§ 25. Study on Stability of High Temperature Superconducting Coil for SMES

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In a large-scale high temperature superconducting (HTS) coil, thermal behavior around a normal spot may be quite different from that of low temperature superconducting (LTS) coil due to the big difference of voltage-current characteristics and much larger heat capacity than LTS. This means that basic concept of LTS coil protection is not applicable to HTS coil and an adequate concept for HTS coil protection should be newly established. Although thermal behaviors in cryocooled HTS coil and LN_2-cooled short sample have been reported, that of LN_2-cooled HTS coil has not been investigated sufficiently yet. Therefore, to investigate a protection technique of large-scale HTS coil for SMES, we constructed a sample coil composed of silver tape and measured thermal distribution within the coil.

It has been reported that a normal spot in HTS conductor can return to its superconducting state without any quenches due to large heat capacity. This means that even in a large-scale coil thermostable condition can be easily obtained in HTS coil. For the design of the large-scale coil system, however, "safty" is also very important factor and should be discussed sufficiently for the protection of the HTS coil system against some disturbances and accidents. Therefore, in this research we focused on not "stability" but "safety" of coil system during its operation. The time from initial temperature to a limiting temperature for continuous operation without any damages to coil was measured as functions of the initial temperature and operating current.

When LN_2 is evaporated during a coil operation, the coil has flux flow or normal state resistance due to temperature increase. In such the coil temperature, most of operating current flows and most of joule heating generates not in HTS region but in silver matrix, so that thermal behavior within the coil is dominated by that of the silver matrix. Therefore, we constructed a single pancake coil using silver tape instead of HTS tape. The inside and outside diameters are 100 mm and 170 mm, respectively and the tape width and thickness are 3.9 mm and 0.238 mm, respectively. For the measurement of temperature distribution, several sets of voltage tapes and thermal couples are attached on the silver tape at a regular interval. Before the measurement, the sample coil is well cooled by LN_2. After removing the cooled sample coil from LN_2 bath, the coil operation was started when the coil temperature reached to a certain initial temperature. The temperature distribution during the operation was monitored by transient recorder. It was observed in a preliminary experiment in a short sample that the silver tape at the initial temperature of 77 K melted at the transport current of around 50 A.

Fig.1 shows an experimental results of temperature distribution at the initial temperature of 77 K and the operating current of 30 A. The slope of temperature distribution in radial direction gradually increased with time. The temperature increases in innermost and outermost layers were smaller than that of middle layers. Fig.2 shows dependence of the time from initial temperature to 280 K on the initial temperature as a function of transport current. Although the time to 280 K increased with transport current, the time was almost independent of initial temperature at the operating current more than 20 A. This may be caused by a rapid increase of coil temperature due to large joule heating and poor heat conduction, especially no coolant around the coil.

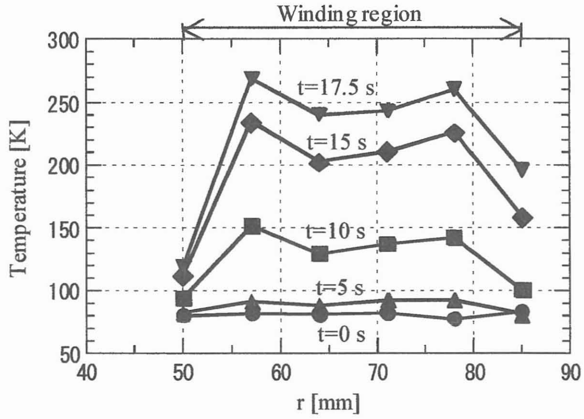

Fig.1 Temperature distribution at the initial temperature of 77 K and the operating current of 30 A.

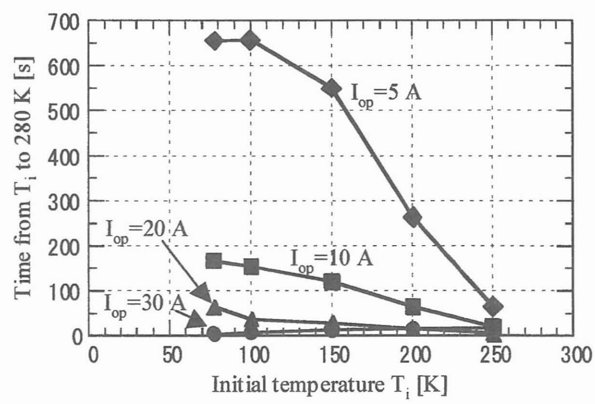

Fig.2 Dependence of the time from initial temperature to 280 K on initial temperature as a function of transport current.