§6. Regenerator Performance Investigations for the Pulse Tube Current Lead

Masuyama, S. (Oshima National College Maritime Technol.),
Iwamoto, A.

Pulse tube cryocoolers (PTCs) that has no mechanical moving parts at the cold region produce compact cooling systems by combining the PTCs and other apparatus such as current leads for superconducting magnets. From the point of view, a pair of prototype pulse tube current leads system has been built and tested as a part of the superconducting magnetic energy storage system technology project by New Energy and Industrial Technology Development Organization [1-3]. A schematic diagram of the pulse tube current lead system is shown in Fig. 1. In previous studies[2], we have confirmed the following experimental results. Cool-down operation was conducted with optimized valve timing for 4-valve mode. The ultimate low temperature that was achieved was 58 K in one hour. When the maximum current capacity of 2,120 A achieved, the cold end temperature increased to 78.9 K because of heat loss of current lead. The results showed that the higher cooling capacity of PTC was required.

To improve the cooling capacity, numerical analysis of stainless steel mesh as regenerator material has been done by using REGEN3.3[4]. The hot and cold end temperatures of the regenerator were fixed at 300 and 20 K, respectively. The operating frequency was adjusted to 2 Hz. The amplitude of mass flow rate of helium gas was 5 g/s. The relationship between the stainless steel mesh with wire diameter and the calculated cooling power and coefficient of performance (COP) at 20 K are shown in Table I. In the same mesh size, the larger wire diameter shows the higher cooling power and COP. This reason is that the larger wire in the same mesh leads to low porosities and high heat transfer coefficient. A 200-mesh with a wire diameter of 0.05 mm shows best performance in Table I.

A single stage PTC has been tested with 4-valve mode. The regenerator was packed with 1,500 screens for 200-mesh stainless steel with a wire diameter of 0.05 mm. The operation of the PTC was conducted with the valve timing of 2 Hz. The initial charging pressure of helium gas was 1.6 MPa, and the electric input power of compressor (Suzukishokan, C-300G) was 7.3 kW at 60Hz. Cool-down experiment starting from room temperature is presented in Fig. 2. This curve shows that the cold head achieved to the ultimate low temperature of 34.2 K in 90 minutes approximately. Cooling power measurement by using an electric heater which was attached on the cold head was also carried out. At temperature of 80 K, the cooling power of PTC was 67 W.

To compare the above experimental results, a 300-mesh stainless steel screens will be tested as the next step. Furthermore, lead spheres will be packed to a part of the cold end instead of the stainless steel screens to increase the regenerator efficiency at temperatures below 40 K.

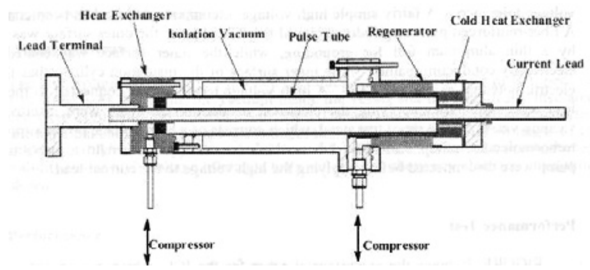

Fig. 1 Schematic diagram of the pulse tube current read system[2]

Table I Calculation results of the cooling power and COP of stainless steel mesh at 20 K

No.	Stainless steel mesh (wire diameter [mm])	Cooling power [W]	COP $\times 10^{-2}$
1	#150 (0.05)	3.22	0.920
2	#150 (0.065)	6.26	1.65
3	#200 (0.03)	1.35	0.397
4	#200 (0.05)	6.53	1.66
5	#300 (0.03)	5.17	1.25

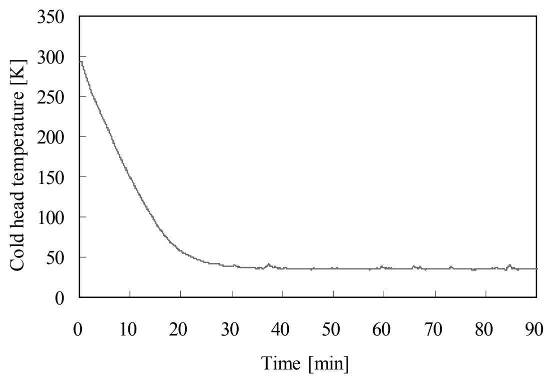

Fig. 2 Experimental result of the cool-down characteristic

1) Matsubara, Y. et al.: ICEC 19 (2003) 625
2) Maekawa, R. et al.: Adv. in Cryog. Eng. 51 (2006) 1711
3) Maekawa, R. et al.: Adv. in Cryog. Eng. 53 (2008) 101
4) Masuyama, S. et al.: Abstracts of CSJ conf. 83 (2010) 54