Conceptual Design of a Rotating Superconducting Magnet for Higher-Capacity Magnetic Refrigeration

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Abstract

Magnetic refrigeration uses the magnetocaloric effect, where applying or removing a magnetic field alters the spin distribution of magnetic materials, causing entropy changes to transfer heat and enable cooling. Hydrogen liquefaction has been demonstrated by NIMS using a reciprocating magnetic refrigeration system, where a magnetic material bed moves axially through a superconducting magnet, alternating inside and outside the magnetic field for cooling.[1)]

The reciprocating system has limitations:

1. Low magnetic field utilization, as only the two regions at the electromagnet ends are usable.

2. Oppositely directed magnetic fields are required to create a zero-field region, reducing magnetic field generation efficiency.

To address these, we propose a rotary system with stacked solenoid coils and gaps, allowing transverse relative movement of the magnetic material bed. This design eliminates the need for oppositely directed magnetic sources, improves magnetic field utilization, and expands the working volume, facilitating large-scale capacity. The bed remains fixed while a layered magnetic column with gaps rotates, enabling efficient large-scale magnetic refrigeration.

However, magnets with gaps experience substantial attractive electromagnetic forces, making the reduction of these forces a critical technical challenge. To address this, the magnetic field environment must be designed to appear symmetric along the stacking direction of the magnets as seen from each coil. Specifically, achieving a magnetic field distribution similar to that of infinitely long stacked magnets is essential. In this study, magnetic yokes were installed at the ends of the layered magnetic column unit to confine the magnetic flux and suppress leakage, thereby reducing the attractive electromagnetic forces.

Finally, we conducted a conceptual design of a rotary-type superconducting magnet for magnetic refrigeration using MgB2, with a nominal magnetic field strength of 3T. The details of this design will be discussed in the presentation.

References

1) https://www.nims.go.jp/eng/press/2022/04/202204110.html

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