THE CRITIC PHASE TRANSITION BETWEEN LN2 AND YBCO BULKS: FROM FEM MODELING TO ITS EXPERIMENTAL STUDY FOR ZFC LEVITATION DEVICES

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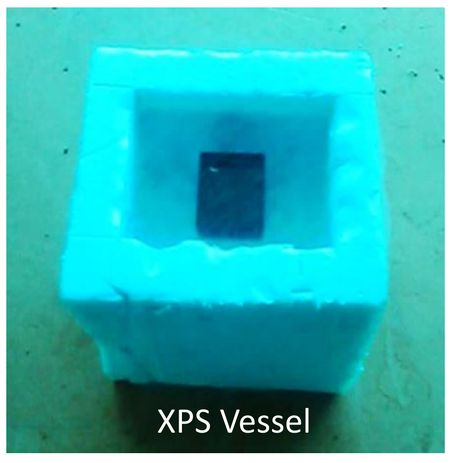
Goals

- Time to Zero-Field Cool (ZFC) a YBCO bulk from environment down to critical temperature of superconductivity ?
- LN2 consumption during the initial ZFC of a YBCO bulk inside a Extruded Polystyrene (XPS) Vessel with top surface open ?
- LN2 consumption rate during the electromagnetic heating (EM) of a YBCO bulk inside a cryostat with top cover ?
- Operative heating time from cryogenic temperature up to critical temperature of superconductivity ?
- Experimental validation of the models used on Finite Element Simulations.



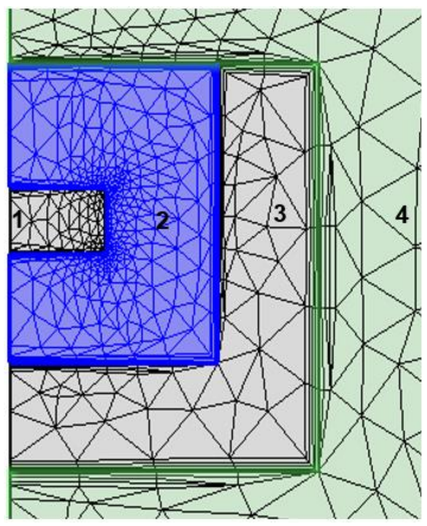
Modeling

Zero-Field Cooling:	• Thermal Diffusion (YBCO) • Thermal Convection-Diffusion (LN2, Air) • Phase-Change (LN2) • Turbulent Bubbly Flow (LN2)
EM Heating in Operation:	• E.M. Induction / Hysteresis Losses • Thermal Diffusion (YBCO) • Thermal Convection-Diffusion (LN2, Air) • Phase-Change (LN2)

$$\vartheta \frac{\partial \emptyset}{\partial t} - \boldsymbol{\nabla} \cdot \alpha \, \boldsymbol{\nabla} \emptyset + u . \boldsymbol{\nabla} \emptyset + \beta \, \emptyset = f$$

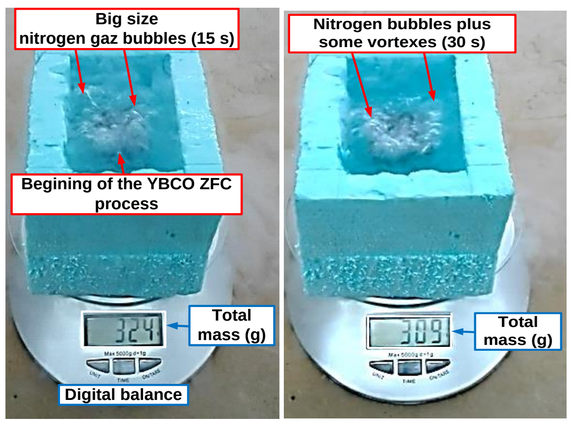
Differential Equation	$\emptyset$	ϑ	α	β	f
Ampere's Law	$\boldsymbol{A}$	-	1	-	$-\mu \boldsymbol{J_s}$
Convection-Diffution	T	1	$\frac{k}{\rho \, C_p}$	-	$\frac{Q}{\rho \, C_p}$
Navier-Stokes	$\boldsymbol{u}$	-	$\upsilon = \frac{\mu}{\rho}$	-	$-\frac{\boldsymbol{\nabla} p}{\rho}$

Finite Element Analysis

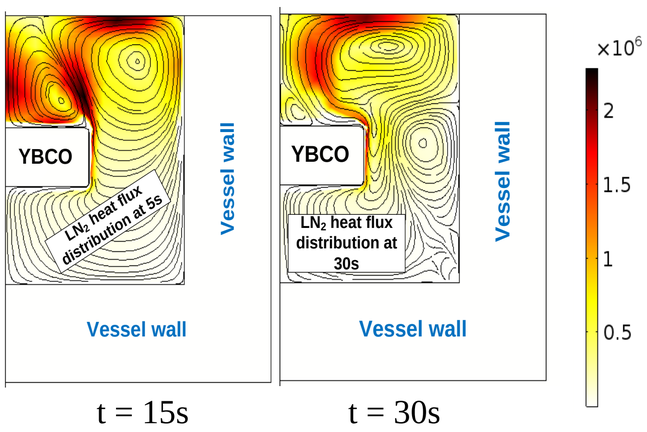


ZFC Results

Experimental measurements

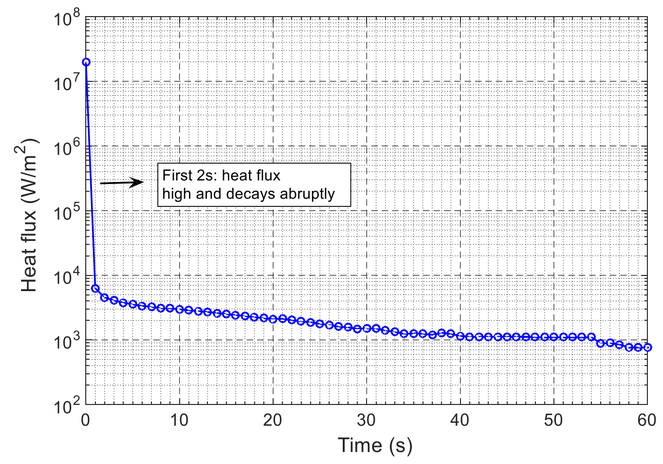


Heat flux (W/m²) & Flow stream lines

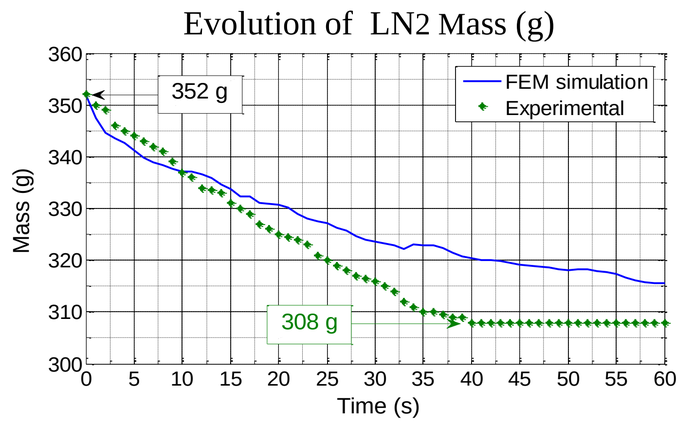


t = 15s t = 30s

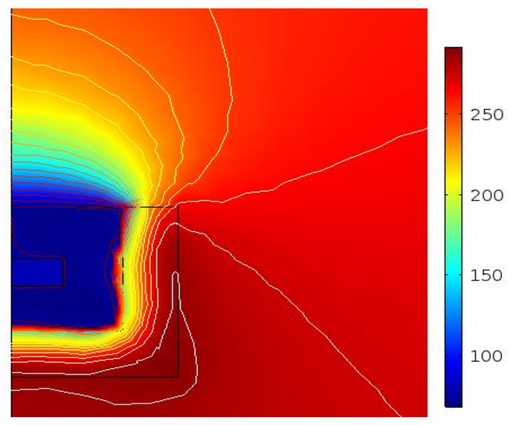
Average heat flux (W/m²) at YBCO/LN2 boundary



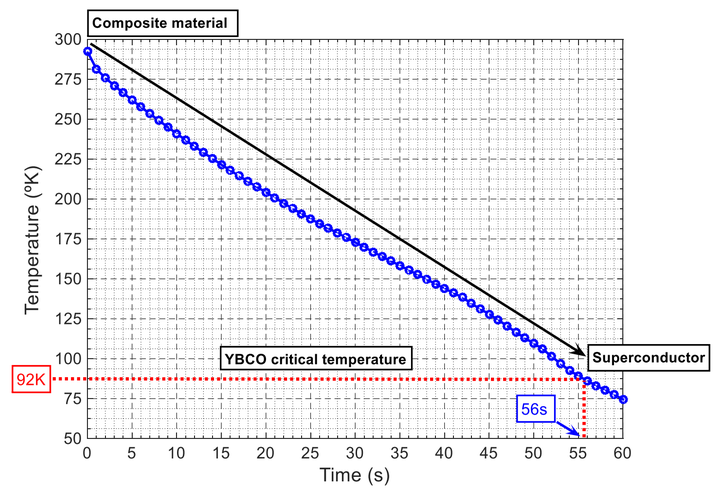
Evolution of LN2 Mass (g)



Thermal contours (ºK) (t=58s)

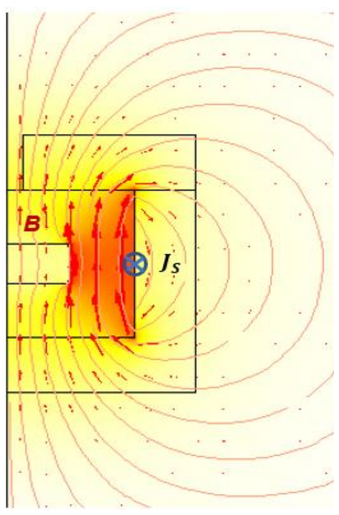


Average YBCO temperature (ºK)

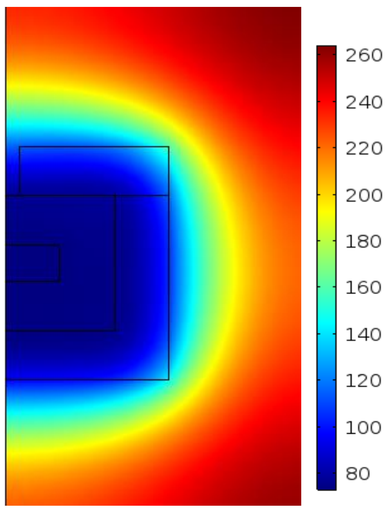


EM Heating Results

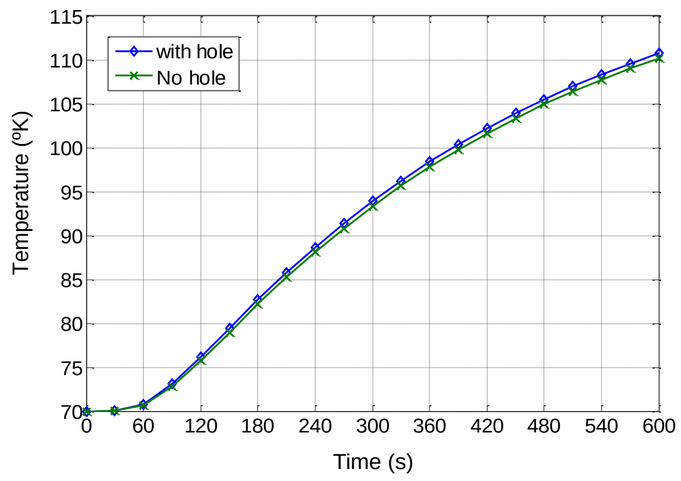
EM Induction Field (T) (t=90s)



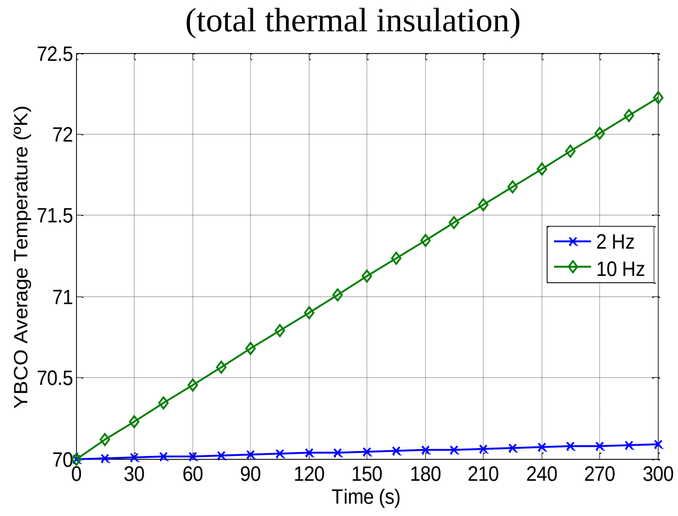
Temperature (ºK) (t=90s)



Average Temp. (ºK) at YBCO side boundary (XPS walls and top cover)



Average YBCO Temperature (ºK) (total thermal insulation)



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[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.

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