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The Electrical behavior of stacked coated conductors concerning the interlayer resistance

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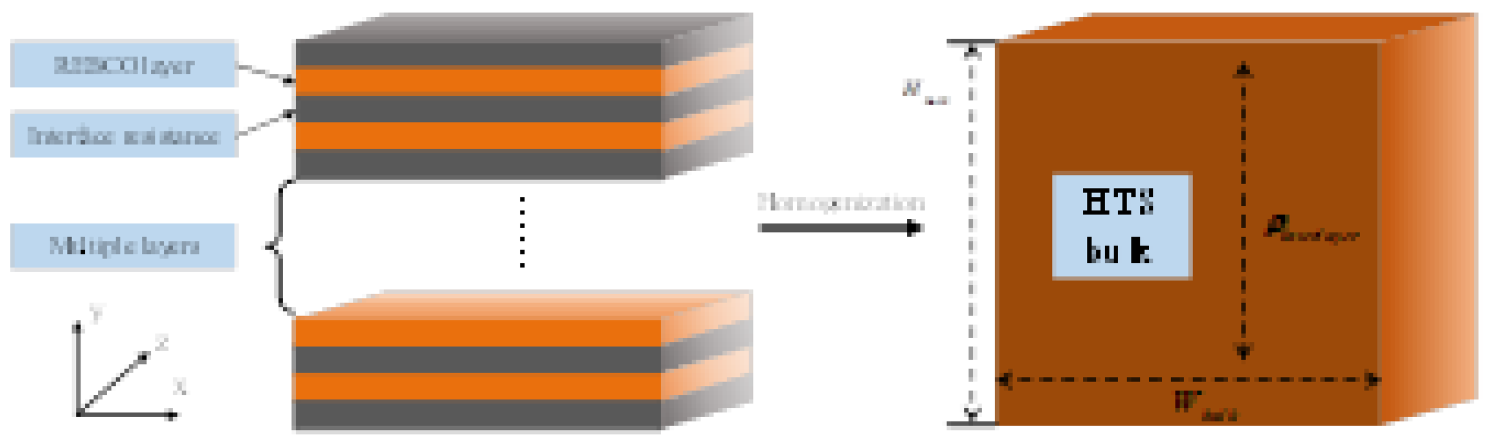
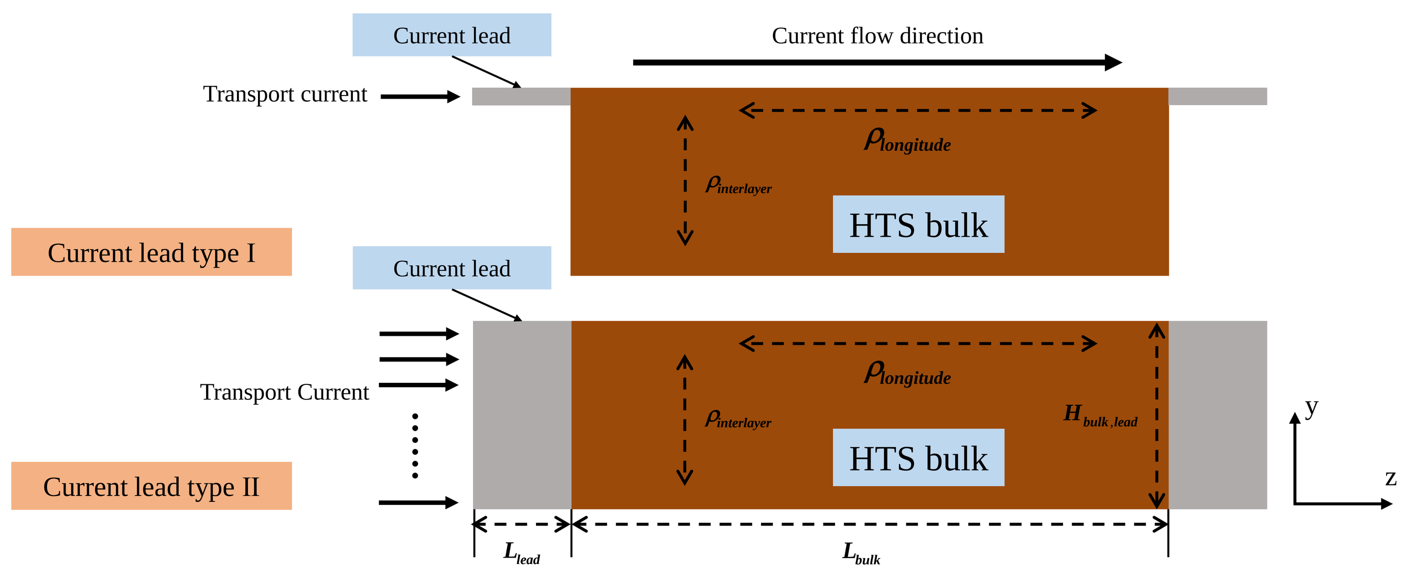
Previews

- The purpose of this work is to investigate the effect of interlayer resistance on the electromagnetic properties of stacked coated conductors by using a 3-D homogenization finite element model (FEM).
- The homogenization model considers multiple REBCO layers with interface resistance as a HTS bulk with an anisotropic resistivity. The $\rho_{longitudinal}$ is the resistivity of the HTS bulk in transverse direction (x) and current transfer direction (z). The $\rho_{interlayer}$ is the resistivity in the direction perpendicular to the REBCO layers (y).
- Two types of current leads (CLs) are designed to illustrate the effects of interlayer resistivity. In current lead type I, the transport current enters from only the upper layer of the HTS stack while in the lead type II, the transport current enters from the entire end surface of the HTS stack. Both current leads are considered as copper with high electric conductivity in numerical calculation.
- The FEM commercial software COMSOL is used for the computation and MATLAB is used for post-processing of data including interpolation and fitting.

Homogenization Model Schematic



Geometry Schematic (Side View)



Methodology

H-formulation

$$\nabla \times \boldsymbol{E} = -\frac{\partial(\mu_0 \mu_r \boldsymbol{H})}{\partial t}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J}$$

Anisotropy

$$\boldsymbol{E}_{xz} = \frac{E_c}{J_c}\left|\frac{J_{xz}}{J_c}\right|^{n-1} \boldsymbol{J}_{sc,xz} = \rho_{longitudinal} \boldsymbol{J}_{share}$$

$$\boldsymbol{E}_y = \rho_{interlayer} \boldsymbol{J}_y$$

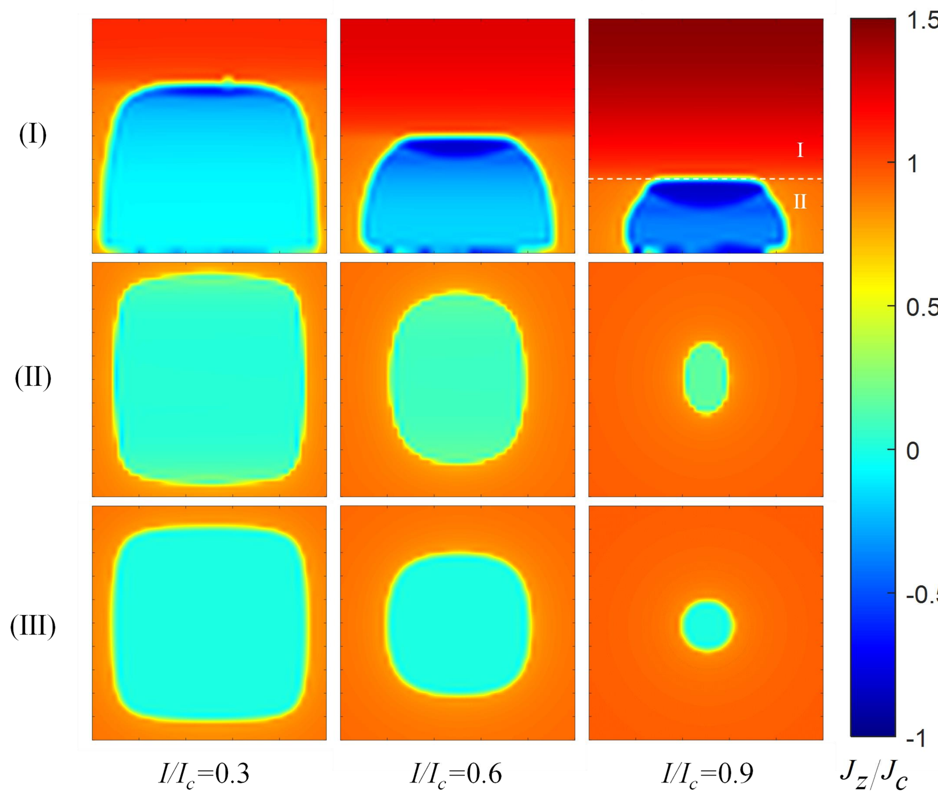
$$\rho_{longitudinal} = \rho_{l,ep-copper} \,//\, \rho_{l,copper}$$

$$\rho_{interlayer} = \rho_{i,interface} \,//\, \rho_{i,outer}$$

Rewritten E-J power law

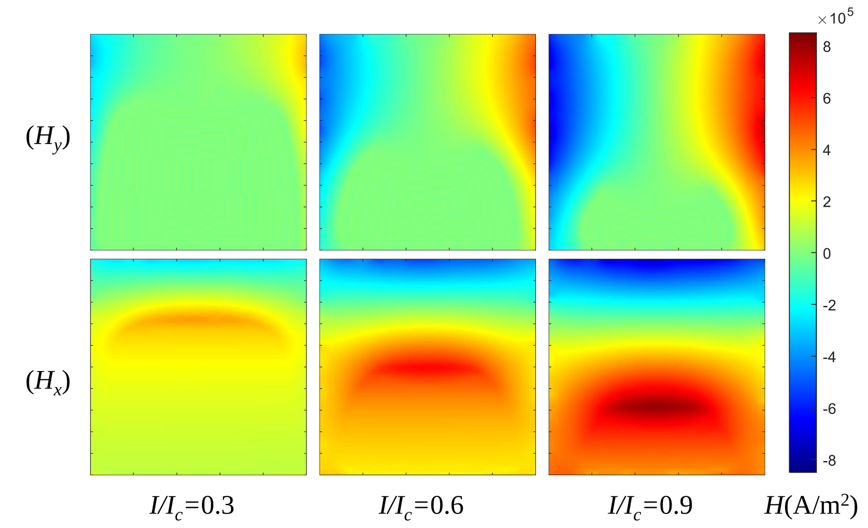
$$\boldsymbol{J}_{xz} = J_c \left|\frac{\boldsymbol{E}_{xz}}{E_0}\right|^{\frac{1}{n}} + \frac{\boldsymbol{E}_{xz}}{\rho_{longitudinal}}$$

Current Density Profiles (Mid-section in z-direction)



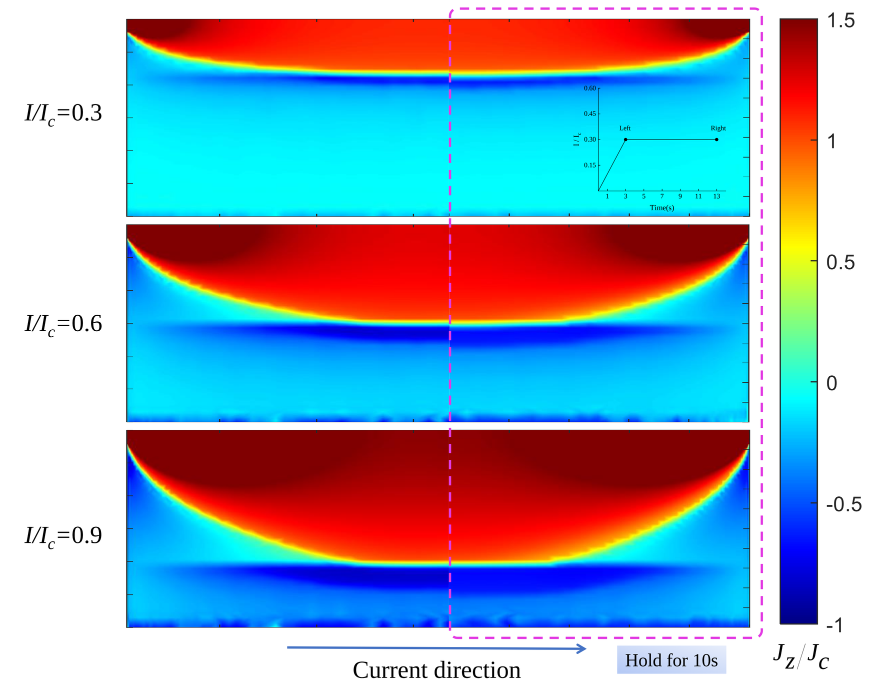
- Transport current grows from 0 to I_c in 10s as a ramp function.
- Three cases are discussed ($\rho_{interlayer}$=3.7×10^{-7} Ω·m):
  - Case I: modelling with the CL I and an anisotropic HTS bulk.
  - Case II: modelling with the CL II and an anisotropic HTS bulk.
  - Case III: modelling with the CL I and an pure SC bulk.
- Current density profiles reveals that with interlayer resistivity:
  - Current sharing becomes difficult due to the interface resistance.
  - Screening current appears below the flux-front line.
  - Reverse current density distributes in the shielded region.
- Case I is adopted for all the following numerical calculations.

Magnetic Field Profiles (Mid-section in z-direction)



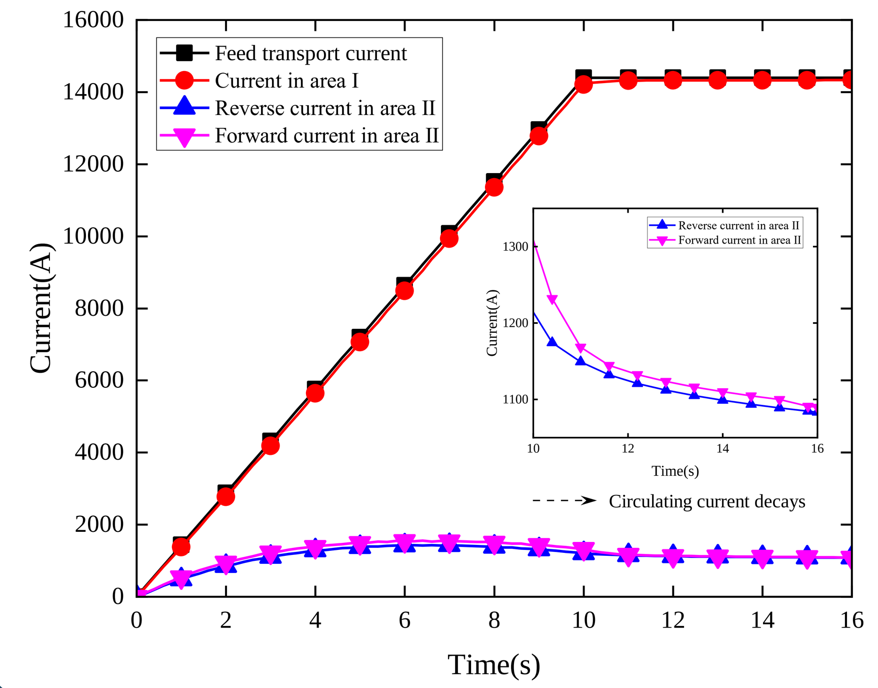
- Magnetic field profiles vary with current density profiles as current grows.
- The transverse magnetic field penetrates the shielded region through the paths provided by interface resistance as the $\boldsymbol{H}_x$ in the figure.
- The perpendicular magnetic field is shielded by screening current in x-z plane because the magnetic field cannot pass through the REBCO layers in y-direction in the shielded region.

Flux-front Profiles (Mid-section in x-direction)



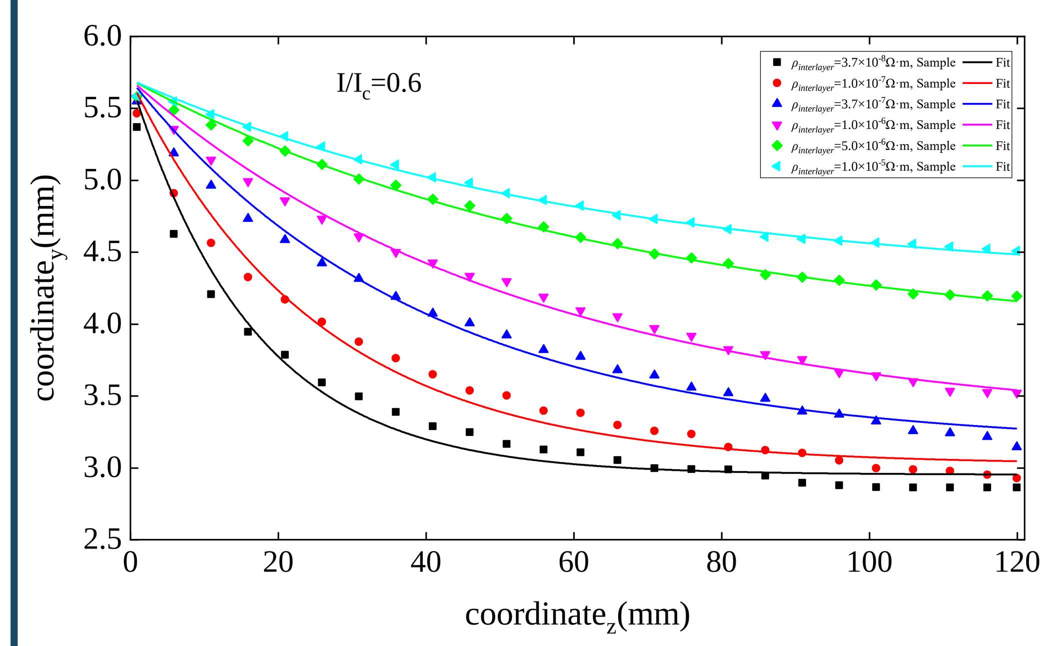
- On the left is the flux-front profiles in the current feeding process.
- On the right are the flux-front profiles with the same feeding current holding for another 10 seconds to investigate the change of current profiles with time.
- Due to the mirror setting with double CLs, the flux-front profiles are influenced by the maximum current sharing distance, i.e., half length of the whole conductor.
- Larger transport current or interlayer resistivity requires larger distance to complete the current sharing process.
- The influence of time on flux-front profiles is mainly inductive distribution of current.

Current Density Integral (Mid-section in z-direction)



- Almost all the feed transport current flows in the area I.
- The reverse component in current density profiles includes the induced screening current in the x-z plane shielding the perpendicular magnetic field $\boldsymbol{H}_y$ and in the y-z plane shielding the transverse magnetic field $\boldsymbol{H}_x$.
- After feeding process is over, the screening current decays with time. We consider the main cause is the screening current in the y-z plane and we predict that it should nearly vanish if the hold time is enough for the completion of current distribution.
- More researches about the effect of time will be conducted in the next stage.

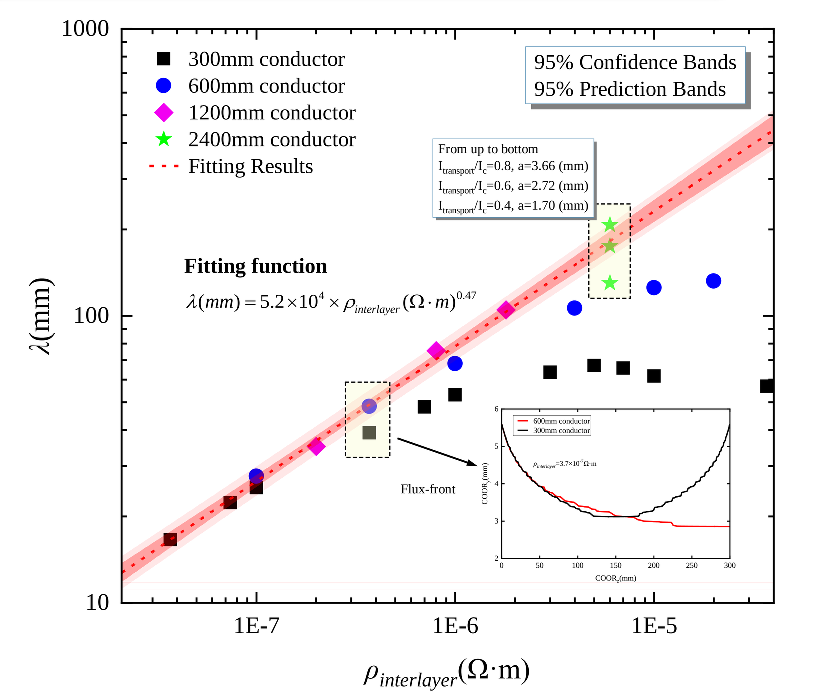
Flux-front Fitting



Flux-front fitting function

$$COOR_y = a \times \left(e^{-COOR_z/\lambda} - 1\right) + H_{Stack} - H_{CL}$$

Investigation of λ



The definition of λ

An characteristic value indicating the minimum current sharing distance.

- For the conductor of 300mm length, we fit the flux-front with sample results between 1mm and 120mm.
- For the conductor of 600mm length, it is between 1mm and 240mm.
- The λ and the $\rho_{interlayer}$ present an power law relationship, which is nearly linear in logarithmic scales.
- We suspect that the slope change in high $\rho_{interlayer}$ zone is caused by the insufficient length of the conductor in our FEM model.