AIR CONDITIONING OF LIGHT WEIGHT VEHICLES USING MAGNETIC REFRIGERATION SYSTEM

Dr. Kamal Kishore Pathak[1]
[1]Principal in-charge
Government Polytechnic Sheikhpura.

Abstract: Paris Agreement on Climate Change, at the 2015 United Nations Climate Change Conference, aimed to keep global temperature rise to well below 2 degrees Celsius above pre-industrial levels by 2100 and called for efforts to limit the temperature increase even further to 1.5 degrees Celsius to avoid serious climate catastrophes around the world. The participants also aimed to reduce the emission of greenhouse gases by promoting the use of zero carbon technologies. The air conditioning system is one of the most important sub-system in automobiles. Conventional vehicles use vapour compression refrigeration technology for air conditioning purpose, but this technology is energy inefficient and the refrigerants that are used in this system are undesirable for environmental reasons. Researchers are constantly attempting to develop a more efficient alternative refrigeration system to avoid the damage to the environment. Magnetic refrigeration is one such emerging technology that has the potential to lower the carbon emissions. Magnetic refrigeration can reduce the energy consumption for refrigeration by 30% without the use of refrigerant. The magnetic refrigeration working principle is based on a phenomenon known as the magneto-caloric effect (MCE). According to magneto-caloric effect (MCE), some exotic materials such as gadolinium and dysprosium, heat up when subjected to a magnetic field and cool down when the magnetic field is removed. The main objective of this paper is to develop an efficient air conditioning system for the light weight vehicles which can operate on magneto-caloric effect and thus helps in reducing carbon footprints.

IndexTerms **- Air conditioning system, Magnetic refrigeration, Magneto-caloric effect**

I. INTRODUCTION

The process of removal of heat from matter which may be a solid, a liquid, or a gas, which results in lowering of its temperature is called refrigeration. There are basically two main types of refrigeration systems i.e. vapour compression and vapour absorption refrigeration system. Generally, in automobiles, the vapour compression refrigeration system is used. In this system, heat is absorbed by the refrigerant at low temperatures and pressures and this heat is rejected to a condensing medium which is at higher temperatures and pressures by means of expansion and compression of the refrigerant [1].

But the vapour compression refrigeration system is energy inefficient. It uses a compressor to compress a large volume of refrigerant vapour. Due to this, energy consumption for the operation is high and thus COP is low. Also, the refrigerant used in the vapour compression refrigeration system is a serious concern for the environment. These refrigerant leakages have a harmful effect on the environment [2, 3]. Therefore, it is required to develop other alternative cooling technologies in vehicles.

Magnetic refrigeration is a new energy efficient and clean refrigeration technology that has great potential to replace conventional vapour compression refrigeration system. It is based on the principle of the magneto-caloric effect which can be applied to various magnetic materials and new alloys named magneto-caloric materials (MCM). Magneto-caloric effect (MCE) is the heating of the magnetic materials or magneto-caloric materials when these are subjected to magnetic field and cooling of these materials when magnetic field is removed [4, 5]. Presently, this technology is in pre-industrialization phase, but in few years it will definitely replace the conventional refrigeration methods. Magnetic refrigeration system has various advantages over conventional vapour compression system in terms of efficiency, cost, noise free operation, compactness, low working pressure and environmental friendliness.

Taking into account these considerations, this paper aims to seek a more energy efficient and eco-friendly replacement of conventional air conditioning system in light weight vehicles. In this study, the concept of magnetic refrigeration which is based on the principle of magneto-caloric effect is explained along with a proposed air conditioning model for light weight vehicles [6].

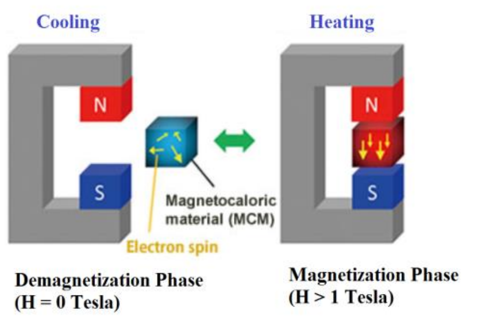

Fig.1: Magneto-caloric effect

II. MAGNETO-CALORIC EFFECT

The magnetic refrigeration is based on the fundamental principle of the magneto-caloric effect (MCE). According to magneto-caloric effect, some magnetic materials heat up when subjected to magnetic field and cool down when the magnetic field is removed. In 1881, A German Physicist E. Warburg first discovered the magneto-caloric effect in metal iron subjected to varying magnetic field. The MCE is a property of magnetic materials which results in a change of temperature of the material when it is subjected to a varying magnetic field. This phenomenon is maximum in the proximity of the ordering temperature of the magnetic material (known as the Curie or the Néel temperature) [5]. Every magnetic material subjected to sufficiently high magnetic fields, exhibits the magneto-caloric effect however the intensity of the effect is dependent on the properties of each material. Researchers continuously attempted to find new materials and alloys with a strong MCE at room temperature. Gadolinium (Gd) is one of the best magneto-caloric material discovered so far.

We have to apply the concepts of thermodynamics in order to understand the cause of the magneto-caloric effect, which establishes a relation between the magnetic variables (magnetization and magnetic field) and thermodynamic variables (entropy and temperature). All magnetic materials exhibit MCE; however the intensity of the effect is dependent on the properties of each material. The physical origin of the MCE is that when the magnetic sub-lattice of the magneto-caloric material is subjected to the applied magnetic field H, magnetic contribution to the entropy of the material changes. This phenomenon is equivalent to the thermodynamics of a gas. The isothermal compression of a gas (when pressure increases, the entropy decreases) is analogous to the isothermal magnetization of a magnetic material (when magnetic field H is applied, the magnetic entropy decreases), while the adiabatic expansion of a gas (when pressure is decreased at constant entropy, the temperature decreases) is analogous to adiabatic demagnetization (when magnetic field H is removed, the total entropy of the material remains constant but the magnetic entropy increases, therefore temperature decreases).

When a magnetic field is applied under adiabatic conditions, the decrease of the magnetic entropy is compensated by an increase of the entropy of the crystal lattice. This transfer of entropy is the origin of warming of the material. And when the magnetic field is removed,the opposite effect is observed which results in cooling of the material [6].

Figure 1 illustrates the working principle of magneto-caloric effect. A magnetic field (H > 1 Tesla) is generated with the assembly composed of two permanent magnets. A magneto-caloric material is exposed to the magnetic field of the permanent magnet and due to change in magnetic entropy, the material heats up. When the magnetic field is removed (H = 0 Tesla), the material gets demagnetized and cools down [7]. We can utilize this cooling effect developed by MCE in magneto-caloric materials to develop an efficient and clean refrigeration system for light weight vehicles.

III. MAGNETO-CALORIC REFRIGERATION SYSTEM

The main objective of this paper is the development of an efficient and clean air conditioning system for light weight vehicles based on magneto-caloric refrigeration. For a better understanding ofworking principle of the magneto-caloric effect, we have developed a new system based on this principle as shown in the figure 2. This system consists of two portions of magneto-caloric materials connected in series and mounted on a rigid frame. These portions are called Regenerators. These regenerators are composed of selected MCM based on their Curie temperature. Also two permanent magnets of opposite polarity are mounted on actuators which assist in the movement of the magnets over the two portions of MCM. The actuators are powered by the energy supplied from the vehicle engine. When magnets are placed over MCM portion 1, the material gets magnetized which results in the rise of its temperature. This heat generated in the MCM will be rejected in the atmosphere. On the other hand, when the magnets move to the MCM portion 2, the MCM portion 1 gets demagnetized and its temperature decreases. At the moment when MCM portion 1 cools down, a coolant (mixture of water and anti-freeze) is allowed to flow over the demagnetized MCM portion with the help of tubes. Coolant rejects its heat to the demagnetized MCM portion and thus the temperature of the coolant decreases to the desired level. This cooled coolant then flows to the air conditioning cabin of the vehicle with the help of a pump. The pumps are operated from the automobile engine power. In the air conditioning cabin, the coolant absorbs the heat and then flows back to the MCM portions. Again, when MCM potion 2 gets demagnetized, the coolant is allowed to flow over MCM portion 2 and thus, coolant rejects heat to the MCM. The motion of coolant to different portions of the MCM is controlled by a 2-way valve which is guided from the motion of the actuators. The coolant is allowed to flow only in that MCM portion which is demagnetized (i.e. cooled) at that moment.

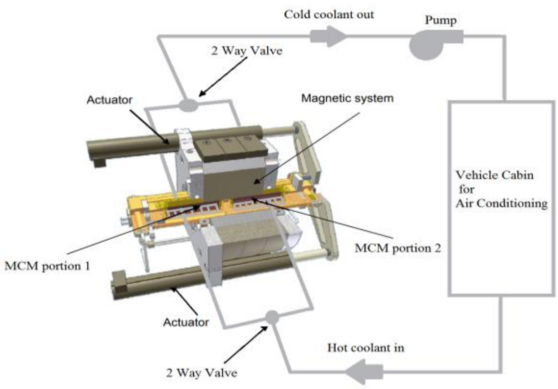

Fig. 2: Magneto-caloric air conditioning system

The cooling capacity of this air conditioning system depends on the properties and on the quantity of the MCM regenerators used. There are some points to be taken care of to ensure optimum efficiency for this air conditioning system, i.e.

- The MCM regenerators must be divided into thin sheets to increase the surface area for heat transfer.
- The magnets used must be of high intensity (H > 1 Tesla), with an air gap > 10 mm.
- The flow of coolant must be laminar to reduce the pressure loss.
- The convective heat transfer coefficient 'h' of the coolant must be high to ensure maximum heat transfer in limited time and surface area.
- The MCM must have high values of specific heat capacity.
- The actuator design should be simple in ensure smooth operation at high frequencies.

IV. CONCLUSION

There are various potential advantages of air conditioning based on magneto-caloric effect as compared with the conventional air conditioning technology in the light weight vehicles. The proposed air conditioning system for the vehicles discussed in this paper can be the future of air conditioning in automobiles because of the following reasons:

- Efficiency of this system is higher than the conventional air
- for the environment. conditioning system of the vehicles.
- Higher efficiency ensures no need of conventional refrigerants which are noxious
- Since no compressor is used in this system, the whole operation in noiseless and vibration free.
- Working pressure is lower (atmospheric pressure) than the conventional vapour compression system.
- Compact and simple design.
- Overall maintenance cost for this system is quite low.

However, there are some fields for further research in order to optimize the efficiency of this system, i.e.

- Permanent magnets have limited magnetic field strength. While, electro magnets and superconducting magnets are (too) expensive. Therefore, further research is required to obtain a cheaper magnet of high magnetic field strength.
- There is a need for protection of electronic components of the vehicle from the magnetic field of the magnets.
- The availability of magneto-caloric materials are scarce. Thus, there is a need for identification of new materials.
- There exist some thermal and hysteresis problems in materials exhibiting magneto-caloric effect that is required to be solved in order to achieve smooth operation.

REFERENCES

[1]Arora, Ramesh Chandra. *Refrigeration and air conditioning*. PHI Learning Pvt. Ltd., 2012.

[2] Kawanami, Tsuyoshi, and Didier Vuarnoz. "Overview of Deployment of Magnetic Refrigeration in Heat Pump Systems." *Newsletter-Iea Heat Pump Center* 33, no. ARTICLE (2015): 24-28.

[3]Refrigeration, Japan, and Air Conditioning Industry Association. "Estimates of World Demand for Air Conditioners (2000-2008)." *Online unter: www. jraia. or. jp/english/est/index. html (abgerufen am 19.2. 2007)* (2005).

[4] Muller, Christian, Carmen Vasile, Michel Risser, J. Heitzler, and Bernard Keith. "New air-conditioning and refrigeration magnetocaloric gas free system." In *Proc. Int. Symp. on "Next Gen. Air Cond. and Ref. Technol"., Feb*, pp. 17-19. 2010.

[5]Russek, Steven L., and Carl B. Zimm. "Potential for cost effective magnetocaloric air conditioning systems." *International Journal of Refrigeration* 29, no. 8 (2006): 1366-1373.

[6] Payá, J., J. M. Corberán, B. Torregrosa-Jaime, and C. Vasile-Müller. "Innovative air-conditioning systems for conventional and electric vehicles." In *EAEC European Automotive Congress, Spain*. 2011.

[7] Zimm, C., A. Boeder, J. Chell, A. Sternberg, A. Fujita, S. Fujieda, and K. Fukamichi. "Design and performance of a permanent-magnet rotary refrigerator." *International journal of refrigeration* 29, no. 8 (2006): 1302-1306.