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# Performance Assessment of a Near Room Temperature Magnetic Cooling System

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## Abstract

In this study, performance of a near room temperature magnetic cooling system was investigated experimentally in terms of temperature span. The current setup has a permanent magnet pairs (0.7 Tesla), a magnetocaloric material (Gadolinium) and a heat transfer fluid (water, ethylene glycol and 10% ethanol-water mixing) furthermore solar energy was used as a power source of liner motion of the magnetic system. The obtained results showed that ethanol-water was the best heat transfer fluid and also that optimum magnetization-demagnetization period for the system was found 10 s.

*Keywords:* Clean energy, gadolinium, heating-cooling,magnetic, magnetocaloric

## 1. Introduction

Recently, reduction of energy utilization for heating and cooling has crucial importance. The main reason for that is heating and cooling occupy the largest portion of overall energy consumption in buildings. According to the EU energy strategy plan this rate is more than 40% of final energy consumption [1]. Conventional cooling systems use compressor which is the main component of energy consuming and also non-environmental (global warming and

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ozone depletion) refrigerants are another problem for the conventional systems. Therefore, different alternative heating and cooling methods have been under research. Magnetic cooling can be a promising solution for cooling also has opportunity for renewable usage in buildings.

In a magnetic cooling system, a magnetocaloric material which is the most important part is being used. When magnetic material enters into the magnetic field its temperature rises and decreases out of the magnetic field. Based on this principle a fluid can be cooled (or heated under magnetic field) while the magnetocaloric material is out of the magnetic field. In the literature, there are many studies on magnetic cooling but most of them are theoretical. The most important studies are given as following in this part; Tishin [2] was applied Mean-Field-Theory (MFT) is used to predict the thermal properties of magnetocaloric materials. The first near room temperature magnetic cooling system development was a mile stone in this area [3]. An important exploration on this topic was the active magnetic regenerator (AMR) which is known as the best efficient magnetic cooling system up to now [4]. Therefore, numerical and experimental studies are mostly related AMR for instance Engelbrecht *et al.* [5] compared 1D and 2D AMR models. Sarlah and Poredos [6] introduced a dimensionless model to determine the heat transfer coefficient of AMR regenerator. In another AMR study, a 1D transient numerical code was developed by Roudaut, *et al.* [7]. In this study, the mean field theory was used to evaluate the magnetocaloric properties of Gadolinium. Engelbrecht *et al.* [8] investigated design and construction aspects of a high frequency rotary AMR system.

They reached 25 K, 20.5 K and 18.9 K temperature span values for the unloaded, 100 W and 200 W of cooling load cases, respectively. Lozano *et al.* [9] developed a prototype which was AMR type magnetic refrigerator. In the AMR they used 2.8 kg packed sphere gadolinium and magnetic field (1.24 T) provided with a permanent magnet. In the current study, magnetic system was analyzed for different design aspects such as type of heat transfer fluid, flow rate, magnetization-demagnetization period. Experimental and theoretical results have been compared.

## 2. Principle of magnetic cooling

All magnetic materials exhibit magneto caloric effect (MCE) and this effect peaks at Curie temperature. Curie temperature is the magnetic phase change temperature of a magnetic material. The MCE is a physical phenomenon that occurs in magnetic materials under the influence of a varying magnetic field. The temperature of magnetic material is increased when magnetic field is applied; this is known as magneto caloric effect [10]. The total entropy of a magnetic material consists of three main components [10]: $S_{magnetic}$, $S_{lattice}$ and $S_{electron}$.

$$S_{total}(B,T) = S_{magnet}(B,T) + S_{lattice}(T) + S_{el}(T) \tag{1}$$

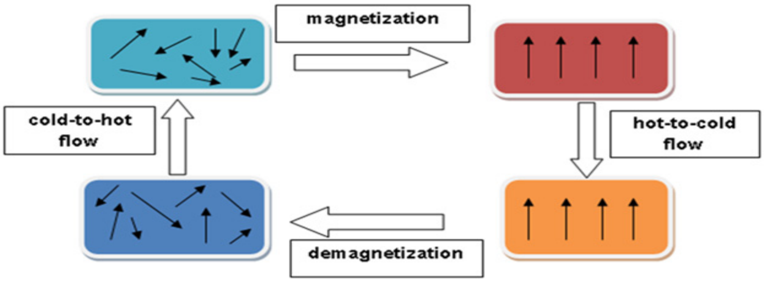

Fig. 1. A principle view of magnetic cooling cycle.

The electron entropy is disregarded since its effect is quite small comparing to the others. Fig. 1 shows the two basic processes of the magnetocaloric effect when a magnetic field is applied or removed in a magnetic system: the isothermal process, which leads to an entropy change, and the adiabatic process, which yields a temperature variation. When the magnetic material is exposed to a magnetic field, molecular moments are forced to align in the same direction resulting in a decrease in the magnetic entropy [10]. As the total entropy is constant, the reduction in the magnetic entropy then is compensated by an increase in the material's lattice entropy. Increase of lattice entropy causes an adiabatic increase in magnetic material temperature. During demagnetization on the other hand, the