Modeling the non-uniform J_c distribution along the c-axis of seeded melt growth (RE)BCO bulks

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Overview

I. Introduction

Superconducting magnetic bearings

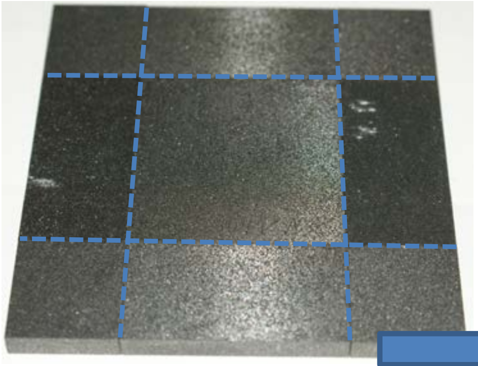
(a) “Century”, Southwest Jiaotong Univ., China, 2014.

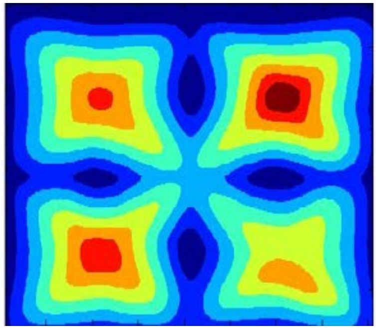
(b) “SupraTransII”, IFW Dresden, Germany.

(c) “Maglev Cobra”, Federal Univ. Rio de Janeiro, Brazil, 2015.

Bulks

GdBCO bulk [2]
D = 41 mm





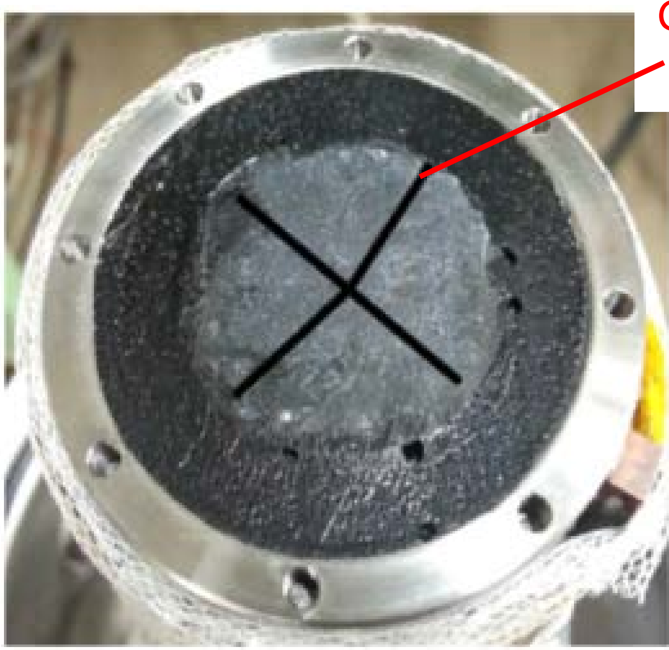
YBCO bulk [1]
40 x 40 x 15 mm

Bi-2223 [3]
D = 59 mm, L = 100 mm

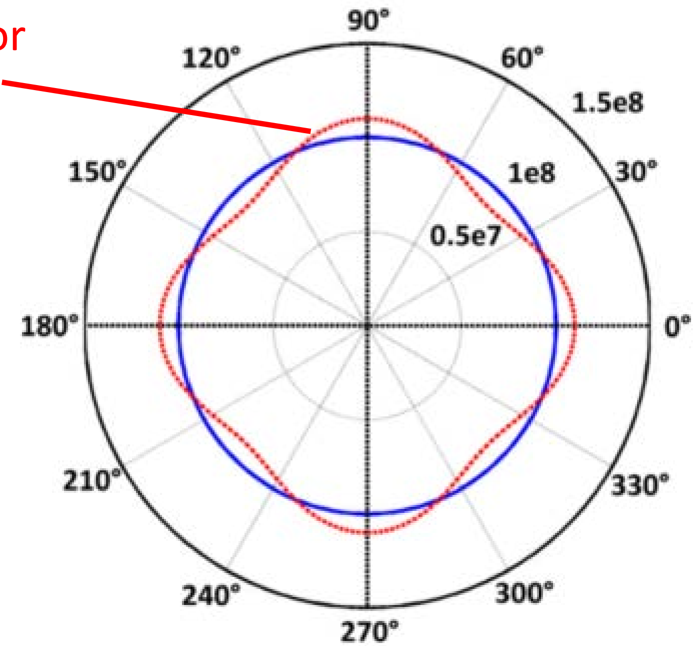
[1] Y. Terao, M. Sekino, H. Ohsaki, H. Teshima, M. Morita, “Magnetic shielding characteristics of multiple bulk superconductors for higher field applications,” *IEEE Transaction on Applied Superconductivity*, vol. 21, no. 3, pp. 1584-1587, 2011.
[2] M.D. Ainslie, H. Fujishiro, T. Ujiie, J. Zou, A.R. Dennis, Y.-H. Shi, D.A. Cardwell, “Modelling and comparison of trapped fields in (RE)BCO bulk superconductors for activation using pulsed field magnetization,” *Superconductor Science and Technology*, vol. 27, id. 065008, 2014.
[3] “Bi-2223 tubes for current limiters,” [Online]. Available: www.can-superconductors.com/current-limiters.html

Seeded melt growth (RE)BCO bulks

Growth sector boundaries



YBCO bulk [1]



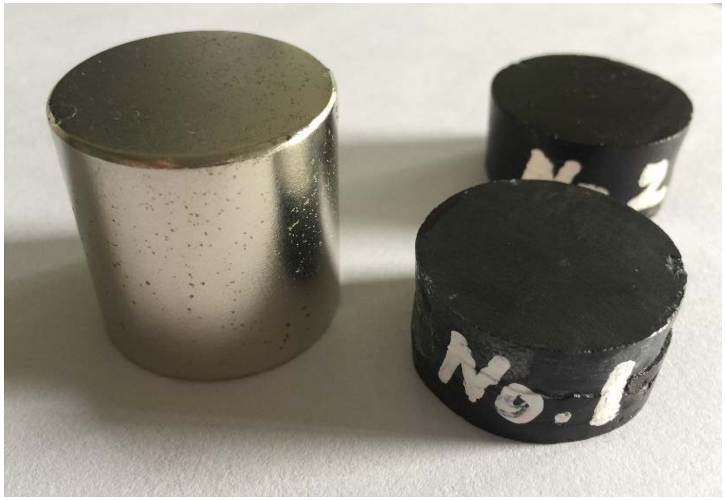
Spatial distribution of $J_c(\theta)$ in the ab-plane of the bulk [1]

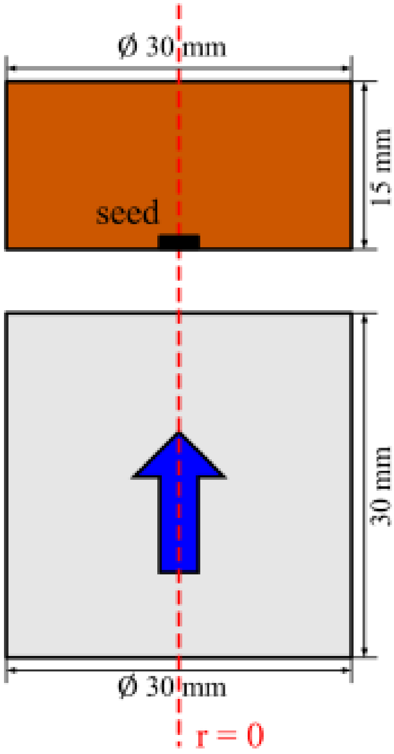
➡ What about J_c along the c-axis ?

[1] M.D. Ainslie, H. Fujishiro, T. Ujiie, J. Zou, A.R. Dennis, Y.-H. Shi, D.A. Cardwell, "Modelling and comparison of trapped fields in (RE)BCO bulk superconductors for activation using pulsed field magnetization," *Superconductor Science and Technology*, vol. 27, id. 065008, 2014.

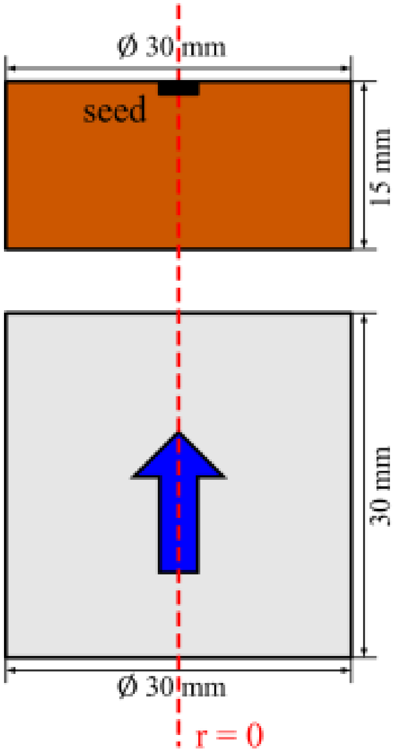
II. Measurement of the levitation force

Geometry

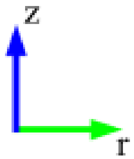




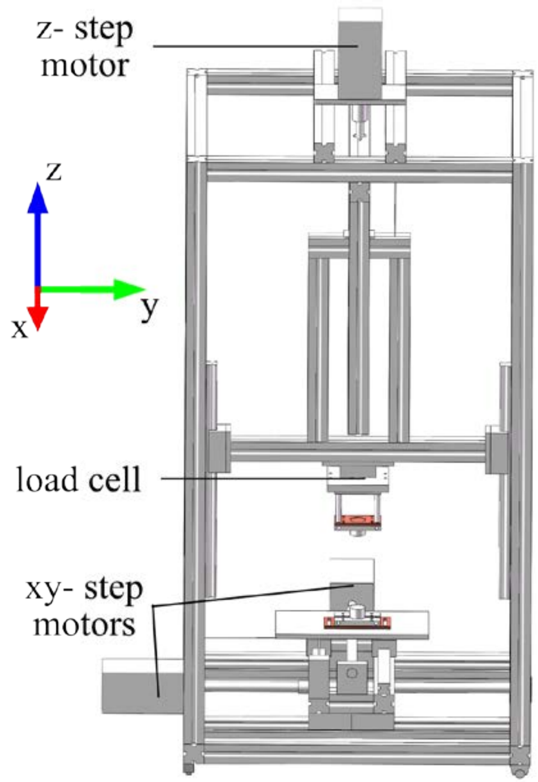
Bottom seed configuration

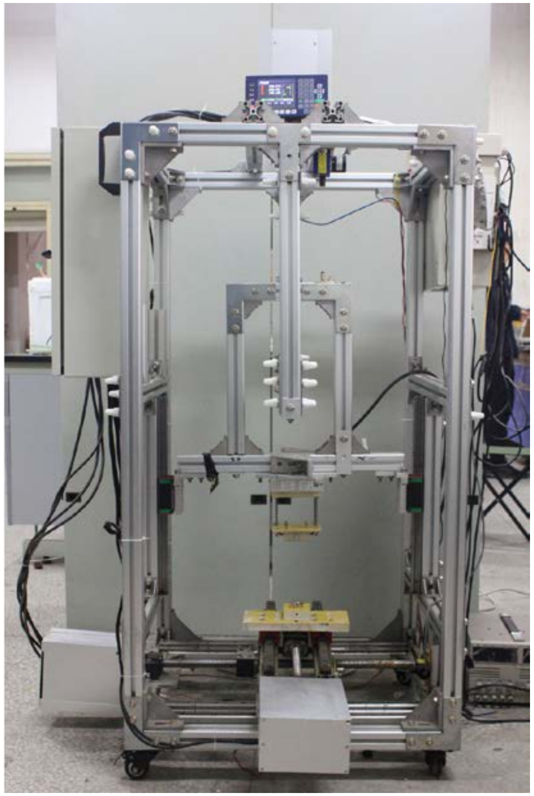


Top seed configuration

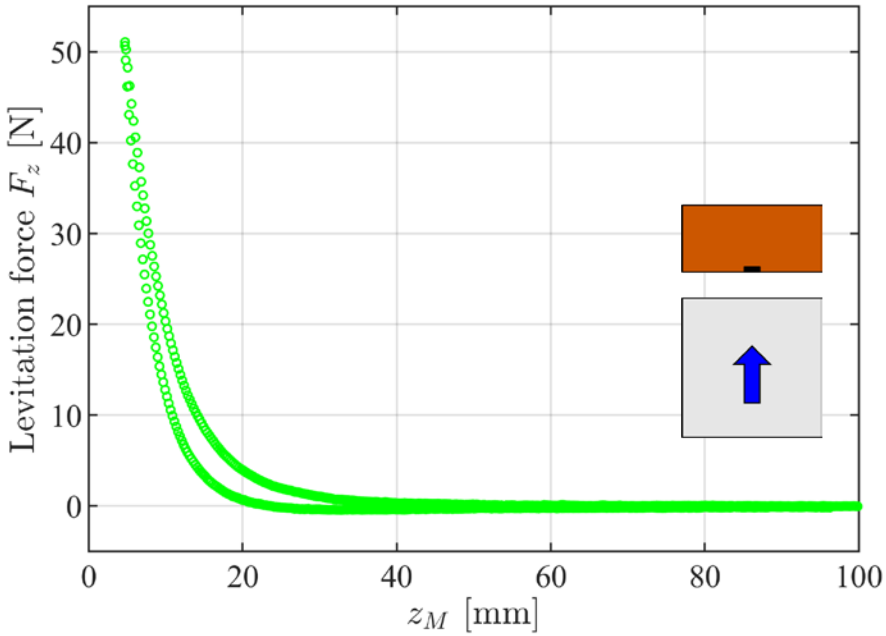


Testbench

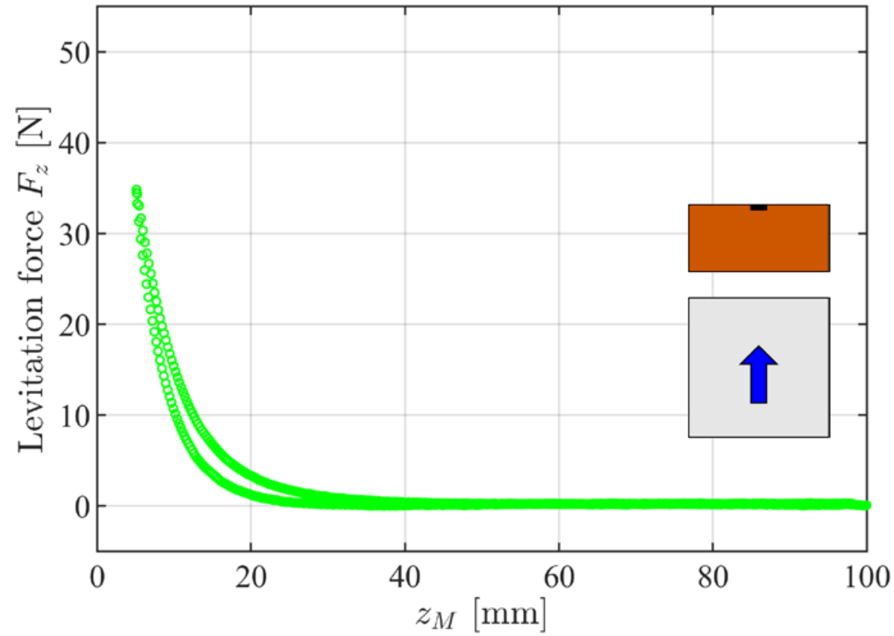




Results



Bottom seed configuration



Top seed configuration

➡ The maximal levitation force measured in bottom seed configuration is 30 % higher than the one measured in top seed configuration.

III. Modeling of a superconducting magnetic bearing

Superconducting magnetic bearings FE models

		2-D	2-D AXI	3-D
A-V	Homemade	Hofman2001 Dias2009 Ma2013	Sugiura1991 Takeda1994 Chun2001 Ruiz-Alonso2004 Wang2006 Sotelo2009	Ueda2006
	Software	-	Li2008	Hauser1997
T-Ω	Homemade	Zhang2008	Zheng2007 Gou2007	Uesaka1993 Tsuchimoto1994 Tsuda1998 Ma2010 Pratap2015
	Software	-	-	-
E	Homemade	-	-	-
	Software	-	-	-
H	Homemade	Lu2015	-	Lu2008 Yu2015
	Software	Sass2015 **Quéval2016**	Patel2015 **Quéval2018**	Patel2015 **Quéval2016**

[Queval2018] L. Quéval, K. Liu, W. Yang, V.M.R. Zermeño, G.T. Ma, "Superconducting magnetic bearings simulation using an H-formulation finite element model," *Superconductor Science and Technology*, vol. 31, no. 8, pp. 084001, March 2018.

Simulation of a superconducting magnetic bearing

➡ Guideway
- Permanent magnet
- Exact geometry
- Iron B-H curve

➡ SC bulk
- 3D
- Movement
- Number of elements

😰 Simulate ?

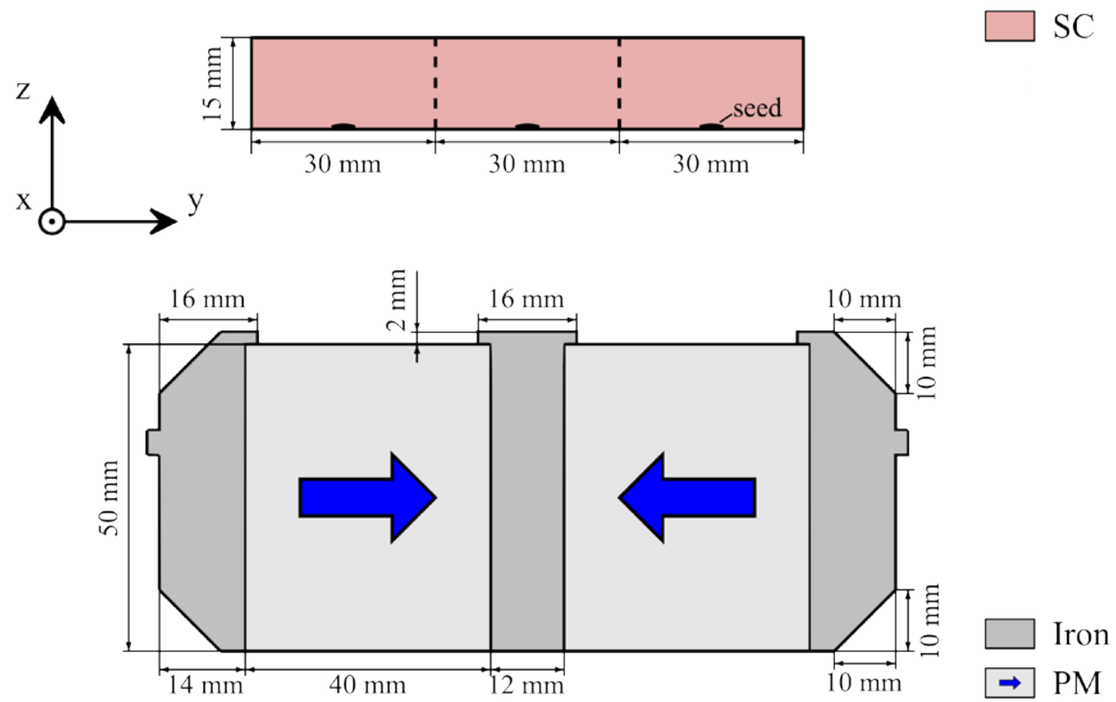


Fig.1 – Superconducting magnetic bearing of the SupraTrans vehicle

Simulation of a superconducting magnetic bearing

Divide

Guideway
- Permanent magnet
- Exact geometry
- Iron B-H curve

SC bulk
- 3D
- Movement
- Number of elements

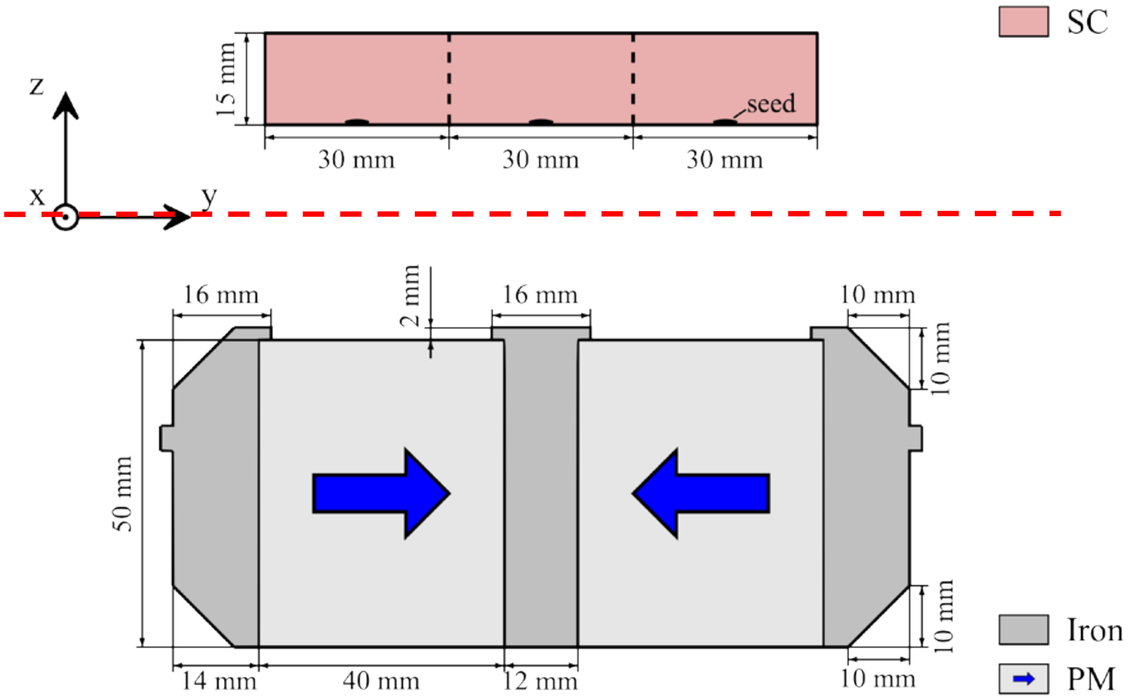


Fig.1 – Superconducting magnetic bearing of the SupraTrans vehicle

Simulation of a superconducting magnetic bearing

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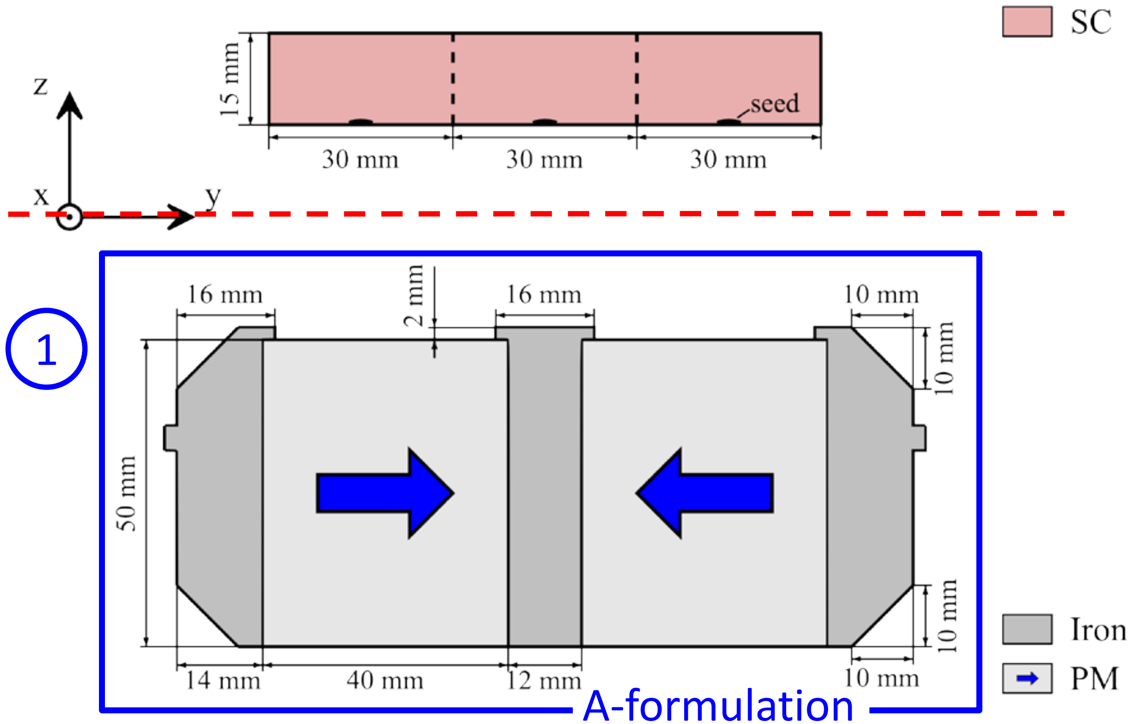


Fig.1 – Superconducting magnetic bearing of the SupraTrans vehicle

Simulation of a superconducting magnetic bearing

Divide

Guideway
- Permanent magnet
- Exact geometry
- Iron B-H curve

SC bulk
- 3D
- Movement
- Number of elements

Conquer !

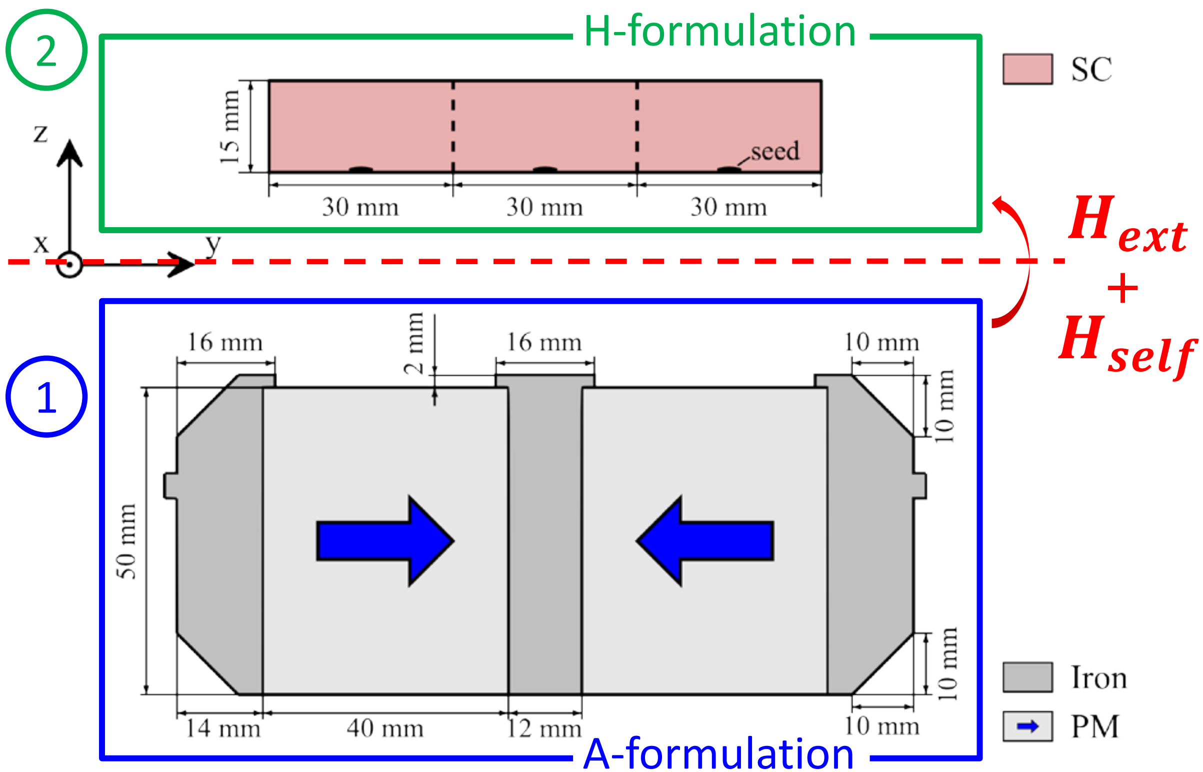
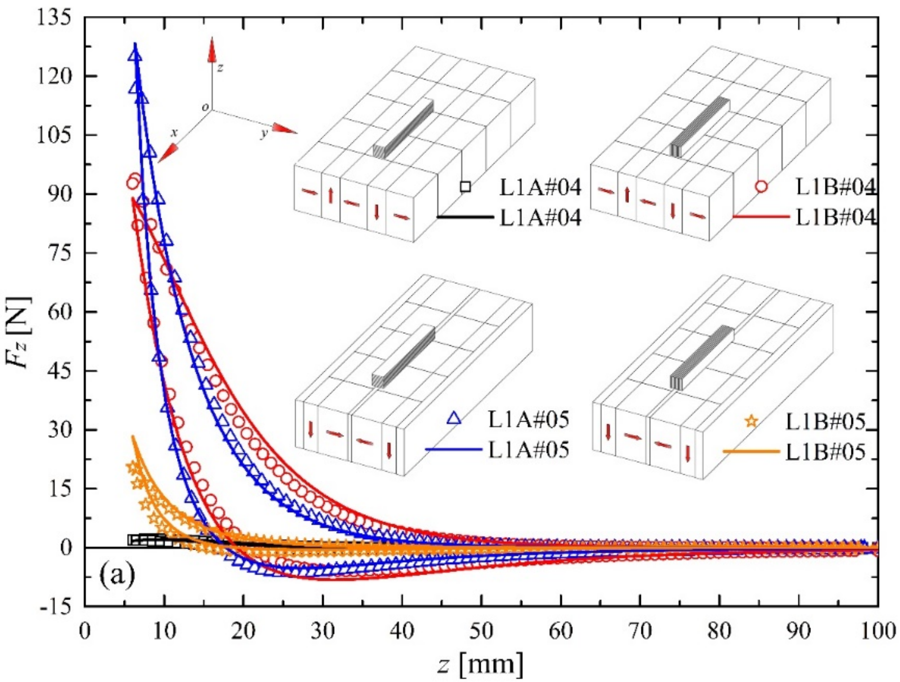
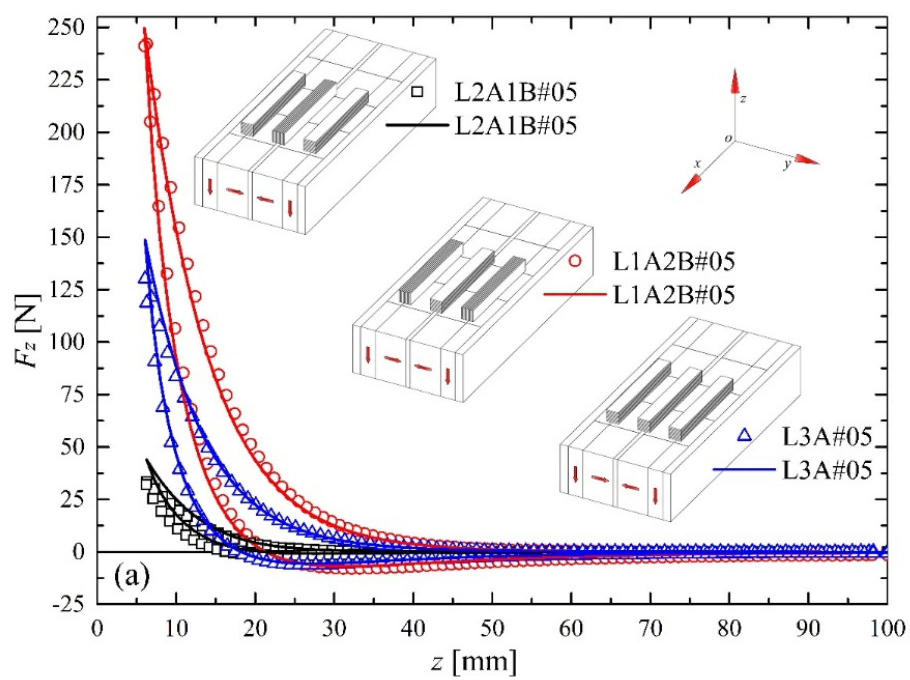


Fig.1 – Superconducting magnetic bearing of the SupraTrans vehicle

Stack-type SMB

- 2-D model
- 1 stack and 3 stacks of 120 tapes
- Systematic validation

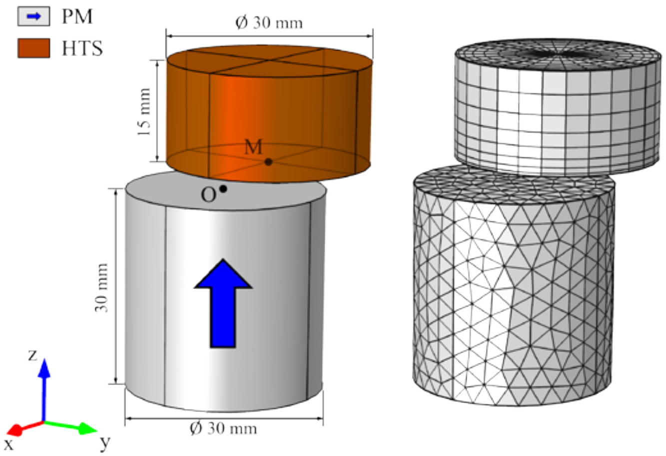


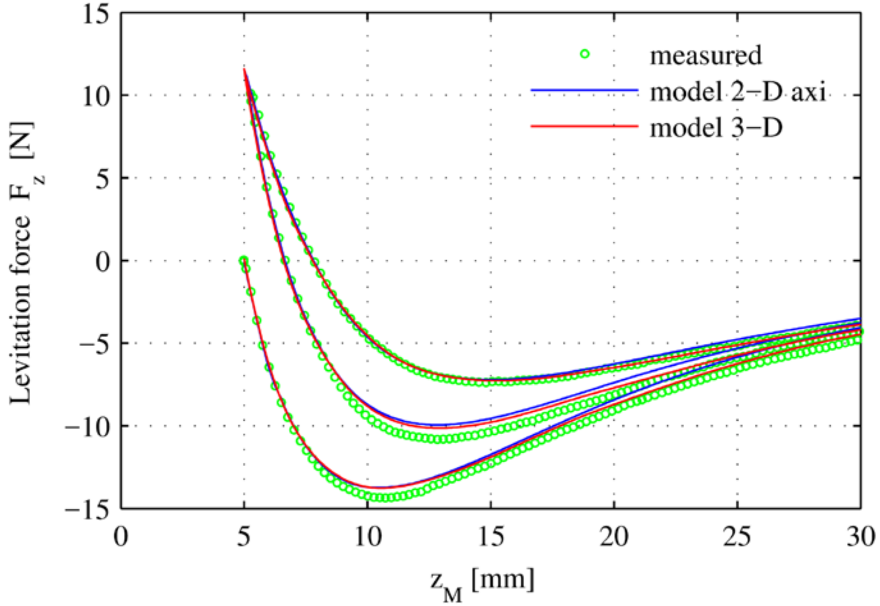


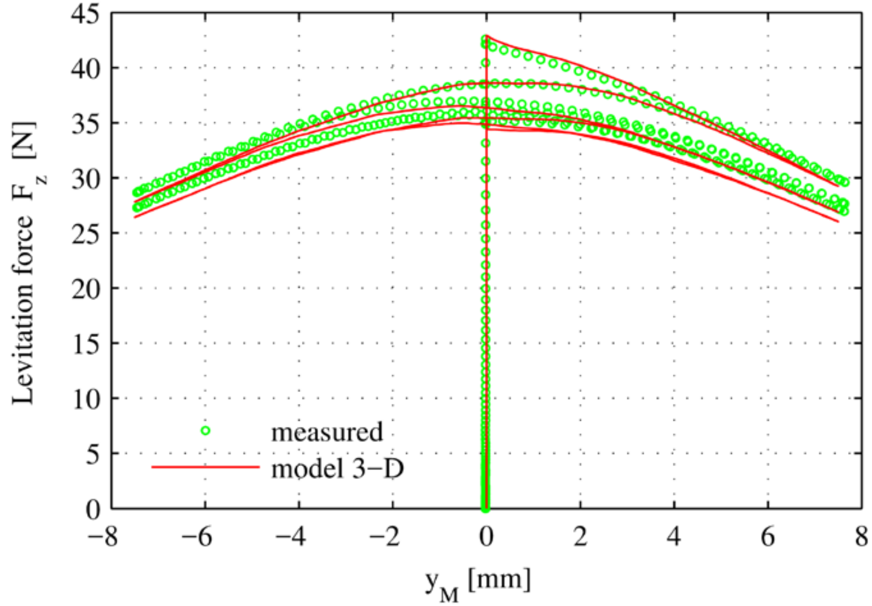
[Liu2017] K. Liu, W. Yang, G.T. Ma, L. Quéval, T. Gong, C. Ye, X. Li, Z. Luo, "Experiment and simulation of superconducting magnetic levitation with REBCO coated conductor stacks," *Superconductor Science and Technology*, vol. 31, no. 1, pp. 015013, Dec. 2017.

Bulk-type SMB

- 2-D axisymmetric model
- 3-D model
- Systematic validation



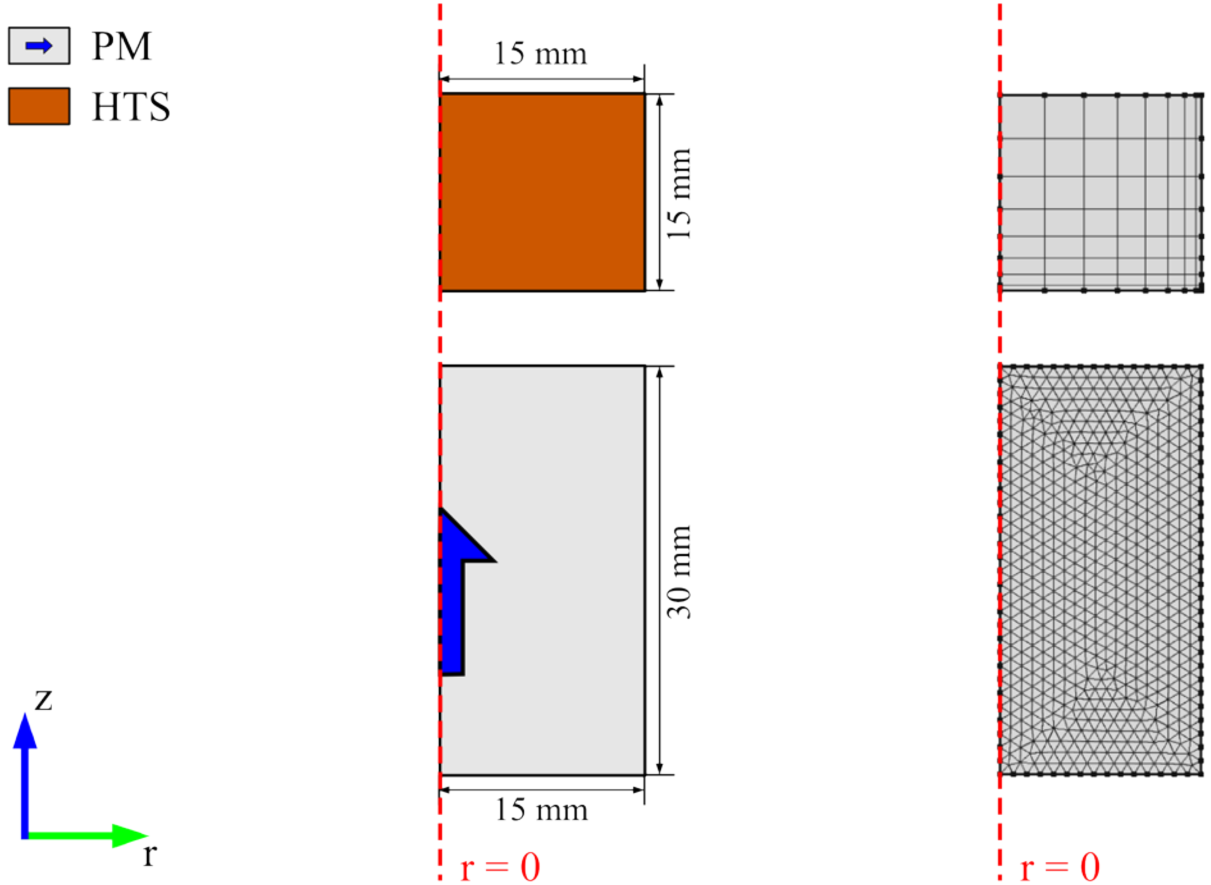




[Queval2018] L. Quéval, K. Liu, W. Yang, V.M.R. Zermeño, G.T. Ma, "Superconducting magnetic bearings simulation using an H-formulation finite element model," *Superconductor Science and Technology*, vol. 31, no. 8, pp. 084001, March 2018.

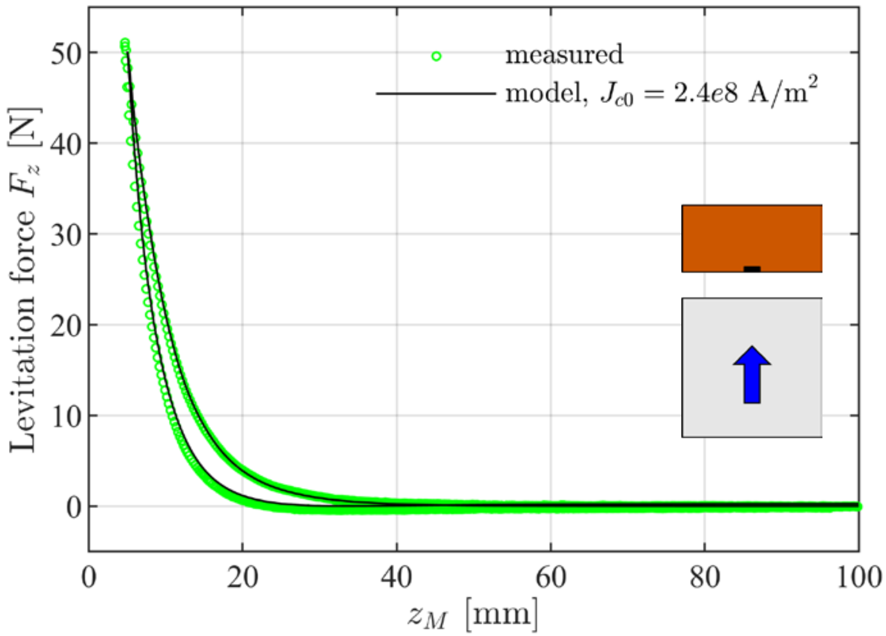
IV. Modeling the non-uniform J_c distribution

Geometry and mesh

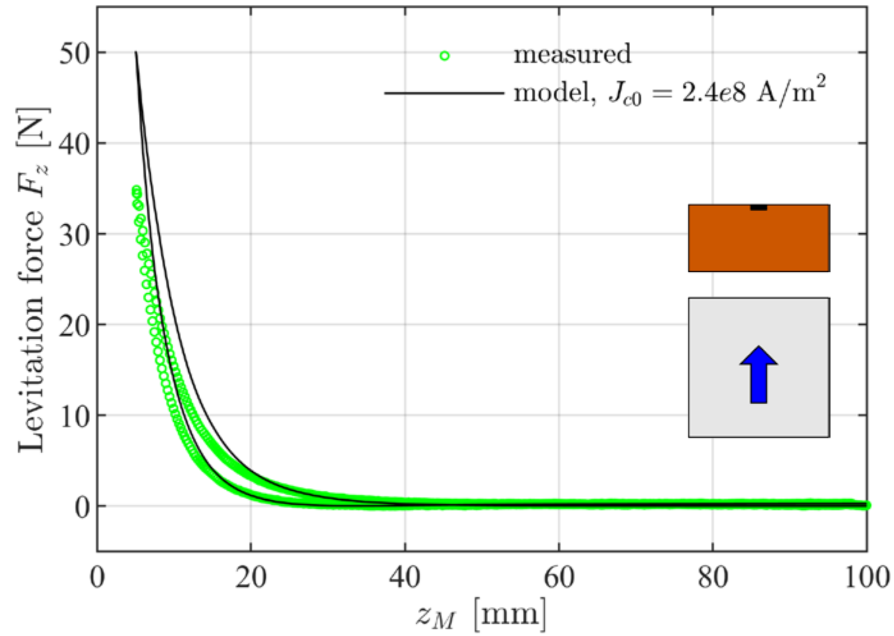


Identification

Hyp: $J_{c0}(z) = \text{constant}$



Bottom seed configuration

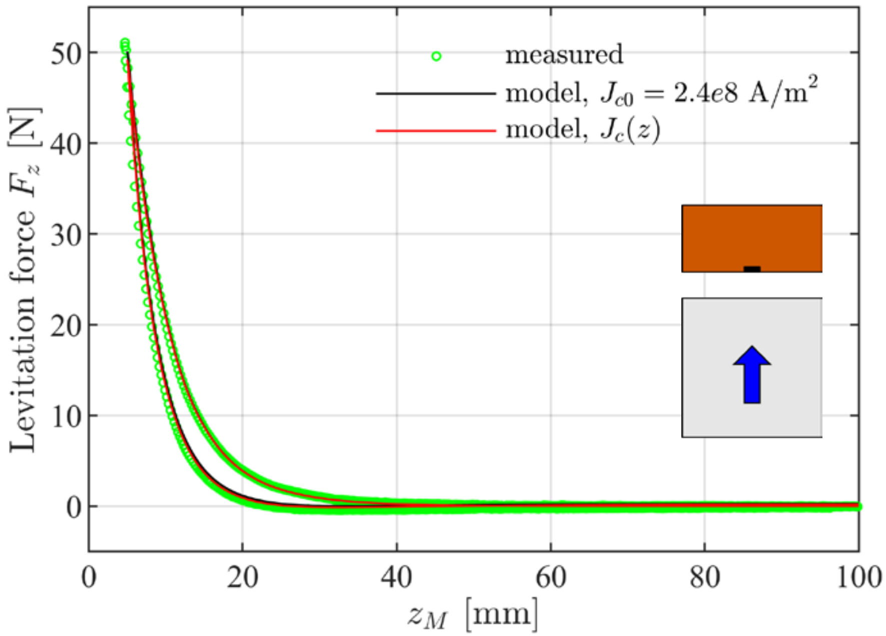


Top seed configuration

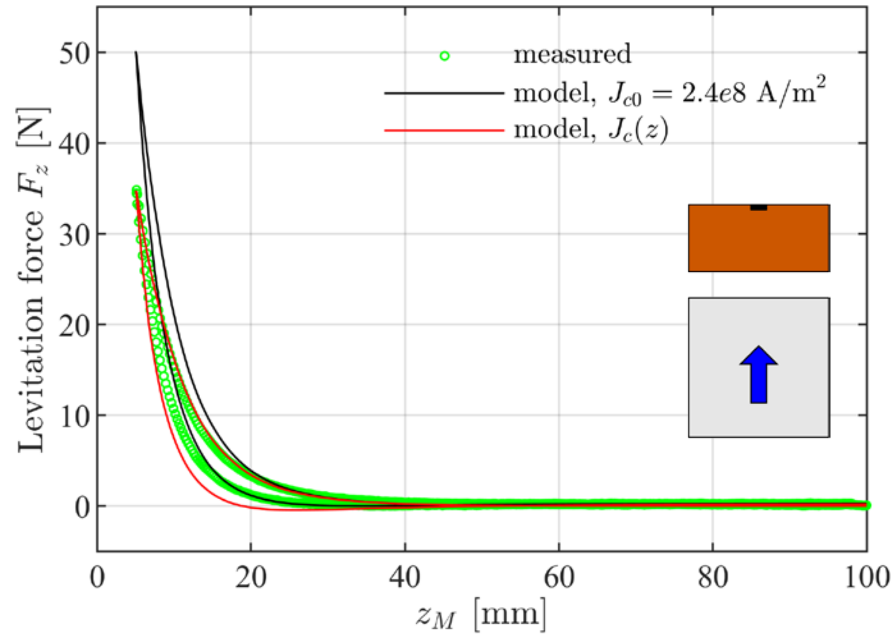
➡ The model with uniform J_{c0} overestimates the force in the top seed configuration.

Identification

<u>Hyp</u>: $J_{c0}(z) = J_{c0,S}(1 - c_0|z - z_S|)$



Bottom seed configuration



Top seed configuration

➡ The model with non-uniform J_{c0} is able to reproduce the force of both the top seed and bottom seed configurations.

V. Applications

VII. Conclusions

Conclusions

- Seeded melt growth (RE)BCO bulks can exhibit a non-uniform J_c distribution along the c-axis.
- For levitation applications, the bottom seed configuration (seed on the bottom surface of the bulk near the PM) is usually selected to maximize the levitation force.
- The non-uniform local critical density should be taken into account when designing systems using seeded melt growth (RE)BCO bulks.
- This can be done by using a linear relationship of the form:

$$J_{c0}(z) = J_{c0,S}(1 - c_0|z - z_S|)$$

Where $J_{c0,S}$ is the local critical current density at the seed location $(0, z_S)$ and c_0 describes the degradation of J_c with the distance from the seed in the c-axis direction.

References

[1] L. Quéval, K. Liu, W. Yang, V.M.R. Zermeño, G.T. Ma, “Superconducting magnetic bearings simulation using an H-formulation finite element model,” *Superconductor Science and Technology*, vol. 31, no. 08, pp. 084001, March 2018.

[2] K. Liu, W. Yang, G.T. Ma, L. Quéval, T. Gong, C. Ye, X. Li, Z. Luo, “Experiment and simulation of superconducting magnetic levitation with REBCO coated conductor stacks,” *Superconductor Science and Technology*, vol. 31, no. 1, pp. 015013, Dec. 2017.

[3] L. Quéval, G.G. Sotelo, Y. Kharmiz, D.H.N. Dias, F. Sass, V.M.R. Zermeño, R. Gottkehaskamp, "Optimization of the superconducting linear magnetic bearing of a maglev vehicle," *IEEE Transactions on Applied Superconductivity*, vol. 26, no. 3, pp. 3601905, Apr. 2016.