Influence of Multifilament Structure on AC Loss and Current Distribution in Bi-2223 Ag-sheathed Tapes

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Only Bi-2223 Ag-sheathed tapes have been developed as superconducting wires with significant properties at liquid nitrogen temperature and a long length in the order of kilometers. When such wires are used as windings in a superconducting apparatus for pulsed or AC use, it is important to understand their AC loss properties in detail. Although the Bi-2223 tapes used at present have a multifilament structure, it is well known that the entire filamentary region behaves as a bulk superconductor due to physical contact or electromagnetic coupling between the filaments. In the numerical simulation of the AC losses, therefore, it is usual that the entire filamentary region is treated as a bulk material for the sake of simplification. This assumption for the AC loss estimation has to be validated quantitatively. In order to reduce the AC losses, on the other hand, the Bi-2223 tapes with structure that a high-resistivity barrier circumscribes every twisted filament have been fabricated recently. However, the current distribution in such multifilamentary tapes with high-resistivity barrier layers has not been discussed yet.

In the first part, the AC losses in various types of non-twisted multifilamentary tapes that actual Bi-2223 Ag-sheathed wires are idealized are numerically evaluated for the application of an external magnetic field perpendicular to the tape face [1]. Bean’s critical state model is used for the numerical calculation to understand only the geometrical effects of the multifilamentary tapes on the losses. It is assumed that the width and thickness of a tape-shaped wire with rectangular cross section are equal to 4.0 and 0.225 mm, respectively. The region occupied by \( N \) filaments of superconductor also has 3.6 mm in width and 0.18 mm in thickness. If the silver ratio of tape wire is fixed in advance, the cross-sectional area of superconductor is obtained. By setting the aspect ratio of the filament itself with elliptic cross section, the filament size identical in each wire can be determined exactly. The obtained filaments are systematically arranged in the filamentary region of wire. Fig. 1 shows the cross-sectional view of typical wire models, and their silver ratios are fixed at 2.5. Here, only the bundle of superconductor filaments without the silver

![Fig. 1. Cross-sectional view of wire models. Only a quarter of the cross section is shown.](image)

![Fig. 2. Comparison between numerical results of AC losses. The dotted curve is for a homogeneous superconductor.](image)
matrix is taken into account for the AC loss estimation with the minimization of magnetic energy [2]. The numerical results of AC losses in the multifilamentary tapes with different filament arrangements are shown in Fig. 2, where $W$ is the AC loss per unit volume of the filamentary region per cycle and $H_m$ the amplitude of perpendicular magnetic field. They are also compared with the losses for a homogeneous superconductor with cross section same as the entire filamentary region so as to confirm the possibility of simplification of the loss estimation. It is found that the AC losses in the multifilamentary tapes almost agree with those for the homogeneous superconductor when the field amplitude is relatively large. In the case of a small amplitude, on the other hand, their discrepancy can be seen clearly and the loss property strongly depends on the filament arrangement.

In the second part, the current distribution in the Bi-2223 multifilamentary tapes with inter-filament barrier is numerically evaluated for the application of an alternating transport current [3]. In the case of barrier materials with an infinite resistivity, the current distribution can be determined with a lumped parameter circuit model including the inductances and resistances of all the filaments. The mutual inductance between a pair of filaments is obtained by estimating their geometric mean distance. The power-law model is also assumed to take into account the effect of resistance in each filament. The wire models are basically same as the first part, except for twisting and silver ratio of 3.0. Fig. 3 shows the numerical results of the current sharing among the coaxial layers for different multifilament configurations. Only the inductances are used for the numerical calculation, and therefore the effect of resistance is ignored absolutely. This means that these results correspond to the case where the amplitude of transport current is very small. It can be seen that the outermost layer always has a main current larger than the applied transport current. It is also found that a minor current with the opposite direction flows in the layer just inside the outermost layer. Furthermore, the inner part of tape wire scarcely carries a current in the case of large number of layers. Next, both the effects of the inductance and resistance are taken into account under a condition of the three-layer structure of superconductor filaments. Fig. 4 shows the numerical results of fundamental amplitudes for current waveforms obtained with the Fourier transform. The $n$-value is fixed at 10, and the frequency varies from 1 to 60 Hz. It can be seen that the current imbalance is obtained in the small range of the current amplitude applied to the tape wire as mentioned above. In the case of very large amplitude, on the other hand, the uniform current sharing is achieved due to the effect of huge series resistance. It is also found that the transition between both the properties shifts to the larger amplitude of transport current with increasing the frequency. Thus, the effect of resistance can rise up to the surface in the relatively large amplitude of transport current.

References