

Application of the Active Chilled Beam in Air-conditioning Engineering

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Abstract: This paper discusses the importance of the active chilled beam in energy saving of air conditioning systems. The application of chilled beam can improve the thermal comfort of indoor environment and reduce the energy consumption of air conditioning operation to achieve building energy saving. Because of the special working principle of the chilled beam, the cooling and heating capacity of the chilled beam is relatively weak, especially for the curtain wall building with large cooling and heat load of the air conditioning. If the chilled beam scheme is adopted, the floor convection is needed at the glass curtain wall in order to ensure the thermal comfort of indoor air conditioning and achieve building energy saving.

1. Introduction

With the development of central air conditioning technology in buildings, chilled beams have been applied in advanced civil buildings as the terminal devices of the central air conditioning system. Compared with the traditional full-air system and the fan-coil unit(FCU) with fresh air supplying system, the chilled beam system belongs to the air-water inducer system and uses the working principle of inducing indoor air (secondary air) to achieve the indoor air conditioning. The chilled beam system has no fan, so it has many advantages, such as high comfort, low energy consumption, low noise and long equipment life. But the coils inside the ceiling chilled beam, it is easy to cause chilled beam condensation, affecting the normal operation of the air conditioning system. Because of the cooling and heating capacity of the chilled beam is low, especially for the curtain wall building with large cooling and heat load of the air conditioning system. If the chilled beam fresh air system is adopted only, it is probably impossible to guarantee the air conditioning require, especially near the window area, which will affect the normal working people near the window. In such air conditioning systems, it is necessary to add floor convection.

2. Active chilled beam

2.1. Structure of the active chilled beam

The active chilled beam consists of box, detachable grid, primary air connecting pipe, inlet and outlet of water pipe and so on, as shown in Figure 1.





Figure 1. Basic structure of the active chilled beam.

2.2. Working principle of the active chilled beam

The working process of the active chilled beam is as follows: After the treated primary air (fresh air) enters the chilled beam box, it ejects through the nozzle, resulting in local negative pressure. It makes the indoor air conditioning (secondary air) inhaled through the coil tube of the chilled beam. The coiled or heated indoor air conditioning (secondary air) is mixed with the primary air (fresh air) that is ejected from the nozzle and supplied into the rooms, as shown in Figure 2.

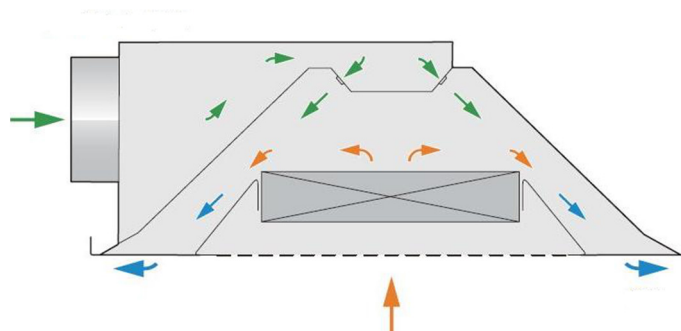


Figure 2. Working principle of active chilled beam.

2.3. Characteristic of active chilled beam

The active chilled beam belongs to the air-water inducer system. Its capacity of cooling and heating is greatly affected by the primary air supply parameters and is restricted by the primary air volume, air pressure, nozzle air velocity, induction ratio and so on. Compared with the fan-coil unit with fresh air supplying system, which is widely used in the central air conditioning system, the chilled beam system has obvious advantages: (1) The chilled beam system does not need to consume the electric power of the fan. (2) The chilled beam with low nozzle air velocity has lower noise than FCU. (3) The chilled beam with low nozzle air velocity has a more uniform and soft air velocity. There is no obvious uncomfortable feeling. (4) The chilled beam has no moving parts, the equipment have longer service life and the maintenance workload is smaller with FCU.

The system also has obvious disadvantages: (1) The air velocity of the secondary air coil in the chilled beam is low, which makes the cooling capacity of the chilled beam lower. And the shape of the cooling beam is larger than FCU. (2) The chilled beam has no fan. The chilled beam coil can only use low efficiency filter, and the chilled beam coil is easy to accumulate dusts. (3) When the primary air system stops working, the chilled beam system can not operate normally. (4) The chilled beam has no fan and the air pressure of the primary air is needed higher. Therefore, the power consumption of

primary air is more than that of the fan-coil unit with fresh air supplying system. (5) Most chilled beam products are dry-coil operating conditions, the chilled beam system is not suitable for the indoor places with high wet load, such as restaurants, swimming pools and so on. At the same time, it is not allowed to open the external windows of the air-conditioned room at will. (6) The equipment of the chilled beam system has higher initial investment.

3. Floor convection

The floor convection is a kind of air-conditioning terminal equipment which installs heat dissipation elements in floor grooves, as shown in Figure 3. According to the working principle, it can be divided into natural convection type and forced convection type. Being different from the fan used in common FCU, the forced floor convection adopts cross flow fan so the volume of floor convection is small, especially in the height of the body. In addition, the floor convection for summer central air conditioning system must be equipped with the condensate pipe system.



Figure 3. Basic structure of the floor convection.

Because of the special working principle of the chilled beam, the cooling and heating capacity of the chilled beam is lower, especially for the curtain wall building with large cooling and heating load. In the air conditioning system of the chilled beam fresh air, the installation of floor convection can significantly eliminate the cooling and heating load of building enclosure structure, optimize the interior surface temperature of the enclosure structure, and improve the thermal comfort of the indoor environment in air conditioning room. The actual operation test results of the floor convection is shown in Table 1~3.

Table 1. The air supply test results of the floor convection.

Air temperature	Air supply relative humidity	Outlet velocity (vertical)	Machine noise	ambient noise
°C	%	m/s	db/A	db/A
14.8	84.8	1.8	55	45

Table 2. The vertical temperature distribution of the glass curtain wall.

Height from the floor	400 mm	800 mm	1200 mm	1600 mm	2000 mm
Internal Surface temperature of Glass Curtain Wall (°C)	23.0	23.5	24.1	24.6	25.8

Table 3. Comparison test results of interior surface temperature of envelopes in summer.

Type	Internal surface temperature of glass curtain wall	Internal surface temperature of external wall	Interior wall
Cold beam with floor convection	24.2	25.5	21.5
FCU	39.6	29.3	27.3
no air conditioning room	48	30.2	29.7

It can be seen from Table 1~3 that the surface temperature of the chilled beam with floor convection is lower than that of the conventional FCU. It can effectively reduces the summer solar radiation from the enclosure structure(especially the glass curtain wall), and the thermal comfort of indoor air conditioning is better.

The above project of central air conditioning for chilled beam with floor convection, the active chilled beam only undertakes 30% of the sensible cooling load in summer (operating under dry conditions), while the other sensible heat load and all wet load are undertook by the fresh air handling unit and the floor convection unit. This distribution proportion has some reference value for other engineering .

4. Engineering application analysis

As a better terminal device for indoor thermal comfort, active chilled beam is being gradually popularized and applied in office buildings. Because of the particularity of the chilled beam system, the design experience of the FCU can no longer be copied completely in engineering. It is necessary to carry out especial measures for using chilled beam.

(1)Cooling load of air conditioning :

Because the chilled beam has no circulating fan, and the low air velocity leads to the low cooling capacity. Therefore, the ratio of cooling beam system to the total cooling load of the whole air conditioning system in summer needs to be carefully accounted for and shouldn't be too large. If the value of the proportion is too large, the summer indoor air temperature would not reach the design value.

(2) The chilled beam layout :

Because there is no circulating fan in the chilled beam, the air supply control ability of the cooling beam is obviously less than FCU. So the distribution of the air conditioning cooling load in the room should be fully considered when the chilled beam is arranged. If the chilled beam is uniformly arranged, other air conditioning terminal devices such as floor convection should be arranged at the area with high cooling load in the exterior enclosure.

(3) Fresh air handling unit:

Because of the particularity of the chilled beam system, the dehumidification capacity of the primary air (fresh air) unit must be fully guaranteed for the independent control system of temperature and humidity under chilled beam's dry working conditions. The check and calculation of the surface cooler of the fresh air unit should not only calculate the refrigerating capacity, but also use the enthalpy and humidity diagram to correspond to the exact dehumidification working point. If the dehumidification capacity of the primary air (fresh air) unit is insufficient and the indoor relative humidity is higher than the set value, the chilled beam will not be able to operate in summer.

(4)The condensation problem of the chilled beam:

Because of the anti-condensation requirement of the active chilled beam, the air-conditioning automatic control system of the active chilled beam is relatively complex. The automatic control of the air-conditioning not only needs to detect the indoor air temperature, but also needs to detect the relative humidity of the indoor air precisely.

(5)The noise problem of the floor convective:

The floor convection adopts cross flow fan. Although the total number of fans will be much smaller than that FCU, the noise problem of the floor convection should be paid more attention to and strict parameter control should be taken into account. The noise of floor convection cannot offset the advantage of low noise of the chilled beam system.

(6) Strict requirements for the condensate pipeline:

The floorboard convectors should undertake the indoor room wet load in summer. The condensate of the floorboard convectors is installed under floor, so the condensate pipe's diameter and slope are required to be carefully, Otherwise the condensate water will overflow the floor in summer.

5. Summary

Active chilled beam system has many advantages, such as high comfort, low energy consumption, low noise, long equipment life and so on. It is a new technology worth popularizing under the background of energy saving and emission reduction in today's green building. The active chilled beam adopts the working principle of the air conditioning system which is induced by the primary air from the nozzle, so the active chilled beam has its own particularity in the design and operation control. The FCU system design experience is no longer completely suitable. Because of the special working principle of the chilled beam, the cooling and heating capacity of the chilled beam is low, especially for curtain wall buildings with high cooling and heat load. In order to ensure the thermal comfort of indoor air conditioning and to achieve building energy saving, the floor convection at the exterior enclosure is recommended to adopt.

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