UNIVERSITÉ DE LORRAINE | GREEN

HTS MODELLING 2016

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https://events.unibo.it/htsmodelling2016

Eddy current modeling in multifilamentary superconductive tapes

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Outline

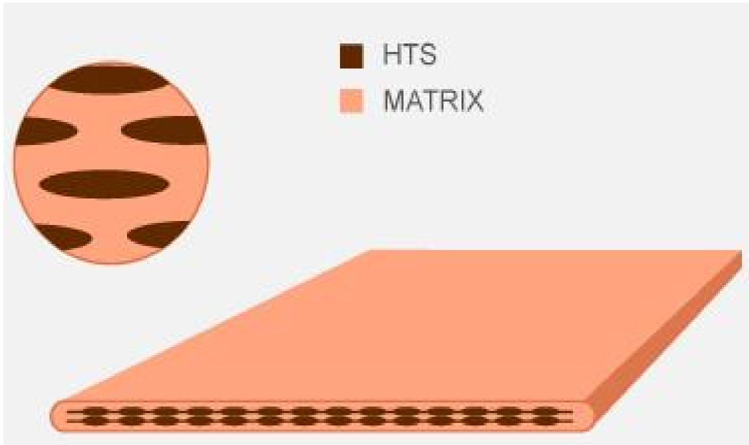
- Context
- Modeling approach & Formulation
- Numerical examples

Context

Modeling of the ELM filed interaction with composites superconductive tapes

Challenges

- Complex geometries (multiscale dimensions)
- Material proprieties (Nonlinearity , anisotropy)
- Limits of conventional numerical tools



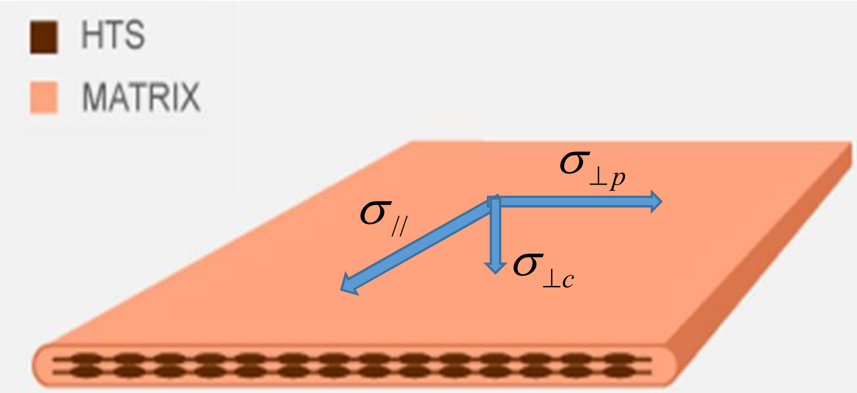
http://www.superox.ru/en/superconductivity/

Motivations

Rapid eddy current losses modeling in multifilamentary HTS composites tapes

Approach

Multi-filamentary composite tapes



$$\overline{\overline{\sigma}}(J) = \begin{bmatrix} \sigma_{//}(J) & 0 & 0 \\ 0 & \sigma_{\perp p} & 0 \\ 0 & 0 & \sigma_{\perp c} \end{bmatrix}$$

$$\mu = \mu_0$$

$$\sigma_{//} = \eta_s \frac{J_{//}}{E_{//}} + (1-\eta_s)\sigma_m$$

$$E_{//} = E_c \left(\frac{J_{//}}{J_c(B)} \right)^n$$

$\sigma_{//}$, $\sigma_{\perp p,c}$ depend on:

- The HTS filaments volume fraction (η_s) and shape
- The matrix conductivity
- The interface between the filaments and matrix
- The source filed orientation

$$J_c(B) = \frac{J_{c0}}{1 + \frac{|B|}{B_0}}$$

H. MENANA, Eddy current modeling in multifilamentary superconductive tapes , HTS Modeling Workshop, Bologna, 2016

Formulation

$\overline{\overline{C}}$ Curl matrix

$\overline{\overline{M}}$ Integral matrix

$\overline{\overline{R}}$ Resistivity matrix

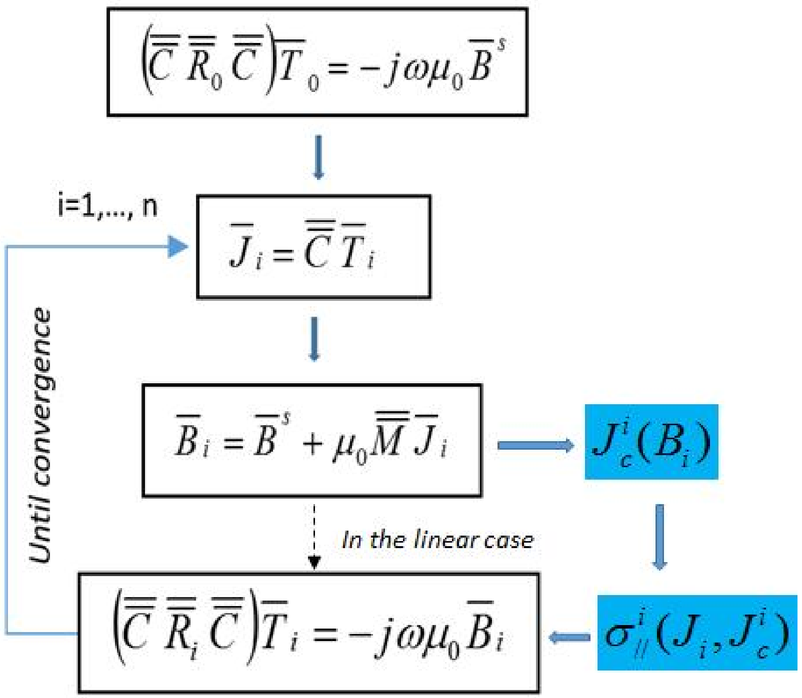
$$\vec{\nabla}.\vec{J} = 0 \rightarrow \vec{J} = \vec{\nabla} \times \vec{T} \qquad \vec{\nabla} \times \overline{\overline{\rho}}\, \vec{\nabla} \times \vec{T} = -\partial_t \vec{B} \qquad (1)$$

$$\overline{B} = \overline{B}^s + \overline{B}^r = \underbrace{\overline{B}^{ext} + \mu_0 \overline{\overline{M}}\,\overline{J}_S}_{\overline{B}^s} + \mu_0 \overline{\overline{M}}\,\overline{\overline{C}}\,\overline{T} \qquad (2)$$

$$\overline{\overline{C}}\,\overline{\overline{R}}(J)\,\overline{\overline{C}}\,\overline{T} = -i\omega\left(\overline{B}^s + \mu_0 \overline{\overline{M}}\,\overline{\overline{C}}\,\overline{T}\right) \qquad (3)$$

Thin layer approximation **J**=(J_x , J_y , 0) , **B**=(0, 0, B_z)

$$\overline{\overline{C}}_{x,y}\,\overline{\overline{R}}_{x,y}(J)\,\overline{\overline{C}}_{x,y}\,\overline{T}_z = -i\omega\left(\overline{B}_z^s + \mu_0 \overline{\overline{M}}_{x,y}\,\overline{\overline{C}}_{x,y}\,\overline{T}_z\right) \qquad \text{(3-bis)}$$



Only the **active parts** are **discretized**
The problem is solved **iteratively** in the **frequency domain**

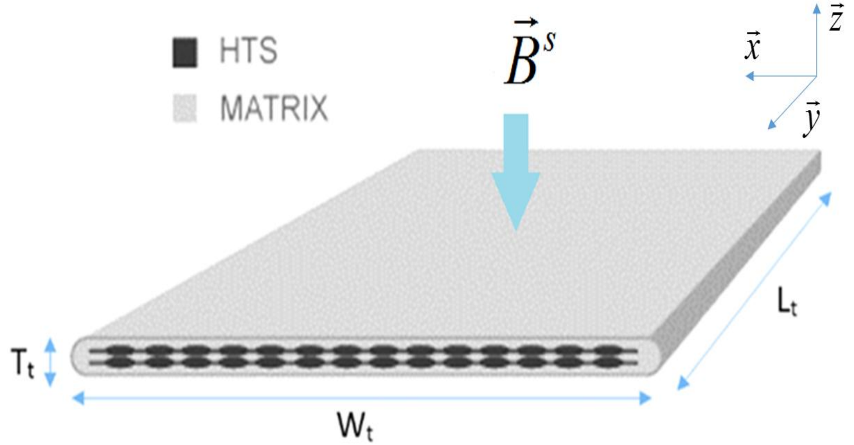
Numerical example

Typical Bi-2223 tape

$$W_t = 3\ 10^{-3}\ m$$

$$T_t = 2\ 10^{-4}\ m$$

$$L_t > L_C$$



$$\eta_s = 0.5$$

$$J_{c0} = 2\ \ 10^7\ A/m^2$$

$$n = 25$$

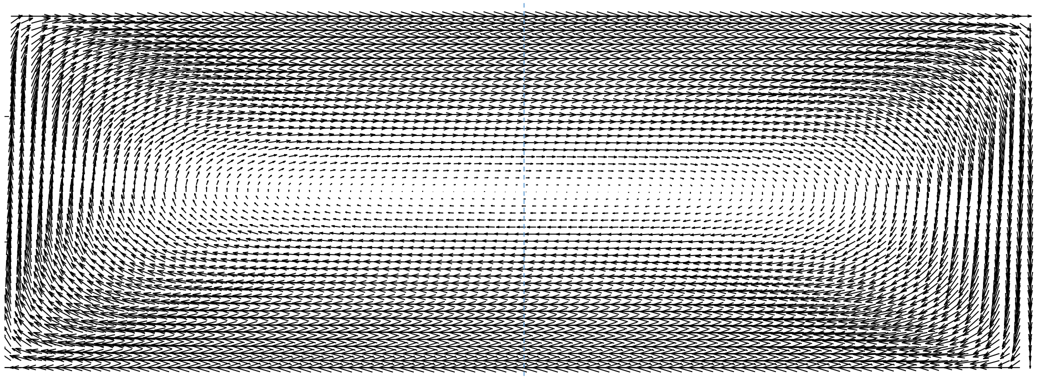
$$\rho_m = 16\ \ 10^{-9}\ \ \Omega.m$$

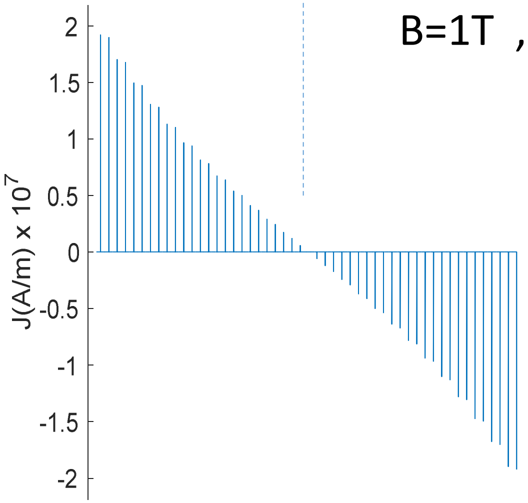
$$J_c(B) = \frac{J_{c0}}{1 + 3.07|B|}$$

From M. P. Oomen (2000)

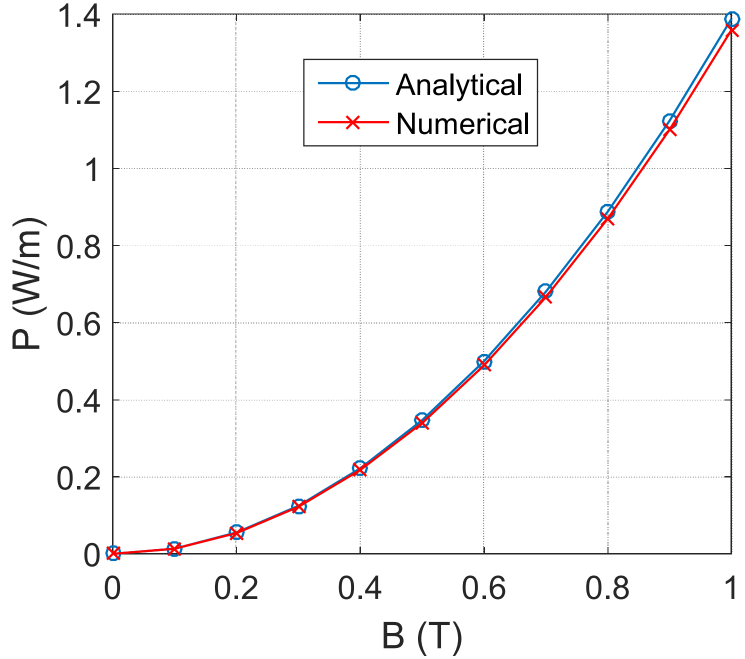
Validation

$$\sigma_{//} = \sigma_{\perp}$$





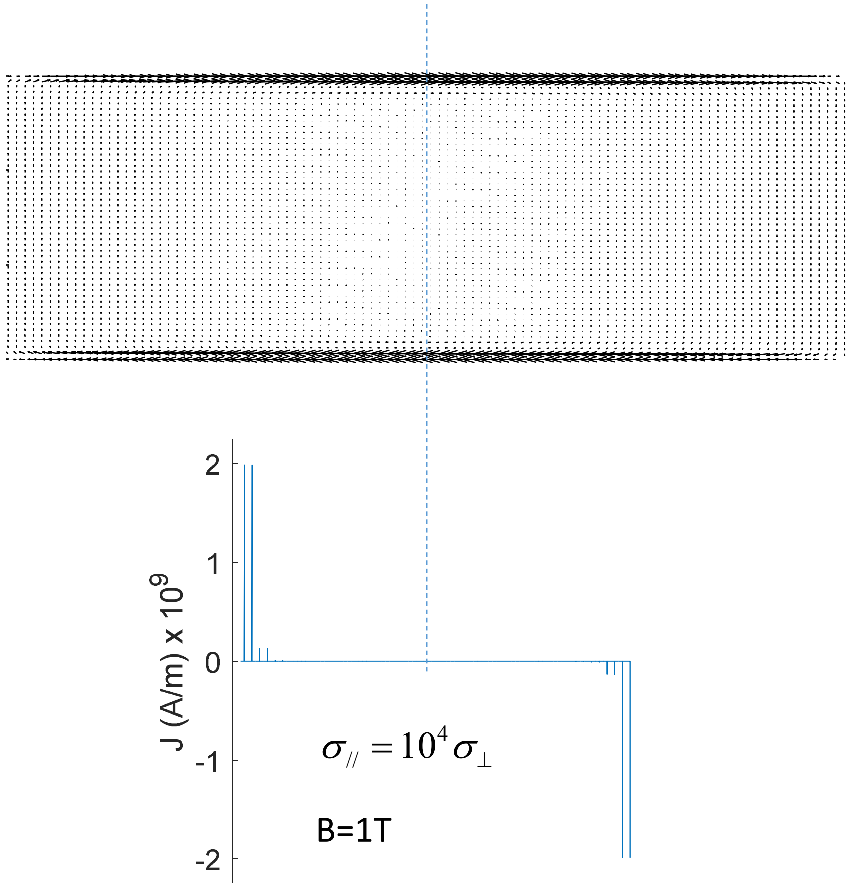
B=1T , f=50Hz



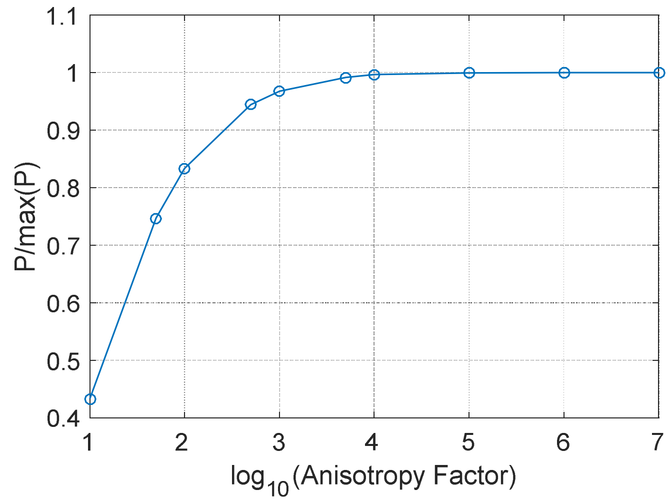
Static error of 2%

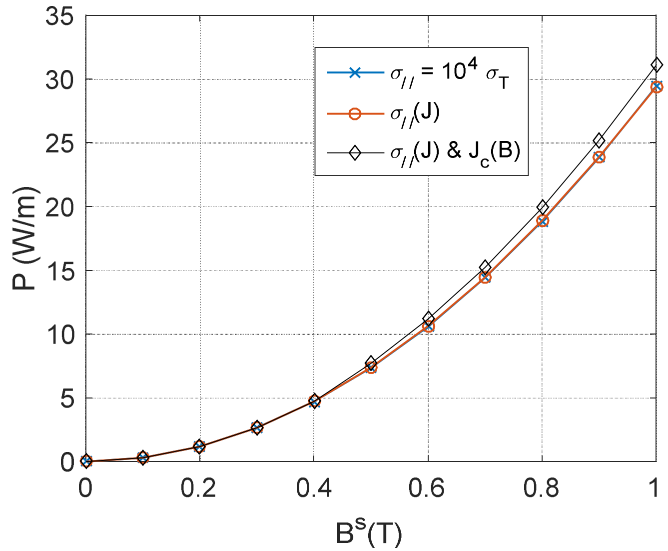
*Analytical model from M. P. Oomen (2000)

$\sigma_{//} >> \sigma_{\perp}$

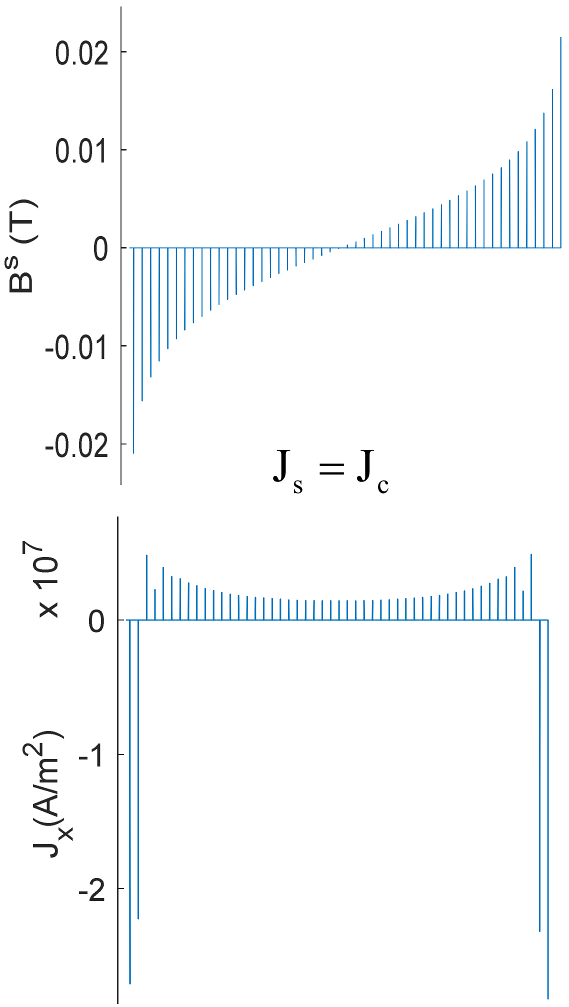


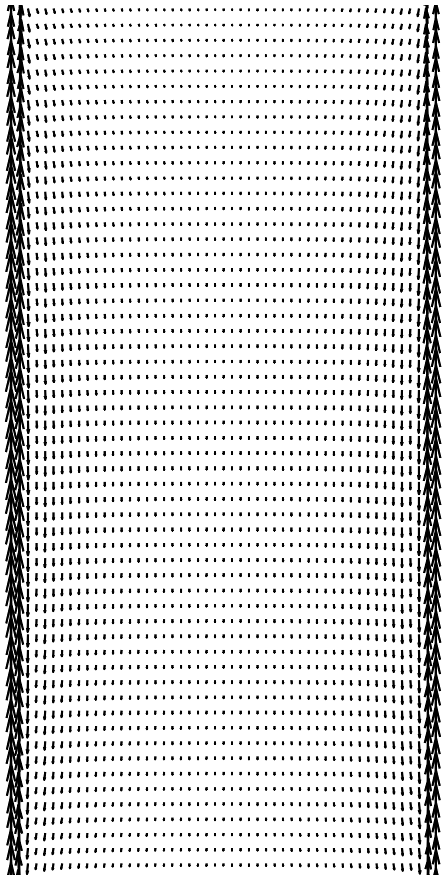
f=50Hz

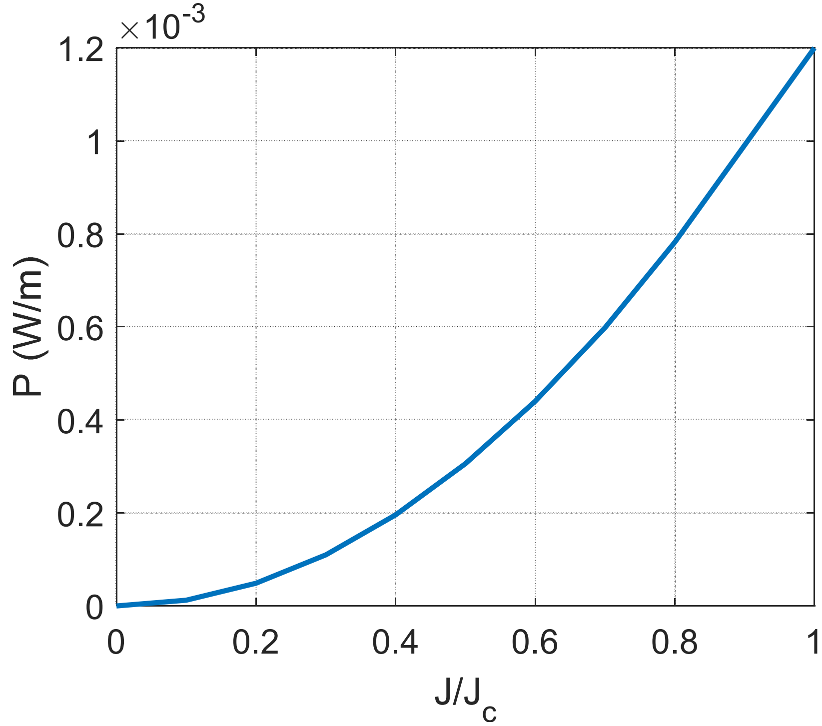




AC losses due to transport current







$\sigma_{//} = 10^4 \sigma_{\perp}$ $f = 50\,Hz$

$J_c = 1.16\,10^8\ A/m^2$

Conclusions

- Rapid approaches are needed for superconductive material modeling
- Better compromise between the accuracy and computing time
- Meet the progress in numerical tools (storage capacity)
- Integral approaches are promising
- Simplifications can be made on material behavior and structures in some cases

Thank you for your attention