AC Losses in Coated Conductors Integrated for Practical Applications and Strategies for Their Reduction

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***Abstract*— The AC loss characteristics of coated conductors integrated with various manners, such as tape-on-tape stack, mono and multi layer polygonal assemblies, are presented and strategies for AC loss reduction are discussed. With respect to the composite structure, we focus on superconductor and ferromagnetic composite structure in an isolated coated conductor and in assembled coated conductors. Influence of non-uniformity of critical current density is discussed from the viewpoint of cutting a coated conductor into narrow strips.**

I. AC Loss Characteristics of Coated Conductors

A. Single Isolated Coated Conductor

In a single isolated coated conductor, AC losses are mostly generated by the magnetic field component normal to its wide face because of its very thin superconductor layer. The magnetization loss under the normal magnetic field can be reduced by striating the superconductor layer: 95% reduction of the magnetization loss was demonstrated by the striation [1].

It should be noted that magnetic substrate increases AC losses. Fig. 1 shows the measured transport loss of a coated conductor using a Ni alloy substrate and that using a less-magnetic clad substrate: use of the clad substrate is effective for AC loss reduction [2].

B. Tape-on-Tape Stack of Coated Conductors [3]

Fig. 2 shows the measured transport losses of stacked coated conductors. The transport losses increase with decreasing space between coated conductors. Fig. 3 shows the measured magnetization losses of stacked coated conductors: the magnetization losses decreases by stacking. Another data indicates that the magnetization loss decreases with decreasing space between coated conductors.

C. Polygonal Assembly of Coated Conductors

In polygonal assembly of coated conductors, narrowing tapes and increasing the number of tapes are effective in approximating the assembly cross-section to that of a circle and, then, to reduce the normal magnetic field component [4]. Fig. 4 shows calculated transport losses of two layer assembly of 2 mm-wide and 4 mm-wide coated conductors: the loss in the outer layer dominates the loss of an entire assembly, and narrowing tape to 2 mm from 4 mm is still effective for AC loss reduction in two layer cables.

If each coated conductor is bended laterally to fit the circular cross-section of former or inner layer as shown in Fig. 5, the AC loss of the cable might be reduced. Preliminary numerical analyses indicate that the AC loss of the two layer assembly can be reduced to about one fifth by bending coated conductors.

Fig. 6 shows the influence of the clad tape on transport losses of hexagonal assembly of coated conductor using IBAD substrate: a clad tape was placed under and / or over each coated conductor in the assembly. Its influence on the transport loss is reasonably small, and the coated conductor with this substrate is promising for applications to power transmission cables.

II. Strategies for AC Loss Reduction

Use of less magnetic substrate is a simple approach for AC loss reduction, though shaping magnetic flux lines by the magnetic substrate may decrease AC losses in some cases.

Cutting the superconductor layer or the entire coated conductor into narrower strips is effective in reducing the AC losses in coils as well as in cables. However, loss of critical current due to cutting must be considered, because it leads to increase I_t / I_c for a fixed I_t and results in the increase in AC losses. J_c near the edges of strips might be degraded due to cutting. Increase in the effective gap between strips resulting frmm the J_c drop near edges must be taken into consideration. Furthermore, if the lateral critical current density distribution

is not uniform and its profile varies along the conductor axis, the cutting might affect the current transport property.

In coils, close winding is preferable if the magnetization loss is dominant, while sparse winding is preferable if the transport loss is dominant.

In power transmission cables comprising multi-layer polygonal assemblies of coated conductors, approaching their cross-sections to that of a circle to reduce normal magnetic field component is effective for AC loss reduction: decreasing gap between coated conductors as well as coated conductor width is a practical method. If each coated conductor is bended laterally to fit the circular cross-section of former or inner layer, the AC loss of the cable can be reduced.

ACKNOWLEDGMENT

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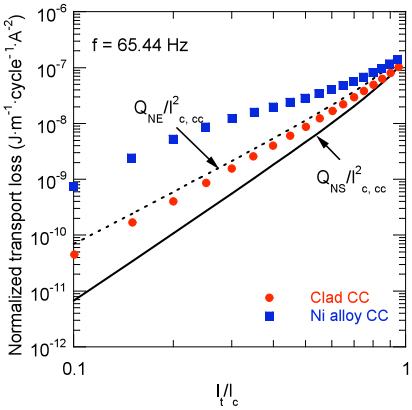

Fig. 1 Measured transport losses of single isolated coated conductors [2].

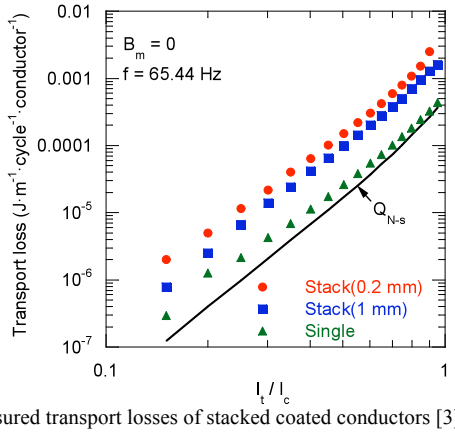

Fig. 2 Measured transport losses of stacked coated conductors [3].

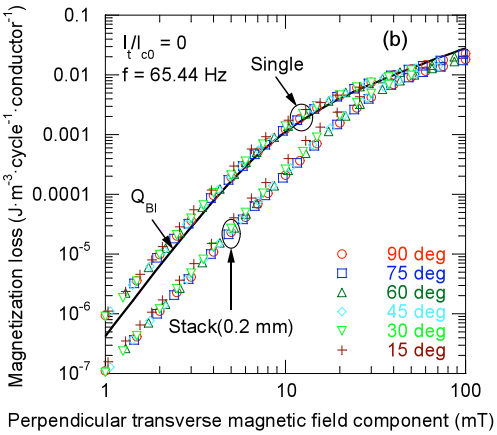

Fig. 3 Measured magnetization losses of stacked coated conductors [3].

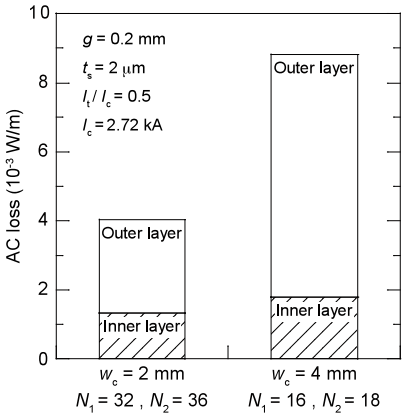

Fig. 4 Calculated transport losses of two layer assembly of 2 mm-wide and 4 mm-wide coated conductors [4].

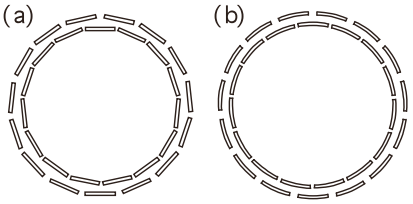

Fig. 5 Cross section of two layer polygonal assemblies of coated conductors: (a) using flat tapes and (b) using bended tapes.

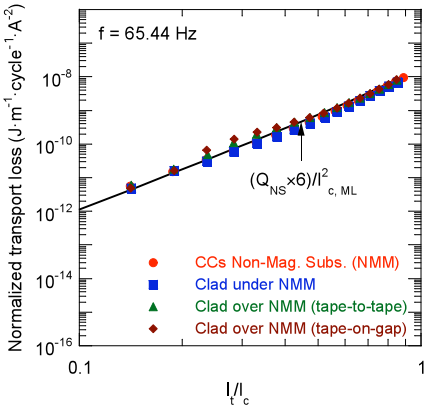

Fig. 6 Influence of clad tape used as substrate on transport losses of hexagonal assembly of coated conductor using IBAD substrate [2].