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Review

Absorption refrigeration cycles: Categorized based on the cycle construction

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ABSTRACT

In this paper, different absorption refrigeration cycles are reviewed. The couplings for absorption cycle construction are summarized. Based on the coupling characteristics, the absorption cycles are classified into the following categories: single effect cycle, external-circuit coupling cycles, internal-circuit coupling cycles and the cycle combined with ejector/compressor. Cycles constructed through external-circuit coupling refer to the multiple stage cycles. In these cycles, the external-circuit heat and mass couplings are employed to improve the cycle performance or temperature lift. Cycles constructed through internal-circuit coupling refer to the GAX cycles. In these cycles, the internal-circuit heat couplings are employed to enhance the cycle flexibility and internal heat recovery. The internal-circuit mass couplings are employed to enlarge the GAX temperature overlap. In the combined cycles, ejector or compressor are integrated to improve the cooling output or decrease the driven temperature. The configurations and theoretical COP of these cycles are introduced with diagrams. Related literatures are reviewed.

Les cycles frigorifiques à absorption: catégorisation basée sur la construction de cycle

Mots clés : Froid à absorption ; Pompe à chaleur à absorption ; Cycle à absorption ; Cycle GAX ; Synthèse

1. Introduction

Nowadays, problems including global warming, energy crisis and environment pollution are increasingly standing out. The need for energy-saving and green technology is urgent. Absorption refrigeration is one of the promising technologies. The absorption refrigeration is energy-saving as it can be driven by solar power or surplus heat (Kim and Infante Ferreira, 2008a; Wang et al., 2009; Zhang et al., 2011). Besides, it uses environmentally friendly working pairs without global warming potential or ozone depletion potential (Dai, 1996; Herold et al.,

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Nomenclature

COP	coefficient of performance
G	generator
A	absorber
C	condenser
E	evaporator
R	resorber
GAX	generator absorber heat exchange
SHX	solution heat exchanger
T	temperature
P	pressure
n	COP of basic cycle
DAR	diffusion absorption refrigeration
x,y	flow rate ratio of the refrigerant
1,2,3. .	number of the component number
SE/DL	single effect/double lift

1996). The importance of absorption refrigeration technology is highlighted under the new background.

The absorption refrigeration was first developed in 1777. Sulfuric acid was adopted as working pair at that time. French scientist Ferdinand Carré invented the absorption unit with ammonia–water solution in 1858. A US patent was applied for the absorption unit in 1860 (Cheung et al., 1996; Reif-Acherman, 2012; Srikhirin et al., 2001). The most common working pairs for absorption refrigeration are LiBr water solution and ammonia water solution (Sun et al., 2012). The LiBr–water absorption chiller is widely used for its high efficiency (Wang et al., 2013). The ammonia–water absorption chiller is popular for no danger of crystallization and the ice-making ability. Besides, the wild concentration range of ammonia–water allows the absorption heat recovery through generator-absorber heat exchange (GAX) (Lazzarin et al., 1996). The absorption refrigeration has different configurations including the single effect cycle, double effect cycle, double lift cycle, GAX cycle and other cycles. Except for the single effect cycle, other cycles are proposed for high efficiency, high temperature lift or strong flexibility. For example, double effect cycle has high COP. Double lift cycle has high temperature lift. GAX cycle has stronger flexibility. These cycles are constructed through different methods including condensation heat recovery, absorption heat recovery, generator absorber heat exchange and other couplings. Researchers including Alefeld, Biermann, Coronas, Grossman, Kang, Radermacher and Ziegler all carried out comprehensive studies on advanced absorption refrigeration cycles.

Although some papers have reviewed on the absorption refrigeration cycle before, there are some researches that are seldom collected. In this paper, these researches and some latest researches are reviewed together with the conventional contents. These cycles are classified based on their constructions. The heat coupling, mass coupling and additional components combining of the absorption refrigeration cycles are selected as the classification criteria. Except for the single stage cycle, other cycles are classified into external-circuit coupling cycles and internal-circuit coupling cycles. Each kind has its own sub-classes. Besides, absorption cycles coupled with compressor and ejector are also introduced briefly.

2. Terminology and methodology

To indicate the inner connections between different absorption refrigeration cycles and make a clear classification, terminologies including “stage”, “lift”, “effect” or “basic cycle” are used. Considering the former references (Alefeld and Radermacher, 1993; Cheung et al., 1996; Kang et al., 2000), terminologies used in this paper are listed as follows:

(1) “Basic cycle” refers to the heat driven single effect cycle and resorption single effect cycle.
(2) “Sub-cycle” refers to the cycle contained in a complete cycle. It can be either a basic cycle or other complete cycles.
(3) “Circuit” refers to the connected flow of solution. Different circuits are connected by the flow of refrigerant vapor.
(4) “Stage” number refers to the number of basic cycle contained in a configuration.
(5) “Effect” number means the times that the major driving heat is used for cooling output.
(6) “Temperature lift” refers to the temperature difference between the heat sink temperature and the refrigeration temperature.
(7) “Lift” number refers to the number of basic cycle temperature lifts contained in a cycle.
(8) “Mass coupling” refers to the coupling between generator and absorber through refrigerant vapor flow.
(9) “Heat coupling” refers to the coupling between two processes through heat transfer.
(10) “Resorption” refers to the absorption process occurring under high pressure level in a circuit.
(11) “Independent” means that the refrigerant and solution flows in two cycles do not connect.

In this paper, simplified P–T–x diagrams are adopted to show the construction of different cycles. In the diagram, isobar is horizontal, isotherm is vertical and isoconcentration line is bias. To simplify the expression, the isoconcentration lines are treated parallel. Full lines represent the flows of fluid. Dashed lines represent the flows of vapor. Curves represent the heat flows. The circles represent the outlets of the main components.

The theoretical COP is calculated according to the simplified heat load model proposed by Alefeld and Radermacher (1993). In a single stage cycle, the heat loads of generator and absorber are set as “1” and the heat loads of condenser and evaporator are set as “n”. Factor “n” represents the COP of single stage cycle. It is smaller than 1.0. In other cycles, the heat loads of these components are still set as “1” and “n” for the circulation of refrigerant per unit. The heat loads of the components are shown in the simplified P–T–x diagram. Heat input is set as positive while heat output is set as negative. As the heat load for the same concentration change is different under different concentrations, the factor “n” differs with the concentration. In order to simplify the calculation, a little change of the model is made; the factor “n” is assumed to be constant for the same working pair.

The cycles are categorized based on the couplings integrated in the configuration. The couplings can be classified to