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New calculation method to solve moisture balance in the room with regenerator heat recovery and infiltration

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Abstract

This paper investigates moisture related performance of a regenerator heat exchanger located in a decentralized ventilation unit for residential building application. The decentralized ventilation solutions have recently become a more and more popular alternative to centralized ventilation systems. Due to the small space available and in order to avoid maintenance of these types of units, they are equipped with regenerator heat exchanger in some cases. In the recent past and also presently, Building Regulations (BR) and European directives have increased demands for heat recovery efficiency in air handling units (AHUs). In the case of regenerator heat exchanger, the higher the heat recovery efficiency obtained the higher risk that condensation might occur. This condensation might form small droplets on the surface of the regenerator that might not be possible to drain in the short switching time of the regenerator and consequently might be evaporated in the next cycle back to the building and cause elevated humidity conditions in the indoor spaces. Due to the fact that the traditionally used dilution equation must not be used to solve moisture balance in the room with regenerator heat exchanger and infiltration, this paper presents a new calculation methodology that takes into account infiltration, condensation in the regenerator, and back evaporation to the room. The paper compares humidity levels in the room ventilated with regenerator heat exchanger and ordinary counter-flow exchanger. Theoretical calculations indicate that the ability of a ventilation system with regenerator to remove moisture from the room is very dependent on moisture loads in the room, air change rate, and infiltration rate.

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Keywords: regenerator heat exchanger; decentralized ventilation; moisture balance, condensation

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Nomenclature

$m_{sources}$ moisture load from people [kg/s]
x_{room} absolute humidity in the room [kg/kg]
x_{amb} outdoor air absolute humidity [kg/kg]
x_{cond} vapour condensation in the regenerator [kg/kg]
x_{sat} absolute humidity of saturated air [kg/kg]
$x_{aft\ reg}$ absolute humidity of inlet air after passing regenerator [kg/kg]
n_{vent} air change rate due to ventilation [h^{-1}]
n_{inf} air change rate due to infiltration[h^{-1}]
ρ air density [kg/m^3]
V_{room} room volume [m^3]
t time [h]
M_{in} total water vapour in the inlet air (ventilation and infiltration) [kg/h]
M_{out} total water vapour in the outlet air (ventilation and exfiltration) [kg/h]
m air mass flow [kg/s]
i time step

1. Introduction

In the recent past and in the upcoming years, Ecodesign and respective EU countries have increased and will increase the demand for minimum heat recovery in ventilation air handling units (AHU). For example, Euro Parliament directive [2] determines a minimum demand for environmentally friendly design of AHU where one of demands is related to minimum efficiency of heat recovery. Directive set heat recovery of two-way AHUs to be minimum at 73% from 1 January 2018 and refers in the appendix to benchmark value at 85%, which is expected required heat recovery in, for example, in Denmark and Germany in the near future.

Heat recovery can be obtained in several different methods, e.g. in counter flow heat exchangers, cross heat exchangers, rotation heat exchangers and regenerators. They all represent very high heat recovery efficiency, approximately 70 – 90 % which makes them very popular in many AHUs. However, in the decentralized ventilation systems (DVS), some of them have more interesting technology than others. Firstly, in the decentralized systems that are often integrated in the building envelope, the size of the unit has to be small and compact due to very limited space. Secondly, the unit should require minimum maintenance due to a large number of units and consequently a potential high cost of operation. Thirdly, it should be possible to drain the unit from condensation and if condensation occurs then it should not be allowed to freeze. The DVS with regenerator heat exchanger is a very interesting candidate and fulfills most of the criteria: It is compact, does not require maintenance, has no moveable parts, and it will not freeze in case of condensation. The only unsolved issue is related to the risk of evaporation of condensation back to the room and, therefore, this should be investigated.

The well-known dynamic dilution equation Eq. [1] can be applied in its unchanged form for counter-flow heat exchanger and infiltration, and this is due to the fact that absolute humidity of inlet air and ventilation air is the same. The dilution equation must not be applied to calculate the regenerator heat exchanger and infiltration because these two air flows might not have the same absolute humidity due to condensation in the regenerator. If one wants to apply the dilution equation to calculate humidity levels in the room ventilated by the air handling unit AHU with regenerator then must not take into account infiltration. However, this is very serious limitation and results could be, especially in winter, significantly affected by the simplification.

$$x_{room} = \frac{\sum m_{sources}}{M}(1 - e^{-n*1}) + (x_{room} - x_{amb}) * e^{-n*1} + x_{amb} \quad (1)$$