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The Analysis of the Performance of Heating and the Economical Efficiency of the Solar Energy and Gas Heat Pump

Hong Hao[a,*], Junbin Yao[a], Guohui Feng[a], Huating Wen[b]

a School of Municipal and Environmental Engineering,Shenyang Jianzhu University, Shenyang, China
b China Northeast Architectural design & research Institute Co.,Ltd , Shenyang , China

Abstract

The solar and gas heat pump heating system is a system that combines the gas heat pump and the solar heat pump driven by electricity. On the one hand, the system makes full use of the solar, and it is a real High-efficiency, energy-saving system. On the other hand, the system use natural gas as an energy source which can relieve the energy crisis, reduce environmental pollution and relieve the pressure of the grid. During the operation of the system, it will save operating costs due to the cheaper price of gas compared with electricity. Therefore, the research of the solar and gas heat pump has a great sense of energy-saving and economical.

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Keywords: Zero energy building; dest; energy saving

1. Introduction

The solar and gas heat pump heating system is a system that combines the gas heat pump and the solar heat pump driven by electricity. On the one hand, the system makes full use of the solar, and it is a real High-efficiency, energy-saving system. On the other hand, the system use natural gas as an energy source which can relieve the energy crisis, reduce environmental pollution and relieve the pressure of the grid. During the operation of the system, it will save operating costs due to the cheaper price of gas compared with electricity. Therefore, the research of the solar and gas heat pump has a great sense of energy-saving and economical.

* Corresponding author. Tel.: +86-15998358017.
E-mail address: 12554978@qq.com

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Since entering the 21st century，there are more and more researches about the solar heat pump system. V• Badescu had a further study on the equipments in the solar heat pump heating system. The result shows that in the process of heating, if the volume of the device used to storage thermal increase, then the power of the compressor of the solar heat pump will increase, but the COP of the heat pump will decrease. R•Yumrutas and others researched the characteristic of the operation in the solar heat pump with seasonal underground thermal storage device. The result shows that there are two aspects will influence the performance of the whole solar heat pump heating system. One of them is the thermal properties of soil. Different soil has different thermal conductivity which will influence the experiment and get different results. Another one is the size of the storage device. When the size is so small, it will not present the heating system. When the size is pretty big, the device of the system will be pretty complex. So the size should be controlled in a reasonable range.

In the 1960s, our country has built the earliest solar hot water project. Tianjin University and Beijing Institute of Architectural Design designed the first solar water heater with natural circulation by researching a series of solar water heaters and built a bathroom with this technology which became an example of solar hot water heating. From 1980s, our country started the research about the gas heat pump. The first institution who started the research first in our country is Thermal Research Institute, Tianjin University. Their research conducted a series of feasibility analysis for the application of the gas heat pump. They also made a series of experimental studies about the gas heat pump which laid a solid foundation for the development of the gas heat pump.

2. Methods

This paper builds a system of solar energy heat pump which is driven by the gas engine , calculates and chooses proper equipments for the system,then simulates some specific parameters like the number that the compressor turns,rotate speed of the engine,the COP of the system and the amount of the heat release of the condensation on it by TRNSYS and Simulink.

Shenyang is located in northeast cold zone in China, the heat load in winter is bigger than the cooling load in summer. So it's necessary to choose the model of the ground heat pump on the basic of the annual heat load of the building. If we want to meet the heat and cooling require, we can not decrease the capacity of the gas heat pump system in the design condition because of the instability of the solar in the process of heating. What we should do is that we should leave a certain amount of capacity to assure the performance of the heating system. So we should assume one of the most unfavorable conditions first like that there is no solar half a day, then select the type of the gas heat pump.

The maximum heat load is 231KW, the design heat load of the gas heat pump is 70% of the whole heat load—162KW. We choose the gas heat pump designed by Rand Air Conditioning Company in this paper. The specific parameters of the system are shown in table 1.

Table 1 Gas heat pump parameters.

Type	GSHP-C0138D		
Heating Effect/KW	170	Input Power of the Refrigeration/KW	37.9
Refrigerating Effect/KW	152	Input Power of the Heating/KW	25.8
Water Flow of the Evaporator when Heating/（m^3/h）	12	Pressure Loss	≤28
Water Flow of the Condenser when Refrigerating/（m^3/h）	23	Pressure Loss	≤70

The main equipments of the solar and gas heat pump are solar collector and storage model, gas engine model, waste heat recovery model and heat pump model. We use TRNSYS to simulate the solar collector and storage model in the system and set the temperature of the water in the buffer tank to 10-20 ℃. The other parameters like

the gas engine, waste heat recovery system, heat pump will be simulated by MATLAB. Regarding the change of the temperature of the water in the solar storage tank as the heat source of the evaporator and choosing R134a as the cycle working fluid of the heat pump. The relevant physical parameters of the cycle working fluid are shown in reference 8. The main simulation model of the system is shown in Fig.1.

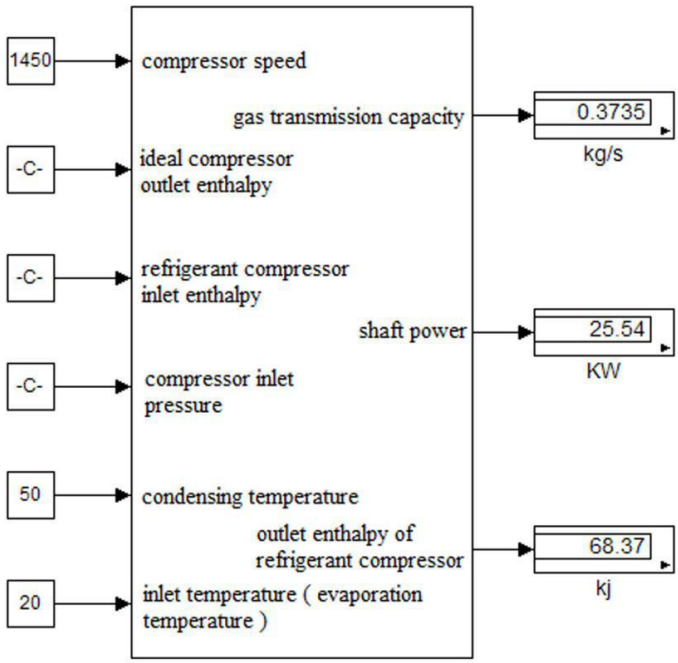

Fig. 1. A system model in MATLAB.

3. Results

Tables and illustrations

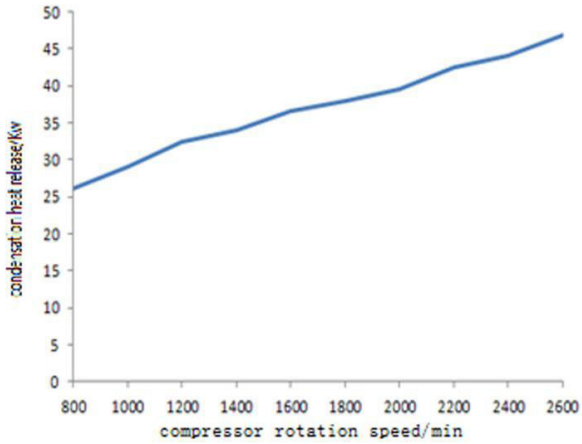

Fig. 2. Relationship between compressor rotation speed and condensation heat release.

Figure 2 shows the change of the condensation heat release with the change of the number of the compressor rotation number under the condition that the evaporation temperature of the solar and gas heat pump is 15℃, the condensing temperature is 45℃. The condensation heat release will increase with the increase of the compressor rotation speed. The compressor rotation speed is one of the factors which will influence the condensation heat release. In order to get more condensation heat release we can increase the compressor rotation speed which means that we should increase the engine speed of the gas engine by control the gas volume which will enter the engine. Considering the stability, security, using time and economy of the heating system, we can not increase the gas volume unlimitedly we should control the amount of gas in a certain range.

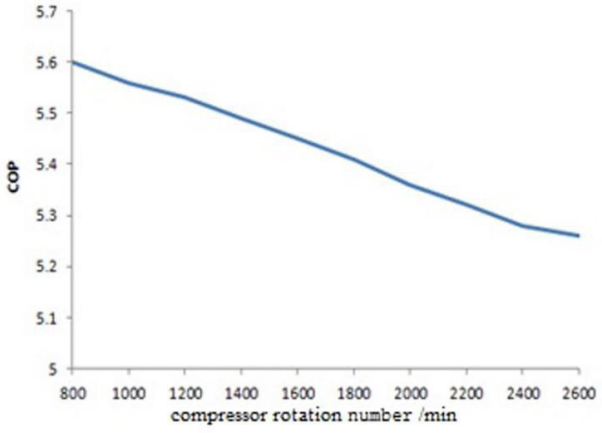

Fig. 3. Relationship between compressor rotation number and COP.

Figure 3 shows the change of the COP of the system with the change of the number of the compressor rotation number under the condition that the evaporation temperature of the solar and gas heat pump is 15℃, the condensing temperature is 45℃. From the graph of the variation we can draw a conclusion that the COP of the system will decrease with the increase of the compressor rotation number. That is because that when we increase the compressor rotation number, we should increase the use of nature gas which means that the energy consumption of the system will increase at the same time. According to the analysis, we should make the compressor rotation number in a proper range in order to get higher COP. If the compressor rotation number is pretty big, the energy consumption of the system will increase which will influence the performance of the system. When the compressor rotation number is small enough, we will get a higher COP, but we can find that the condensation heat release will decrease which means that we can not assure the comfort of the heating system. Therefore, we can learn that when the compressor rotation number in the range of 1600-2000 Rev / min, the performance and the comfort of the solar and gas heat pump heating system are best from the Fig 1 and Fig 2. In a word, we should control the compressor rotation number in the range of 1600-2000 Rev/min by controlling the use of the natural gas in the operation of the system.

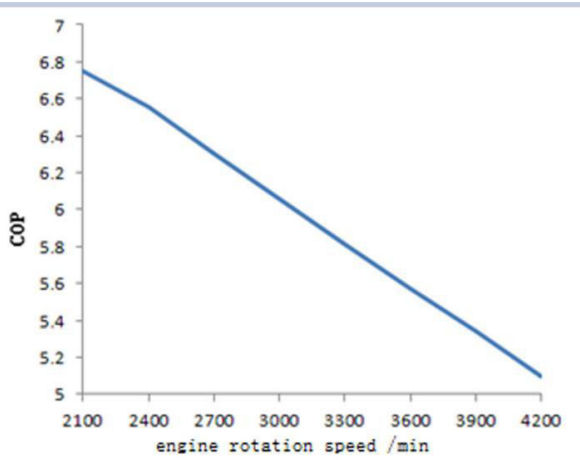

Fig. 4. Relationship between engine rotation speed and COP.

Figure 4 shows the change of the COP of the system with the change of the engine rotation speed under the condition that the evaporation temperature of the solar and gas heat pump is 15℃, the condensing temperature is 45℃. Compared with the figure 4, the range of the COP is pretty big which is because of the recover of part of the waste heat of engine and the performance of the system is improved.

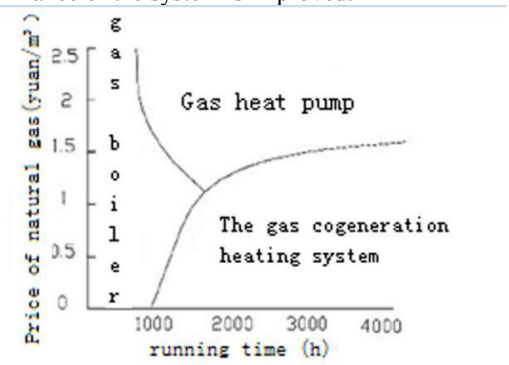

Fig. 5. Comparison of three kinds of gas hot economic.

The Fig.5 is gained in the condition that the price of the electricity is 0.65 yuan/(KW • h). We can find that when the using time is short, using the gas boiler for heating is more economical. But when the using time is long and the price of the natural gas is low, the gas cogeneration heating system is more suitable. When the using time is long and the price of the natural gas is high, the gas heat pump is more economical. In shenyang, the heating time is from 1 November to 31 March, means 151 days,or 3624 hours.And the price of the natural gas is 4.8 yuan/m^3 . We can know that shenyang is in the area that the gas heat pump is more economical, which means that the gas heat pump is more suitable in shenyang.

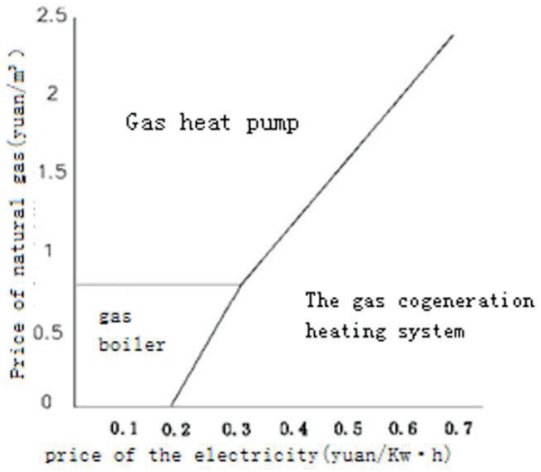

Fig. 6. Three kinds of gas heating economic zone.

The Fig.6 gives the economic distribution of the gas heating withe the change of the price of electricity and the natural gas. We assume the hour of heating is 3000. We can see that the gas boiler is more economical the the price of the natural gas and the electricity are low. The gas cogeneration heating system is more economical when the price of the electricity is high and the price of the natural gas is low. When the price of the electricity and the natural gas are all high, the gas heat pump heating system is the most economical. In shenyang, the price of the electricity is 0.74 yuan, we can see that the gas heat pump heating system is more economical easily.

4. Equations

(1)For gas-fired boiler and gas heat pump, the annual operating costs Z of each of the heating capacity is:\

$$z = \gamma \cdot v + C_f \cdot b \cdot h \tag{1}$$

(2)For the gas cogeneration system, the generating income should be cut from the cost, therefore:

$$z = \gamma \cdot v + \frac{C_f - \eta_e C_e}{\eta_{tot} - \eta_e} h \tag{2}$$

5.Names and units

v——the system investment of each of the heating capacity, yuan/KW;

γ——the depreciation rate which is the reciprocal of the system uses life;

b——the primary energy rate of the system;

C_f——the price of the natural gas, yuan/m³

C_e——the price of the electricity, yuan/(Kw • h)

6.Discussion

The solar and gas heat pump heating system is a system that combines the gas heat pump and the solar heat pump driven by electricity. On the one hand, the system makes full use of the solar, and it is a real High-efficiency, energy-saving system. On the other hand, the system use natural gas as an energy source which can relieve the energy crisis, reduce environmental pollution and relieve the pressure of the grid. During the operation of the system, it will save operating costs due to the cheaper price of gas compared with electricity. Therefore, the research of the solar and gas heat pump has a great sense of energy-saving and economical.

7.Conclusion

1) From the simulation analysis, we can know that the rotate speed of the compressor is in the range of 1600-2000 r/min, the heating performance and the comfort of the solar and gas heat pump heating system are best. The heat release of the system and the rotation number of the compressor are all high at the same time.

2) According to the price of the natural gas and electricity in shenyang, we analyze the gas boiler, gas heat pump and the gas cogeneration heating system and draw a conclusion that the gas heat pump heating system is the most economical system in shenyang.

3) From the comparison of the three different systems, we can know that when the heating system is short, the gas boiler is economical, even though the consumption of source and the price of the heating source are high. The advantage of the gas heat pump and the gas cogeneration heating system will show when the heating time is long.

Acknowledgements

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