§2. Detection of a Minor Normal-transition in the 17th Experimental Cycle with the LHD Superconducting Helical Coils

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The pool-cooled superconducting helical coils of the Large Helical Device (LHD) (major radius 3.9 m, helical pitch number 10) have been stably operated[1] during the past 17 experimental cycles so far. The liquid helium supplied to the valve-box is cooled through a heat exchanger, and the inlet temperature of the helical coils is maintained at 3.2 K to improve the cryogenic stability since the installation of cold compressors in the 10th experimental cycle. The outlet temperature is ~4 K.

A minor normal-transition was detected in the excitation test in the 17th experimental cycle when the toroidal magnetic field was raised from 2.75 T to 2.8958 T (at the magnetic axis with the major radius of 3.6 m). The conductor current was 11.2 kA at the time of a transition. Figure 1 shows the waveforms of the balance voltage signals of the H-I blocks observed during the transition. Two different frequency ranges of low-pass filters were used for measuring the balance voltage: the 10-Hz regime detected the transition and the 10-kHz detected the mechanical disturbance that initiated the transition. The normal-zone appeared with a maximum balance voltage of ~15 mV (for the 10 Hz measurement), and it naturally recovered back into the superconducting state within a duration of 0.5 s. Note that the judgment for a quench is set at 200 mV and 2 s. At the timing of the mechanical disturbance, acoustic emission (AE) signals were also observed. There are four AE sensors attached on the helical coil cases located at Section #2, #5, #7 and #10. The earliest observation of AE#7 suggests that the disturbance occurred near Section #7. Signals from the pick-up coils, distributed along the helical coil cases, determine that the normal-zone started at the bottom of Section #8, which is consistent with the AE measurement.

Despite the observation of this minor transition, which was the 25th one since the first one observed in the second experimental cycle, we consider that there has been no apparent deterioration for the mechanical properties of the helical coil windings. This is confirmed using the pulse height analysis (PHA) applied to the spike signals observed in the 10-Hz regime balance voltage. The total intensity of spike signals is an effective measure to investigate the changes of mechanical properties of the coil windings, and it shows a continuous decrease with the experimental cycle as shown in Fig. 2. We here note that the PHA finds that the obtained distribution function of the balance voltage signals shows two components: high-energy and low-energy during a ramp-up phase. It is found that the saturation of the intensity already started from the 6th experimental cycle for the high-energy component. This suggests that the probability of observing a normal-transition has not been significantly changed since then.

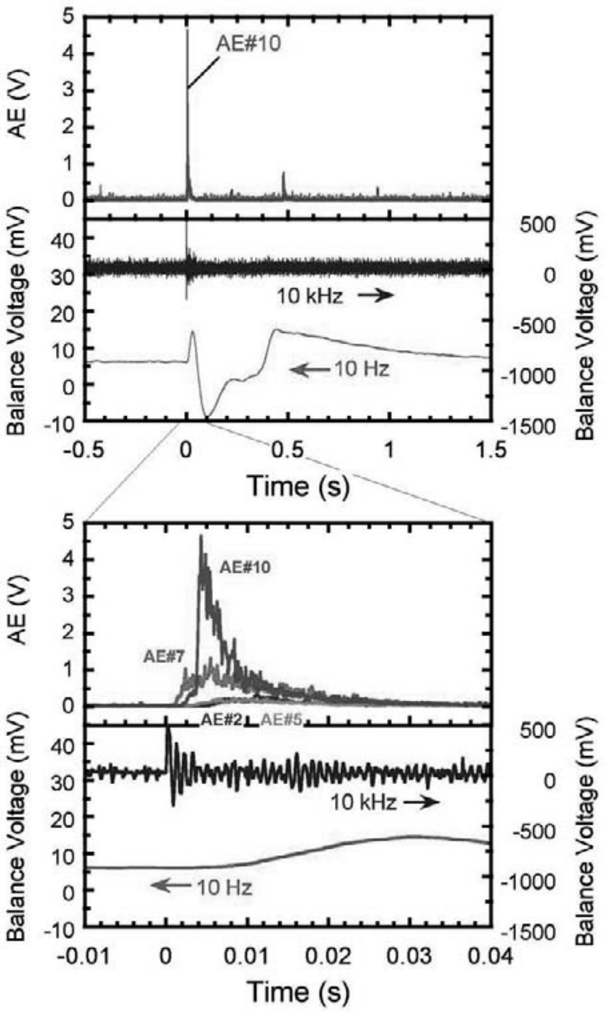

Fig. 1. Waveforms of AE signals and balance voltage signals (at two frequency resolutions) for a normal-transition observed in the 17th experimental cycle.

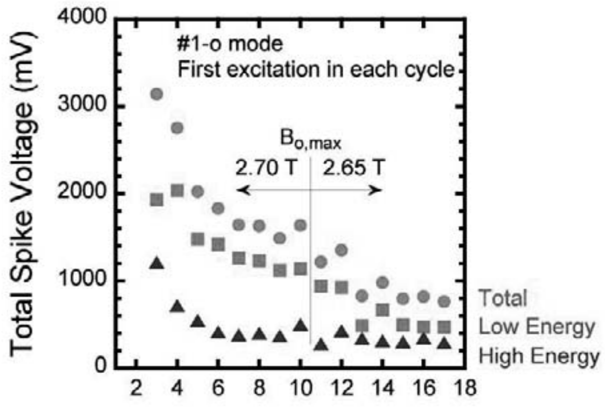

Fig. 2. Variation of the total spike signals of the H-I balance voltage during the first ramp-up in each experimental cycle.

1) Yanagi, N., Imagawa, S., Sekiguchi, H.: Fusion Science and Technology **58** (2010) 571.