window ledges and provided with heat recovery exchangers. Figure 1 shows a perspective and section of such a system [1].

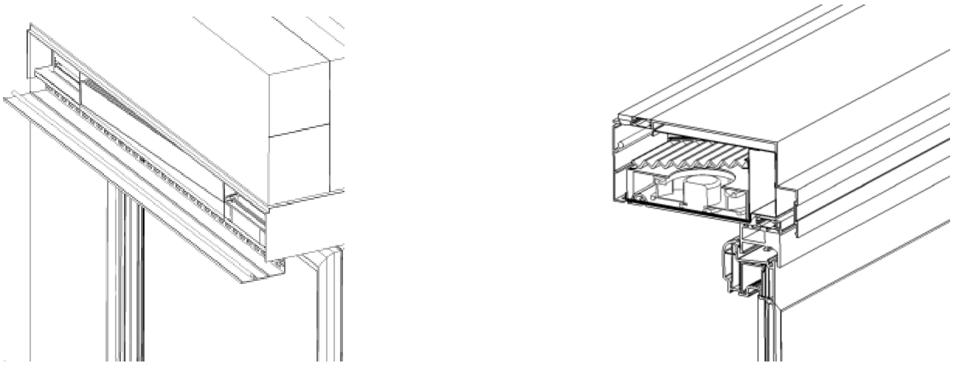

Figure 1. Decentralized Air Handling Terminals perspective and section.

Building ventilation models are interesting tools to predict the behavior of different types of ventilation systems interacting with the building envelope air tightness [2].

The aim of this paper is to define a model of DAHT including supply and exhaust fans models as well as heat exchanger model.

The efficiency of air flow control through the use of CO2 or humidity indoor probes is assessed. The influence of the building air tightness on the efficiency of heat recovery is assessed as well.

Finally, the authority of supply and exhaust fans is checked.

DAHT MODEL DESCRIPTION

A building envelope air tightness and natural ventilation model can be built on the basis of the following generic equation regarding pressure drop through air apertures, and allowing mass air flows to be positive or negative, depending on the air flow direction [1]:

$$\Delta p = K.\left|\dot{M}\right|^{n}.\dot{M} \tag{1}$$

Δp: Pressure drop through ventilation aperture *Pa*

$\dot{M}$: Mass air flow rate through ventilation aperture *kg/s*

n: Exponent ranging from *0* when the flow is laminar to *1* for a turbulent flow

K: Constant $Pa.(s/kg)^{1+n}$

The driving forces are due to wind pressure and to buoyancy effects:

$$\Delta p_{buo} = g.\frac{(z_2 - z_1)}{v} \qquad \Delta p_{wind} = p_c \cdot \frac{u^2}{2.v} \tag{2}$$

A model of a window can be built integrating the stack effet over the window height (Fig. 2).

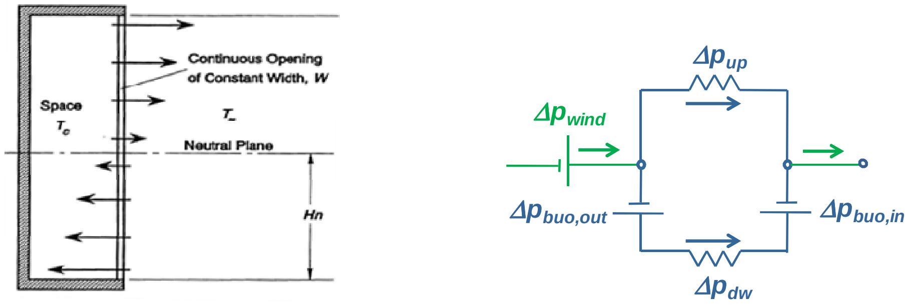

Figure 2. Window ventilation model.

DAHT supply/exhaust fans are modelled through a zero flow pressure generator followed by a pressure drop resistance. The heat exchanger adds another pressure drop resistance (fig. 3).

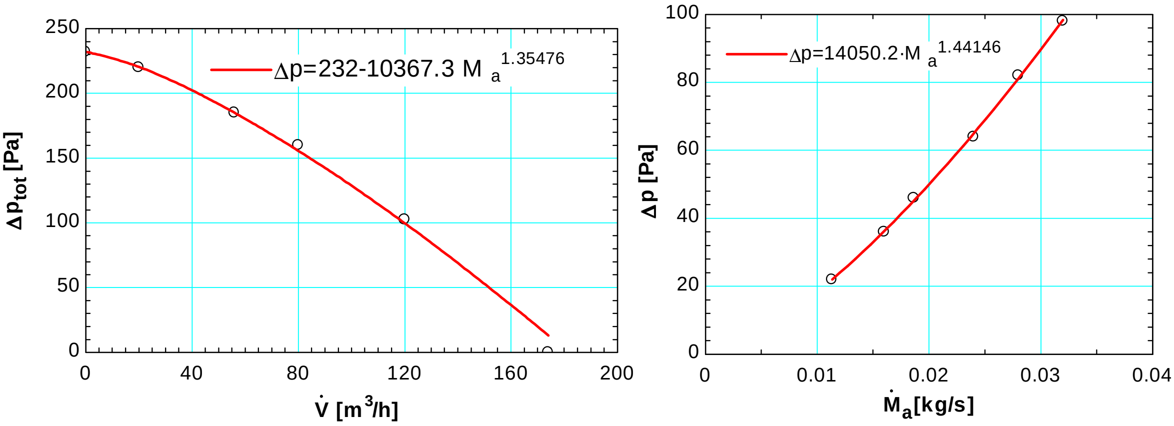

Figure 3. Regression laws: fan pressure/air flow curve (left) and heat exchanger pressure drop (right).

A model of the DAHT can be added to the window model (fig. 4).

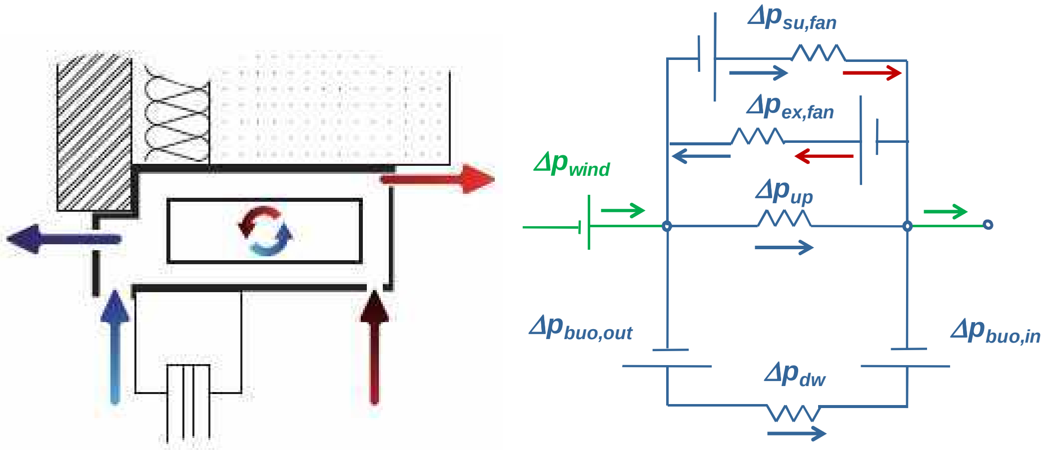

Figure 4. Model of the window provided with a DAHT.

TEST CASE STUDY

The model was used in order to assess the efficiency of decentralized air handling terminals in a semi detached house located in Belgium [1]. The house has 119 m2 floor area. It includes a living room with an open kitchen as well as a laundry at the first floor, three bedrooms and a bathroom at the second floor. It is supposed to be occupied by four inhabitants. The air tightness level is average, i.e. 12 m^3/h air flow per square meter of external wall at 50 Pa. This is equivalent to $n_{50}=8.2\ h^{-1}$.

Zones are shared between dry zones (living room and kitchen as a whole zone on the first floor, bedrooms on the second floor) and wet zones (sanitary and laundry on the first floor, bathroom on the second floor). Humidity generation profiles are defined according to occupants presence and activities (showers, clothes drying, floor cleaning). The humidity generated by cooking is supposed to be removed through a separate kitchen exhaust fan. Annual simulations are performed with EES solver on a hourly basis with average Belgium weather data.

Simulations over a whole year with a very detailed model of the heat exchanger [3] showed that energy savings provided by latent heat recovery, due to condensation of the indoor exhaust air humidity, is only about 2 % of the whole energy saving provided by the heat recovery, so that only the sensible part of heat recovery will be considered. Measurements performed on the heat recovery exchanger showed that its efficiency is averaging 0.80 [4]. Simulations are performed with a constant 0.80 sensible heat recovery efficiency.

1. Air flow control

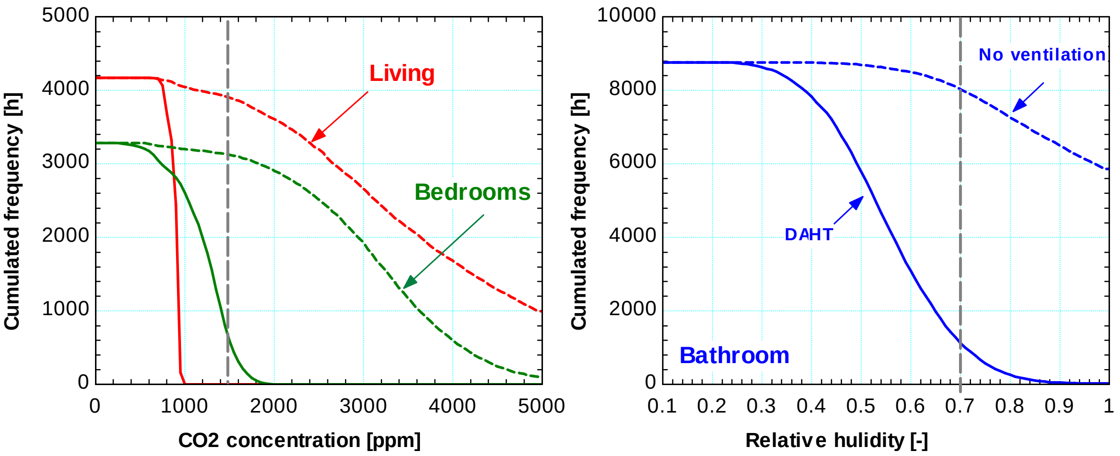

Fig. 5. Cumulated frequencies of indoor air CO2 concentration (left) and relative humidity (right) with and without ventilation through DAHT (respectively full and dotted lines).

A first simulation is performed with no ventilation system, the building air renewal beeing only provided by infiltration. Figure 5 (dotted lines) shows that CO2 concentration is exceeding 1500 ppm during most of the occupancy hours in the livingroom and in the bedrooms (the outdoor CO2 concentration is equal to 400 ppm). The relative humidity is exceeding 0.7 most of the time in the bathroom.

A second simulation is performed with DAHT for ventilation. DAHT are sized according to Belgian standards: a supply fresh air flow of 3.6 m3/h per square meter of floor area is required in dry zones, and an exhaust air flow of 3.6 m3/h per square meter of floor area is required in wet zones with a minimum of 30 m3/h per room. The living room is supposed to be occupied 14h per day during the week and 17h per day during the weekend. DAHT fans are supposed to work at 100% load during occupancy hours, and at 10% load during no occupancy hours. In bedrooms, DAHT fans work continuously at 10% load to prevent noise problems.

Figure 5 full lines show the results related to DAHT ventilation. Air quality requirements, i.e. maximum 1500 ppm CO2 concentration and 0.7 relative humidity are respected. The livingroom appears to be overventilated. Ventilation air flow control is provided in order to avoid overventilation.

Air flow control is performed through CO2 probes in the livingroom and in the bedrooms, while it is performed trough relative humidity probes in the laundry and in the bathrooms. The frequency curves of figure 5 are almost the same that those observed without control, except for the livingroom where the overventilation disappears providing energy savings as displayed on figure 6: ventilation heat losses decrease by 10 kWh per year and per square meter of floor heated area.

2. Building envelope air tightness

The influence of building airtighness level on the heat recovery energy performance is highlighted by the following simulation: the building average air tightness level i.e. 12 m3/h air flow per square meter of external wall area at 50 Pa or n_{50}=8.2 h^{-1}, is improved to reach a high air tightness level i.e. 1 m3/h.m2 at 50 Pa, or n_{50}=0.68 h^{-1}. The result is displayed on figure 6: ventilation heat losses decrease by 3.5 kwh per year and per square meter of floor heated area. The humidity level in the bathroom and the CO2 concentration in the livingroom are not affected, while the CO2 concentration in bedrooms increases beyond 1500 ppm half of the occupancy hours, suggesting an increase of the minimum DAHT fan load from 10 to 15%.

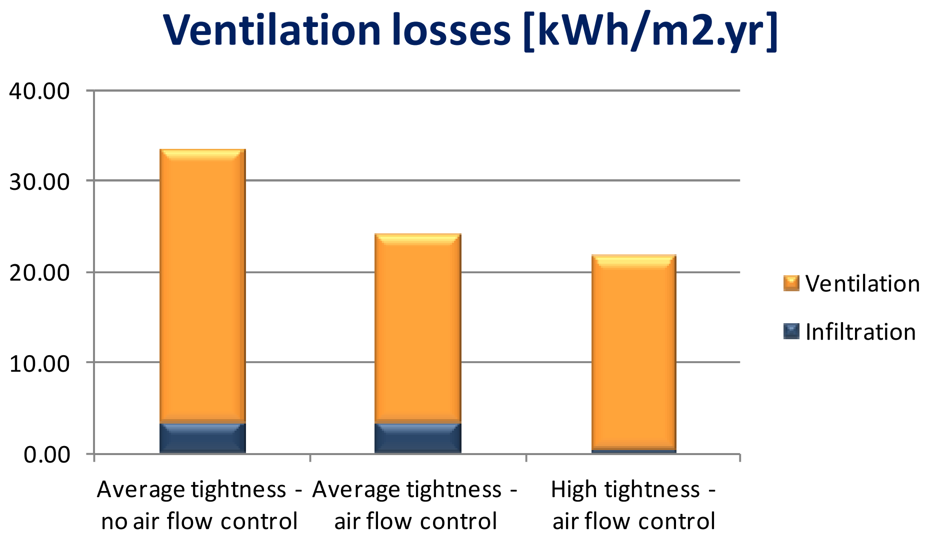

Fig. 6. Yearly specific ventilation heat losses for an average building airtightness without and with air flow control, and for a high tightness level combined with air flow control.

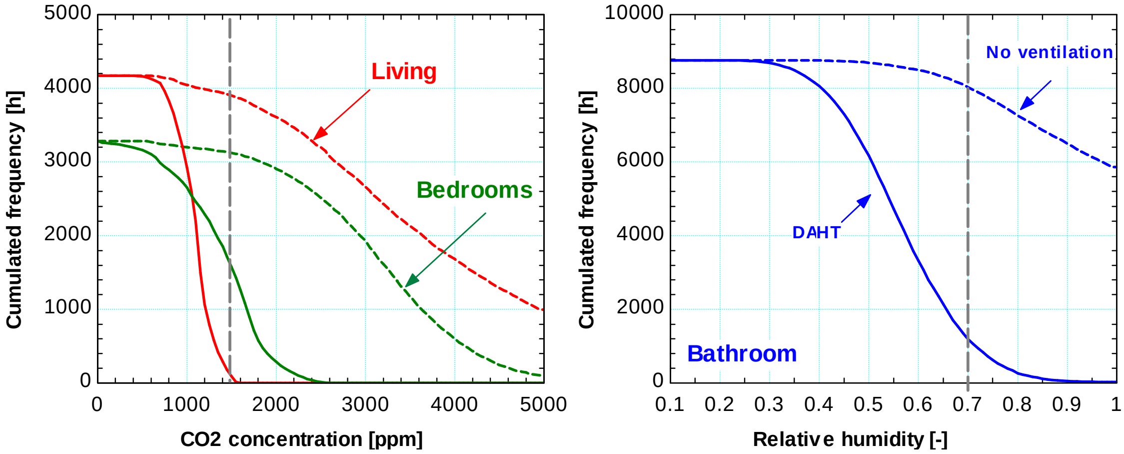

Fig. 7. Cumulated frequencies of indoor air CO2 concentration (left) and relative humidity (right) without and with controlled DAHT and high tightness level (respectively full and dotted lines).

3. Fans authority

Simulation of ventilation system interacting with the building envelope is also usefull in order to predict the level of pressure difference the DAHT fans must be able to face.

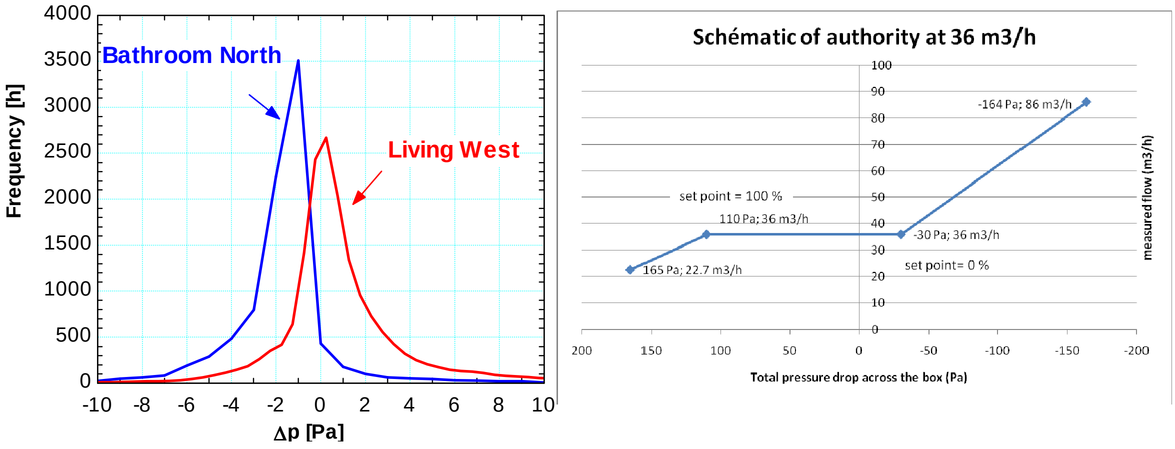

Fig. 8. Frequencies of pressure differences between DAHT fans terminals (left) and measured DAHT fan authority (right).

Results regarding a West facing DAHT in the living room and a North facing DAHT in the bathroom are presented on fig. 8, the first system being mostly pressurized, the second being mostly depressurized. The over/under pressure never exceeds + or – 20 Pa and is comprised between - and + 10 Pa most of the time suggesting that the measured DAHT fan authority is sufficient (fig. 8).

CONCLUSION

Different simulations are performed on a house case study in order to assess the energy performance of Decentralized Air Handling Terminals provided with heat recovery exchangers.

DAHT fans can be modeled through a pressure generator followed by a resistance, and coupled to a whole model of the building.

Air flow control through CO2 and relative humidity indoor probes provides a reduction of 10 kWh heat losses per year and per square meter of floor heated area. An improvement of the building air tightness level adds up a 3.5 kWh/yr.m^2 reduction.

The authority of DAHT supply and exhaust fans must be comprised between + and – 20 Pa in order to ensure that the expected fan air flow is reached.

ACKNOWLEDGEMENTS

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