§5. Computer Simulation of Mechanical Properties and Stability in a Conductor for Large Superconducting Magnets

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1. Introduction

CIC Conductor is indispensable for large superconducting magnets from the point of view of the cooling ability, the mechanical intensity and coil rigidity, structure of insulation. However, the quantitative discussion about the disturbance like frictional heating induced by strand motion, AC losses and current imbalance, which are related to the instability of CICC has not made as the behavior of strands during energizing has not been clarified. In this work, analyses were carried out by Monte Carlo method in order to evaluate the stability in CICC. The mechanical behavior and stable position of strands during the energizing and discharging and the distribution of contact stress and strand motion were calculated.

2. Calculation method

In this analysis, the each strand was divided into meshes and the position of each mesh which gives the minimum potential energy of the system were calculated. Each mesh was moved a short distance ($\Delta X, \Delta Y$) decided by the random number and then the potential energy was calculated. The before potential energy and after potential energy were compared. When the potential energy after the movement was lower than that before, the strand positions were renewed as the more stable positions. This procedure was performed in all meshes, and one run was called '1 Monte Carlo Time'. This process was continued until the potential energy came to be stable. The energies considered in this work were 1) 'Est', the strain energy induced by the stretched strand, 2) 'Ebend',the strain energy induced by the bended strand, 3) 'Econtact', the strain energy between strands due to strand deformation in radial direction, 4) 'Ereact', the strain energy between strands and conduit, 5) 'Eelect', the electromagnetic energy, respectively. The energy was defined as the potential energy of whole cable. The strain energy induced by the sharing strand was considered when the strands in contact were moved relatively.

3. Conclusion

CICC that was set the void fraction at 38% was made in computer, and the strand position was established as initial position before energizing. Each strand position during charging and discharging three times was calculated by Monte Carlo method and the strand motion was simulated. Fig1 shows the distribution of the contact stress before, during, after charging. Compared with the peak of the contact stress before 1st charging, the peak during 1st charging shifts to higher stress region with energizing. It shows that the stress distribution after 1st discharging is different from that before charging. This indicates that the rearrangement of strand position is induced. Compared with that after 1st discharging, the frequency of contact during 2nd charging increases at higher stress region. However comparing with that during 1st charging, the frequency of contact during 2nd charging is lower stress region. It is suggested that the AC losses in the system are changing together with the number of energizing. Fig 2 shows the strand motion during charging and discharging. The Y-axis in Fig 8 represents the square of transport current 'I^2' that was proportional to the Lorentz force. Each strand moved suddenly when the Lorentz force becomes higher than the static frictional force. The mechanical losses were caused by the hysetresis loops of the strand motion during charging and discharging. As the number of charging increases, the mechanical loss decreases. These results are caused by training effect and reproduce the practical behavior in CICC.

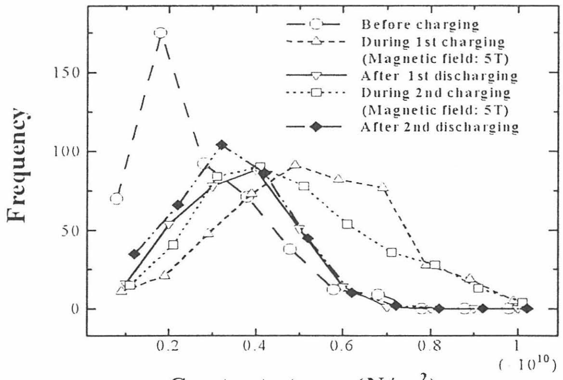

Fig. 1.Distribution of contact stress between strands

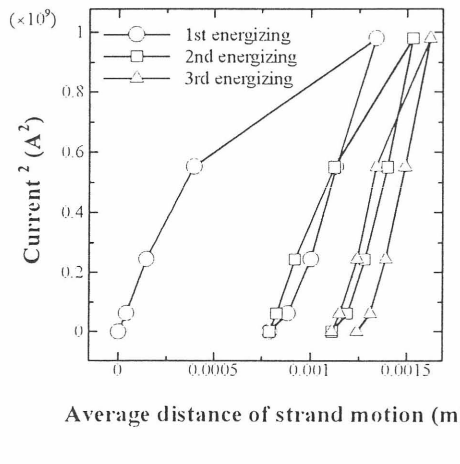

Fig.2.Strand motion during charging and discharging

References

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