A new method of magnetizing and demagnetizing the magnetic refrigerants by dint of dynamic-magnetic-link

D.W.Lu, H.B. Wu, G.Q.Yuan, Y.S.Han, X.N.Xu, X.Jin

National Laboratory of Solid Microstructures, Department of Physics, Nanjing University, Nanjing 210093, P.R.China

A new alternative method of magnetizing and demagnetizing the magnetic refrigerant in a room temperature magnetic refrigerator is proposed in the present paper. We called the new method as a dynamic-magnetic-link method. The permanent magnetic system in the new method is made up of two groups, one is the rest magnet group and the other is the moving or rotating part. The later is moved to different places or switched to different directions in turns to magnetize and demagnetize the working materials in a space. The numeric calculation about the new method is given in the paper.

INTRODUCTION

The room temperature magnetic refrigeration (RTMR) may be a hopeful candidate to replace the traditional refrigeration method. Since the cooling method was suggested, there have been a lot of fruitful results to be gotten. As a milestone of the RTMR study, Brown [1] made a try of signality in 1976. With a superconductivity magnet he used metal Gd to succeeded in getting a large temperature span of 47 K. Barclay et. al. [2] developed a new concept of the active magnetic regenerator(AMR) to be used in a magnetic refrigerator in 1982. In 1998, Zimm et.al. [3] succeeded in carrying out a magnetic refrigerator with a high coefficient of performance(COP). In the very beginning of 21st century, the permanent magnet had been been triumphantly applied in the magnetic refrigeration in U.S., Japan, China and other countries [4]. According to the summary of the room temperature magnetic refrigerator history given by Gschneider in the March Meeting of 2003, the field supplied by the permanent magnet for the RTMR is less than 0.8 Tesla. Since the permanent magnet does not offer an enough magnetic field, which is a very key factor to magnetic refrigeration power, we should find a better method to enhance the magnetic field. Because the rotatory magnetic refrigerator uses the driving arms to drive the magnetic refrigerant bed to rotate, we cannot use the O-shaped magnet arrays here as we can in a reciprocating magnetic refrigerator. Although the C-shaped magnet arrays is suitable in a rotatory magnetic refrigerator, its magnetic field will decrease in comparison with the O-shaped magnet arrays. As compensation, we may fill the permanent magnetic materials into the extra gap of the C-shaped magnet arrays to reduce the loss of magnetic field. Besides the compensation method we suggest another method to enhance the magnetic field. We discard the method of relative movement (that is popular in the present magnetic refrigerators) between the magnet and the working materials. We carry out the process of magnetizing and demagnetizing the magnetic refrigerant with a so-called dynamic- magnetic-link method that is not a bit same as the traditional one. We control a “magnetic switch” to make a varying magnetic field in the space of the working materials. In terms of the new method, the magnet does not move relatively to the magnetic refrigerant. We will introduce the new method in details by an example.

MODEL AND EXPLANATION

It is well known that the superposition principle is suitable for the magnetic system, namely the total magnetic filed is a vector superposition of the magnetic field of all the magnetic moments. The magnetic field superposition principle is the base of yielding a varying field in the space of working materials.

We consider a common cubic magnet arrays that generates an approximately uniform magnetic field in the cavum(see Figure 1). The magnet arrays are made up of 8 magnet units. In every unit the magnetic field is uniform respectively. In the magnet arrays system, the field direction of each permanent magnet unit is set up varying 45^{o} one unit to another to form a closed circuit. So assembled magnet arrays will offer an enough magnetic field for magnetic refrigerators in the cavum. But it is still, and there is no moving part in the magnet arrays, so the magnetic field is constant.

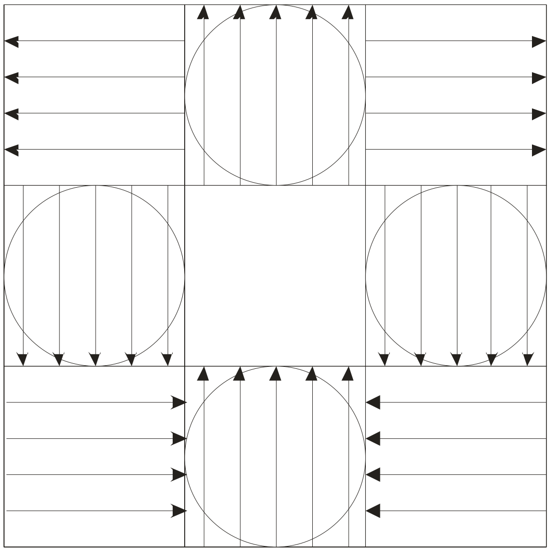

Figure 1   The vavum is located in the center of the arrays

In the 4 proximate magnet units to cavum, if we cut out 4 magnetic cylinders which have a diameter of 3 centimeters each, and let each cylinder turn around itself axis at the same time, according to the superposition principle, we may find the magnetic field of the cavum will change.

To calculate the change of the magnetic field in the cavum, we use the limited unit calculation method. The calculation expression of the magnetic field of all the magnetic moments is as follows.

$$\vec{B}(\vec{r}) = \frac{1}{4\pi}\mu_0 \iiint_{V'} dV' \{3\vec{m}(\vec{r}\,')\cdot(\vec{r}-\vec{r}\,')(\vec{r}-\vec{r}\,')/(|\vec{r}-\vec{r}\,'|)^5 - \vec{m}(\vec{r}\,')/|\vec{r}-\vec{r}\,'|^3\}$$

where $\vec{B}$ is the magnetic induction, and $\vec{r}$ is the position vector of field point, $\vec{r}\,'$ is the position vector of magnetic moment, μ_0 is the vacuum magnetic conductivity and V' is the occupying volume of magnetic moments. If we suppose each magnet array unit to be magnetized saturated and the magnetic coercive force to be large enough, we may get the magnetic field distribution in the cavum. We suppose the size of the cubic magnet arrays to be 9 centimeters long each side, and the cavum has 4 sides of three centimeters. The calculation result of the maximum field distribution is shown in Figure 2. The length of the arrow-axises denotes the intensity of the magnetic field.

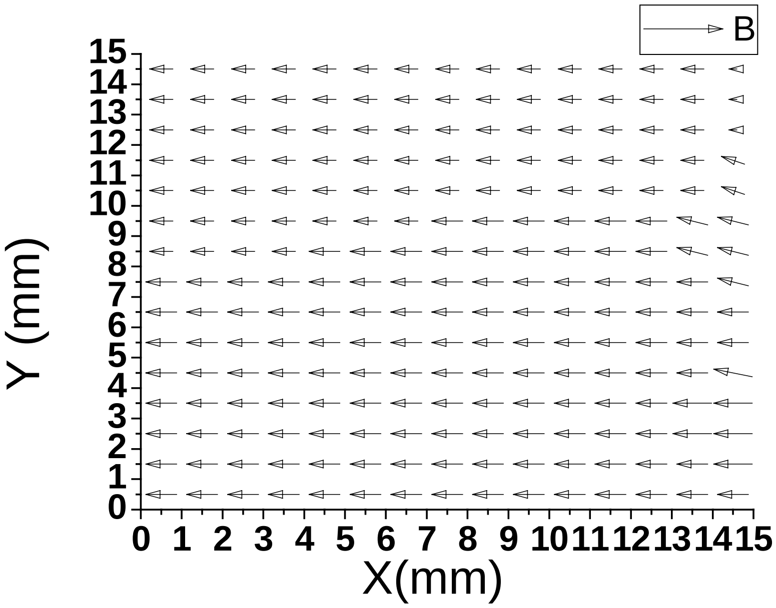

Figure 2 The maximum field distribution at positive state

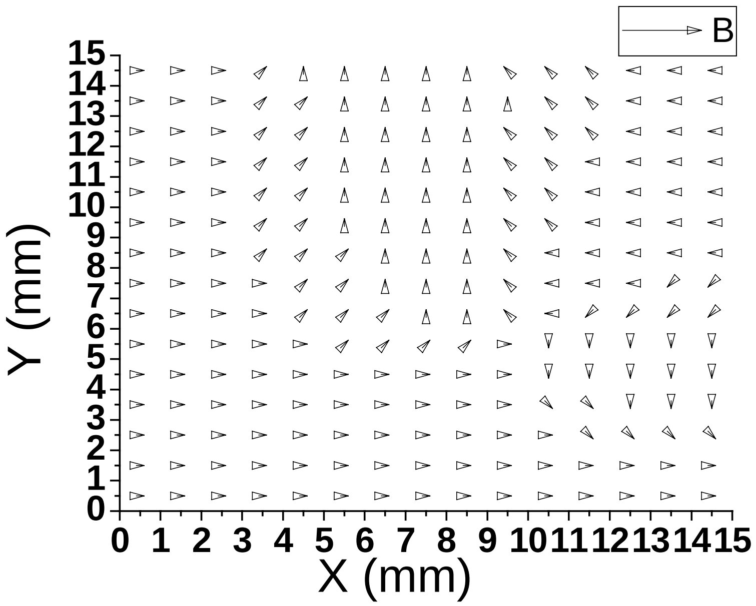

Figure 3 The minimum field distribution at negative state

As shown in Figure 2, when all the magnetic moments direct as them does in Figure 1, the mean field is about 1.2 Tesla. When the magnetic moments in the cylinders direct oppositely in comparison with Figure 1, the magnetic field in the cavum is minimum by absolute value, about 0.1 Tesla (see figure 3). In other status, the magnetic field in the cavum oscillates from 0.1 Tesla to 1.2 Tesla, and the magnetic field direction in the cavum varies at the same time.

QUESTION AND DISCUSSION

Because permanent magnetic materials have magnetic hysteresis, there will appears magnetic field decay and heat yielding in the magnet arrays after the cylinders turns some periods. Maybe the difficulty may be overcome by choosing low magnetic hysteresis materials.

The dynamic-magnetic-link is a concept method which may be realized in many forms. Its realization is quite different from the example presented here. For example, if we have a cylinder magnet arrays whose magnetic field directions in the cavum are periodic along its axis, we may let the cylinder be cut into two equal parts along the axis, which is shaped as a hemi-cylinder. Given that the magnetic fields in the hemi-cavum of the hemi-cylinder direct entad or outside, if we put together the two hemi-cylinder face to face and force them to slide alone the axis, the magnetic field in the cavum will vary periodically from 0 to maximum. If we curve the cylinder into a shape of the ring and redo the above operation, the dynamic-magnetic-link magnet may be used in a rotatory magnetic refrigeration cycle.

If we replace the 8 cubic magnetic array units as 8 columned array units, and let them turn at the same time in step, then the field in the cavum will turn. It may be used in other field besides the magnetic refrigeration.

The magnetic field distribution in the middle state is shown in Figure 4.

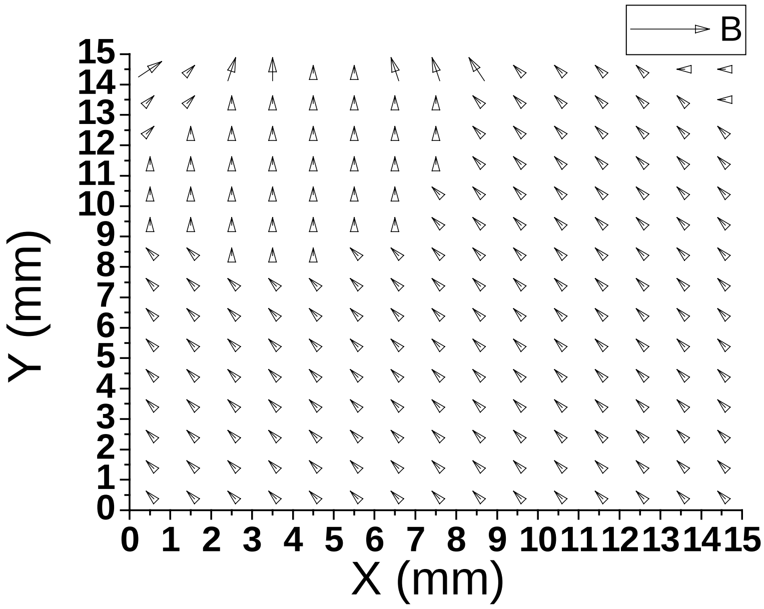

Figure 3 The middle state of the dynamic-magnetic-link field directions

ACKNOWLEDGEMENT

This work was supported financially partly by the project of the Key Technologies of Research and Development (99-A30-01-03), and partly by the HTRDP(863) of P.R. China government, the serial number of the project is 2002AA324010.

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