COPPE UFRJ

# Modelling of two topologies of trapped-flux machines using second generation tapes with T-A 3D formulation

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# Overview

- Various superconducting machines with HTS are investigated on current literature.

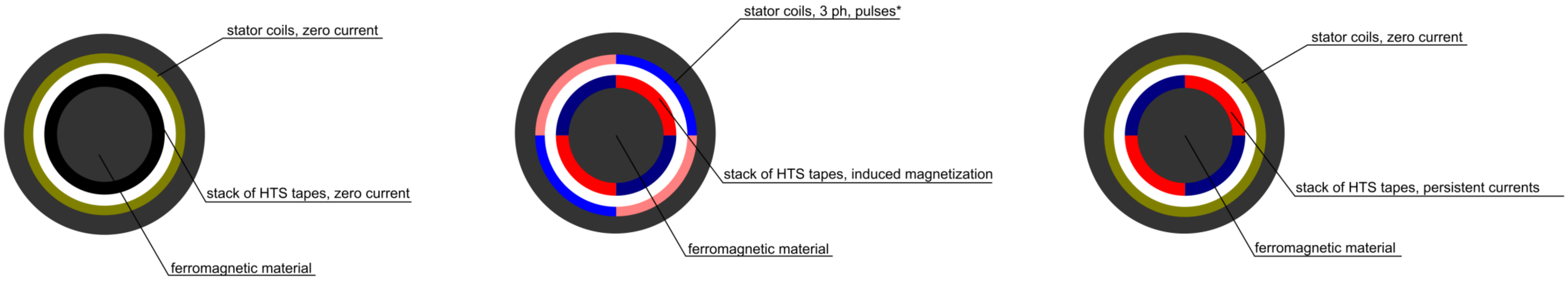
- An interesting general topology is the trapped flux superconducting machine:
  - with bulks
  - with stacks of 2G tapes

- FEM simulations: powerful tools to help design superconducting electric machinery.
  - H formulation
  - A-V formulation
  - T-A formulation

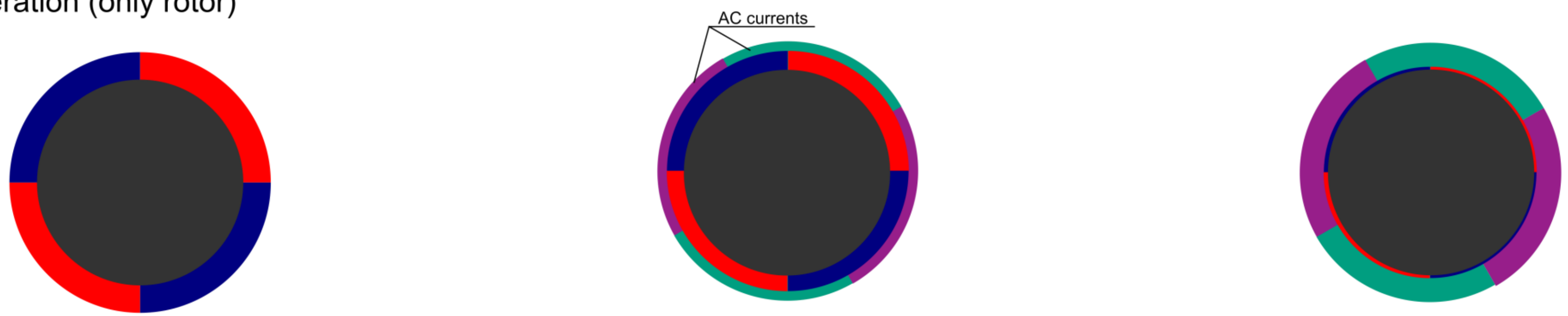
# Trapped-flux machines with stacks

Partially superconducting machines with stacks of tapes acting as *quasi*-permanent magnet

Magnetization




Operation (only rotor)




slip = 0

No AC currents, no AC losses

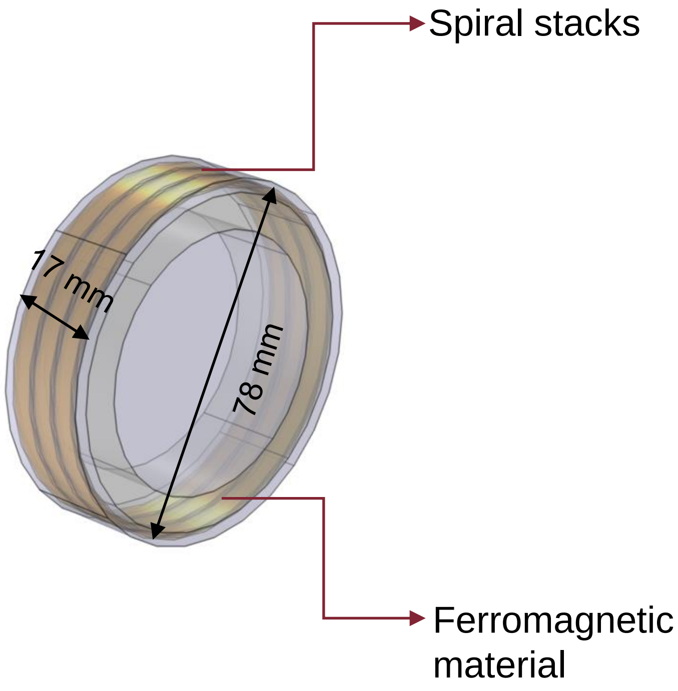
slip ≠ 0, low field

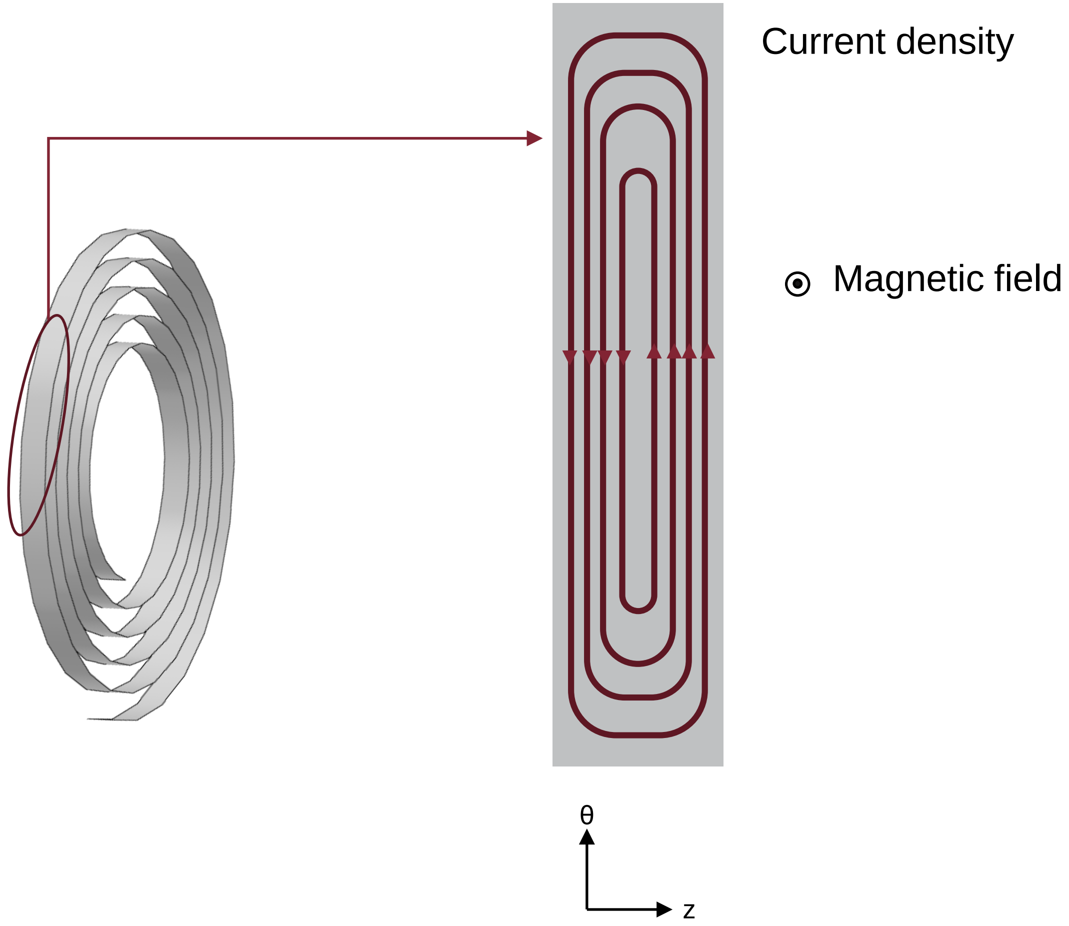
AC currents << DC currents, low AC losses

slip ≠ 0, high field

AC currents >> DC currents, high AC losses

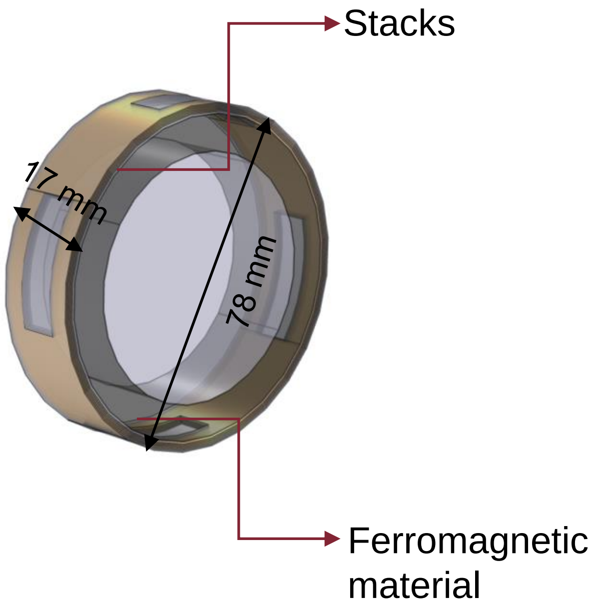
# Topology T1

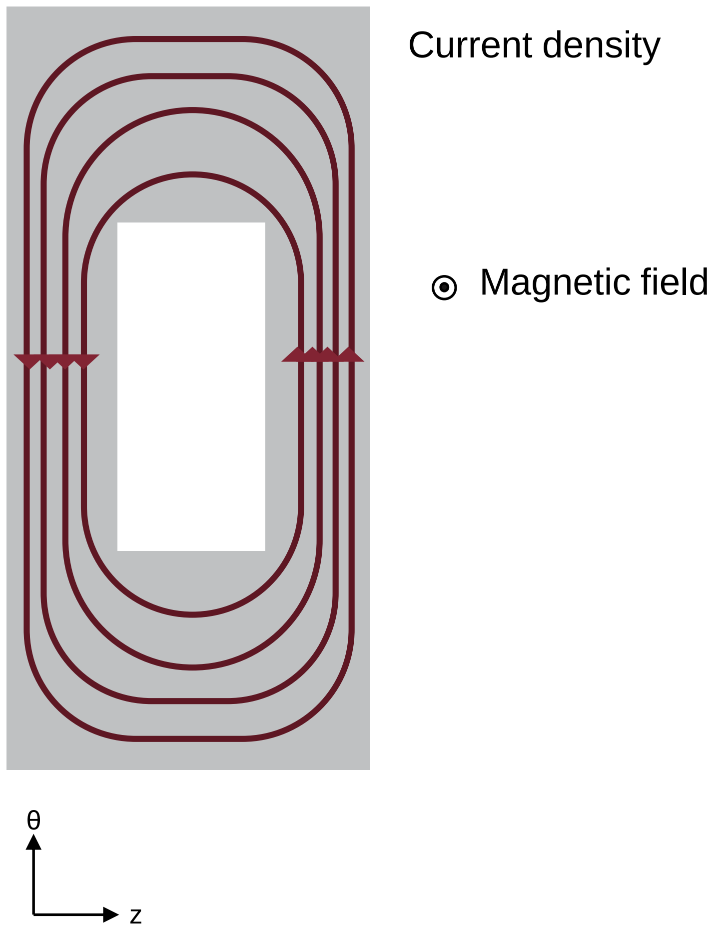



*stator not shown

# Topology T2




*stator not shown

# Methodology - overview

- Simulation using finite element method (COMSOL Multiphysics) 3D with T-A formulation;
- Objective: compare magnetization capabilities of T1 and T2;
- Method: simulate the response to a pulse of current density applied to the stator forming four magnetic poles and check the current density in the superconducting material after the pulse.

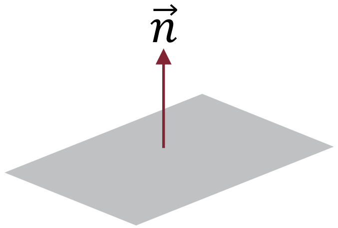
# T-A formulation

$$\nabla \times \left(\frac{1}{\mu}\right) \nabla \times \vec{A} = \vec{J}$$

$$\nabla \times \rho \nabla \times (\vec{T} \cdot \vec{n}) = -\left(\frac{\partial \vec{B}}{\partial t}\right) \cdot \vec{n}$$

$$\nabla \times \vec{A} = \vec{B}$$

$$\nabla \times \vec{T} = \vec{J}$$

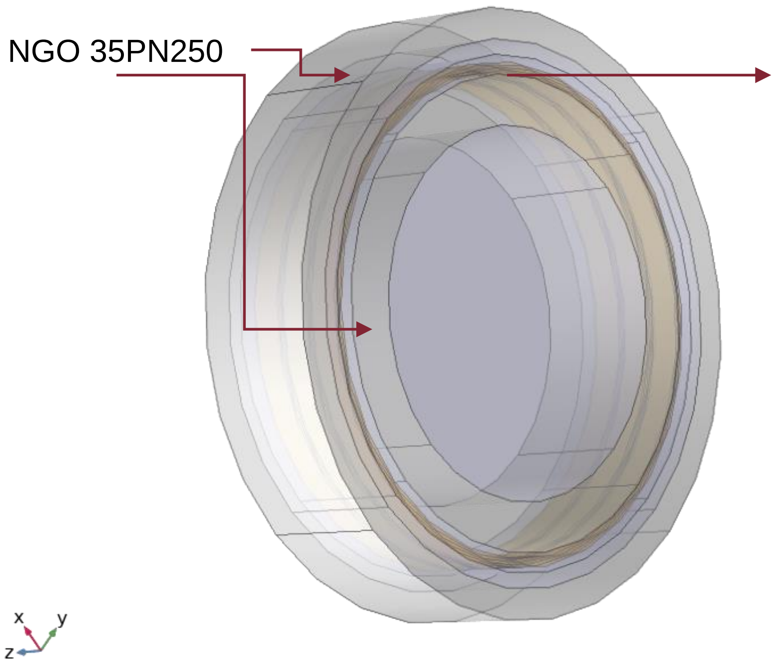


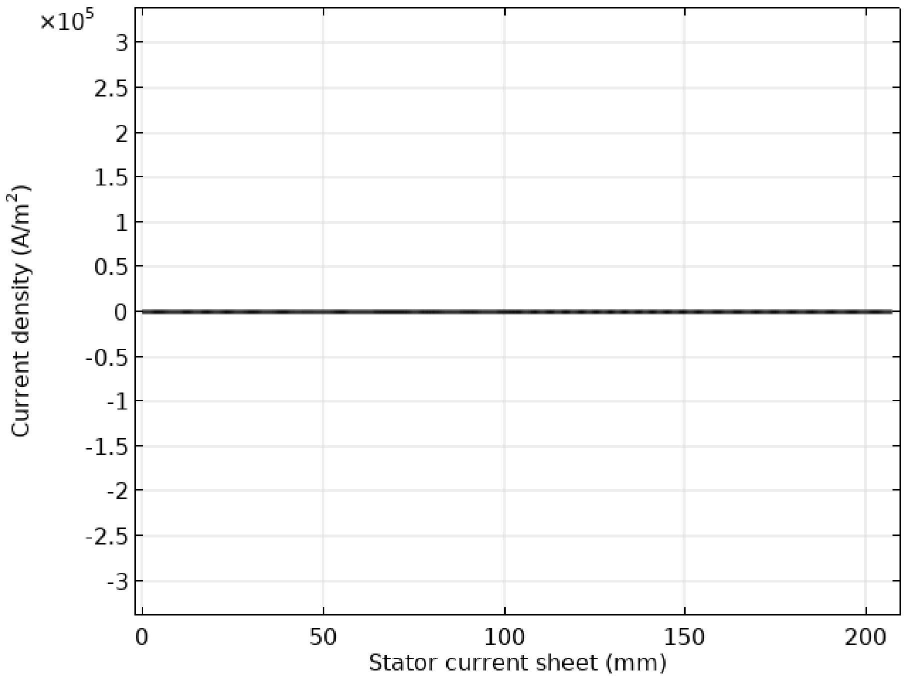

Boundary conditions

$$\vec{n} \cdot \vec{B} = 0$$

$$I_{total} = \oint \vec{T} \cdot d\vec{l} = 0$$

# Simulation parameters



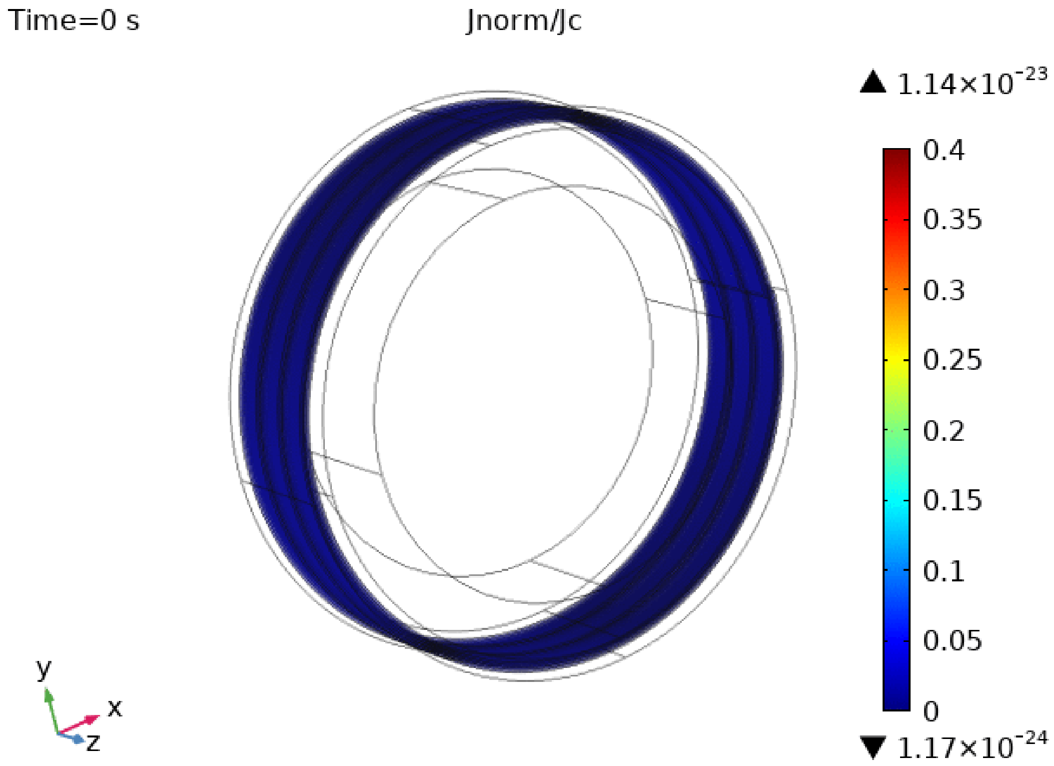



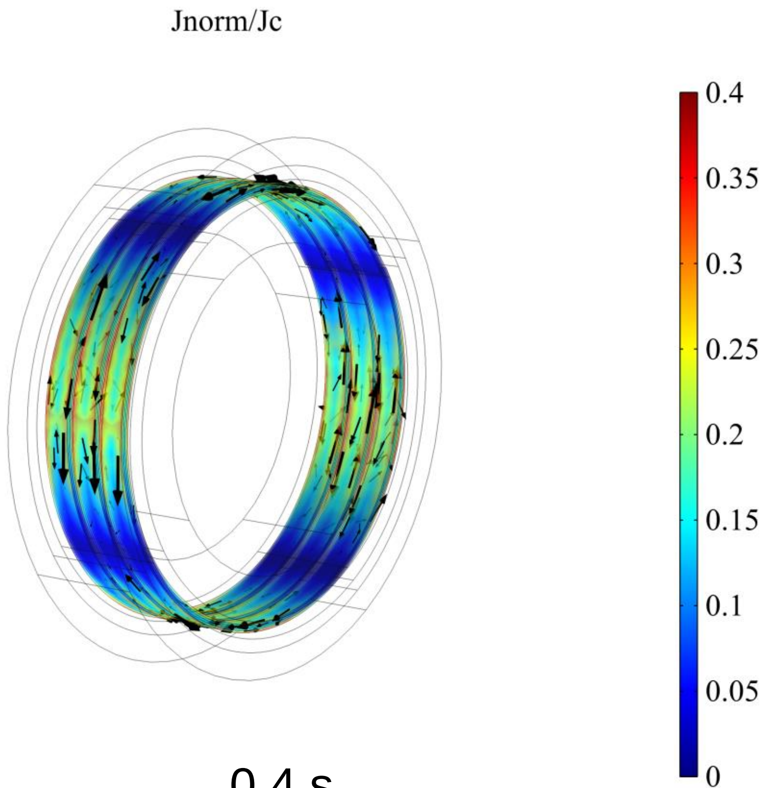

*SuperPower advanced pinning model: 4 mm, Ic @ 0 T = 47 A
Ic(B) curve from the HTS tape database @ Univ. of Wellington

0 – 0.2 s – no current
0.2 s to 0.4 s – with current
0.4 s to 0.5 s – no current

# Results – T1

Current density in the stacks (J/Jc)

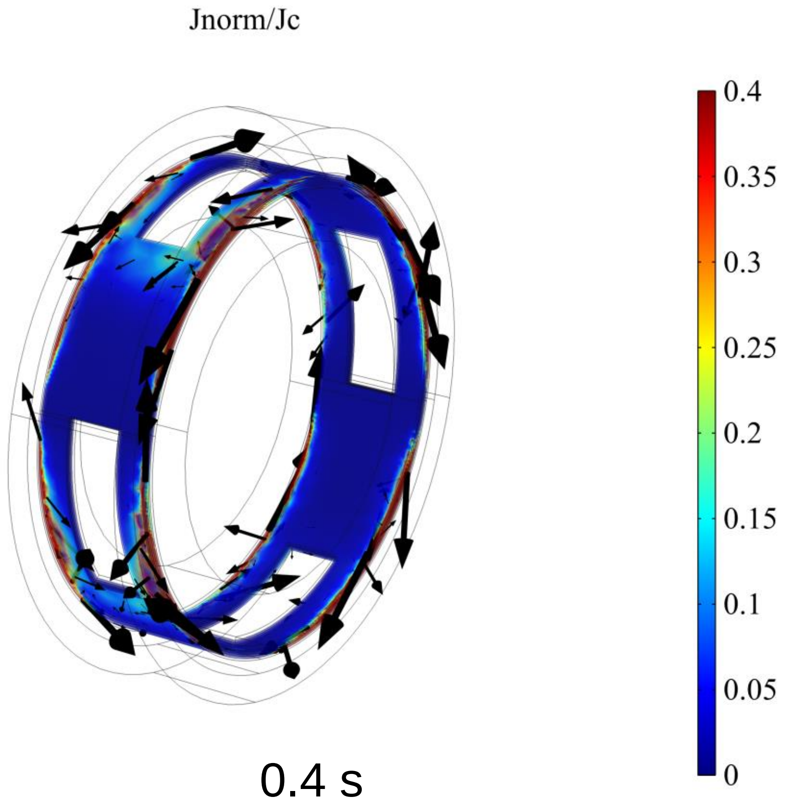



0.4 s
Pulse ended

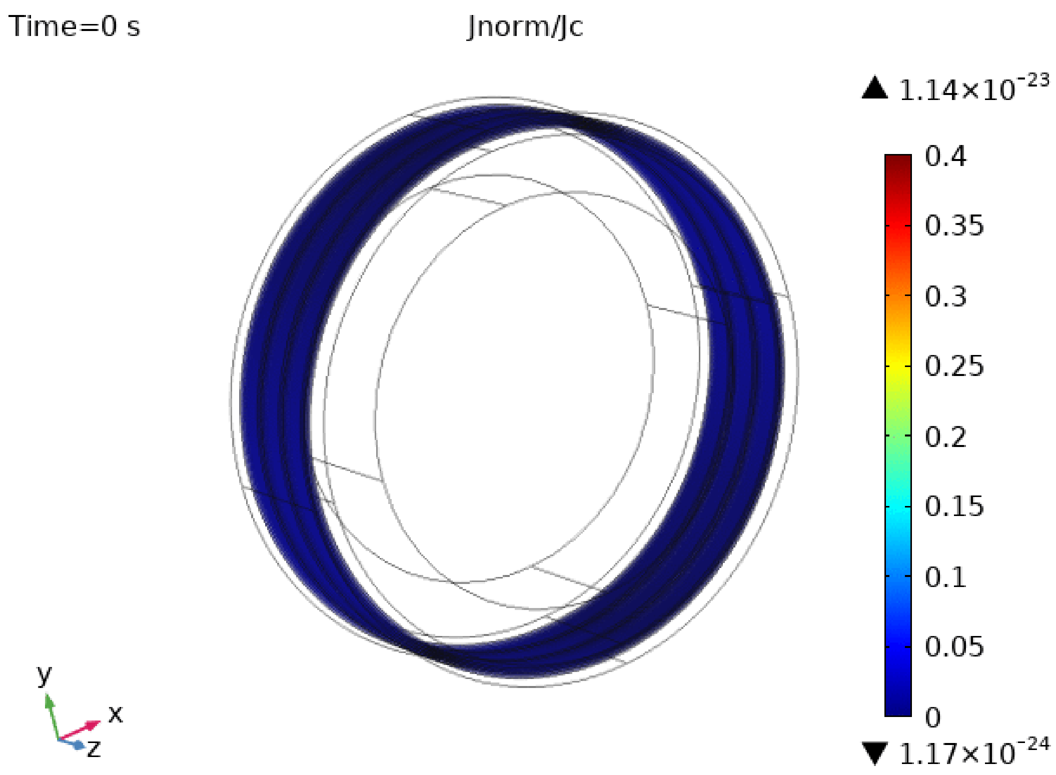
# Results – T2

Current density in the stacks (J/Jc)

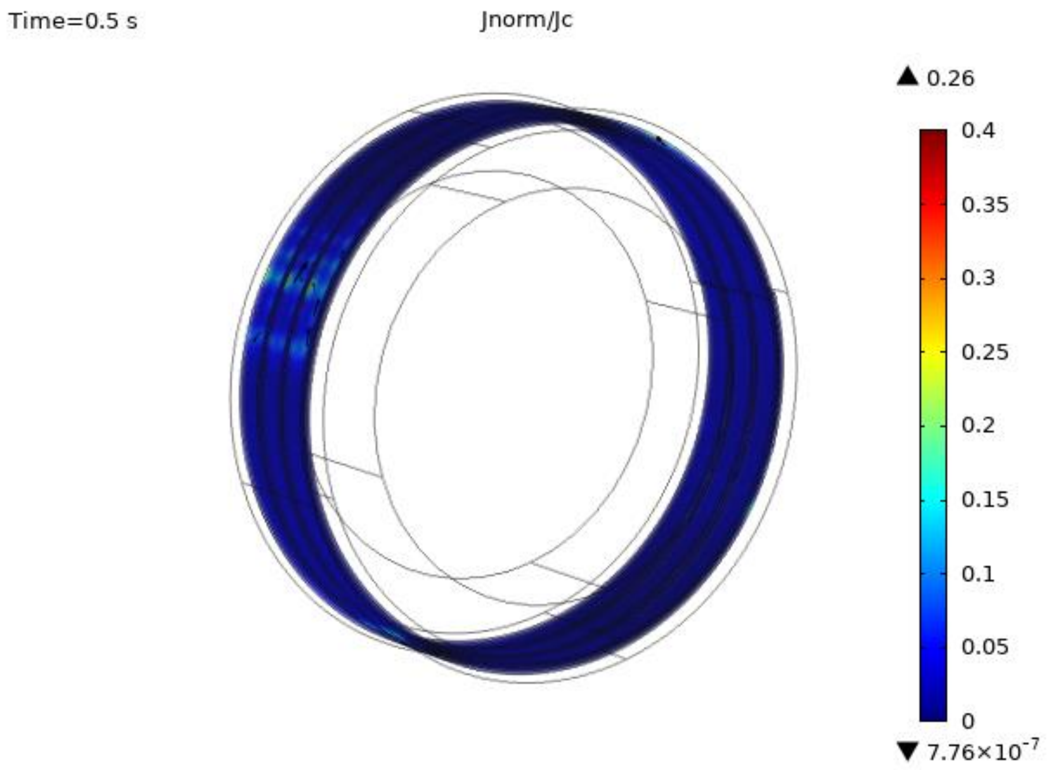



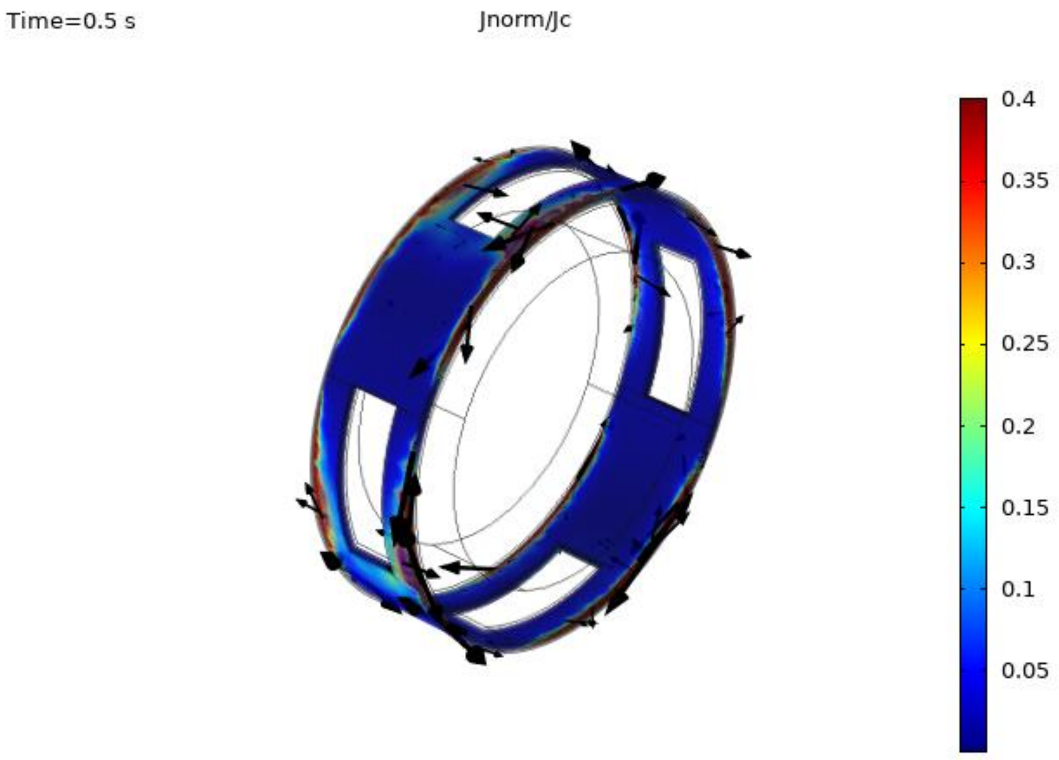

0.4 s
Pulse ended

# Comparisons between T1 and T2




# Comparisons between T1 and T2



# Conclusions

- Because of its geometric characteristics, topology T2 shows better magnetization capabilities;
- Topology T2 is also more likely to generate reluctance torque;
- Further investigation is needed to determine the optimal configuration for T2.

# Thank you!

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