CONTRIBUTIONS TO THE DEVELOPMENT OF A SINGLE ROOM VENTILATION UNIT WITH HEAT RECOVERY

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By

Samuel GENDEBIJN

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To my family,
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ABSTRACT

The present thesis contributes to the knowledge, characterization and development of single room ventilation with heat recovery (SRVHR) systems dedicated to the residential sector. Investigation focuses on both the thermal and hydraulic aspects of such units. Thus, a large part of the thesis focuses particularly on air-to-air heat exchangers dedicated to SRVHR systems.

Impacts of the operating conditions (dry, partially wet and frosting conditions) on the performance are investigated. The thesis relies on the results of experimental and modeling studies carried out on several polystyrene air-to-air heat exchangers. An experimental apparatus was built in order to characterize the thermal and hydraulic performance of air-to-air heat exchanger under various operating conditions. The first developed model includes prediction of thermal and hydraulic performances in dry conditions but also in totally and partially wet conditions. The developed model is based on a moving boundary model (“two zones” heat exchanger model) initially dedicated to cooling coil. The validation of the developed model is first realized on a cooling coil experimental data set and then on experimental results collected on an air-to-air heat exchanger. In order to characterize the behavior under frosting conditions, the moving boundary model is later improved by taking into account the frost growth (three zones heat exchanger model). This dynamic model allows to determine the heat transfer rate as well as the pressure drop evolution due to the presence of frost. Once again, validation of this developed dynamic model is carried out by means of experimental results collected on an air-to-air heat exchanger. Strategies under frosting conditions are presented and compared by using a newly defined factor of energy performance.

In the frame of the design of heat exchanger dedicated to SRVHR unit, a methodology in order to choose the best geometry parameters for the heat recovery exchanger is proposed. This methodology is based on the optimization of the overall coefficient of performance of the unit. This corresponds to the best trade-off between hydraulic and thermal performance and involves numerical and experimental investigations. An innovative method in the field of air-to-air heat exchanger was developed. It consists in determining the evolution of pressure drop as a function of flow rate on a sample composed of only two “corrugated” plates. Those plates have been quickly fabricated thanks to a rapid prototyping process. Finally, the so-called optimized heat exchanger was manufactured and tested by means of the developed test rig. A deep study of the core of the heat exchanger was realized. This investigation permits to highlight some manufacturer defects, which were verified by comparison with the predictions of a new heat exchanger simulation model.

A whole newly developed SRVHR unit (composed of fans, filters, heat exchanger) is also experimentally characterized. The main characteristic of the investigated device is its possible integration into windows ledge, which makes it particularly suitable for housing retrofitting. In the performance assessment of this unit, both thermal and hydraulic performances of the unit have been investigated. First, each single component of the unit (fans, filters, heat exchanger) has been tested separately. It has been decided to use a technique, called pressure compensated box method, in order to determine the flow rate delivered by the device. Initially, this method is dedicated to measure flow rate delivered by fan coil units. Fan performance curves have also been experimentally determined for various rotational speeds. Tests in climatic chamber have been carried out to determine the performance of the overall device. Once the whole performance of the device has been characterized, a performance map was established. The perfect knowledge of the device performance (on the contrary to centralized system which depends on the ducting characteristics) allows us to compare the system to several types of ventilation in terms of primary energy, CO₂ emissions and energy costs by means of the Heating Degree Day (HDD) method, given a specific climate.
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