Performance evaluation of a Heat Valve ventilation and heating system for residential buildings

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The study introduces a new combined air heating and ventilation system designed for residential buildings, particularly effective in temperate climates. This innovative system, featuring Heat Valves, allows for the independent regulation of air temperature in each room using a single heating coil. It efficiently combines heating and ventilation, offering precise control over indoor temperatures while minimizing energy consumption. The system's design and performance were thoroughly evaluated through laboratory experiments and practical application in a building, demonstrating its potential in enhancing residential heating and ventilation efficiency.

Introduction

In temperate climate zones, characterized by mild summers and cold winters, a substantial portion of a building's total energy use attributed to space heating has necessitated thermal insulation and air tightness. To enhance building energy efficiency further, mechanical ventilation systems with heat recovery from the exhaust air are typically required [1]. Consequently, due to the improved air tightness of buildings and the need for heat recovery, mechanical ventilation systems are increasingly being used in residential buildings.

The significant reduction in the need for space heating, combined with the presence of mechanical ventilation systems in buildings, presents excellent opportunities for space heating systems that utilize air as a heat distribution medium.

These systems are well-suited for low-energy buildings, where the necessary heating energy can be supplied at an airflow rate that is close to the minimum required for ventilation [2]. The lower the demand for space heating, the less additional energy is required to heat the supply air and to operate the fan.

A combined air heating and ventilation system is an economically viable option, particularly in terms of installation and maintenance costs, as it eliminates the need for a separate heat distribution system. Additionally, the lower thermal inertia of air heating systems compared to water heating systems can be considered an advantage, owing to their faster response time and, consequently, more precise regulation of the system.

Several constraints associated with conventional systems, primarily concerning the challenge of achieving desirable thermal conditions in individual rooms, hinder the successful implementation of air heating systems in residential buildings [3-6]. Enabling air temperature control in each room can significantly enhance occupant satisfaction regarding thermal conditions.

This project evaluates the performance of a novel, combined air heating and ventilation system. The unique feature of this system is its ability to precisely control the temperature in each room independently, using just a single heating coil. A full-scale prototype of the proposed system was constructed and analyzed in a laboratory experiment, aimed at characterizing and assessing the impact of the system's design on its performance. Furthermore, the system's performance was also evaluated in a building.

Design of the system

In the proposed system, air is supplied at a constant airflow volume (CAV). The conditioning of the supply air to a specific temperature occurs initially in the air handling unit, where it is filtered and heated in the heat recovery unit. Subsequently, the air is distributed through the main supply duct to a manifold located in an apartment or single-family house. The primary function of this manifold is to divide the total supply airflow rate into separate ducts that serve the corresponding rooms. Within the manifold, the supply air is further heated and then delivered to each room through these supply ducts to meet the individual heating and ventilation requirements of the rooms.

The airflow pattern through the manifold is determined by the positions of Heat Valves, which are installed at each outlet of the manifold, **Figure 1**. Each heat valve comprises two blades mounted on a rotary axle, with the angle between the blades being fixed. The position of each heat valve dictates the proportion of air that either passes through or bypasses the heating coil. However, it's important to note that the position of the heat valve does not affect the total airflow rate in the corresponding supply ducts.

Figure 2 depicts the design of the manifold, which receives supply air (1) from the air-handling unit. The manifold is divided into two sections: the upper section (2) contains a built-in heating coil, while the lower section (3) is unoccupied. An insulation layer separates these two parts to inhibit heat transfer between them. This design enables the supply air to either flow through the heating coil or bypass it, allowing for the mixing of air to achieve the desired temperature (4).

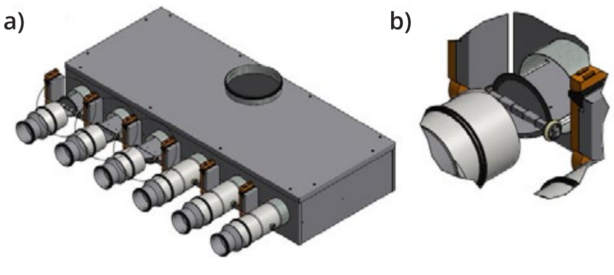

Figure 1. Illustration of the manifold – the 3D view (a), the heat valve detail (b).

The position of the heat valve can be adjusted from 0% (as depicted in **Figure 2**, Vertical Cross-Section A-A) to fully open at 100% for heating (**Figure 2**, Vertical Cross-Section C-C). When the heat valve is set anywhere between 0% and 100% (**Figure 2**, Vertical Cross-Section B-B), the air delivered to the corresponding duct is divided into two flows: heated and unheated. These flows are then combined after passing through the heat valve (5). This configuration enables continuous and independent regulation of the supply air temperature at each outlet of the manifold.

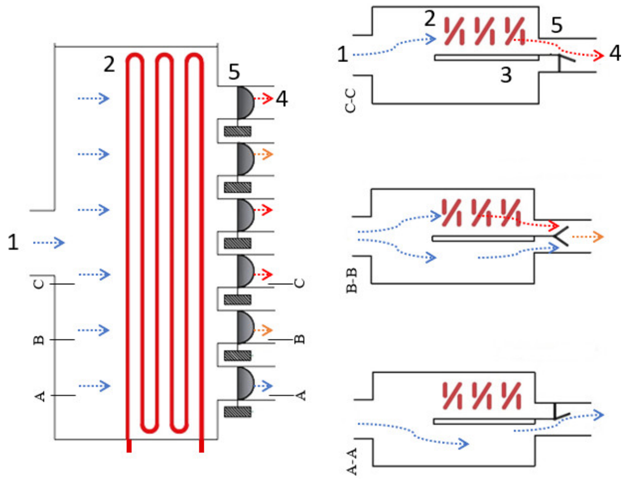

Figure 2. Illustration of the airflow pattern through the manifold.

The position of each heat valve, and consequently the temperature of the supply air in the corresponding duct, is adjusted by an actuator based on signals from a room controller. This controller continuously measures the room's temperature and compares it to a user-defined set point. Depending on the difference between these two values, the heating output from the manifold in the corresponding supply duct is adjusted by the Heat Valves to maintain the desired temperature in the room.

Results

During the continuous operation of the system under investigation, the quantity of air that either passes through or bypasses the heating coil varies, depending on the position of the Heat Valves. To characterize the relationship between the heat valve position and the supply air temperature in the corresponding supply duct, the supply air temperature was measured while altering the position of the Heat Valve.

Figure 3 shows the air temperature measured at various positions across the manifold with different settings of the Heat Valve. 'Air temp cold side t_1' refers to the temperature of the supply air from the air handling unit. 'Air temp warm side t_2' indicates the air temperature after it passes through the heating coil. 'Air temp at the outlet of the manifold t_3' represents the temperature of the air supplied to the room. 'Water inlet temp' denotes the temperature of the water fed into the heating coil. The heating coil's efficiency allows the manifold to supply air to the rooms at a temperature that is only marginally lower than the temperature of the supply water.

During the operation of the proposed system in an actual building, **Figure 4**, temperature regulation in the rooms was accurately maintained, due to the low thermal inertia of air the heating system.

Conclusions

The investigations showed that incorporating the manifold with Heat Valves into the new combined system permits the independent regulation of the supply air temperature at each outlet of the manifold, thereby enabling control of the air temperature in each room.

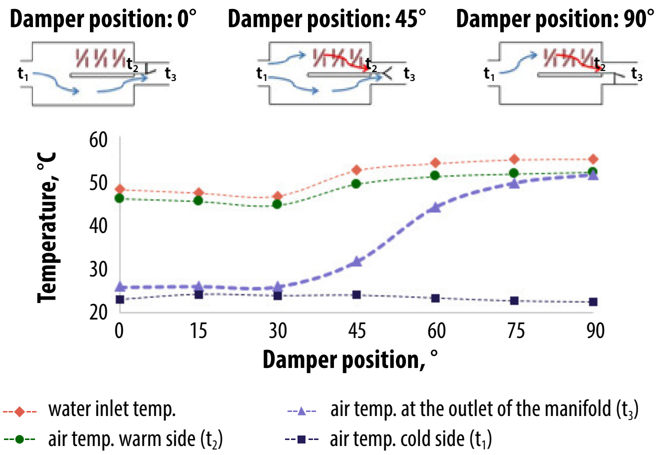

Figure 3. Air temperature measured across the manifold in relation to the heat valve position.

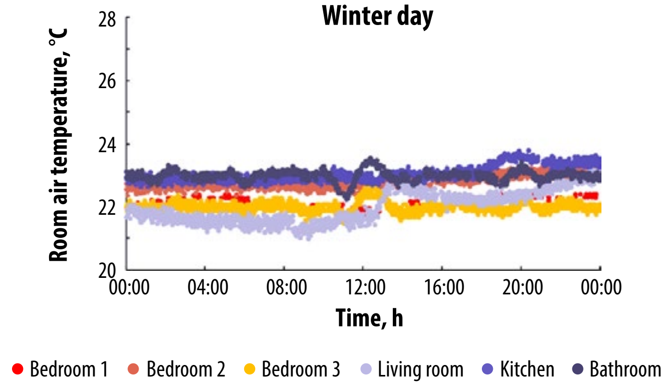

Figure 4. Indoor air temperature measured in a house with 6 rooms during a winter day.

The maximum temperature of the supply air is determined by the heating capacity of the coil, the temperature of the supply water, and thermal losses through the manifold and ductwork. Conversely, the minimum supply air temperature is defined by the outdoor air temperature, the extract air temperature, and the efficiency of the heat recovery unit.

This study introduces a new combined air heating and ventilation system designed for residential buildings. The system's innovative feature is its ability to regulate the supply air temperature in individual ducts using just one heating coil, thereby facilitating temperature control in each room. The findings demonstrate that utilizing Heat Valves enables precise air temperature control in each room. ■

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