THERMODYNAMIC MODEL OF HVAC UNDER BUILDING EXTERIOR WALL

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In order to solve the problem under the exterior wall of a building, the author proposes a thermodynamic model for HVAC. Scientific and technological progress has promoted social development, under the new development situation, people have higher requirements for living environment. In architectural design, residential environment design is the key content, especially the design of indoor temperature control system. With the continuous promotion of the national sustainable development strategy, the current architectural design pays more attention the green design concept, and the HVAC design is the key design content in realizing the green architectural design. In order to make HVAC design more scientific and reasonable, the author studied the concept that HVAC design needs to follow from the perspective of green buildings, and analyzed the specific application methods of HVAC design technology. The experimental results indicate that the building envelope parameters have a great impact on the building thermodynamic performance, and the annual cooling and heating loads of buildings should be comprehensively considered, reasonably determine the building envelope parameters. The building load has a low support value, so only low quality energy can meet the building load demand, when selecting the HVAC system, consider the matching of energy quality, try to introduce low grade energy, and improve energy utilization efficiency.

Key words: *external objects of buildings, HVAC, thermodynamics*

Introduction

Generally speaking, building energy system is mainly composed of building envelope, HVAC system, lighting system and other equipment systems. The building energy system is considered to be composed of two parts: building envelope and HVAC system. The outdoor environment of the building influences the indoor environment of the building through heat transfer, air infiltration*, etc.*, and then forms the cooling and heating load of the building. In order to maintain an appropriate indoor production and living environment, the HVAC system provides the energy required to maintain the indoor environment by consuming energy, thereby generating energy consumption of the HVAC system. The author mainly explores the thermodynamic performance of building envelope and HVAC system, analyzes them with energy analysis and exergy analysis methods, and optimizes the building energy system in combination with measures to reduce fresh air energy consumption, so as to reduce building energy consumption. The building envelope separates the indoor environment from the outdoor environment, the indoor and outdoor heat exchanges through the building envelope, the thermodynam-

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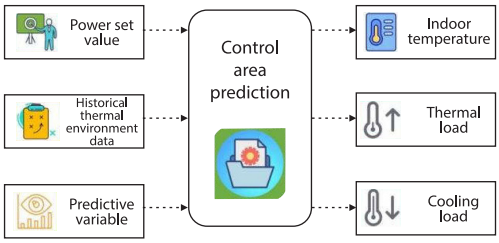

Figure 1. The HVAC thermodynamic model

ic performance of the building envelope has a significant impact on the building energy consumption. With the increasing attention paid to building energy conservation, people have carried out extensive and in-depth research on the thermodynamic performance of building envelope, countries have successively formulated corresponding standards or specifications, the thermodynamic performance of building envelope shall be specified. As shown in fig 1.

Literature review

Energy is one of the basic elements of human social and economic development. With the development of society and the progress of science and technology, the world's energy consumption is growing. The consumption of primary energy has been growing steadily, especially since the 21st century, reaching 2735.2 millionns of standard oil by 2012. Global primary energy consumption has grown steadily, reaching 12476.6 millionns of standard oil by 2012 [1]. The study points out that in this century, human beings will face an increasingly shortage of energy, and the ecological environment deterioration caused by energy consumption will become more serious. Human construction activity is an indispensable aspect of social and economic life, and also one of the important driving forces to promote economic and social development, however, its consumption of social resources and energy is an important source of contemporary energy and environmental crisis. According to statistics, buildings consume 30% of the world's raw materials, 25% of wood and 16% of water, building energy consumption accounts for 30-40% of the world's primary energy consumption, and the resulting greenhouse gas emissions account for 40-50% of the world's total. The environmental impact caused by building energy consumption in Europe accounts for 15-45% of the total environmental impact, and the energy consumed by manufacturing and transporting building materials accounts for 10% of the total energy consumption, the operating energy consumption of building lighting and air conditioning is about 30-50% of the total building energy consumption, about half of the energy consumption in Europe is directly or indirectly consumed in buildings, at the same time, it has become the main source of environmental pollution. Between 1999 and 2001, building energy consumption was about 27% of the national energy consumption, but it is estimated that its proportion will increase to 35% by 2020. With the process of urbanization, this proportion may increase. However, according to statistics, as of 2008, energy-saving buildings only accounted for 16% of the total number of existing buildings, by 2008, the total building area has reached 43 billion square meters, it is estimated that the building area of the country will increase to 68.6 billion square meters by 2020, building energy conservation has a long way to go. The national implementation of building energy conservation cannot only ease the tension of domestic energy and resources, but also reduce the environmental pollution caused by energy consumption. Building energy conservation is crucial to the development of the entire national economy. According to statistical data, the energy consumption of building operation is about 45%, of which the energy consumption of HVAC system is an important part, accounting for about 50% of the building operation energy consumption, and some even exceed 2/3 [2]. Therefore, energy conservation of HVAC system is particularly important for building energy conservation. As shown in fig. 2, from the point of view of energy flow, the building can be considered as an energy source, that is, a building that produces electricity. Focus on reducing HVAC system energy consumption.

Building energy efficiency can be considered building envelope and HVAC systems. Internal and external influences affect the interior of the building through the building envelope, resulting in cold and hot air. In order to maintain the appropriate indoor environment (temperature and humidity) for human production and living needs, the HVAC system provides the necessary indoor energy to control the environment. is the power of the HVAC system.

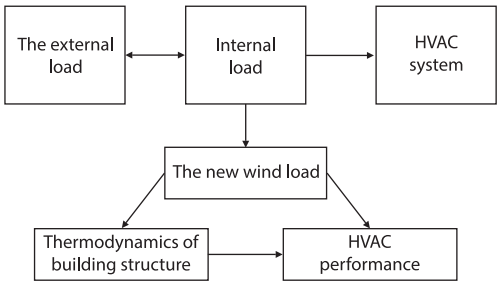

Figure 2. Energy flow

Research Methods

In the process of modern social development, energy consumption is very fast, and many countries are facing great pressure on energy supply. At the same time, the problem of energy waste is widespread, in order to obtain a good sense of environmental experience, people install a large number of refrigeration and heating equipment in the building, however, the unreasonable application of these temperature control devices leads to a large amount of energy being wasted, thus increasing energy consumption. The temperature control system accounts for a very large proportion in the total energy consumption of buildings. With the progress of urbanization, more buildings will appear, this means that the application proportion of temperature control equipment will continue to rise. If no measures are taken to control the construction of building temperature control system, the problem of energy waste will become increasingly prominent. Therefore, optimization of HVAC design can reduce energy consumption, improve energy utilization and solve the problem of building energy shortage, which plays an important role in alleviating the problem of energy supply. Therefore, in-depth analysis of HVAC design is a work beneficial to the country and the people.

In the optimization of building environment, HVAC plays an important role, it cannot only scientifically regulate the indoor temperature of buildings, but also dynamically regulate the indoor and outdoor air exchange of buildings, providing a good indoor environment for people and meeting their experience requirements. The core of building is energy conservation and emission reduction, through new technologies, new materials and new methods, the energy consumption of some building structures is reduced, therefore, in the HVAC design, attention should be paid to energy utilization and conservation, so as to reduce energy use as much as possible and improve energy application efficiency. Therefore, the design of HVAC shall comply with the following requirements [3, 4].

The HVAC design

In order to ensure better implementation of the architectural concept, we need to follow certain design principles in the HVAC design process. When designing the HVAC system, the concept of energy conservation and environmental protection should be deeply integrated to ensure the scientific nature of the entire design process. First of all, it is necessary to meet the architectural design requirements to ensure that the basic functions of HVAC can be realized, and on this basis, meet the requirements of energy conservation and environmental protection. Secondly, the HVAC system lay-out should be co-ordinated with other structural lay-outs in the architectural design, not only to ensure the safety of use, but also to ensure that people's environmental experience is improved. Third, pay attention the concept of environmental protection and minimize the environmental pollution caused by the operation of HVAC, such as

gas pollution, noise pollution, thermal energy pollution, *etc*. Fourth, based on the perspective of energy consumption, consider the application of HVAC energy, give play to the advantages of renewable energy application, and then improve energy utilization. Fifth, establish a recycling model based on *energy conservation recycling*, maximize the value of resource utilization, solve the problem of resource waste, and reduce energy consumption. The HVAC design is a comprehensive project, which needs to consider the optimization and innovation of multiple design links, reduce the energy consumption and environmental pollution problems caused by HVAC operation through more scientific methods, which will help to deepen the implementation of the concept of green buildings, so as to better achieve the design goal of green buildings and promote the green development of the construction industry [5, 6].

Thermodynamic performance analysis of building structure

In terms of building energy, the temperature of the building envelope directly affects the load on the HVAC system, which in turn affects the total energy use of the building. Therefore, the thermodynamic efficiency of the building envelope plays an important role in reducing the energy consumption of buildings. As mentioned earlier, the energy efficiency of a building is determined by the building envelope and the HVAC system, as the focus is on the energy consumption of the HVAC system. At the end of the building envelope is the HVAC system load, the main characteristics of which are external wall heat transfer coefficient, window-to-wall ratio, window temperature, visible heat emission from interior light, heat emission from indoor workers, *etc*, the air environment in which the buildings are located will have a significant impact on it. Due to the gradual increase in the cost of energy-efficient buildings, the country conducted relevant research in the 1980's and developed special guidelines, such as energy-saving design standards for public buildings and energy-saving design standards for buildings in cold and cold regions. The energy efficiency design standards of residential buildings in hot and cold summers, the energy efficiency design models of buildings in hot summers and cold summers, *etc.*, the temperature of the building envelope is few [7].

As people attach importance to building energy conservation and research is deepened, various new technologies continue to emerge, in recent years, new technologies such as ground source heat pump, water source heat pump, condensate heat recovery, and solution dehumidification air conditioning have emerged and been applied in practical projects, the effective reduction of energy consumption in building use, especially in the air conditioning system, has played a great role in promoting the development of building energy conservation. However, with the deepening of research, researchers pay more and more attention the research and development of various energy-saving equipment to minimize the energy consumption of air conditioning from the perspective of equipment performance, so as to achieve the purpose of reducing the energy consumption of buildings.

Experimental study

Thermodynamic performance analysis model of building envelope

Calculation method of building load

The so-called thermodynamic performance of building envelope refers to that, the thermodynamic performance of the building envelope on the external and internal environment of the building, it is usually characterized and measured by the annual or typical daily cooling and heating load of the building envelope. Therefore, in order to analyze the thermodynamic performance of buildings, it is necessary to first calculate the load and composition of buildings:

– The first stage is the period of steady heat transfer calculation, namely the period of steady-state calculation.

At this stage, researchers did not distinguish the concept of heat gain and load, and believed that the heat gain of stable heat transfer was the load of the building. At this stage, people's understanding of building load is relatively simple, which is the initial stage of the development of air conditioning technology. However, due to the relatively thick structure of the houses at this stage, the floors are relatively low, and there is no large-scale building, therefore, the disadvantages of the steady-state heat transfer method on the building load calculation are not obvious, which can basically meet the requirements of the building air conditioning system design.

– The second stage is the quasi steady-state heat transfer calculation period.

With the passage of time, the research on air conditioning system is gradually deepening, so the method of building load calculation is also constantly improving. Especially after the WWII, the building load calculation method has developed rapidly. It should be noted that the equivalent temperature difference method, which is a common calculation method, was developed by the American researcher C O. Mackey and L.T. Wight proposed in their published paper *Periodic Heat Flow One – Combined Wall or Roof*. Its basic idea is to disturb the external environment of the building to the building, such as the disturbance of building load caused by the change of outdoor air temperature, and the disturbance of building load caused by solar radiation, after periodic calculation, it is transformed into the calculation form of stable heat transfer, thus the concept of *equivalent temperature difference* is obtained. This calculation method is widely accepted and applied in the United States, which is called a major calculation method and included in the ASHREA manual. At this stage, other researchers, such as Frassol and Shkroville of the former Soviet Union and Mino Maeda of Japan, have also made similar studies and put forward similar concepts [8, 9].

Load calculation software

With the development of computer technology and the introduction of building load calculation, building dynamic energy consumption simulation software has emerged. After the oil economic crisis in the 1970's, people paid more attention energy consumption, especially building energy consumption, building energy consumption simulation methods continue to emerge, represented by two software developed in the United States that have a great impact on subsequent building energy consumption simulation – BLAST and DOE, later, it developed software such as TRNSYS, TASE, EnergyPlus*, etc.* The USA has always been the world leader in building energy consumption calculation software.

Thermodynamic performance analysis of reference building envelope

Annual cooling and heating load analysis

Building load is the embodiment of the thermodynamic performance of building envelope, and the annual performance of building load is the decisive factor of the energy consumption of HVAC system. Building load is calculated by building energy consumption simulation software IES-VE. According to the thermodynamic analysis model of building envelope, the thermodynamic analysis of reference building is carried out. The definition of reference environment for building energy system analysis takes indoor ambient air parameters as reference environment.

In order to better study the change of building annual load, the change of annual heating load and cooling load with time (month) is obtained through energy consumption sim-

ulation calculation, as shown in figs. 3 and 4. It can be seen that the maximum monthly heating load of the whole year occurs in January, which is 15.55 MWh, and the maximum monthly cooling load of the whole year occurs in July, which is 72.60 MWh. It can be seen from fig. 5 that the highest monthly average temperature of the region occurs in July and the lowest in January, which partly explains the reasons why the maximum monthly cooling and heating load occurs in January and July, respectively.

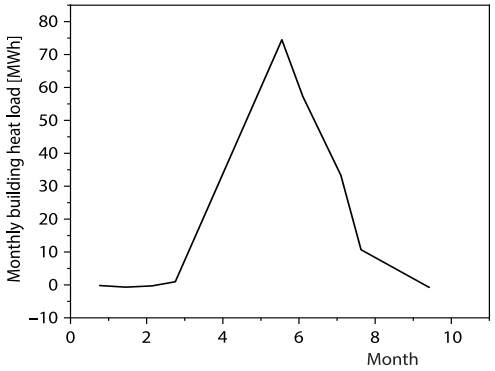

Figure 3. Annual monthly cooling load

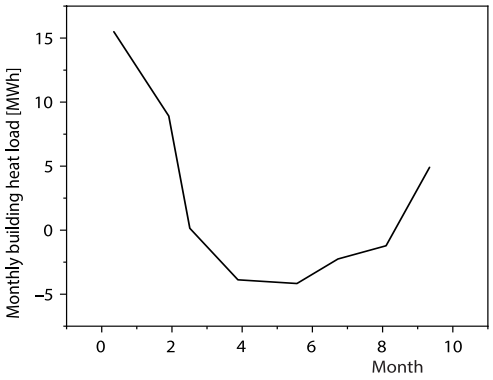

Figure 4. Annual monthly heat load

According to the analysis method of building thermodynamic performance, the building load of the reference building in heating season and air conditioning season is analyzed from the perspective of energy and support analysis, and the corresponding energy value, exergy value and exergy loss are calculated, as shown in tab. 1. In the table, for the studied building, energy flows into the building as input, and energy flows out of the building as output. As can be seen from tab. 1, for reference buildings, their building load energy values are 39.00 MWh (heating season) and 258.73 MWh (air-conditioning season), respectively. The building load is 2.90 MWh (heating season) and 15.13 MWh (air-conditioning season), respectively. It can be seen that the annual load is mainly air conditioning load. Comparing the energy value and smoke value of the load, it can be found that the energy value is smaller than the energy value, with a large difference. Its energy value represents the amount of heat or cold needed, while its energy value represents the quantity of heat or cold needed. It can be seen that the load flash value in heating season and air conditioning season is small, and only low energy quality energy can meet the needs of heating and air conditioning. In practice, they often meet the needs of heating and air conditioning by consuming a large amount of high quality energy, such as electricity and fossil energy, this leads to the loss of support, which is also the problem that the energy analysis method cannot solve. Therefore, in practice, low grade cold or heat sources should be introduced as far as possible to reduce the use of high quality energy such as electricity and fossil energy, and reduce building energy consumption from both the quantity and quality of energy [10].

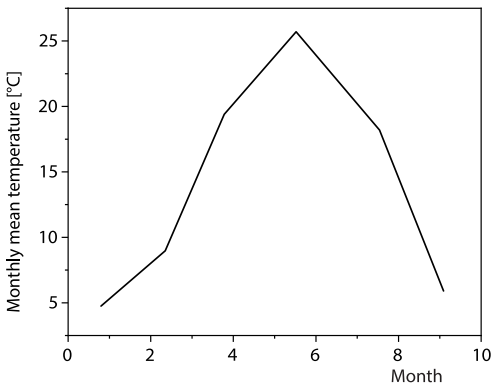

Figure 5. Annual monthly average outdoor temperature

Table 1. Annual building cooling and heating load

Season	Energy [MWh]	Jiong [MWh]
Winter air condtioning season	39	3
Air conditioning season in summer	258	15

Analysis of air conditioning heat load in winter

According to the thermodynamic performance analysis method of building envelope, the indoor heat balance equation of the building is established, and the composition of each part of the heat load of the reference building in the heating season is analyzed from the perspective of energy analysis and support analysis, the heat load of air conditioner in winter is 39.01 MWh. The input part in the drawing refers to the building, annual net energy inflow. Output refers to the annual net energy outflow for buildings. As shown in the figure, by comparing the energy values and support values of various energies, only the energy values of solar radiation are close to the value of the sparkle, while the sparkle values of other energies are smaller than their energy values, with a large difference. It can be seen that the solar radiation has a strong energy to change the reference environment because its surface temperature is 6000 K, which deviates greatly from the reference environment temperature, it is high quality energy, while the heat source temperature of other parts of energy is close to the reference ambient temperature, which is low quality energy. It is particularly important to reduce the energy output in the heating season, for the energy output part, it can be seen from the energy analysis and the exergy analysis that the heat transfer output of the peripheral protective structure is the main energy output, and the energy value and exergy value are 94.20 MWh and 3.66 MWh, respectively. It can be seen from the composition of heat transfer loss of the peripheral protective structure that the heat transfer of the external window plays a leading role, and the heat transfer loss of the external wall and roof is small. Therefore, in order to reduce the heat loss of the outer enclosure structure, the emphasis should be placed on reducing the heat transfer and heat loss of the outer window, such as using multi-layer glass windows to strengthen the thermal insulation performance of the outer window.

The results show that the building envelope parameters have a great impact on the building thermodynamic performance, and the annual cooling and heating loads of buildings should be comprehensively considered, reasonably determine the building envelope parameters. The support value of building load is low, only relatively low quality energy can meet the building load demand, when selecting the HVAC system, we should consider the matching of energy quality, and try to introduce low grade energy to improve the energy utilization efficiency.

Conclusion

In a word, HVAC design is crucial for the stable development of green buildings, as the energy consumption of HVAC has become an important issue in building energy consumption, this problem directly affects the development of green buildings, so it is necessary to deal with the energy consumption of HVAC, through optimization and adjustment, the design of HVAC is more co-ordinated with the concept of green buildings. Therefore, when designing building HVAC systems, it is necessary to pay attention the energy-saving design content of equipment, define energy-saving design standards, and optimize the design scheme through new technologies and new materials.

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