A Green Solution To Cold Storage Using Magnetic Refrigeration System

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Abstract

In the last few decades the wastage of food items is due to insufficient cold storage facilities in India. This is largely due to the high electricity costs of vapor compression refrigeration cycles. This has prompted to use the alternate refrigeration cycles. This paper is devoted to using magneto-caloric effect of ferromagnetic materials for maintaining the temperature about 280K so as to keep the perishable items preserved for some period of time.The main objective of this type of refrigeration is use of solid refrigerant called magneto caloric material. This type of material can increase or decrease the temperature when they are magnetized or demagnetized. Magnetic refrigeration systems are like traditional cooling units, but they don't use as much electricity which make it highly efficient to be use for cold storage system. The effect of solid state refrigerants, water based heat transfer fluids increases the efficiency with minimum contribution to global warming & ozone depletion making it highly sustainable which is the need of the hour.

Keywords: Green refrigerating system, Magneto-caloric refrigeration, cold storage system, global warming,Erricson cycle

1. Introduction

The use of ice for prolonging the storage time period of foodstuff dates back many millenniums. Ice owes its effectiveness as a cooling agent to its constant temperature of 00 C. therefore on soften, ice ought to absorb 333 kJ kg_1. Up to the centre of the last century, all ice used for cooling was from natural sources. This ice was taken from lakes in winter then keep. In 1890, the U.S. still exported twenty-five million tons of ice p.a. usually, the natural snow was mixed with salt therefore on win low temperatures (from 1600). The assembly of afters is known to be a tired step with this technology in ancient Rome. However, the pollution of lakes, the aggressiveness of the new technology and no ability to follow the increase of the demand have caused the tip of this business.

Refrigeration is that the strategy of cooling or maintaining the temperature of a given volume of the house at a temperature not up to the surrounding temperature. There are two ways of production of the cold: the physical method of change of state with compression then relaxation and physical-chemical process (absorption system). In France, Ferdinand Carre´ developed the first cooling system with ammonia and water. The first machine of refrigeration with compression was projected by Jacobs Perkins in 1834 that used ether as a refrigerant. In 1913, the first domestic white merchandise was designed. In 1929, DuPont invents CFCs (chlorofluorocarbons), marketed to a lower place the name "Freon". Dichlorodifluoromethane (CCl2F2) is scentless, non-flammable and presents low toxicity. In 1931, the first industrial manufacturing was completed by Electrolux. The business was driven by the event of electricity production and so the expansion of the assembly of the electrical motors The refrigeration business achieved a major development with the arrival of refrigerants like CFC-R12, HCFC-R22 (1935) and CFC-R502 (1961), hydrofluorocarbon R134 (1993), etc. The HFCs haven't any gas depletion advantages over R22; however, they still have some heating potential impact (GWP). the specified characteristics for a refrigerant are environmental acceptability, chemical stability, materials compatibility, refrigeration-cycle performance, non-flammability and non-toxicity, boiling purpose, etc.

Refrigeration could be a vital key at intervals the days and it's in continuous to progress. In 2007, domestic refrigeration accounts for over twenty-seven million devices in France. In 2007, the energy consumption of deep-freeze refrigerators represents 21st of total electricity consumption in France, i.e. eighteen billion kWh consumed and identical to 2.25 billion tons of gas (ADEME, 2007). From 1973, the presence of CFCs at intervals the atmosphere is rumoured. Since then refrigeration occupies scientists and politics. Environmental protection is an additional challenge to beat. Refrigeration techniques are the most focus of two issues. Initial of all the destruction of the ozone layer (CFC, HCFC), second the intensification of greenhouse gases (CFC, HCFC and HFC). These two preoccupations have given rise to the urban centre and Kyoto protocols.

These international rules provide an honest likelihood for the emergence of the most recent refrigeration technologies and new product. Consequently, further economical refrigerants and instrumentality were developed in recent years. The factitious refrigerants have an awfully harmful impact on the atmosphere that has forced the refrigeration business to look to numerous ways of cooling. The refrigeration technology is covering the flat aspects therefore on live up to the demand of gift equally attributable to the long run generation. This refrigeration technology uses magnetic materials as a refrigerant that's eco-friendly in nature. Magnetic cooling technology employs the use of magneto-caloric materials whose temperature and entropy change attributable to the influence of a flux. This ability is akin to it of compression and growth of refrigerants in ancient refrigerators. Such a change within the temperature of the magnetic material attributable to a modification within the strength of the flux is known as the magnetocaloric impact.

2. Methodology

2.1 Magnetocaloric effect

Magneto-caloric effect (MCE) consists of entropy modification of magneto-caloric materials (MCMs) because of magnetic flux variation.

MCE may be a magneto thermodynamic phenomenon during which a reversible change in temperature of an acceptable material is caused by exposing the material to an ever-changing magnetic flux. If we tend to introduce a magneto-caloric material during a magnetic field then its temperature rises. On removing the magnetic flux the material loses its heat drastically and cools to a low-temperature counting on its properties.

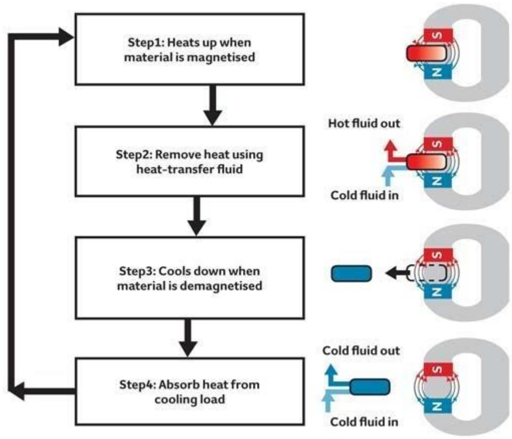

FIG 1. Block diagram representation of magneto-caloric effect

2.2 Magnetocaloric Material

Some materials like Gadolinium (Gd) have the property to vary its temperature ranges from 4K to 300K under continuous magnetization and demagnetization. These materials are called magneto-caloric materials. They have been known to be used in the large hadron collider at CERN, where the temperature reaches to 4K.And here we are using an alloy of gadolinium i.e.**Gd0.88Dy0.12** (Gadolinium Dysprosium) which has been found through research to work in a temperature range of 280K to 300K.So this material can be used as a possible cooling source for cold storage, where different food items can be stored where it can be preserved for certain duration of time.

2.3 Working of the cooling system

The magnet is connected to the shaft of the motor and rotated stepwise such that it stops momentarily about each magneto-caloricmaterial. The material inside the magnetic field is heated (magnetization)while the material coming out of the magnetic field is cooled(demagnetization).Water as refrigerant passes through the cold material and is cooled to280K. It passes through the regenerators and absorbs heat from the coldroom. It returns into the system and passes through the heated magneto-caloric material at300K.It is then transferred to the hot chamber outside from where it is pumped out to the regenerator and heat is released to the atmosphere. The cycle repeats itself when the magnet rotates by 180^0. The rotary valves make sure that the hot fluid does not flow into the cold chamber. Our proposed method works on magnetic Ericsson refrigeration cycle at room temperature. It consists of two isothermal processes and two iso-field processes.

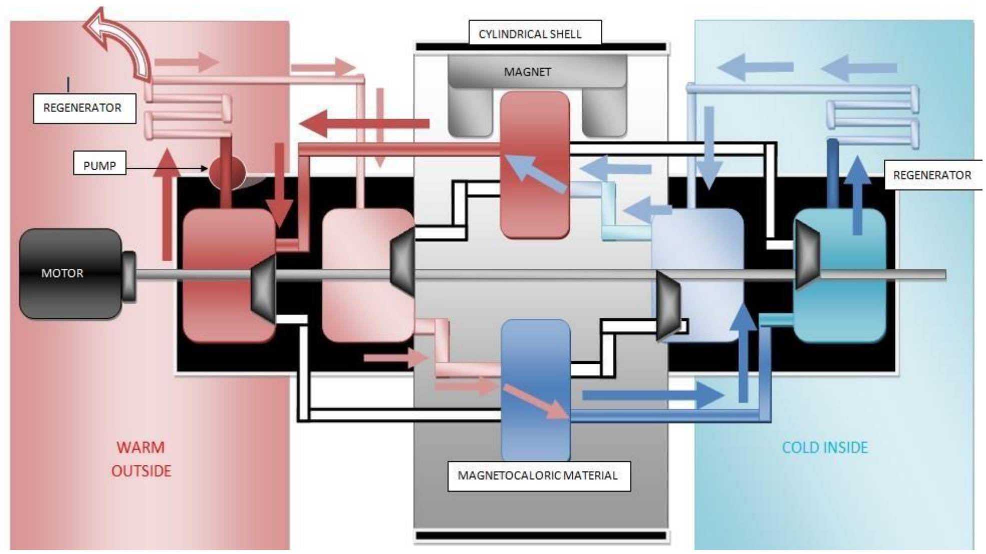

FIG 2: Block diagram of cooling system

3. Results and Discussion

Our proposed method works on magnetic Ericsson refrigeration cycle at room temperature. It consists of two isothermal processes and two iso -field processes.

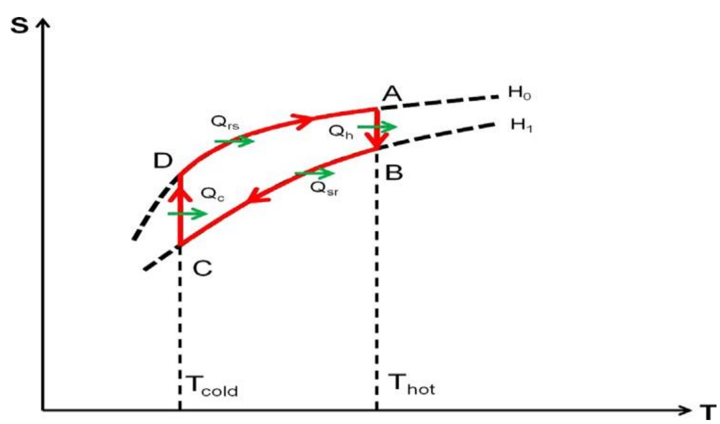

FIG 3: S-T diagram of magnetic Erricson refrigeration cycle

1. Isothermal magnetization process(A-B)
2. Isofield cooling process(B-C)
3. Isothermal demagnetization process(C-D)

3.1 Isofield heating process(D-A)

In the cycle, the heat $Q_c$is absorbed during the isothermal process C-D and heat Q_h rejected at the isothermal process A-B can be calculatedby:

$$Q_c = \int_{C\to d} TdS = -T_{cold}\ \Delta S(\Delta H, T_{cold}), \qquad \ldots\ldots\ldots\ldots 1)$$

Where isothermal entropy change(ΔH , T_{cold})is defined as

$$Q_H = \int_A^B TdS = T_{hot}\ \Delta S(\Delta H, T_{cold}) \ldots\ldots\ldots\ldots 2)$$

If C_H (H_0, T) and C_H(H_1,T) are the iso-field heat capacities at low and high magnetic field respectively. The heat Q_{rs} absorbed from the regenerator by the working substance during the iso-field process D-A and the heat Q_{sr}rejected by the working substance to the regenerator at the isofield process B-C can be evaluated by

$$\Delta S(\Delta H, T) = S(H_1, T) - S(H_0, T) = \int_{T=0k}^{T} \frac{[C_H(H_1,T) - C_H(H_0,T)]}{T} dT \qquad \ldots\ldots\ldots\ldots 3)$$

For most the MCMs . Now at temperature T_0 , C_H (H_0,T) ≥ C_H (H_1,T) for T≤ T_0 and C_H (H_0,T)<C_H (H_1,T) for T ≥ T_0 ; so T_0 is the temperature at which maximum entropy change is obtained , which plays a very important role in isothermal entropy change cycle

$$\text{Qrs} = \int_D^A Tds = \int_{T_{hot}}^{T_{cold}} C_H\,(H_0, T)dt$$

$$\text{Qrs} = \int_D^A Tds = \int_{T_{hot}}^{T_{cold}} C_H\,(H_0, T)dt$$

As per the previous analysis , for a refrigeration magnetic Ericssion refrigeration cycle, regenerated heat quantity is obtained by

$$\Delta Q = -(\text{Qrs} + \text{Qsr}) = \int_{T_{cold}}^{T_{hot}} [\,C_H(H_1, T) - C_H(H_0, T)\,]\,\text{dT}$$

$$= \int_{T_{cold}}^{T_{hot}} T\ \frac{\partial \Delta S(\Delta H, T)}{\partial T}\ dT \quad \ldots\ldots\ldots\ldots 4)$$

Now the net cooling quantity $Q_L = Q_c - \Delta Q$ with regenerative heat quantity ΔQ expressed as of equation

$$Q_r = \int_{\max(T_{cold,}T_0)}^{\max(T_{hot,,}T_0)} [C_H\,(H_1,\text{T}) - C_H(H_0, T)]dT$$

$$Q_r = \int_{\max(T_{cold,}T_0)}^{\max(T_{hot,,}T_0)} T \frac{\partial \Delta S(H,T)}{\partial T} dT$$

$$= T_{cold}\Delta S(\Delta H, T_{cold}) - T_{hot}\Delta S(\Delta H, T_{hot}) + \int_{T_{cold}}^{T_{hot}} T \frac{\partial \Delta S(\Delta H,T)}{\partial T} dT$$

$$W = -(Q_C + Q_h - \Delta Q)$$

Now, According to the 1st law of thermodynamics, work input of refrigeration cycle is defined as

COP= Q_L/W.

3.2 The magnetic Ericsson refrigeration cycles based on Gd_xDy_{1-x}

The experimental isothermal entropy change versus temperature curves for alloys with an applied magnetic field change of 1 T is given in the following graph for different values of x.

Now putting the values of T_{hot} as 300K and T_{cold} as 280K and we have T_0=280.8K for x=0.88 and Gd_xDy_{1-x} ΔS_c=3.0 J/Kg-K and ΔS_h=0.7 J/Kg-K.
Putting these values in equation 1-6 we will get

Table 1.

Qc=850.3 J/Kg	**-Qh= 236.1J/Kg**	**ΔQ=650.0 J/Kg**
Qr=655.5 J/Kg	**QL=194.9 J/Kg**	**Wi=35.82 J/Kg**
Wi=35.82 J/Kg	**COPsystem=5.45**	**COP CARNOT =14**

Calculating the COP of refrigeration for VCRS between 30°C and 7°C using R-134a as refrigerant we get:
h_1=255.04kJ/kg h_2=
278.27kJ/kg
h_3=129.31kJ/kg=h_4
Thus COP_{VCRS}= (h_1- h_4)/ (h_2- h_1) = 5.41
COP_{VCRS}= 5.41

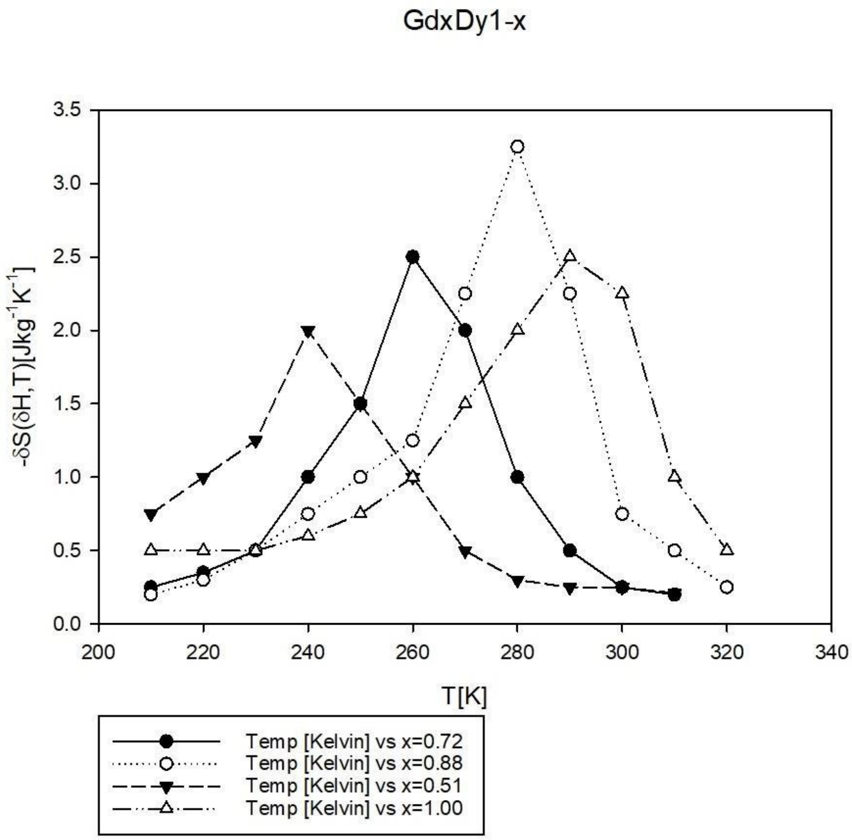

FIG 4: Isothermal entropy change vs. temperature curves for Gd_xDy_{1-x} alloys. Dotlines are guidance for the extraction of each alloy t0

4. Future scope

The list of possible applications involves all domains of refrigeration, heat pump technology and power conversion. But this technology also has some limitations which make it difficult for widespread use.The first is the temperature span. If the temperature difference between hot and cold body is very large, then the number of stages becomes also large and the cost becomes very high for practical use.The second condition is the stability of the running conditions. Because the MCE is limited to a domain around the Curie temperature where the continuous phase transition occurs, it is difficult to operate magnetic refrigerating machines under highly fluctuating conditions.

5. Innovation

In remote areas where there is less electrical supply this kind of a system will be an alternative green technology forcooling. This type of refrigeration is less noisy with high durability hence they can be used both for commercial as well as in industrialization purpose.Every year there is 2-3 million losses in vaccines has been reported by WHO data. So this type of refrigerant will be a boon to reduce these losses.

6. Advantages

There are many advantages of these system. Like they are, eco-friendly: In this type of technology there is no use of conventional refrigerants. Hence it doesn't produce CFC's & HFC's making it clean and green. Least Noisy system: magnetic refrigeration doesn't require compressor system hence it can be implemented for commercial purposes. Reduction in Electrical consumption: Since in this system no compressor is required hence it reduces the electrical consumption. Therefore it can be applicable for cold storage as well as household purposes. Highly efficient:

Magnetic cooling systems are expected to provide up to 50% saving versus traditional systems with a Carnot efficiency of more than 60%.Energy conservation: In this era of globalization, this type of refrigeration is a green alternative measure to reduce the losses due to lack of advance cold chain technology. Magnetic refrigeration is highly sustainable with having more expected durability than traditional refrigeration.

7. Conclusion

The analyses bestowed during this article are often wont to estimate any MCM performance because the operating substance, in such magnetic refrigeration cycle, directly from its experimental $\Delta S(\Delta H, T)$ curve and so to optimize the planning of the room-temperature magnetic refrigerators. The MCM entropy modification curve versus temperature has a similar form for these alloys, however, the height position T0 is admittedly the foremost vital parameter as a result of it'll management the regeneration loss. If a fabric has its T0 enclosed within the operating temperatures interval [T_{cold}, T_{hot}] then its Qc, Qr and QL curves versus T_{cold} can behave equally to the alloy 0.88 ; if its T0 is below the operating temperatures then its Qc, Qr and QL curves versus T_{cold} can behave equally to the alloy zero.51and,in the last case, fits T0 is larger than the operating temperatures then its Qc, Qr and QL curves versus Tcold can behave equally to the alloy 1.00. The choice of a magnetic material would rely on the position of its T0 (usually getting ready to Tc) comparatively to the expecting operating temperatures. Progress of temperature magnetic refrigeration is created worldwide. However, heaps of development is, however, to require place during this field. Temperature magnetic refrigeration is a brand new refrigeration methodology with extreme potential on account of high potency and setting safety.

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