DC modeling & characterization of HTS coils with non uniform current density distribution

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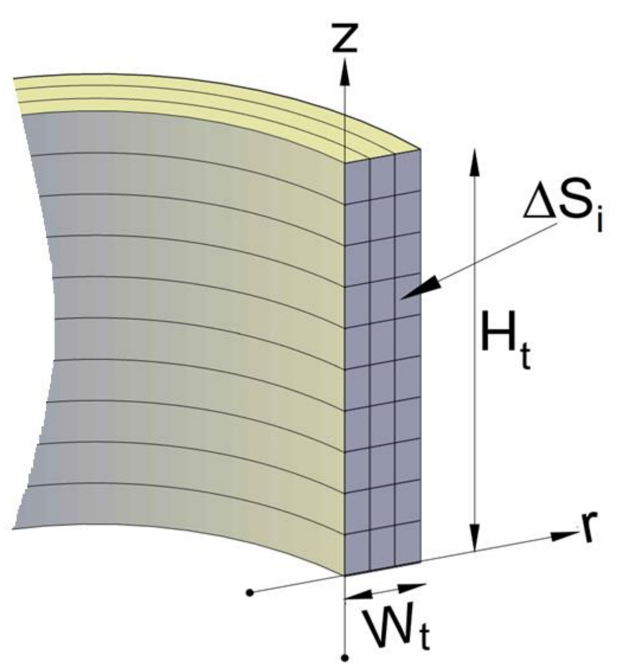
Abstract

This work presents a DC modeling approach for the calculation of current density distribution in a 1G HTS pancake coils taking into consideration the non-uniformity of *J* in the HTS tape section using a power minimization criterion. Integral equations are used to evaluate the magnetic flux density, enabling to discretize only the active parts of the system.

The modeling approach

The modeled system



$$\begin{cases} E(J,B) = E_c \left| J\, J_c^{-1}(B) \right|^n \\ J_c(B) = \dfrac{J_{c0}}{\left(1 + B_0^{-1}\sqrt{k^2 B_z^2 + B_r^2}\,\right)^{\beta}} \end{cases}$$

$$\left\{ \overline{A} = \overline{\overline{G_A}}\,\overline{I};\quad \overline{B_r} = \overline{\overline{G_{BR}}}\,\overline{I};\quad \overline{B_z} = \overline{\overline{G_{BZ}}}\,\overline{I} \right\}$$

Considering the non uniformity current density distribution

The current I_i flowing in an elementary section ΔS_i ➡

$$I_i = \frac{\Delta S_i \langle r \rangle_t J_c(B_i)}{S_t\, r_i \langle J_c(B) \rangle_t} I_a \times \frac{|I_a|}{\sum |I_i|}$$

$$I_a, J_{c0}, B_0, k, \beta, E_c, n, N_t, N_r, N_z, S_t, \Delta S_i, \varepsilon$$

↓

$$I = I_a/(N_r \times N_z),\ J = I/\Delta S_i,\ E(J_{c0}),\ P_0$$

↓

Evaluate $B_r, B_z, J_c(B_r, B_z), E(J_c), \langle J_c \rangle$

↓

Evaluate the new distribution of *I*, and *P*

↓

$|P_k - P_{k-1}|/|P_k| < \varepsilon$ — Yes → End

k=1, 2,3 … (loop back)

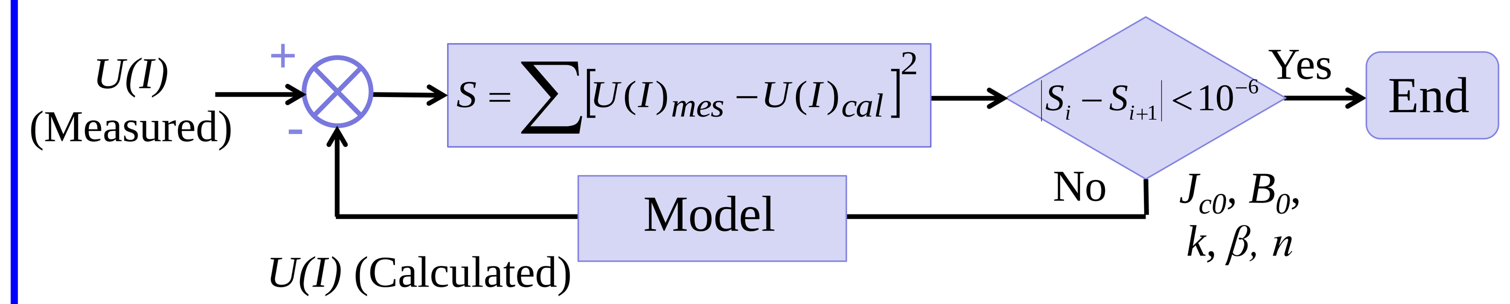
Application

System specifications

Parameter	I_c	E_c	L	W_t	H_t	R_o	R_i	N_t
Value	170 A	1 µV/cm	102 m	0,23 mm	4,3 mm	27 cm	9 cm	92

DC Characterization

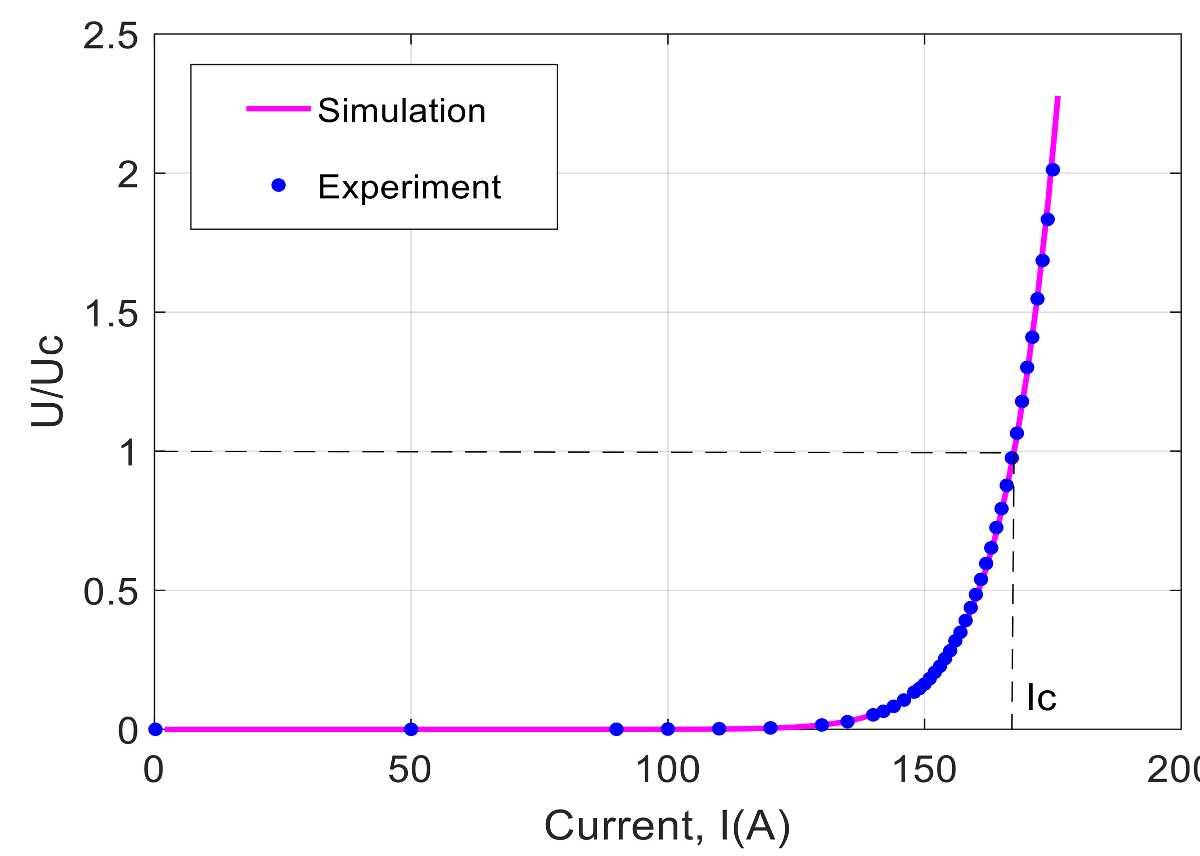
The modeling approach is combined with a least square method to determine the parameters of the *E(J) & $J_c(B)$ laws* using experimental U-I curve.



The identified parameters

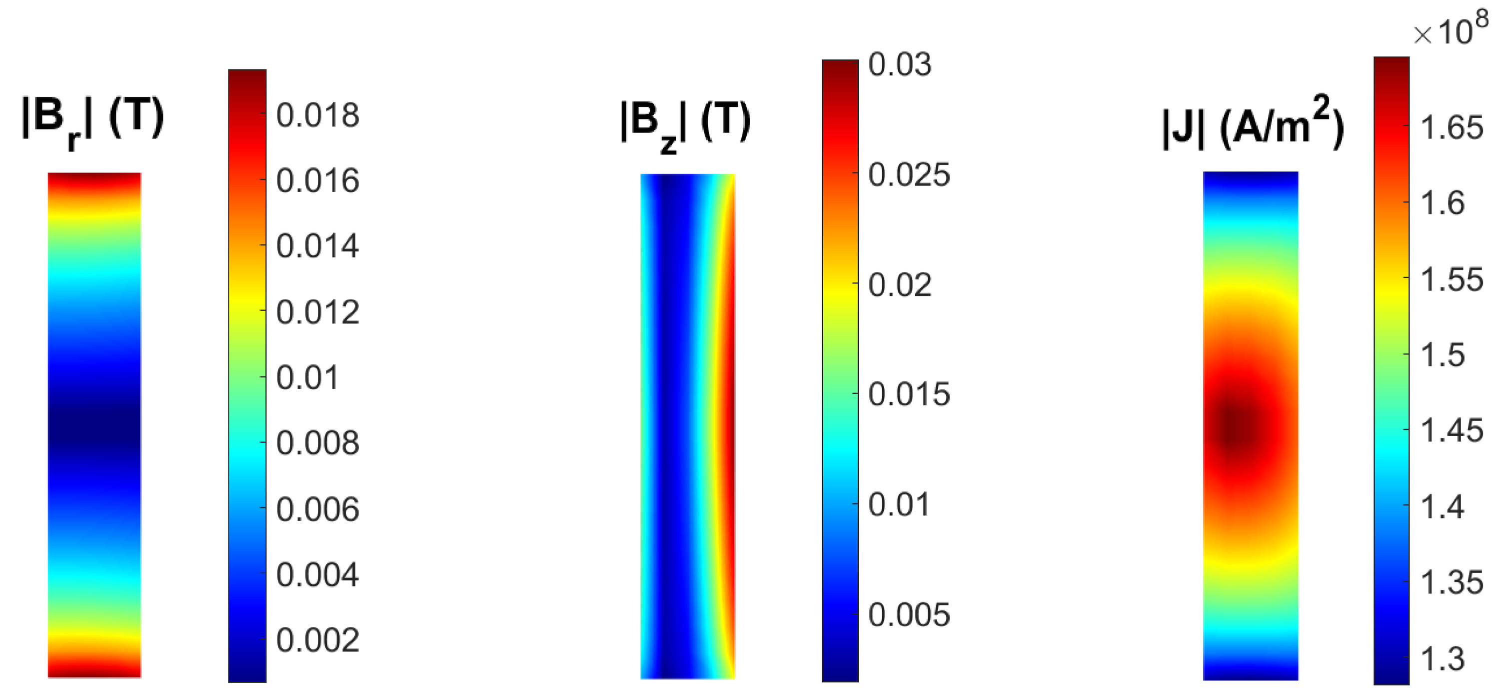
Parameter	I_{c0}	k	B_0	β	n
Value	184,82 A	0,14	0,14 T	2,26	15

Calculated and measured U-I curves of the HTS coil



Results

Current density and magnetic field distributions in the inner tape, for an applied current I_a =150 A.



Evolution of the power dissipated in the coil during the iterative solving for I_a =150 A & $\varepsilon = 10^{-6}$,