WBP4-1

Evaluation of Critical Current Superconducting Junction with a Crack by Using FEM

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The junction of the superconducting wires is considered to exhibit a current density distribution different from that of normal superconducting wires, and a stress distribution when receiving a force. Understanding them is essential in designing an applied device. When the junction receives an external force, damage such as cracks may occur. The current density distribution should also be considered when the superconductor wire is defective.

In this study, in order to clarify the electrical and mechanical properties of the junction of superconducting wires, the junction is numerically simulated using the finite element method (FEM) (the simulation tools are JMAG-Designer 17.0 and COMSOL Multiphysics®), and electrical and mechanical properties were evaluated.

We used a 1 µm thick YBCO superconducting film to act as a superconducting wire and jointed two such films together for current density simulation. The analysis was conducted from the left of the model by passing current, calculated using the finite element method, and revealed the current density distribution of the cross section. As shown in Fig. 1, the calculation in the case where there is a crack in the film in the vicinity of the junction was similarly performed. Magnetic field dependence of the critical current density is based on the experimental results of $YBa_2Cu_3O_{7-\delta}$.

Fig. 1 shows the flow direction of the current around the crack. The current density is concentrated on the other side of the crack, which makes the critical current of the superconducting film small. In other words, the maximum current that the superconducting wire can withstand becomes smaller.

Fig. 2 shows the *E-J* characteristics on the superconducting film with various crack width. It is found that the critical current is drastically reduced by increasing the width of crack.

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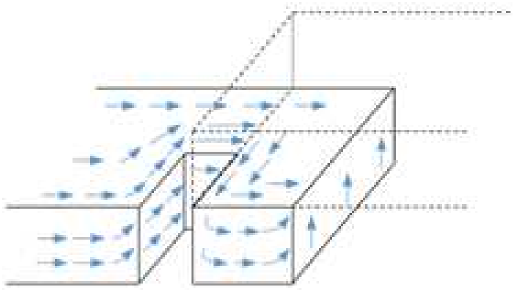

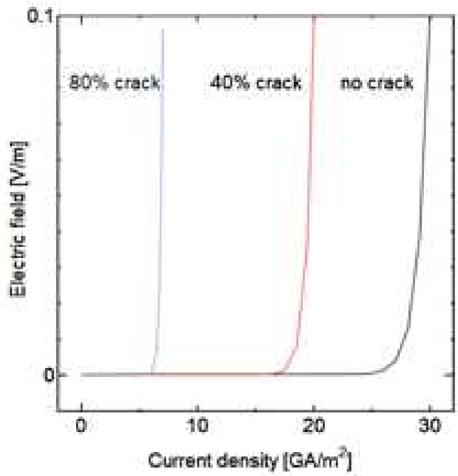

Fig. 1 Superconducting layer with a crack. The arrows indicate the direction of current density.
Fig. 2 *E-J* characteristics on the superconducting film with various crack width.

Keywords: Critical current density, Superconducting joint

WBP4-2

Peculiarities of dissipative phenomena in coated YBCO tapes carrying constant current during flux creep

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The effect of flux creep on the dissipation phenomena in tapes based on YBCO leading to the essentially nonlinear voltage-current characteristic of a superconductor is discussed. The obtained results are compared with the calculations, made in the framework of the existing thermal stabilization theory based on the model assuming jump transition from a superconducting state to a normal one. It is shown that this model incorrectly describes the dissipation states in a temperature range up to the critical temperature of the superconductor. It is shown that the type of nonlinearity of VCC has a significant effect on the dissipative phenomena in tapes. As a result, the allowable currents stably flowing in superconducting tapes may be higher than a priory defined critical current determined for continuously increasing voltage-current characteristic. Therefore, the critical current of high-T_c superconducting tapes, which is determined using continuously increasing voltage-current characteristic, has no physical meaning. Accordingly, fundamentals of the thermal stabilization theory must consider real temperature dependence of the dissipation energy in high-T_c superconducting tapes, which is a function of nonlinearity of their voltage-current characteristic.

WBP4-3

Numerical Study on AC Loss Properties of Two-Layer REBCO Power Cable by 3D Finite Element Method

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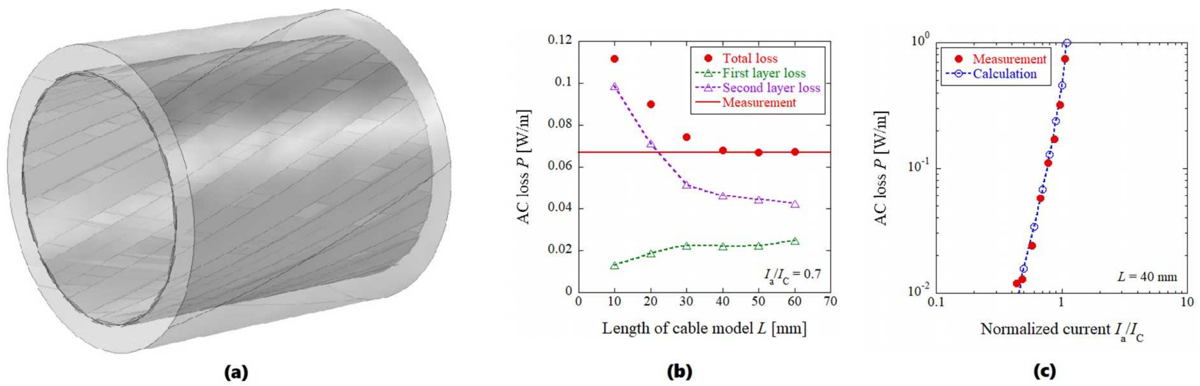
This study investigates the loss properties in a two superconducting-layer REBCO power cable fabricated by researchers at Furukawa Electric Co. Ltd. The losses were calculated by a three-dimensional finite element method (3D FEM) using COMSOL, which is based on H formulation without the thin-strip approximation of the superconductor. Fig. (a) shows the cable model which has the helical pitches of first layer and second layer are 340 mm (S-direction) and 280 mm (Z-direction), respectively. Fig. (b) plots the losses as functions of length of the cable model, fixing the normalized current $I_a/I_C = 0.7$. Here, I_a and I_C are transport current and critical current of the cable. As the length of cable model L is too short, a layer current of the outer layer is calculated as high, then a layer loss of the outer layer is obtained as high. Therefore, a total loss becomes large in comparing with a measurement. To get an accurate calculation, it is found that the L should be longer than 40 mm in this cable. Fig. (c) plots the total losses of the cable as functions of I_a /I_C, fixing L = 40 mm. As cab be seen, the calculated value is almost equal to the measurement.
Fig. (a) Model of two-layer cable, (b) AC losses versus length of cable model, (c) Comparison with measurement and calculation of AC loss of two-layer cable.



Keywords: AC loss, REBCO power cable, 3D FEM, EC model

WBP4-4

Evaluation of SUperconductive Assisted Machine (SUAM) with Superconducting Coated Wires using Finite Element Method

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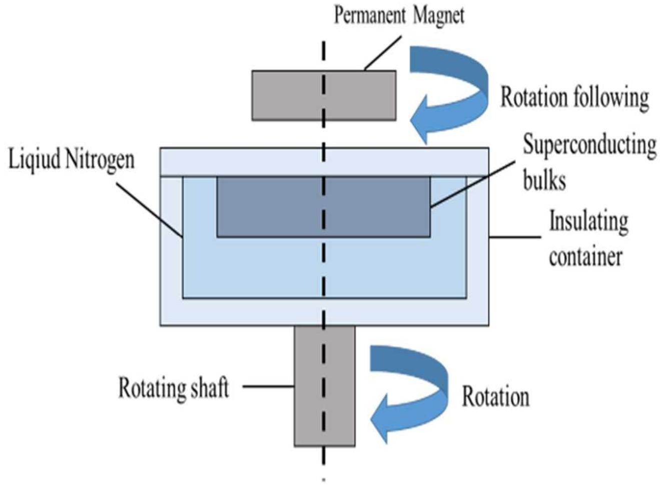
Various processing methods are used including lathe processing and magnetic polishing. At the present time, it is difficult to apply the hollow processing method to complicated shapes due to the restriction of the interference of tools as machining. In order to solve these problems, we have developed SUperconductive Assisted Machining method (SUAM) using the flux pinning phenomenon of bulk superconductors as shown in Fig.1. This SUAM is composed of a single-sided four-pole permanent magnet and a superconducting bulk, and is a method utilizing magnetic levitation that occurs when cooled in a magnetic field with the permanent magnet held in the air. In this method, the superconductor receives attractive, repulsive, restoring and driving forces. In this study, we evaluate these performances of the superconducting coated wire numerically using the finite element method, and compare with the superconducting bulk at each force.
We use JMAG to calculate by FEM, and use an *n*-value model to calculate the *E*-*J* characteristics. We use the experimental result of $GdBa_2Cu_3O_{7-\delta}$ superconducting bulk for the bulk and the experimental result of $YBa_2Cu_3O_{7-\delta}$ for the superconducting wire for the magnetic field dependence of the critical current density. We bring a 450 mT permanent magnet close to the superconducting bulk or superconducting wire at a speed of 0.1 mm/s. We make the superconducting wire into a laminated structure and calculate the total force of the force received by laminating 2 μm thick superconducting 20 layers.
Fig.2 shows the difference in repulsive force between the superconducting bulk and the superconducting coated wire. The repulsive force increases as decreasing the distance to the permanent magnet. As a whole, the superconducting coated wire has a smaller repulsive force than the superconducting bulk. About the attractive force and the rotational torque, the superconducting bulk similarly gives larger force. It is considered that a larger force can be obtained by increasing the number of superconducting coated wires.

This work was partly supported by JSPS KAKENHI Grant Number 19H00771.



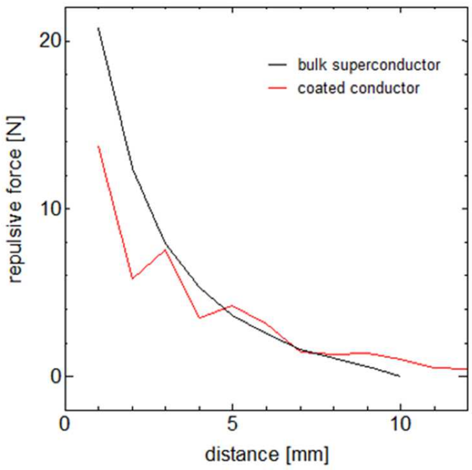


Fig.1 SUAM(SUperconducting Assisted Machine)
Fig.2 Difference in repulsive force between bulk supercondcting and coated conductor

Keywords: FEM, SUAM, magnetic levitation, coated conductor

WBP4-5

3D Numerical Study on Magnetization Losses in Twisted Soldered-Stacked-Square (3S) HTS wires

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Magnetization loss is an important parameter in the design of high temperature superconductivity (HTS) power devices. In order to reduce magnetization loss, a novel soldered-stacked-square (3S) HTS wire with 1 mm width is firstly proposed and manufactured by our group. In previous work, numerical and experimental results have shown the magnetization loss in the 3S wire is one order smaller than that in the original 4 mm tape with similar critical current under perpendicular magnetic field. However, unexpected large eddy current loss and coupling loss will be generated under parallel field. Therefore, the 3S wire has been twisted in this paper to further reduce the magnetization loss. Firstly, a three-dimensional (3D) numerical model is built for calculating the magnetization loss of the twisted 3S wire. Then, the frequency dependence and structure dependence of the twisted 3S wires are also been evaluated. Finally, the magnetization loss in the twisted 3S wire are compared with that in the original 3S wire to verify whether twisting could reduce the magnetization loss.

Keywords: 3D numerical model, 3S wires with 1 mm width, magnetization loss, twisting