Magnetic Refrigeration

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Abstract— Modern society largely depends on readily available refrigeration methods. Up till now, the conventional vapor compression refrigerators have been mainly used for refrigeration applications. Nonetheless, the conventional refrigerators – based on gas compression and expansion – are not very efficient because the refrigeration accounts for 25% of residential and 15% of commercial power consumption due to the use of high power consuming compressors. Moreover, Conventional Refrigerators utilize ozone depleting refrigerants like Freon which release CFCs, which have a detrimental effect on our environment. This motivated us to design and fabricate a model that produces a refrigeration effect utilizing a green technology, namely Magnetic refrigeration which is a novel concept that incorporates the principle of the magneto-caloric effect and can act as a substitute for the conventional refrigerating systems. The elimination of compressors considerably reduces the power consumption and makes refrigeration a noiseless process, while the elimination of Freon makes it an environmentally friendly refrigerating technique.

Key words: CFCs, Magnetic refrigeration, Magneto Caloric Wheel

I. INTRODUCTION

Magnetic refrigeration is based on the magnetic caloric effect, which is the heating or cooling of a magnetic solid in a varying DC magnetic field. The goal is to achieve a heating and cooling system with a high cofficience of performance. Magnetic refrigeration depends on two essential parts: A high magnetic field and a magnetic material with large magneto caloric effect. Magnetic refrigeration is a physical process that exploits the magnetic properties of certain solid material that produce refrigeration. When specific materials are magnetized or demagnetized (subjected to a varying DC magnetic field), they heat up or cool down. This is known as the magneto caloric effect . When the magneto caloric effect materials are in a magnetic field, the spinning electrons align with the field, thereby magnetizing and raising in temperature. When removed from the field, they demagnetize and the electrons return to a disordered magnetic spin, whereby the temperature drops.

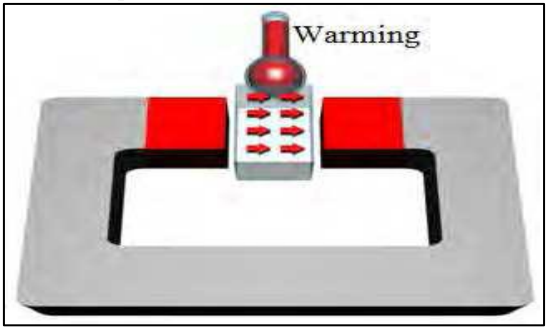

Fig. 1.1: Heating Up of the Magneto-Caloric Material by the Alignment of Magnetic Dipoles

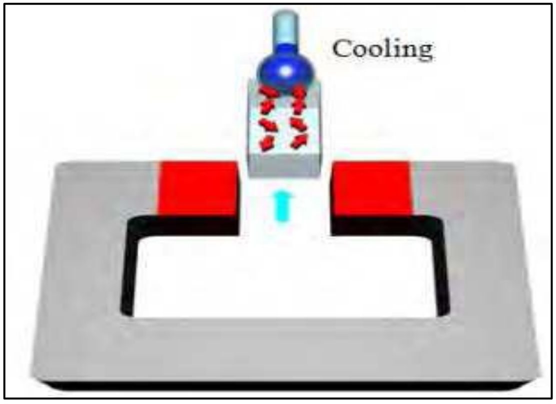

Fig. 1.2: Cooling Of the Magneto-Caloric Material by the Randomization of Magnetic Dipoles

II. SETUP

A. *Casing:*

1) *Cold Heat Exchanger Casing:*

It is a cubical casing fabricated out of MS of dimensions 500×150×150 mm. It is provided with two openings for inlet and outlet of the coolant (ref. Figure 2.2).

2) *Isolation Casing:*

This casing is also fabricated out of MS and is radial in its shape, inner radius being 120 mm and outer radius as 250mm (ref. Figure 2.2). The thickness of the casing is 150 mm and the length of the arc is approximately 550 mm. The casing is covered with metal on all sides, sparing a guide way for the arm of the magneto-caloric wheel.

3) *Hot Heat Exchanger Casing:*

An extension of the isolation casing forms the casing for the hot heat exchanger. It covers an arc of approximately 170 mm for a radius of 250 mm.

B. *Electromagnet:*

An iron rod of 30 mm diameter is fabricated into a circular shape of radius 100 mm. The length of the arc is approximately 300 mm. A series of copper wires are wound on the periphery of the iron rod. The rod runs concentric to the casing.

C. *Magneto Caloric Wheel:*

The wheel comprises of an arm, a clamp and the material. The arm is made up of a steel rod of diameter 30 mm and has a length of 180 mm. The clamp is made up of plastic or any suitable insulated material. The wheel is mounted on a motor.

D. *Motor:*

A motor is used to drive the magneto-caloric wheel.

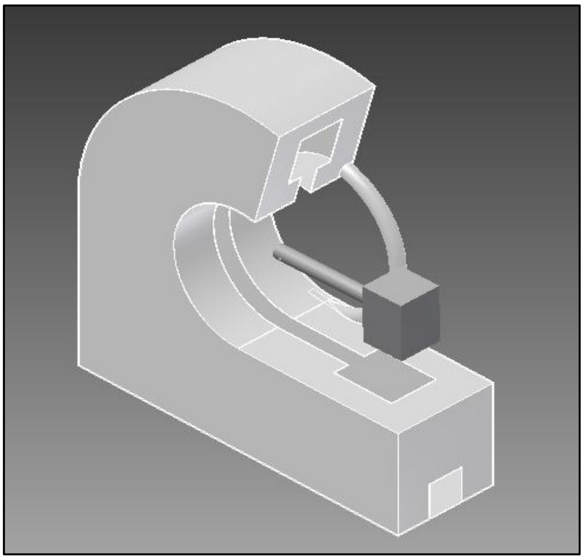

Fig. 2.1: Modified Design of the Magnetic Refrigeration Setup

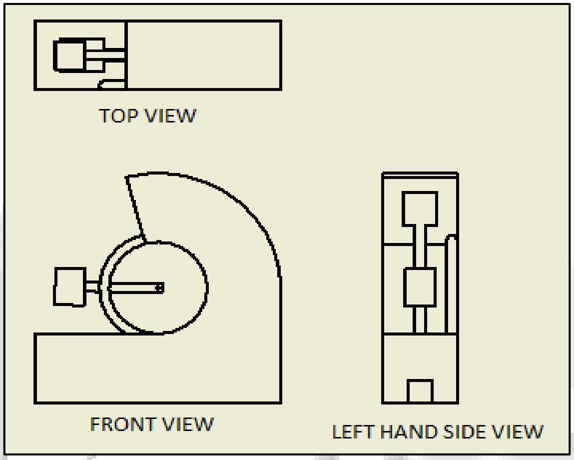

Fig. 2.2: 2-D Views of the Modified Design

III. WORKING OF THE DESIGNED MODEL:

The cold heat exchanger casing is filled with chilled water or coolant and is provided with inlet and outlet openings for continuous flow of water. The material at a state of high temperature enters this casing and transfers heat to the coolant. The magneto-caloric wheel now enters the cold heat exchanger where the coolant absorbs the heat from the refrigerant while it is still under the influence of magnetic field resulting in our second process of isomagnetic enthalpy transfer.

The material then enters the isolation casing. This casing comprises of thermocol or mica sheets which provide complete isolation from the environment. When the material enters this casing, it is shielded from the magnetic field and is subjected to conditions suitable for adiabatic processes. Magnetocaloric effect takes place in this region and the refrigerant reaches freezing temperatures.

In the next stage the material enters the hot heat exchanger. Refrigeration effect takes place in this particular section of casing. The casing is separated from the isolation casing by providing a partition, to ensure that complete heat exchange takes place. Air is isolated in this casing by means of themocol and mica sheets. The refrigerant enters this chamber and absorbs the heat, thus providing the refrigeration effect.

The material the enters the magnetic field of the electromagnet. An iron rod with copper coils wound along its periphery serves as an electromagnet. This electromagnet stretches from the end point of hot heat exchanger and terminates at the end of cold heat exchanger. It serves the purpose of providing magnetic field to the material.

The motor rotates the arm and the arm in turn rotates the refrigerant which is clamped to it, in anti-clockwise direction. It passes through various sections of the casing undergoing the four processes of magnetic refrigeration.

The motor provides power to the magnetocaloric wheel, which enables the wheel to rotate in the anti-clockwise direction. This wheel is concentric with the electromagnetic wheel, as a result of which it is subjected to a constant magnetic field, paving way to adiabatic magnetization

IV. CONCLUSION

The temperature difference obtained by experimenting on the setup will be limited.

The materials used for the experimental setup may not be of the highest purity. Substitutes for Gadolinium and its alloys or other ferromagnetic compounds may be used to make the setup cost effective.

The magnetic field used is limited from 0.1T to 0.2T (Actual starts from 0.6 T up to 10 T).

Experiment will be performed under environmental laboratory conditions (Perfect isolation is required in the ideal case).

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