VENTILATION OF WINDOW INTERPANE CAVITY AIMED AT A HIGHER TEMPERATURE OF THE INNER PANE

by

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An experimental study of the thermal performance of an air-flow window with triple glazing is described. The measurements were carried out in a climatic chamber under conditions close to a winter season. In the experiments, the temperature and heat-flux distributions on each pane surface, and also the air-temperature distribution over the window height at the middle of the ventilated cavity were determined. The thermal performances of forced and naturally ventilated windows with internal cavities of various thicknesses are reported for a wide range of air-flow rates.

Introduction

In wintertime, a low temperature of the inner surface of window glazing is one of the reasons for thermal discomfort in a room. The use of air-flow windows is an effective method for increasing the inner-pane temperature. In the present study, two ventilation schemes using warm indoor air were considered: the first method employs forced ventilation of the interpane cavity and the second uses its natural ventilation.

Windows with forced ventilation

Such windows have been used in some European countries, for instance, in Sweden, Finland, Germany, and France, since early 70s. In wintertime, organization of exhaust ventilation through windows permits a better heat economy of buildings and raising the temperature of the inner panes of windows, what makes the room climate more comfortable. The ventilation of a window is organized as follows. In the top and the bottom part of the window a slot is provided for ensuring communication between the interpane cavity and the indoor air. The air is sucked out from the interpane cavity through an exhaust duct or immediately leaves it passing outdoors. In the latter case, the room pressure should be in excess of the outdoor one, for which an air-supply system is needed. One of the first experimental studies of exhaust air windows was carried out by the Swedish Research Institute for Construction Engineering 1 . During the last 30 years, several studies of the thermal performance of such windows have been reported 2–4 . Examination of available data have allowed to formulate unsolved problems in this research area 5 . In previous works concerning forced ventilation of window cavities, the following points have not been adequately addressed: data on the heat-flux distribution over the glazing surface, and the relation between the thickness of inter-pane cavity and the thermal performance of the window. Besides, the data obtained by different authors are hard to compare and sometimes controversial.

Windows with natural ventilation

To ensure air circulation through windows, mechanical ventilation systems are usually used. However, one can simultaneously raise the inner pane temperature, using natural ventilation of the interpane space. In such windows, the inter-pane cavity, adjacent to the inner pane, communicates, in its top and bottom parts, with indoor air. In this manner, an air exchange between the inter-pane space and the room is ensured. This method of organizing ventilation of the interpane cavity remains poorly studied. The authors of 6] suggest using a window ventilated in this manner for increasing the comfort level in a room under the hot climatic conditions. At the same time, no data were reported concerning the use of naturally ventilated windows under conditions with low outdoor temperatures.

Here, results of an experimental study of windows with triple glazing ventilated with indoor air are described. Two series of tests were performed. The first series was aimed at revealing thermal characteristics of an air-flow window with forced ventilated inner inter-pane cavities of various thicknesses in a wide range of air-flow rates. The second series was aimed at studying the thermal performance of a window with natural ventilation of the inner inter-pane cavity with indoor air.

Experimental setup

The experiments were conducted in a small climatic chamber. The schematic of the setup is shown in Fig. 1. The window model was a wood window frame 465 × 965 mm in size, with a triple 345 × 854 mm glazing. The transparent part of the window consisted of a double-glass unit having the dimensions 4 × 16 × 4 mm, installed on the side of the cold section of the climatic chamber, and a single 4-mm-thick glass sheet installed on the side of the warm section (room). The thickness of the ventilated cavity, *i. e*. the distance between the double-glass unit and the single glass sheet was 12, 18, 27, and 40 mm. In the top and bottom parts of the window frame, 10-mm-wide slots were provided through which air entered the inter-pane space and left it. The temperature in the cold section of the climatic chamber was maintained constant (–30 °C). The indoor-air temperature was 18 °C.

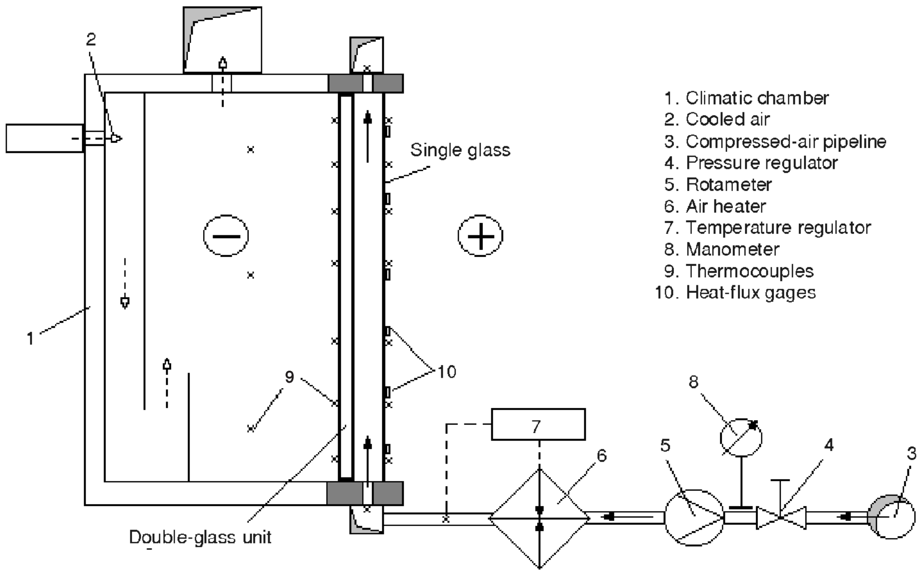

Figure 1. Experimental setup

In the series of forced-ventilation tests, the constant flow rate of the air circulating through the interpane cavity was provided by a special air-supply system. The temperature of the air entering the interpane cavity was kept equal to the indoor-air temperature. The air between panes was ascending from bottom to top of the cavity, and then it was exhausting outdoors. In the experiments, the air-flow rate, G, was 9–56.4 m^{3}/h per one meter of the glazing width.

In the course of the experiments, the temperature and heat-flux distributions on each pane were determined, as well as the air-temperature distribution over the height of the middle plane of the interpane cavity. An analog-to-digital converter was used to process the signals generated by thermocouples and heat-flux meters. Special computer code was used to organize data acquisition and processing.

Preliminarily, the model of the window with triple glazing without ventilation was tested. The obtained data showed that the thermal resistance ensured by the window compared well with the values typical for such windows (R = 0.55 m^{2}°C/W)

Results and discussion

Window with forced ventilation

The distribution of the inner-pane temperature, T_{gi}, over the window height for various rates of air flow through the ventilated cavity is shown in Fig. 2a. Here y is the longitudinal coordinate reckoned from the lower edge of the glazing and H is the glazing height. It is seen from the figure that the inner-pane temperature increases appreciably with increasing rate of air flow. Compared to the window with triple glazing without ventilation, the increase in temperature is most pronounced in the lower part of the window. It follows from the figure that the supply of warm air into the inter-pane cavity permits raising the inner-pane temperature by 2–7 °C in the middle part of the window and by 8–13 °C in its bottom part. The temperature difference between the indoor air and window and wall inner surfaces is an important indicator of climatic comfort in a room. For the highest rate of air flow in the inter-pane cavity, 56.4 m^3/hm, the difference between the indoor-air temperature and the inner-pane temperature was less than 4 °C throughout the entire window height. Such a temperature difference meets currently adopted standards for the near-window zone of a room.

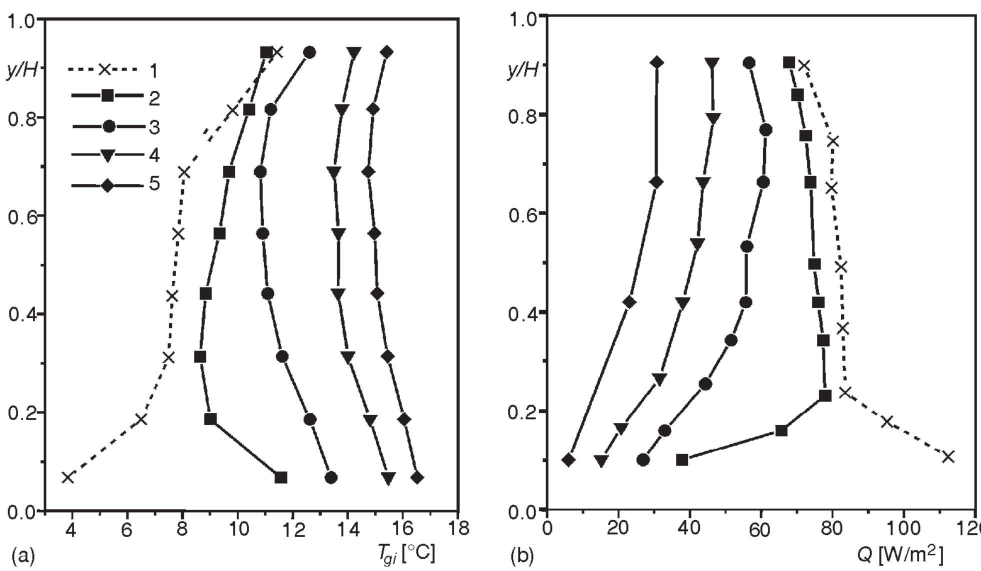

Figure 2. Temperature (a) and heat-flux (b) distributions over the height of the inner pane of the window with forced ventilation of the interpane cavity
1 – conventional triple-pane window without ventilation, 2–5 – air-flow window (2 – G = 9 m³/hm, 3 – 12.9, 4 – 26.4, 5 – 56.4)

The heat fluxes, Q, measured at the inner pane of the air flow window are shown in Fig. 2b. It is seen that ventilation of the interpane cavity considerably reduces the heat flux out of the room. With air-flow rates of 9 m^3/hm and 56.4 m^3/hm, the heat flux turned out to be reduced by 15% and by more than 3.5 times, respectively, compared to the window without air flow. As in Fig. 2a, the effect due to air flow is more pronounced for the bottom part of the window, into which the warm indoor air entered. The heat flux is distributed rather uniformly throughout the glazing area.

The dependence of the thermal performance of the air-flow window on the air-flow rate in the interpane cavity is shown in Fig. 3. The thermal resistance of windows, R, is one of the main thermal characteristics of a building envelope. In the present study, the magnitude of this parameter, both for the air-flow window and for the window without ventilation, was calculated by the formula:

$$R = \Delta T/q + 1/\alpha_o + 1/\alpha_i$$

wher ΔT is the temperature difference between the inner and outer panes of the window, and α_o and α_i are the conventionally acceptable values of the heat-transfer coefficients at the outer and inner surfaces of the glazing, respectively (α_o = 23 W/m^2°C and α_i = = 8.7 W/m^2°C).

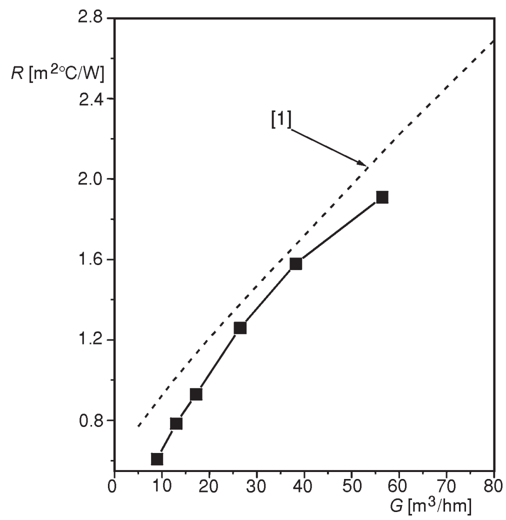

Figure 3. Thermal resistance of the window with forced ventilation of the interpane cavity

For the maximum air-flow rate examined in this study, the thermal resistance displayed by the air-flow window was 1.91 m^2°C/W, which is 3.5 times higher than the same parameter for a conventional window with triple glazing. It should be noted that the *R vs. G* dependence becomes more gently sloping as the rate of the air flow through the interpane cavity increasing; hence, further increase in the air-flow rate adds little to the improvement of the thermal performance of the window. The latter factor is of great importance in choosing the optimum rate of air flow through the window. For comparison purposes, in Fig. 3 results obtained by the Swedish authors for an exhaust air window 1 are also plotted. Since, in 1 , the geometric characteristics of tested model windows are not reported, the data shown in the figure are hard to compare correctly enough. However, almost identical slopes of the curves provide evidence for a good correlation between the *R vs. G* dependences obtained in 1 and in the present study.

Window with natural ventilation

The distributions of the air temperature, T_a, over the middle plane of the inner interpane cavity for the triple-glazed windows with and without air flow are shown in Fig. 4. Inside the inner cavity communicating with the indoor air there arises a steady air flow directed downward. The temperature of the air that enters the inner inter-pane cavity through the upper slot gradually decreases as it moves downward. The temperature difference between the inlet and outlet air turned out to be in excess of 17 °C. The air temperature profiles over the height of the inner interpane cavity in the windows with

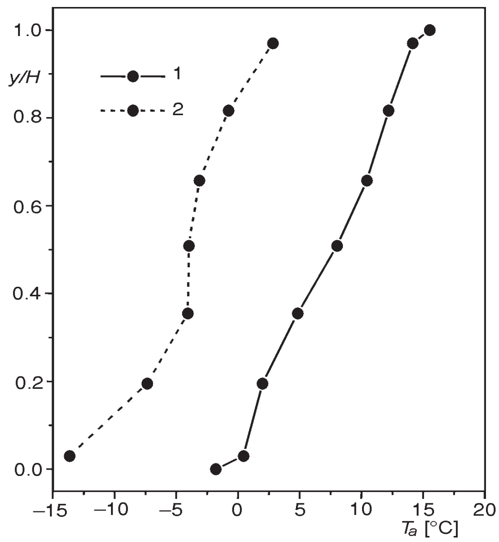

Figure 4. Air-temperature distribution at the middle of the interpane cavity in the triple-pane window
1 – window with natural ventilation, 2 – window without ventilation

and without air flow were similar, but the magnitude of air temperature in the air flow window was higher by 12 °C, on the average.

The difference between the indoor-air temperature, T_i, and the inner-pane temperature for various types of the window are shown in Fig. 5(a). As is seen from the figure, this difference for the air-flow window is 2–5 °C and 5–9 °C smaller than that for the ordinary triple- and double-pane windows, respectively. Furthermore, the temperature profile over the height of the air-flow window is more uniform than that for the conventional types of windows. A slight increase in the outer-pane temperature for the triple-pane air-flow window compared to the ordinary triple-pane window deserves mention – see Fig. 5(b). However, as compared to the double-glazing case, the difference between the outer-pane temperature, T_{go}, and the

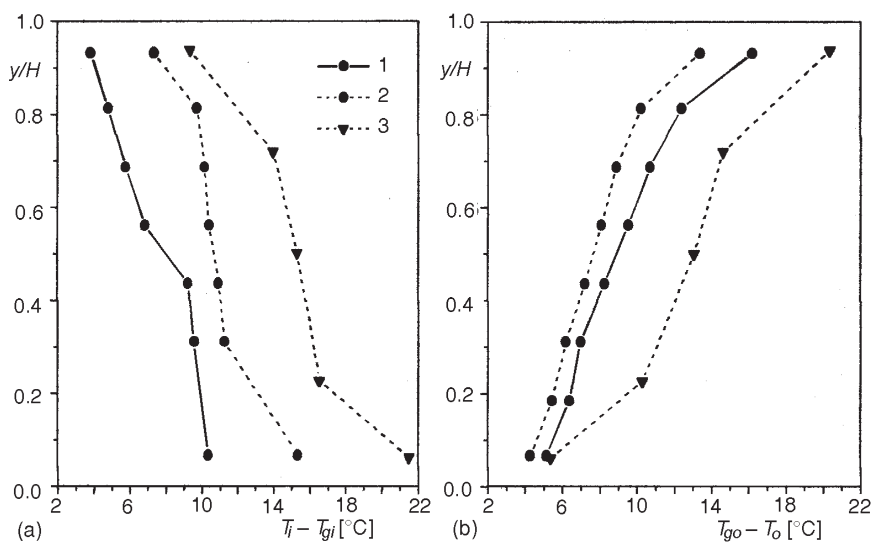

Figure 5. Temperature difference between the indoor air and the inner-pane surface (a) and between the outer-pane surface and the outdoor air (b)
1 – triple-pane window with natural ventilation, 2 – conventional triple-pane window 3 – conventional double-pane window

outdoor-air temperature, T_o, is smaller both for the conventional triple-pane window and for the window with natural ventilated inner cavity.

The heat flux at the inner pane of the window with natural ventilation is 35 W/m^2 lower throughout the entire window height than that for the ordinary triple-pane window and 100 W/m^2 lower than that for the ordinary double-pane window.

Conclusions

From the experimental study of the air-supply window, the following conclusions can be drawn.

The forced ventilation of the window with indoor air allows one (I) to ensure a comfortable temperature difference between the indoor air and the surface of the inner pane (lesser than 4 °C) over the entire height of the window and (II) to increase the thermal resistance of the transparent part of the window by a factor of 3.5 (at an air-flow rate of 56.4 m^3/hm) compared to the standard triple glazing.

With increasing rate of air flow through the inter-pane cavity, the following facts are observed:

(a) the air temperature at the window outlet decreases,
(b) the inner-pane temperature increases simultaneously leveling out throughout the window height, and
(c) the heat losses through the inner pane of the window unit decrease and, hence, the thermal resistance of the window increases.

The studies of air-flow windows with triple glazing and natural ventilation of the inner inter-pane cavity with indoor air showed that (I) the such type of window ensures a higher temperature of the inner pane compared to the window without air flow; (II) the heat flux through the inner pane of such window is appreciably lower than the heat flux through conventional windows; (III) organization of natural ventilation of the inter-pane cavity is easier than that of forced ventilation.

In the triple-pane window , a special device can be installed providing the opportunity of passing from the ordinary operating regime with air-sealed inter-pane cavities to the regime of air-flow window. The decision whether it makes sense or not to use certain regime depends on thermal conditions in the room and on comfort requirements for near-window zone of the room.

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