International Journal of Thermal Sciences 50 (2011) 1308–1325

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

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

Dynamic model for multi-compartment indirect cooling household refrigerator using Z-transfer function based cabinet model

Enxin Lin [a], Guoliang Ding [a,*], Dan Zhao [a], Yunhu Liao [a], Nan Yu [a], Jun Yamashita [b]

[a] Institute of Refrigeration and Cryogenics, Shanghai Jiaotong University, 800 Dongchuan Road, Shanghai 200240, China
[b] Refrigerator Design Department, Toshiba Home Appliances Co. Ltd., 991 Anada-Cho, Seto-Shi Aichi 489-8610, Japan

ARTICLE INFO

Article history:
Received 3 February 2010
Received in revised form
14 December 2010
Accepted 31 January 2011
Available online 15 March 2011

Keywords:
Adaptive time step
Dynamic model
Household refrigerator
Indirect cooling
Z-transfer function

ABSTRACT

Multi-compartment indirect cooling household refrigerator is widely used and the prediction of the dynamic performance based on dynamic model is useful for improving refrigerator performance and saving energy. The dynamic model to be developed should be accurate, fast and robust, especially considering the computation in dynamic simulation increases dramatically with the compartment numbers. This paper presents a dynamic model for multi-compartment indirect cooling household refrigerator, in which a Z-transfer function based cabinet sub-model, a semi-dynamic compressor sub-model, an approximate analytic capillary sub-model integrated with effective enthalpy method, a multi-zone heat exchanger sub-model, and an implicit curve-fitting method for refrigerant thermodynamic properties are integrated. The model is carried out with the predictor–corrector method as well as the adaptive time step algorithm and the time step interpolation method to match the adaptive time step for dynamic model and the fixed time step for cabinet model. A case study shows that the calculation speed of the Z-transfer function based cabinet sub-model is about 40,000 times faster than that based on direct differential equation solving with a difference of less than 0.06 °C in predicting air temperature with these two methods. Simulation of 24-h running process of a refrigerator by the dynamic model on a personal computer costs 178.3 s; and the differences between the predictions and the experimental data are within 2 °C for compartment air temperature, within 2 °C for evaporating/condensing temperature, and within 10% for compressor input power.

1. Introduction

Multi-compartment indirect cooling household refrigerators, meeting requirements of reserving different foods separately in suitable temperature and making the air temperature in compartment more uniform, become popular home appliances. In order to save energy and improve its performance, simulation tools including steady state model [17] and dynamic model [15,23] have been used for designing household refrigerators, and have shown their advantages of cost and time saving comparing with experiment [10,22]. The dynamic model is especially useful for household refrigerators because it has a lot of useful functions that a steady state model does not have, e.g. prediction of the air temperature variation inside a compartment, and prediction of the effect of a new control algorithm. So it is necessary to develop a dynamic model for multi-compartment indirect cooling household refrigerator.

The dynamic model for multi-compartment indirect cooling household refrigerator should be accurate, robust and fast in system simulation. The reasons for these technical characteristics are: i) any slight error in calculation step may cause unacceptable error of the simulation results considering error accumulation, ii) unconvergence of any calculation step can cause the failure of dynamic simulation, and iii) the air temperature inside different compartments decouples each other, resulting in the computation speed decreasing obviously with the increase of the compartment number.

The existing dynamic models for direct cooling household refrigerators focus on dual-compartment household refrigerator [4,16,18,21]. The existing dynamic models for indirect cooling household refrigerators focus on single/dual-compartment household refrigerators [15,26,27,29,30]. Until now, there are no reports on dynamic models for multi-compartment indirect cooling household refrigerators (more than two compartments) in open literatures. Differencing from single/dual-compartment indirect cooling household refrigerator, a multi-compartment indirect cooling household refrigerator has more than two compartments. If

* Corresponding author. Tel.: +86 21 34206378; fax: +86 21 34206814.
E-mail address: glding@sjtu.edu.cn (G. Ding).

1290-0729/$ – see front matter © 2011 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.ijthermalsci.2011.01.024