Applied Thermal Engineering 62 (2014) 823–829

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

Improving heat recovery using retrofitted heat pump in air handling unit with energy wheel

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HIGHLIGHTS

- Analysis on efficiency in an energy wheel heat recovery system, with and without retrofitted heat pump.
- Validated computer model of an energy wheel ventilation heat recovery system in TrnSys.
- Significant improvement of heat recovery rate in energy wheel heat recovery systems.
- Possibility to reduce environmental impact by reducing energy use in buildings.

ARTICLE INFO

Article history:
Received 14 September 2012
Accepted 24 September 2013
Available online 17 October 2013

Keywords:
Ventilation heat recovery
Efficiency
Heat pump retrofit

ABSTRACT

The world is facing a challenge to reduce energy use to meet the environmental goals set for the future. One factor that has a great impact on the energy performance of buildings is the ventilation losses. To handle these losses, heat recovery systems with rotating heat exchanger are often implemented. These systems have been shown to recover about 60–70% of the energy in the exhaust air on an annual basis.

After a heat recovery system is installed it is hard to improve the efficiency of the installed recovery system with an acceptable economic payback period. In the present paper one way to improve the energy performance of a building with this type of heat recovery system by the use of a heat pump is investigated by simulations in TrnSys.

The heat pump system is arranged so that the evaporator is connected to a heat exchanger mounted in the exhaust airstream after the energy wheel, and the condenser of the heat pump is mounted so that the temperature of return water from the heating coil is increased.

The simulations show that there is a possibility to increase the heat recovery rate of the air handling unit in a significant way by retrofitting a heat pump to the system.

1. Introduction

The energy performances of any building located in a region were the heating demand is significant during the year, depends on several factors. The main factors are thermal losses through the building envelope, ventilation losses and losses due to air infiltration/exfiltration. In new buildings the thermal losses through the building envelope and through air infiltration are greatly reduced compared to the buildings that was built more than 20 years ago, making ventilation the single biggest source of thermal heat loss [1]. For older buildings intended for commercial use the thermal loss through the ventilation is normally the most dominant factor, the reason for this is that buildings intended for commercial use often have high ventilation air change rate (ACH). The thermal loss from ventilation can account for more than 50% of the total thermal loss from the building [2]. This often leads to a poor energy performance of the building. To reduce the influence on the energy performance due to heating of ventilation air, a heat recovery system is often implemented. There are several different types of heat recovery systems; one of the most common types of heat recovery system is the energy wheel. Roulet et al. [2] studied how the global ventilation heat recovery systems performed through numerous field measurements, they showed that the global heat recovery rate varies a lot but the three best systems recovers about 60–70% of the energy in the exhaust air. This means that the losses from the ventilation system typically account for 30–40% of the ventilation heating demand.

In recent years the costs for energy have increased in Sweden, this introduces new economical incentive when it comes to the energy conservation measures. The higher energy price provides new possibilities. However there is little to be found on heat

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1359-4311/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.applthermaleng.2013.09.059

recovery systems that combine two traditional heat recovery systems to increase the annual recovered heat. The present paper will analyze the potential to combine a traditional energy wheel heat recovery system with an exhaust air heat pump.

The cost to implement measures to improve the energy performance of air handling units in existing buildings can be high relative to the savings; this means that the payback period is often longer than what many organizations will allow. In order to find new system solutions that will respond to the demand of the building owners, different ways to improve the efficiency of ventilation heat recovery systems have been investigated [3]. In the present paper the preliminary results for one of these ideas is presented. The proposed system solution is intended to increase the heat recovery rate by installing a heat exchanger in the exhaust duct after an existing energy wheel heat exchanger; the retrofitted heat exchanger is connected to a heat pumps cold side (evaporator). The hot side (condenser) of the heat pump is connected to the return water side of the ventilation heating system, see Fig. 2.

2. Ventilation heat recovery systems

There are several different types of heat recovery systems for air handling units; for example:

- Rotating heat exchanger system
- Cross flow heat exchanger system
- Run around coil heat recovery system
- Heat pipe heat exchanger system
- Exhaust air heat pump

All of the systems have advantages and disadvantages, rotating heat exchangers have the advantage of being efficient but with the disadvantage of leakage between the exhaust and supply air. The performance and operation of heat recovery systems have been investigated by a number of researchers. For example Roulet et al. [2] investigated the real heat recovery of 13 air handling units. Fehrm et al. [4] investigated different system setups of exhaust air heat pump recovery systems, making economical and technical comparisons. Juodis [5,6] investigated how the heat recovery of the ventilation system operates if the effects of internal gains are considered. Lazzarin et al. [7] investigated technical and economical analysis of recovery systems for ventilation. Riffat et al. [8] studied the efficiency of different types of heat pipe heat recovery systems used in naturally ventilated buildings. When it comes to analyzes related to run around coil heat recovery systems, Emerson [9], Forsyth et al. [10,11] and Zeng et al. [12] looked into the design and efficiency. Wallin et al. [13] investigated which factors that influence the efficiency of run around coil heat recovery system. Madani et al. [14,15] studied if the efficiency of run around coil can be increased by retrofitting a heat pump to the system.

The investigations mentioned above shed light on many of the interesting aspects of heat recovery in ventilation. However the new era with high energy prices and a hunt to reduce the carbon footprint in the building sector, gives new incentive to improve existing heat recovery systems. Very few publications in this field deals with the implications that surrounds this type of efficiency measure. Of the mentioned publications only Madani et al. [14,15] have looked into the possibility to improve existing recovery systems with the help of heat pumps.

2.1. Energy wheel heat recovery systems

An energy wheel is a rotating heat exchanger that transports energy from the warm exhaust air to the cold supply air. Fig. 1 shows an air handling unit with energy wheel heat recovery.

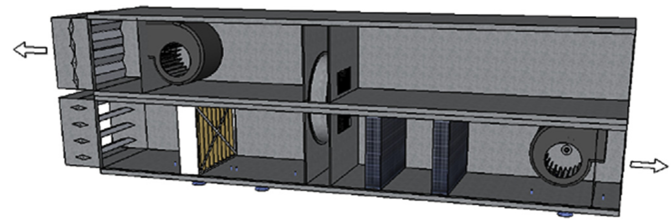

Fig. 1. Air handling unit with energy wheel heat recovery.

The advantage with this type of heat recovery system is the relative high recovery rate compared to other types of systems and the cost of the heat exchanger. Examples of the drawbacks include the need to have the supply and the exhaust airstream close to each other and the leakage between the two air streams. The heat recovery rate is also fairly easy and inexpensive to control; by adjusting the rotational speed of the heat exchanger.

2.2. Exhaust air heat recovery with heat pump

The exhaust air from a building is a near constant temperature heat source which makes it a good heat source to be used together with a heat pump. Since the heat pump can “lift” the temperature of the source, heat pumping technology can make a source more useful. Heat pump heat recovery can therefore be used in the building heating system or even produce domestic hot water using a low energy grade source. The efficiency of heat pumps depends on the temperature difference between the heat source and the heat sink. Since domestic hot water demands a high temperature compared to space heating or heating of supply air, a heat pump will be more efficient if it is connected to a well designed heating system.

Exhaust air heat recovery system have the advantage of being flexible in that sense that the supply and exhaust air streams does not have to be close to each other. Another fact that makes it a flexible recovery system is that the recovered heat don’t necessarily have to be used to heat the supply air, the heat pumps ability to “lift” the temperature enable the opportunity to recover heat to other users. Drawbacks with this type of system are that they are much more complicated and require more maintenance compared to other heat recovery systems.

2.3. Heat recovery with a combination of energy wheel and exhaust air heat pump

In the present paper an energy wheel air handling unit is retrofitted with an exhaust air heat pump heat recovery unit, see Fig. 2.

The objective of the present paper is to investigate and analyze the technical possibility to retrofit a heat pump in order to increase the heat recovery rate in an air handling unit that already has energy wheel. The heat pump extracts heat from the exhaust air stream and “lifts” the temperature to a level enabling the utilization of the recovered heat to reheat the return water stream from the ventilation heating coil. The motivation for this system set up is that it is technically viable in many existing ventilation systems.

3. Investigation approach

To investigate the possibilities of the proposed system solution, a simulation model has been built in the simulation tool TrnSys [16]. The model is based on the specification and measurements of an air handling unit installed in an office building in Stockholm,