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Effects of relative orientation of magnetocaloric inserts with the magnetic flux

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ABSTRACT

This paper presents the study of the magnetic change of the magnetic flux density into the magnetocaloric materials (MCMs). The MCMs are shaped in thin parallel plates separated by a fluid forming together an insert. It is shown that keeping all the parameters equal, the unique modification of the orientation of the insert induces a change of the magnetic flux density into the magnetocaloric materials. Like all paramagnetic and ferromagnetic materials, the MCMs have variable magnetic permeability according to the density of flux that crosses them. The influence of a thermal circuit on a permanent magnetic circuit assembly is also evaluated. In order to ensure the heat exchange between the magnetocaloric materials and the outside space, the use of a heat transfer fluid is needed. The heat transfer fluid goes along the mini plates and is also placed inside the magnetic field. Because a fluid is generally a diamagnetic element, this increases the total magnetic reluctance of the assembly.

Two different configurations named serial and parallel have been studied and evaluated in order to find the configuration that causes minimal disturbances to the magnetic flux and thus increases the magnetocaloric effect (MCE). Both configurations were also compared in respect to the induction obtained inside the vacuum gap of the magnet assembly.

Effets de l’orientation relative des inserts magnétocaloriques selon le flux magnétique

Mots clés : Magnétique ; Matériau ; Plaque ; Champ magnétique ; Flux ; Densité ; Transfert de chaleur ; Fluide actif

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Nomenclature

B	magnetic flux density (T) or (Wb m^{-2})
e	width of one heat transfer fluid or MCM layer (mm)
F_m	magnetic driving force of the magnet (A)
F_g	gap terminal magnetic potential (A)
H_{vg}	magnetic potential in the vacuum gap (A m^{-1})
L_x	width of the assembly on Ox axis $\vec{x}$ (mm)
L_z	length of the inserts on Oz axis $\vec{z}$ (mm)
L_u	useful dimension inside the magnet assembly gap (mm)
n	number of heat transfer fluid or MCM layers (dimensionless)
R_i	reluctance of the "i" element (H)
S_e	magnetic flux passage section (mm^2)
S_h	heat exchange surface between the fluid and the MCM (mm^2)
U_i	magnetic force of the "i" element (A)
V	heat transfer fluid volume or MCM's volume (mm^3)

Greek symbols

Φ	magnetic flux (Wb)
μ_0	vacuum magnetic permeability (H/m)
μ_r	material's magnetic relative permeability

Subscripts

ag	air gap
c	circuit
g	gap
h	heat
htf	heat transfer fluid
l	leakage
MCE	magnetocaloric effect
MCM	magnetocaloric material
S	serial configuration
P	parallel configuration
u	useful
v	vacuum
vg	vacuum gap

1. Introduction

Energy has an important role to play in economic growth of every country in the world, but the explosion of energy demand makes the world energy context difficult. Heating and cooling account for as much as half of a home's energy use and in automotive industry, nine out of 10 cars get air-conditioning equipment. In these conditions, saving energy and contributing to a cleaner environment is quite a challenge for nowadays researchers and engineers. Mitigating greenhouse gas emissions by lowering the emission of chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs) and supporting all the countries in adapting to climate variability and risk are also a priority.

In this respect, magnetic heating and cooling appear to be a promising technology (Tegus et al., 2002; Gschneidner et al., 1999; Yu et al., 2003; Brück et al., 2003).

Classical refrigerators or air-conditioning systems use CFCs, HCFCs and ammonia (NH_3) as heat transfer medium, which release vapours that are known to damage the environment. Instead of these gases, magnetic refrigeration technology uses magnetocaloric materials (MCMs), and offers a lot of other advantages, like considerable operating cost savings, mechanical stability, light weight and better performance over the conventional refrigeration technology (Pecharsky and Gschneidner, 1999).

Researchers and engineers are now in the optimization stage of their work. The actual challenge is to maximize the magnetic induction inside the MCM and to minimize the magnetic leakage around.

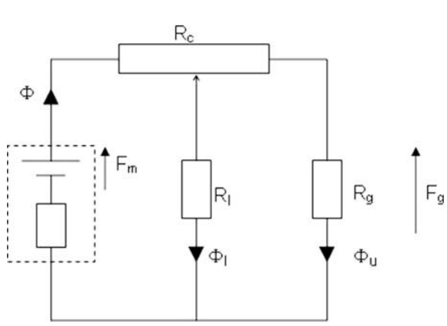

Fig. 1 – The equivalent scheme of a generic magnetic circuit.

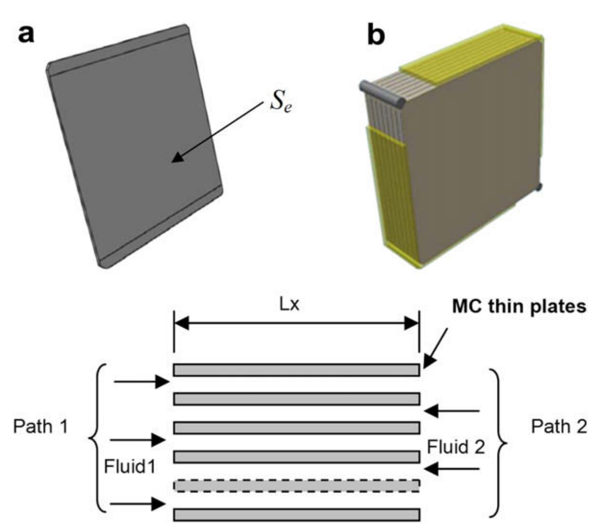

Fig. 2 – MCM insert composed of thin plates and fluid layers in between (Vasile and Muller, 2006). (a) Single MCM thin plate. (b) Stack of MCM thin plates.