Abstract

Air conditioning and mechanical ventilation (ACMV) system, which determines the indoor thermal comfort and the total building energy efficiency, attracts increasing popularity throughout the world. In modern society, a series of problems such as sick building syndrome (SBS), sensation of draught and energy waste arise with the massive usage of air conditioning. Prioritizing green building-ACMV system can improve occupants fitness level and deliver dramatic energy saving. Among the various ACMV schemes, the active beams (active chilled beam and active thermosiphon beam), as typical kinds of air-water configuration ACMV system, have outstanding performance on energy saving, indoor air quality improvement and space saving. However, the existing research is still inadequate and some technical difficulties stand as major obstacles for application of the air terminals especially in tropical regions. To fulfil the gaps, this thesis focuses on the mechanical design, modeling and performance optimization of the active beam terminal units. The contributions of this thesis are summarized as follows:

1. A simple yet accurate hybrid model of active chilled beam terminal is developed with respect to air buoyancy. The model demonstrates the air entrainment characteristics in air chamber and the heat transfer process in cooling coil. Compared with the existing active chilled beam (ACB) model, the proposed model captures the effects of air buoyancy and further reduces the complexity of cooling coil model. The ACB model requires only two equations with nine unknown model parameters that can be identified by Levenberg-Marquardt method with experimental measurements. Experimental validation in the thermal room proves that the model is effective to predict the supply air flow rate and heat transfer process in a wide range of operating conditions. The proposed model is expected to be further examined in optimization and performance evaluation applications for ACB system.
2. To improve the heat transfer efficiency and eliminate the condensation problem of the traditional ACB, the mechanical design of the terminal unit is optimized. Combining air entrainment effect and displacement ventilation, the active thermosiphon beam (ATB) is developed with innovative nozzle arrangement, cooling coil placement and air chamber configuration. An experimental comparison of ATB is conducted under a wide range of

operating conditions to estimate its thermodynamic and hydrodynamic performances. The comparison results indicate that 1) the cooling capacity of ATB is around 40% higher than ACB and PDV; 2) the ATB has better dehumidification ability with the sensible heat ratio of 0.42; 3) the initial cost of ATB system is the lowest under same cooling load requirement. More importantly, the experimental findings provide a guideline for the design and operation of ATB system.

3. A model-based optimization approach for ATB system is developed to minimize the total energy consumption and maintain indoor thermal comfort. The thermal models of the terminal unit and the energy consumption models of the energy consuming components are established based on the experimental results. Accordingly, the global optimization strategy is formulated to find the optimal setting points of the ATB system with regard of total energy consumption and operating constraints. The experimental results indicate that the optimized operating parameters obtained by the GA can significantly reduce the total energy consumption while maintain the indoor thermal comfort. The obtained findings demonstrate that the ATB system is a promising ACMV system in terms of cost, thermal comfort and energy saving for a variety of applications.

Publication

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