MODEL-BASED COMMISSIONING FOR FILTERS IN ROOM AIR-CONDITIONERS

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Summary This paper proposes a model that can estimate filter resistance. Two sorts of value are used as inputs to estimate filter resistance. One is the power consumed by the fan in the indoor unit and the other is the thermal performance. For the room air-conditioners that the real time indoor unit fan power consumption is available, fan power consumptions are used as inputs to estimate filter resistance.For the room air-conditioners that are equipped with refrigerant pressure and temperature sensors, this model estimates filter resistance using refrigerant pressure and temperature, air temperature or enthalpy difference between supply and indoor air. The maximum and average difference between estimated and measured filter resistance are 12.72% and 5.89% when using the fan power consumption as inputs. When using the air-conditioner thermal performance data, the maximum and average estimation errors are13.12% and 5.96%. Based on this model, the method for commissioning filters in air-conditioner is discussed.

Keywords: Automated commissioning; Filter resistance; Modeling; Room air-conditioner

1. INTRODUCTION

Most researches about filters in a Heating, Ventilating and Air-Conditioning (HVAC) system study the capability of a filter to retain particles, dust, bacteria and molds [1], survival and growth of microorganisms on a filter [2], releasing Volatile Organic Compounds (VOC) from a filter [3] [4]. Papers can seldom be found about the influence of filter fouling on energy consumption. However, a measurement done by this research shows that a Gas-engine Heat Pump (GHP) indoor unit fan efficiency decreased 35.8% when the filter resistance increased to twice of initial resistance because of dust accumulation, as shown in Figure 1. Furthermore, this research studied the heat produced by the GHP during winter. The heat production decreased 33.1% when the filter resistance doubled, as shown in Figure 1. So filter fouling can not only decrease fan efficiency, but also decrease the heating/cooling capacity of room air-conditioners. It is important to timely detect an over-fouled filter and clean or replace it. Generally room air-conditioners are not equipped with pressure sensor to measure air flow resistance through a filter, which represents the filter-fouling situation. So it is necessary to develop a method to estimate air flow resistance through a filter without the requirement of adding filter pressure sensor for the purpose of saving the cost of pressure sensors, which is relatively expensive.

For the purpose of detecting filters' fouling situations without pressure sensor, this research focuses on developing a model that is able to estimate the air flow resistance through a filter only using air-conditioner's thermal or energy performance data. For the increasingly spreading multi-evaporator air-conditioners, which are equipped with refrigerant pressure and temperature sensor and room air temperature sensor for the purpose of controlling and balancing the heating/cooling capacity of each indoor unit, the air-conditioners' thermal performance data can be available. So it is feasible to develop a model to estimate filter resistance using currently obtainable data.

Such a model is useful for commissioning filters in room air-conditioners. As defined by ASHRAE, building commissioning is the process of ensuring that building systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent [5]. Commissioning is considered to be a viable method to help ensure energy-efficient operation of buildings and their efficiency conservation measures [6].

Based on the filter model, a commissioning method for filters in room air-conditioners is proposed for the sake of ensuring the energy-efficient operation of room air conditioners.

2. MODEL

The model proposed to estimate filter resistance is shown in the following equations.

$$\Delta P_{ft} = \Delta P_f + \frac{r v_i^2}{2} - \Delta P_{OC} - \frac{r v_o^2}{2} \tag{1}$$

$$\Delta P_f = r_a N^2 D^2 C_h \tag{2}$$

$$C_h = a_0 + a_1 C_f + a_2 C_f^2 + a_3 C_f^3 + a_4 C_f^4 \tag{3}$$

$$C_f = \frac{V_a}{N D^3} \tag{4}$$

$$\Delta P_{OC} = x \frac{r_a v_{fo}^2}{2} \tag{5}$$

$$v_i = \frac{V_a}{A_i}, \quad v_o = \frac{V_a}{A_o}, \quad v_{fo} = \frac{V_a}{A_{fo}} \tag{6}$$