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

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Regenerative cryocoolers have been used frequently in fusion 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].

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 air cooled compressor are RDK-101D (SHI) and CNA-11 (SHI), respectively. The electric input power is 1.3 kW at 60 Hz. The experiments have been done at the operating frequency of 1.2 Hz and the initial charging pressure of helium gas of 2.0 MPa.

A schematic drawing of the two types of the 2nd stage regenerator structures is shown in Fig. 2. A two-layer structure (hereinafter called "Normal type") is shown in Fig. 2 (a). The filling volume of $HoCu_2$ and lead (Pb) spheres are 50%, respectively. A two-layer structure with bakelite rod (hereinafter called "Bake type") is shown in Fig 2 (b). This 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 $HoCu_2$ spheres are filled. A quantity of $HoCu_2$ 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 $HoCu_2$ weight are listed in Table I. The length of bakelite rod was fixed to 50 mm, and the diameter was changed to 7, 10 and 12 mm.

The cooling power at 4.2 K and the lowest temperature are summarized as a function of the reduction of $HoCu_2$ weight shown in Fig. 3. The reduction rate of 0% is equal to the characteristics of the Normal type. The cooling power of the Normal type at 4.2 K is 0.18 W. When the reduction rate is 18% (Bake 1), the cooling power achieves 0.19 W that is the largest in this GM cryocooler. The lowest temperature difference between 0 and 18% is only 0.03 K. Furthermore, the reduction rate of 0 and 20% produces the same cooling power. This proves that a quantity of $HoCu_2$ is able to economize by 20% without deterioration of the cooling power at 4.2 K. As a next step, we will test to find out the optimum bakelite aspect ratio, location, and geometry.

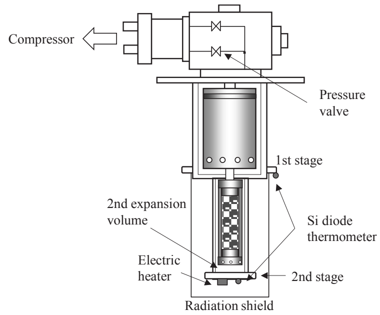

Fig. 1. Schematic drawing of the two-stage GM cryocooler.

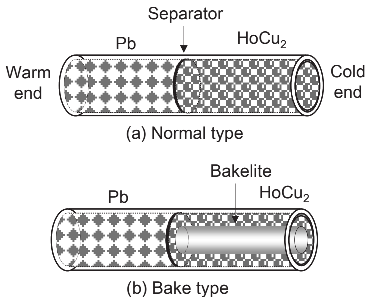

Fig. 2. Structures of the 2nd stage regenerator: (a) Normal type and (b) Bake type.

Table 1. Specifications of the bakelite rod and the reduction of $HoCu_2$ weight.

Regenerator type	Bakelite diameter (mm)	$HoCu_2$ weight (g)	Reduction of $HoCu_2$ weight (%)
Normal	-	52	0
Bake 1	7	43	17
Bake 2	10	32	38
Bake 3	12	23	56

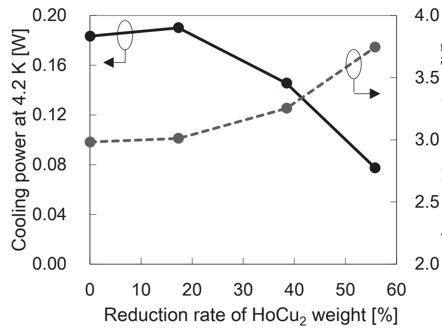

Fig. 3. Measured cooling power at 4.2 K and lowest temperature as a function of the reduction of $HoCu_2$ weight.

1) Masuyama, S., Hiratsuka, Y, and Numazawa, T.: *Advances in Cryogenic Engineering* **59B**, 1162-1168 (2014)