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Experimental investigation on airflow pattern for active chilled beam system

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ABSTRACT

Experimental results of the airflow pattern for Active Chilled Beams (ACB) system are investigated in this paper, where the air velocity and turbulence intensity for the air jet near the ceiling are tested and recorded under both isothermal and non-isothermal conditions. Based on the results, the velocity profile along streamwise direction is found to be significant in analyzing air detachment from the ceiling. It is revealed that the Coandă effect can be enhanced by a high pressure drop of ACB terminal unit and impeded by the temperature difference between supply air and room air. The self-similarity for the air jet is observed to be feasible for a certain downstream distance where the vertical maximum velocity is within 1.25 slot heights. A comparison study has been conducted for two mathematical models describing the self-similarity with the experimental data. It turns out that Verhoff's model has an overall better performance than Schwarz and Cosart's model. The turbulence intensity, which tends to be larger for points with lower velocity, is higher in areas where the entrainment effect is stronger.

1. Introduction

Chilled beams have been proven to be a reliable solution for Heating, Ventilation and Air Conditioning (HVAC) systems ever since they were introduced in the 1980s. The chilled beam system can be generally classified into Active Chilled Beam (ACB) system and passive chilled beam system according to whether there is forced primary airflow. Passive chilled beam system can only provide cooling effects mainly by natural convection, while ACB system is able to offer cooling or heating function as well as fresh airflow to the occupied space. Because of its better performance in terms of energy efficiency, thermal comfort and noise control with less space requirement, ACB system has been increasingly popular in not only Europe, but also North America and Asia. It has been widely utilized in a variety of commercial buildings, schools, laboratories and hospitals [1]. However, the research related to ACB is still at a preliminary stage as it is relatively new for HVAC applications. In the literature, there are some reports on the basic cooling performance. Guan and Wen [2] investigated the entrainment ratio of ACB in order to improve its cooling efficiency by studying its geometric structure. Chen et al. [3,4] proposed an effective circuitry arrangement and tube connection scheme with satisfied heat transfer performances. Some models were built to better predict and control the performance of ACB system. Cammarata and Petrone [5] established an ACB model integrated with the occupied space to predict the velocity pattern and settling time for achieving a stationary condition. Chen et al. [6] built a mathematical hybrid model for the confined air jet and cooling coil of ACB terminal unit, which could be used to control the coil temperature to avoid condensation. Increasing attention has been drawn to the thermal comfort performance produced by ACB systems. Kosonen et al. [7] and Rhee et al. [8] compared the ACB system with other conventional HVAC systems and concluded that ACB system achieved a better thermal performance. True et al. [9] and Kosonen et al. [10] studied various factors, such as the height of the room, the arrangement of ACB and thermal loads, which may result in the draught sensation under ACB system.

Airflow pattern has a significant effect on the thermal comfort in the occupied zone. It is of great importance to investigate the airflow pattern of ACB system to ensure a satisfied thermal comfort environment. Koskela et al. [11] studied the airflow pattern and thermal comfort in various office environments. They found that the downfall of inlet jets and large-scale circulation causing high air speeds were the two main reasons for the draught risk. The convection airflows had a notable effect on the thermal conditions in the room. Cao [12] suggested that the airflow direction may affect the sensation of a draught, especially when air flowed from behind the neck and toward the face. Fredriksson et al. [13] examined the airflow patterns around the chilled beams based on a

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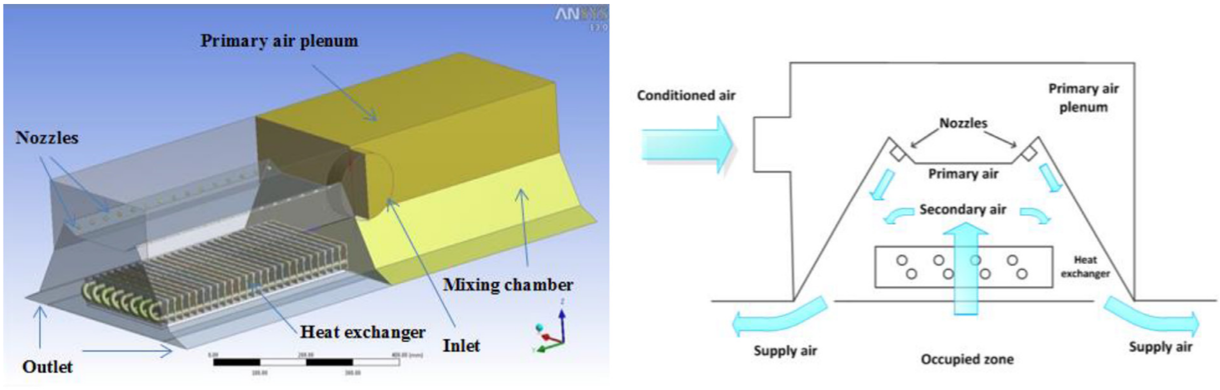
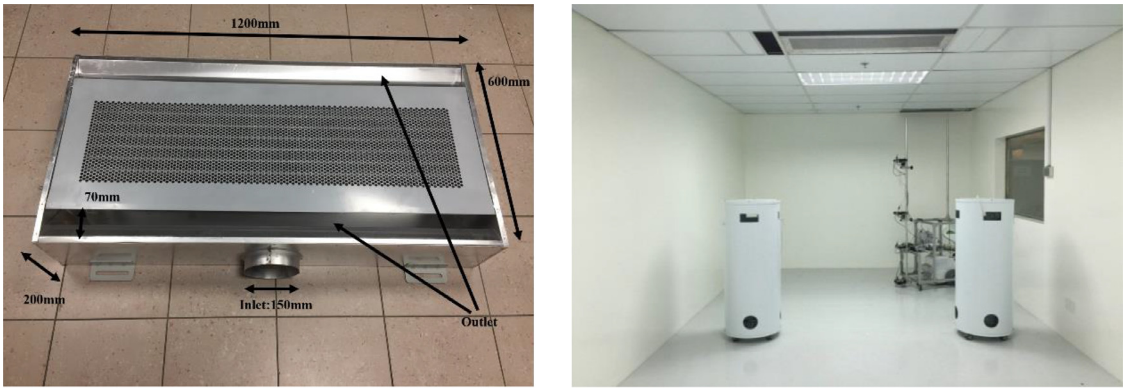


(a) (b)

Fig. 1. (a) Structure of ACB; (b) Schematic diagram of ACB.



(a) (b)

Fig. 2. (a) ACB terminal unit; (b) Thermal isolated room.

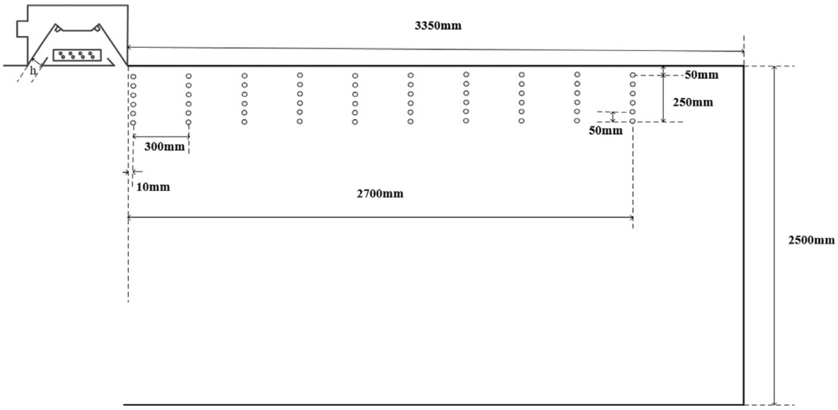


Fig. 3. Measurement point distribution.

Table 1
Sensor specifications.

Sensor	Application	Type	Range	Accuracy	Standard
Air velocity transducer	Room air velocity	TSI 8475	0–2.5 m/s	±3% reading, ±1% full scale	ASHRAE Standard 113
Air velocity transducer	Outlet air velocity	TSI 8455	0–10 m/s	±2% reading, ±0.5% full scale	ASHRAE Standard 70
Differential pressure transmitter	Pressure drop of ACB	Dwyer MS-111	0–250 Pa	±2%	ASHRAE Standard 200
Temperature transducer	Air temperature	S+S HFTM	0–50 °C	±0.2 °C	EN 15116
Multifunction transmitter	Primary airflow rate	KIMO C310	0–9216 m^3/h	±5%	ASHRAE Standards 200
Micromanometer	Secondary airflow rate	TSI 8710	42–4250 m^3/h	±3%	ASHRAE Standards 200