§15. Mechanical and Stability Analysis of a Cable by Numerical Simulation

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1.Introduction

The Large Helical Device (LHD) has been operated since 1998 in National Institute of Fusion Science in Japan and the performance of the poloidal coils constructed of CIC conductors have been evaluated. It has been found that the change of pressure loss with the number of excitation time and the loss that cannot be explained by electromagnetic phenomena are induced.

In this work, Using Monte Carlo method the mechanical behavior of strands during the magnet operation was analyzed. The experimental results obtained in LHD were compared with the calculated results. The effect of the strand motion on the characteristics of the CIC conductor is discussed.

2. Calculation method

The calculation is made by Monte Carlo method. The each strand in CIC conductor is divided into meshes and the position of mesh, which gives the minimum potential energy, is calculated. In order to obtain the positions, each mesh is moved small distance decided by the random number and then the potential energy is calculated. The potential energy before and after movement is compared. When the potential energy after the movement is lower than that before, the strand positions are renewed as the more stable positions. When the potential energy after the movement is higher than that before, the probability appear the state is calculated and obeying the probability the new position is accepted. The procedure is performed in all meshes. The procedure is continued until the potential energy comes to be minimum. From the strand positions in the equilibrium state, the contact stress and frictional heating between strands could be calculated.

3. Conclusion

The strand motion during energizing is calculated by means of the Monte Carlo method. The cable is encapsulated in the conduit and the void fraction is set at 38%. The mechanical loss was calculated by summing the frictional loss between strands. The losses between the strands and the conduit were also added.

The results are presented in Fig.1. In this figure the transport current is also shown. It is found that the mechanical loss increased suddenly at the certain current level. This current corresponds to that where the electromagnetic force exceeds the frictional force and the strands start to move macroscopically. Fig. 2 shows the result of the loss measurement in IV coil. The transport current is also shown in this figure. The loss measurement was performed when only the IV coil was energized. The loss was estimated from the enthalpy difference between the inlet and the outlet of the CIC conductor. The maximum transport current was 15.6KA and the maximum field at the current was 4T. The solid line presents the measured losses. The broken line shows the calculated AC losses, which is sum of hysteresis and coupling loss. The difference between the calculated and the measured loss is the loss that cannot be explained by the electromagnetic phenomenon. The loss comes to be high just before the maximum transport current. The generation of the loss is very similar to the calculated result shown in Fig.1. It strongly suggests that the loss is originated from the mechanical disturbances due to the strand motion.

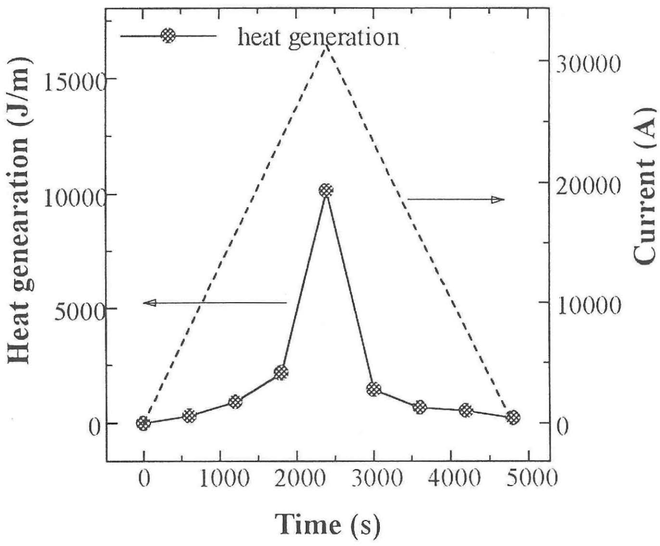

Fig.1.Mechanical loss during charging-discharging process

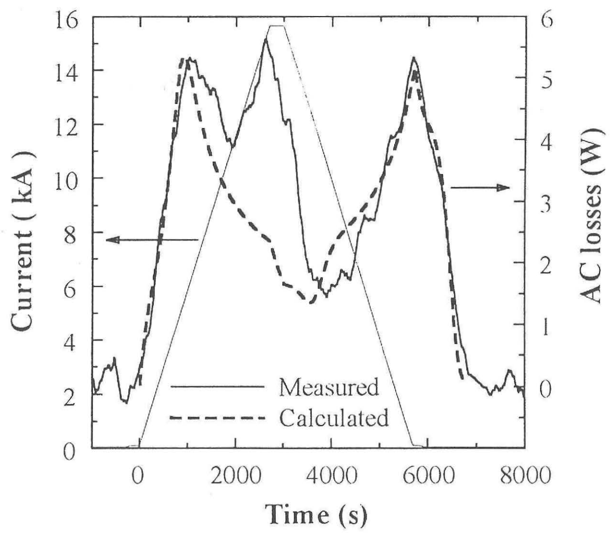

Fig.2. AC loss evaluated from the enthalpy in IV coil