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

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Pulse tube cryocoolers (PTCs) have no mechanical moving parts at the cold region. It has become possible to construct compact cooling systems by combining the PTCs and other apparatus such as current leads for superconducting coils. From the point of view, a pair of prototype pulse tube current leads has been fabricated and tested as a part of the superconducting magnetic energy storage system technology project by New Energy and Industrial Technology Development Organization [1-3].

Fig. 1 and Fig. 2 show a schematic diagram and a top view photo of the pulse tube current lead system, respectively. This system consists of a hollow co-axial PTC and a copper rod current lead with a diameter of 16 mm. The current lead, which is inserted into the center of PTC, is cooled by conduction cooling via both heat exchangers of PTC. The total length of pulse tube current system has approximately 690 mm. The outer diameter and inner diameter of the regenerator are 88.6 mm and 58 mm, respectively. The length is 82 mm. Stainless steel meshes are adapted for regenerator material. The diameter of pulse tube and its length are 50 mm and 370 mm, respectively. In previous studies[2], we have confirmed the following experimental results. Cooldown operation was conducted with optimized valve timing for the 4-valve mode. The cooldown from room temperature to the lowest temperature, 58 K, was achieved approximately in one hour. Maximum current capacity was 2120 A. When the maximum current was supplied to the current lead, the cold end temperature increased from 59.3 to 78.9 K because of heat loss.

Improvement of the cooling power is a significant point for this pulse tube current lead system. As a phase shifter for adjusting mass flow and pressure in PTCs, the simple orifice mode is often chosen to measure cooling performance. This reason is the easiest to check the energy balance in the PTC. Therefore, cooldown experiment was conducted using the simple orifice mode where the current lead was inserted in the PTC. As a result, cooldown from room temperature to the lowest temperature was 120 K level. This result, however, is not enough for our target. The electric power consumption of compressor was 7.3 kW.

The cooling characteristics of PTC largely affect the performance of current capacity of this pulse tube current lead system. Reducing the enthalpy loss (regenerator loss) in the regenerator is one of main factors to improve the cooling characteristics. Required factors for regenerator materials are a large specific heat and a large heat transfer coefficient. As one of the effective methods to decrease the enthalpy loss and to increase the cooling performance, fine meshes are used in the cold part, and coarse meshes used in the warm part of the regenerator. Table I shows the calculation results of cooling power at 20 K with a few kinds of stainless steel meshes as regenerator materials. No. 5 regenerator indicates the highest cooling power. Stainless steel meshes #300, #250 and #200 are filled from the cold end. Their volumetric ratios are 10 %, 40 % and 50 %, respectively. We will confirm this effect by experiments as a next step. Disturbance of helium flow within a regenerator also enlarges enthalpy loss. Particularly, this turbulence tends to happen in large size PTCs. To avoid it, a few copper punching metal meshes are inserted in the regenerator. In the next step experiments, the effect of punching metal mesh will be investigated closely.

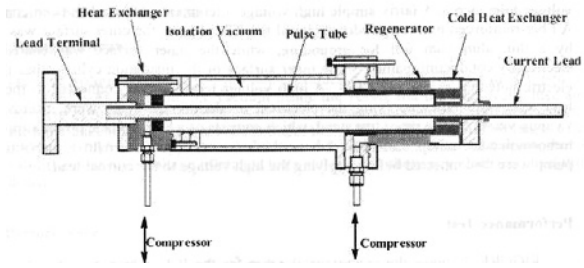

Fig. 1. Schematic diagram of pulse tube current read system[2]

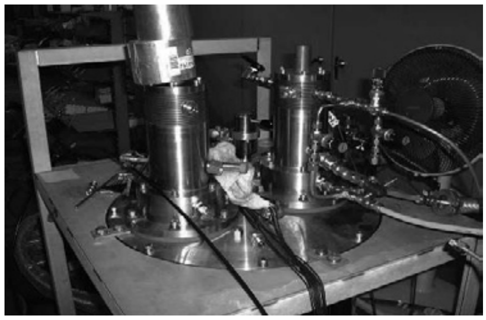

Fig. 2. Photo of pulse tube current lead system (top view)

Table Ⅰ. Calculation results of cooling power at 20 K

No.	Stainless steel mesh (volumetric ratio [%])	Cooling power [W]
1	#300 (100%)	5.1
2	#250 (100%)	5.1
3	#300 (40%), #250 (60%)	5.5
4	#250 (50%), #200 (50%)	5.1
5	#300 (10%), #250 (40%), #200 (50%)	6.0

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