Energy 80 (2015) 706–714

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

A modified mathematical model of heat pump's condenser for analytical optimization

Jozsef Nyers [a, b, *], Laszlo Garbai [c], Arpad Nyers [c]

[a] Obuda University Budapest, Becsi ut 96, 1034 Budapest, Hungary
[b] Subotica Tech, Marko Oreskovic 16, 24000 Subotica, Serbia
[c] Budapest University of Technology and Economics, 1111 Budapest, Muegyetem 3-9, Hungary

ARTICLE INFO

Article history:
Received 16 October 2014
Received in revised form
30 November 2014
Accepted 8 December 2014
Available online 3 January 2015

Keywords:
Condenser
Heat pump
Optimum
Circulation pump
Mathematical model
COP

ABSTRACT

The aim of this article is to present the reason and the process of creating new modified mathematical model of heat pump plate condenser. The fundamental mathematical model is modified according to analytical optimization procedure. The adaptation is carried out by applying the procedure of elimination. The modified mathematical model include 2 governing equations instead of 6. The two governing equations contain 2 unknown dependent variables and 6 known parameters. The modified mathematical model is validated using the comparative method. The compared data are obtained by numerical simulation using fundamental and modified mathematical models. Applying both models the obtained data fully coincided. By using the new modified mathematical model and implementing the optimization process may lead to the determination of the maximum energy efficiency of hot water subsystem. The subsystem comprises a condenser, a circulation pump, a connecting pipeline and the heating units. The objective function in the optimization process is the coefficient of performance, COP, as a function of the mass flow rate of the hot water or of the circulation pump power. The paper offers the implementation of modeling the circulation pump power to achieve the maximum value of the COP.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

It is difficult to find in the world's leading scientific journals articles which address the issue addressed by the present paper. Most articles dealing with global mathematical modeling and optimization of the entire heat pump system fail to go into deeper, more substantial details referring to hot water subsystem.

The subject matter considered in this paper has been rarely studied in the literature. Ongoing efforts mostly deal with mathematical modeling and optimization of heat pump systems without going into deeper detail about the hot water subsystem.

Yun-Chao Xuet al. [1] proposed a physical analysis-based, theoretical, global optimization method for the condenser and evaporator heat transfer vapor by introducing the entransy dissipation theory and thermodynamic analysis for compressor and expansion valve. Heat transfer and thermodynamic analyses were integrated and they formed the overall physical optimization model to describe the relation between the unknown parameters and the known conditions. The unknown parameters were analytically obtained. For example, the optimization of the refrigeration system with various working conditions minimizes the total heat transfer area of the condenser and the evaporator.

Oussama Ibrahimet et al. [2] presented a dynamic simulation model to determine the performance of an air source heat pump water heater. The developed model was used to assess its performance for four Lebanese climatic zones. The energy savings and the reduction of greenhouse gas emissions were investigated for each zone. Furthermore, an optimal management model for the air source heat pump water heater was developed and applied for a winter day in Beirut. In addition, the dynamic model was used to compare the performance of three similar ASHPWH systems with different condenser geometry. The result was that the use of mini-condenser geometries increased the COP (coefficient of performance).

A. Moreno-Rodríguez et al. [3] showed the development of a theoretical model to determine the operating parameters and consumption of a domestic hot water system with a direct-

---

* Corresponding author. Obuda University Budapest, Becsi ut 96, 1034 Budapest, Hungary. Tel.: +36 381 63 84 777 99.

E-mail addresses: jnyers1@gmail.com (J. Nyers), garbai@epgep.bme.hu (L. Garbai), nyarp@yahoo.com (A. Nyers).

http://dx.doi.org/10.1016/j.energy.2014.12.028
0360-5442/© 2014 Elsevier Ltd. All rights reserved.

expansion solar assisted heat pump. The heat pump was filled with refrigerant R-134a and the power demand of the compressor was 1.1 kW. The collector's total area was 5.6 m^2. The study was conducted over a year for several representative days. For the obtained experimental results the coefficient of performance was between 1.7 and 2.9, while the tank water temperature was 51 °C.

J.M. Corberan et al. [4] developed a mathematical model, which described the quasi-steady state performance of water–water heat pump. The system was used for heating and cooling a building located in a Mediterranean climate. The mathematical model was structured for the heat pump refrigerant circuit, the ground loop-cold water circuit and the building loop-hot water circuit. Heat pump heating and cooling capacities and COP were considered. The mathematical model was validated by using data from a water—-water heat pump system. The validated mathematical model was used to examine the system performance sensitivity to different control optimization strategies.

Hongtao Qiao et al. [5] developed a new mathematical model for steady-state heat transfer within the plate heat exchanger. The plate heat exchanger could be used for the condenser as well. The mathematical model of the considered heat exchanger was two-dimensional with distributed parameters. A finite difference scheme was used for discretization. The behavior of heat exchanger-condenser was investigated in terms of the internal heat transfer. They investigated the influence of constructive details on the heat transfer within the plate heat exchanger-condenser. The external influences on the heat exchanger-condenser performance were not discussed.

Róbert Sánta [6] investigated the mathematical models of several authors. He implemented the models he simulated and compared the results of condensing heat transfer coefficients as a function of the vapor quality. Coefficients were presented graphically depending on the vapor quality of the refrigerant. The results significant differences in values and the tendency related to the arithmetic mean value. According to his study, the best characteristics were presented by Shah's model. In their arithmetic mean value, the values of coefficients by Shah were closest to all the examined coefficients showed.

We applied the mathematical model of heat transfer coefficient by Yi-Yie Yan et al. [7] for the purposes of this paper. They developed a mathematical model of condensing heat transfer coefficient for plate condenser. The model validity was done based on the performed refrigeration system. The advantage of the model was that it verified, completed, and moreover consisted of a model for refrigerant and for hot water as well. The condensing heat transfer coefficient depended on the vapor quality and was valid for R134a.

Jozsef Nyers et al. [8–10], in their earlier reported articles thoroughly presented and explained the development of the fundamental mathematical model of heat pump's plate condenser and the numerical mathematic method for solving the proposed mathematical model as well.

In the present paper, the reasons for creating a new mathematical model were the conditions for the energy optimization of the thermal-hydraulic processes in the heat pump's plate condenser using an analytical-numerical method. The working medium was refrigerant R134a. For numerical optimization a fundamental steady-state mathematical model with lumped parameters is necessary and sufficient, while analytical-numerical optimization needs a model with a reduced number of dependent variable. The energy balance-based fundamental mathematical model of the condenser was created separately for the cooling part and for the condensing part of the condenser, Fig. 1. Further in the paper the cooling part is referred to as the first section and, the condensation part as the second section. In both sections the structure and the form of the equations was the same, i.e. the heat flux was defined in three manners. The first equation described the heat flux absorbed by hot water, the second described the heat flux through the wall between the superheated or saturated vapor and the hot water, and the third described the heat flux of condensation or cooling the refrigerant. The heat transfer process considered was steady-state; hence the heat fluxes were constant.

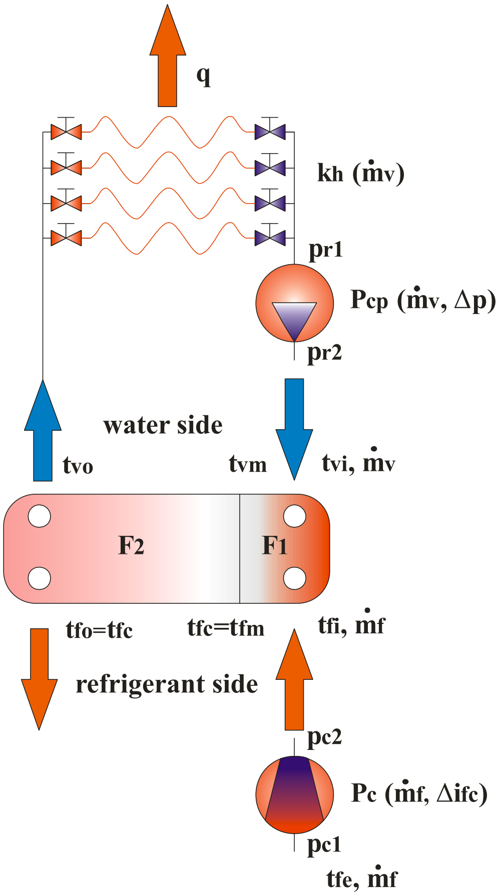

Fig. 1. The physical model of heat pump hot water subsystem with condenser, circulation pump, compressor, pipeline and heating bodies.

Unfortunately, the fundamental mathematical model applicable for the iterative numerical determination of all unknown variables was not suitable for the analytical-numerical optimization. Analytical-numerical optimization requires the elimination of some unknown parameters, thus only the requested variables were kept in the model. In the present case, the requested variables were the mass flow rate of the hot water and the mass flow rate of the refrigerant.

The reason for eliminating the unknown parameters was the condition of the analytical-numerical optimization process. The process was based on partial differentiation. The differentiation was possible only if the needed variables were presented in the model's equations.

However, the modified mathematical model had several advantages over the fundamental model. The number of the equations was reduced in the new model, thus it comprised only the two unknown quantities, the heat flux in the first and the second section, q_1 and q_2. The output temperature of the hot water, the output temperature of the refrigerant and the heat transfer surface of the first and second sections were eliminated. After the elimination, heat fluxes q_1 and q_2 became dependent on variables, such as hot water mass flow rate and refrigerant mass flow rate. The greatest advantage of the modified model is that it is applicable for the

Download English Version:

https://daneshyari.com/en/article/1732045

Download Persian Version:

https://daneshyari.com/article/1732045

Daneshyari.com