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Experimental study of heat transfer characteristics for a refrigerator by using reverse heat loss method ☆

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ABSTRACT

The present study has been carried out to predict the heat transfer characteristics of a residential refrigerator through insulation wall by using reverse heat loss method. The temperature time history characteristics were measured to achieve the steady state condition. In this experiment the steady state condition was reached at about 20 h of heating. The temperature and heat inputs were then averaged with one hour data and considered as the steady state temperature and heat input. From the measured values of temperature and heat input, one can conclude that, the temperature differences between the inside and outside of a refrigerator has a nearly linear relationship with heat input. The overall heat transfer coefficients have been derived by introducing the optimal heat loss function to analyze the heat loss characteristics. The accuracy of heat loss prediction has been checked with various experimental data and the normalized errors of the obtained result are found to be within 2.5%.

1. Introduction

It is a very interesting fact that a refrigerator inside a house runs for 24 h per day and 365 days in a year until it is out of order. There is no home appliance other than a refrigerator which always runs in the world. The annual worldwide production of refrigerators was about 80 million in 2009 and the production is increasing steadily and rapidly. From the aforementioned facts, it is clear that, the use of electric power energy by domestic refrigerators might be considered as a huge cost. So reducing electric power consumption of a refrigerator could introduce not only competitiveness for a refrigerator maker but also beneficial in global energy saving. There are several ways to reduce the electric power energy of a refrigerator, some of them are—substituting energy saving compressor, optimal control of refrigerator operation, use of proper insulating material, etc. The electric energy consumption of a refrigerator is mainly related to the heat transfer rate through the insulation walls. In order to predict the characteristics of heat transfer for a refrigerator, many researchers [1–4] have studied the heat transfer phenomena in a refrigerator both experimentally and numerically. The amount of heat loss through the magnetic door seal has also been conducted experimentally [5] to see the effect of air penetration on the refrigerator's energy consumption. In reverse heat loss method, the insulation performance has also been investigated [6,7] by using a VIP (vacuum insulation panel).

This work has been carried out with a purpose to analyze the quantitative heat transfer characteristics of reverse heat loss method. The experiment of time mean temperature was conducted to obtain the steady state condition. Spatial temperature distribution was measured to get a representative time mean temperature in a refrigerator. Heat input and temperature differences between the inside and the outside of a refrigerator were measured to analyze the empirical relation between them. By introducing an optimization heat loss function, the overall heat transfer coefficients, which characterize the heat losses quantitatively, were obtained with several sets of temperature and heat input data.

2. Experimental method

The experimental apparatuses for the present study consist of a constant temperature and constant humidity chamber, a sample refrigerator, a heating system (heaters), a voltage regulator and a data acquisition system. The schematic diagram for the experiment is shown in Fig. 1. The inner size of the chamber is 1.6 m × 1.6 m × 2.2 m. The operating temperature range is −50 °C–150 °C. In the present study, the temperature outside of the sample refrigerator is maintained at −16 °C. The inner volume of the sample refrigerator is 760l, and is of bottom freezer type with vacuum insulation panel. The configuration image is shown in Fig. 2.

The reverse heat loss method to evaluate the amount of heat loss through the insulation wall of a refrigerator has different characteristics of operating temperature, i.e. the temperature inside the freezer should be maintained at 32 °C and that of the refrigerator, 10 °C. The real operating temperatures are, −16 °C for the freezer and 6 °C for

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