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A review of frosting in air-to-air energy exchangers

Mohammad Rafati Nasr*, Melanie Fauchoux, Robert W. Besant, Carey J. Simonson

Department of Mechanical Engineering, University of Saskatchewan, 57 Campus Drive, Saskatoon, SK, Canada S7N 5A9

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ABSTRACT

Air-to-air heat/energy exchangers are often used with heating or cooling systems in buildings, to transfer heat and moisture from an airstream at a high temperature or humidity to an airstream at a low temperature or humidity. Frosting inside heat/energy exchangers is common in cold regions such as Canada and northern Europe, and results in a significant decrease in the performance of the exchangers. The desire to improve the performance and control strategies of heat/energy exchangers under cold air conditions has led to significant research and development equipment over the past 30 years, however, from an energy savings point of view, this problem has not been researched in as much detail. In this paper, a detailed review of the research on frosting and defrosting techniques, specifically in air-to-air heat/energy exchangers is presented.

Contents

* Corresponding author. Tel.: +1 306 966 5479; fax: +1 306 966 5427.
E-mail address: mh.rafati@usask.ca (M. Rafati Nasr).

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1. Introduction

Global demands for environmentally clean energy and a shortage of energy resources have led to the development of more energy efficient technologies. In cold countries, 30–50% of the total energy consumed is used for residential and commercial buildings, and 60% of that is dedicated to space heating and cooling [1,2]. Many studies have focused on ways to reduce the amount of energy used by Heating, Ventilation and Air-conditioning (HVAC) systems [2–5,6,7]. Heat/Energy Recovery Ventilators (HRV/ERV) are types of HVAC systems that are designed to reduce energy consumption. An ideal heat/energy exchanger allows sensible and latent (for energy exchangers) heat transfer between supply and exhaust air under all operating conditions without significant cross-contamination. Typical HRV/ERV units contain a heat/energy exchanger, fans, supply and exhaust ducts, air filters, a drainage system and controllers. To design an efficient heat/energy exchanger some factors should be considered such as, pressure drop, fouling, corrosion, maintenance, controls, condensation and frost formation [8].

Frost formation in exchangers is common in cold regions where the outdoor temperature is below $-10\ ^{\circ}\mathrm{C}$ for the majority of the cold season. Conventional problems created by the formation of frost in energy exchangers are:

- partial or full blockage of air flow passages [9],
- increase in pressure drop through the exchanger or decrease in air flow rate [10–12],
- increase in electric power for the fans [13,14],
- decrease in the heat transfer rate between the two air streams [12] and
- draught in the space due to low supply air temperatures [13].

Additionally, frosting in heat exchangers has been reported as a reason for operational problems in the air conditioning systems of aircraft [10], boats and ships, and electro power systems [15]. Each of the aforementioned problems can result in a reduction in the effectiveness of the equipment over a short time period or physical damage to the equipment over a longer time.

Energy recovery is most beneficial when the outside air is very cold, because high temperature and humidity differences between the indoor and outdoor air creates the potential for high energy transfer rate and energy savings. However, a considerable reduction in the effectiveness of exchangers under frosting conditions reduces energy recovery, exactly when the most energy can potentially be recovered. In this paper, an overview in the open literature in the category of frosting in heat/energy exchangers is presented. Also, a brief review of the process of frost formation and frost properties on simple surfaces is provided. This paper reviews the open literature in the field of frosting in air-to-air heat/energy exchangers, summarizes the findings of previous research, finds similarities and differences in the results, presents defrosting/frost protection techniques or methods to decrease the negative effect of frosting and finally highlights the gaps in the literature.

2. Air-to-air heat/energy exchangers

Energy can be recovered in the form of sensible (heat transfer) or latent (moisture transfer) or both. In air-to-air exchangers two air streams, one is exhaust air from the building and the other is outdoor air (supply air), enter the exchanger core. Depending on the design, energy is transferred directly or indirectly from one air stream to the other. Air-to-air exchangers can be categorized into different groups based on the geometry of the exchanger and the orientation of the airflow. These include fixed plate exchanger, rotary exchanger, run around coils, heat pipe heat exchangers, and twin tower energy recovery loops [8,16], however plate heat/energy exchangers and heat/energy wheels are more widely used, and thus will be the focus of this paper.

2.1. Types of air-to-air heat/energy exchangers

2.1.1. Fixed plate heat/energy exchangers

In this type of exchanger, the supply and exhaust air pass through adjacent channels with parallel surfaces, in counter-flow or cross-flow configurations. If the surfaces are made of an impermeable material (e.g. aluminum or plastic), only heat will transfer between the two streams, while if the surface is a permeable material (e.g. treated paper [17], or a semi-permeable membrane [18,19]) both heat and moisture will transfer between the two streams Fig. 1.

2.1.2. Rotary air-to-air heat/energy exchangers (heat/energy wheels)

A rotary energy exchanger is made of a rotating cylinder, filled with an air-permeable structure with a high surface area in contact with the air. Supply and exhaust air pass through the wheel, in a counter-flow configuration. Heat/moisture are transferred from one air stream to the surface, then the wheel rotates 180° and the heat/moisture from the surface are released in to the other air stream [20] Fig. 2.