§4. Measurement of Time Constants of Coupling Losses for the Helical Coil Superconductors

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Time constants of coupling losses were measured for the pool-cooled composite-type superconductors used for the LHD helical coils. Prior to the operation of LHD, it is important to evaluate the AC losses of the superconductors which will be subjected to an external field change during an emergency shutdown of the coil system and with the time varying poloidal field in the Phase II operation mode.

The helical coil conductor consists of a Rutherford-type cable with 15 NbTi/Cu superconducting strands, a pure aluminum stabilizer and a copper casing. For Rutherford-type cables, the largest contribution to the AC losses is usually the interstrand coupling losses with a time varying external field in the perpendicular direction. Here we have applied a new method for the measurement of AC losses; direct measurement of the magnetic field on the conductor surface by Hall probes (see Fig. 1). Conductor samples with 660 mm long (five times the cabling pitch) were installed in a 9 T-split coil. The coil was shut down (exponentially dumped) with a time constant τ_0 = 14.1 sec from the central field of 3 T, and both the field on the conductor surface and the vacuum field were measured by Hall probes during the decay.

The time-dependent magnetic field on the conductor surface can be analytically given by solving the one dimensional diffusion equation in a slab material (width : $2w$, conductivity : ρ),

$$B(x,t) = B_0 e^{-t/\tau_0} + G\frac{4B_0}{\pi}\sum_{k=0}^{\infty}\frac{(-1)^k f}{(2k+1)^3 - f} \cos\frac{(2k+1)\pi x}{2w}\left\{e^{-t/\tau_0} - e^{-t(2k+1)^2/\tau}\right\} \qquad (1)$$

where $\tau = 4w^2\mu_0/\pi^2\rho$ corresponds to the time constant for the screening currents to decay in the material and G is a geometric coefficient introduced for the two dimensional correction.

Figure 2 shows the observed field decay after the shut down. By fitting the data by eq. (1), the time constant τ can be evaluated to be ≈ 4.4 sec, which is approximately consistent with another experimental result using pick up coils[1].

In the LHD conductor, the perpendicular field on the cable might be partially shielded by a pure aluminum stabilizer with its low electrical conductivity under the cryogenic temperature[2]. To investigate this effect, we have examined another sample with the aluminum stabilizer removed. In this case, the time constant was ≈ 6.6 sec, which supports the above possibility.

Finally, the analysis of the temperature rise of the helical coils during the emergency shut down are being conducted using these observations.

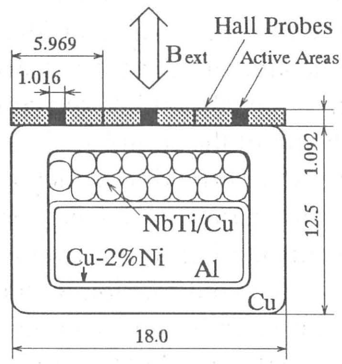

Fig. 1. Cross-section of the conductor sample with the Hall probes.

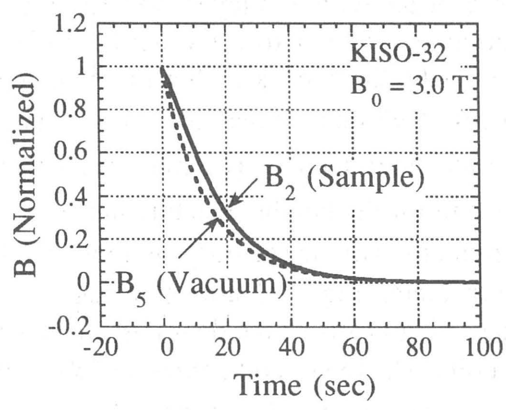

Fig. 2. Magnetic field measured by the Hall probes during the field decay.

References

1) Sumiyoshi, F., et al., IEEE Trans. Mag. 30 (1994) 2491
2) Takács, S., et al., Cryogenics 34 (1994) 679