§7. Effect of Disturbance Duration on the Normal Zone Propagation of the LHD Helical Coil

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The helical coil conductor of Large Helical Device (LHD) has an asymmetric configuration in cross-sectional area. In the previous studies, we carried out the transient stability tests of the small test coil wound by the conductor cooled by pressurized He I and He II. The stability limit current of the conductor was improved by He II cooling by factor 1.5 or 2 compared to He I cooling. However the dynamic one-side propagation of a traveling normal zone was observed in wider current area. This phenomenon has been observed in the helical coil during the LHD tests with He I.

In order to clarify the transient stability of the LHD conductor precisely, and to propose a standard for stability valuation of large-scale superconducting magnets, we developed a 2-dimentional analysis code for the LHD conductor in which the Hall effect is taken into consideration. The simulation code successfully showed the asymmetrical dynamic normal zone propagation, but the traveling velocities could not be exactly simulated [1]. The other factors that can not be considered in the 2-D analysis, such as transversal Hall current in the cross-section of conductor, are assumed to be the cause.

Then a 3-dimensional analysis code was developed [2]. The transport current, the hall current and joule heat and temperature distribution are calculated with an analytical 3-dimensional LHD conductor model as shown in Fig.1. The mesh dimension for calculus for finite difference are dx =0.44mm ×20mesh (8.8mm), dy= 0.22mm ×57mesh (12.54mm), dz =1.0mm ×200mesh (200mm). The simulated heat input is applied at the bottom-center of the conductor model.

One of the simulation results are shown in Fig.2. Fig.2-(a) shows hall current distribution and Joule heat density presented in contour in half cross-section of the conductor at 0.3 ms after pulse heat injection. The result shows that the hall current flows around the boundary between the Rutherford cable and copper sheath.

Fig.2 (b)-(d) shows also the Hall current and the Joule heat density in the longitudinal cross-section of the position x indicated by the dotted line. Complicated distribution in the Hall current can be seen not only center cross-section. The 3-D simulation code also successfully presents the asymmetrical dynamic normal zone propagation. The traveling velocities, however, can not be exactly simulated. It can be said that asymmetrical Hall current distribution causes asymmetrical normal zone propagation, but more detailed simulation model of the Rutherford cable should be necessary.

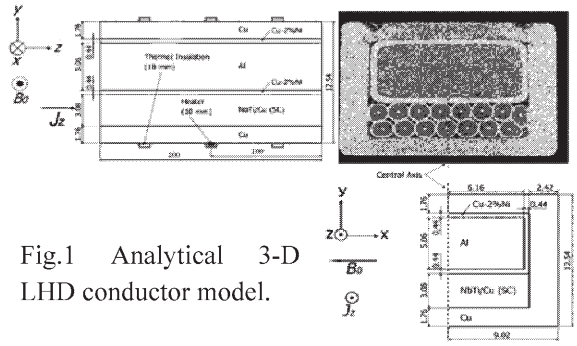

Fig.1 Analytical 3-D LHD conductor model.

1) Y. Shirai ,et. al., *IEEE Trans. Appl. Supercond.*, Vol.18, No.2, pp.1275-1279, June 2008.
2) H.Kobayashi, et.al., the papers of technical meeting, IEE Japan, ASC-09-24, 2009.

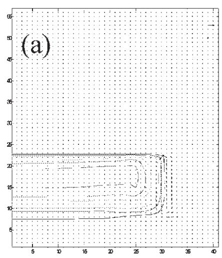

Fig.2. Hall current distribution in arrows and Joule heat density in contour lines after 0.3 ms from the initiation of the heat input.
(a) transversal cross-section
(b)-(d) longitudinal cross-sections

(b)
(c)
(d)