Hybrid Controlled Trickle Ventilators

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SUMMARY

The performance of “hybrid controlled” trickle ventilators, that is background ventilators whose opening area depends upon both the pressure difference across the vent and the relative humidity of the room air, are investigated by means of computer simulation and compared to that of conventional fixed ventilators for two internal moisture production rates. The results show the hybrid ventilator performs better than the fixed ventilator, resulting in lower ventilation heat loss while maintaining lower relative humidity.

INTRODUCTION

In UK dwellings “controlled” background ventilation is often provide by the installation of trickle ventilators. These units are controllable to the extent that they can be opened or closed by residents. They do not adjust automatically to environmental conditions. The relationship between the opening area of such vents and indoor air quality has recently been investigated [1]. It was noted that the ventilation provided by such ventilators is highly dependent upon weather conditions, leading to the possibility of both under and over ventilation unless appropriately controlled by occupants. Automatic ventilators however have the potential ability to react appropriately to environmental conditions. Two types of automatic ventilator, pressure and relative humidity, RH, controlled, are currently commercially available. Pressure controlled ventilators reduce their opening areas when exposed to higher pressure differences, reopening at lower pressures. Such ventilators could in theory reduce over-ventilation due to gusts of wind, leading to improved comfort and energy efficiency. Relative humidity controlled ventilators open when internal relative humidity is high and partially close when relative humidity is low, potentially leading to improved indoor air quality, energy efficiency and comfort.

The possible benefits of automatic ventilation control of trickle ventilators, in dwellings have been recently investigated [2]. Results confirmed that active vents could be of use in eliminating over ventilation and hence reducing ventilation heat loss whilst at the same time as ensuring adequate air quality. An improved type of automatic ventilator however, would be controlled by both RH and pressure, closing in times of high pressure only if internal RH was below a given threshold. This current work then focuses on the potential performance of such a ‘hybrid’ trickle ventilator i.e. a combined RH and pressure device. An extensive series of relevant simulations have been performed and this paper reports on the performance of such a device. The simulations explore the potential benefits of the hybrid ventilator, compared to fixed ventilators, specifically in relation to different internal moisture productions rates. When internal moisture production is low, the hybrid vent should react by reducing the ventilation rate and hence ventilation heat loss, reducing over ventilation. When
the moisture production rate is higher, the hybrid ventilator should increase the ventilation rate and hence reduce the occurrence of high internal RH.

Hybrid ventilators in low moisture producing houses should have the potential to reduce ventilation heat loss, but not improve indoor air quality. In dwellings with high moisture production rates hybrid vents will increase ventilation heat loss in order to improve indoor air quality. The relationship between the equivalent opening area of the ventilators, pressure, moisture production rate and internal relative humidity can be represented in a simplified manner mathematically, in the following equations. The internal vapour pressure excess, $V_x$ (Pa), can be expressed in the following form:

$$V_x = G \cdot R_v \cdot (T_i + T_e)/(2n \cdot Vol) \quad (1)$$

where: $G$ is the rate of moisture production, (kg/hr), $R_v$, water vapour gas constant 462 Pam3/kgK, $T_i$, internal air temperature, (K), $T_e$, external air temperature, (K), $n$, air change rate, (ach$^{-1}$), Vol, Volume of dwelling, (m$^3$).

Note, this equation assumes zero hygroscopicity of the building and furnishings. The air flow through the ventilator is related to the open area of the ventilator $A_i$:

$$A_i = 1272.5(p)^{0.5} \cdot q_v \quad (2)$$

Assuming $n$, the whole house ventilation rate, is the sum of the ventilation through ventilator $n_v$, and background ventilation, $n_b$, through cracks, and if we make the simplifying assumption that air enters through half of the ventilators and exits through the other half, and that the flow through all ventilators is equal in magnitude, then:

$$q_v = n_v \cdot Vol/N \cdot 1.8 \quad (l/s) \quad (3)$$

$$n = n_v + n_b \quad (4)$$

If

$$Z = G \cdot R_v \cdot (T_i + T_e)/2 \cdot Vol \cdot ((SVP_i \cdot R_{Hi}) - V_e) \quad (5)$$

then

$$Z - n_b = (1.8N \cdot A (p)^{0.5})/1272.5 \cdot Vol \quad (6)$$

given

$$n_b = A_b (p)^{0.5}/1272.5 \cdot Vol \quad (7)$$

then

$$1272.5 \cdot Vol \cdot Z = [1.8N \cdot A_b (p)^{0.5}]$$

Given the internal and external temperatures, the external relative humidity, the volume, external façade area and air permeability of the dwelling, and the number of ventilators, then the equivalent opening area of each ventilator needed to maintain a given indoor RH as a function of pressure and moisture production rate can be calculated and graphed, figure 1. In this example the following has been assumed: $T_i = 293$ K, $T_e = 278$ K, $R_{Hi} = 0.80$, house volume of 200m$^3$, an external façade area of 170m$^3$, with a measured air permeability of 5m$^3$/hr/m$^2$, 10 ventilators. When pressure across the ventilator is high and moisture production is low, only a small equivalent opening area is necessary to maintain acceptable room RH. With moisture production rate of 8kg per day and a pressure of 6Pa, an opening area of 1000mm$^2$ is sufficient to result in RH of less than 65%. At a higher moisture
production rate of 12 kg/day and lower pressure differences, of only 1Pa an equivalent opening area of 4000mm$^2$ is required to maintain RH below 70%.

**METHOD**

In order to assess the theoretical benefits of automatically controlled trickle ventilators, annual simulations of a test house using EnergyPlus were carried out. Energy Plus [3], was chosen as the computer simulation model as it allows the thermal, energy, ventilation and moisture performance of the house to be modelled simultaneously in one program. In order to simulate automatic control of the ventilators, a visual basic routine was used to set the ventilator opening schedules, based on room RH and pressure across the ventilator, and a series of iterative simulations run. The ventilators are modelled in a standard dwelling previously detailed by the authors [1] used to test the performance of standard trickle ventilators. A schematic layout of the house showing positioning of the trickle ventilators is given in Figure 2. The air infiltration of 5m$^3$/hr/m$^2$ at 50Pa is distributed evenly among the three external walls. The external climate used for the modelling was the Kew, (London, UK), TRY.

![Theoretical performance of Hybrid controlled ventilator](image)

Figure 1. Theoretical performance of a hybrid controlled ventilator
Two ventilators were modelled were:

1) A standard fixed vent with a fixed open area of 4000mm²

2) A hybrid (pressure and RH) controlled ventilator with an opening area of 1000 mm² if room RH < 60% OR pressure > 6Pa, and 6000mm² for room RH > 60% OR pressure < 6Pa

Two moisture production rates are modelled 6kg/day and 12 kg/day.

RESULTS

The results of annual simulations comparing the performance of the 2 ventilators are summarised in Table 1, for both the low and high moisture production rates. The average heating season ventilation rate, ventilation heat loss and average RH are presented. The heating season was assumed to be October to April inclusive.

<table>
<thead>
<tr>
<th>Ventilator (moisture production)</th>
<th>Mean background ventilation rate (ach⁻¹)</th>
<th>Mean Vent Heat Loss (KWh)</th>
<th>Mean RH (%)</th>
<th>Hours RH &gt;70 (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed (lower)</td>
<td>0.51</td>
<td>1760</td>
<td>49.9</td>
<td>20</td>
</tr>
<tr>
<td>Fixed (higher)</td>
<td>0.51</td>
<td>1760</td>
<td>58</td>
<td>496</td>
</tr>
<tr>
<td>Hybrid (lower)</td>
<td>0.32</td>
<td>1093</td>
<td>50.6</td>
<td>2</td>
</tr>
<tr>
<td>Hybrid (higher)</td>
<td>0.43</td>
<td>1425</td>
<td>58.9</td>
<td>394</td>
</tr>
</tbody>
</table>
DISCUSSION AND CONCLUSIONS

The results show the hybrid ventilator performs better than the fixed ventilator, which cannot react to the moisture load. At the lower moisture load the hybrid ventilator reduces ventilation heat loss by 38% compared to the fixed ventilator without incurring an increased number of hours when average internal RH is above 70%. At the higher internal moisture production the hybrid ventilator still reduces the ventilation heat loss by 19% at the same time as reduces the number of hours RH>70% by 21% compared to the fixed ventilator. It is noted that the method of simulating the performance of hybrid trickle ventilator is a simplification, considering only two discrete states, (opening area), and does not model the ventilator continually adjusting to changing conditions. The absolute values of the improvements in ventilation heat loss and relative humidity are of course subject to many uncertainties and assumptions. Further work is underway to develop the model and these results should only be treated as a proof of concept, indicating that hybrid controlled ventilators appear to be of benefit when compared to fixed ventilators. Moisture is considered as the only pollutant, the presence of other indoor contaminants may require greater ventilation rates than those provided by a ventilator designed purely to control on internal relative humidity and pressure differences.

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REFERENCES