§13. Quench Protection of High-Temperature Superconductors with Indirect Cooling for FFHR

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The study for applying high-temperature superconducting (HTS) conductors for the helical reactor (FFHR) has been started as a counter option of low-temperature superconducting (LTS) conductors using such as Nb_3Sn or Nb_3Al. Operations of HTS conductors are available at elevated temperature above 20 K. At this temperature, the heat capacity of the conductors is about 100-1000 times larger than that at temperature 4.2 K. Therefore, HTS conductors are expected to be stable due to the large heat capacity. However, the thermal diffusion velocity is much slower due to the large heat capacity. As a result, HTS conductors are prone to make a hot-spot, and the detection of a normal-transition and the protection of the coils become difficult. In this study, the quench protection of HTS conductors is investigated using a numerical analysis with finite element method (FEM).

A schematic design of a HTS conductor is shown in Fig. 1. The HTS conductor consists of transposed HTS tapes and copper tapes, the aluminum-alloy jacket and insulation. The HTS conductor has a dimension of 50 mm square, and it has the operation current of 100 kA at temperature 25 K under the maximum magnetic field of 13 T. The superconducting bundles have the HTS tapes of ReBCO, and the copper to HTS tape ratio is 7.0.

The temporal evolution of the temperature distribution has been numerically analyzed using FEM by taking account of the non-linear E-J characteristics of the HTS tapes given by the percolation model 1). The aluminum-alloy jacket reduces the Joule heating and increase the heat capacity. The temporal evolutions of temperature distributions after the heating are shown in Fig. 2. The minimum energy required for generating a normal-zone in the HTS conductor is about 1 kJ. This value is about 1000 times larger than that for LTS conductors. It is confirmed, therefore, that the stability of HTS conductors is much larger than that for LTS. However, the velocity of thermal propagation in HTS conductors is about 100 times slower than that for LTS. It means a hot-spot can be created rather easily. The temporal evolutions of the maximum temperatures are shown in Fig. 3. The delay for the detection of the normal-transition with a threshold voltage (100 mV) is about 20 s after heating. The maximum temperature is less than 200 K after the dump (time constant 20 s).

From the present results, we consider that protection of HTS conductors with aluminum-alloy jacket is available.

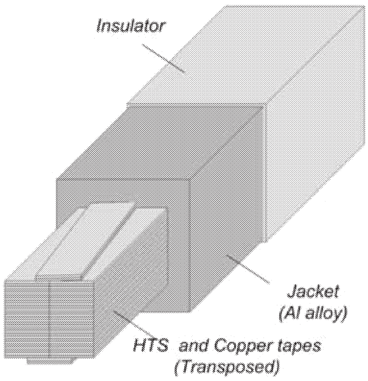

Fig. 1. Example of HTS conductor design.

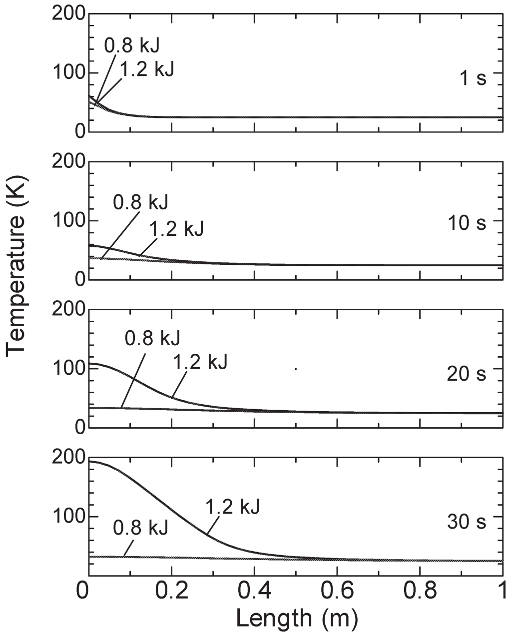

Fig. 2. Temperature distribution after heating in longitudinal direction.

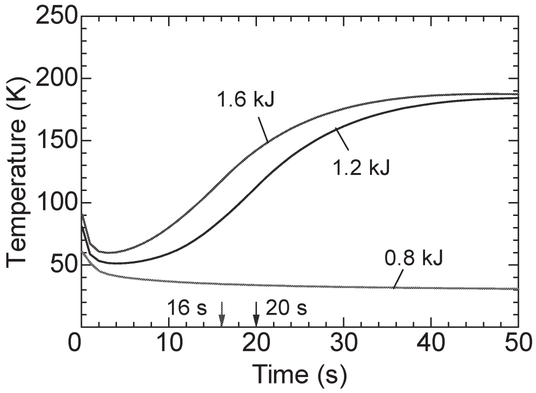

Fig. 3. Temporal evolution of the maximum temperature.

Reference
1) Kiss, T. et al., Physica C 392-396 (2003) 1053.