Applied Thermal Engineering 184 (2021) 116405

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

A determination method of defrosting start time with frost accumulation amount tracking in air source heat pump systems

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ARTICLE INFO

Keywords:
Air source heat pump
Frost deposition
Defrosting control
Image processing

ABSTRACT

In this paper, a novel determination method of defrosting start time based on frost accumulation amount tracking (FAAT) is proposed for air source heat pump systems. This method keeps tracking of the amount of newly deposited frost every time step using typical sensors adopted in the commercial heat pump systems. This is to predict the current volumetric blockage ratio in real-time and determine the defrosting start time. To develop the method, firstly, the reliability of the prediction results is validated with experimental data. Then, the feasibility of the suggested determination method is evaluated under various air ambient and system operating conditions. The result shows that the determination method has a root mean square error of 6.2% on a time basis and 5.1% on a capacity basis. Lastly, the influence of non-uniform frost distribution on the evaporator is investigated. It is shown that the determination method attains the robustness under varying frost non-uniformity.

1. Introduction

Air source heat pump (ASHP) has been widely adopted to provide thermal comfort to occupants in residential and commercial buildings with its advantageous characteristics such as high efficiency, eco-friendly operation, and convenient installation [1,2]. One of the main challenges in ASHP operation is frost accumulation at the evaporator in winter season. The frost layer appears onto the fin surface when the ASHP operates under the frosting condition that the temperature of the cold fin surface is below the dew point temperature of air and the freezing temperature of the water. This frost layer increases both flow and thermal resistance of the evaporator [3]. To maintain the performance of the heat pump system under the frosting conditions, it is required to remove the accumulated frost from the evaporator periodically.

Several defrosting methods have been reported such as electric heating [4], hot gas bypass [5], and reverse cycle defrosting [6]. Among the defrosting methods, the reverse cycle method has been widely regarded as a standard defrosting method for ASHP systems so far with its simplicity and high efficiency [7,8]. Wang et al. [9] classified failures of the proper defrosting control into two types. One is to execute the defrosting cycle unnecessarily when no frost or only a little frost is observed in the evaporator. The other is not to start the defrosting cycle even after the frost is fully accumulated in the evaporator. They reported that this 'mal-defrosting' reduced the average heating capacity up to 43.4% when applying the time–temperature control (TTC) method [10], which is a basic control method in commercial heat pump systems.

To overcome this mal-defrosting, other determination methods also have been developed so far. Those methods can be classified into two types. One is to utilize the sensor information that is indirectly related to the amount of accumulated frost or the evaporator blockage ratio. The other is to directly refer to the frost volume with their own measuring and calculating methods. The indirect parameters adopted in the former methods include the degree of superheat (DSH) [11], refrigerant flow instability [12], effective mass flow fraction of the air through the evaporator [13], and frost surface temperature [14]. Zhu et al. [15] also developed a frosting map to control the defrosting cycle with time, temperature, and humidity information and Datta et al. [16] suggested determination methods based on the artificial neural network using various system information. While those determination methods can determine the defrosting start time with typical sensors in the commercial heat pump systems, the indirect parameters are less reliable under varying unpredictable operating conditions and diverse system specifications. In fact, system parameters such as DSH, flow instability, and frost surface temperature are easy to be disturbed by the fluctuating operating conditions in actual operation. In short, those methods based on the indirect parameters are inevitably vulnerable to system

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https://doi.org/10.1016/j.applthermaleng.2020.116405
Received 5 September 2020; Received in revised form 18 November 2020; Accepted 27 November 2020
Available online 3 December 2020
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