§14. A Thermal Analysis of Composite Superconductor

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It is important to set an appropriate stability margin of composite superconductor in design of superconducting magnet.The MQE(Minimum Quench Energy) of the conductor under the operating current and the applied external magnetic field should be one of key design parameters. The conductor is heated locally and the quench is occurred on whole of the conductor in operating condition. The MQE is calculated by the energy input from the heater. A thermal analysis of the finite element computer simulation code is necessary to estimate the net energy input from the heater in the experiment.

Figure 1 shows the configuration of a heater and a conductor. The heater is composed of a non-inductive winding stainless steel tape with the polyimide surface insulation. The pulse heating is adopted in the stability margin experiment.The input energy of the heater is calculated by the measurement of the heater current and voltage during the pulse.In the series of the experiment, the MQE is varied with the applied magnetic field and the conductor current. The heater input energy is divided into three parts, one is transferred into the liquid helium directly, the second part rises up the temperature of the heater itself, and the third part rises up the temperature of the conductor. Since specific heats of alloy and polymer are mainly proportional to the cubic of the temperature in low temperature region, the considerable amount of input energy may be dissipated to heat the heater itself.

Figure 2 shows a cross-sectional view of composite superconductor. We carried out the two-dimensional thermal analysis to simulate heating the conductor. The heat transfer coefficient is assumed to be 5000W/m2K,and the other calculation condition is adopted from the experiment to perform the simulation.

Figure 3 shows a result at a high power and short pulse experiment. The temperature of NbTi filament exceeds the critical temperature Ts near the end of the pulse duration. The energy distribution can be estimated by integrating this curve, and calculate the minimum quench energy.

Figure 4 shows a result at a low power and long pulse. It shows remarkable temperature rise at each finite element and the element of NbTi exceeds Ts at an early stage of heating. It means that most of the input energy is used to heat the heater and the conductor after transition into normal state. It suggest that the stability margin of the conductor is overestimated if the MQE is equal to the input energy of the heater.

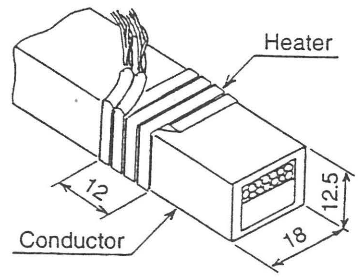

Fig.1 Heater on a composite superconductor

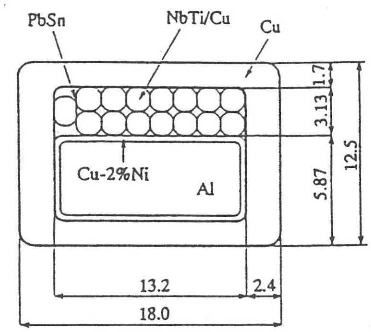

Fig.2 Cross–sectional view of the conductor

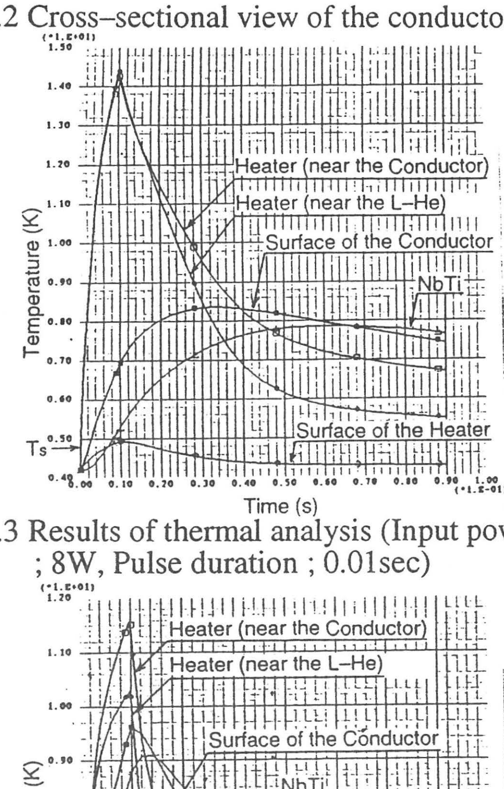

Fig.3 Results of thermal analysis (Input power ; 8W, Pulse duration ; 0.01sec)

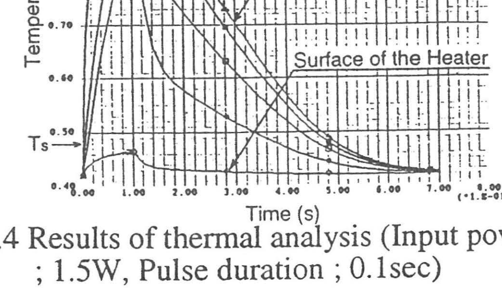

Fig.4 Results of thermal analysis (Input power ; 1.5W, Pulse duration ; 0.1sec)