Electromagnetic coupling between filaments in multifilament coated conductors with finite transverse conductance

- Comparison between numerical analyses and experiments in various systems -

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***Abstract*—Electromagnetic coupling between filaments in multifilament coated conductor with finite transverse conductance between filaments was studied numerically and experimentally. We are particularly interested in coupling time constants. The important characteristics of the conductors such as finite electric field – current density characteristics as well as transverse conductance can be determined by the comparison between calculated and measured temporal behaviors of magnetic fields and coupling time constants. The analyzed and measured object include short pieces of conductor, pancake coil, and cables.**

Keywords—coated conductor, coupling time constant, multifilament, transverse conductance

I. INTRODUCTION

One of the drawbacks of coated conductors is their wide tape shape which generates large shielding-current-induced fields (SCIFs) and large AC losses. The striation of superconductor layer of a coated conductor to form filaments is a measure to decrease its SCIF and AC loss. Multifilament coated conductors can be classified into two types: one in which filaments are insulated electrically one another; one with a certain transverse conductance between filaments. The former is ideal for the reduction of magnetization, *i.e.* SCIFs and AC losses, but the latter is preferable from the viewpoint of current sharing between filaments, which improves stability and helps protection. In this presentation, we focus on the electromagnetic coupling between filaments of the latter. First, we review our numerical and experimental results from the viewpoint of key issues of numerical electromagnetic field analyses of multifilament coated conductor with finite transverse conductance. Then, we present our latest results mainly on such a conductor composing cables.

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II. KEY ISSUES OF NUMERICAL ELECTROMAGNETIC FIELD ANALYSES OF MULTIFILAMENT COATED CONDUCTORS WITH FINITE TRANSVERSE CONDUCTANCE

A. 3D Geometry of Thin Superconductor Layer of Coated Conductor

Even in a pancake coil, which is one of the coil with the simplest geometry, we have to consider its spiral structure as shown in Fig. 1 in its electromagnetic field analysis. Furthermore, in various practical applications, coil geometries are much more complicated. Therefore, the consideration of 3D geometries of thin superconductor layer of coated conductor is required essentially for their electromagnetic field analyses.

B. Finite Electric Field – Current Density Characteristics of Superconductors

When we look at the temporal behaviors of SCIF, the finite electric field (E) – current density (J) characteristics of superconductors at low electric field region are important. Such E – J characteristics at low E region cannot be obtained by transport measurements.

C. Transverse Conductance between Filaments

The transverse conductance between filaments is the critical parameter, which dominates the coupling time constant, but it is difficult to measure directly.

III. VARIOUS SYSTEM FOR ANALYSES AND EXPERIMENTS

A. Single Short Pieces of Conductor and Their Stack

We measured and calculated the frequency dependence of magnetization loss at small field amplitude using short pieces of a multifilament coated conductor, whose schematic cross section is shown in Fig. 2. Fig. 3 shows a model for its single short piece for numerical electromagnetic field analyses. When we plot the measured or calculated magnetization loss per cycle against frequency, the coupling time constant can be determined from the frequency which gives the peak of the curve. Through comparison between the coupling time constant obtained experimentally and numerically, we can determine the transverse conductance. Furthermore, measurements and analyses were conducted using stacks of short piece samples in order to study the effect of mutual coupling of coupling current, which may appear between coupling currents in adjacent turns of a pancake coil.

B. Pancake Coils

We wound a pancake coil using a monofilament coated conductor and placed it in a cusp magnetic field to apply the magnetic field normal to the coated conductor. From the temporal change of the magnetic field, which was affected by the shielding current, we could determine the $E - J$ characteristics at low E region: comparing the measured magnetic field with the calculated magnetic fields using various $E - J$ characteristics. Next, a similar experiment and analyses was conducted using a pancake coil wound with a multifilament coated conductor.

C. Cables

We proposed a new concept of cable which consists of multifilament coated conductor with finite transverse conductance. The measured and calculated electromagnetic behaviors of this cable will be presented.

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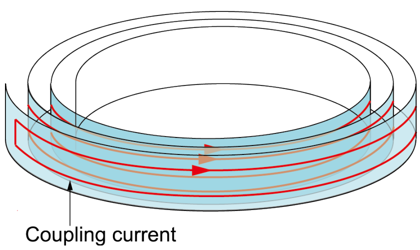

Fig. 1. Mutual coupling between the sections of the coupling current path in different turns of a pancake coil [1].

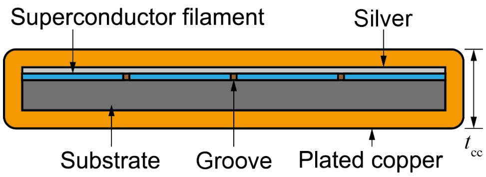

Fig. 2. Schematic cross section of striated coated conductor. The thickness of the coated conductor is t_{cc}. [1].

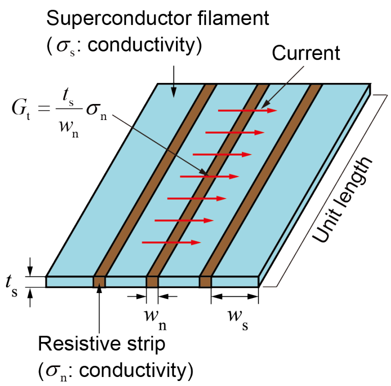

Fig. 3. Thin analysed layer consisting of superconductor filaments, whose width is w_s, and narrow resistive strips between superconductor filaments, whose width is w_n, for numerical electromagnetic analyses [1].

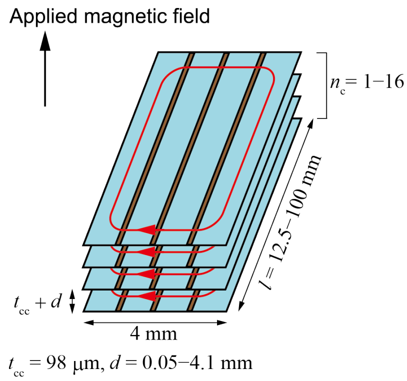

Fig. 4. Coupling currents in stacked striated coated conductors [1].

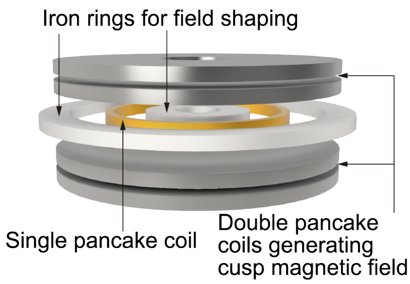

Fig. 5. Single pancake coil placed between two double pancake coils, which generate cusp magnetic field, with iron rings for field shaping [2]