§20. One Dimensional Simulation of Normal State Propagation in Superconducting Cable

Emoto,M. (Nihon Sun) Yamaguchi,S.

The previous simulation demonstrated the peaked magnetic field caused normal state stagnation. This simulation focused on how recovery current depends on magnetic fields and heat transfer modalities[1].

Our simulations of the test sample experiments for LHD coil were done in the following way: With the initial temperature distribution right after the heat pulse as the starting point, changes in temperature distribution were computed by means of a differential method, and regional distributions of normal and superconducting states were obtained. Whether the normal-state region grew, shrank, or stagnated, depended on the initial temperature distribution, the magnitude of the electric current, as well as the distribution and strength of the magnetic field. The Hall effect which induced by the magnetic field is in itself two dimensional effect, we took it into consideration by using experimental measurements of the resistivity and assuming the resistivity ρ can be written as a linear formula of the magnetic field B, such as

$$\rho = \rho 0 + \alpha B \qquad (1)$$

where α=1.6x10-11[Ωm/T] and ρ0=3.4x10-11[Ωm] are based on experimental data.

This resistivity is almost 2 to 3 timese larger than the resistivity of the conductor which is calculated by the parallel circuit of the conductor materials.

The relation between the quantity of heat required to produce the initial temperature distribution and the induced recovery current of the short model, which has a uniform magnetic field, and the long model, which has a uniform magnetic profile, are indicated in Fig. 1. The recovery current used here was defined as the largest current to induce the normal-state region to grow. They are plotted for electric currents increasing in steps of 0.5 kA, so the accuracy of the recovery currents are 0.5 kA approximately. It is important to note that the recovery current is higher in the short model than in the long model.

In order to study influence of the heat transfer, four modalities of heat transfer from the sample to liquid He, which based on the experimental measurements, was introduced. Modality A features a continuous and modality B a discrete transition from the nucleate boiling state to the filmy boiling state. The remaining two modalities follow the Maddock heat transfer model; the transition temperature was 6.2 K in modality C and 9.3 K in modality D. Figure 2 depicts how the different heat transfer modalities affected the recovery current. The exposure ratio, i.e. the perimeter, was changed from 30% to 70%, and the greatest difference in recovery current of 4 kA occurred at a perimeter of 50%. The recovery current was found to be proportional to the 0.29-0.34 th power of the perimeter, which differ from the 0.5 of the approximate analysis equation that assumes a single transfer ratio not affected by temperature.

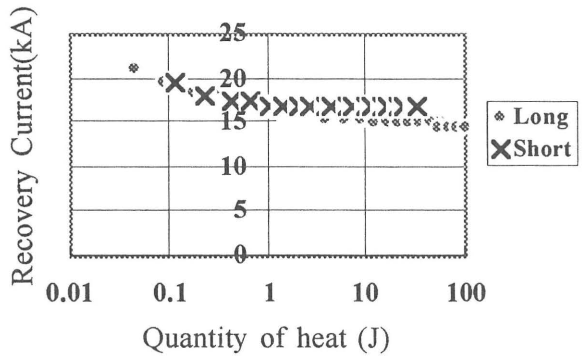

Figure. 1: Recovery current and quantity of heat

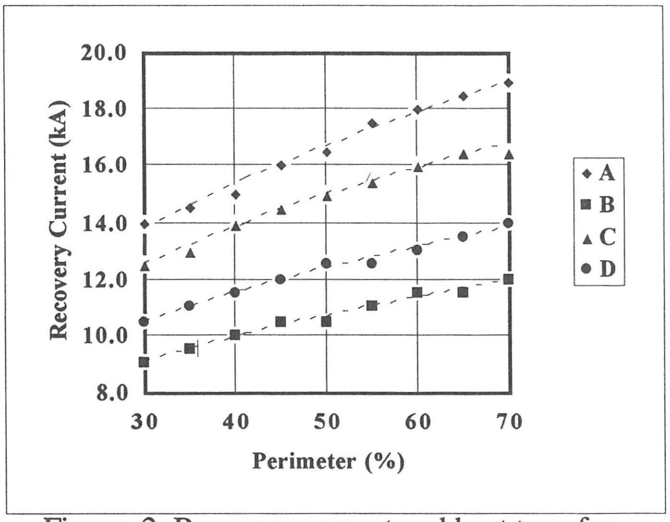

Figure. 2 :Recovery current and heat transfer modality

Reference

[1]M.Emoto, T.Senba, N.Yanagi, S.Yamaguchi, et al. "One-Dimensional Simulation of Normal-state propagation in a Composite Superconducting Conductor", ICEC16/ICMC, PS2-e2-28