Rotary exchange

Bill Ellul, M.AIRAH, makes a coefficient of performance comparison between heat pumps and rotary heat exchangers.

A heat pump (HP) can be viewed as simply two heat exchangers (HEs) powered by a compressor circulating a refrigerant between them. Each HE (fan coil) has fan-forced air flowing through it, and either heats or cools the airstream, depending on the temperature of the coil.

In the case of an air conditioner, the HEs are typically the outdoor and indoor fan coil units.

Heat is transferred (pumped) from outside to inside in winter and reversed in summer, which is termed "reverse cycle".

The performance of an HP is characterised by its coefficient of performance (COP). This is simply the dimensionless performance parameter or characteristic, which is the ratio of the total heat transferred in kW, from the airstream flowing through one HE to that of the other HE and the total electrical energy in kW, used to drive the HP.

A rotary heat exchanger is in effect two heat exchangers in one

This energy usage includes the power to run the compressor as well as the air fans for each HE. In other words, the COP is the heat transferred in kW per kW electrical energy input.

For the case of a domestic refrigerator the cooling HE, termed the evaporator, is placed inside the refrigerator while the heating HE, termed the condenser, is placed outside the refrigerator at its back side.

Typically, the COP of a HP can be as low as one and as high as four to five. The heat transferred is therefore usually several times the input electrical energy used to drive the HP, giving its ability to outperform other forms of heating.

An interesting comparison is that of the common resistive electrical heater, which is usually described as 100 per cent efficient but by definition it has a COP of only unity. The HP can be up to 500 per cent more efficient. This is also the reason why it can be more economical than natural gas heating.

ROTARY HEAT EXCHANGER (RHE)

An RHE transfers heat energy between two different temperature airflows. Typically, they are an outdoor, fresh airflow and an indoor, exhaust airflow. Thus, energy is conserved by recycling waste energy from an air-conditioned exhaust

It does this most efficiently by rotating a porous matrix rotor, which picks up heat from the flow on one side and transfers it to the other side. This is achieved in a continuous process of heating the matrix immediately followed by cooling the matrix as the rotor rotates slowly between the two flows inside the rotor frame.

The frame is especially sealed to prevent leakage or bypass of any contaminating air flows between the two sides. At typically 18rpm, a full revolution occurs every 3.33 seconds. It is this mechanical movement that enhances heat transfer, combined with the normal conduction and convection processes, to achieve its high performance.

An RHE is in effect two HEs in one. These HEs are physically divided by the diametral boundary, which separates the two fresh and exhaust airflows.

Like the HP, each of these flows require a fan to drive the flows through the matrix of the rotating rotor.

THE COP COMPARISON

In a comparison with the HP, the waste heat recovery RHE transfers heat from the exhaust air to the incoming fresh air in winter and reverses the heat flow in summer. The law of thermodynamics will ensure that this happens. No compressor and recirculating refrigerant or reverse cycle is required. It stands to reason that the COP of an RHE, which is the total heat transferred per unit electrical power usage, will be far higher than that of a HP.

The HP can deliver more heat than is thermodynamically available to the RHE, but at a significantly lower COP and thus at a higher electrical usage cost.

A TYPICAL RHE EXAMPLE

For a typical case of an indoor pool exhaust/fresh air heat recovery using a high 90 per cent efficiency RHE used to deliver 8,000L/s "free" heated fresh air requiring only 300W electrical to rotate the rotor and about 4kW to drive the combined airflow. Consider a 10°C winter day and an indoor pool air of 27°C.

Heat transferred and recycled will be 8 x 1.2 x 1.012 x (27-10) x 0.9 = 165kW

COP = 105/4.3 =38

This is a COP of 7.7 times that of a very efficient HP with COP of 5.

To transfer 165kW the efficient HP would require 165/5 = 33kW of electrical energy instead of the 4.3kW required by the RHE.

CONCLUSION

The rotary heat exchanger when used for air conditioning energy recovery will deliver "the low hanging fruit" in energy conservation terms and with less electrical energy usage and a much higher COP than a heat pump.

From a decarbonising perspective, we still need to replace the use of natural gas heating with electrically driven heat pumps, but for energy conservation, energy recycling, heat recovery and reducing waste, the highly efficient HE will always be in great demand.

ABOUT THE AUTHOR

Bill Ellul, M.AIRAH, is CEO of Rotary Heat Exchangers, the sole manufacturer of an Australian CSIRO design rotary heat exchanger. He published several papers in AIRAH publications on RHEs while working for the CSIRO Division of Mechanical Engineering in the 70s and 80s, and has presented at AIRAH conferences.