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NUMERICAL APPROACH TO SOLAR EJECTOR-COMPRESSION REFRIGERATION SYSTEM

by

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A model was established for solar ejector-compression refrigeration system. The influence of generator temperature, middle-temperature, and evaporator temperature on the performance of the refrigerant system was analyzed. An optimal generator temperature is found for maximal energy efficiency ratio and minimal power consumption.

Key words: *ejector-compression refrigeration system, simulation, optimal middle-temperature, optimal generator temperature*

Introduction

With rise of environmental pollution and cost of conventional energy, the utilization of renewable energy such as solar energy and geothermal energy has been caught more and more attention. The solar-assisted ejector refrigeration system has been used popularly for its simple structure, few moving parts and low cost [1]. So, ejector refrigeration system has become a major topic in recent years. Alexis *et al.* [2] studied the performance of an ejector cooling system driven by solar energy and R134a as working fluid. Ersoy *et al*. [3] studied the performance of solar powered ejector cooling system with an evacuated tube collector for some cities located in the southern region of Turkey. Pollerberg *et al*. [4] investigated the performance of solar driven steam jet ejector chiller that had a cooling capacity of 1 kW. However, some newly developing trends currently observed are directed toward reducing the use of absorption chillers.

As previously described, the performance of ejector refrigeration system driven by solar energy is directly dependent on solar radiation and ambient temperature in the daytime. Thus, Hernandez *et al*. [5] proposed a hybrid compressor and ejector refrigeration system, which uses a mechanical compression subsystem to increase the coefficient of performance of ejector refrigeration system. Zheng *et al*. [6, 7], and Tian *et al*. [8] studied the dynamic thermal behavior of solar ejector-compression refrigeration system. However, in the literature related, such a simulation model about solar ejector-compression combined refrigeration system has just a few, and the scanty study on the optimization of the generator temperature and middle-temperature was found. So, in this paper, a steady-state simulation model was established, and the influence of the generator temperature and middle-temperature on solar ejector-compression combined refrigeration system has been studied.

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Simulation model

The following assumptions are made to simplify analysis.

– The exchange of heat between the system and the environmental atmosphere is ignored.
– The system is in steady-state operation.
– The refrigerant is in saturation state at the outlet of the condenser.
– The pressure drop and the resistance of the system are negligible.

The cooling capacity can be determined:

$$Q_e = m_e(h_9 - h_8) \tag{1}$$

where m_e [kgs^{-1}] is the refrigerant mass flow of evaporator side, h_8 and h_9 [kJkg^{-1}] – the import and export enthalpy of evaporator side.

The electrical power of the refrigerant pump is defined by:

$$W_p = \frac{m_g(h_5 - h_4)}{\eta_p} \tag{2}$$

where m_g [kgs^{-1}] is the refrigerant mass flow of generator side, h_5 [kJkg^{-1}] – the refrigerant inlet-enthalpy of generator, h_4 [kJkg^{-1}] – the refrigerant outlet-enthalpy of condenser, η_p – the pump efficiency, 0.8 was selected.

The electrical power of compressor can be expressed:

$$W_{com} = \frac{m_{com}(h_{10} - h_9)}{\eta_{com}} \tag{3}$$

where, m_{com} [kgs^{-1}] is the refrigerant mass flow rate of compression system, h_{10} [kJkg^{-1}] – the refrigerant inlet-enthalpy of condenser, η_{com} – the compressor efficiency.

The overall mechanical power consumption of the system is:

$$W = W_p + W_{com} \tag{4}$$

The energy efficiency ratio (*EER*) can be expressed:

$$EER = \frac{Q_e}{W} \tag{5}$$

Based on the previous analysis, a simulation program was developed by using the software of engineering equation solver. The simulation flow diagram of the computational procedure can refer to the literature [9].
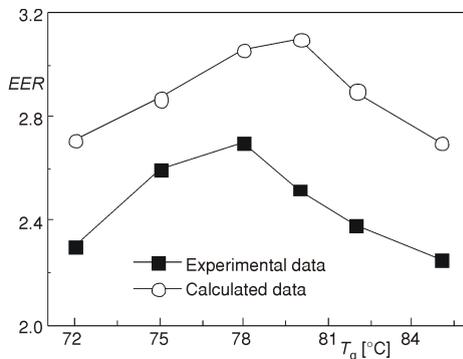
Figure 1. Validation of simulation model

Results and discussion

Figure 1 shows the validation of the mathematical simulation model carried out to obtain *EER*, under the condition of evaporator temperature –5 °C, middle-temperature 10 °C, and the condenser temperature 35 °C. The simulated results are found to be in good agreement with the experimental data, and the deviations is no more than 18.7%.

Figure 2 illustrates the *EER* against the generator temperature under the condition of $T_e =$

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= –5 °C, –10 °C, –15 °C, T_{int} = 10 °C and T_c = = 35 °C. It is evident that the maximum *EER* are obtained when the optimal generator temperature is between 78 °C and 80 °C. The variation of power consumption with generator temperature is shown in fig. 3.

Figure 4 presents the variation of system *EER* with middle-temperature between 2 °C and 20 °C under the condition of T_c = 35 °C, T_e = –5 °C, and T_g = 75 °C, 80 °C, and 85 °C, respectively. It is indicated that the system *EER* increases initially and then decreases with middle-temperature increasing, under the condition of evaporator temperature –5 °C. It can be seen that the maximum *EER* is obtained (*EER* can reach 3.39), when the optimal middle-temperature is between 7 °C and 10 °C.
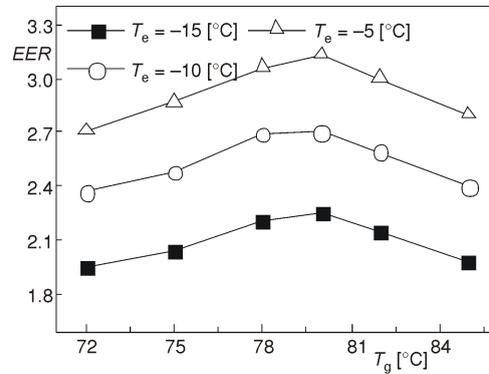
Figure 2. Variation of *EER* with T_g
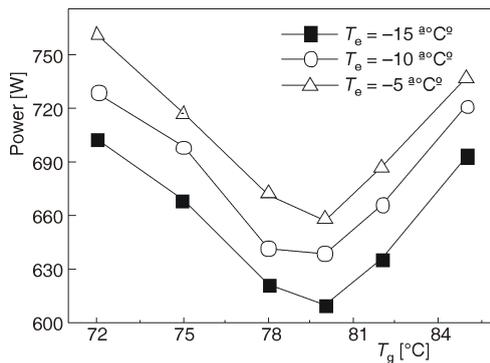
Figure 3. Variation of power consumption with T_g
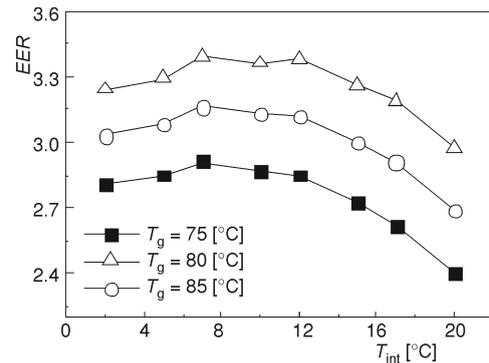
Figure 4. Variation of *EER* with T_{int} (T_e = –5 °C)

Conclusion

A model was established for solar ejector-compression combined refrigeration system, and the influence of generator temperature and middle-temperature on the refrigerant system performance was studied experimentally. The main conclusions derived from the study can be summarized: the generator temperature has influenced deeply on the system performance. It indicated that the *EER* increases initially and then decrease with the generator temperature increasing, while the trends of power consumption is opposite. The maximum *EER* and minimum total power consumption are obtained when the optimization middle-temperature is between 7 °C and 10 °C. In consequence, the optimal generator temperature and middle-temperature have been achieved.

Acknowledgment

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