The heat pipe heat exchanger: a review of its status and its potential for coolness recovery in tropical buildings

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The heat pipe heat exchanger (HPHX) is a proven device for heat recovery in HVAC systems, and competes effectively with other available systems such as heat recovery wheels and run-around coils. This paper reviews major research work done on heat pipe heat exchangers (HPHXs) installed in HVAC systems since 1970. It reveals that research work on HPHXs for HVAC heat and coolness recovery has been done mostly in North America, Britain and Australia. Literature reviews further reveal that only limited research work on HPHXs for HVAC heat and coolness recovery has been conducted in subtropical and tropical climates and therefore, more HPHX research work for HVAC applications should be carried out in these regions in the interests of energy conservation and global green environment strategies.

Practical applications: The review on recover heat or coolness in HVAC systems since 1970 described in this paper enables necessarily good understanding on recover heat or coolness technologies for the impact of energy consumption and dehumidification in buildings before actual research or retrofitting is conducted to the space’s conditioning system. The results obtained from a considerable number of research work in subtropical and tropical climates could serve as a preliminary guide for mechanical and electrical (M&E) engineers and researchers who are intending to apply heat pipe heat exchangers as ‘coolness’ recovery and dehumidification devices in HVAC systems operating in tropical countries.

Glossary of terms

Cooling performance factor (CPF) \(CPF = \frac{T_{ev,i} - T_{ev,o}}{T_{ev,i} - T_{wc,i}}\)
where \(T_{ev,i}\) is the air temperature entering the evaporator, \(T_{ev,o}\) is the air temperature leaving the evaporator and \(T_{wc,i}\) is the wet-bulb temperature of the air entering the condenser.

Energy efficiency ratio \(\varepsilon = \frac{(mC)_ev}{(mC)_{min}} \left(\frac{T_{ev,i} - T_{ev,o}}{T_{ev,i} - T_{wc,i}}\right)\)
where \(T_{ev,i}\) is the air temperature entering the evaporator, \(T_{ev,o}\) is the air temperature leaving the evaporator and \(T_{wc,i}\) is the wet-bulb temperature of the air entering the condenser; and where \((mC)_{ev}\) is the evaporator air mass flow rate times the specific heat of the air;


Heat and coolness recovery
Heat and coolness recovery in HVAC systems; high space’s conditioning temperature for heat recovery and low space’s conditioning temperature for coolness recovery.

Latent energy-efficiency ratio
The latent cooling effect of the evaporator coil divided by the total electrical input to the system

Moisture efficiency
The mass of condensate removed divided by the compressor energy use (kg/kWh)

Sensible energy effectiveness
The sensible energy effectiveness, $\varepsilon_{sen}$, can be determined using the equation below provided in the ASHRAE Standard 84-1991 [50]:

$$\varepsilon_{sen} = \frac{\dot{m}_s}{\dot{m}_{air}} \frac{T_1 - T_2}{T_1 - T_3}$$

where $T_1$ is the fresh air dry bulb temperature (state1), $T_2$ is the coil entering air DBT (state 2) and $T_3$ is the coil leaving DBT (state 3); and where $\dot{m}_s$ is the dry air mass flow rate of the supply fresh air; $\dot{m}_{e}$ is the dry air mass flow rate of the exhaust coil leaving air; and $\dot{m}_{min}$ is the smaller of $\dot{m}_s$ and $\dot{m}_e$.

1 Introduction

The energy policy of the Malaysian government advocates the promotion of renewable energy and energy savings as the fifth fuel in its fuel diversification strategy. In turn, this policy leads to the consideration of the use of energy saving devices such as the heat pipe heat exchangers (HPHXs), heat recovery wheels, run-around coils and plate-to-plate heat exchangers to be installed in heating, ventilating and air conditioning (HVAC) systems for the purpose of energy savings.

Energy is very important in supporting economic growth of a country. Tropical countries such as Malaysia, Singapore, Indonesia, Brunei and Thailand have been putting a great deal of effort into developing the so-called fifth source of energy. For example, Malaysia, under the 8th Malaysian plan, is expected to save 500 000 MWh electric power and USD 250 million worth of cost through the fifth source of energy. Moreover, in Malaysia, which can be regarded as a model of developing countries, energy conservations policies and code of practice for Uniform Buildings By Law (UBBL) pose special constraints and challenges to M&E consulting engineers in ensuring that thermal comfort conditions in buildings remain acceptable. Therefore, the application of HPHXs for coolness recovery in tropical climates may be widely used in the next 5 years. However, literature reviews reveal that limited work has been done on this topic, so little is known of their likely performance in such conditions.

A heat pipe is a sealed tube that transfers energy by the internal evaporation and condensation of a working fluid so that no moving parts or external power sources are required as shown in Figure 1. It is a device having high thermal conductance, thus enabling highly effective heat transfer. Even with relatively small temperature differences between the evaporator and condenser side, large heat fluxes may be attained in a heat pipe because of the phase change of the working fluid inside it.
restrictions of single heat pipes for three types of wick and three working fluids were studied, firstly through computer simulation. Manufacture of heat pipes, including cleaning, installing the wick, evacuating the heat pipes, filling the fluid and installation of filled heat pipes, was also conducted. After achieving a suitable heat flux, the air-to-air 3-row HPHX consisting of eight individual heat pipes was designed, manufactured and examined under low temperature (15–55°C) operating conditions with methanol as the working fluid. Experimental results for absorbed heat by the HPHX evaporator at 84.5 W were in good agreement with the theoretical heat transfer rate at 100 W obtained from computer simulation.

4 Concluding summary

HPHXs are proven to be able to recover heat or coolness in HVAC systems as revealed in literature reviews from almost all research work since 1970. However, most research work on HPHXs for HVAC heat or coolness recovery and dehumidification enhancement has been performed in North America, Britain and Australia. Almost all of this research is concerned with the use of HPHXs to recover heat or coolness from the return air of general commercial buildings. Literature reviews reveal that only one study has been conducted on the use of HPHXs to recover heat from the exhaust air of operating theatres. Note that, in the new innovative concept of using a double HPHX HVAC system discussed in this paper for tropical buildings with operating theatres, the fresh air is first pre-cooled at the first HPHX evaporator zone through coolness recovered from the contaminated exhaust air. In addition, the literature review reveals that only limited research work on the use of HPHXs for HVAC heat or coolness recovery has been done in subtropical and tropical climates, and therefore, more HPHX research work for HVAC applications in coolness recovery and dehumidification, especially in the usage of coolness recovery in operating theatres where a fresh air system of 100% should be installed for hygienic reason, must be carried out in these areas as tropical countries such as Singapore, Malaysia, Thailand, Brunei and Indonesia are experiencing rapid economic growth.

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