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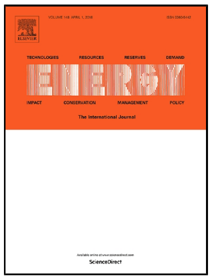

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Optimal Operating Conditions and Cost-Effectiveness of a Single-Stage Ammonia/Water Absorption Refrigerator Based on Exergy Analysis

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Abstract:

In this paper, optimal design/operating conditions are presented by considering the cost-effectiveness and operability of a single-stage ammonia/water absorption refrigerator (AAR) via exergy analysis. Chemical exergy change constitutes complexity with respect to exergy analysis of absorption systems. In the study, Gibbs free energy is considered in the exergy analysis to precisely evaluate the absorption and rectification processes including chemical exergy change. The theoretical maximum exergy efficiency of AAR and the influence of its design/operating conditions on exergy efficiency/destructions are investigated under an ideal condition. The analysis indicates the importance of the evaporator outlet liquid (bleed) ammonia mass fraction and the desorber temperature. A condition of bleed mass fraction control is illustrated. In addition, the study involves performing a sensitivity analysis of design parameters (pinch temperatures) with respect to exergy efficiency and optimal desorber temperature. Finally, design conditions that maximize exergy efficiency per cost are derived relative to the sum of thermal conductance as a cost parameter. The study demonstrates the potential for downsizing the AAR without reducing exergy efficiency. The results indicate that approximately 39% total thermal conductance reduction, maintaining nominal efficiency, or 19% total thermal conductance reduction with an exergy efficiency increase of 16% are expected when compared to those in a commercial AAR.

Keywords:

Exergy, Absorption refrigerator, Ammonia/Water, Optimization, Cost effectiveness.

1. Introduction

Absorption refrigeration is a thermally-activated technology for cold production. Absorption refrigerators were developed considerably earlier compared to compression refrigerators, between the late 1700s and early 1800s. However, they possess low market share when compared to that of compression refrigerators, and this is primarily because of lower efficiency and relatively high capital costs.

Conversely, sustainability and entropy generation reduction are the keywords of society in recent years. Various temperature levels of exhaust heat are generated by the consumption of low-entropy energy. Absorption refrigerators convert this type of exhaust heat to useful refrigeration, and thus, it is important to investigate it.

Moreover, coefficient of performance (COP) is widely used for performance evaluation of refrigerators, chillers, and heat pump systems. It is considered as an efficiency measure based on the first law of thermodynamics. Performance evaluation by COP is possible as long as the temperature conditions of a refrigeration system (e.g., heat source, cooling water, and output temperatures) are constant. However, they vary based on circumstances as well as settings. Thus, COP cannot express this type of system performance; evaluation by exergy is a strong method to resolve this problem. Exergy indicates the quality of energy, and the second law of thermodynamics corresponds to the impossibility of exergy efficiency to exceed 1.

Previous studies reported second-law-based analyses of single-stage absorption refrigeration and heat pump cycles [1-13]. Furthermore, the Kalina cycle [14,15] or power and cooling integrated