§17. Improvement of Superconducting Pulse Coils using Tapes with High Aspect Ratio of Cross-section

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In order to develop fusion devices of second generation, it is required to develop superconducting conductors and coils with high stability. Recent development of technology that creates wire from high-temperature superconductors (HTS) progresses. Bi-system and Y-system superconducting wires are marketed. However, it is not sufficiently enough to study about HTS conductor and coils with large current capacity under high magnetic fields. Especially, it is desired to improve the performances of conduction cooling HTS coils. On that account, the development of the technology for removing heat generated in a coil efficiently is important. Recently, oscillation heat pipes (OHP), which have high heat transport properties at very low temperature, have been developed. By applying the OHP to conduction cooling HTS coils, extremely high performances of the HTS coils can be realized. The purpose of this study is to establish the optimum design method of the conduction cooling HTS coils with the OHP. For the purpose, thermal and electromagnetic properties of the OHP are clarified experimentally. In this year, design of a test coil with OHPs was carried out, and then thermal properties of the coil were evaluated by numerical analysis using the finite elementary method (FEM analyses) [(1)].

Configurations of our test coil with OHPs are explained. OHPs are formed into plate shape. The test coil is operated at 20 K, so the gas for OHPs is hydrogen gas. The dimensions of the OHPs are 95 mm in width, 210 mm in length and 5 mm in thickness, respectively. The test coil is composed of two single pancake coils. Four OHPs with plate shapes are put between the two pancake-coils. These OHPs are radially arranged every 90 degree. The winding tape is Bi-2223 multifilamentary tape, Type Hi, which are commercially available from Sumitomo Electric Industries, Ltd.. The critical current of the tape is 180 A at 77.3 K in self-fields.

In order to estimate the electromagnetic properties of the test coil, magnetic fields profile has been calculated when amplitude of the transport current of the test coil is 300 A. The maximum parallel fields applied the winding tape is 2.9 T and the maximum perpendicular field is 0.6 T. The ac losses are calculated based on the above magnetic field profiles by Bean-London model. The frequency is 0.2 Hz.

Next, as one of studies to check the feasibility of the HTS coil using OHPs, the calculation of temperature distributions in the test coil are carried out under conditions mentioned above. Transport current is ac current with 300 A of amplitude and 0.2 Hz of frequency. The calculations are carried out using 3D FEM. The model is 1/8 model of real size. The initial temperature is 20 K. Cooling areas are both edges of OHPs on inner and outer sides. The boundary conditions are as follows; the temperature of cooling area is restricted at 20 K, other boundaries are adiabatic conditions. The calculations are carried out on two cases, which are thermal conducting plate of OHPs and aluminum nitride (AIN). OHP's thermal conductivity is assumed 1000 W/mK which include thermal contact resistances between OHPs and winding tape. Thermal conductivity of AIN is assumed 100 W/mK.

Fig. 1 shows the results of calculations on temperature distributions in the test coil. Fig. 1(a) shows the results on thermal conduction plate of OHPs, and Fig. 1(b) shows the results on that of aluminum nitride (AIN). Circles show the maximum achieved temperature points. These maximum achieved temperatures are 24 K and 46 K, respectively. It is found that temperature rise of the winding tape decrease drastically in case using OHPs compared with case using AIN. The results indicate that the HTS coil introduced OHPs has high thermal transport properties.

Consequently, it is clarified that our HTS coil with OHPs has very high heat transport properties.

1) T. Osako, et al., Abstracts of CSSJ Conference, Vol. 91 (2015), p. 141.

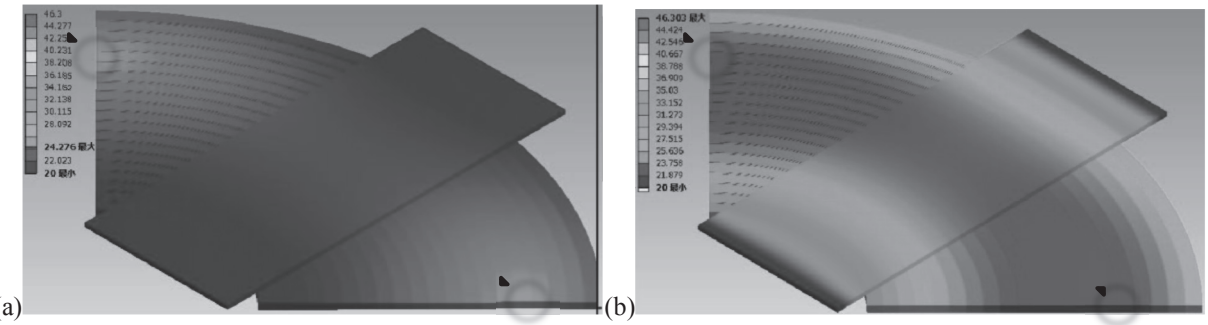

Fig. 1 The results of calculations on temperature distributions in the test coil, (a) and (b) represent results on thermal conduction plates of OHPs and AIN. Circles show the maximum achieved temperature points.