§9. Evaluation of Transient Stability for the Helical Coils of LHD

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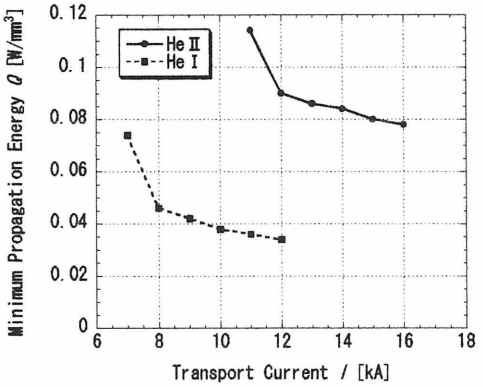
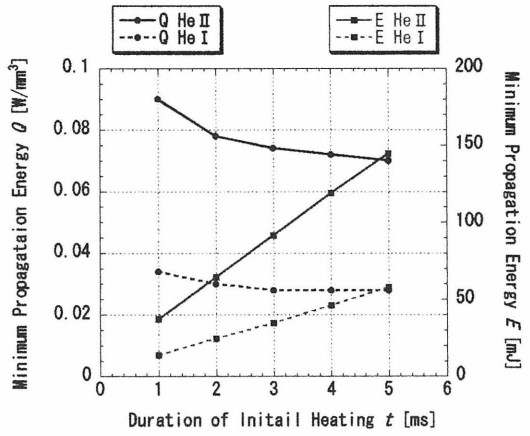
In the case of the transient stability analysis of large superconductors stabilized aluminum whose electrical resistivity is much lower than that of copper, it is pointed out that the effect of current diffusion in the cross-sectional direction of the conductor can't be ignored. To investigate the transient stability, we have been developing a computer code based on the finite element method analysis of the transient thermal and electromagnetic behaviors of large aluminum stabilized superconductors. We adopted two-dimensional analysis in the longitudinal direction of the conductor for thermal and current diffusion. We investigated the transient stability affected by the coolant (lq.He), the Hall current generation, the cross-sectional area ratio of Al to NbTi/Cu region, and so on.

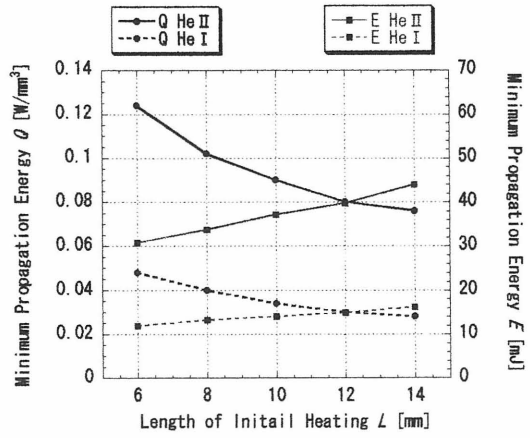
We have developed a computer program of two-dimensional finite element method due to electrical and thermal problem for transient stability of the helical coils of LHD. And the results of numerical computation agreed with that of the short sample experiments for the helical coils of LHD. We investigated the minimum energy, which caused to propagate the front of the normal region to the longitudinal direction. This energy is called the "minimum propagation energy", and we investigated this minimum propagation energy from the point of view of the transient stability. Consequently, we confirmed that the normal front propagated to the longitudinal direction when the length of normal region became the constant length. Otherwise, the normal region disappears. This constant length of normal region depends on external magnetic field and current, and doesn't depend on amount, duration and length of initial heat input. The external magnetic field is the larger, the amount of the initial heat is the smaller in order to propagate the normal front. And we confirmed that there is possibility that the very small amount of the initial heat cause to propagate the normal front at 11kA, 6T especially. Under such operating conditions, it is necessary to enhance the transient stability of the helical coils of LHD since the normal front propagates even if the small normal region appears. Accordingly, we investigate whether the thermal margin by using He-II affects the transient stability of the helical coils of LHD. We estimated the transient stability under various operating condition, e.g. external magnetic field, different and amount, length and duration of the initial heat. As a result, we confirmed that He-II causes to enhance the transient stability. And we investigate whether the transient property of heat transfer or the temperature of He-II gives the large effect on the transient stability. Of course, both affect the transient stability. However, the thermal margin of He-II temperature is more effective than the heat transfer. Moreover, we confirmed that under He-II operating condition the normal region disappears if the initial normal region is small. And the normal front propagates to the longitudinal direction when the length of normal region becomes the constant length. This constant length of normal region depends on external magnetic field and current, and doesn't depend on amount, duration and length of initial heat.



a) Minimum Propagation Energy vs. Transport Current (External Magnetic Field7T).



b) Minimum Propagation Energy vs. Duration of Initial Heating.



c) Minimum Propagation Energy vs. Length of Initial Heat.

Fig.1 Minimum Propagation Energy under some Conditions