Numerical study on self-field losses of HTS model cable comprising strips of YBCO tapes

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Abstract The self-field losses of the high-T_C superconducting (HTS) model cable are calculated by the electric circuit (EC) model. The HTS model cable is constructed by G-FRP former and three HTS layers, which was fabricated by Furukawa Electric Company (FEC). Each YBCO tape is divided to 5 strips by laser processing and the HTS layers comprise 85 strips. The length of the model cable is 0.3 m. The current-dependent resistance of HTS layers in EC model is estimated on base of Norris expressions for thin strip. The helical pitch of each layer is designed by Yokohama National University (YNU), but the value is not disclosed. The author supposes the value from the self-field loss of 0.054 Wm^{-1} at transporting 1 kA$_{rms}$. The calculated losses are compared with the experimental results measured by 4-terminal method by FEC. The calculations are almost equal to the measurements at wide transport-current range. Moreover, the author designed the helical pitch to obtain the minimum self-field loss. The minimum self-field loss is 0.046 Wm^{-1} at transporting 1 kA$_{rms}$ on the optimum helical pitch.

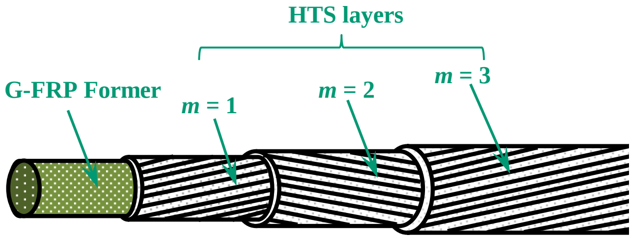

Fig. 1 Schematic diagram of HTS model cable comprising strips of YBCO tapes. The HTS model cable is constructed by G-FRP former and three HTS layers. Each YBCO tape is divided to 5 strips by laser processing and HTS layers comprise 85 strips. The length of the cable is 0.3 m. The G-FRP former is used to measure the self-field loss precisely, because the former doesn't cause the eddy current loss and the ohmic loss. In this figure, the helical direction of second HTS layer is drawn as the opposite to the other layers. The helical direction is an author's supposition, because the cable construction is not disclosed (in particular, the helical direction and the helical pitch length).

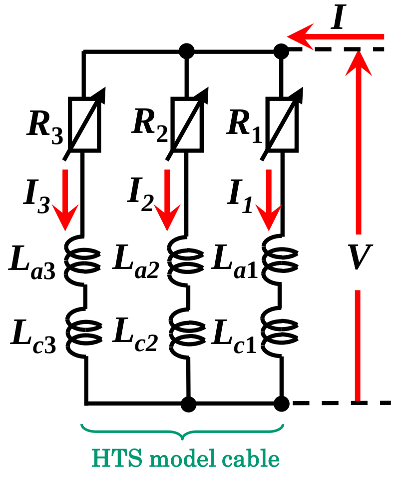

Fig. 2 EC model for HTS model cable. The current-dependent resistance of HTS layers in EC model is estimated on base of Norris expression for thin strip. The description of mutual inductances is omitted to avoid congestion. The author calculated the helical pitch, P_m(FEC), from the self-field loss of 0.054 Wm^{-1} at transporting 1 kA$_{rms}$. The value is reported by FEC. The self-field losses calculated by the helical pitch of P_m(FEC) is named as W_{FEC}. On the other hand, the self-field losses calculated by the optimum helical-pitch, P_m(min), is named as W_{min}.

Table 1 Main parameters of HTS model cable. A construction of the HTS model cable is designed by YNU and the model cable is fabricated by FEC.

Layer m	Radius r_m [mm]	Helical direction	Numbers of strips N_m	Layer I_C [A]
1	19.60	S	25	642.0
2	19.80	Z	30	770.4
3	20.00	S	30	770.4

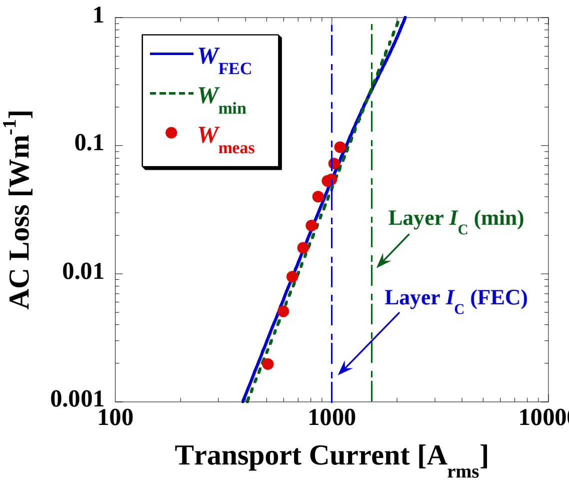

Fig. 3 Self-field losses as function of transport currents for HTS model cable in logarithmic scale. The red solid circles indicate the measurements W_{meas}. The measurements have been referred by FEC's data. The blue solid line indicates W_{FEC}. The calculation W_{FEC} is almost equal to W_{meas}. The author calculated P_m(min) giving the minimum self-field loss at transporting 1 kA$_{rms}$. According to the calculation, the minimum self-filed loss becomes 0.046 Wm^{-1} at transporting 1 kA$_{rms}$. The green dashed line indicates W_{min}.

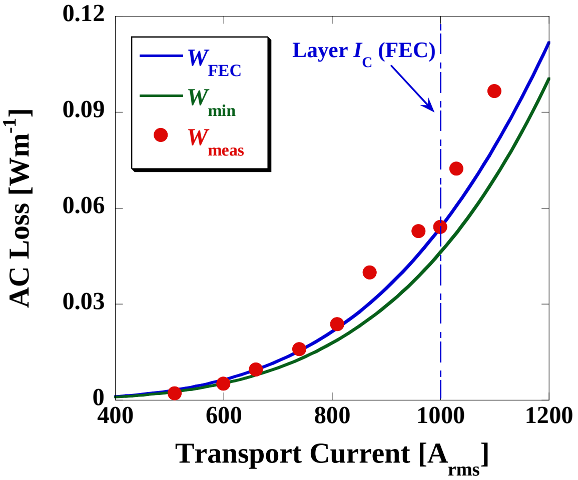

Fig. 4 Self-field losses as function of transport currents for HTS model cable in liner scale. The deviation between W_{FEC} and W_{meas} becomes lager above the transport current of 1 kA$_{rms}$ where the peak layer current becomes lager than the layer I_C in case of P_m(FEC). Therefore, the loss of 0.054 Wm^{-1} is possible to be measured in the normal state at 1 kA$_{rms}$. In this figure, it is clear that W_{min} is smaller than W_{FEC}.

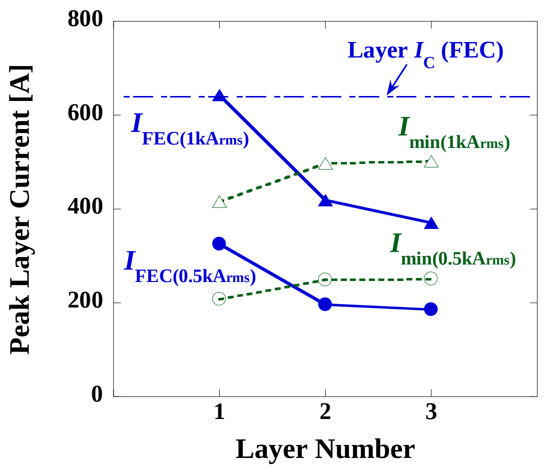

Fig. 5 The peak layer current as function of layer number for HTS model cable. The blue solid circles and blue solid triangles indicate the peak layer currents, I_{FEC}, at 0.5 kA$_{rms}$ and 1 kA$_{rms}$ in case of P_m(FEC). The green open circles and green open triangles indicate the peak layer currents, I_{min}, at 0.5 kA$_{rms}$ and 1 kA$_{rms}$ in case of P_m(min). The current distribution in case of P_m(min) is almost uniform. On the other hand, in case of P_m(FEC), I_{FEC} in layer 1 is higher than the other layers. At transporting 1 kA$_{rms}$, I_{FEC} in layer 1 is above the layer I_C.