§3. Measurement of Time Constants of Coupling Losses with Linear Sweeps on the Superconductors for the Helical Coils of LHD

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The time constants of coupling losses have been measured for the pool-cooled composite-type superconductors used for the helical coils of LHD, with the main aim of evaluating the AC loss generation due to the field change in the coils, especially during emergency discharges.

We have applied a method of directly measuring the magnetic field above the conductor samples using Hall probes[1] with an external field change. Conductor samples with 660 mm long (five times the cabling pitch of the superconducting cable) were installed in a 9 T split coil. This time the measurements have been performed using linear sweeps of the magnetic field, in addition to the previous case of using exponential discharges of the coil.

Generally, the magnetic field distribution in flat cables can be calculated in the low frequency region only. Here we simplify the calculation by considering a slab of thickness $2w$ and solve the one-dimensional flux diffusion equation

$$\frac{\partial^2 B}{\partial x^2} = \frac{1}{D}\frac{\partial B}{\partial t} \qquad (1)$$

where D is the diffusion coefficient. In the linear regime of $B_e = B_0\, t/t_0$, the general solution of Eq. (1) is given for the magnetic field measured at the cable center as

$$B(0,t) = B_0\, t/t_0 - B_0 G \frac{\tau}{t_0}\left\{\frac{\pi^2}{8} - \frac{4}{\pi}\sum_{k=0}^{\infty}\frac{(-1)^k}{(k+1)^3}e^{-t/\tau_k}\right\} \qquad (2)$$

where G is the shape factor which includes the geometrical effects of the demagnetization, the finite distance of the Hall probes from the screening current, etc. For $t > 5\tau$, the relative magnetization at the cable center has a constant contribution and

$$\Delta B/B_0 \approx -\pi^2\, G\tau/8t_0 \qquad (3)$$

Thus we can determine the product $G\tau$ from the linear part of the field change, although each parameter cannot be determined independently, not as in exponential discharge cases.

Figure 1 shows the obtained results with the linear sweep of $\dot{B}_0 \approx 0.03$ T/s. In this case, the time constant at the cable center (B_3) is determined as 5.5 s under the assumption of $G = 1$. The gradual decrease of the field deviation at the end phase of linear sweep might be caused by flux creep.

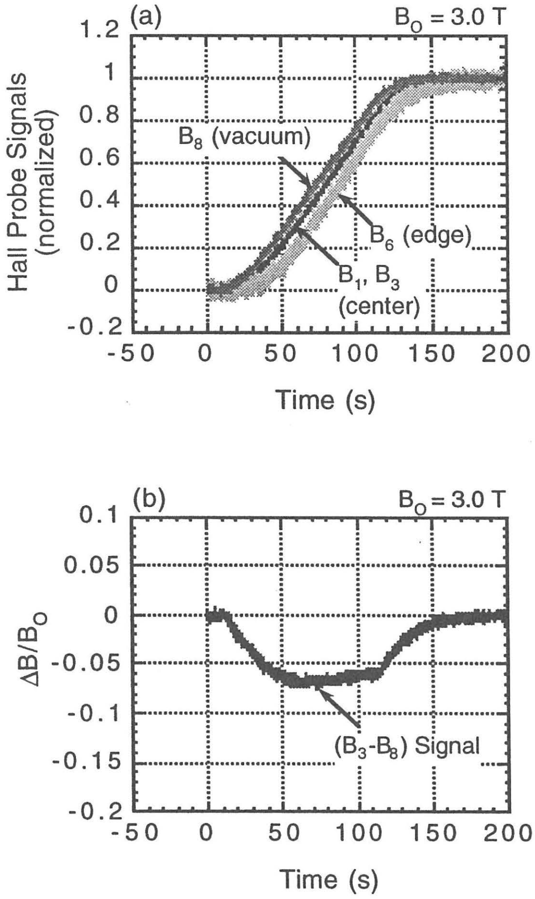

Fig. 1. (a) Magnetic field measured with the Hall probes during the linear sweep. (b) Field deviation between the conductor sample and the vacuum.

References
1) Yanagi, N., Takács, S., Mito, M., Takahata, K., et al., Measurement of time constants for coupling losses in the LHD superconductors, Proc. ICEC16/ICMC, Kita-kyushu, (1996) pp. 1253-1256.