A Study on Indoor Environments Made by Thin Line Type Ventilators in Apartment Houses

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Abstract
Total heat recovery type ventilators that are connected to each room with ducts are mainly installed in Korea, but they raise concern over duct pollution. In this study, indoor environments made by thin line type ventilators installed in dwelling units of apartment houses are investigated by CFD. Results show the case that thin line type ventilators installed in each room - including kitchens - make the best indoor environment that maintains air velocity at under 0.25m/s, and evenly distributes the age of air in all areas.
Keywords: Ventilator, CFD, Age of air

Introduction

Sick house syndrome (SHS) has been a big social issue in Korea recently, and many people are interested in the indoor air quality (IAQ). Hence, apartment house suppliers were obliged to install ventilators that comply with regulations on architectural equipment standards enacted on February 13, 2006. Under consideration of energy conservation, total heat recovery type ventilators were mainly installed. This type of ventilators is usually connected to each room with a duct. However, ventilators connected with ducts raise concerns over duct pollution and cannot be adjusted to respond to different demands in each room. Thin line type ventilators examined in this paper are installed on window frames in each room and do not need to be connected with ducts (see Fig. 1). The ventilators are composed of total heat exchangers, fans, filters and thin line slots. In this study, air flow fields, temperature fields and the distribution of age of air in a dwelling unit of an apartment house that is equipped with a thin line type ventilator are investigated by computational fluid dynamics (CFD).

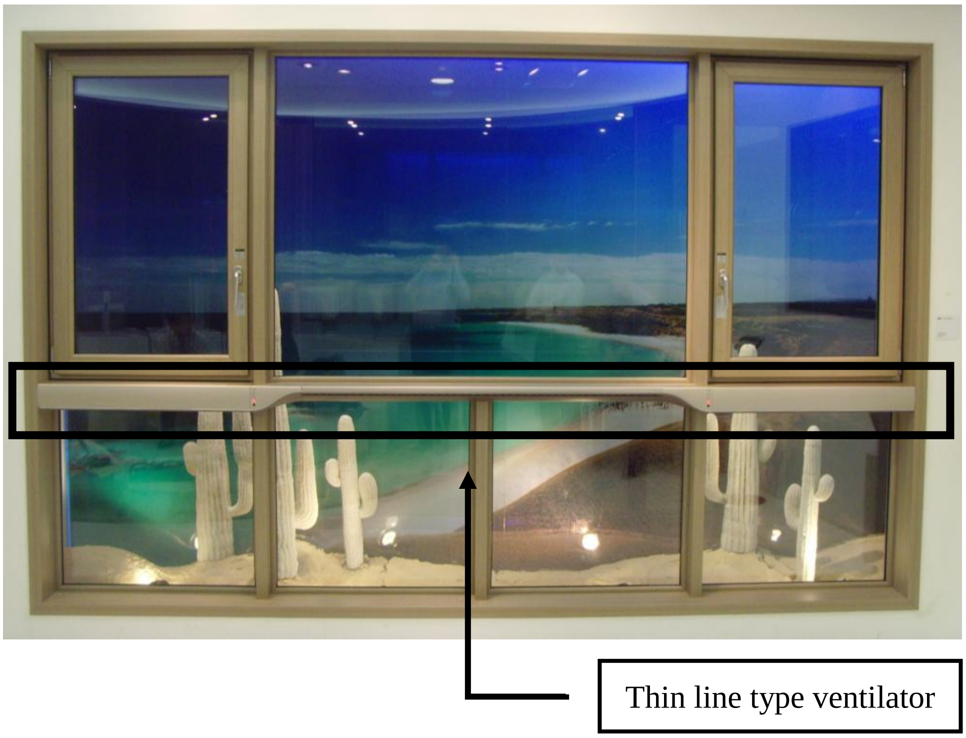


Fig. 1 Thin line type ventilator installed on a window frame

Methods

Air flow characteristics of a thin line type ventilator installed on window frames were investigated by CFD simulation in a dwelling unit of apartment house as shown in Fig. 2. The dwelling unit was composed of one living room, one dining kitchen and three bedrooms. Meshes for CFD simulation were made of hexahedron meshes as shown in Fig. 3 except Case A (see Table 1), in which they were made of tetrahedron meshes; the number amounted to about 600,000 in each. The CFD simulation was conducted using the standard k-ε model as the turbulence model.

Simulation cases and boundary conditions are as shown in Table 1. In case A, a duct type ventilator, which is the general type in Korea is applied. Supply and exhaust air volume in all cases except Case D are adjusted to 150 CMH to satisfy the air change rate of 0.7 h^{-1} which is a legal guideline in Korea. Under this condition, a thin line type ventilator is installed in each room except the living room, where two ventilators are installed. In Case D, a thin line type ventilator is installed on the window frame of the kitchen, whereas in Case B and Case C, there is no ventilator in the kitchen. Supply air temperature was calculated applying 75% of sensible heat recovery efficiency under winter conditions with an outdoor air temperature of 11.3℃. Indoor space is heated by *Ondol* system - a Korean traditional floor heating system. Indoor air temperature and exhaust air temperature are at 20℃.

Fig. 2 Floor plan of apartment house

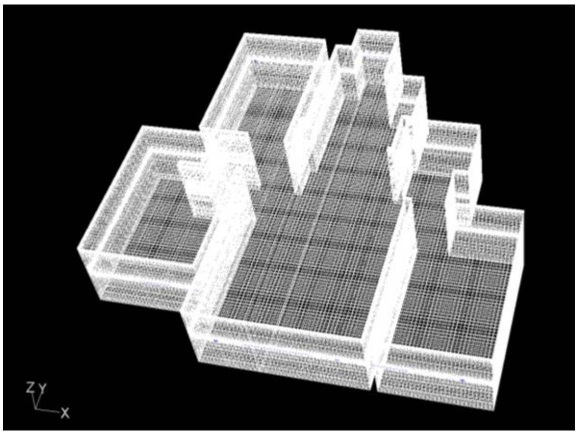


Fig. 3 Meshes for CFD simulation

Table 1 Simulation cases and boundary conditions.

Cases	Features	Supply /exhaust Air volume [CMH]	Air change rate [h^{-1}]	Supply air velocity [m/s]	Return air velocity [m/s]	Supply air temperature [℃]
Case A	Duct type with pan diffuser	150	0.72	1.45	2.36	12.175
Case B	Thin line type, except kitchen, horizontal supply (30CMH ×5 EA)	150	0.72	2.0	1.19	12.175
Case C	Thin line type, except kitchen 30° upward supply, (30CMH × 5EA)	150	0.72	2.0	1.19	12.175
Case D	Thin line type, kitchen included, 30° upward supply, (30CMH × 6EA)	180	0.87	2.0	1.19	12.175

Results and Discussion

Air flow fields, temperature fields and age of air distributions of each case are as shown in Table 2 and Table 3.

1) Duct type ventilator with pan diffuser (Case A)

In this case, pan type supply diffusers are installed on the ceiling near the windows in each bedroom, and two diffusers are installed in the living room. Two return diffusers are installed on the ceiling of the kitchen, near the entrance, whereas there is no return diffuser in the rooms. As shown in Table 2, in all areas except near supply diffusers, air velocity is maintained under 0.25m/s which is the recommended air velocity for preventing draught by ASHRAE. The temperature field at the horizontal section shows about 18℃ in room 1 and room 2, even though the average indoor air temperature is maintained at 20℃. The reason to this may be because the area rate of windows by room in those rooms is relatively large in comparison to the other rooms. The age of air distribution at the horizontal section shows a relatively even distribution. Age of air is under 70 minutes near windows where supply diffusers are installed on the ceiling in the neighborhood; under 80 minutes in the inner space of each room and the living room; and about 100 minutes in the kitchen where only return diffusers are installed.

2) Thin line type ventilator with horizontal supply (Case B)

In this case, thin line type ventilators are installed on window frames of each room except the kitchen. Air is supplied horizontally at 2m/s, a relatively high speed. A spot 1.2m away from the supply slot shows air velocity of about 0.3m/s, and dwellers may be able to feel a draught. The temperature field at the horizontal section shows an area of about 16℃ according to the air flow supply, even though the average indoor air temperature is maintained at 20℃. The age of air distribution at the horizontal section shows relatively even distribution.

3) Thin line type ventilator with 30° upward supply (Case C)

In this case, air is supplied in a 30° upward direction under the same conditions of Case B. Supplied air is pushed up by the air flow induced from the lower part of the indoors (See Table 3). By this way, supplied air flows first to the ceiling, and then to the inner part of indoor space. Air velocity is under 0.25m/s in all indoor space except in front of the supply slot, and the draught is no longer an issue. Temperature field at the horizontal section shows relatively even distribution, and the reason may be because the relatively cold air supplied in an upward direction at about 12℃ is mixed well with indoor air near the ceiling, before it

Table 2 Results of CFD analysis in Case A and Case B

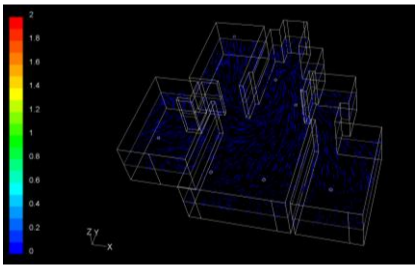
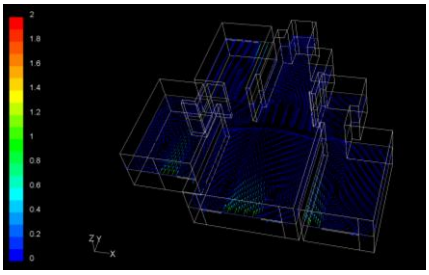
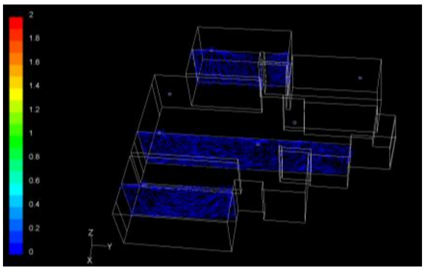
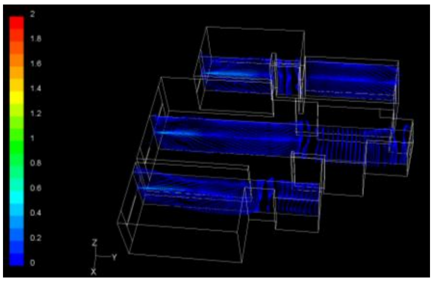
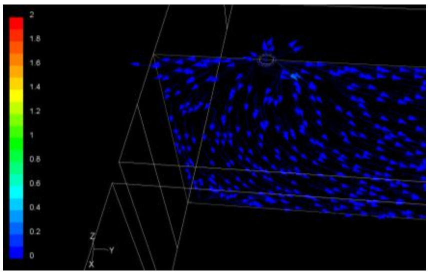
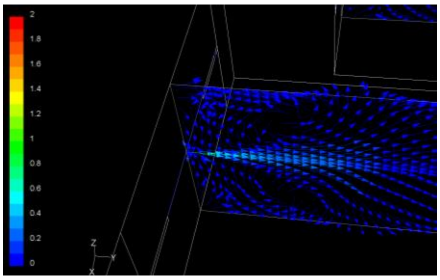
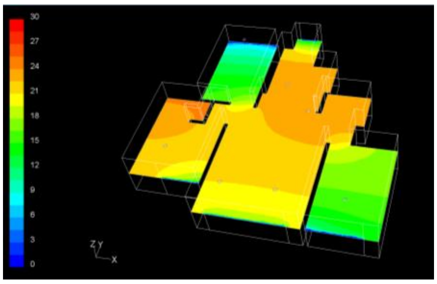
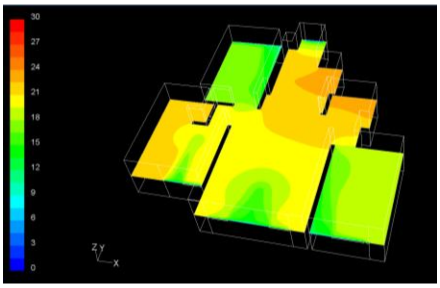
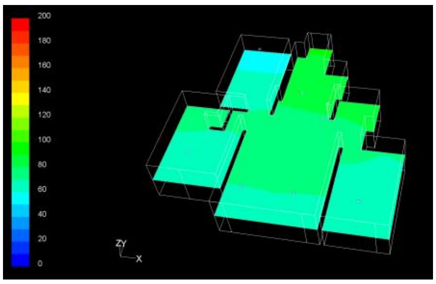
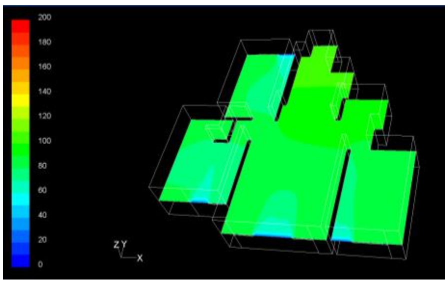
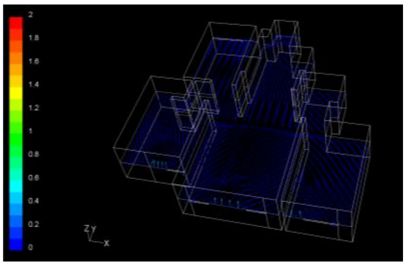
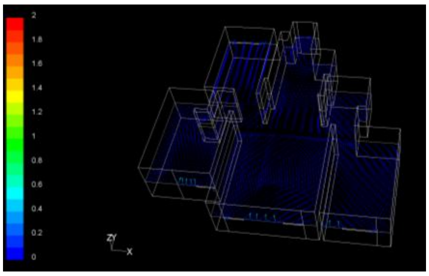
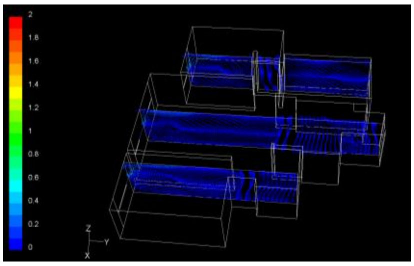
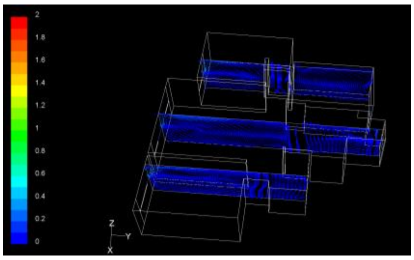
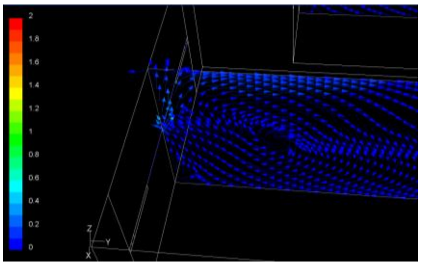
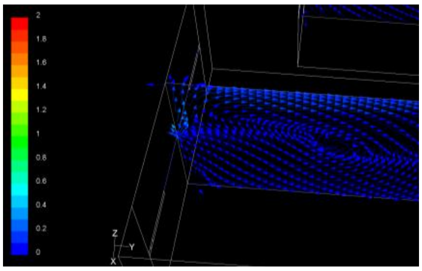
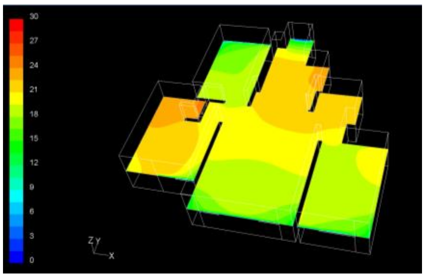
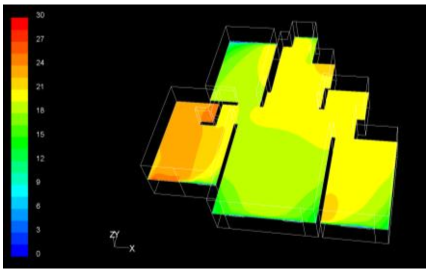
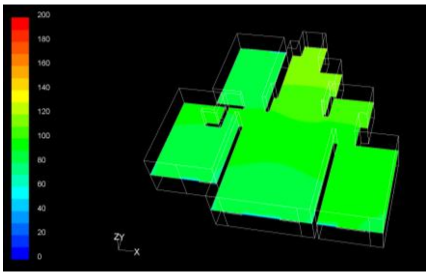
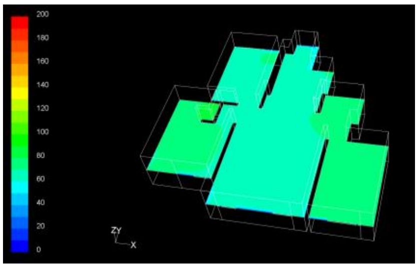
Cases	Case A	Case B
Air velocity field at a horizontal section		
Air velocity field at a vertical section		
Air velocity field magnified at a vertical section		
Temp. field at a horizontal section		
Age of air distribution at a horizontal section		

Table 3 Results of CFD analysis in Case C and Case D

Cases	Case C	Case D
Air velocity field at a horizontal section		
Air velocity field at a vertical section		
Air velocity field magnified at a vertical section		
Temp. field at a horizontal section		
Age of air distribution at a horizontal section		

flows into the inner part of indoor space. This air flow pattern affects the distribution of age of air, and shows a relatively even distribution. However, the age of air reaches about 120 minutes in the kitchen because there is no ventilator.

4) Thin line type ventilator with 30° upward supply, kitchen included (Case D)

In this case, a ventilator is installed in the kitchen under the same condition of Case C. Air at about 12℃ is supplied in a 30° upward direction from the slot of the ventilator installed on the kitchen windows. As seen in Table 3, air flow field and temperature field show almost identical results with Case D. The age of air is improved in all areas including the kitchen at about 70 minutes.

Conclusions

1) In the case of the duct type ventilator, air velocity is maintained under 0.25m/s, and the age of air is under 70 minutes near windows and about 100 minutes in the kitchen where only return diffusers are installed.

2) In the case of the thin line type ventilator with horizontal supply, dwellers may be able to feel a draught.

3) In the case of the thin line type ventilator, in which air is supplied in a 30° upward direction but not installed in the kitchen, air velocity is under 0.25m/s in all the indoor space except in front of the supply slot. However, the age of air shows about 120 minutes in the kitchen which is relatively high.

4) In the case of the thin line type ventilator, in which the kitchen is included, air velocity is under 0.25m/s and the age of air is improved in all areas.

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