§25. Effect of Shielding Currents on Current Decay Behaviors in HTS Coils

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HTS coils with persistent current operation are employed for high beta plasma confinement by dipole field with an internal ring. The current decay behaviors have been evaluated using the joint resistance and E-J characteristics of the HTS tape. In the past studies of LTS coils, the effect of the decay of coupling currents was discussed1). It was suggested that the transport current could be changed by the decay of coupling currents. In the case of HTS coils, the flux creep of the shielding currents is supposed to play the key role to affect the transport current in place of the coupling currents in the LTS wires. In order to achieve magnetic stability of 0.1 ppm/h like NMR magnets, the effect of shielding currents on magnetic stability of HTS coils in persistent current operation has to be studied, and a series of experiments have been carried out and a numerical analysis using finite element method (FEM) was conducted2).

A Bi-2223/Ag tape having the critical current of 104 A and n-value of 24.4 (at temperature 77 K under self-field) was used to wind HTS coils with a number of turns of 160 and the inductance of 4.0 mH. The joint resistance is 8 nΩ as a whole. From the experimental results at temperature of 60 K, it was found that the decay rate of the persistent current could not be fitted by an exponential function of time up to about 1000 s. In the long-time range after 1000 s, it is well fitted by an exponential function which can be determined by the joint resistance. The effective resistance can be evaluated from the decay rate of the current and the result is shown in Fig. 1. It was also found that the current decay behaviors could be changed by excitation process, as is shown in Fig. 2. In the case of an overshooting excitation, the effective resistance becomes close to the value given by the joint resistance.

The current decay behavior has been numerically analyzed using FEM by taking account of the non-linear E-J characteristics of the HTS wires. The HTS coil is assumed to be a double-pancake coil of 8 turns with the same inner radius and tape configuration. The joint resistance is assumed to be zero in the present calculation. The calculated current decay behaviors by changing the excitation process are shown in Fig. 3. The current decay behaviors are improved by having an overshooting excitation process in which the current distribution is gradually changed to the reverse direction. In the overshoot case which is first charging to 120 A, ramping down to 60 A and then switching to a persistent current mode, the magnetic field direction, which is made by the shielding currents, becomes the same as that of the major field of the coil. Therefore, the transport current increases due to the decrease of the shielding current.

In summary, current decay behaviors of HTS coils in persistent current operations are discussed by carrying out experiments and numerical analysis. The current decay behaviors are found to be affected by shielding currents. It has been shown that the improvement in decay behaviors is possible using appropriate excitation process. We can conclude that the current decay behaviors of HTS coils should be determined by the joint resistance, the E-J characteristics of HTS wires and shielding currents.

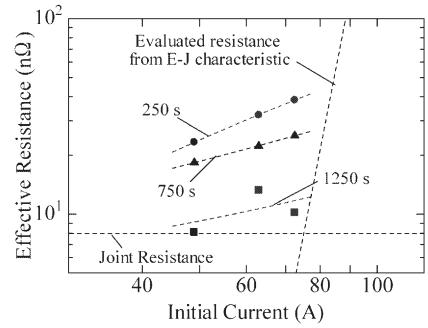

Fig. 1. Effective Resistances evaluated from current decay.

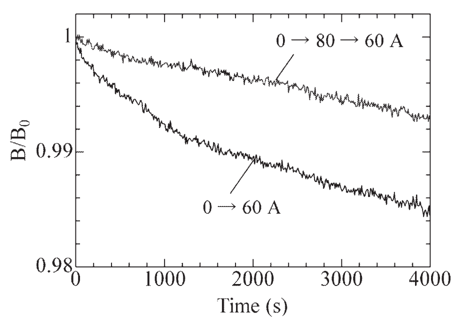

Fig. 2. Effect of excitation process on current decay.

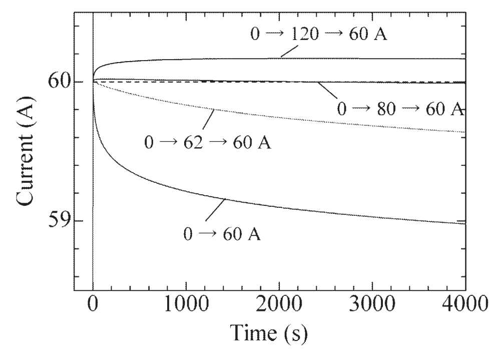

Fig. 3. Calculation results of current decay properties.

Reference

1) Cesnak, L. et al., Cryogenics 17 (1977) 107
2) Hemmi, T. et al, to be published in Fusion Engineering and Design