§11. Development of Thermal Analysis Code for Peltier Current Lead

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Fusion energy is expected as a new clean energy without CO_2 emission. For the nuclear fusion, plasma should be confined by large superconducting magnets, for which large current is fed by huge bus lines. For such large current transmission, superconducting distribution systems seem to be effective. And also, future large energy generation by fusion systems would require highly effective transmission systems for actual use of electric power. Thus, we should develop high performance superconducting systems with low thermal loss.

For small systems, dominant heat leak comes from current leads at the terminals. We have developed a Peltier current lead (PCL) for the thermal insulation on the current lead[1]. In the PCL, the Peltier modules are inserted in the current lead. On the current lead, main heat sources are Joule heat and conduction heat from the outside. Thermoelectric materials can pump out the heat from the low temperature part by the Seebeck effect and also insulate the conduction heat by the low thermal conductivity (Fig. 1). We develop a simulation code to calculate the heat leak of the PCL and optimize the shape of them, where gas cooling effects are included as conventional gas-cooled leads are known as a high performance current lead for superconducting magnet systems.

We used thermal equations for the heat leak estimation including the Seebeck effect[1], where the temperature distribution and the heat leak were calculated by the developed code. Gas cooling is expressed by the heat exchange ratio f between cold gas and the current lead. f = 0 means the no heat exchange, which is conduction cooling. f = 1 means that the cold gas can exchange the heat with the current lead in the equilibrium condition, which is self cooling. The simulation code can calculate the temperature distribution on the current lead, and then we can obtain minimum heat leak conditions which are the optimum shape factors. Here, we optimize the shape factors of the current lead for the current of 100 A and compare three modules those have different thermoelectric parameters[2].

Figure 2 shows figure of merits for out test modules. We can obtain optimum shape factors using the developed code. Thus we can see the difference of perfomace of current lead the dependence of the gas cooling conditions in Fig. 3. We also discuss about the detailed thermoelectric parameter dependence such as resistivity on the performance using the simulation code for the future develop of the suitable thermoelectric materials.

We have succeeded in developing the simulation code of PCL for the use of large current applications. It seems to be useful for the optimization of the heat leak of total systems[3]. When we combine the low heat leak terminals and cryogenic double pipe sysytems[4], we can obtain the high performance total systems and they can fit to internet data centers for example, with compact high performance circulation sysytems[5].

Finally, we will extend to the simulation code to the multi stage structures for the future optimizations based on the code developed in this cooperative research.

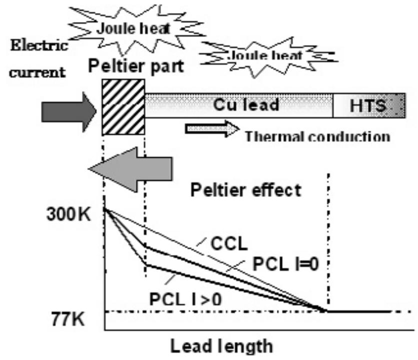

Fig. 1. Temperature profiles of a CCL and a PCL.

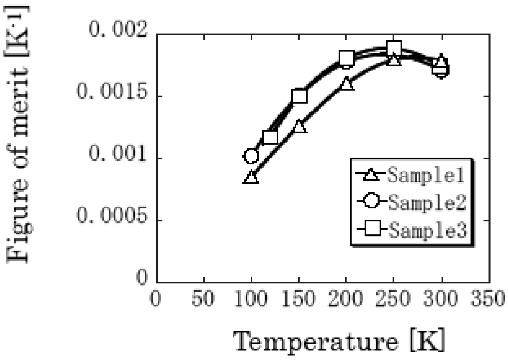

Fig. 2. Temperature dependence of figures of merit.

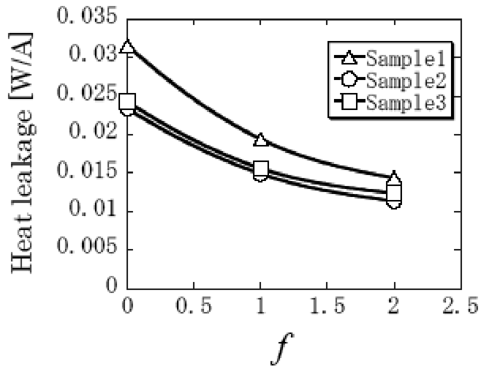

Fig. 3. f dependence of minimum heat leakage

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