Coupled Analytical Tool of Ventilation Calculation and CFD in Annexation System of Cool/Heat Tube and Natural Ventilation

Song Pan[1], Harunori Yoshida[2], and Mingjie Zheng[1]

[1] Sanko Air Conditioning Co.LTD., Nagoya, Japan
[2]School of Engineering, Kyoto University, Kyoto, Japan

ABSTRACT

Natural ventilation airflow rate is generally calculated using indoor and outdoor temperature difference without consideration of heat balance based on the vertical air temperature distribution in simple analytical method. However, room air temperature is influenced by natural ventilation airflow rate, and airflow rate is influenced by room air temperature, so it is necessary to perform a coupled analysis taking into account both heat balance and ventilation to obtain the correct result. Moreover, when there is marked indoor vertical temperature distribution, as found in large enclosures, or when ventilation airflow rate is small, significant computation error will occur if the set value of room air temperature differs greatly from the actual value.

To solve two problems mentioned above, the authors developed a natural ventilation tool that takes into account indoor vertical temperature distribution and proposed a coupled simulation method using this tool in conjunction with CFD to simultaneously calculate indoor air flow/temperature distribution and natural ventilation airflow rate. In this paper, the difference between this method and the simple analytical method was shown clearly by comparing calculation results of the two methods about an actual annexation system of cool/heat tube and natural ventilation in a gymnasium.

KEYWORDS

cool/heat tube, natural ventilation, coupled analytical tool with natural ventilation and CFD

INTRODUCTION

Natural ventilation not only saves energy, but is a psychologically and physiologically comfort method of ventilation. However, introduction of outdoor air into rooms passing cool/heat tubes can result in a decreasing outdoor air heat load, as outdoor air is preheated through heat exchange with soil. Recently, use of natural ventilation systems with cool/heat tubes as a means of introducing outdoor air is generating a lot of attention.

A simple static method for analysis of natural ventilation in buildings was proposed almost 40 years ago (Ishihara, 1969). This method is based on an analysis of pressure balance without consideration of heat balance. Several pieces of software have been developed for use in building ventilation analysis, based on a ventilation network method created by applying the simple method to multi-zone scenarios. Commonly used software includes COMIS (developed by Annex23 of IEA (Anne, 2002)) and VENTSIM (developed by Building Research Institute (Utumi, 2005)). By using these ventilation analysis tools, natural ventilation airflow rate can be calculated according to the temperature difference between fixed room air points and the outdoor air, or between adjoining rooms, taking each room as one node, but heat balance calculation can not be performed.

However, room air temperature is influenced by natural ventilation airflow rate, and airflow rate is influenced by room air temperature, so to get the correct calculation result, it is necessary to perform a coupled analysis taking into account heat and airflow balances. Therefore, coupled analysis of TRNSYS (Hensen, 1995) and EnergyPlus (Huang, 1999) with COMIS, respectively were developed. Moreover, a ventilation analysis model based on thermal and ventilation networks is included in DeST (Jiang, 2005), a program for simulating energy consumption in buildings.

NETS(developed by Okuyama, 1998) is a ventilation analysis software based on the airflow network theory. When properties of indoor air temperature distribution and airflow distribution are known roughly, air temperature of division sub-zones and airflow between adjoining division sub-zones can be calculated simultaneously by using NETS depended on the appropriate division sub-zones of indoor and outdoor space. CFD is based on heat/movement and continuity equation of air, however ventilation calculations carried out using NETS are essentially calculations of total pressure, and thus NETS is not appropriate for use in the prediction of airflow and temperature distribution of indoor.

As each room is handled as one node, the ventilation calculation tool mentioned above cannot reproduce the driving force of buoyancy ventilation originating from indoor vertical temperature distribution. Therefore, there is a necessity for a