High Efficient Magnetic Heat Pump for Air Conditioning of Low-Energy Buildings

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ABSTRACT: *Our goal is to develop a magnetic heat pump for the heating, ventilation, and air conditioning (HVAC) systems of buildings. The magnetic heat pump uses the magnetocaloric effect, making it 30% more efficient than compressor based heat pumps. To do this we will develop the magnetocaloric composites material that will be used in a newly constructed magnetic heat pump with a special focus on regenerator design and the magnetic field source. This would lead to a more efficient energy use in low-energy buildings.*

Keywords: Heat Pump, Magnetic Pumbs, Ventilation, Energy efficiency

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1. Introduction

There are several different technologies available today to meet the refrigeration and cooling demand resulting from increased living comfort and substantial number of energy sources that we apply in our daily life. Most of them are based on vapour compression of gas refrigerants, characterised not only by the low exergy efficiency (e.g. between 20% for small devices to maximum 60% for large scale, optimized devices) [1], but also by the use of either environmentally harmful refrigerants (CFCs, HCFCs) or different, also harmful substitutes (FCs and HFCs). The use of alternatives like CO2, highly purified propane, Hydrofluoro-olefin, HFO-1234yf [2], Ammonia (R744), etc. solves the problem of ODP (ozone depletion potential) and GWP (global warming potential), but leads sometimes to lower energy efficiency [2] and problems related to very high pressures, flammability, explosion hazards, etc.

Today's arguably most promising alternative, [3], especially for small scale refrigerators or heat pumps with the cooling or heating power up to 5 kW, is the magnetic refrigeration. This technology applies the magnetocaloric effect (MCE), similar as gas refrigeration is based on the compressibility of a refrigerant (Figure 1). [4]

The magnetocaloric materials have GWP (Global Warming Potential) and ODP (Ozone Depletion Potential) potentials equal to zero. Analogue to vapour compression and expansion are the processes of the magnetization and the demagnetization. The last two processes are reversible. Therefore the energy efficiency of a magnetic refrigerator may be up to 30% higher than that of conventional technologies. Furthermore the operation of magnetocaloric devices is silent and without vibrations.

Today's MC heat pumps suffer from low manufacturability of magnetocaloric material, low power density, and the high cost of rare earth magnetic materials. The low manufacturability can be resolved by introducing new techniques of producing magnetocaloric materials, like melt spinning, spark plasma sintering and the production of composites, that will produce dimensions

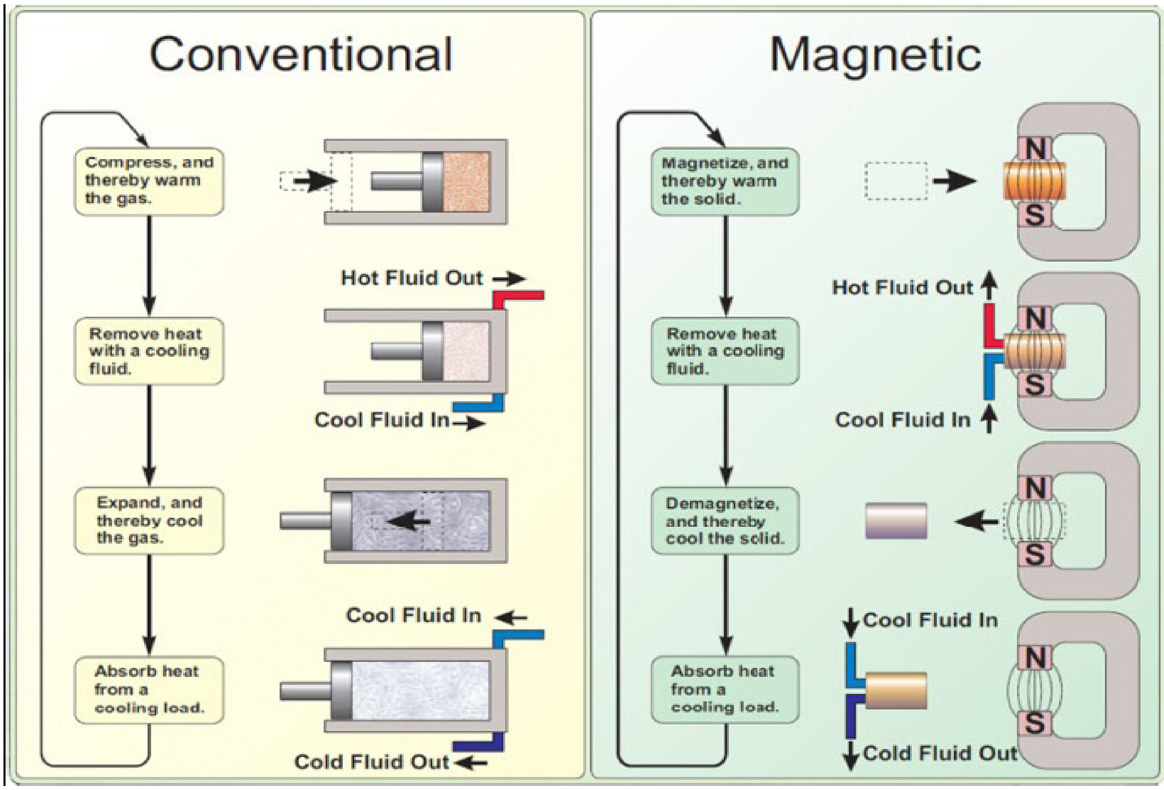

Figure 1. Comparison of a vapor compressor and a magnetic refrigerator

and properties, both magnetocaloric and mechanical, to fulfil the requirements needed to produce a stable and efficient magnetic heat pump with a temperature range between -20 °C and 40 °C. To achieve faster and more efficient heat transfer we would develop devices which are based on thermal diodes with embodied magnetocaloric materials. The thermal diode is a thermal switch or »heat semiconductor«, which can manipulate the direction of the heat flow. This would be totally new approach on the magnetocaloric energy convection, which has not been used up to date. To reduce the cost of the magnetic material used to magnetize the magnetocaloric material, one can substitute Nd-Fe-B magnets with AlNiCo magnets and use different design principles of the magnetic field source to achieve magnetic fields by rotating only certain parts to avoid the rotation of large masses. All the suggested new technologies will be tested in a prototype assembly in cooperation with the Faculty of Mechanical Engineering, which will generate 2 kW of cooling or 3 kW of heating power, in order to experimentally prove the market potential of such a device.

According to the Reportbuyer.com the global heat pumps market is estimated at 58.3 million units in 2013 and forecasted to grow at a 2014-20 with the rate of 10.6%. The heat pumps market worldwide is further projected to reach 116.9 million units by 2020. There is a strong interest in this technology by different Slovenian manufacturers of heat pumps (e.g. Termo-Tehnika d.o.o.), household refrigerators and freezers (e.g. Gorenje d.d.), as well as the manufacturers of air conditioning systems (e.g. Kolektor d.o.o.). These represent a broad variety of different products which could be enhanced with magnetocaloric energy conversion. Furthermore these products will have of high added value because they will be characterized by high efficiency, environmentally friendly operation and components, and silent operation. Additionally they will provide a better energy efficiency of buildings, which would help them being energy independent.

References

[1] Paul, J. (2011). Quo vadis, heat pump ?, Presentation at the International IIR Congres, ICR 2011, 2011

[2] Kuijpers, L. J. M. (2011). Refrigeration Within A Climate Regulatory Framework, Plenary lecture at the International IIR Congres, ICR 2011 , 2011.

[3] Brown, J. S., Domanski, P. A. (2011). Assessment of Alternative Cooling Technologies, ICR 2011, IIR Congress, presentation and article.

[4] Warburg, E. (1881). Magnetische Untersuchungen über einige Wirkungen der Koerzitivkraft. *Ann. Phys*. 13, 1881, pp. 141 –164.