INVESTIGATION ON THE PERFORMANCE OF NATURAL GAS ENGINE DRIVEN HEAT PUMP

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Abstract: Investigation on the performance of natural gas- driven heat pump has been finished. The results show that the heat pump unit driven by natural gas engine (GEHP) is efficient, and energy saving with the Primary Energy Ratio (PER) is higher than 1.52 under experimental conditions. And the satisfactory partial load characteristics of GEHP and variable speed regulation were obtained in this experiment.

Key Words: ***GEHP; PER; natural gas engine***

1 INTRODUCTION

Heat pumps driven by natural gas engine have been considered by increasing numbers of people as a preferable choice in the heating and air-conditioning scheme. The Primary Energy Ratio of GEHP in heating scheme is 110% and 75% higher than that of coal-burning and gas-fired boiler respectively [1]. Because the GEHP can make full use of the waste heat from the engine and adopts the vapor compression cycle, whose coefficient of performance (COP) is higher than that of the absorption cycle. And the use of clean fuel makes the GEHP be in favor of environmental protection and sustainable development. According to the current price of energy consumption in China, the annual energy consumption costs for heating and air conditioning by the GEHP is approximately 67% of that of direct-fired absorption chillers or 88% of that of electricity driven heat pump [2]. Also the emission of greenhouse gases and contaminations in the scheme is far less than that of other heating and air conditioning schemes. On the other hand, using large numbers of electricity driven air-conditioners results in the ill provision of electricity in many cities, but the supply of natural gas is relatively in surplus during summer. Therefore the employ of the GEHP can improve the structure of energy resources, that is, it can balance the seasonal difference between peak and valley loads of electric equipment and solve the problem of imbalance between the production and supply of natural gas both in summer and winter. Based on our previous studies such as the technical and economy analysis, the steady and dynamic simulation of the system, the controlling strategy and scheme decision, the primary optimal design and so on, a test stand of the compressed type water-to-water heat pump driven by natural gas engine was set up. Experimental investigation has been conducted and satisfactory results are obtained.

2 EXPERIMENTAL APPARATUS

The test stand of the water-to-water GEHP is composed of a heat pump system, a bi-fuel (natural gas/gasoline) engine, a heat sink and source system and the fuel supply system, as shown in Figs. 1 and 2. The stepless speed regulation of the

Figure 1: Test stand of heat pump driven by bi-fuel engine

compressor can be realized when the speed lies between 500 rpm and 3000 rpm. The exhaust gas heat exchanger is a horizontal shell-and-tube one. And the TCLE7-1/2MC thermostatic expansion valves have been introduced into the system. The outer heat source system is composed of a condenser loop and an evaporator loop, while the evaporator loop is mainly comprised of chilled water tank, evaporator, pumps, relevant pipelines and so on. The condenser loop consists of cooling water tank, condenser, cylinder jacket heat exchanger, exhaust gas heat exchanger, outdoor fan coils, pumps, relevant pipelines and so on.

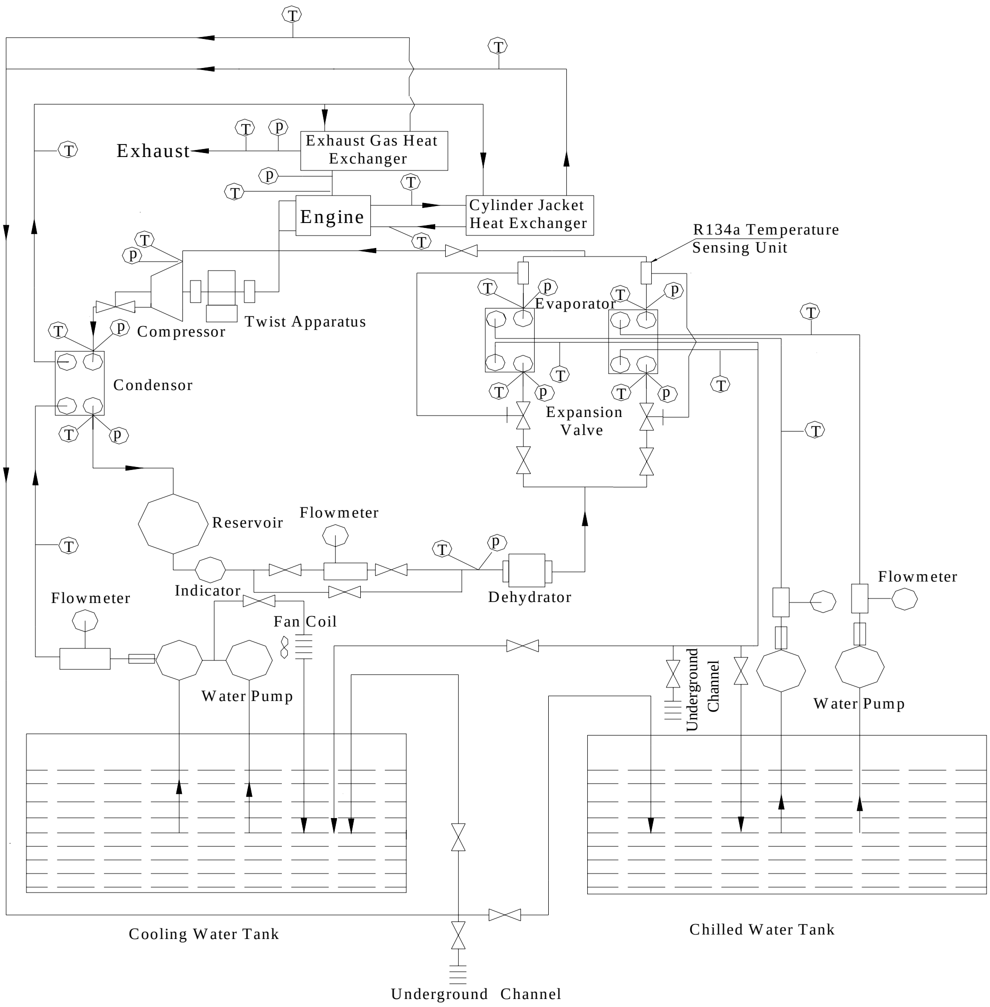

Figure 2: Schematic of the water-to-water heat pump driven by a natural gas engine (GEHP)

3 RESULTS and DISCUSSION

3.1 Recovery of waste heat

Figures 3-6 show the recovery of waste heat from the engine of GEHP. With the increase of the engine's power and rotary speed, the recoveries of waste heat from the exhaust gas and cylinder jacket heat exchangers go up and consequently the total waste heat recovery increases. But when the rotary speed reaches 3000 rpm, the incremental rate of recovery of waste heat becomes slow, which is determined by the load performance of the engine.

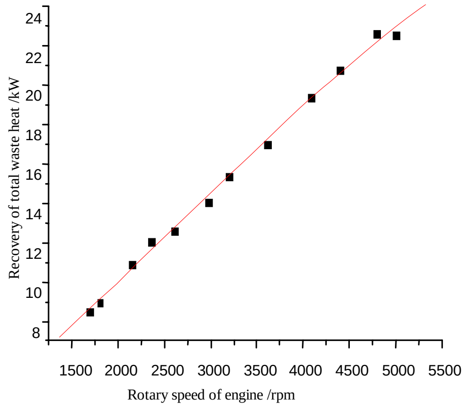

Figure 3: Relationship between the rotary speed of engine and the recovery of total waste heat

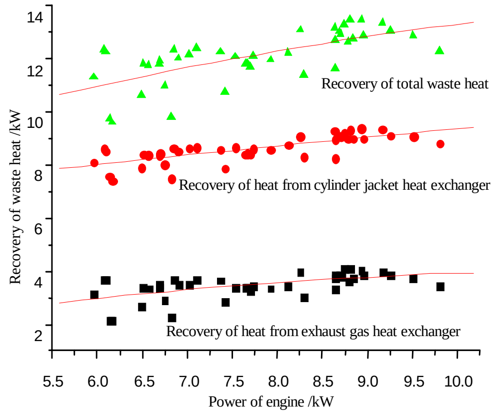

Figure 4: Relationship between the power of engine and the recovery of waste heat (Rotary speed of engine: n=1689.65r.p.m)

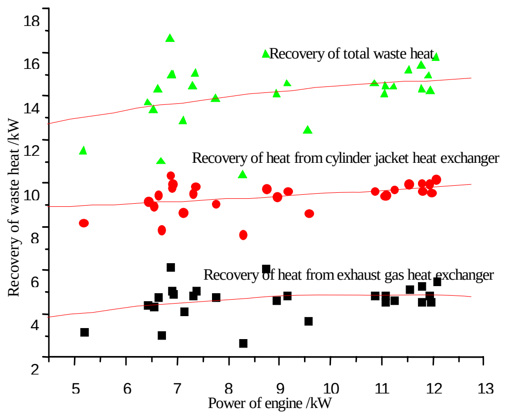

Figure 5: Relationship between the power of engine and the recovery of waste heat (Rotary speed of engine)

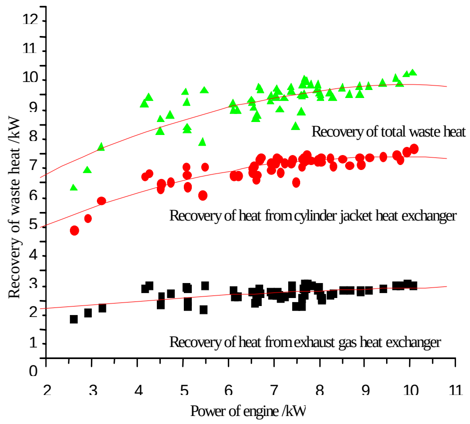

Figure 6: Relationship between the power of engine and the recovery of heat (Rotary speed of engine:

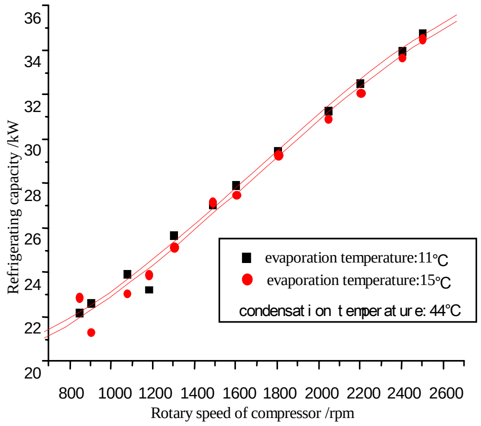

Figure 7: Relationship between the rotary speed of compressor and the refrigerating capacity

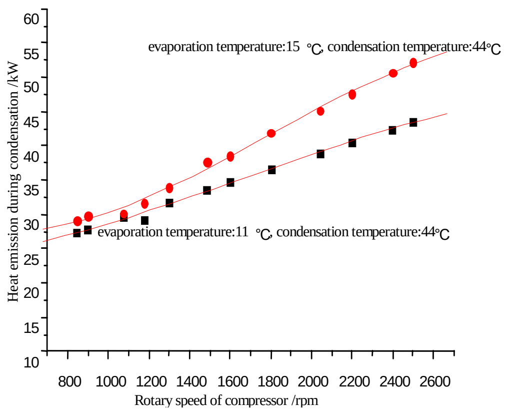

Figure 8: Relationship between the rotary speed of compressor and the heat emission during condensation

3.2 Characteristics of heat pump sub-system

Fig. 7-10 show the experimental characteristics of the heat pump system. With an increase in the rotary speed of the compressor, the refrigerating/heating capacities of heat pump and the energy consumption of the compressor increase, while the coefficient of performance (COP) and the Energy Efficiency Ratio (EER) of the system are reduced slightly.

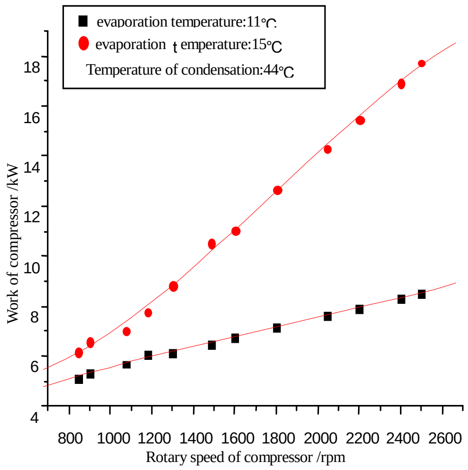

Figure 9: Relationship between the rotary speed and the work of

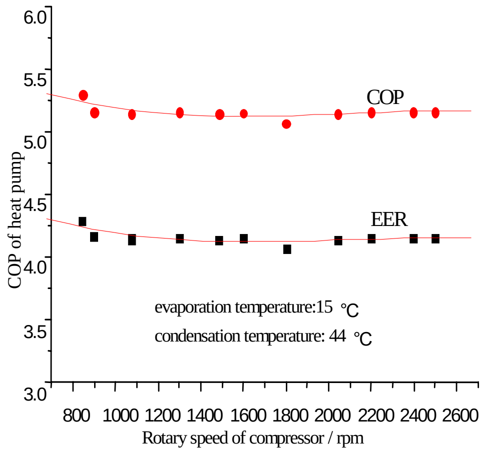

Figure 10: Relationship between the rotary speed of compressor and the

3.3 Overall characteristics of system

Fig. 11-14 show the overall characteristics of the GEHP system, including relationships between the rotary speed and the COP, PER, the refrigerating and heating capacities. With a decrease in the rotary speed, the PER increases. Hence when the system is operated under partial loads, the reduction of the engine's rotary speed can change its output power and consequently the refrigeration capacity is

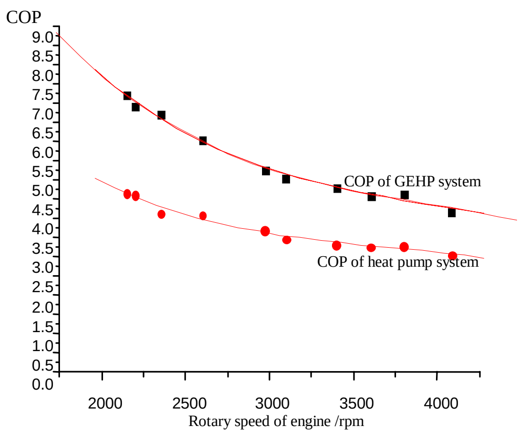

Figure 11: Relationship between COP and the rotary speed of

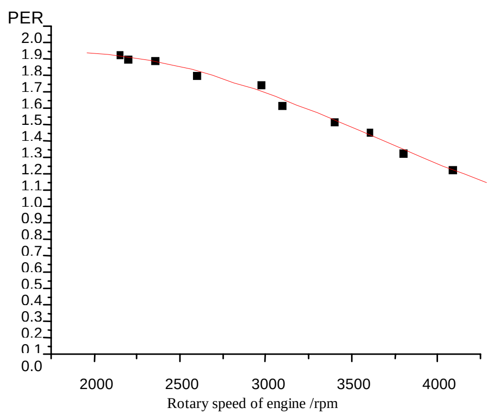

Figure 12: Relationship between PER and the rotary speed of engine

adjusted, which also avoids the turn on/off adjustment of the system.

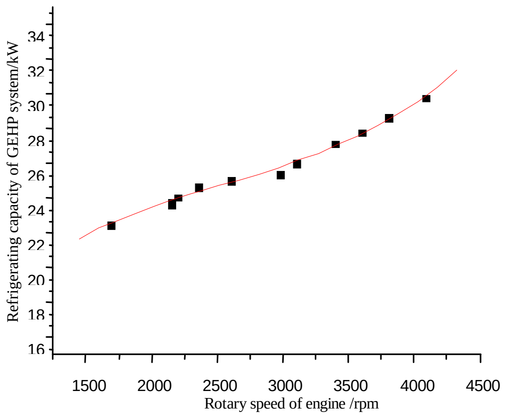

Figure 13: Relationship between the rotary speed of engine and the refrigerating

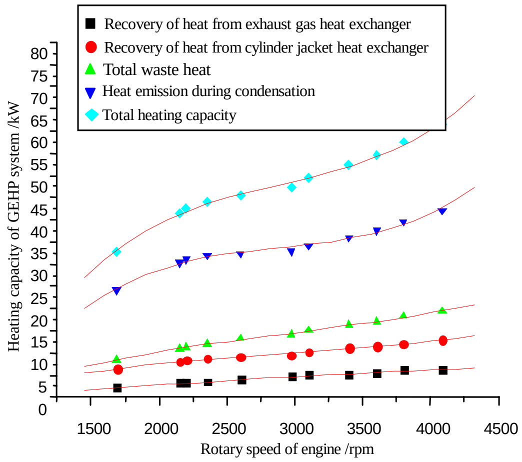

Figure 14: Relationship between the rotary speed of engine and the heating capacity

Fig. 15-16 show relationships between the rotary speed of engine and the refrigerant flux and the fuel consumption of the system. With an increase in the rotary speed of the engine, the rotary speed of the compressor increases proportionally and consequently the refrigerant flux increases. At the same time, the power of the engine is also increased with its increasing speed, such that the fuel consumption is increased. Because the engine runs more efficiently in the speed range of 2500-4000 rpm, the fuel consumption gradient decreases after the rotary speed of engine is more than 2500rpm. The high efficiency zone of the engine is not the same for different fuel. It is about 2000-3500 rpm for the natural gas fuel.

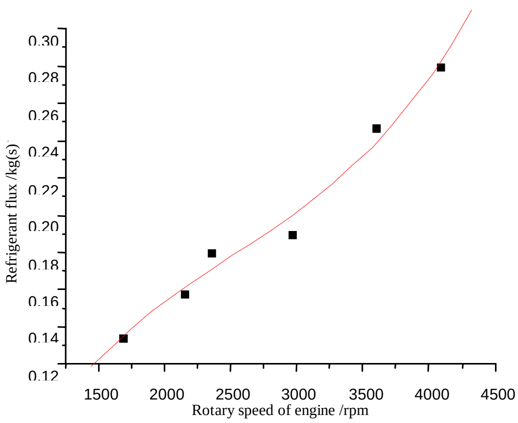

Figure 15: Relationship between the rotary speed of engine and the

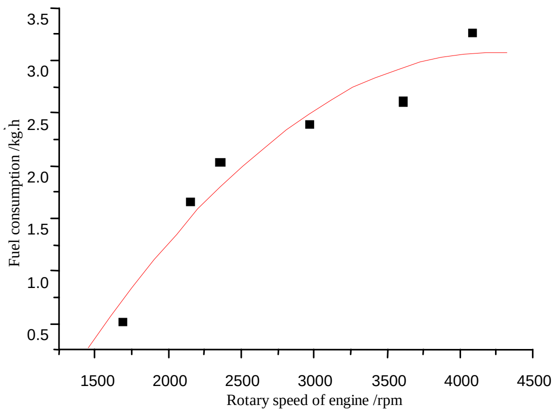

Figure 16: Relationship between the rotary speed of engine and the fuel

4 CONCLUSION

The experimental results show that the characteristics of the natural gas fuelled engine, the refrigeration system and the performance of the entire heat pump system driven by a natural gas engine (GEHP) are satisfactory, and the primary energy ratio (PER) of the system can reach 1.13~1.79 under the experimental conditions and the system has fine partial loads characteristics, which indicates its excellent potential for energy-saving and environmental protection effects. In addition, the potential for the performance improvement of the GEHP is significant if the efficiencies of the engine and compressor are improved.

5 ACKNOWLEDGEMENT

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