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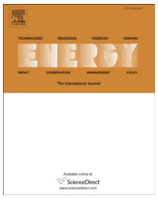

Toward cost-effective and energy-efficient heat recovery systems in buildings: Thermal performance monitoring

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ABSTRACT

Recent studies show that it is possible to reduce heating or cooling demand of a building as using heat recovery systems. Heat recovery technology is basically utilised to mitigate the heat loss, and hence energy consumption due to HVAC. Within the scope of this study, thermal comfort analyses of a test house integrated with a novel polycarbonate heat exchanger are conducted. At pre and post-retrofit case, temperature, relative humidity and CO_2 measurements are carried out for a test period of one week. The results indicate that the internal CO_2 concentration is not at desirable range due to lack of ventilation in the test house at the pre-retrofit case. However, following the integration of the novel ventilation system into the test house, CO_2 concentration is found to be varying notably from 350 to 400 ppm which corresponds to the actual comfort conditions for indoor environments. It is also concluded from the results that the average relative humidity inside the test house at the post-retrofit case is found to be 57%, which is in the desired range whereas it is considerably high before retrofitting.

1. Introduction

Total energy consumption of the world, and hence energy demand increases due to rapid growth of the world. Current predictions and data gathered by International Energy Agency (IEA) show that the growing trend will continue [1–5]. Latest research indicates that the building sector is responsible for 20–40% of the total energy consumption [6,7]. Most of the energy consumption occurs due to heating, cooling and ventilation demand of the occupants. In addition to this figure, day by day, the energy demand in HVAC sector rises as a result of technological development and desire of better thermal comfort conditions. In this respect, researchers attempt to find alternative solutions to minimise energy consumption and to maximise energy gained from renewables or any other sources. It is well-documented in literature that building-integrated photovoltaic thermal collectors and systems have a great potential to mitigate building-oriented energy consumptions and carbon emissions [8–15]. A recent study reveals that energy demand of new office buildings for heating and cooling applications decreases with use of renewables [16]. On the other hand, it is achieved to reduce heating or cooling demand of a building as using heat recovery systems. Heat recovery technology is basically utilised to mitigate the heat loss, and hence energy consumption due to HVAC. A basic heat recovery system is simply defined as heat exchange between two streams at different temperatures. It provides an effective pre-heating or pre-cooling of inlet fresh air depending on the season. The system slightly decreases the space heating cost in winter as supplying pre-heated fresh air. Main advantages of such a system are its high pre-heating and pre-cooling potential, its simplicity and cost-effectiveness. Additionally, it requires almost no maintenance and low operational cost. Moreover, the system presented here contributes in CO_2 emissions. Despite having remarkable efficiency, effectiveness and COP values, these performance figures depend on the sort of stream, material type, target area of the application etc. A recent study indicates that it is possible to get around 90% of thermal efficiency via a proper heat recovery system [17]. In this study, pre and after-retrofitting details of a novel heat recovery system integrated to a residential house in United Kingdom is presented in detail. Standardized thermal comfort analyses [18] are conducted before and after the integration of novel ventilation system and the enhancements achieved are evaluated.

The main components of a typical heat recovery system are heat exchanger core, ducts and fans. Two fans are usually used in these

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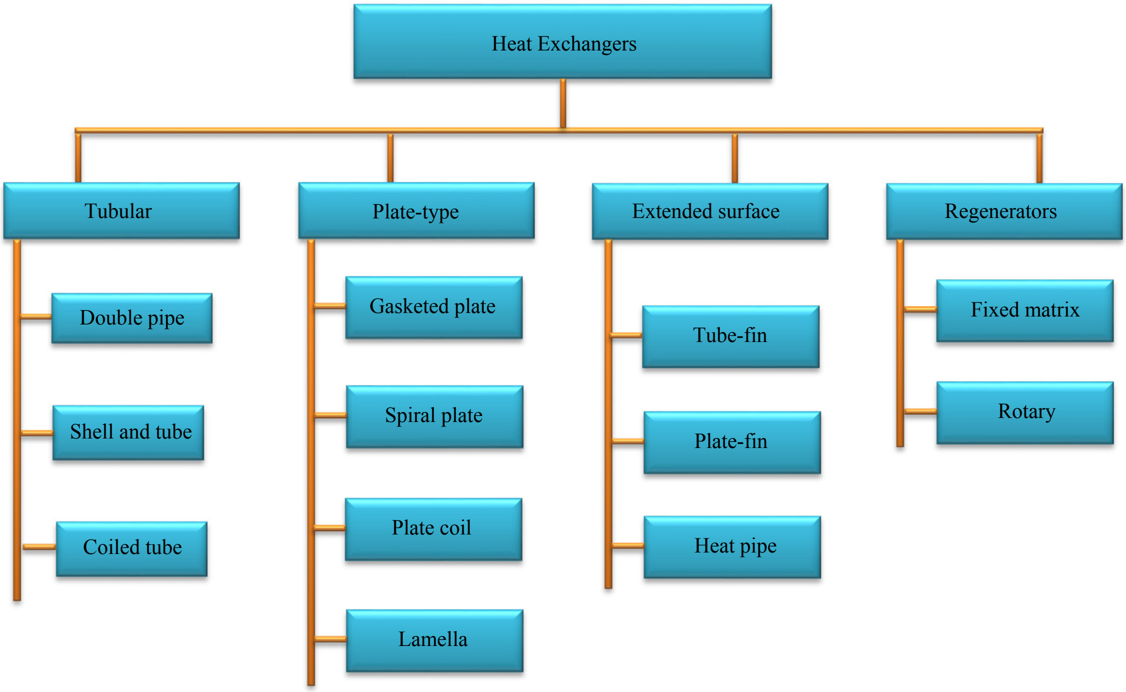

Fig. 1. Common classification of heat exchangers for heat recovery systems [6].

systems. The first fan is utilised to take the fresh air inside while the second fan is used to exhaust the stale air. The heat exchanger core is the meeting point of the incoming fresh air from outside and the outgoing stale air from inside [6]. From this point of view, fresh air is preheated or precooled by stale air depending on the season. There are various types of heat recovery systems utilised in different industries such as metallurgy, chemistry, etc. Heat exchangers are the most significant parts of heat recovery systems, and they have a wide use in power engineering, petroleum refineries, food industries etc. [19–21]. Heat exchangers have plenty of different types as illustrated in Fig. 1, and can be split into two categories as indirect and direct contact types [22,23]. Mardiana and Riffat [24] report in their recent research that heat pipe, fixed plate, run-around and rotary wheel heat exchangers are the most common types, and rotary wheel heat recovery systems still have the highest efficiency values as given in Table 1. It is clearly reported in literature that the heat recovery systems have a notable potential to reduce the energy demand of buildings, and thus the carbon emissions. Hybrid heat recovery technologies are in the centre of interest in recent years. Besides multifunctional benefits of heat recovery systems, there are also some drawbacks as shown in Table 2 [25] which need to be addressed. Current cost of the heat recovery systems in market is still high. However, future predictions reveal that the manufacturing costs of these systems will considerably drop depending on the developments in material science and technology. Among all types of heat recovery systems, plate type heat exchangers are very promising owing to their promising heat recovery effectiveness rates and low costs.

Table 1
A comparison of heat recovery types by their efficiency ranges and potential advantages [22].

System type	System efficiency	Advantages
Fixed-plate	50–80%	Compact, highly efficient due to high heat transfer coefficient, no cross contamination, can be coupled with counter-current flow which enabling to produce close end-temperature differences.
Heat pipe	45–55%	No moving parts, no external power requirements, high reliability, no cross contamination, compact, suitable for naturally ventilated building, fully reversible, easy cleaning.
Rotary-wheel	above 80%	High efficiency, capability of recovering sensible and latent heat.
Run-around	45–65%	Does not require the supply and exhaust air ducts to be located side by side, supply and exhaust duct can be physically separated, no cross contamination.

Table 2
Potential drawbacks of heat recovery technologies [25].

System type	Disadvantages
Shell and tube heat exchangers	Less thermally efficient than other types of heat transfer equipment, contains dead zones on the shell side which can lead to corrosion problems, subject to flow induced vibration which can lead to equipment failure.
Compact heat exchangers	Narrower range of allowable pressures and temperatures, gasketed units need specialized opening and closing procedures, material of construction selection is crucial since wall thickness very thin (usually less than 10 mm).
Air Cooled Heat Exchangers	Notably high initial cost, require relatively large footprint, higher process outlet temperature.

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