Experimental Evaluation of Current Distribution in Three-Strand Transposed Parallel Conductors Composed of REBCO Superconducting Tapes

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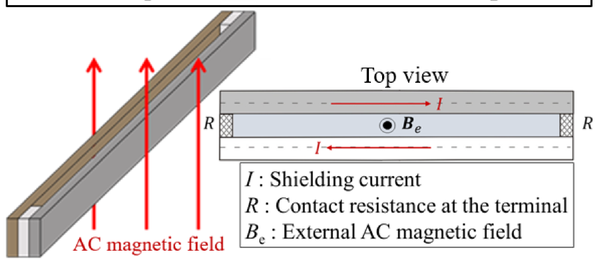
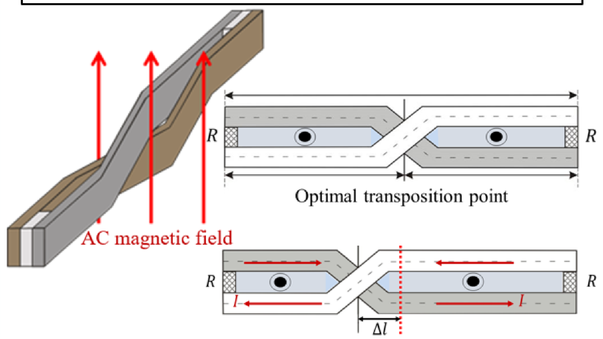
Introduction

Two-strand parallel conductor with **no transposition**



Two-strand parallel conductor with **transposition**



If transposition point deviates from optimal one, shielding current occurs, and additional AC loss generates.

Parallel conductor

- **Large current capacity** and **low AC loss properties** are required for AC applications using REBCO tapes
- **The configuration of transposed parallel conductors is an effective technique to increase the current capacity**

Current distribution

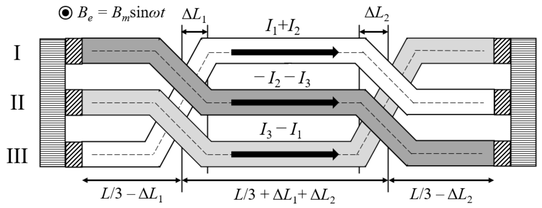
- Our recent study clarified **additional AC loss** properties of **three-strand** transposed parallel conductors, but understanding of current distribution was unsatisfactory
- Non-uniform current distribution disturbs large current capacity because **one of the strands can possibly reach the critical current (I_c) earlier than others**. As a result, that can increase additional AC loss rapidly

◆ **Understanding and predicting current distribution are essential for designing and manufacturing superconducting AC applications**

What we did

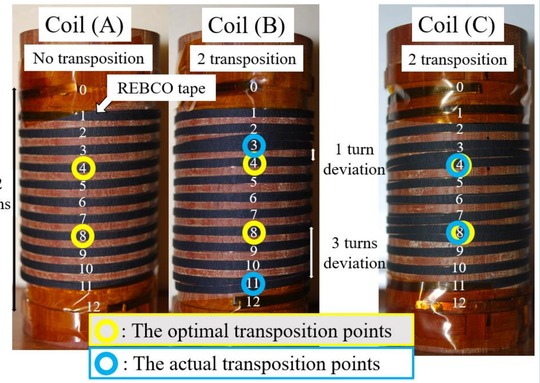
- Measuring the current distribution in REBCO three-strand transposed parallel conductors using Rogowski
- Comparing that with the calculation predicted using the theoretical expression derived in our recent study

Experimental Procedure

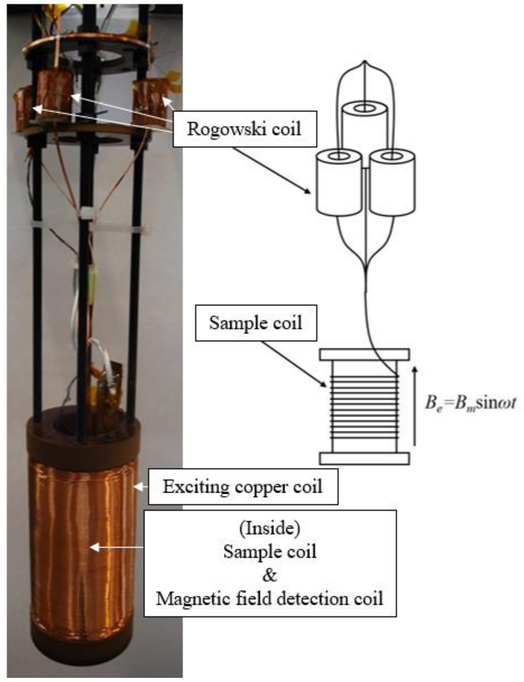


Three-strand transposed parallel conductor

In the case of **three-strand** parallel conductors subject to a uniform magnetic field, tapes should be transposed **twice** at equal intervals



Three insulated REBCO tapes are co-wound into a one-layer **solenoidal coil**



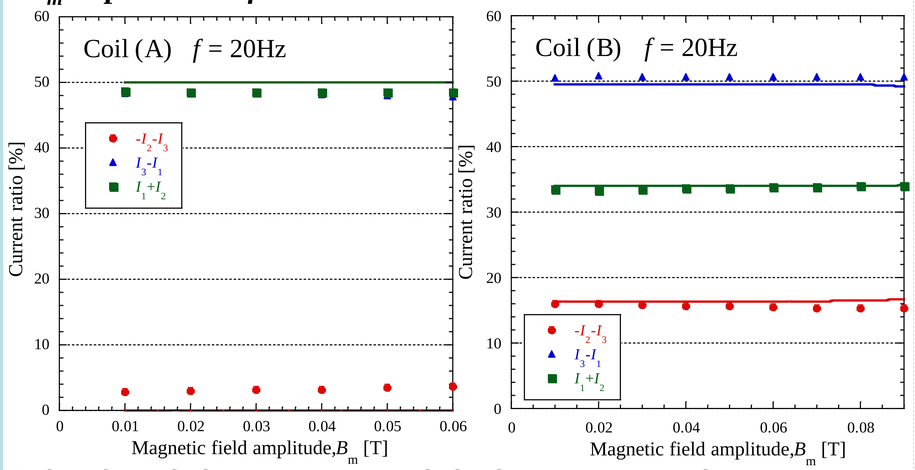
Current distribution measurement system

Sample coil is not energized in direct contact, and the current is induced only by the B_e

Results and Discussion

The calculated values were derived from the theoretical expression in our previous study and using a software system, "**Wolfram Mathematica**"

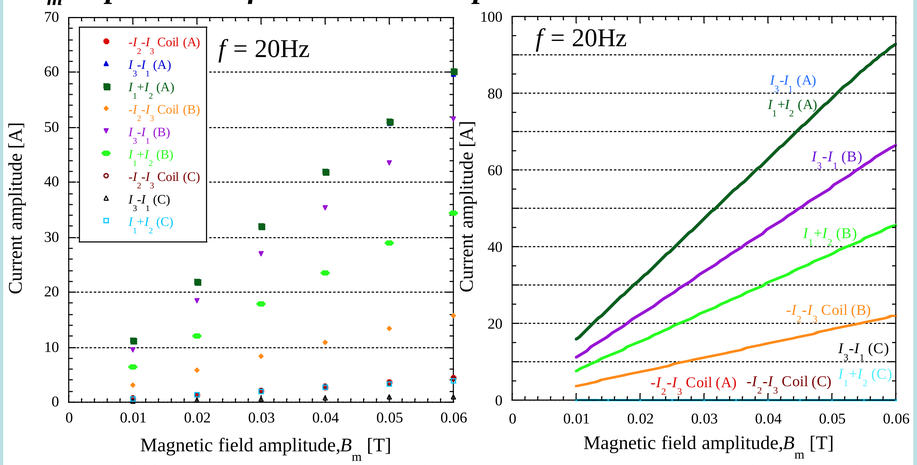
B_m Dependence of The Current Ratio



In the right graph, the current ratio was calculated as its transposition deviations are **1.3 and 2.6 turns** assuming they deviate from the right points (1 turn and 3 turns)

- The measured one roughly corresponds to the calculation
- The current ratio depended on the amount of the magnetic fluxes interlinking each closed-loop composed of the tapes, that is, **the inductances of the closed-loops**

B_m Dependence of The Current Amplitude

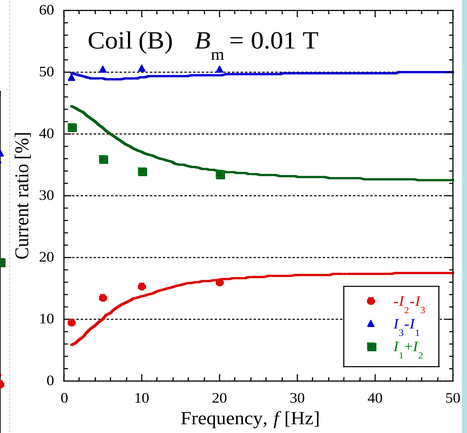


- The coil (C) current, which has optimal transpositions, is relatively small compared to the others

◆ **The transposition is effective in making the current distribution uniform in parallel conductors**

- All the current amplitude is proportional to the B_m. It is compatible with the fact that the additional AC loss is proportional to the square of the B_m under non-saturated conditions where the shielding current is less than the I_c
- Although the current ratio is correctly predicted, the current amplitude differs between the measurement and the calculation
- The most likely cause ··· The actual B_m is smaller than expected. As shown in above graphs, the deviation of the B_m has excellent effects on the current amplitude

f Dependence of The Current Ratio



- The measured one roughly corresponds to the calculation
- **The current has the *f* dependence** in the low *f* region of 0 - 30 Hz, but it doesn't in the high *f* region. It seems to be due to the difference in the decay time constant of the shielding current hypothesizing the critical state model.

Summary

- The measured current ratio roughly corresponds to the calculation

◆ When constructing a three-strand parallel conductor, we can predict whether the shielding current due to the transposition deviation is negligibly small compared to the primary current

- The shielding current has **the *f* dependence**, and that characteristic is observed by hypothesizing the critical state model
- The measured current amplitude deviated from the calculation. It seems to be due to the problem in the measurements, especially about the magnetic field

Upcoming study

- Calculation of the current distribution under a non-uniform magnetic field
- Considering the practical cases, we will evaluate experimentally and theoretically the **current distribution in parallel conductors wound into pancake coils** designed for the armature of rotating machines