§11. Study on Stability of Superconducting Cables under Cooling with He II

Shintomi, T., Kimura, N., Ogitsu, T., Nakamoto, T., Haruyama, T., Makida, Y. (High Energy Accelerator Research Organization),
Sasaki, K. (Hokkaido University),
Mito, T., Iwamoto, A., Maekawa, R.

1. Introduction

Nuclear fusion systems require relatively high magnetic field. In case that Nb-Ti superconductor is used to satisfy the requirement, superconducting magnets need to be cooled with He II. However, superconducting magnets with the Nb-Ti superconductor are sometimes unstable in He II because of the reduced specific heat of elements, which constitute superconducting magnets, in comparison with those cooled at 4.2 K. Therefore, it is very important to know stability of superconducting magnets under He II cooling condition. The purpose of this study is to carry out investigation for the stabilities of superconductors and then to get necessary information to develop stable superconducting magnets under the He II cooling. We have carried out experimental studies and developed a simulation code for analyzing stability problems for superconductors to explain the experimental study.

2. Experiment

We have carried out experimental studies of heat conduction in He II depending on micro-channels in electrical insulation films for superconducting cables. The dependence on the size and shape of micro-channels were simulated using an equipment which has a cavity and a micro-channel connected to a He II bath. The obtained results have been compared with data from experiments for stability using a superconducting magnet cooled below the lambda point. Furthermore, in order to know heat conduction in He II, an experimental study has been carried out for relation between temperature gradient and heat input for various channel sizes.

3. Development of simulation code and calculation

The compacted strand cable has been used for various type of magnets. In order to simulate normal zone propagation on the cable at quench, we have developed a simulation code. In this code, we have considered magnetic field distribution on the cable, heat generation by the current commutation between cable strands and heat conduction between strands. When a cable becomes normal, the current commutation occurs between strands and affects a normal zone propagation velocity. This is given by numerical calculation of the following equation;

$$C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\kappa \frac{\partial T}{\partial x}\right) + \rho J^2 + g_c + \frac{h_c \Delta T}{S}$$

where C_p is heat capacity of the cable, ρ resistivity, g_c heat generation at the contact resistance between strands and h_c thermal conductivity between strands.

Figure 1 shows an example of calculation for the current commutations using the developed code. In the figure, the time dependent current commutations are shown according to the electrical conductance σ_c and heat conductivity h_c. This is a case that the electrical conduction σ_c is small. As shown in Fig. 1, the current commutation is affected by the cable twist pitch in case of the low conductance. The time distance between peak-to-peak corresponds to the twist pitch. This may be understood that a region for the current commutation spreads more over one cable twist pitch. We can see that the current commutations change with the heat conduction between strands. This simulation agrees well with the experimental results.

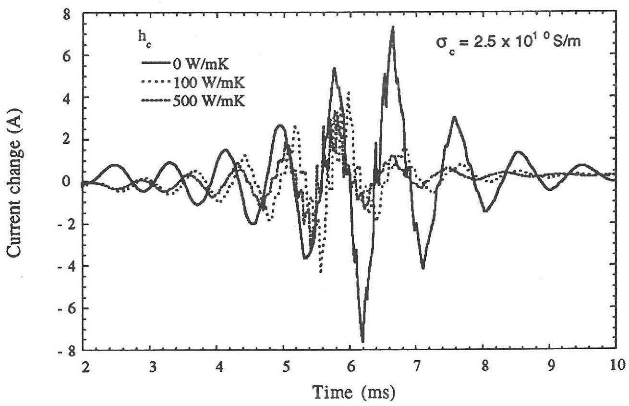

Fig. 1 The behavior of the current commutations at low electrical conductance between strands.

4. Summary

We have carried out the experiment of heat conduction through micro-channels in pressurized He II and developed a simulation code to analyze normal zone propagation in a compacted strand cable. The experimental data were compared with calculation using the developed code and explained well with the simulation. The data obtained by this experiment gives us important information to estimate stabilities of superconducting magnets under pressurized He II cooling which will be required for nuclear fusion systems.

The work will be performed more realistically, e. g. including heat conduction to coolant, to know the stability of superconducting magnets cooled with He II.