Theoretical and Experimental Investigations on Additional AC Loss Properties of Three-Strand Parallel Conductors Composed of REBCO Tapes

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Abstract

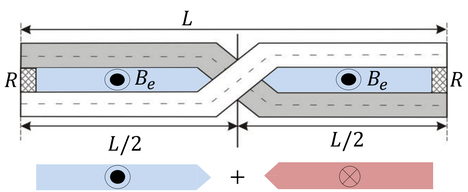
The additional AC loss due to formation of three-strand parallel conductors, composed of $REBa_2Cu_3O_y$ (REBCO, RE = rare earth) superconducting tapes, were investigated theoretically and experimentally. The purpose of this study is to derive a theoretical expression of additional AC loss and prove the validity of this theoretical expression by experiments. The additional AC loss was measured by the pickup coil method under an applied AC magnetic field with various amplitudes and frequencies. The measured value and the theoretical value were in good agreement.

Strand parallel conductor

REBCO tape

Parallelize
Improvement of I_c
(new losses occur)

Constitution strand
parallel conductor
Low loss



Linkage magnetic flux is canceled and no additional AC loss occurs

Theory

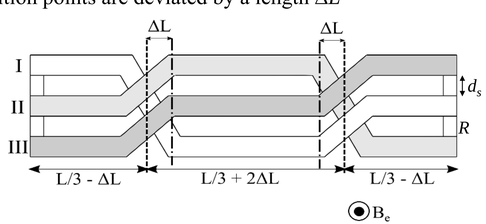
We consider the additional AC loss of three-strand parallel conductors where the transposition points are deviated by a length ΔL on both sides from the optimal transposition points.

$$W = \int_0^{\frac{2\pi}{\omega}} \frac{\left(2R + 2V_c \frac{I^{n-1}}{I_c^n}\right) I}{3uwL}$$

Where, shield current I is obtained by numerically analyzing the following equation.

$$\omega \Phi_{B(x)} \cos \omega t + d_s \mu_0 \frac{K'}{w} \frac{dI}{dt} L = -\left(2R + 2V_c \frac{I^{n-1}}{I_c^n}\right) I$$

$$\Phi_{B(x)} = d_s \left\{ -\int_0^{\frac{L}{3} - \Delta L} B_m dx + 2 \int_{\frac{L}{3} - \Delta L}^{\frac{2L}{3} + \Delta L} B_m dx - \int_{\frac{2L}{3} + \Delta L}^{L} B_m dx \right\}$$



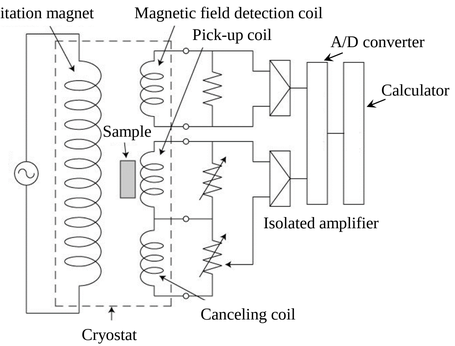
u, w, L are the thickness, width, and length of the wire, respectively. K' is a value determined by the arrangement of parallel conductors

Experimental Procedure

A sample coil composed of three-strand parallel conductor of REBCO tapes is placed, and a magnetization signal is detected. The AC loss can be obtained by measuring the externally applied magnetic field B_e and the magnetization signal V_p - mV_c which is obtained from the pickup coil signal V_p and the cancellation coil signal V_p.

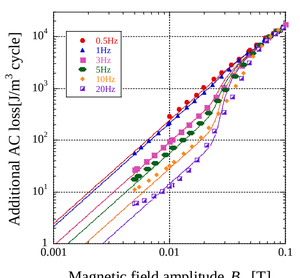
$$W = -\frac{L_p}{v_s N_p} \int_0^T dt B_e \left(V_p - mV_c\right)$$

Sample coil



Experimental Result

	SAMPLE
Rare earth	Gd
Superconducting layer thickness	~ 1.5 μm
Total thickness	108 μm
Width	2 mm
Critical current, I_c	53.0 A
n-value	15.0
Contact resistance	~7×10^{-7} Ω
Inner diameter	39 mm
Number of turns	12
Insulation layer thickness	0.25 mm



The measured W corresponded to theoretical values well. However, There is a part where the measured value is lower than the theoretical value.

→ There is a possibility that I_c or / and n-value decreased by the applied magnetic field.

Summary

The theoretical expression of the additional AC loss for three-strand parallel conductors was derived. The measured values corresponded to theoretical values, indicating the correctness of the theoretical expression. The case where both sides were derived became clear both experimentally and theoretically. However, if only one of them deviates, the theoretical formula is also different. In the near future, they will be studied theoretically and experimentally.

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