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Modelling of Electromagnetic and Thermo-Fluid Dynamics Occurring in ZFC-YBCO bulks under Alternate Magnetic Fields and Immersed in Liquid Nitrogen (LN_2) → Abstract 73

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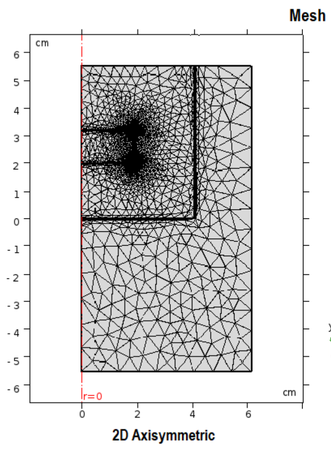
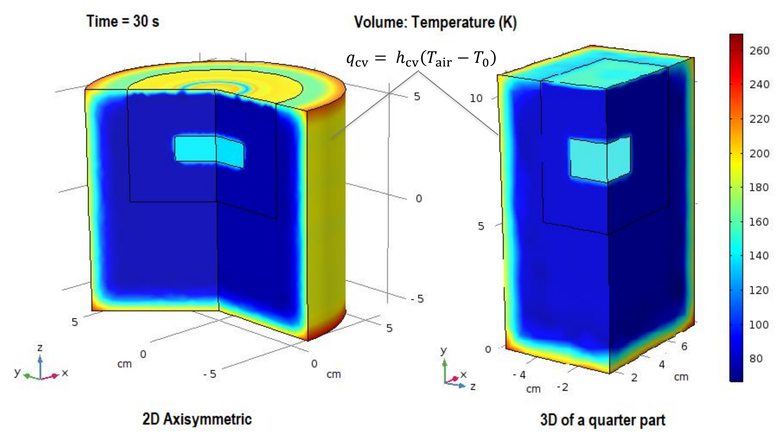
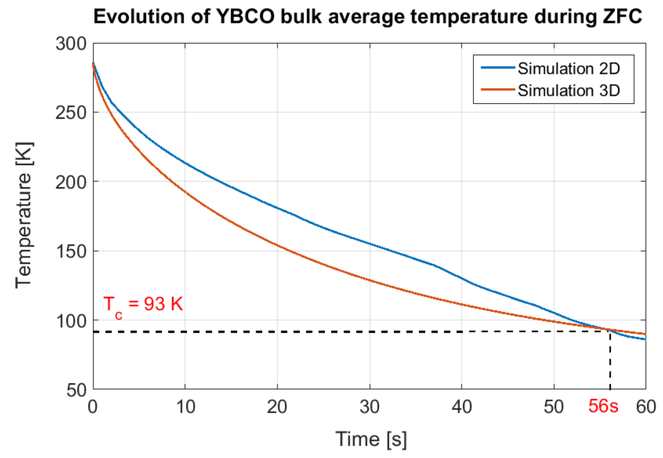
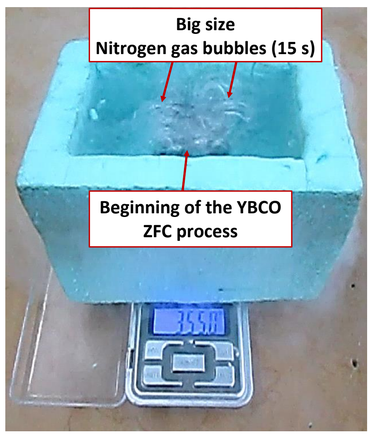
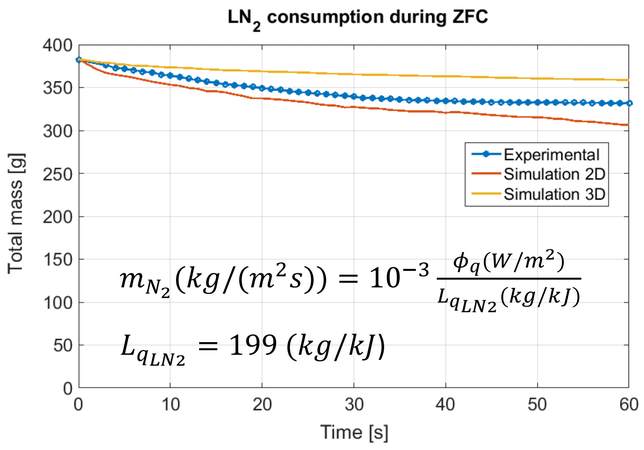
Fast Zero-Field Cooling (ZFC) → Heat Transfer (HT) with phase change + Turbulent Bubbly Flow (TBF)

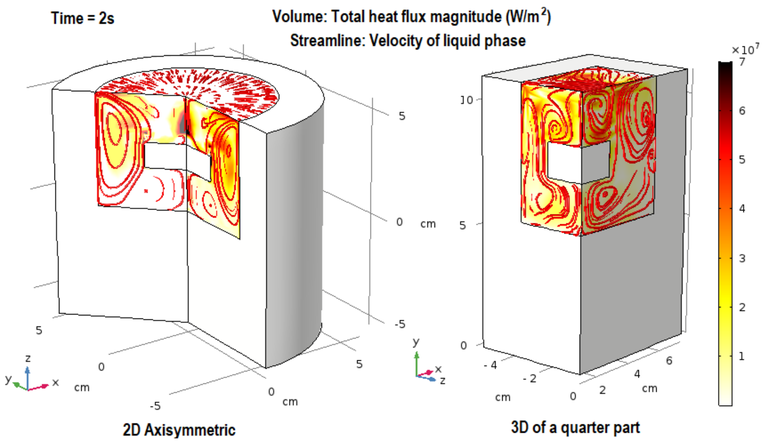


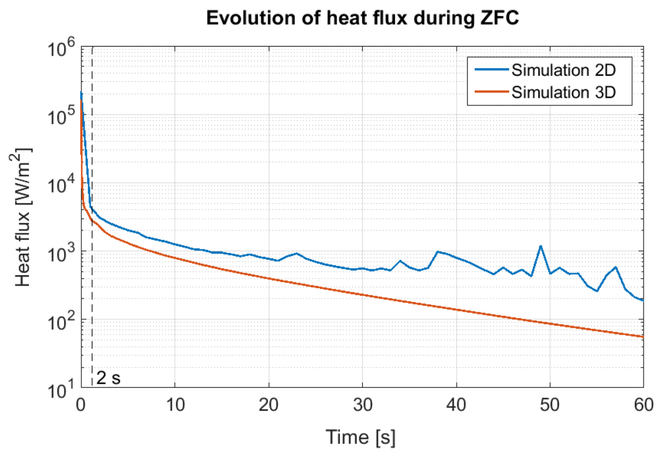




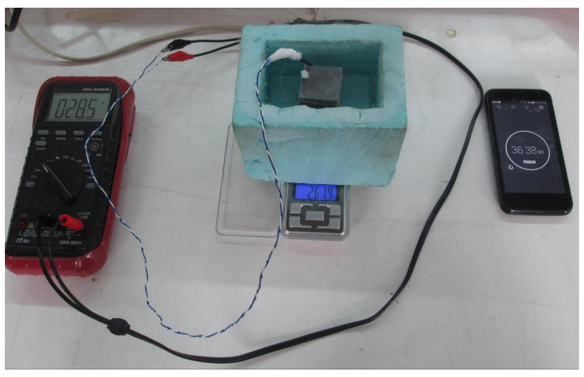








Heating by room temperature after ZFC and FC → HT with phase change + Laminar Flow (LF)

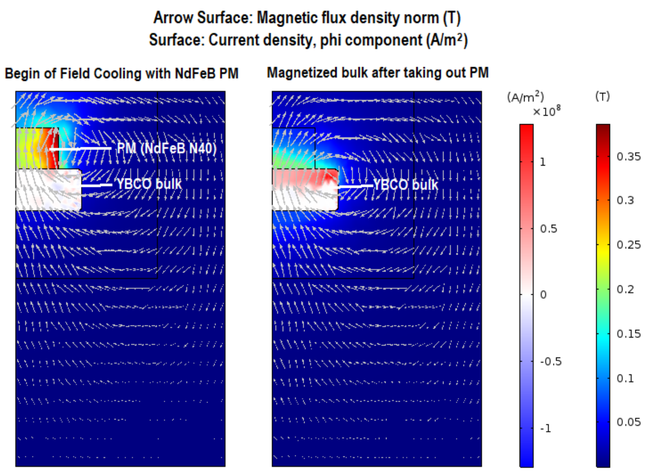


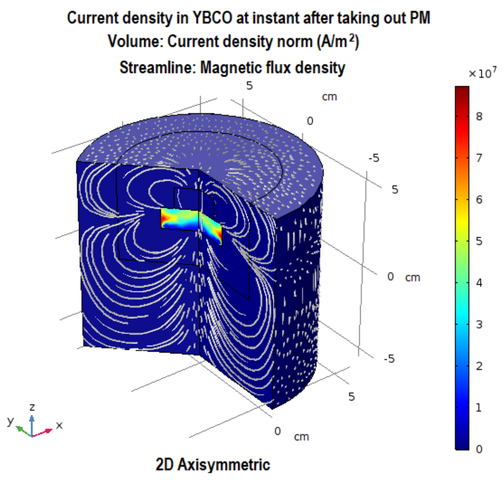
Convection-Diffusion: $\rho\, C_p \frac{\partial T}{\partial t} + \rho\, C_p\, \boldsymbol{u} \cdot \boldsymbol{\nabla} T - k\, \nabla^2 T = Q$

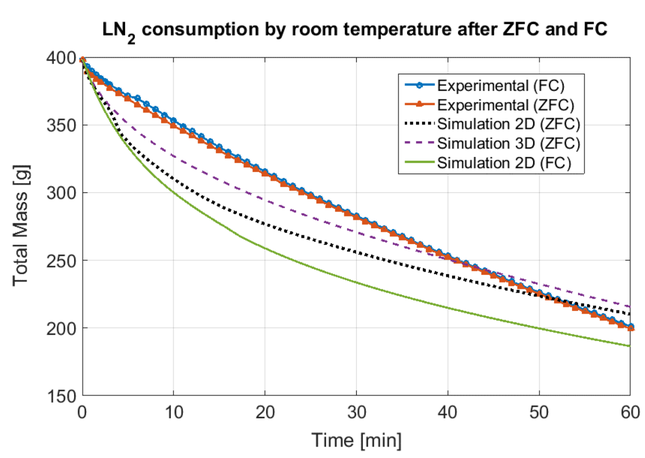
Phase-Change: $\rho = \theta\, \rho_1 + (1-\theta)\, \rho_2\ ;\quad k = \theta\, k_1 + (1-\theta)\, k_2$

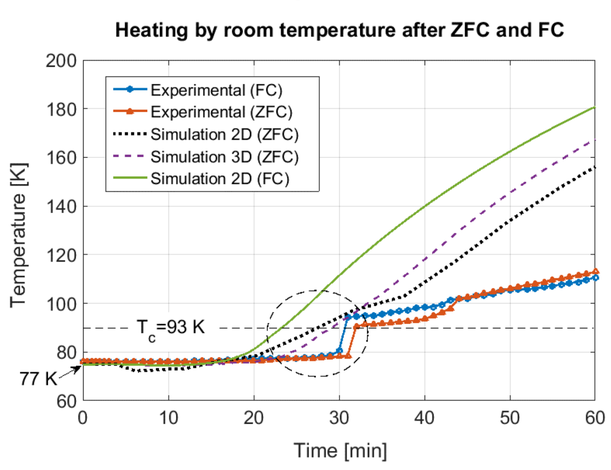
Navier-Stokes: $\rho \frac{\partial\, \boldsymbol{u}}{\partial t} + \rho\, \boldsymbol{u}\,.\boldsymbol{\nabla}\, \boldsymbol{u} - \mu\, \nabla^2\, u = -\boldsymbol{\nabla}\, p$

Values ρ, k, C_p, μ for XPS, YBCO and LN_2 in [3]

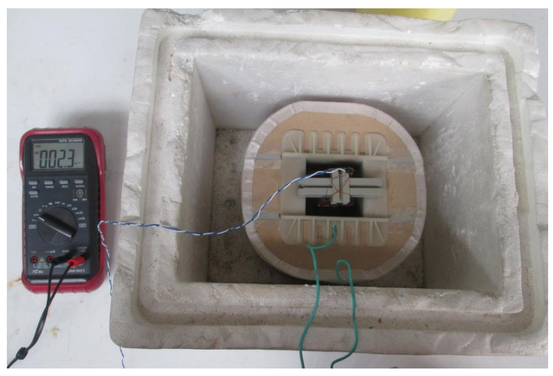








Heating by induction under alternate B field → HT with phase change + Magnetic Induction

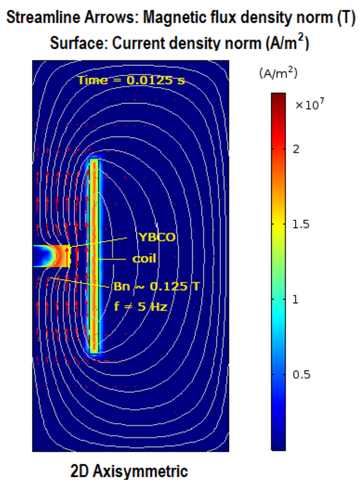


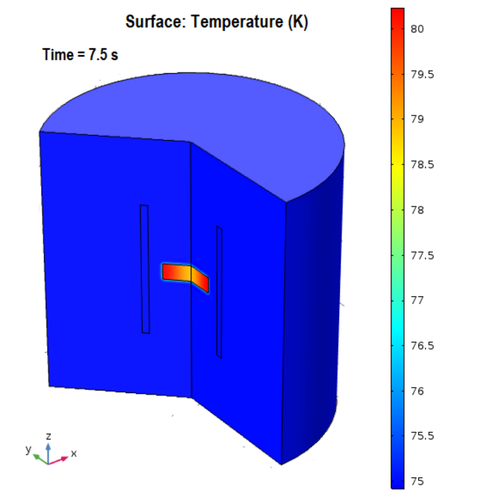
EM Induction: $\boldsymbol{\nabla} \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$

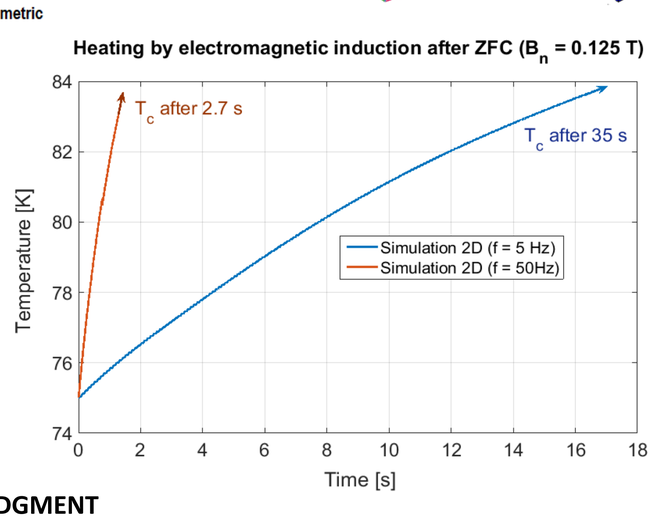
SC model: $J = J_C \left(\frac{E}{E_0}\right)^{1/n}$

$J_C = \alpha \left(1 - \left(\frac{T}{T_C}\right)^2\right)^{3/2} \frac{B_0}{B_0 + B}$

Values $n,\ \alpha,\ E_0$ and B_0 in [1]







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[1] J. Arnaud, and P.J. Costa Branco, "Electrothermal characteristics of YBCO bulk magnets deep in LN2: a preliminary analysis for its use as excitation system of low-speed synch. generators," IEEE Trans. on App SC. vol. 26(3), April 2016.

[2] A.J. Arsénio, M.V. Carvalho, C. Cardeira, R. Melício and P.J. Costa Branco, "Experimental Setup and Efficiency Evaluation of Zero-Field-Cooled (ZFC) YBCO Magnetic Bearings." IEEE Trans. on App. SC, vol. 27, no. 4, Jun. 2017.

[3] A.J. Arsénio, M.V. Carvalho, C. Cardeira, R. Melício and P.J. Costa Branco, "The Critic Liquid–Gas Phase Transition Between Liquid Nitrogen and YBCO HTS Bulks: From FEM Modeling to its Experimental Study for ZFC Levitation Devices", IEEE Trans. on App. SC, vol. 28, no. 4, Jun. 2018.

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