Study on cause of quench at joint between multifilamentary superconducting cable and copper plate using 3-D FEM

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STUDY ON CAUSE OF QUENCH AT JOINT BETWEEN MULTIFILAMENTARY SUPERCONDUCTING CABLE AND COPPER PLATE USING 3-D FEM

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1. Introduction

In the ac superconducting electrical machine, the superconducting cable is connected with the normal conducting copper wire through a copper plate. If the ac current is increased, the quench occurs at the joint. As a resulut, the rated current of the superconducting electrical machine is limited to a smaller value than that of ac superconducting cable itself. Since the superconducting cable is multifilamentary, it is difficult to analyze 3-D current distribution at the joint. Therefore, the cause of quench was not clear.

Since 3-D numerical method for analyzing the twisted multifilamentary conductor has been developed by us [1], the current distribution is calculated taking into account of eddy current. It is found out that the cause of the quench is the extreme concentration of current at the joint due to the remarkable skin effect in the copper plate under liquid helium temperature.

2. Analysis

The current distribution in the copper plate shown in Fig.1(a) is analyzed. The conductivity of the copper plate is 5×10^9S/m(at 4.2°K). The twist pitch of the superconducting cable is 31.5mm. The effective value of the applied ac current is equal to 4500A. The multifilamentary superconducting cable is treated as macroscopic one having anisotropic conductivity[1]. 3-D distributions of applied current and the eddy current are analyzed independently. The distribution of the total current is obtained by superposition. Since the extremely fine mesh is required near the surfaces of the copper plate and superconducting cable at 50Hz due to the skin effect, the current distribution at 2Hz is analyzed. Fig.2 shows the boundary conditions.

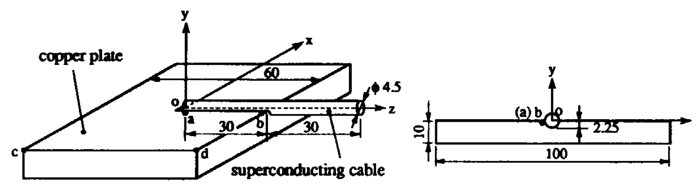
3. Results and Discussion

Fig.3 shows the current distribution at a cross section of the copper plate. Fig.4 shows the current distributions near the surface of the copper plate. Fig.5 shows the distribution of the maximum value of the x-component Jx of the current density which flows into the superconducting cable from the copper plate along the line a-b(x=-2.25, y=0) in Fig.1. In the case of dc($\sqrt{2}$x4500A), Jx at the point a is larger than that at the point b. On the contrary, when the frequency is increased, the current is concentrated near the point b as shown in Fig.4 due to the skin effect, because the conductivity is very high(5×10^9S/m) under liquid helium temperature.

The effects of the shape and size of the copper plate, and twist pitch and conductivity of the superconducting cable will be shown in the full paper.

Reference

[1] N.Takahashi, T.Nakata, Y.Fujii, K.Muramatsu, M.Kitagawa and J.Takehara: "3-D Finite Element Analysis of Coupling Current in Multifilamentary AC Superconducting Cable", IEEE Trans. Magnetics, MAG-27, 5 (1991).



(a) whole view (b) x-y cross section

Fig.1 Analyzed model.

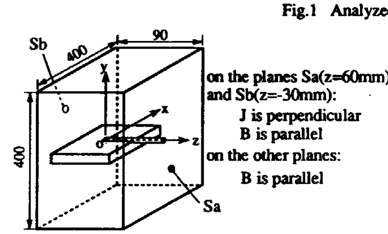


Fig.2 Boundary conditions.

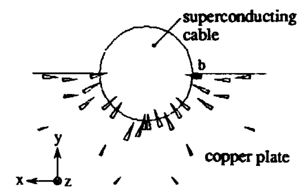
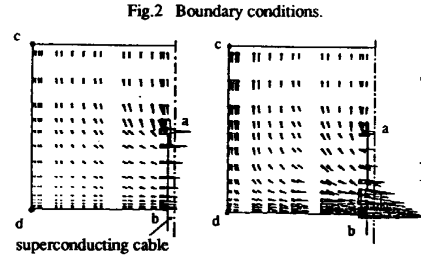


Fig.3 Current distribution at a cross section of the copper plate (2Hz, z=29.8mm).



(a) dc (b) ac (2Hz)

Fig.4 Current distributions near the surface (y= -0.3mm) of copper plate.

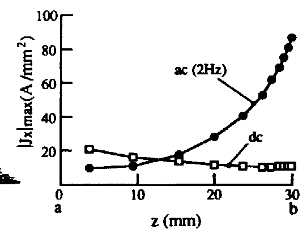


Fig.5 Current density flowing into superconducting cable.