§3. Acoustic Emission (AE) Measurement of the LHD Helical Coils

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It has been observed in the helical coils (HC) of the Large Helical Device (LHD) that the balance voltage signals between the corresponding pairs of the coil blocks contain a number of spike signals during excitation. Pulse height analysis (PHA) has been successfully applied to analyze these signals in order to clarify the mechanical properties of the coil windings [1]. In addition, four acoustic emission (AE) sensors are attached to the HC-cans and comparison between the balance voltage and AE signals is conducted, which is useful to investigate the mechanical disturbances in the coil windings and to determine the area where a normal-zone is initiated.

Figure 1 shows a schematic illustration of the toroidal distribution of the AE sensors along the HC-cans. The signal cables of the AE sensors are lead from the LHD cryostat through feed-through connectors and fed into preamplifiers located near the cryostat. Envelopes of the AE signals are output by the AE analyzers and they are digitized with a sampling rate of 10 kHz. The AE data can be observed and stored by computers in the control room via LAN with optical fibers. A number of AE pulses are observed during ramp-up and ramp-down of excitation. It has been confirmed that many of the AE pulses are correlated with the spike signals of the balance voltage of the helical coils as well as those of the poloidal coils. The total intensity of AE signals decreases from the second excitation with the same operation condition.

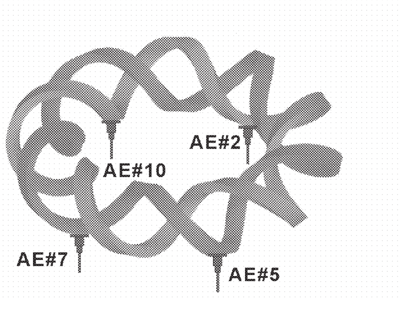

Fig. 1 Distribution of AE sensors along the helical coils.

We have been considering that the normal-transitions in the helical coils are initiated by mechanical disturbances in the windings (conductor motions). In this respect, the AE measurement is supposed to be effective to confirm this scenario. Figure 2 shows the waveforms of the AE signals and balance voltage when the 17th normal-transition was observed. The balance voltage was measured with two different frequency ranges at 10 Hz and 10 kHz. The 10 Hz signal observes a normal-transition as the resistive component is extracted from the waveform, whereas the 10 kHz one detects a spike signal just before the transition. This indicates that a mechanical disturbance actually initiates a normal-transition.

Expansion of the waveforms (Fig. 3) shows that the AE sensor attached to No.10 sector of the HC-can responds first among the four sensors and its signal amplitude is the largest. This suggests that the mechanical disturbance that caused this normal-transition was generated near this section. Other three sensors also detected signals, and their time delays correspond to the traveling time of the sound waves through stainless-steel plates in the HC-cans and supporting structures. On the other hand, it was confirmed by the measurement with 120 pick-up coils attached along the HC-cans that the normal-zone actually started from No.10 sector in this case, which shows good agreement with the AE measurement.

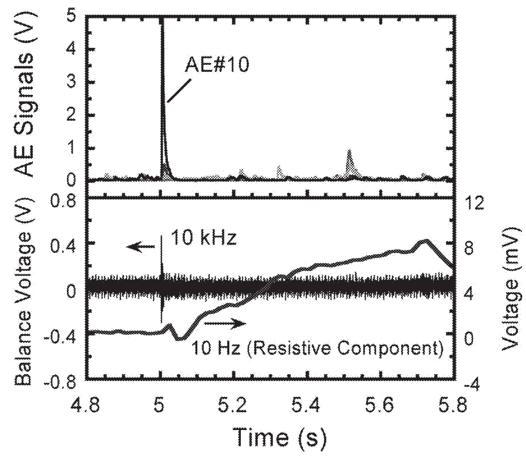

Fig. 2 Waveforms of AE signals and balance voltage signals (at two frequency resolutions).

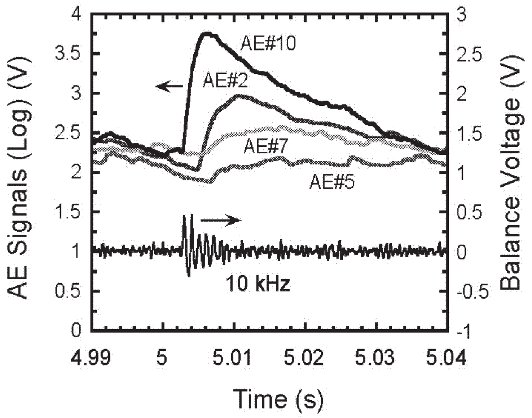

Fig. 3 Expansion of waveforms of Fig. 2 for the AE signals and balance voltage signal (at 10 kHz)

References
1) Yanagi, N. et al.: IEEE Trans. Appl. Supercond. 12 (2002) pp.662-665.