§18. Experimental Study of a Regenerator Material Economizing Method for GM Cryocooler

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In order to implement fusion studies, low temperature technologies have been utilized widely. In particular, regenerative cryocoolers are used frequently in these areas. Because the cryocoolers are able to make easily the low temperature environment, and apply to the basic studies for fusion science, such as small size system, neutron irradiation and explosion proof radiation research. To achieve the cooling temperature of 4K level in the cryocoolers, a magnetic regenerator material that has a transition temperature at around 4 K is always required. A quantity of the magnetic material directly affects to the fabrication cost of cryocoolers. From this point of view, this paper introduces a regenerator material economizing method by using a novel regenerator structure [1].

As a first step to confirm the effect of the novel regenerator structure, we adapted it to lead (Pb) regenerator material in the 2nd stage regenerator of GM cryocooler. A schematic drawing of the two-stage GM cryocooler is shown in Fig. 1. Two calibrated silicon (Si) diode thermometers are attached at each stage, and an electric heater is attached at the 2nd stage to measure the cooling power. A radiation shield that is cooled with the 1st stage covered the 2nd stage and cylinder. The model of cold-head and compressor are RDK-408D2 (SHI) and C300G (SUZUKI-SHOKAN), respectively. The electric input power is 7.3 kW. The operating frequency is 1.2 Hz.

A schematic drawing of the two types of the 2nd stage regenerator structures is shown in Fig. 2. A general filling method (hereinafter called "Normal type") is shown in Fig. 2 (a). A filling weight of Pb spheres with a diameter of 0.212-0.3 mm is 660 g. A regenerator structure with bakelite rod (hereinafter called "Bake type") is shown in Fig 2 (b). The structure is that a bakelite rod, which acts as a dummy volume, is inserted in the co-axial layout to avoid the turbulence of helium flow in the radial direction in which Pb spheres are filled. A quantity of Pb is adjusted by the volume of bakelite rod. Three types of bakelite rods have been inserted in the 2nd stage regenerator. Specifications of the bakelite rod and the reduction of Pb weight are listed in Table I. The length of bakelite rod was fixed to 140 mm, and the diameter was changed to 15, 20 and 24 mm.

From the experimental results, the lowest attainable temperature (around 5 K) of the 2nd stage rises slightly as a result of reducing the Pb weight. However, a reduction of Pb weight by 41% does not affect the deterioration of the cooling power at above 9 K. Figure 3 shows dependence of the cooling power at 20 K on the reduction of Pb weight, where the horizontal axis of 0% means the cooling power of the normal type of 17.9 W. As shown, the difference of the cooling power between the reduction of Pb weight of 0 and 41% is approximately 1%. Thus, the bake type structure is able to economize the regenerator material.

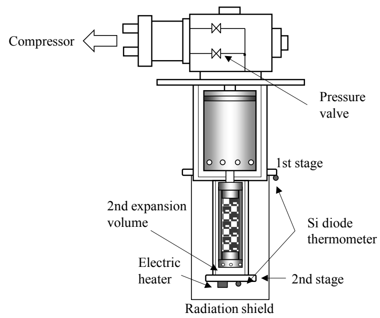

Fig. 1. Schematic drawing of the two-stage GM cryocooler.

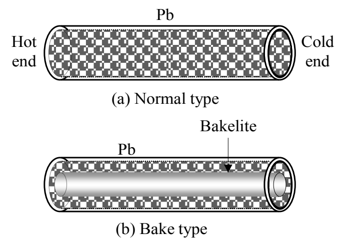

Fig. 2. Structures of the 2nd stage regenerator: (a) Normal type and (b) Bake type.

Table I. Specifications of the bakelite rod and the reduction of Pb weight.

Regenerator type	Bakelite diameter (mm)	Bakelite length (mm)	Reduction of Pb weight (%)
Normal	-	-	0
Bake 1	15	140	21
Bake 2	20	140	41
Bake 3	24	140	61

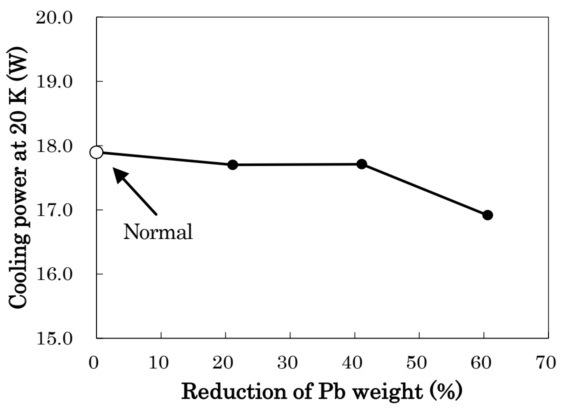

Fig. 3. Dependence of the cooling power at 20 K on the reduction of Pb weight.

1) Masuyama, S. and Hiratsuka, Y.: *J. Cryog. and Supercond. Society of Japan* 48-7, 358-363 (2013) (in Japanese)