

Cooling/heating floor air conditioning systems in residential buildings^{*}

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Abstract: The present HVAC equipments for the residential buildings in the Hot-summer-and-Cold-winter climate region are still at a high energy consuming level. So that the high efficiency HVAC system is an urgently need for achieving the preset government energy saving goal. With its advantage of highly sanitary, highly comfortable and uniform of temperature field, the floor radiation heating system has been widely accepted. This paper has put forward a new way in air-conditioning, which combine the fresh-air supply system and such floor radiation system for the dehumidification and cooling in summer or heating in winter. By analyzing its advantages and limitations, we found that this it can improve the IAQ of residential building which is called Cooling/ Heating Floor AC System, while keep high efficiency quality. We also recommended an methodology for the HVAC system operating, which will ensure the reduction of energy cost of users.

Keywords: cooling/ heating-floor; floor heating; energy saving, residential building; air conditioning

1. Introduction

The purpose of air conditioning is to offer a health and comfortable environment for the people to study, work and live. Along with the economy developing in China, people is requesting large rooms, temperature and humidity of indoor air in order, fresh air. Because of badly heat performance of its enclosure, residential buildings waste lots of energy when using air conditioners.[1] It is the orientation of HVAC engineers to work hard for the purpose of improving thermal comfort degree, saving energy and protecting environment.

As a new set of terminal equipment in air-conditioning system, the mechanism of radiant floor is heating or cooling the room mainly through radiation and convection. Compared with traditional air-conditioning, its advantages lie in thermal comfort, energy efficiency, free use of spacing and etc. The radiant heating floor is gradually applied in northern regions in China. In Europe and U.S. A , The residential buildings newly-built using radiant floor to heat are above 80 %. In France, nearly 20% residential buildings used radiant floor to heat till 1994. In Germany, roughly for 41 %, Austria for 25 %, Switzerland is 48 %.[2,3]

In the middle and lower reaches drainage area of Yangtze River, it is hot in summer and cold in winter. If we make the radiant floor cooling in summer, such

as changing hot water to cold water, it can be one method of air conditioning in summer, satisfying air conditioning request both in summer and winter, as well as economizing the investment, avoiding two systems of heating/cooling systems presently. Increasing the temperature of chilled water supplied in the summer, it can also increase the EER of the refrigeration system to save the energy. The radiant floor heating in winter and cooling in summer, is called "heating/cooling floor air conditioning system".

Early in 2000, we have made a test in the lab, using the GSHP(ground source heat pump) equipment supplying hot or cold water. This paper introduces an applied example in a residential building.

2. The general situation of project

The area of this suit of house is 137 m², the area need air conditioning and heating is 100 m². It includes a restaurant, a living room, a studying room and two bedrooms. The wall is 200 mm thick. The plastic-steel window is of single layer. The floor of the studying room and two bedrooms are wooden , others are ceramic glazed tile.

2.1 System design

The air conditioning system is component with fan – coil system and cooling /heating floor. The cooling energy source is air-cooling heat pump, the

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refrigerating capacity is 10.5 kW.

The refrigerating capacity of cooling /heating floor can be calculated approximately by the following equation:

$$Q = qF \Delta t \quad (1)$$

where q is the thermal exchange rate between cooling /heating floor and indoor air per floor area and per dispersion between floor surface temperature and air temperature indoor, almost is $6.3 \text{ W/m}^2 \cdot ^\circ\text{C}$; F is the area of the cooling /heating floor, m^2 ; Δt is dispersion between floor surface temperature and air temperature indoor, $^\circ\text{C}$.

2.2 The constitution of cooling /heating floor

Because the effect of cooling/heating floor is directly decided by the way of laying coils, distance of coils, the water rate of cooling/heating of floor coils and distributing of the floor surface temperature. The floor coils adopt DN15 polythene pipe. The outside diameter of pipe is 16 mm, and the inside diameter of pipe is 14 mm. The space between floor coils is 200 mm. The idiographic constitution of cooling/heating floor is showed in the figure 1.

According to the practical shape of every room, the floor coils were lied double ophidian with three circuits. The length of each round is 100 m. The practical layout of floor coils is in the figure 1.

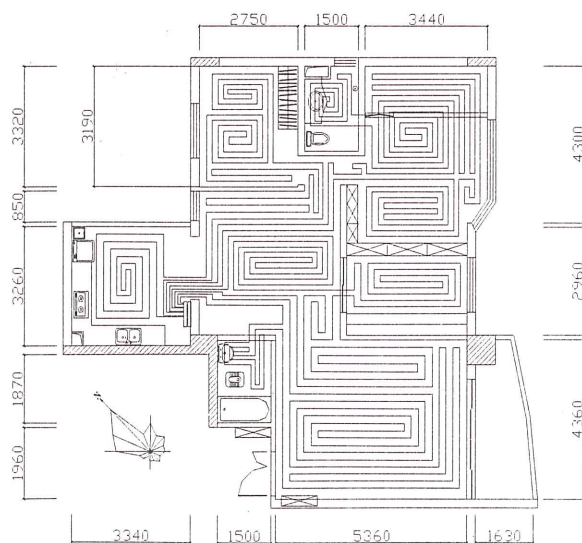


Fig.1.The ichnography of ground coils

In this project ,the humidity is reduced and got ride of by fan-coil and cooling floor.

The fan-coil is high static pressure. The ventilation rate is $1000 \text{ m}^3/\text{h}$, and the outlet static pressure is 70 pa.

The fan-coil is hung on the top of dining-room. The returned air is mixed with the fresh air. The mixed air is cooled or heated by the fan-coil. The worked air is supplied to every room by air pipe. The air is sent and returned both from the top of the room. The air outlet can be adjusted and closed electric, so it's convenient and economical.

2.3 The water system

1) Cooling condition of summer: There is a water pump in the floor coils system in order to keep the system steady. The cooling water first enter into the fan coil unit, then part of them enter into the floor coils, others return to the heat pump. The rate of cooled water entered into the floor coils is decided by electric water valve according to the temperature of the water from the header.

2) Heating condition of winter: The fan-coil system is not need in winter. The heating water flows to the floor coils header directly and then to the floor coils of the rooms, exchanging heat with room air and enclosure, returns to the heat pump.

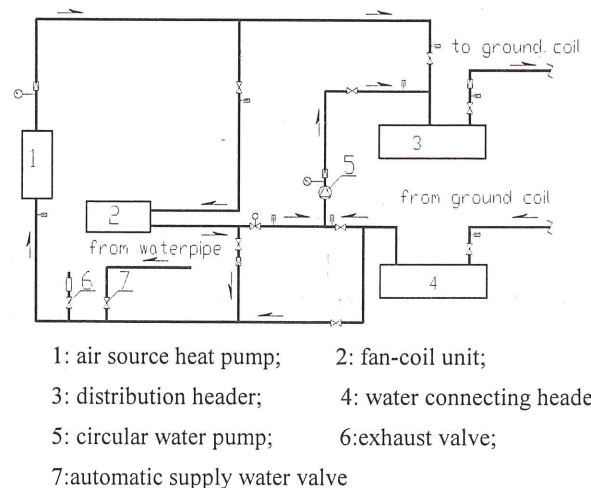


Fig.2. the flow chart of water system

3. The analysis of operating condition

Because the air-conditioning system of the cooling/heating floor has two heat exchanging system, there are many ways to be chosen. In summer, the cooling floor and the fan-coil are both used; in the transitional days, cooling floor and natural ventilation are used; sometimes only the fan-coil system is run; in the winter, only heating floor is used.

The cooling /heating floor air-conditioning system in winter is correspondingly simple. So there are only the analysis of running condition in summer.

1) The temperature and rate of supplying water which enters into the cooling floor is mostly considered, besides the control of refrigerating effect of refrigerating machine, the control of cooling effect of fan-coil. The cooling water enters into floor coils of every room. The water valve controls the water rate of each room.

The temperature of cooling floor should be controlled by the thermoscop of dew point temperature, which controls the header valve of floor coils. When the temperature of the floor surface is lower than the dew point temperature of the room air, the valve of floor coils is adjusted in order to reduce the low temperature water flux which is inflow to the floor coils. And part of the water from the fan-coils flow into the heat pump. But the controller of dew point temperature is expensive and the control plan of the system is also difficult. So in this project, the controller of water supplying pipe controls the water flux flowing into the floor coil, In order to keep the temperature of floor surface higher than the dew point temperature of room air. The upper limit temperature of the controller is 21°C, the lower limit temperature is 19°C. When it is the upper limit temperature, the electric valve is opened; When it is the lower limit temperature, the electric valve is closed.

2) Because the temperature of supplying water is higher in the cooling /heating floor air-condition system, the dehumidification and refrigeration of fan-coil can be improved by increasing the supply water rate. In this way, the EER of equipment can be improved, and the energy can be saved. The temperature of supply water can't be too high, so the temperature can be determined by calculating the equipment requirement. The temperature of returning water of air-cooling heat pump is 15°C in this project. Because of the two compressors of air-cooling heat pump, the temperature of supplying water changed according to the air conditioning load indoor. The circular water flux of the system is 1.8 m³/h, and the circular water flux of floor coils in summer is 1.2 m³/h.

4. The analysis of the result

The experiment began in June, 2003. Circuits is examined whether it works perfectly or not. At June 7, the system is tested unceasingly.

1) Starting system at 15:00. Temperature of floor dropped apparently. The temperature of the exit of the

floor coils in dinning room has got 20.7°C at 16:30. The lowest air temperatures of semi-bedroom was 20.9°C, and highest air temperature is 24°C. The lowest air temperature was 21.8°C, and the highest air temperature was 23.8°C in bedroom. But all above never condensed.

2) At 17:30, the semi-bedroom had the perfect hot environment, the average temperature of floor was 21°C; the air temperature indoor descended to 25°C. It was comfortable. The room was closed and no fresh air in, and the floor had no dew.

3) The outward wall of the main bedroom is facing the sun. When natural ventilation and cooling floor were all working in this room, the heat gain from the sunlight was bigger and the requirement of fresh air was also higher. As a result, the descendent of air temperature is not obvious, but the descendent of the floor surface is apparent especially under the bed where convection is weak and no sunshine.

4) Apparently condensing phenomenon at 20:30. The water trace had the same shape as the floor coils. The temperature of surface that had water was 16.5°C. The temperature of room reduced greatly. You would felt cold when coming into the room. The dew water was mainly found on ceramic tile and not found on wooden floor of bedroom. And the temperature of wooden floor surface is higher than that of tile.

5) The air-cooling heat pump stopped very frequently when it was working. Because the system with the protection of 3 minutes delaying, when started working, the temperature of the returning water changed greatly, from 15°C when was working normally to 26°C when air-cooling heat pump stopped working. So it is concluded that it is better to choose the compressor with the frequency conversion controller to avoid the frequent starting and stopping of the machines, which leads to bigger change of water temperature in system and at the same time lengthens the using time of machines.

5. Conclusion

The cooling/ heating floor system is an energy saving and comfortable air-conditioning system. It is fit for residential buildings, hotels and offices. But it is short of many calculative data and good project methods, for less research and application had been done. So it's application limited. But we are sure that with a great development in the research of cooling/

heating floor AC system, there will be more and more application of cooling/ heating floor air condition system.

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