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Parametric Investigation of the Role of Contributing Factors on Thermal Comfort and Inhaled Air Quality for a Room with Stratum Ventilation

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ABSTRACT

Stratum ventilation method is the most promising option for reducing energy consumption of ventilation systems in near future. In this method, which is currently implemented in some modern countries, the ventilation of only a stratum of indoor space in which occupants' head and chest are located, is pursued. In the current study, 17 stratum ventilated cases with a manikin sited behind a desk and with different manikin's sitting locations, outlet positions and contaminant source locations are numerically modeled. To investigate the effects of sitting location, outlet position, and contaminant source location on thermal comfort and inhaled air quality, a parametric study with four different evaluation indexes is performed. The results of this study can help improve the design and performance of stratum ventilation systems.

KEYWORDS

Stratum Ventilation, Outlet Position, Sitting Location, Contaminant Source Location.

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1- INTRODUCTION

Modifying ventilation systems to consume the minimum energy can result in reducing carbon emission and also cost saving. Several governments in East Asia have taken proactive actions in this regard [1-5]. Even in United States, a survey from The International Facility Management Association shows that many facility professionals are adjusting the thermostat to higher settings in the summer to reduce the energy consumption [6]. Generally, many countries prefer to increase the normal summer temperature a bit to reduce energy consumption. But would such practice decline indoor environmental quality, especially the thermal comfort? To answer this question, the new ANSI/ASHRAE Standard 55-2010 presents new provisions that allow the elevated air movement to broadly offset the need to cool the air in warm conditions [7]. In revising EN ISO 7730, Olesen adopted Fountain and Arens' (1993) theory that higher air speed was required to offset increased indoor temperature [8]. Based on these advisements, there are currently two major ventilation methods which have potential to reduce the energy consumption: task station ventilation and stratum ventilation where both the occupants stay in the flow of supply air jet(s).

2- METHODOLOGY

2-1- NUMERICAL MODELING

Using Fluent 6.3 based on SIMPLE algorithm, collocated variable arrangement and tetrahedral unstructured meshing, indoor air flow is modeled. The numerical model is validated via experimental results of Tian et al [9]. They investigated air speed, temperature and CO_2 concentration of a stratum ventilated office experimentally. All four cases they studied had the same geometry (Figure 1) but different inlet velocity and temperature. For validation of the numerical model case no 3 is modeled via code. In this case, V_{in} =1.19 m/s, t_{in} =18.9 ^{o} C and c_{in} =496.9 ppm.

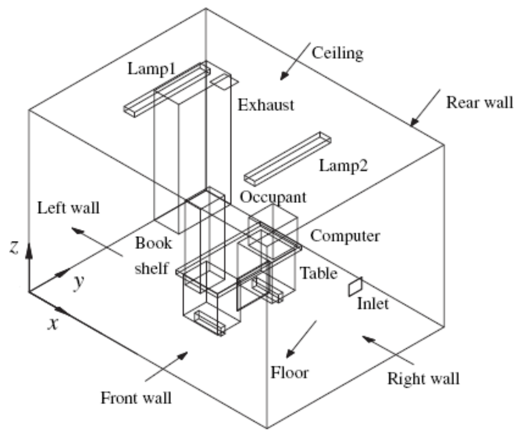

Figure 1: Configurations of Tian's test chamber [8].

Velocity magnitude, temperature and CO_2 concentration obtained from the numerical modeling and experimental investigation for vertical line at x=1.85m, y=1.45 at different elevations are compared in Figure 2-4. As displayed in these figures, an acceptable accuracy of the numerical model is obvious.

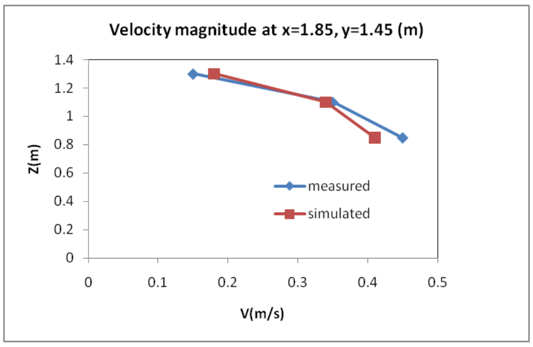

Figure 2: Measured and simulated velocity magnitude at different elevations of vertical line at x=1.85m, y=1.45

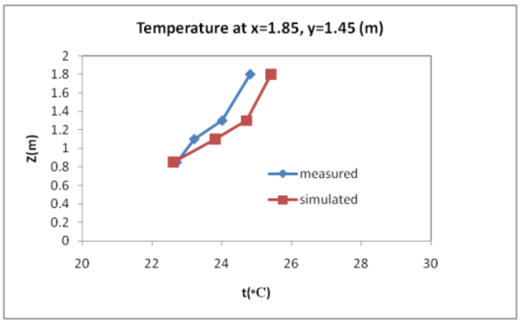

Figure 3: Measured and simulated temperature at different elevations of vertical line at x=1.85m, y=1.45

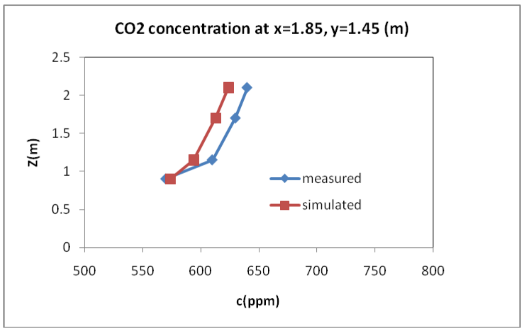

Figure 4: Measured and simulated CO_2 concentration at different elevations of vertical line at x=1.85m, y=1.45

2-2- EVALUATION INDEXES

Four indexes are used to perform quantitative evaluations as below:

a. Mean EDTS

The effective draft temperature for stratum ventilation (EDTS) is defined as

$$EDTS = (t_x - t_c) - (v_x - 1.1) \quad (1)$$

b. Ventilation effectiveness

T

$$E_t = (t_{out} - t_{in})/(t_{bz} - t_{in}) \quad (2)$$

c. Relative efficiency

$$\eta = (c_{out} - c_{in})/(c_{bz} - c_{in}) \quad (3)$$

d. new scale for inhaled air quality (NSIAQ)

$$NSIAQ = \frac{c_m}{c_{IA}} \frac{D_m}{L_2} \quad (4)$$

2-3- CASES STUDIED

In this study, 17 cases are investigated. 9 of them have no contaminant source while the other 8 have a contaminant point source. The geometry of first 9 cases is a small office, 4m long×3m wide×2.6m high, ventilated via a 300 mm×200 mm rectangular air diffuser located in the middle of the right wall with three different outlet positions and three different sitting locations. Combining these three outlet positions and three sitting locations, nine cases have been produced. Each case is identified by a name and a number. For example, case "Right2" means the case which manikin's sitting location is at the center and outlet is positioned at outlet position 2.

The 8 cases with a contaminant source have the same geometry as the first 9 cases. In these cases, the manikin is placed at the center and air is ventilated through outlet positioned at 2 or 3. Combining 4 contaminant source location (a, b, c and d) and two outlet position 8 cases are produced which are named as a2, b2, c2, d2 and a3, b3, c3, d3. The inlet velocity, temperature and CO_2 concentration are uniformly 1.2 m/s, 19 ^{o} C and 300 ppm, respectively.

3- RESULTS AND DISCUSSION

The four evaluation indexes are presented in Figures 5-8.

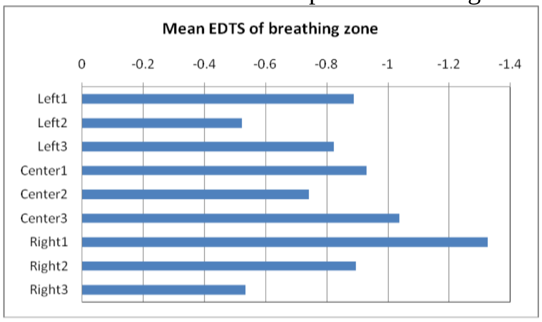

Figure 5: Mean effective draft temperature for stratum ventilation (EDTS) for cases studied.

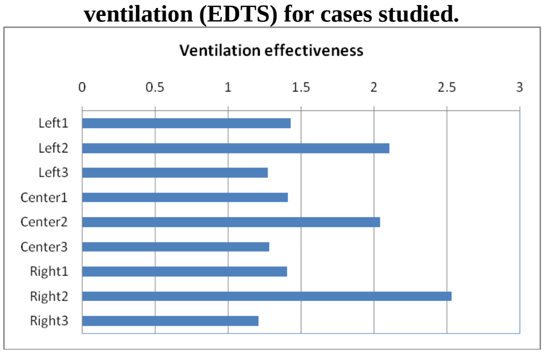

Figure 6: Ventilation effectiveness for cases studied.

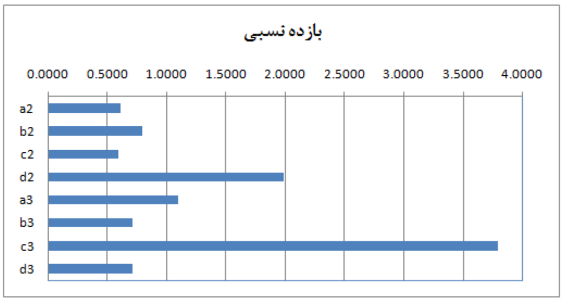

Figure 7: Relative efficiency for cases studied.

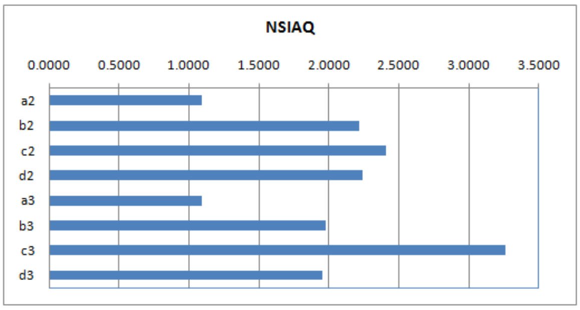

Figure 8: NISQ for cases studied.

4- CONCLUSION

17 cases with different outlet positions, sitting locations and contaminant source locations are modeled via a numerical model which is validated with the experimental results of a similar case. The results show great influence of outlet position and sitting location on the thermal comfort and inhaled air quality.

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