§8. Temperature and Field Dependence of the Normal Zone Propagation Velocity of the LHD Helical Coil

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In the previous studies, we carried out the transient stability tests of the small test coil wound by the helical coil conductor of the Large Helical Device (LHD) cooled by pressurized He I and He II. It was confirmed that the stability limit current of the conductor with He II cooling was improved by factor 1.5 or 2 compared to helium I cooling. However the dynamic one-side propagation phenomenon of a traveling normal zone initiated by a certain thermal disturbance was observed in wider current area below the quench current at the lower liquid helium temperature. This phenomenon has been observed in the tests with original LHD conductor cooled by He I.

To clarify the phenomena, we carried out the experiment and have also developed the numerical code to predict the dynamic one-side propagation of LHD conductor cooled by saturated, sub-cooled and superfluid helium.

The propagation velocities of the normal zone with finite size were evaluated by the tap voltage change with time. Square symbols (Dashed line) in Fig.1 shows experimental results of the asymmetrical propagation velocity of “traveling normal zone” as a function of transport current with T_b=2.0 K. The normal zone diminished with 12 kA of transport current. The one-side propagation was observed with 13.5 and 15.1 kA and the both side propagation was observed with 16.8 kA. The slow side propagation velocity was less than half of the fast side one.

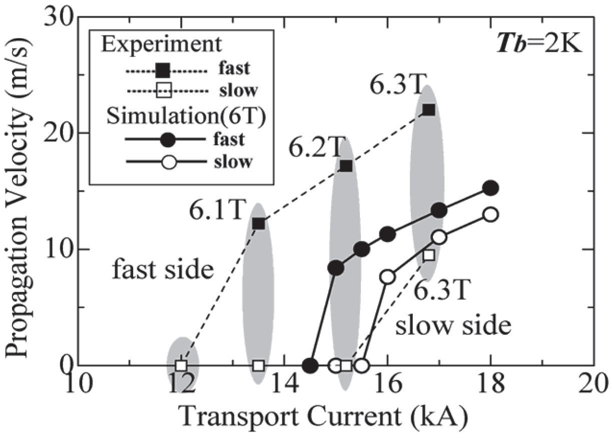
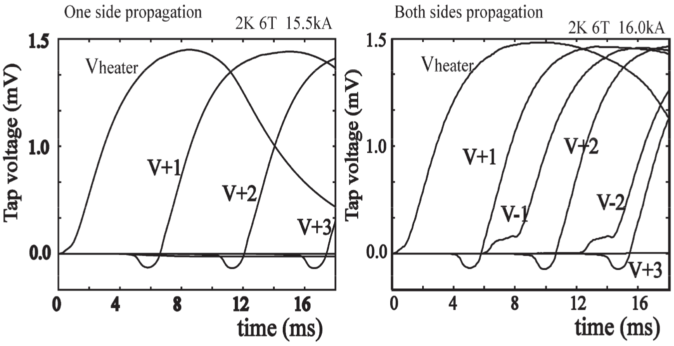


Fig. 1. Asymmetrical propagation velocity of “traveling normal zone” for the transport current. (Experimental and simulation results: T_b=2.0 K HeII)

With these experimental results, it was expected that the asymmetrical propagation velocities of the traveling normal zone were due to the Hall current distribution inside the conductor. However, because it is difficult to measure the Hall current, the simulation study to investigate the electro-magnetic transient behavior inside the conductor was carried out.

Simulation results of the tap voltage change with time were shown in Fig. 2 (a) one-side propagation (*I*=15.5 kA) and (b) both-side propagation (*I*=16 kA). The subscript +x of V denotes faster side tap voltage and the subscript –x denotes slower side one. Fig. 2 (a) expressed corresponding experimental results well. The back swing was observed at the beginning of rising up in both simulation and experimental tap voltages. This is due to the eddy Hall current flowing through the copper sheath near the normal front.

The propagation velocity was also calculated using the tap voltages of the simulation results and the experimental ones. One-side propagation and asymmetric both-side propagation were also seen in the simulation results. However, the fast-side propagation velocity was smaller than those in the experiments. It is supposed that the more detailed simulation model of the conductor, especially the Rutherford cable is needed for precise evaluation of the propagation velocity.



(a) (b)

.Fig. 2. Simulation results of the tap voltages. (a) one-side propagation (*I*=15.5 kA), (b) both-side propagation (*I*=16 kA). (*Tb*=2 K, *Bo*=6 T)

The asymmetrical propagation of the traveling normal zone under various test conditions was investigated based on the experimental and simulation results in order to find a clue to the elucidation of this phenomenon.

Asymmetric propagation velocity of the normal zone was caused by the asymmetric Hall current distribution due to the Al stabilizer of asymmetric configuration.

1) Y. Shirai ,R.Ikuta, T. Goto, M.Ohya, M. Shiotsu, and S. Imagawa, *IEEE Trans. Appl. Supercond.*, (in press)