Magnetization loss in REBCO Roebel cables with varying strand numbers

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Background

- Many high temperature superconducting (HTS) applications require parallel-connected assembled coated conductors with large current-carrying capacity.
- Two ways to assemble coated conductors: vertically stack the coated conductors or continuously transposed Roebel cables.
- Roebel cable is preferred because it offers mechanical flexibility as well as low AC loss.
- No measurements have been reported comparing magnetization loss in Roebel cables and their equivalent stacks: vertical stacks with the same number of layers and the same total conductor width as the cable.

Objectives

- Magnetization loss in Roebel cables with varying strand numbers from six to fourteen is measured using our newly developed AC loss measurement system [1];
- The applied field amplitude, the frequency and the field angle (the angle between the magnetic field and the tape-wide surface) are varied;
- The loss values of the Roebel cables are compared with those of the equivalent stacks as well as COMSOL modeling results using the H-formulation.

Experimental Method

- Our measurement system employs the calibration-free method [2], but we use one magnet instead of using two magnets;
- The magnet was wound using Litz wire with 36 copper strands, one strand of which was used as a pick-up coil for registering the loss signal of the sample inside the magnet;
- The field can be varied by rotating the sample holder extended to room temperature.

Sample Preparation

- 14/4, 10/4, 6/4 Roebel cables: source material of Roebel strands is Fujiyama wire (FYS-C510);
- No insulation between the Roebel strands, and the cables were wrapped with PTFE tapes to prevent deterioration of the strands;
- Measurement conditions: 77 K, field amplitude up to 130 mT at 67.9 Hz and 120 mT at 87.6 Hz, field angle: 90ºdeg, 71ºdeg, 65ºdeg, 45ºdeg, 30ºdeg and 15ºdeg.
- Length of samples: 14/4, 10/4 and 6/4 Roebel cable: 422 mm, 336.5 mm and 309 mm; equivalent stacks composed of three, five, and seven conductors: 255 mm.

Results

- The loss in Roebel cable is hysteretic;
- The loss in Roebel cables for different field angles are in a good agreement;
- The loss per strand decreases as the number of strands increases: because the screening effect of the strands becomes stronger as the number of strands increases [3], [4];
- The loss per strand decreases as the number of strands increases because the screening effect of the strands becomes stronger as the number of strands increases;
- The loss in the stacks is hysteretic, and agrees with the COMSOL results;
- The loss values in stacks for different field angles are in a good agreement;
- The loss decreases with the number of conductors increases due to the increased shielding effect [5], [6];
- The loss decreases with the number of conductors increases due to the increased shielding effect [5], [6];

References


Conclusion

- We measured the magnetization loss in Roebel cables with varying strand numbers and reference stacks of coated conductors at different field angles and frequencies. Magnetization loss in the Roebel cables is dominated by the perpendicular component of the external magnetic field;
- The magnetization loss per strand in the Roebel cables decreases and the Bep value increase with increasing number of Roebel strands due to the increased shielding effect;
- A Roebel cable offers magnetization loss reduction over its equivalent stack only when the magnetic field amplitude exceeds the cable’s Bep value;
- The magnetization loss of the Roebel cable is half of the loss value of the equivalent stack when the external magnetic field is much larger than the Bep values of both the Roebel cable and the equivalent stack.

Table: Specifications of the Fujiyama wire

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (mm)</td>
<td>0.1</td>
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<tr>
<td>Thickness of the tape (μm)</td>
<td>2.1</td>
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<tr>
<td>Thickness of GdBCO layer (μm)</td>
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<tr>
<td>Critical current at 77 K, self-field (A)</td>
<td>402</td>
</tr>
<tr>
<td>Substrate</td>
<td>Hastelloy</td>
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<tr>
<td>Thickness of substrate (μm)</td>
<td>100</td>
</tr>
</tbody>
</table>

Photo of the 14/4 Roebel cable and Roebel strand

3-tape stack versus 10/4 Roebel cable

7-tape stack versus 14/4 Roebel cable

Fujikura wire specifications

- Width (mm): 10
- Thickness of the tape (μm): 0.1
- Thickness of GdBCO layer (μm): 2.1
- Critical current at 77 K, self-field (A): 402
- Substrate: Hastelloy
- Thickness of substrate (μm): 100

References
