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Irreversible absorption heat-pump and its optimal performance

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Abstract

On the basis of an endoreversible absorption heat-pump cycle, a generalized irreversible four-heat-reservoir absorption heat-pump cycle model is established by taking account of the heat resistances, heat leak and irreversibilities due to the internal dissipation of the working substance. The heat transfer between the heat reservoir and the working substance is assumed to obey the linear (Newtonian) heat-transfer law, and the overall heat-transfer surface area of the four heat-exchangers is assumed to be constant. The fundamental optimal relations between the coefficient of performance (COP) and the heating load, the maximum COP and the corresponding heating-load, the maximum heating-load and the corresponding COP, as well as the optimal temperatures of the working substance and the optimal heat-transfer surface areas of the four heat-exchangers are derived by using finite-time thermodynamics. Moreover, the effects of the cycle parameters on the characteristics of the cycle are studied by numerical examples.

Keywords: Finite-time thermodynamics; Absorption heat-pump; Heat resistances; Heat leak; Internal irreversibilities

1. Introduction

Absorption heat-pumps can be driven by 'low-grade' heat such as waste heat in industries, solar energy and geothermal energy, and have a large potential for

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reducing the heat pollution of the environment. Thus, absorption heat-pumps for industrial and domestic uses are generating renewed interest throughout the world [1]. In recent years, finite-time thermodynamics [2–5] was applied to the performance study of absorption heat-pumps [6–14], and a lot of results, which differ from those obtained using classical thermodynamics, have been obtained. Chen and Yan [7,8], Herold [9], Goktun [10] and Chen [11] analyzed the performance of the three-heat-reservoir absorption heat-pump cycle with the loss of heat resistance [7–9], with losses due to heat resistance and internal irreversibility [10], and with losses due to heat resistance, heat leakage and internal irreversibility [11] with a linear (Newtonian) heat-transfer law. Chen et al. [12–14] studied the performance of the endoreversible three-heat-reservoir absorption heat-pump cycle with the linear phenomenological heat-transfer law, $Q \propto \Delta(T^{-1})$. A three-heat-reservoir absorption heat-pump cycle is a simplified model of the absorption heat-pump that the temperature of the condenser is equal to that of the absorber, but a real absorption heat-pump is not. A four-heat-reservoir absorption heat-pump cycle model is closer to a real absorption heat-pump. Chen [15] established a four-heat-reservoir absorption heat-pump cycle model, considering the effects of heat resistance and internal irreversibility, and studied its performance with a linear (Newtonian) heat-transfer law.

On the basis of these research studies, a generalized irreversible four-heat-reservoir absorption heat-pump cycle model with a linear (Newtonian) heat-transfer law and which includes heat resistance, heat leak from the environmental reservoir to the heated space, and the irreversibility due to the internal dissipation of the working substance besides the finite-rate heat-transfers between the working substance and the external heat-reservoirs and heat leak, is established in this paper. The fundamental optimal relation between the coefficient of performance (COP) and the heating load, the maximum COP and the corresponding heating load, the maximum heating load and the corresponding COP, as well as the optimal temperatures of the working substance in the four heat-transfer processes and the optimal heat-transfer surface areas of the four heat-exchangers of the cycle coupled to constant-temperature heat-reservoirs are derived. In the analysis, the total heat-transfer surface area of the four heat-exchangers is assumed to be constant. The results obtained herein can provide a theoretical basis for the optimal design and operation of real absorption heat-pumps.

2. A generalized irreversible-cycle model

An irreversible four-heat-reservoir absorption heat-pump cycle consists of a generator, an absorber, a condenser and an evaporator, as shown in Fig. 1(a). The flow of the working substance in the cycle is stable and the working substance exchanges heat with the heat reservoirs at temperatures T_g, T_a, T_c and T_e in the generator, absorber, condenser and evaporator, respectively, during the time τ. There exists thermal resistances between the working substance and the external heat-reservoirs. The corresponding temperatures of the working substance in the