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Heating fresh air by hot exhaust air of HVAC systems

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ABSTRACT

The present work concerns heating fresh air by the hot exhaust air of all–air heating ventilating and air conditioning HVAC systems. To proceed, a prototype is implemented and a parametric analysis is carried out to test the effect of temperatures and mass flow rates on the performance of the heat recovery system. Experiments are performed under typical conditions simulating the HVAC operation in cold climates. On the other hand, a generalized procedure of calculation is suggested based on the experimental results. It allows to simulate heat recovery designs and to perform parametric study without need to perform new experimental studies. It was shown that powers up to 110 W can be economized in cold climates and for low air flow rates of around 0.1 kg/s and 0.005 kg/s for respectively the hot exhaust air and the fresh cold air. Extrapolation shows that economized power can exceed 1 kW for a room of heating load 4 kW if all of the supply air is exhausted.

1. Introduction

The actual world tendency is towards the reduction of fuel consumption and carbon dioxide emission. This is mainly accomplished nowadays by using renewable energy and energy management systems [1–4]. Particularly, heat (energy recovery) is one of the main axes in the energy management development [5,6]. There are many applications of heat recovery such as internal combustion engines, chimneys, shower water and Heating Ventilating and Air Conditioning HVAC [5,6]. The principle of heat recovery is to use the waste heat released from a system in another heating or non-heating application. In fact, waste heat occurs in many systems in particular the industrial applications [7,8].

On the other hand, Heating, Ventilating and Air Conditioning HVAC systems has changed from being luxury to essential need for people and thus involve many energy components which need to be more and more managed. In this context, the present work suggest a new design that permits to couple between the two energy axes described above: energy recovery and HVAC. It particularly use the hot exhausted air from a conditioned space in cold climates to heat/preheat cold fresh outdoor air.

There are three main categories of HVAC systems: All-Water, Water-Air, and All-Air systems. An All-Air system has acquired this name in HVAC since temperature and humidity are controlled by supplying only air to the conditioned space. Fig. 1 shows a schematic of the operational mode of this category of HVAC system [9].

The assembly of components shown in Fig. 1 and known as “Air handling unit” has as objective to remove energy from or add energy to airstreams before their supply to conditioned spaces. It particularly permits to heat, cool, humidify, dehumidify, clean, and distribute air to the various conditioned spaces in a zone or zones. Also, outdoor air can be admitted and room air can be exhausted through the air handling system. In general and in order to adopt compromises between comfort and economy, a fraction of the return air from the conditioned spaces will be exhausted and instead an amount of outdoor air will be mixed. This permits to have

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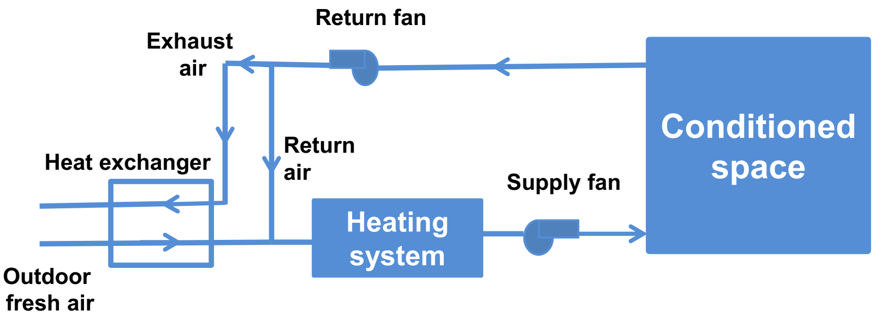

Fig. 1. Schematic of all-air HVAC system and the integrated heat recovery system.

continuously fresh air entering the spaces and to reduce the amount of energy required to condition the supply air required completely from the outdoor air.

The heat recovery concept suggested in this paper consists on pre-heating the cool fresh outdoor air by the relatively hot exhausted air in cold climates. This is accomplished by a cross-flow air-to-air compact heat exchanger having as airstreams the outdoor air and exhaust air flows, as seen in Fig. 1.

The remaining of the paper is organized as follows: Section 2 presents the experimental setup and configurations, Section 3 shows the results and analysis, and finally Section 4 draws the conclusions of the work.

2. Experimental setup and configurations

To achieve the concept of the heat recovery system and to study its performance, a prototype is implemented. It consists mainly of a room (the conditioned space) simulated by a wood box of 6.7 m^3 (Fig. 2), an air conditioning split unit of 5.6 kW (18,000 Btu/h) capacity simulating the hot air supply of the central system to the room, and the ducting system forming the heat recovery system. The heat recovery system corresponds to an insulated metallic duct including an air to air cross flow tubes-and-fins heat exchanger and a variable speed fan of flow simulating the exhaust air of the HVAC system. The flow in the exchanger simulates the outdoor fresh air flow.

To test the performance of the system, it is important to measure the temperature and velocity (flow rate) at different locations of the system. For this purpose, 5 digital type-K thermocouples with 0.5 °C error are used to read continuously the temperature in the wood room, at the inlet and outlet of the exchanger, and in the duct upstream and downstream of the exchanger. Two velocity anemometers are used to measure the air velocity at different locations in the outlet sections of the exchanger and different locations in a plane downstream of the exchanger and parallel to it. On the other hand, a compressor is used to simulate the outdoor cold weather (outdoor air flow).

In the experimental setup, there are two main flow rates that need to be measured: the air flow passing through the exchanger and the air flow passing in the exchanger geometry. After measuring the velocity at different locations on the outlet section of the exchanger and on a plane downstream of the exchanger, the flow rates passing in the exchanger $\dot{m}_{exchanger}$ and through it $\dot{m}_{duct}$ can be calculated as follows:

$$\dot{m}_{exchanger} = \rho_a A_{out,exchanger} V_{av,out} \tag{1}$$

$$\dot{m}_{duct} = \rho_a A_{duct} V_{av,duct} \tag{2}$$

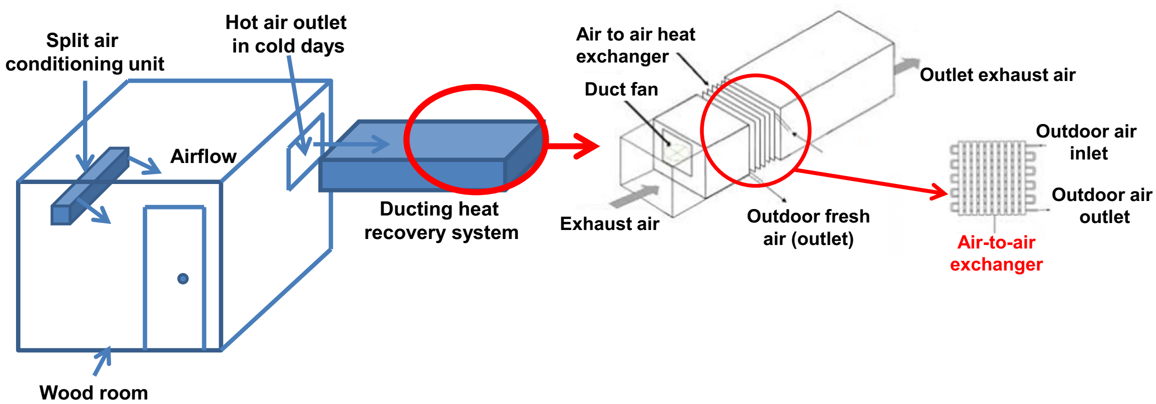

Fig. 2. Schematic of the implemented prototype.