## §2. Monitoring and State Estimation of LHD Coils

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In an excitation test and an engineering experiment of the LHD system, the excitation process is monitored in detail using a balance voltage of the superconducting helical coil and a signal of AE sensor attached on the helical coil vessel. Particularly, the AE sensor (Fig. 1) is effective in order to observe directly a mechanical oscillation induced by the excitation. In case of a high field excitation, a small normal zone transition happens to be observed occasionally. In such a case, always AE signals are observed in synchronous with a spike signal of the balance voltage. So, it is clearly accepted that a mechanical disturbance is the origin of the normal zone transition. Therefore, it is very effective to investigate the variation of the AE signal in accordance with the excitation of the coil for the monitoring of the internal state of the coil.

In the first excitation test of the 11th cycle experiment, at toroidal field region of 2.5 T～2.65 T, a wave shape of the envelope of the AE signal was recorded as shown in Fig. 2. With the increase of the coil current (the field strength measured by a Hall element attached on the surface of the helical coil vessel), AE signals are observed together with many spike voltages in the balance voltage. The AE signal is not necessarily synchronous with the balance voltage signal of the helical coil. The reason is estimated to be that AE sensor detects also the mechanical disturbances generated in the poloidal coil. The integrated value of the AE signal in the excitation region shown in Fig. 2 is plotted with the number of the excitation as shown in Fig. 3. From Fig. 3, it is recognized that the AE signal decreases with the iteration of the excitation because the mechanical disturbance decreases by the improvement of the mechanical binding by the electromagnetic force applied to the winding. However, the extent of the decrease of the AE signal is about 20 %. It is estimated that the position of the conductor of the winding has been located at the enough stable position by the many times cooling and excitation so far.

As the next step, it is planned to investigate the change of the balance voltage and AE signal in various excitation patterns to the same magnetic field. The excitation patterns under consideration are as follows;

(a) Starting the excitation from the outermost coil block HO, next the middle block HM, and lastly the inner most block HI.

(b) Starting the excitation from the inner most coil block HI, next the middle block HM, and lastly the outermost block HO.

For these excitation patterns, now we are going to calculate the distribution of the electromagnetic force.

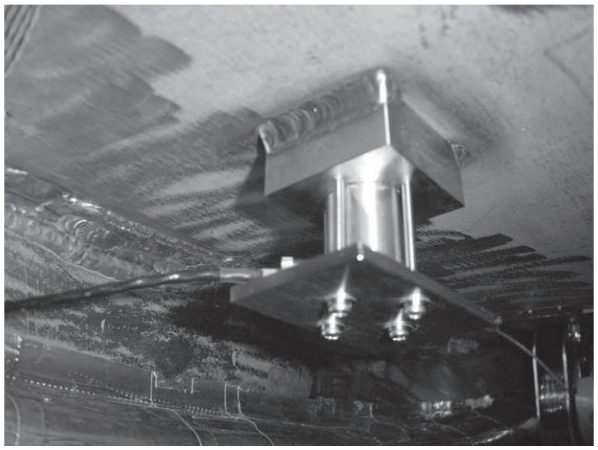

Fig. 1. The attached AE sensor on the helical coil vessel.

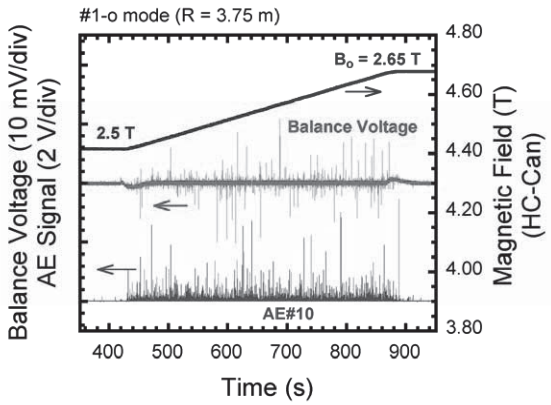


Fig. 2. The balance voltage and the AE signal in an excitation test at toroidal field of 2.5～2.65 T.

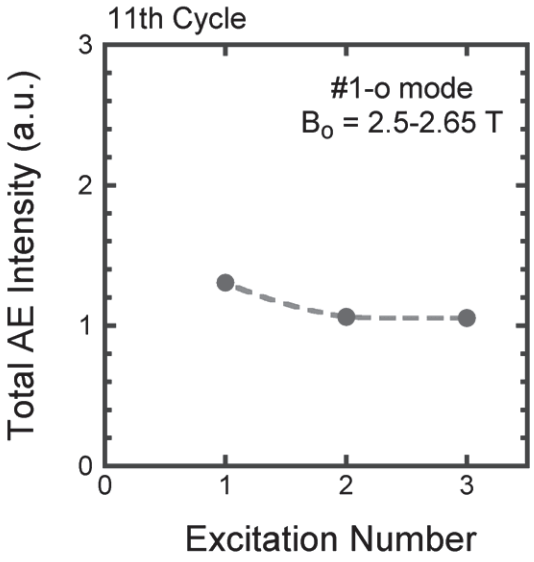


Fig. 3. The variation of the integral value of the AE signal with the number of the excitation in the excitation test at toroidal field of 2.5～2.65 T.