

Simulation of Current Distribution in Twisted 2G Tapes in Terms of the H Formulation Taken in Account the Stress Induced by Torsion

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Summary

- Motivation
- Objectives
- Introduction
- The formulation applied
- Results
- Final Considerations

Motivation: Large Magnet cables

The goal:

equal-distribution of the current in the wires of a strand



Transposition

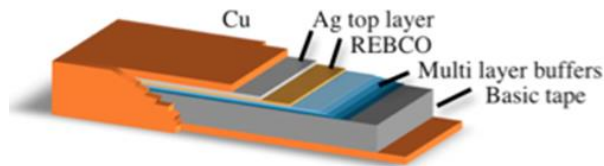
Roebel

Complex manufacturing

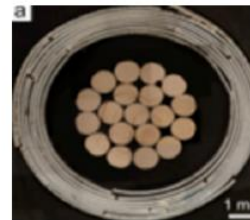


CORC

Larger amount of tape
Not fully transposed



Helicoidal



Not fully transposed



Twisted stacks



Not fully transposed

We are proposing a new model for a twisted wire!!!!

Objectives

➤ General

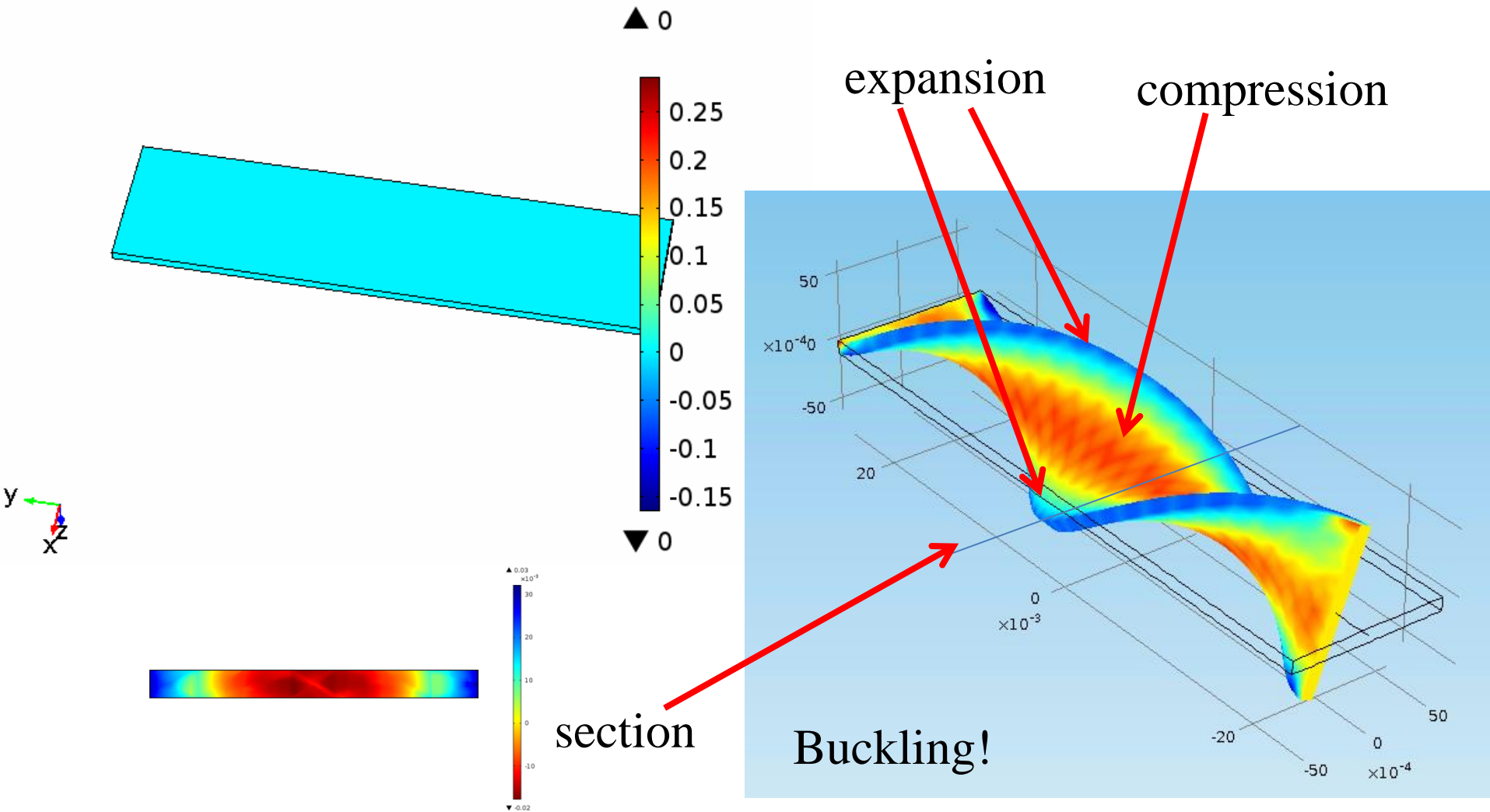
To simulate a stacked twisted wire cable
(under development)

➤ In this work

To present a model for one coated
conductor submitted to torsion

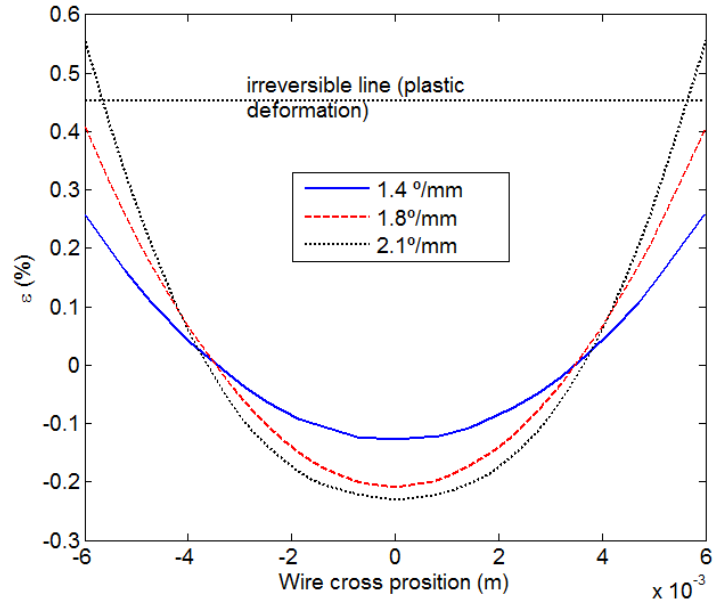
Twisted coated conductor

paramv(1)=0 Surface: Volumetric strain (1)

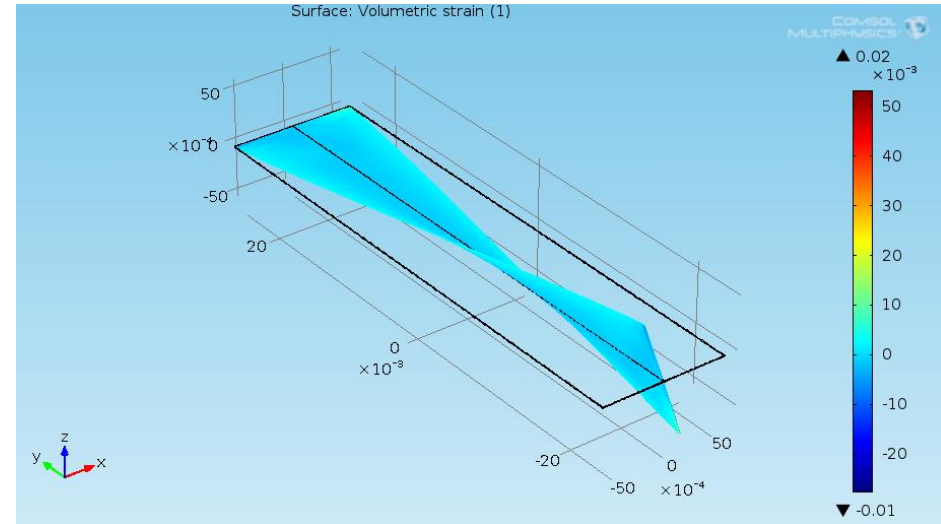


J_c depends on the strain. How it affects the current distribution?

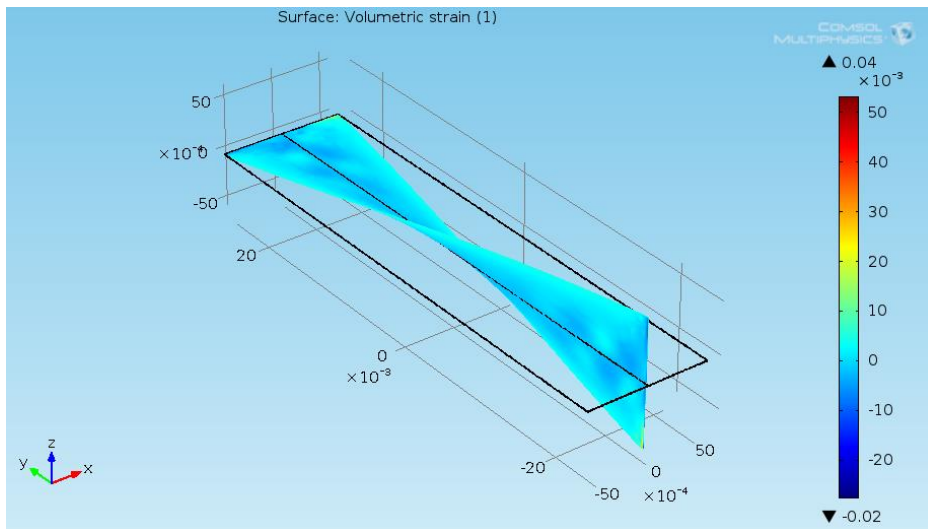
3D Mechanical FEM



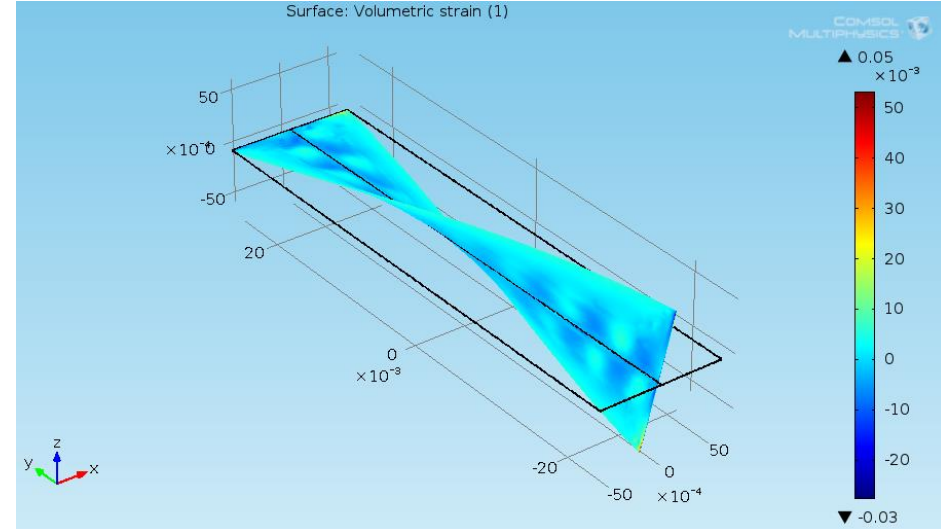
1.4°/mm



1.8°/mm

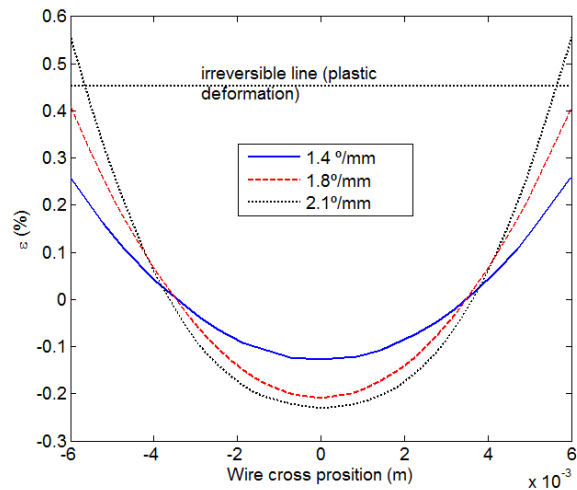


2.1°/mm

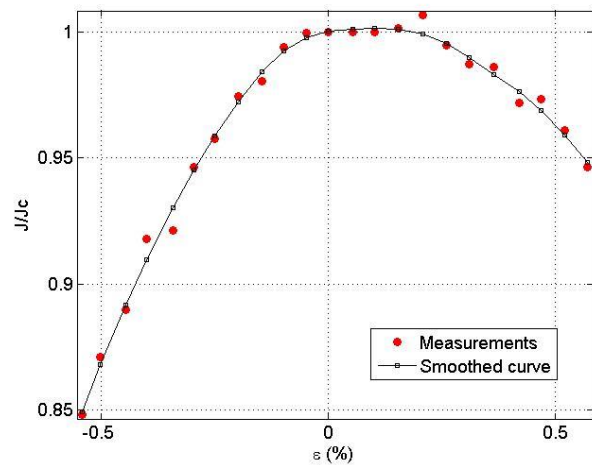


Twisted wires: idea

Strain as a function of the position and pitch (3D FEM)

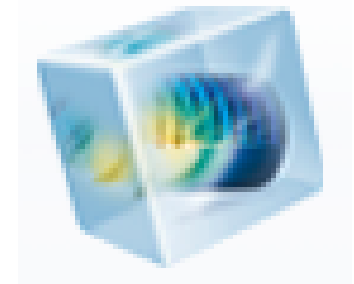


J_c as a function of the strain (exp.), [1]

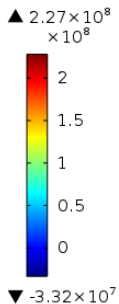


Commercial program,
H formulation

$J_c(x, \text{pitch})$



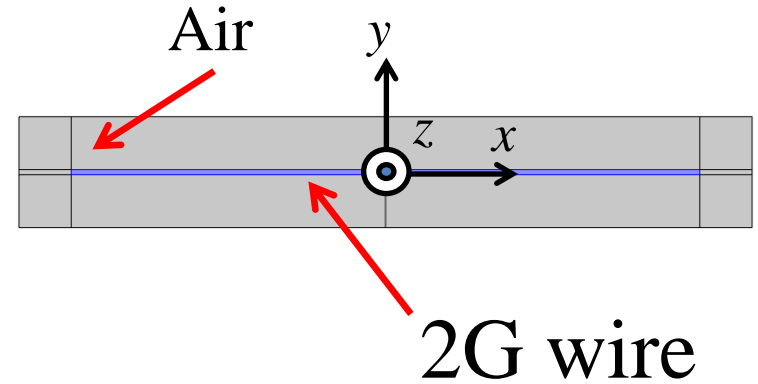
To obtain the current density in a
HTS under torsion



The H formulation (2D)

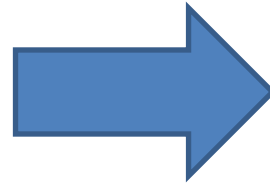
$$H_z = E_x = E_y = J_x = J_y = 0$$

$$\rho = \frac{1}{\sigma} = \frac{E_c}{J_c} \left| \frac{E}{E_c} \right|^{1-1/n} = \frac{E_c}{J_c} \left| \frac{J}{J_c} \right|^{n-1}$$



$$\mu \frac{\partial \vec{H}}{\partial t} + \nabla \times \vec{E} = \vec{0},$$

$$\vec{J} = \nabla \times \vec{H}.$$



$$\mu \frac{\partial H_x}{\partial t} + \frac{\partial E_z}{\partial y} = 0,$$

$$\mu \frac{\partial H_y}{\partial t} - \frac{\partial E_z}{\partial x} = 0,$$

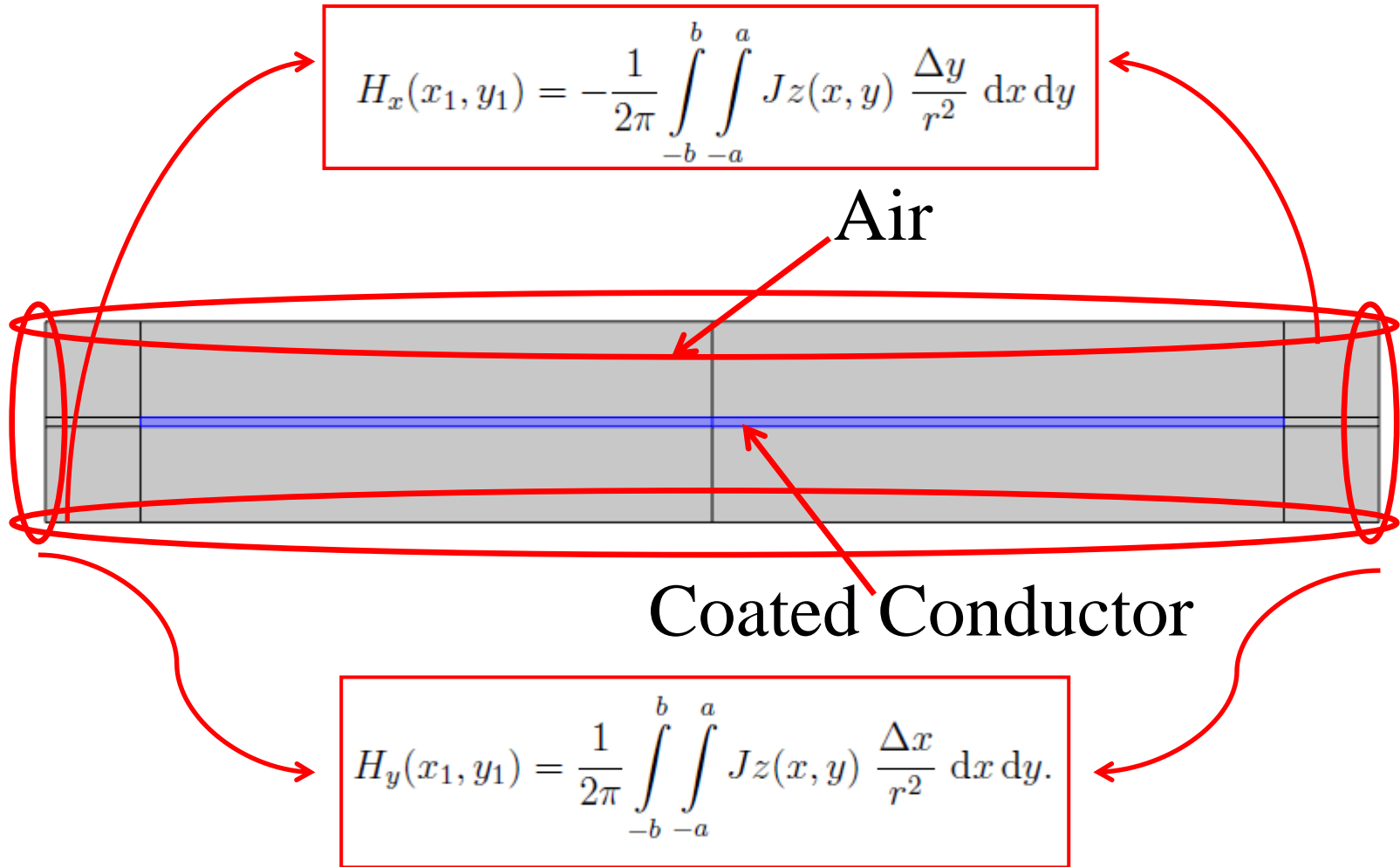
$$J_z = \frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}.$$

$$E_z = \rho J_z$$

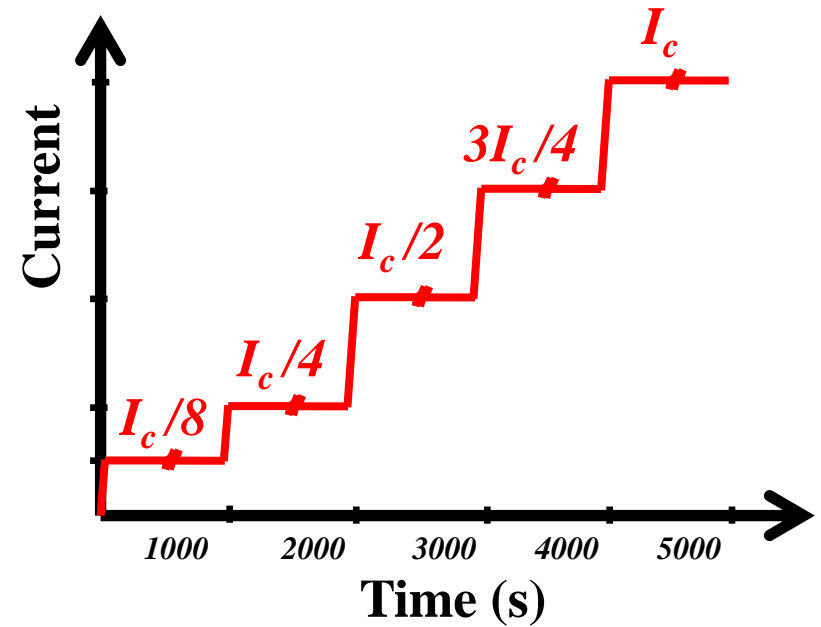
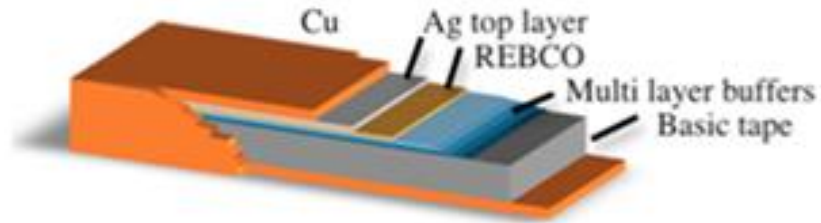
$$J_z = J_c(B, x, \text{pitch})$$

The Boundary Conditions

Edge Elements [2]



Studied cases



$w = 12 \text{ mm}$

$h = 100 \text{ }\mu\text{m}$

$$T = 77 \text{ K}$$

$$I_c = 400 \text{ A}$$

$$J_c = 3.33 \times 10^8 \text{ A/m}^2$$

$$n = 31$$

Pitches

0.0 °/mm

1.8 °/mm

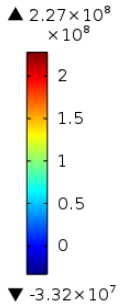
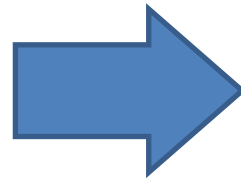
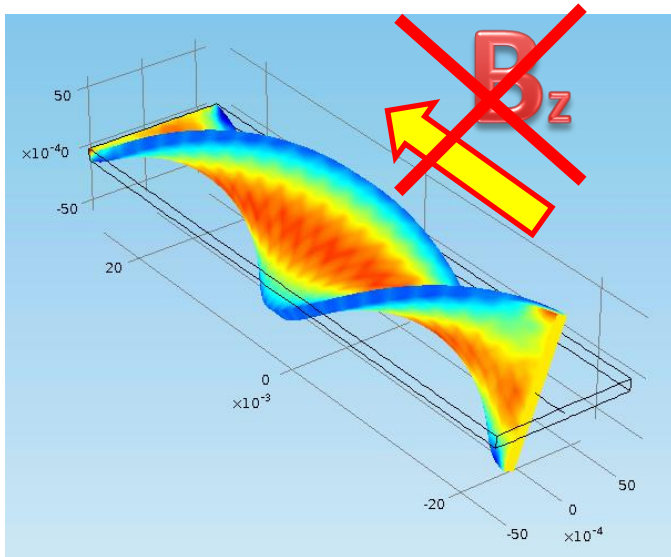
1.4 °/mm

2.1 °/mm

Twisted wires: limitation

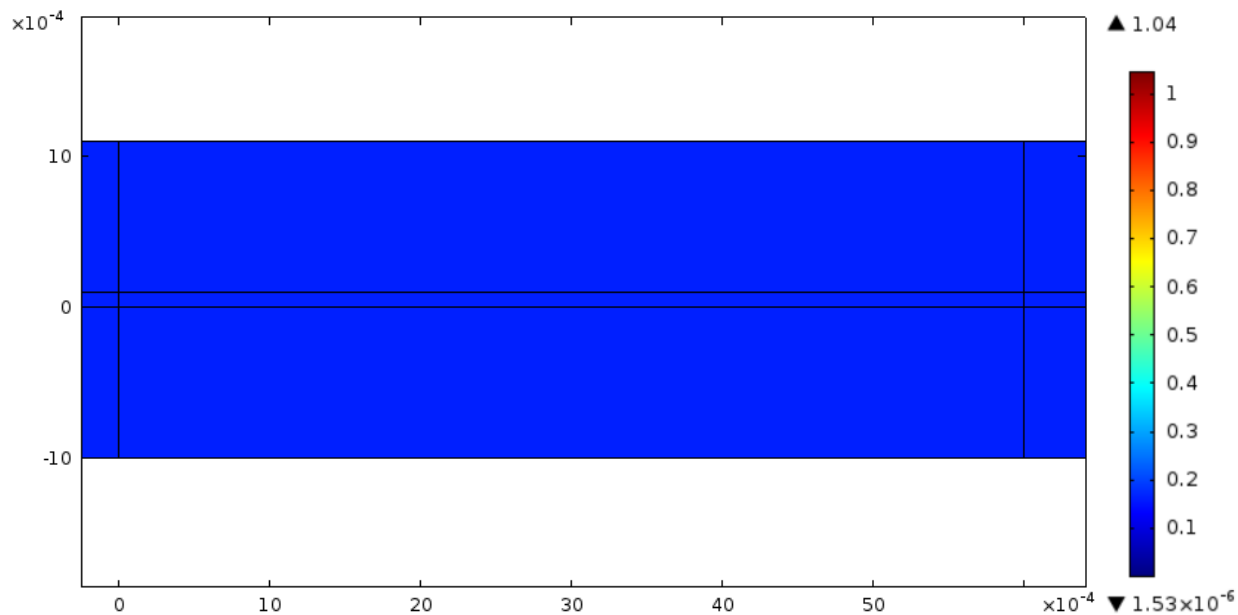
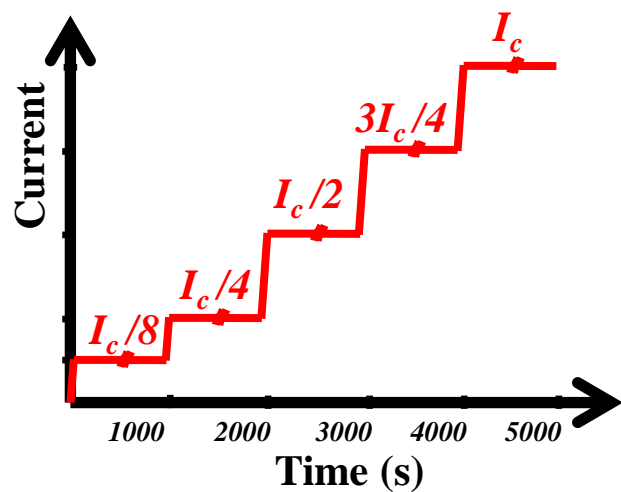
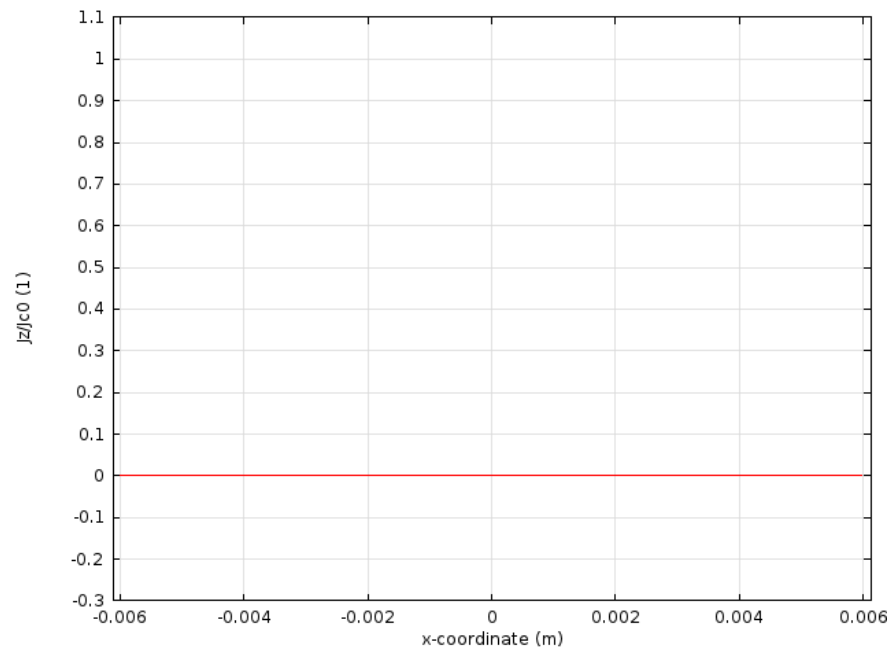
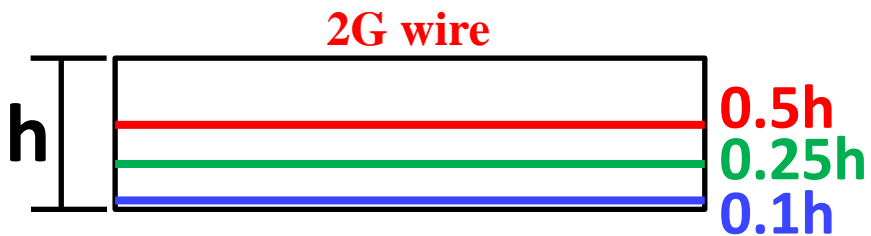
Simplifications assumed here:

3D \rightarrow 2D

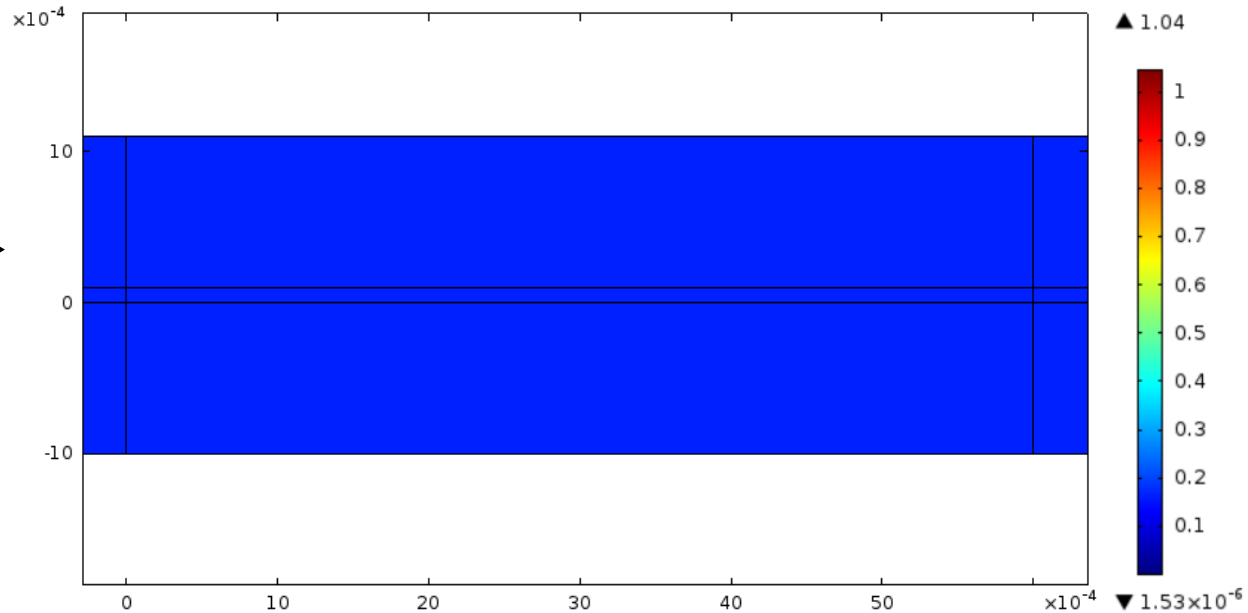
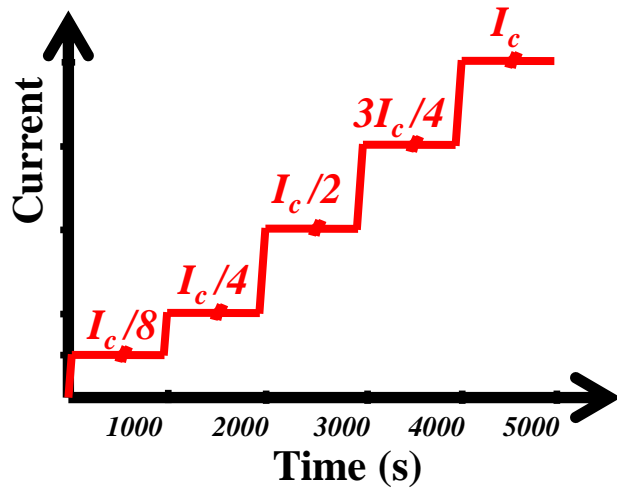
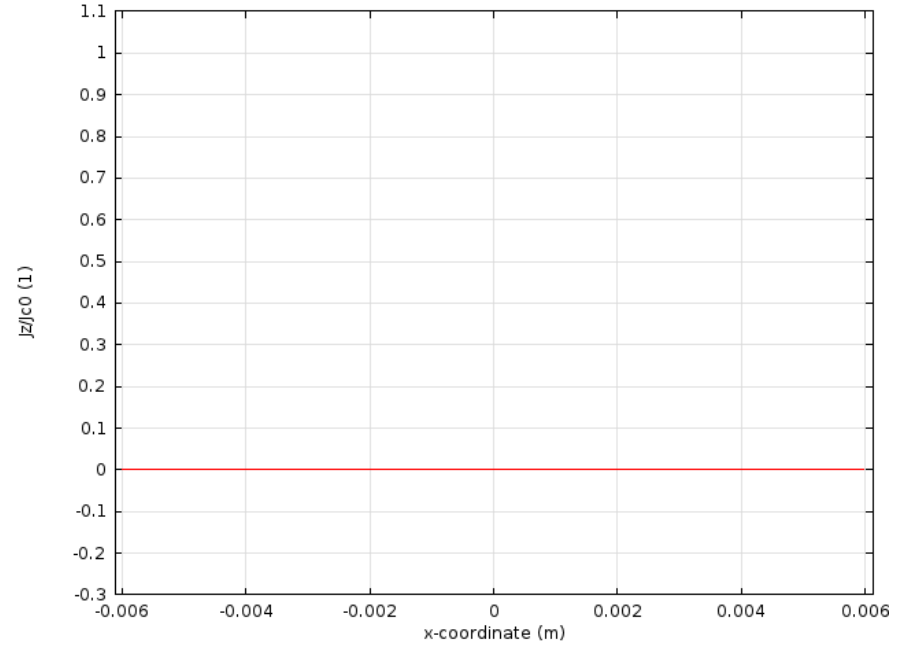
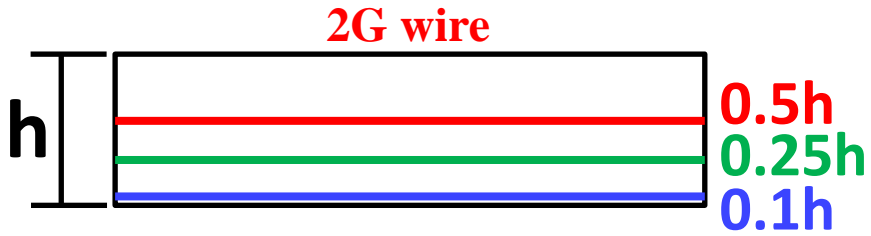


Results

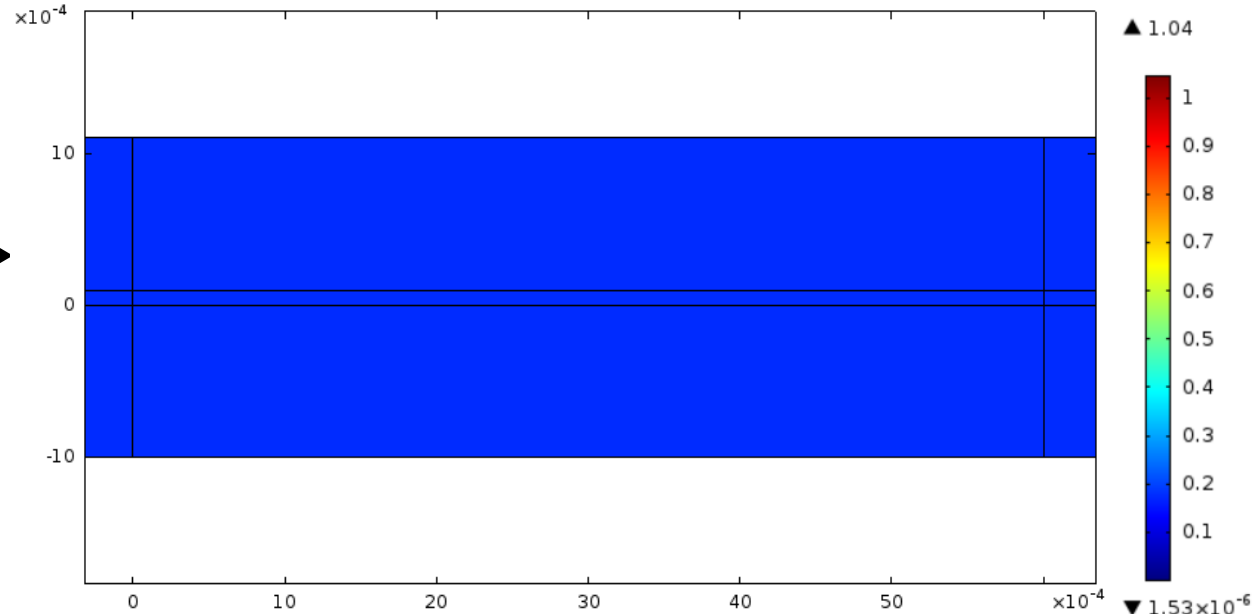
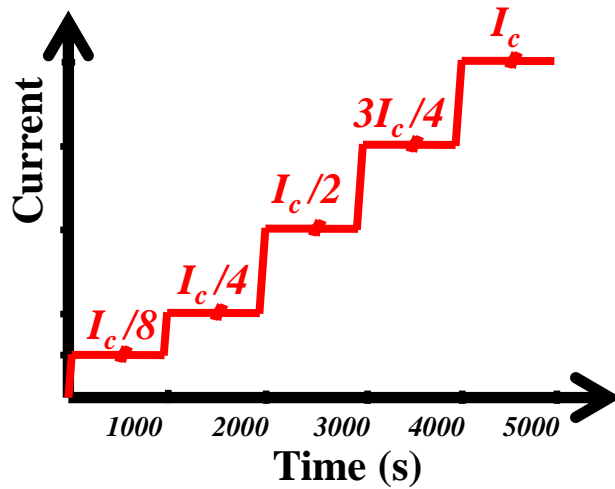
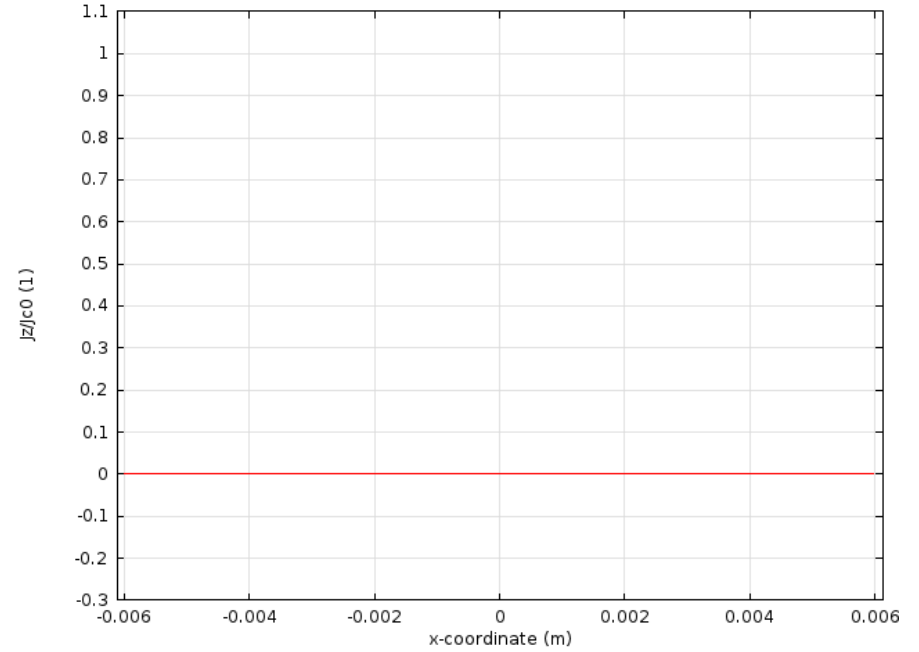
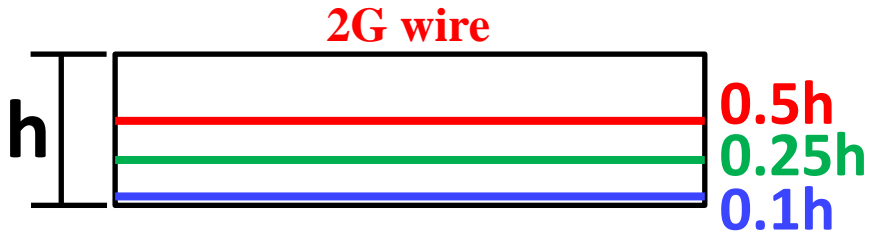
Results: J_c/J_{c0} , Pitch = $0^\circ/\text{mm}$



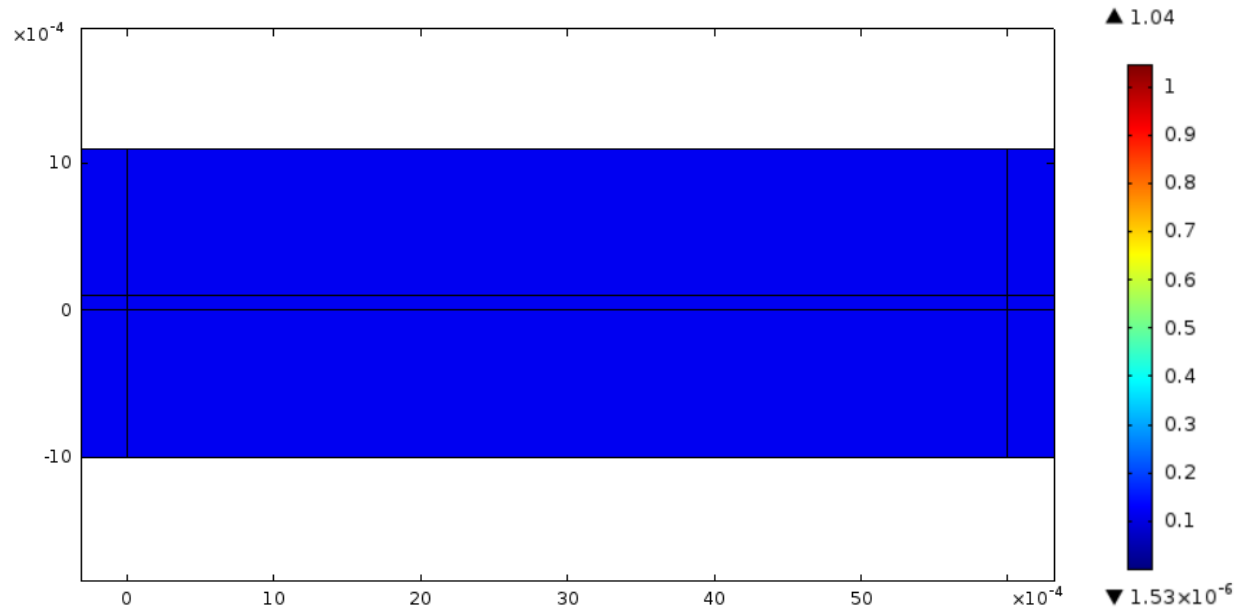
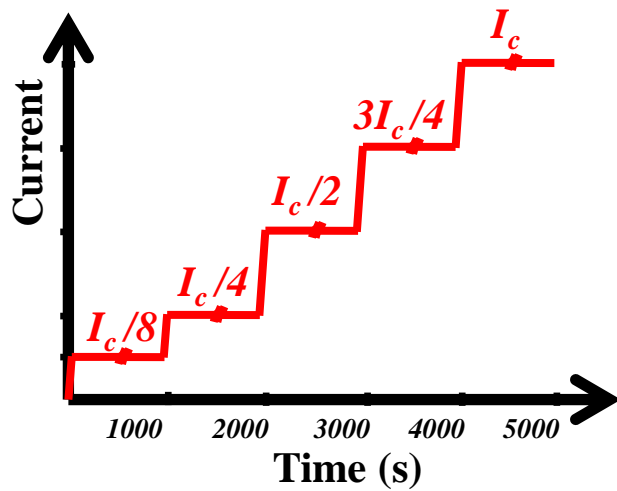
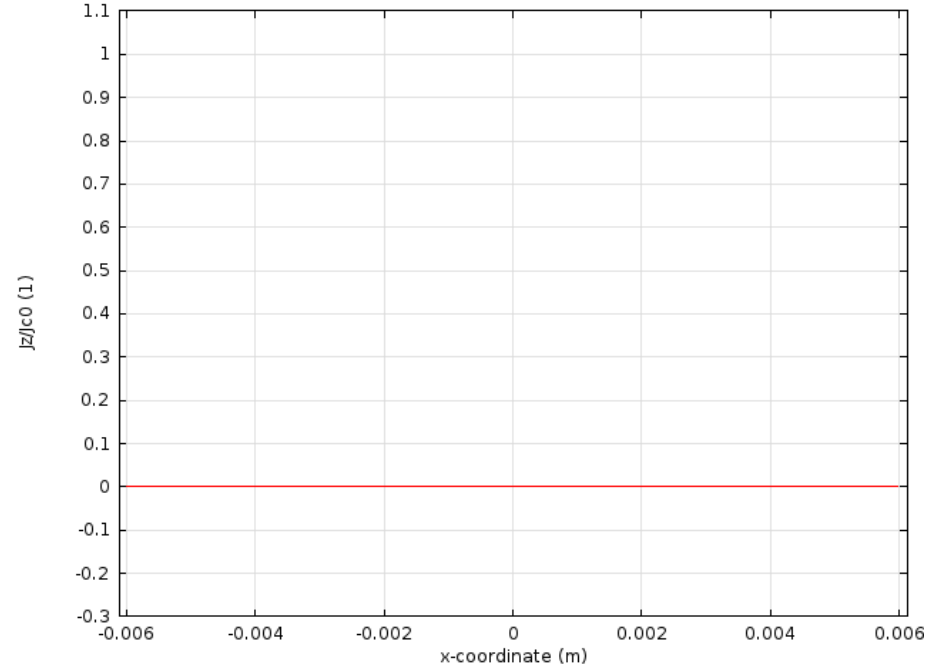
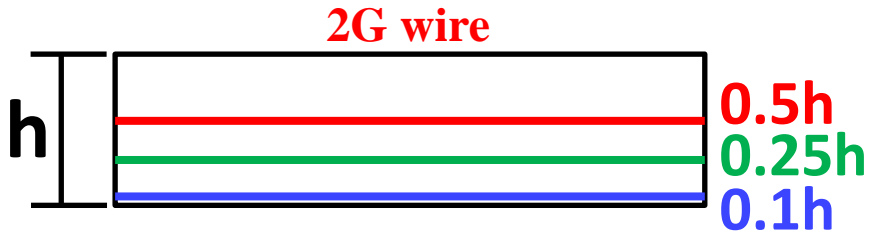
Results: J_c/J_{c0} , Pitch = $1.4^\circ/\text{mm}$



Results: J_c/J_{c0} , Pitch = $1.8^\circ/\text{mm}$



Results: J_c/J_{c0} , Pitch = $2.1^\circ/\text{mm}$



Results: 0.25 Ic

Pitch = 0.0 °/mm

Pitch = 1.4°/mm

Pitch = 1.8°/mm

Pitch = 2.1°/mm

▲ 0.52

0.5

0.4

0.3

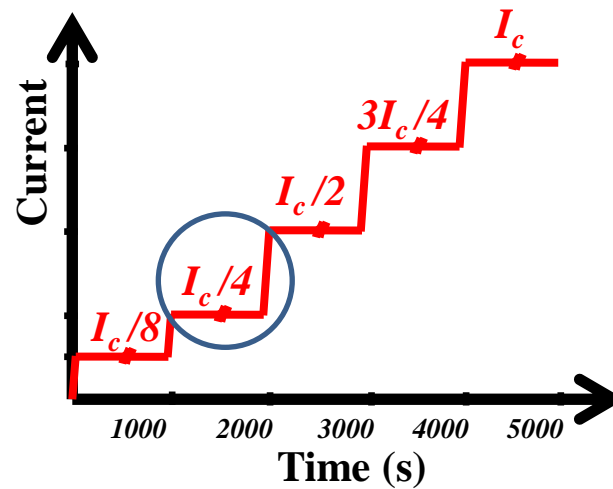
0.2

0.1

0

-0.1

▼ -0.1



Results: 0.5 I_c

Pitch = 0.0 °/mm

Pitch = 1.4°/mm

Pitch = 1.8°/mm

Pitch = 2.1°/mm

▲ 0.58

0.5

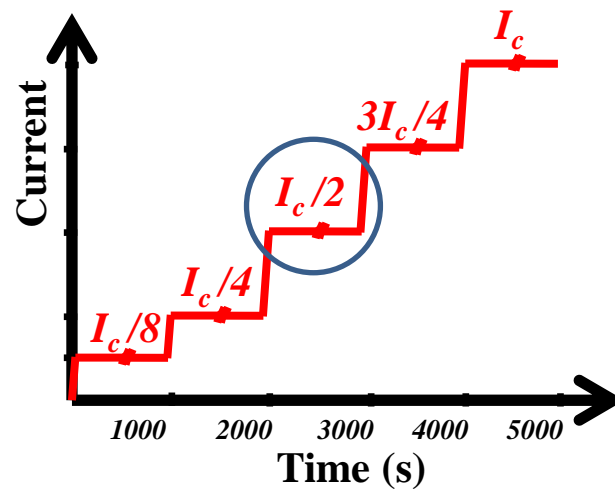
0.4

0.3

0.2

0.1

▼ 1.32×10^{-7}



Results: $0.75 I_c$

Pitch = $0.0^\circ/\text{mm}$

Pitch = $1.4^\circ/\text{mm}$

Pitch = $1.8^\circ/\text{mm}$

Pitch = $2.1^\circ/\text{mm}$

▲ 0.77

0.7

0.6

0.5

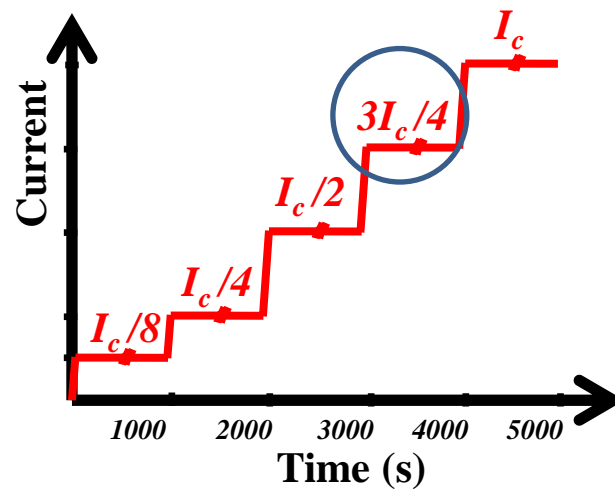
0.4

0.3

0.2

0.1

▼ 1.12×10^{-6}



Results: I_c

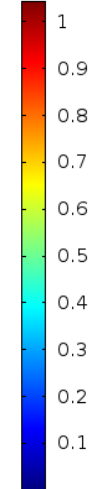
Pitch = $0.0^\circ/\text{mm}$

Pitch = $1.4^\circ/\text{mm}$

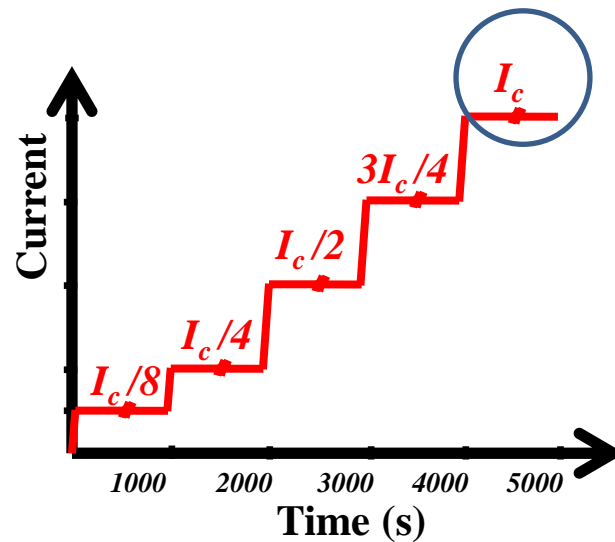
Pitch = $1.8^\circ/\text{mm}$

Pitch = $2.1^\circ/\text{mm}$

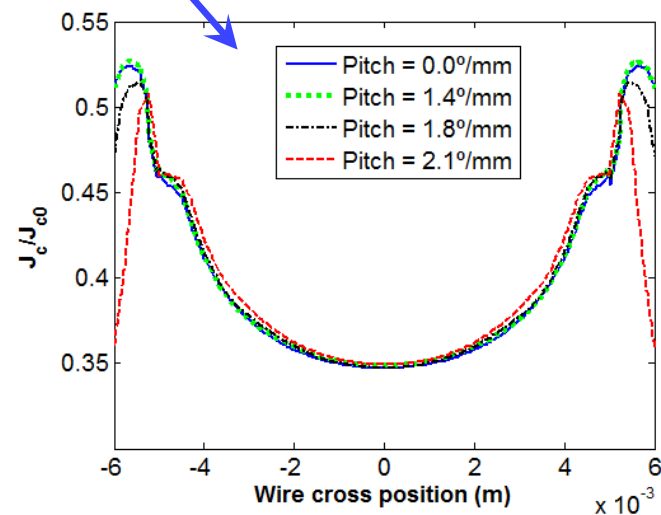
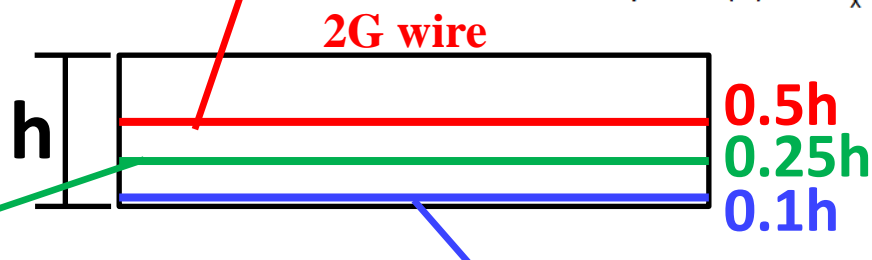
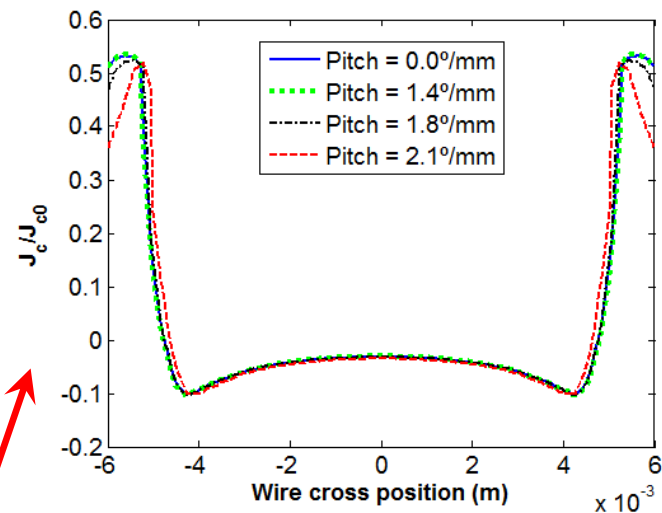
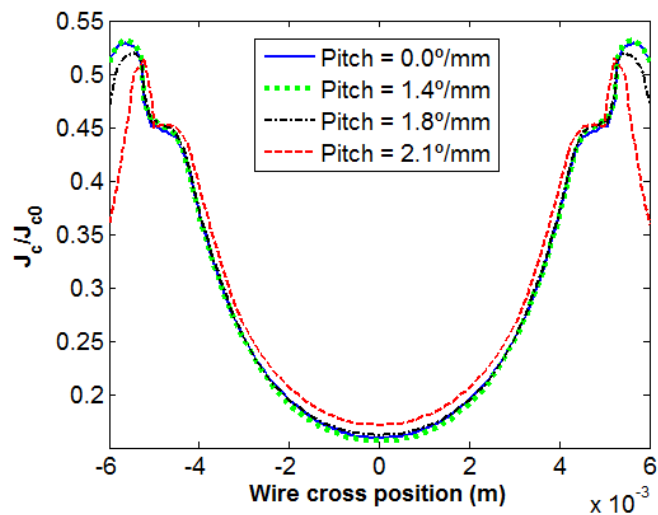
▲ 1.04



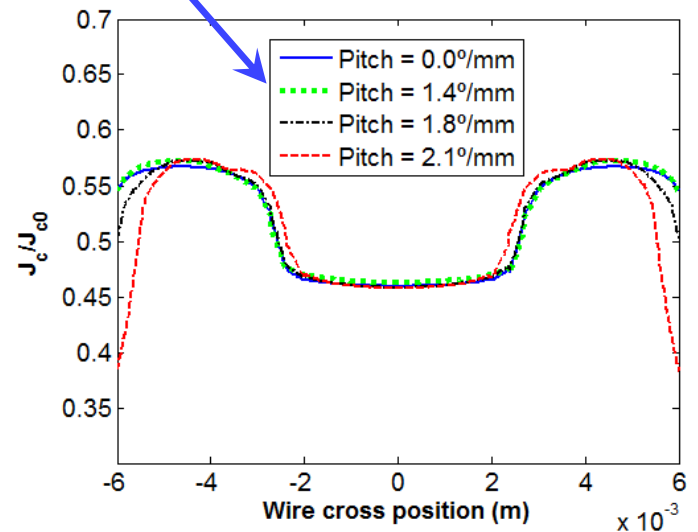
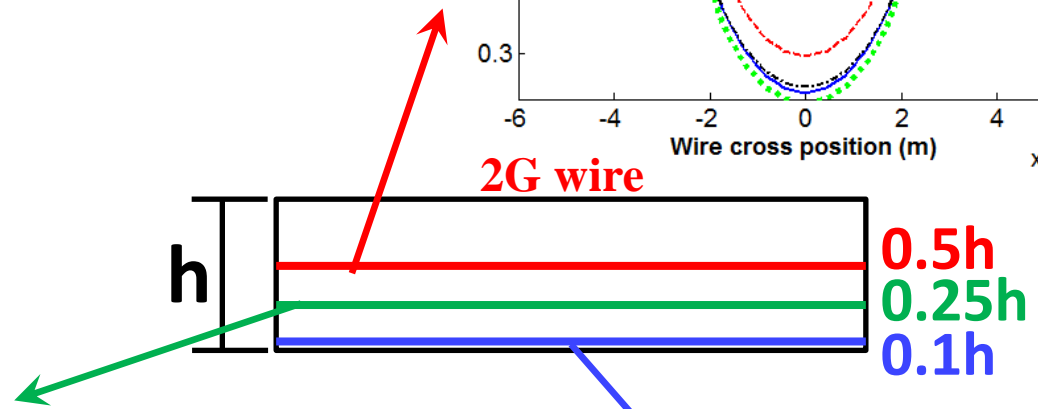
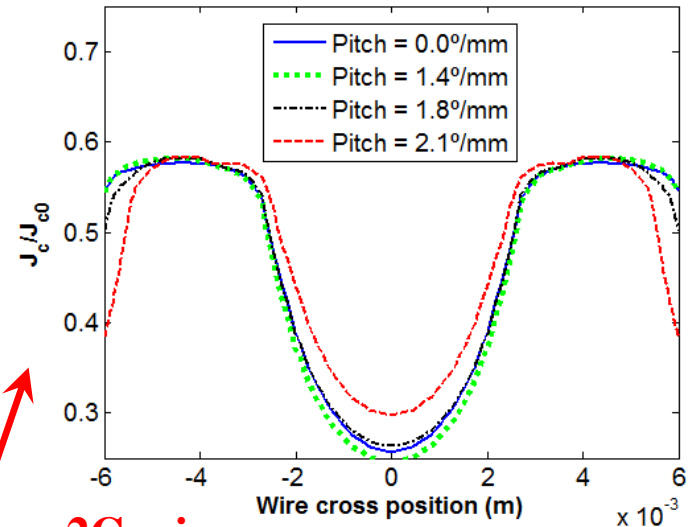
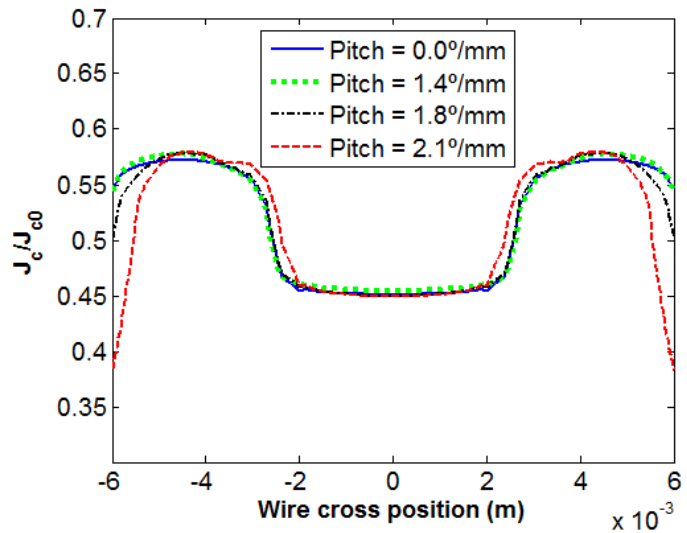
▼ 1.53×10^{-6}



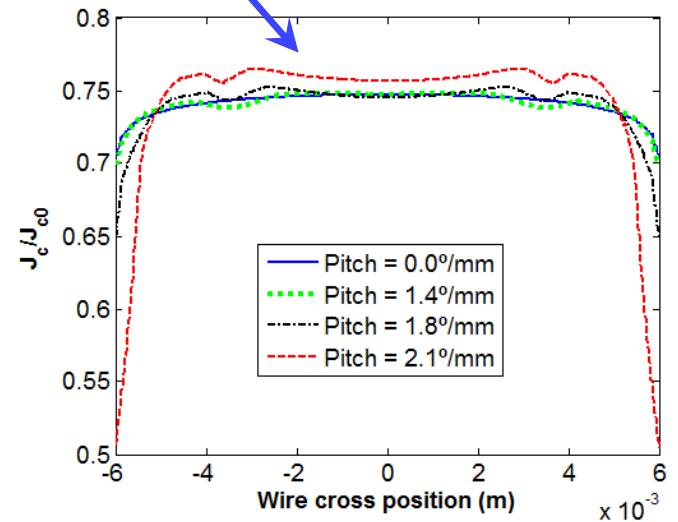
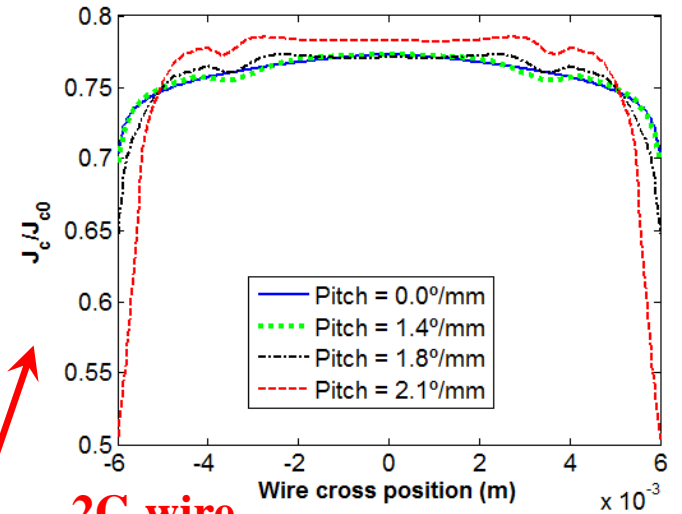
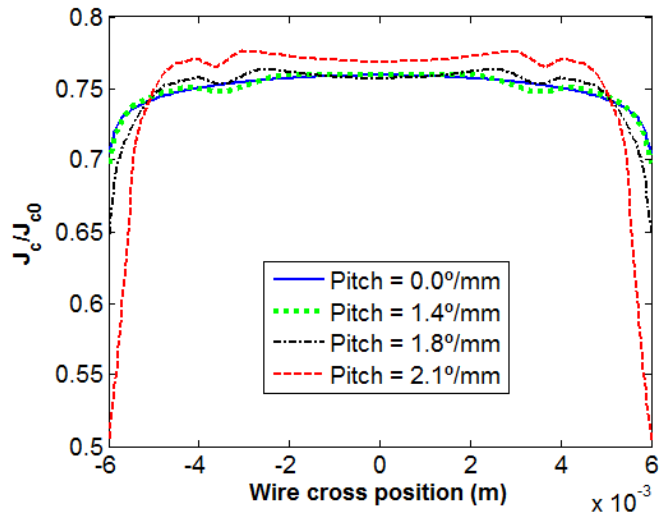
Results: 0.25 Ic



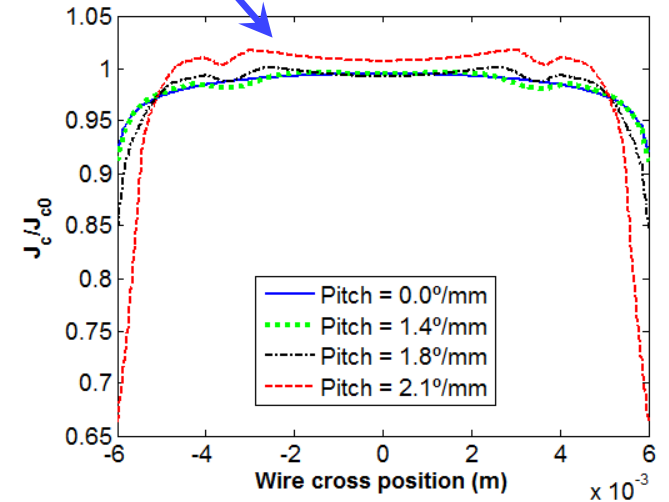
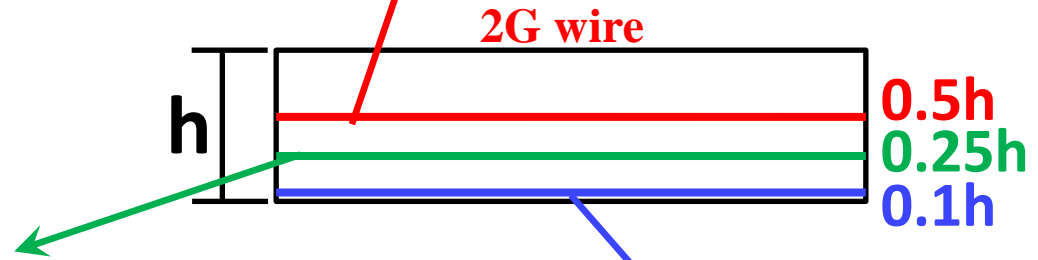
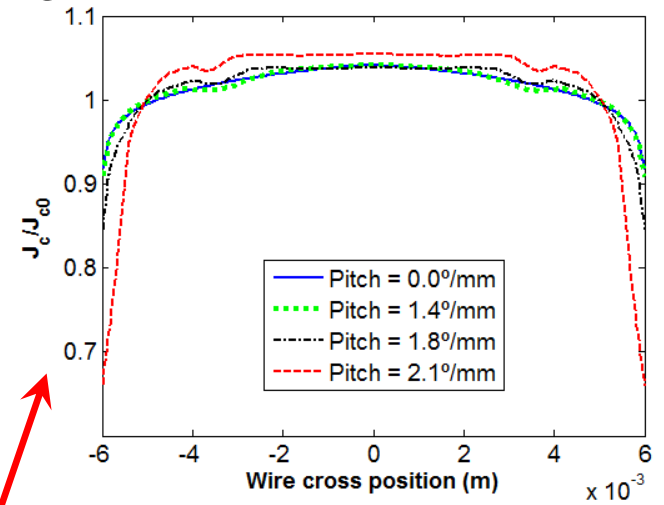
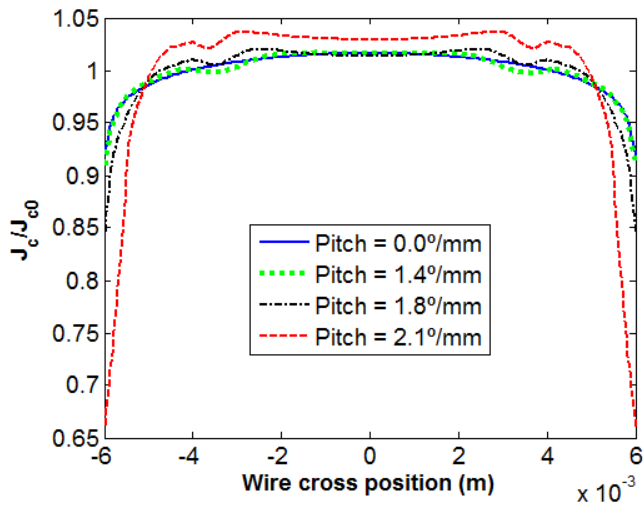
Results: 0.5 Ic



Results: 0.75 Ic



Results: Ic



Final Considerations

- A new method to simulate twisted wires in 2D was presented
- A J_c variation in the wire was observed as the pitch was changed
- The validation of this model is under development
- The model should be applied as a first study to the design of a twisted cable, since it is fast to solve and easy to implement

Thank you
for your attention!