WANG Jun, Liu Kai,Wang Haixia, Bi Wenfeng

School of civil construction, Henan University of Technology, Zhengzhou, China

Simulation Computation and Analysis of Dynamic Operation Energy of Seawater Source Heat Pump

***Abstract**. Air temperature could influence air conditioning load of buildings and sea water temperature whose change, in turn, could alter performance of seawater source heat pump. Hence, taking variations of air and seawater temperature, this research carries out simulation computation of operation energy of seawater source heat pump on the basis of air conditioning loads of buildings simulated with DeST software*

***Streszczenie.** Temperatura powietrza wpływa na jakość urządzeń klimatyzacyjnych i podobnie temperatura wody morskiej wpływa na właściwości pomp cieplnych pompujących tę wodę. W artykule przedstawiono symulację pracy pomp cieplnych bazując na podobnych analizach układów klimatyzacji. (**Symulacja komputerowa i analiza dynamiki pomp cieplnych zasilanych woda morską**)*

Keywords: seawater source heat pump, operation energy, seawater temperature
Słowa kluczowe: pompy cieplne,, dynamika przenoszenia ciepła

Introduction

Seawater source heat pump system provides air conditioning cool and warm water for buildings with the use of affluent ocean thermal energy. It has wide applications in China, a country rich in ocean thermal energy. Regarding the application of seawater source heat pump system, operation energy has aroused wide public attention.

For seawater source heat pump, air temperature could influence air conditioning load of buildings and sea water temperature whose change, in turn, could alter performance, cooling and heating capacity of seawater source heat pump. Hence, air temperature and seawater temperature have become main factors to influence operation energy of seawater source heat pump. This research takes one seawater source heat pump system of Qingdao as object; simulates and analyzes dynamic operation energy of the pump system with simulation of hourly air conditioning load and analysis of observation temperature data of Qingdao municipality.

General introduction of the project

The seawater source heat pump system for the research object is open indirect with design conditions described in Table 1.

Table 1 design working conditions of seawater source heat pump

	Seawater temperature/□	Glycol water temperature/□	Air conditioning water temperature /□
Cooling conditions in summer	24~29	25~30	7~12
Heating conditions in winter	3.7~0.7	2.7~-0.3	50~45

Seawater is pumped into plate heat exchanger by immersible pump, where it exchanges heat with glycol water before being discharged into sea again. The glycol water then

enters hydrothermal heat pump package as heating cooling media to supply air conditioning cold hot water for the building. All air system and fan coil plus fresh air system have been adopted at the end of the building in accordance with different functions of rooms.

Simulation computation of dynamic operation energy of seawater source heat pump system

Computation methods of the dynamic operation energy

Air temperature could influence air conditioning load and sea water temperature whose change, in turn, could alter input power, cooling and heating capacity of seawater source heat pump package. Based on this fact, this part computes hourly load of air conditioning system and then dynamic operation energy of the pump system.

First of all, operation characteristics of hydrothermal heat pump package is analyzed to take entering water temperatures at different locations and analyze the variations of input power, cooling and heating capacity of heat pumps. Next, number of heat pumps in operation is judged in accordance with hourly load of air conditioning system and cooling and heating capacity of heating pump package at the same time. Finally, hourly energy consumption of the heating pumps is computed with help of input power and number of the pumps in operation. In this way, in the computation, the system could adjust the number of heating pumps in operation in accordance with air conditioning load, cooling and heating capacity of heating pumps, so that the general cooling capacity is always up to the requirement of system load.

The hourly energy consumption of heating pumps is calculated under the following conditions.

(1) Number of heating pumps is determined in accordance with hourly load of air conditioning system, cooling and heating capacity of heating pumps under seawater temperature of the day. Round figure should be taken.

(2) Effects of partial loads on performance of heating pumps are not considered when heating pumps operate in full load.

(3) Energy consumption of heating pumps is calculated according to input power of heating pumps under seawater temperature of the day.

(4) Flux of air conditioning system is decided in accordance with cooling and heating capacity, heat balance and temperature difference of supply return water. Air conditioning cool hot water, glycol water and seawater temperature difference are as design conditions indicate (see table 1).

(5) Energy consumption of water pumps is calculated as per nominal working condition; number of water pumps in operation decided by flow and taken as round figure.

(6) Operation time of heating pumps and water pumps are both form 8:00 hours to 20:00 hours.

2.2 Analysis of characteristics of varying duty operation of hydrothermal heating pumps

The input power, cooling and heating capacity of hydrothermal heating pumps are calculated with Spline, programmed with Matlab software. Leaving water temperature of heating pumps on load side in computation, in summer cooling operation, in winter heating operation, and temperature difference of air conditioning air supply return in summer and winter are a constant, 7□, 50□ and 5□ respectively.

Seawater temperature data in computation are supplied by Xiaomaidao Oceran Observation Station of Qingdao municipality in accordance with its data of year 2004-2005. The average value is taken as seawater temperature of the day. Since plate heat exchanger is adopted in the project to realize heat exchange between seawater and glycol water; temperatures of glycol water in heating pumps and of seawater are different from each other. According to design conditions, temperatures of glycol water in summer cooling condition and in winter heating condition are 1□ higher and 1□ lower respectively than corresponding seawater temperatures. Hence, temperature difference of 1□ is adopted in the simulation on assumptions that temperature of glycol water varies with that of seawater.

2.3 Computation results for dynamic duty energy consumption of sea source heating pump

Fig one lists cooling, heating capacity and dynamic duty energy consumption of the heating pumps in the research project. Considering considerable difference of energy consumption with different system forms at the end of air conditioning system, energy consumption of only heating pump package and water pumps is included in this research and operation energy consumption at the end of air conditioning system is excluded.

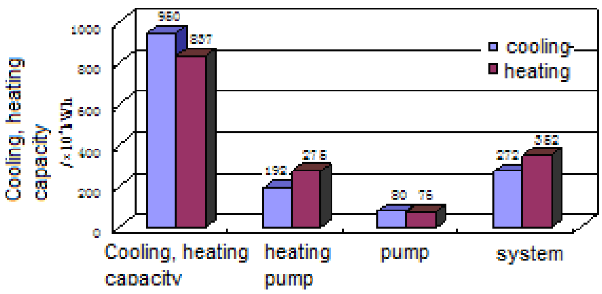


Fig. 1. Cooling, heating capacity and operation energy consumption of a whole year

It could be seen from fig 1 that the heating pump consumes more energy in winter than in summer even though its heating capacity in winter is lower than its cooling capacity in summer. The main reason is that seawater temperature is lower in winter in Qingdao district, so more input power is needed to obtain the same amount of energy for heating capacity. Meanwhile, because of large number of circulation water pumps, the proportion of energy consumed by water pumps is large, up to 29.4% and 21.6% in winter and summer respectively.

According to computation data in fig 1, seasonal energy efficiency ratio of seawater source heat pump system could be calculated as per formulas (1) and (2).

(1) $$\text{Pump seasonal energy ratio} = \frac{\text{Pump cool(Hot)supply}}{\text{Pump Energy Consumption}}$$

seasonal energy efficiency ratio of the heating pump = heating (cooling) capacity/electricity consumption of the heating pump

$$\text{System seasonal energy ratio} = \frac{\text{Pump cool(Hot)supply}}{\text{Pump Energy Consumption}}$$
(2)

seasonal energy efficiency ratio of the system = heating (cooling) capacity/electricity consumption of the heating pump + electricity consumption of water pumps.

It could be seen from fig 2 that regarding energy efficiency ration of both heating pumps and system, the data of seawater source heating pumps is far higher in summer than in winter (62.8% and 46.6% higher for each respectively). This condition is decided by characteristics of seawater temperature change in Qinghai waters. Despite lower seawater temperature in winter which is harmful for the performance of the heating pump, efficiency ratios of the heating pumps and the system have reached 3.04 and 2.38 respectively, a relatively high level.

Comparison and contrast of dynamic operation energy consumption for seawater heating pumps and air source heating pumps.

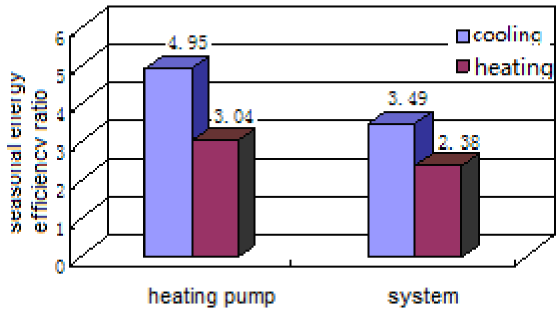


Fig. 2. Seasonal energy efficiency ratio of the heating pump

Computation of dynamic operation energy consumption of air source heating pump

Computation of dynamic operation energy consumption of air source heating pump is similar to that of seawater source heating pump. First of all, air/seawater source heat pump which is similar to the heat pump package in the research project is selected as cooling and heating source of air conditioning system; then, operation characteristics of thermal heat pump package is analyzed to obtain variation rules of input power, cooling and heating capacity of air/seawater source heat pumps under different outdoor temperature. Next, number of heat pumps in operation is judged in accordance with hourly load of air conditioning system and cooling and heating capacity of heating pump package at the same time. Finally, hourly energy consumption of the heating pumps is computed with help of input power and number of the pumps in operation. Computation method for operation energy consumption of air source heat pump and water pump remains the same with that for seawater source heat pump.

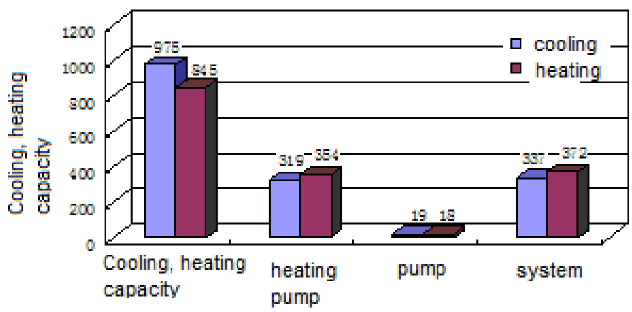


Fig. 3. Cooling, heating capacity and operation energy consumption of a whole year

Computation results and analysis of dynamic duty energy consumption of air source heating pump

It could be seen from fig 3 that the heating pump consumes more energy in winter than in summer even though its heating capacity in winter is lower than its cooling capacity in summer. The main reason is that air temperature is lower in winter in Qingdao district, so the heating capacity goes down rapidly and more input power is needed. It should be noted that frosting and defrosting of air source heat pumps are not considered in computation of energy consumption in heating season, for which, more energy is consumed in actual heating season.

The cooling (heating) capacities for air/seawater source heat pumps, obtained from computation, are different from each other due to calculation methods and selection of equipment. Since the difference is minor, only within 3%, the cooling (heating) capacities could be regarded as the same, which is the basis of this research in comparison and analysis of energy efficiency of the two heating systems.

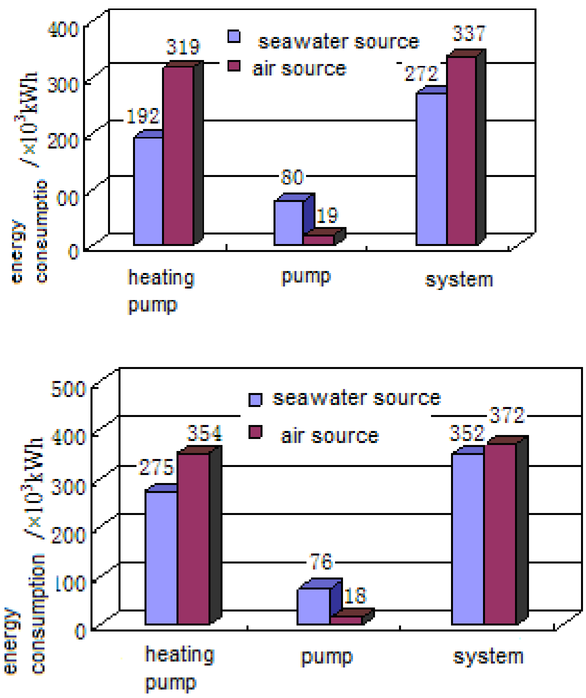
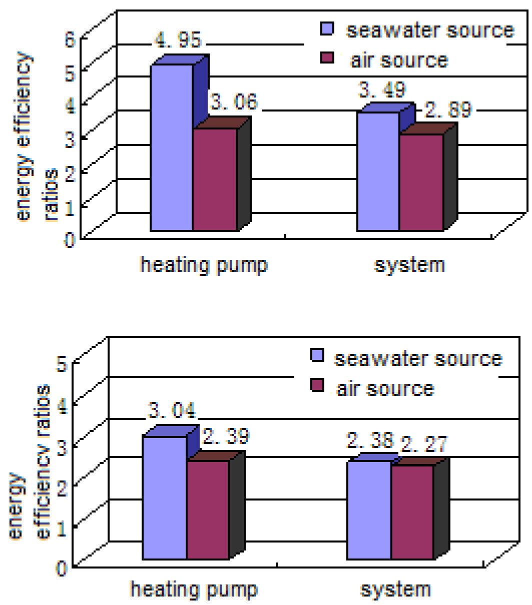


Fig. 4. a) cooling season b) heating season

Comparison of energy consumption of the two pump systems



a) cooling season b) heating season

Fig. 5. Comparison of energy efficiency ratios of the two pump systems

Based on data of fig 4 and fig 5, it could be shown that seawater source heat pump is superior to air source heat pump due to retardance of seawater temperature. For this reason, seawater source heat pump consumes less energy for the same cooling (heating) capacity. The seasonal energy efficiency ratio of seawater source heat pump in cooling and heating seasons is higher by 61.8% and 27.2% respectively than that of air source heat pump. The system seasonal energy efficiency ratio of seawater source heat pump is higher by 20.8% and 4.8% respectively than that of air source heat pump. Meanwhile, as more water pumps are included in seawater source heat pump, energy consumed by water pumps in seawater source heat pumps is more than that by air source heat pumps, 4.2 times higher in both cooling and heating seasons. For this reason, energy consumption of water pumps occupies larger proportion in total energy consumption of seawater source heat pump system, up to 29.4% and 21.6% respectively in cooling and heating seasons respectively compared with 5.6% and 4.8% for air source heat pump systems.

Conclusions

(1) The simulation computation results show that for seawater source heat pump system, seasonal energy efficiency ratios in cooling and heating seasons reach 3.49 and 2.38 respectively and the energy consumption by water pumps in the same season accounts for 29.4% and 21.6% respectively of total energy consumption of the pump system.

(2) In comparison of dynamic operation energy consumption of air/seawater source heat pump systems, seawater source heat pump system has higher value for both system and water pump energy efficiency ratios.

(3) Considering more energy consumption by water pumps in seawater source heat pump system, frequency conversion control of water pumps in seawater source heat pump system has wider applications in the future.

Acknowledgement. Henan provincial key scientific and technological projects: Project No. 01241050415.

REFERENCES

[1] Yu Liqiang. Feasibility study of establishment of large seawater cooling (heating) source heat pump station in East Development Zone of Qing Dao. Heat supply air conditioning system. 1996, (5): 10~13

[2] Li Zheng, Duan Muling, Shu Haiwen et al. Development of seawater source air conditioner and its current applications in China. Heat supply air conditioning system. 35(11): 20~26

[3] DeST Development Team of Tsinghua University. Analysis on simulating method of building environment system-DeST. China Machine Press, 2006: 1~23

***Authors**: WANG Jun, Liu Kai,Wang Haixia, Bi Wenfeng, School of civil construction Henan University of Technology, Zhengzhou, China.*

The correspondence address is: e-mail: wj0371wj@126.com