Research on Passive Ultra Low Energy Residential Building Fresh Air System

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Abstract. In recent years, outdoor air pollution has become increasingly serious, with frequent haze. The installation of fresh air systems in residential buildings has become a new trend, but the energy consumption issue of fresh air systems needs to be taken seriously. This paper describes the current situation of the existing fresh air system in residential buildings. Through comparative analysis, in view of the characteristics of passive ultra low energy consumption buildings, it introduces the fresh air system that is more suitable for passive ultra low energy consumption buildings, namely, the heat recovery fresh air system plus the kitchen air supplement system. Based on the analysis of typical project cases, it proposes optimization strategies such as peak shift of fresh air, smoke exhaust and air supplement linkage, edge computing control system, provide reference for reducing the energy consumption of fresh air systems in passive ultra-low energy buildings.

Keywords: carbon peaking; carbon neutrality; building energy efficiency; ultra low energy buildings; heat recovery fresh air system.

1 Introduction

Passive ultra-low energy buildings are low energy buildings constructed by combining various passive energy-saving methods (such as natural ventilation, natural lighting, solar radiation, and indoor non heating heat sources) with efficient energy-saving technologies for building envelope structures. In the 1990s, Germany built the world's first passive house. This concept has not only been advocated abroad, but also received strong support and promotion from Chinese government departments [1]. The document "Notice on Issuing the Key Points for the Development of Passive Ultra Low Energy Building Industry in Hebei Province in 2023" requires an annual increase of 10% in the area of newly constructed passive ultra low energy buildings, promoting the large-scale development of passive ultra low energy buildings.

The heat recovery fresh air system, as a way to reduce building energy consumption, has been widely used. This article analyzes the current situation of the fresh air system in residential buildings, and studies the fresh air system of passive ultra-low

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energy residential buildings based on an actual engineering case. It proposes some operational optimization measures, providing reference for the design of the fresh air system in passive ultra-low energy residential buildings, and helping to achieve carbon peak and carbon neutrality goals.

2 Current situation of fresh air system in ordinary residential buildings

Ordinary residential buildings have two types of ventilation methods: natural ventilation and mechanical ventilation[2]. The main forms include opening windows, using exhaust fans, installing unidirectional ventilation units and using heat recovery fresh air units [3]. In the face of intensified air pollution, it has become a new trend for people to install clean fresh air systems in residential buildings. The clean fresh air system can not only ensure the demand of fresh air volume, but also meet the pursuit of indoor personnel for air quality and residential comfort.

The fresh air systems are usually divided into two types: centralized fresh air systems and household fresh air systems. The centralized fresh air system requires a room for the fresh air fan, which does not occupy the indoor ceiling space. The indoor environment is beautiful and has low noise, but the system cannot be controlled separately and unable to adjust air volume. To avoid cross contamination and ensure the health and safety of residents, the heat recovery mode of the centralized fresh air system is limited. Due to continuous operation throughout the year, the energy consumption of fresh air is relatively high. In addition, the centralized fresh air system also faces issues of uneven air volume and difficulty in charging.

The household based fresh air system effectively solves the above problems, does not have the hidden danger of household cross pollution, and has the advantage of strong user autonomy, meeting the requirements of behavioral energy conservation. The household dual flow fresh air system adds a heat exchange module inside the host, namely the heat recovery fresh air system, which can achieve the heat exchange between the exhausted air and the fresh air, thereby recovering cold and heat, reducing the energy consumption of winter heating and summer cooling. On the basis of improving indoor air quality, it minimizes the impact on indoor temperature as much as possible. Therefore, compared to centralized fresh air systems, household based fresh air systems are more suitable for residential buildings.

3 Current situation of fresh air system in ordinary residential buildings

Due to the low natural ventilation capacity of ultra-low energy buildings[4], relying on the convection of natural air unable to meet indoor hygiene and human comfort needs. Mechanical fresh air systems have become a necessary means for passive ultra-low energy buildings to meet the demand for fresh air, but the increase in fresh air volume will inevitably lead to an increase in building energy consumption. Therefore, adopting an efficient household heat recovery fresh air system is an essential measure to achieve ultra-low energy consumption residential buildings.

3.1 Basic Principles of Efficient Fresh Air Heat Recovery System

The high-efficiency fresh air heat recovery system is a new type of household ventilation system composed of various fresh air ventilation equipment and high-end intelligent control units. It adopts a dual flow ventilation method to send outdoor fresh air (fresh air) into the room while discharging indoor dirty air (dirty air) to the outside. The fresh air sent into the room is purified by multiple air filtration devices to deliver fresh and clean air to each room as needed. At the same time, the efficient heat exchange device inside the machine can maximize the retention of indoor energy (heat) to save energy. The working principle of the system is shown in Figure 1.

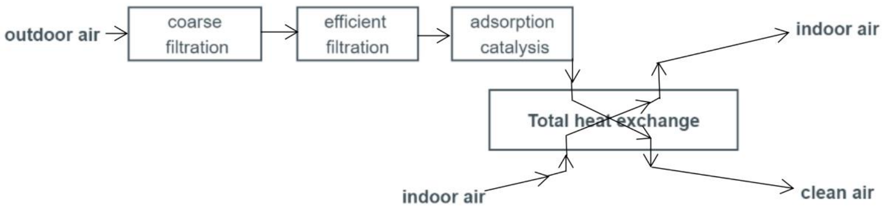

Fig. 1. Working principle diagram

The indoor unit of the heat recovery fresh air system is a fresh air equipment that can achieve bidirectional flow of mechanical air intake and mechanical exhaust. It has functions such as providing fresh air, heating and cooling, dual filtration, total heat exchange, humidity control, and intelligent monitoring. By using an intelligent control panel to adjust temperature and wind speed, the temperature and air volume of the fresh air fan can be adjusted.Outdoor units provide cold and heat sources for indoor units. Equipment can be selected based on the indoor cooling and heating load and fresh air demand, providing separate air supply for bedrooms, living rooms and other rooms. Centralized return air is set up in the living room. The system comes with a sensible heat recovery device, which has cooling and heating functions in winter and summer, and respond in the indoor cooling and heating load.

According to the national "Technical Standards for Near Zero Energy Consumption Buildings" GB/T51350-2019, it is recommended to install an independent air supply system in residential kitchens. Due to the large amount of oil smoke and water vapor generated during the use of the kitchen, in order to effectively eliminate pollutants, achieve high instantaneous ventilation and eliminate negative pressure and reduce indoor air disturbance, the kitchen needs to set up an independent oil smoke exhaust and air supplement system [5] to avoid affecting the balance of cold and heat in the room. The bathroom[6] needs to be equipped with exhaust ventilation ducts with backflow prevention structure, and independent exhaust fans are used for ventilation. Users can achieve independent exhaust according to their needs. And the exhaust fan of the bathroom needs to be linked with the system. When the exhaust fan is turned on, increase the fresh air volume of the system to supplement the air volume discharged from the bathroom.

4 Application Case and Optimization Methods

4.1 Application Case

A certain project in Shijiazhuang, Hebei Province is a passive ultra-low energy residential building. The external wall insulation system of the project adopts 250mm thick graphite polystyrene board+250mm thick rock wool fire insulation belt, and some nodes use vacuum insulation board, thermal bridge treatment measures are taken for parts such as through-wall pipelines to improve the quality of external wall insulation construction and meet the energy-saving requirements of passive rooms.

This study takes a certain unit room as a sample and tests the operation of the heat recovery fresh air unit in the room. The plan of the room is shown in Figure 2. This project adopts a bidirectional flow positive pressure air supply system, which is equipped with one 350m^3/h bidirectional flow fresh air fan. The heat recovery fresh air unit adopts the top air supply form of upward supply and upward return, and adopts high-efficiency heat recovery core, high-efficiency low noise fan, and high-efficiency filter to save energy by 75%. The physical diagram and internal structure schematic diagram of the fresh air fan are shown in Figure 3. The entire unit is designed and installed in the ceiling of the kitchen, and fresh air is sent indoors and discharged through U-PVC circular ventilation ducts. The indoor ventilation is equipped with adjustable double-layer louvers, and the outdoor ventilation is equipped with stainless steel rainproof vents. The reserved interface for the supplementary air duct of the kitchen ventilation system is shown in Figure 4.

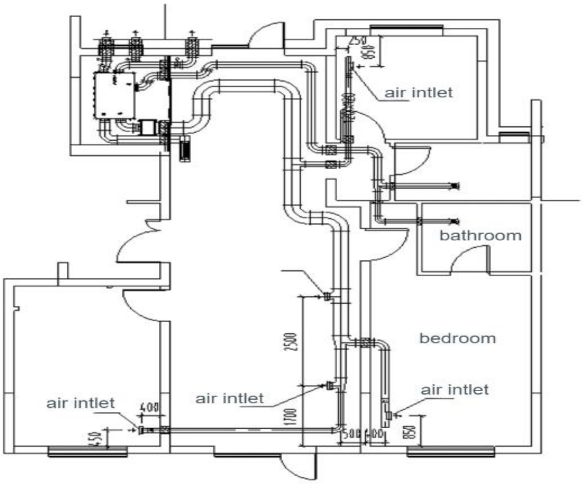

Fig. 2. Plan of a certain unit type

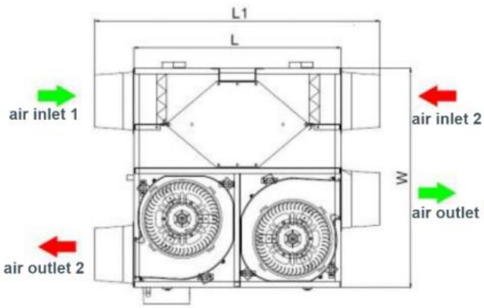

Fig. 3. Internal structural drawings of the fresh air fan.

Fig. 4. Reserved interface for kitchen air supply.

4.2 Operational optimization

When the fixed operation mode of the fresh air fan does not change the operation mode with the change of the number of residents, the thermal comfort of indoor personnel and the air quality, the energy consumption will be greatly increased, which does not meet the requirements of low energy consumption operation [7]. In view of this problem, the following three operation optimization measures are put forward:

(1)Under the premise of controlling the indoor carbon dioxide concentration, the fresh air fan adopts a "peak shifting" operating mode. Different operating modes are adopted for different climatic conditions. In the spring and autumn seasons, when there is no demand for heating and cooling, choose the fresh air mode or bypass mode reasonably based on the outdoor air quality situation; In summer, due to the low outdoor temperature and low air enthalpy value at night, fresh air mode can be adopted. However, during the day, the outdoor air temperature is high and the outdoor air enthalpy value is high. It is necessary to turn off fresh air during the hottest time and use indoor circulating return air to reduce the operating time of the fresh air fan; Similarly, in winter, turning on the fresh air switch during the day and noon when the outdoor air temperature is high can further reduce the fresh air energy consumption of the system.

(2)Because the kitchen has a high exhaust air volume during use, in order to avoid indoor air conditioning air being discharged and save air conditioning energy consumption, the kitchen can use outdoor fresh air for supplementary air supply [8] , outdoor fresh air is directly taken and discharged. Install an electric valve at the air supply outlet, which can be opened when needed and linked with the range hood to achieve real-time air supply and exhaust in the kitchen. Install an electric control valve on the exhaust and air supply pipeline, which is interlocked with the exhaust fan to open and close. When the oil fume exhaust fan is turned on, the electric valve on the air supply pipeline opens, and fresh air is introduced from outside to provide negative pressure air supply for the kitchen; When the exhaust hood is closed, the electric valve on the air supply pipeline is closed to prevent outdoor air infiltration and affect the balance of cold and heat in the room. The schematic diagram of kitchen air supply is shown in Figure 5.

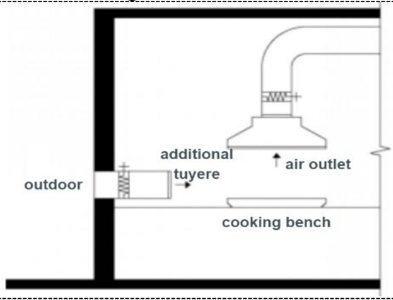

Fig. 5. Schematic diagram of kitchen air supply.

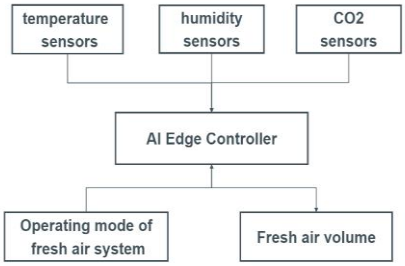

Fig. 6. Schematic diagram of edge computing system.

(3)In order to meet the needs of indoor thermal comfort and energy saving, distributed temperature and humidity measuring points, carbon dioxide measuring points and other indoor air quality measuring points can be added in each room. Through the household intelligent edge computing control system, the humanized intelligent control of on-demand air supply and comfort based air supply can be realized. Sensors such as temperature and humidity sensors and carbon dioxide sensors can collect indoor air quality in real-time, effectively solving the problem of time delay changes in loop control during the energy consumption control process of HVAC. By enhancing the performance of the control loop, energy consumption can be reduced. When the indoor air quality changes, the sensor collects data, and the system's adjustment components refer to this value to adjust the operating mode and fresh air volume of the fresh air system, and timely and effectively adjust the indoor air state. The edge computing system is shown in Figure 6.

5 Conclusion

This article points out that most residential buildings still remain in the stage of window ventilation and simple mechanical ventilation, resulting in a significant waste of energy [9]. Therefore, this paper introduces the fresh air system suitable for ultra low energy consumption residential buildings, and analyzes the actual case, and puts forward optimization strategies such as fresh air peak shifting, kitchen linkage air supplement, edge computing control system, etc. In order to meet the indoor fresh air demand and thermal comfort at the same time, try to reduce the energy consumption of the fresh air system and achieve low carbon development of the building.

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