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Numerical Study of Entropy Generation in an Irreversible Solar-Powered Absorption Cooling Systems

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ABSTRACT: *The ideal three-heat-reservoir (THR) model for absorption refrigeration cycles is extended to include external and internal irreversibilities. Three empirical functions are used to model the internal entropy generation of the cycle. The parameters of these functions are estimated by fitting data obtained by simulation to the predictions of the THR model. The THR model using a linear function or a logarithmic function for the internal entropy generation is able to reproduce performance data for absorption systems with good accuracy.*
Keywords: *Absorption cooling, Irreversibilities, Entropy generation, Simulation.*

I. Introduction

The interest in absorption refrigeration technology has been growing because these systems use such pairs of refrigerant and absorbent which do not deplete the ozone layer. Moreover, waste heat or solar energy can also be expended for their operation, helping in control of global warming [1]. These eco-friendly aspects of these systems overshadow their low coefficient of performance.

During the last 20 years, finite-time thermodynamics has been applied successfully to performance study of absorption refrigerators [2–10]. The significance of using the concept of finite-time thermodynamics to investigate thermodynamic cycles has been appreciated; many important results have been obtained. It is well known that the endoreversible cycle models [11–13] have played an important role in the development of finite-time thermodynamics. They can reveal the effects of the irreversibility of finite rate-heat transfer on the performance of thermodynamic cycles. However, a real absorption refrigerator is a complex device. There are other sources of irreversibilities besides the irreversibility of finite rate-heat transfer, such as internal dissipation of the cyclic working fluid, irreversibilities caused by mass transfer and so on.

The internal entropy generation depends on the nature of the irreversible processes undergone by the working fluid. For the vapor compression cycle, these irreversible processes are easily identified and the entropy increase during these processes can be expressed in terms of the high and low temperatures of the working fluid. For the real absorption cycle, which includes several irreversible processes, it is difficult to obtain the internal entropy generation in terms of the temperature levels. It is clear that the inclusion of the internal irreversibilities require a simplified representation of the processes undergone by the working fluid of the cycle.

The aim of the present work is to extend the three-reservoir model to include entropy generation in the working fluid due to internal irreversible processes of the cycle. This is done in a semi-empirical manner that gives good reproduction of performance data obtained by detailed computer simulation.

II. Analysis

Ii.1.Methodology of Analysis

In this section the analysis of the three-heat-reservoir absorption cycle including internal and external heat transfer irreversibilities is developed. A schematic diagram of the THR cycle is shown in Fig. 1.

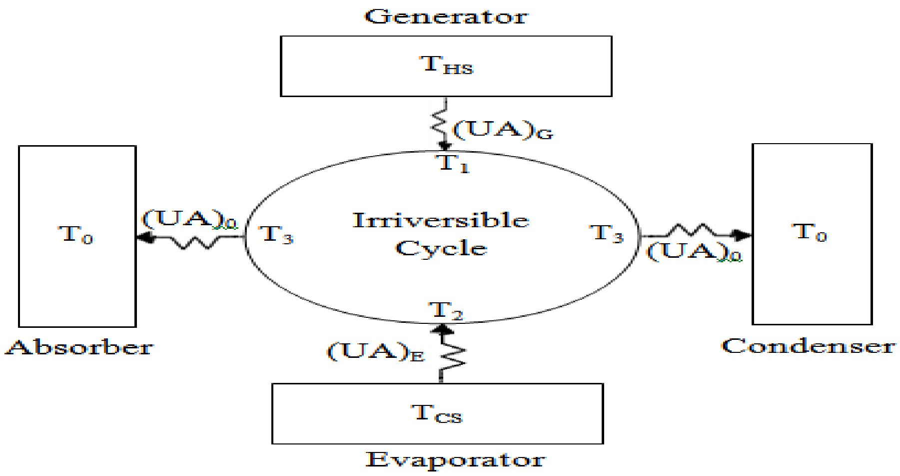

Figure 1. Schematic diagram of the three-heat-reservoir (THR) model of the absorption refrigeration system

Although four heat reservoirs are included to represent the generator, the condenser, the evaporator and the absorber of the absorption machine, the temperature of the absorber and condenser reservoirs are assumed to be equal in the present analysis. This helps to make the governing equations considerably simpler. The working fluid exchanges heat with the four heat reservoirs isothermally and there is an external heat transfer irreversibility at each heat reservoir caused by the finite heat conductance between the working fluid and the heat reservoir. The working fluid is also assumed to undergo a series of irreversible adiabatic processes which constitute the internal irreversibilities of the cycle. The work input to the system is neglected.
Application of the first law to the closed system consisting of the working fluid gives;

$$\dot{Q}_G + \dot{Q}_E - \dot{Q}_0 = 0 \tag{1}$$

where Q_0 is the total heat transferred at the condenser and the absorber reservoirs.
The heat transfers between the working fluid in the heat exchangers and the external heat reservoirs are carried out under a finite temperature difference and obey linear heat transfer law $Q \infty \Delta(T)$. Additionally, these heat exchange processes are assumed to be isothermal and the equations of heat transfer may be written as:

$$\dot{Q}_G = U_G A_G \left(T_{H.S} - T_1\right) \tag{2}$$

$$\dot{Q}_E = U_E A_E \left(T_{C.S} - T_2\right) \tag{3}$$

$$\dot{Q}_0 = U_0 A_0 \left(T_3 - T_0\right) \tag{4}$$

In Equation (4) the working fluid is assumed to have the same temperature during the heat interactions with the absorber and condenser reservoirs and it is assumed that the condenser and absorber have the same overall heat-transfer coefficient U0.
The writing of Second Law of Thermodynamics satisfies the following equation;

$$\frac{dS}{dt} = \frac{\dot{Q}_0}{T_3} - \frac{\dot{Q}_G}{T_1} - \frac{\dot{Q}_E}{T_2} + \dot{S}_{in} \tag{5}$$

The expression of the coefficient of performance of the refrigerating machine is

$$COP = \frac{Q_E}{Q_G} \tag{6}$$

In real absorption machines, the internal entropy generation is a complex function of the various processes undergone by the working fluid in the cycle. In the present analysis the internal entropy generation rate is determined in a semi-empirical manner by matching the predictions of the model with actual performance data.

II.2.Internal entropy generation function

The internal entropy generation depends on the nature of the irreversible processes undergone by the working fluid. For the vapor compression cycle, these irreversible processes are easily identified and the entropy increase during these processes can be expressed in terms of the high and low temperatures of the working fluid [14]. For the real absorption cycle, which includes several irreversible processes, it is difficult to obtain the internal entropy generation in terms of the temperature levels. Therefore, in the present study the internal entropy generation is treated in a semi-empirical manner by using simple functions to represent the entropy of the working fluid. Three such functions are considered in the following section [5, 8, 15].
The first function assumes that the internal entropy generation in the working fluid is a constant. Therefore;

$$\dot{S}_{in} = S_0 \quad (7)$$

The second function assumes that the increase in entropy due to the irreversible processes varies linearly with temperature. This may be expressed as;

$$\dot{S}_{in} = \beta_1 (T_1 - T_3) + \beta_2 (T_3 - T_2) \quad (8)$$

where the parameters β_1, β_2 are to be estimated by fitting detailed simulation data to predictions.

The third function assumes that the entropy increase of the working fluid can be represented by an expression similar to that for an ideal incompressible fluid. Considering the entropy changes, the following expression may be written for the overall internal entropy generation.

$$\dot{S}_{in} = \lambda_1 Ln(T_1/T_3) + \lambda_2 Ln(T_3/T_2) \quad (9)$$

II.3.Procedure to determine the constants

Equations (l), (5) and (6) are used to eliminate heat-transfer rates to obtain an expression for the coefficient of performance in terms of the entropy generation and the working fluid temperatures. The result may be written as

$$COP = \frac{Q_E (T_3 - T_1)}{T_1 \left[Q_E (T_2 - T_3) - T_2 T_3 \dot{S}_{in} \right]} \quad (10)$$

To obtain the best estimates of the parameters β_1, β_2, λ_1 and λ_2 from simulated performance data [16] the following least-square procedure is used. At each data point, the COP, the cooling capacity and the reservoir temperatures are known. The best estimates of these parameters is determined by minimizing the square-error-sum, $\sum \left[COP_{Sim} - COP(\dot{S}_{in}) \right]^2$ where the summation is over all the data points, which cover the entire range of temperatures and cooling capacities for the absorption machine. It is seen that the procedure is similar to linear regression to obtain best-fit parameters.

III. Results

The analytical procedure described in the preceding section was applied to a practical NH_3/H_2O absorption cooling system to predict its coefficient of performance over a range of operating conditions. The effective thermal conductances and the reservoir temperatures assumed in the present computation are the same as those given in [16].

The three empirical functions used to represent the entropy generation in the working fluid involve parameters that have to be estimated by a data fitting procedure. The simple least square estimation method described earlier was used to obtain the best estimates of the parameters.

The variation of the COP predicted by the proposed method using the best estimates of the parameters is shown in Figures 2, 3 and 4.

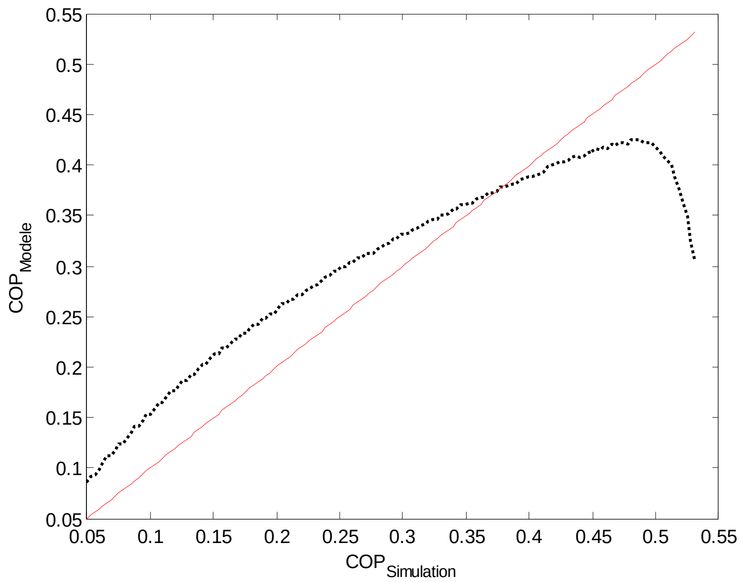

Figure 2. Predicted COP using constant function against COP from simulation [16].

It is seen that the predictions of the constant entropy function are poor. In real absorption cooling systems, the internal entropy generation is a function of several processes that occur in the system. The most important of these are the mixing and circulation irreversibilities that occur in the absorber and the generator. To assume that these irreversibilities are independent of the working fluid temperatures is an over simplification which makes the predictions of the constant entropy function poor.

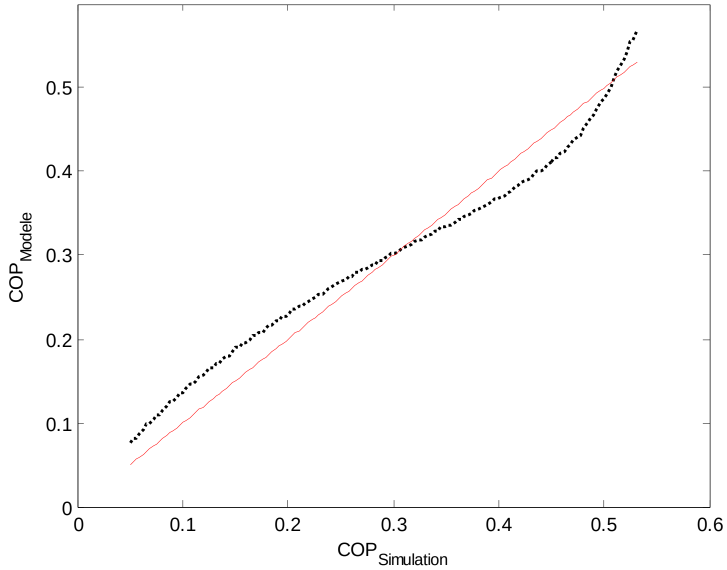

Figure 3. Predicted COP using linear function against COP from simulation [16].

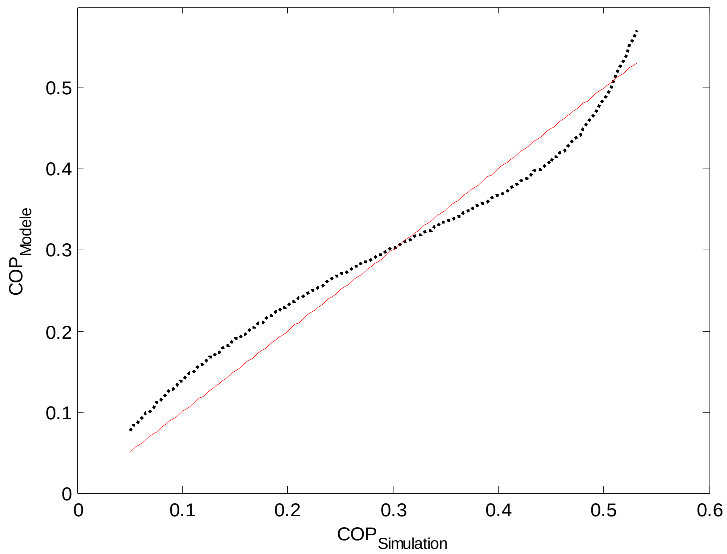

Figure 4. Predicted COP using logarithmic function against COP from simulation [16].

In Figures 3 and 4, the COP predicted by the model using the linear function and the logarithmic function is plotted against the corresponding values obtained from detailed simulation [16]. Most of the points fall within about 10% of the 45° line. The few points that fall outside this range are for low values of the hot reservoir temperature for which the COP is also low. The linear function and the logarithmic function could therefore be used to represent internal irreversibilities of an absorption refrigeration system better than constant function.
It is clear that by using more elaborate entropy functions which include several parameters it may be possible to obtain better prediction of the simulation results. However, the proposed procedure which is simple to implement could be used to estimate the performance with good accuracy over a range of reservoir temperatures and cooling capacities. Once the parameters were estimated, the procedure could be used to represent the performance characteristics of the absorption machine and also for use as sub-component models in larger thermal system simulations.
From the regressions we obtain

$$\dot{S}_{in} = 5.7310^{-3}\, kW \tag{11}$$

$$\dot{S}_{in} = 0.041210^{-3}\left(T_1 - T_3\right) + 0.184310^{-3}\left(T_3 - T_2\right) \tag{12}$$

$$\dot{S}_{in} = -0.0152\,Ln\left(T_1/T_3\right) + 0.0553\,Ln\left(T_3/T_2\right) \tag{13}$$

IV. Conclusion

A simple procedure was developed to extend three empirical functions to represent the internal entropy generation. The linear entropy function and the logarithmic entropy function were found to give the good prediction of the COP for single stage absorption machine. The two parameters involved in the entropy function were estimated by the least-squares method.

References

[1] S. Aphornratana, IW. Eames, "Thermodynamic analysis of absorption refrigeration cycles using the second law of thermodynamics method," *International Journal of Refrigeration*, 18(4), 1995, 244-252,.

[2] S. Sieniutycz, J.S. Shiner, "Thermodynamics of irreversible processes and its relation to chemical engineer: second law analyses and finite time thermodynamics," *Journal of Non-Equilibrium Thermodynamics*, l(19), 1994, 303–348.

[3] S. Özkaynak, S. Göktun, H. Yavuz, "Finite-time thermodynamic analysis of a radiative heat engine with internal irreversibility," *Journal of Physics D: Applied Physics*, 27(6), 1994, 1139-1143.

[4] J. Chen, "The influence of multi-irreversibilities on the performance of a heat transformer," *Journal of Physics D: Applied Physics*, 30(21), 1997, 2953-2957.

[5] N.E. Wijeysundera, "Performance of three-heat-reservoir absorption cycles with external and internal irreversibilities," Applied Thermal Engineering, 17(12), 1997, 1151-1161.

[6] J. Chen, J.A. Schouten, "Optimum performance characteristics of an irreversible absorption refrigeration system," *Energy Conversion & Management*, 39(10), 1998, 999-1007.

[7] L. Chen, C. Wu, F. Sun, "Finite time thermodynamic optimization or entropy generation minimization of energy systems," *Journa of Non-Equilibrium Thermodynamics*, 24(4), 1999, 327-359.

[8] J.M. Gordon, K.C. Ng, *Cool Thermodynamics*, Cambridge Int. Science Publishers, 2000.

[9] N.E. Wijeysundera, "An irreversible-thermodynamic model for solar-powered absorption cooling systems," *Applied Thermal Engineering*, 68(1), 2000, 69-75.

[10] L. Chen, "Finite Time Thermodynamic Analysis of Irreversible Processes and Cycles," Higher Education Press, Beijing 2005.

[11] G. De Mey, A. De Vos, "On the optimum efficiency of endoreversible thermodynamic processes," *Journal of Physics D: Applied Physics*, 27(4), 1994, 736-739.

[12] N.E. Wijeysundera, "Performance limits of absorption cycles with external heat-transfer irreversibilities,"*Applied Thermal Engineering*, 16(2), 1996, 175-181.

[13] C. Wu, L. Chen, F. Sun, "Optimisation of solar absorption refrigerator," *Applied Thermal Engineering*, 17, 1997, 203-208.

[14] G. Alefeld, R. Radermacher, Heat Conversion Systems, CRC Press, Ann Arbor. 1995.

[15] C. Petre, M. Feidt, M. Costea and S. Petrescu, "A model for study and optimization of real-operating refrigeration machines," *International Journal of Energy Research*, 33(2), 2009, 173-179.

[16] Y. Boukhchana, A. Fellah and A. Ben Brahim, "Transient modeling and simulation of an ammonia-water absorption solar refrigerator," *International Journal of Mechanics and Energy*, 3(1), 2015, 33-42.