Development of kW-class Magnetic Heat Pump Aimed at Application to Rolling Stock Air-Conditioning System

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1. Introduction

Conventional refrigeration is based on the compression and expansion of chlorofluorocarbons (CFCs) or hydrochlorofluorocarbon (HCFC). HCFCs are greenhouse gases and will be discontinued in 2020. Thus, the use of natural refrigerants and research on new refrigeration technologies are making rapid progress. One such technology, known as magnetic heat pump technology refers to refrigeration technology that exploits the phenomenon (magneto-caloric effect) of heat being generated and absorbed when a magnetic field is introduced to a magnetic material. The magnetic refrigeration has many advantages: the heat cycle efficiency of magnetic refrigeration is higher than gaseous refrigeration and thus reduces energy consumption; it is environmentally friendly without the need for CFCs or HCFCs; and it is quiet with low levels of vibration because compressors are not used. Thus magnetic refrigeration is expected to find applications in future air conditioners and refrigerators. Our research aims to apply this magnetic heat pump technology to rolling stock air-conditioning systems and this article describes our initial work towards that goal.

2. Development of kW-class magnetic heat pump

The rolling stock air-conditioning systems are relatively large (25-50 kW class) systems and there was no magnetic refrigeration system with cooling capacity exceeding 1 kW in Japan before our development. Therefore, we made an initial goal to develop a unit with a cooling capacity that exceeds 1 kW by using a magnetic refrigeration method to validate the feasibility of a kW-class magnetic refrigerator. We built a “ring-shaped Halbach arrayed permanent magnet” having magnetic flux density of up to 1.5 Tesla, developed by RTRI, into the kW-class magnetic heat pump and installed gadolinium alloys as the magnetic material (Fig. 1).

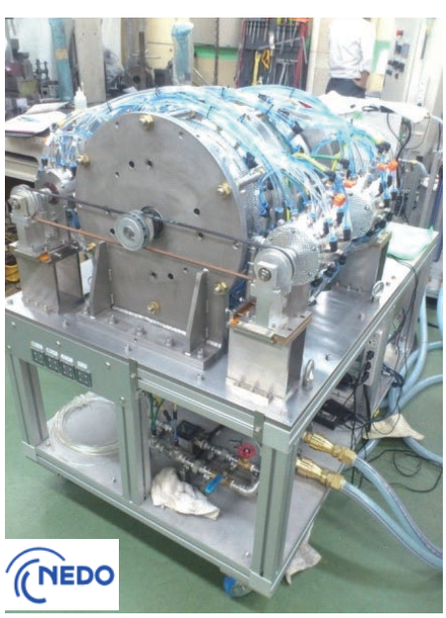

Fig. 1 kW-class Magnetic Heat Pump

3. Cooling capacity

The cooling capacity reached 1.4 kW at room temperature and exceeded the initial target (Fig. 2). Since this magnetic heat pump system has introduced the ring-shaped Halbach array, it has a larger cooling capacity per unit mass magnetic material than conventional magnetic refrigerators and, consequently, is advantageous in terms of downsizing (Fig. 3). The results of our latest development have indicated the applicability of magnetic heat pump technology using magneto-caloric effect to large refrigeration and cooling systems. We aim to apply this technology to rolling stock air-conditioning systems by further enhancement of refrigerating performance and efficiency and by downsizing and incorporating weight saving measures in the future.

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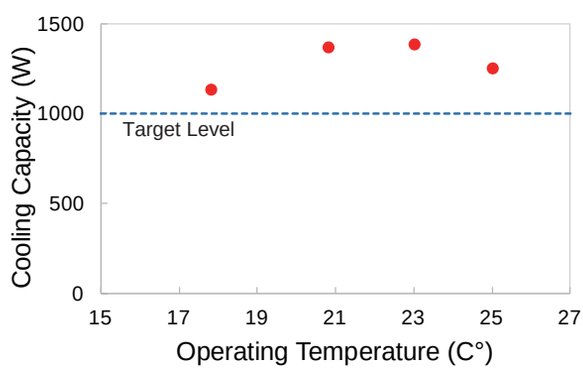

Fig. 2 Cooling Capacity Dependencies on Operating Temperatures

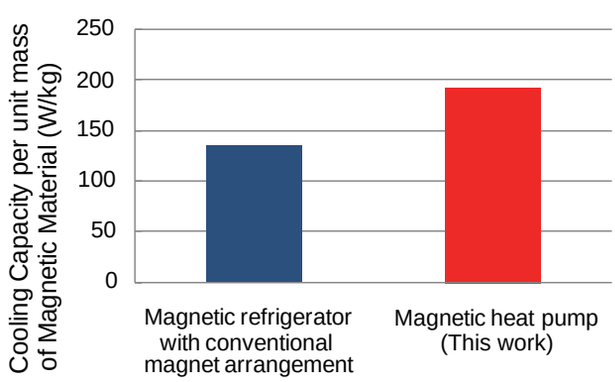

Fig. 3 Cooling Capacity per unit mass of Magnetic Material