§ 1. Observation of the Propagation of a Normal-zone in the LHD Helical Coils by Pick-up Coils

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The propagation and recovery of normal zones have been observed several times in the LHD helical coils [1]. In order to detect the position of the induced normal zone, pick-up coils were installed on the top cover of the helical coil, as shown in Fig. 1, after the fourth campaign. Those are arranged by the pitch of 30 degree of the poloidal angle at the right or left side alternately to evaluate the position of normal zones along and inside the helical coils. The pick-up coils are designed to detect the change of magnetic field by current transfer between the superconducting strands and an aluminum stabilizer at the front and end of a normal zone. The turn number of the pick-up coil is 10,000. The output of each pick-up coil on the H1 coil is balanced by that on the H2 coil at the opposite toroidal angle. The balance voltages are acquired by the sampling rate of 50 Hz with the low-pass filter of 30 Hz.

In the sixth campaign, the propagation of normal zones has been induced seven times that are the 10th to 16th propagation from the first campaign. The position and the velocity of the propagation were detected successfully. All the seven normal zones were listed in Table 1. The 10th normal zone was initiated at the bottom of #10 section. The following four normal zones were initiated at the same or near position. The 15th and 16th normal zones were induced in the reverse excitation at the bottom of #5 section. All the seven normal zones propagated in one side, which is the downstream of the transport current, with recovery at the opposite side. The asymmetry of the propagation velocity is considered to be caused by electromagnetic interaction between the transfer current and the magnetic field.

The outputs of the right pick-up coils for the 14th and 15th normal zones are shown in Fig. 2. The outputs of the left pick-up coils are almost half of the right coils. Therefore, the normal zones were initiated at the right side inside the helical coils, where the magnetic field becomes higher at the inside and bottom position. The ripple of the field in a pitch is about 0.4 T. Figure 2 shows that the propagation of the 14th normal zone stopped at the top of the next pitch, which is the lower field area. The 10th to 13th normal zones also stopped at the top position within a pitch; that is, the propagation length is almost the half pitch. On the other hands, the 15th and 16th normal zones propagated almost three pitches and stopped near the layer to layer joint, which is located at the outside of the torus. The propagation velocity was 7 to 9 m/s. It becomes faster at higher currents. In the reverse excitation, the normal zones propagated beyond one pitch in spite of relatively lower currents. The reason is not clear. The cryogenic stability of the H2 coil might be less than H1 coil, or the direction of propagation to the distribution of magnetic field might affect the dynamic heat balance.

Reference

1) S. Imagawa, et al., IEEE Trans. Appl. Supercond., Vol. 11 (2001) 1889-1892.

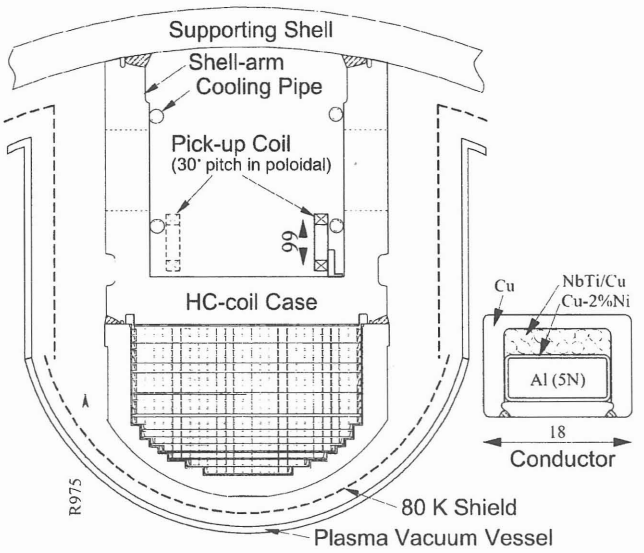

Fig. 1. Setting of pick-up coils for LHD helical coil.

Table 1 Propagation of normal zones in the 6th cycle.

No.	Mode	Current (kA)	Coil	Position	Date
10th	#1-c_R4.1 m	11.16	H1-I	#10	'02/9/27
11th	#1-o_γ1.258	10.94	H1-I	#10	'02/11/6
12th	#1-o	11.04	H1-I	#10	'02/11/28
13th	#1-o	11.15	H1-I	#10	'02/12/6
14th	#1-d	11.30	H1-I	#10	'02/12/12
15th	#1-c	-11.08	H2-I	#5	'02/12/25
16th	#1-o	-11.11	H2-I	#5	'03/2/5

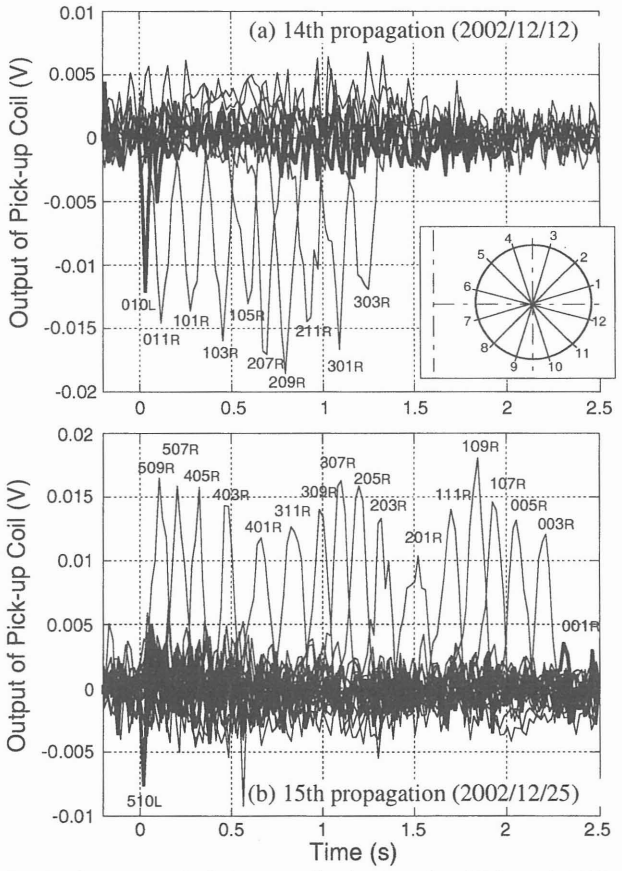

Fig. 2 Outputs of pick-up coils during the 14th and 15th propagation of a normal-zone. Numbers of three figures mean the sector and the poloidal position of the coils.