Parametric Study of Electromagnetic Characteristic of Liquid Metal Level Sensor

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Introduction

❖ Basic principle

- ✓ AC power on primary coil
- ✓ Magnetic field distribution
- ✓ Induced voltage on secondary coil

❖ Governing equations

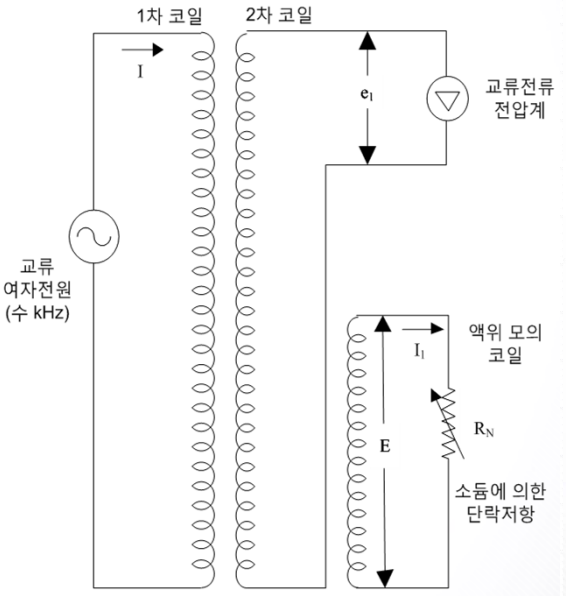
Faraday's Law of Induction $\nabla \times E = -\frac{\partial B}{\partial t}$

Gauss's Law for Magnetism $\nabla \bullet B = 0$

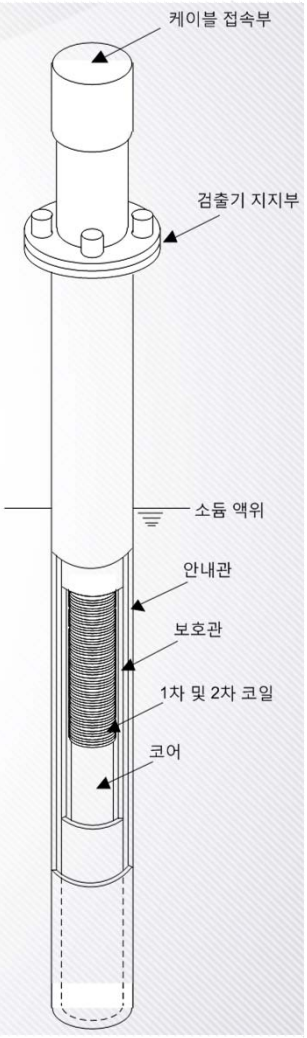
Ampere's Law $\nabla \times H = J + \frac{\partial D}{\partial t}$

Gauss's Law for Electricity $\nabla \bullet D = \rho$

❖ Magnetic field (H-field) → $|\vec{H}| \propto N \cdot I$



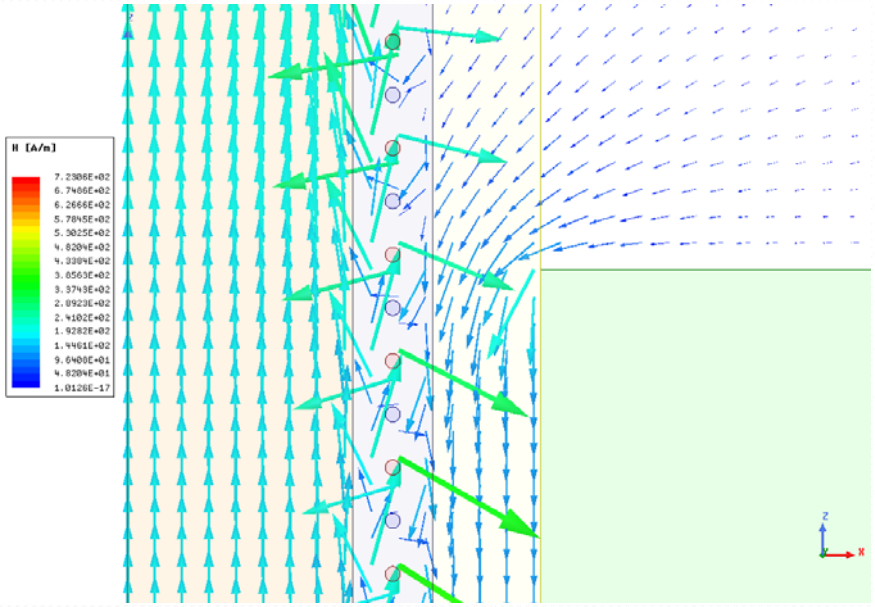
< Equivalent Circuit >



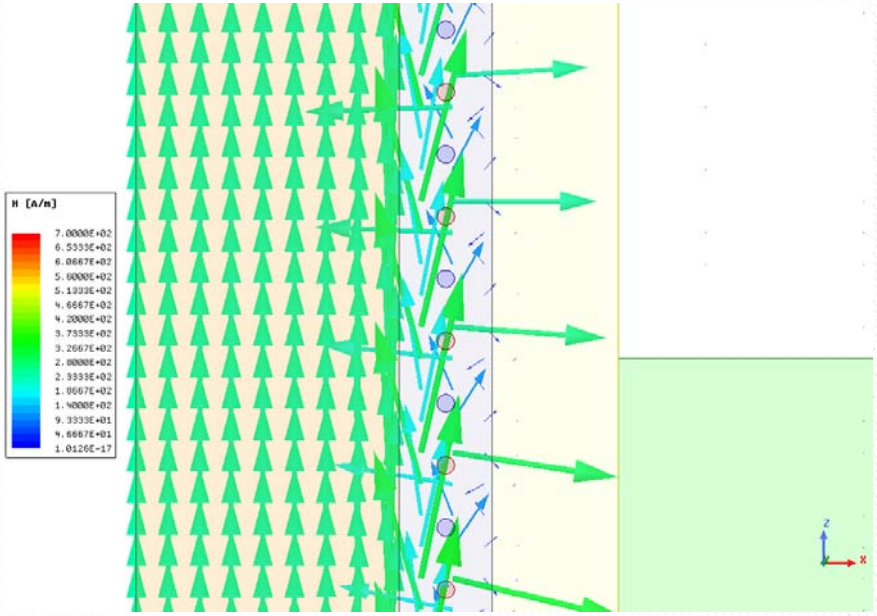
< Basic Concept >

Introduction

Liquid Na

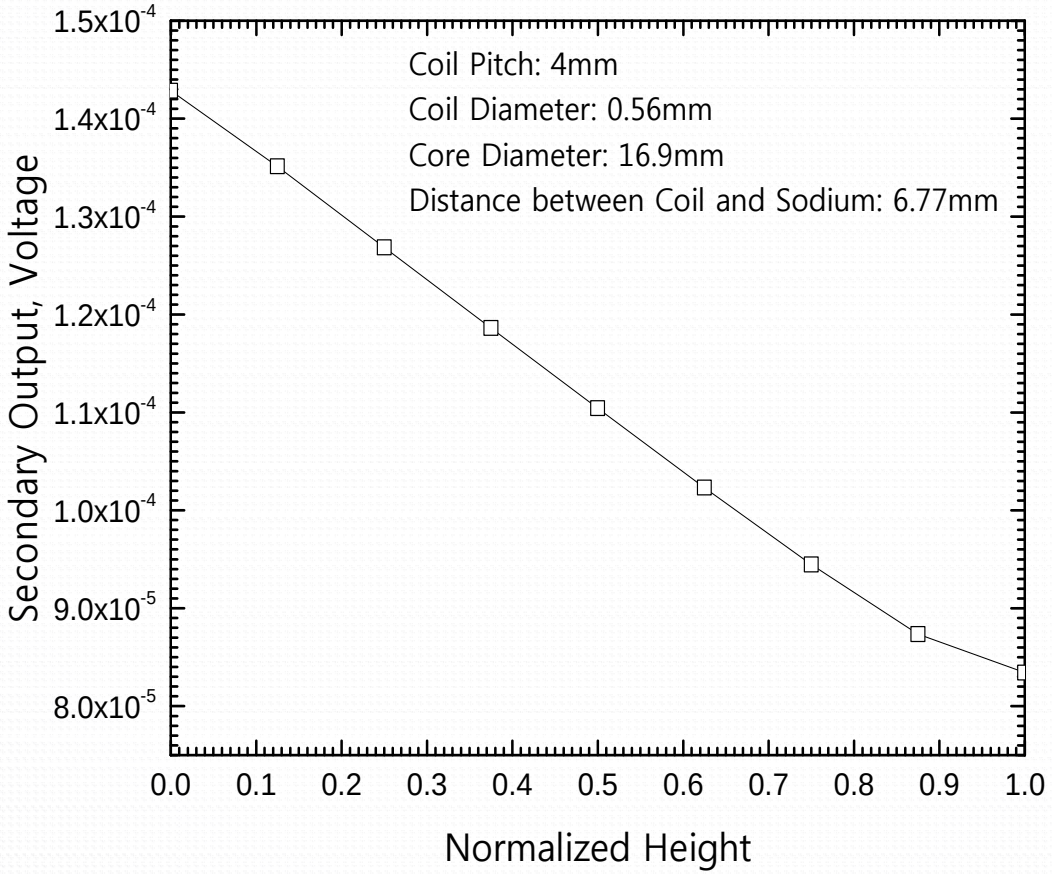


No Liquid Na



Introduction

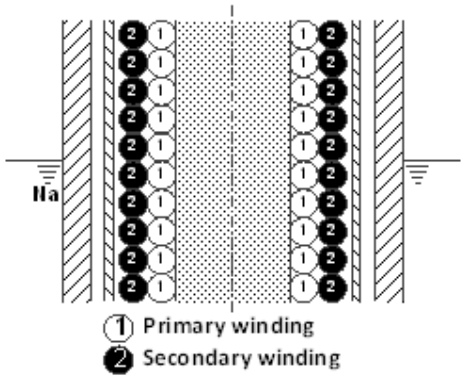
❖ Change of induced Voltage on secondary coil

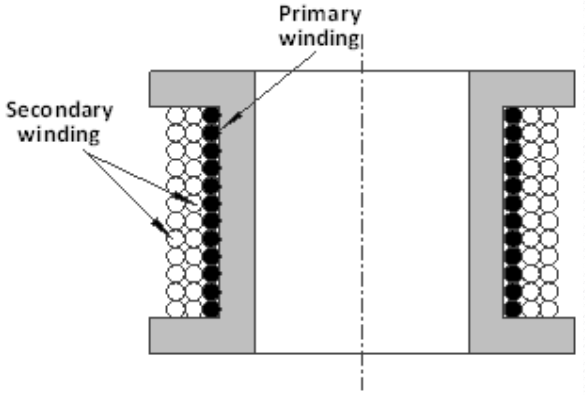


Parameter Selection

❖ Parameters of interests

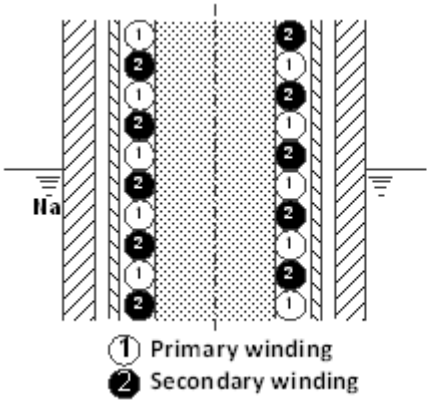
- ✓ Coil winding method
- ✓ Coil diameter
- ✓ Coil winding pitch
- ✓ Core diameter
- ✓ Effect of guide tube
- ✓ Distance between coil and Na

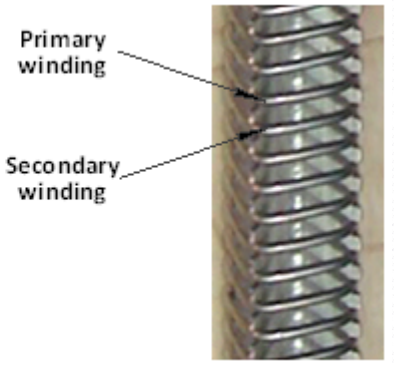




❖ Analysis results

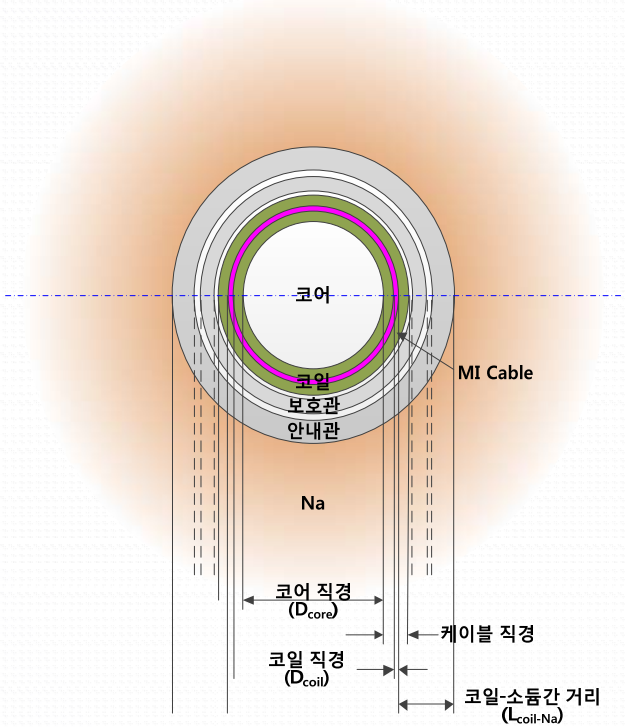
- ✓ Induced Voltage on secondary coil

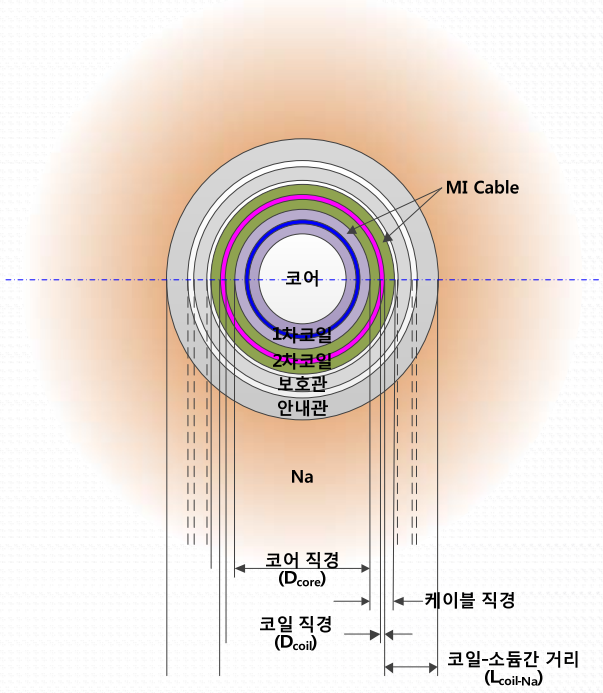


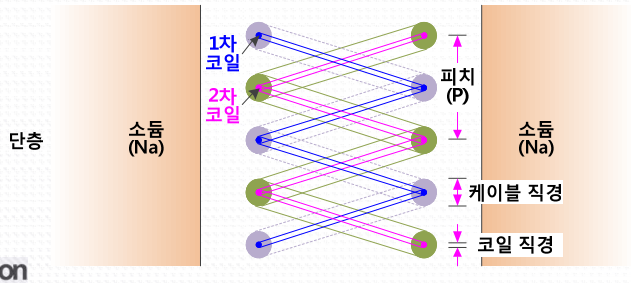


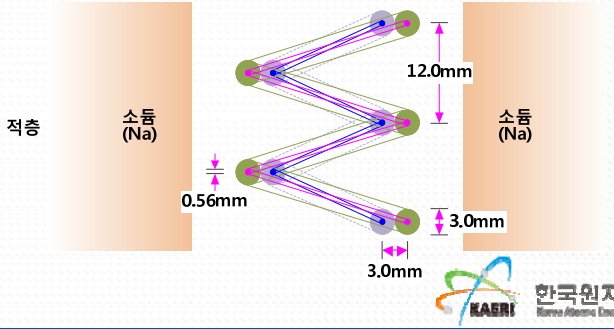
Analysis Model

❖ Schematics of model

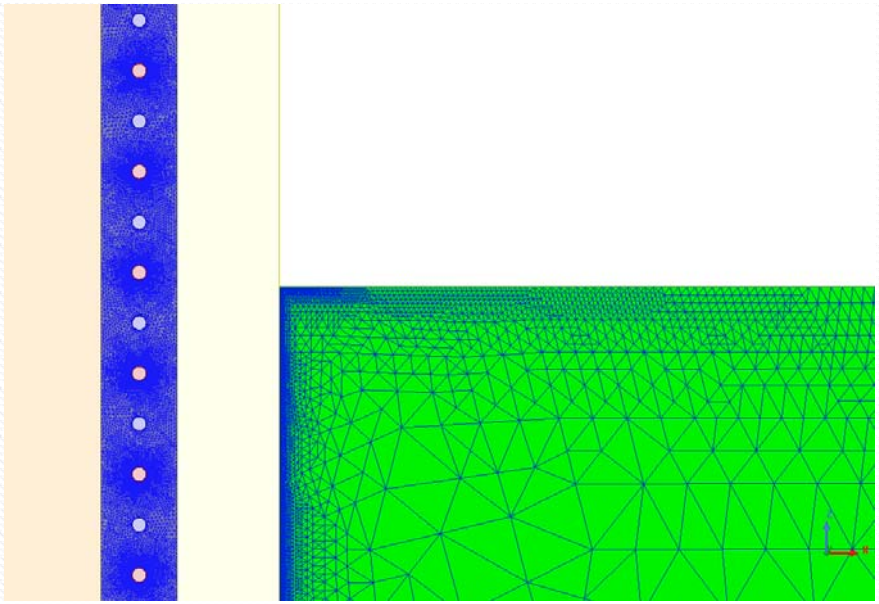
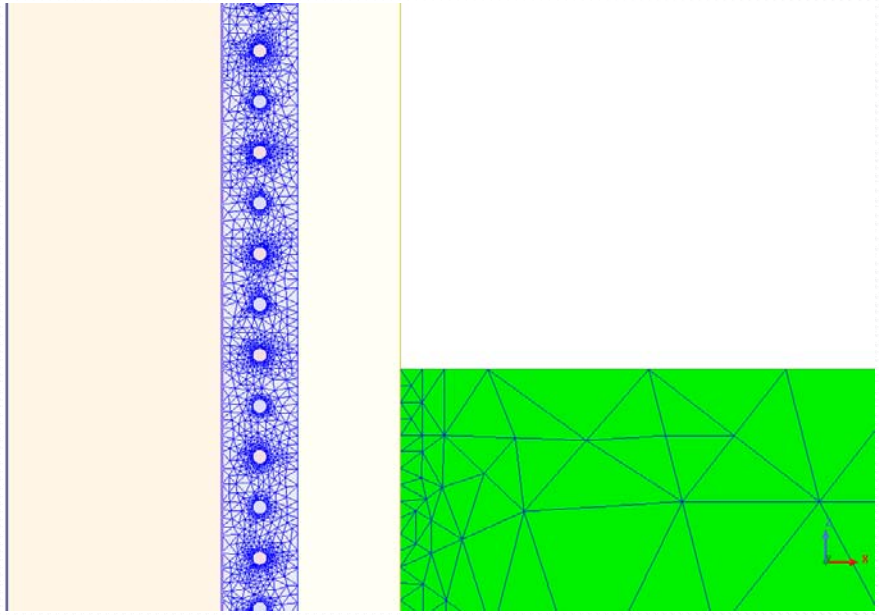








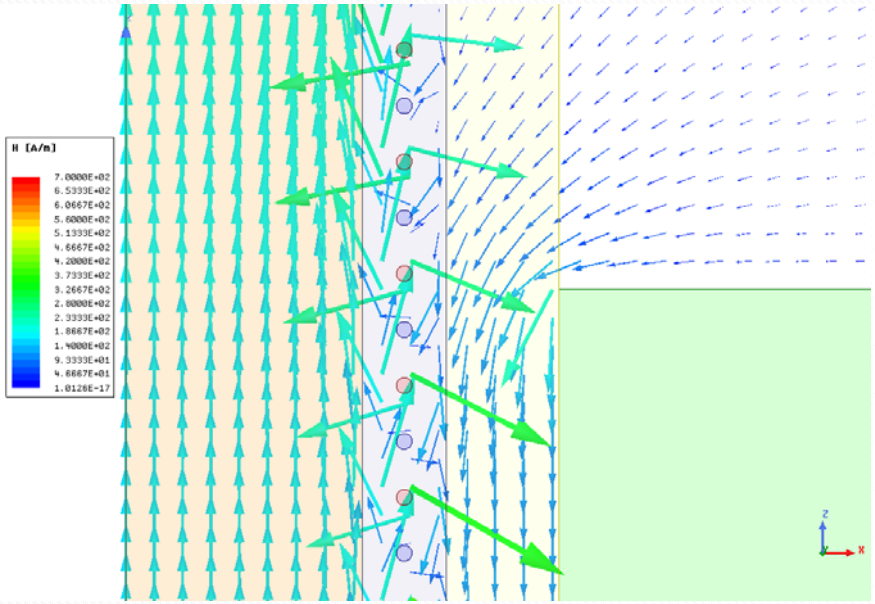
Mesh Configuration

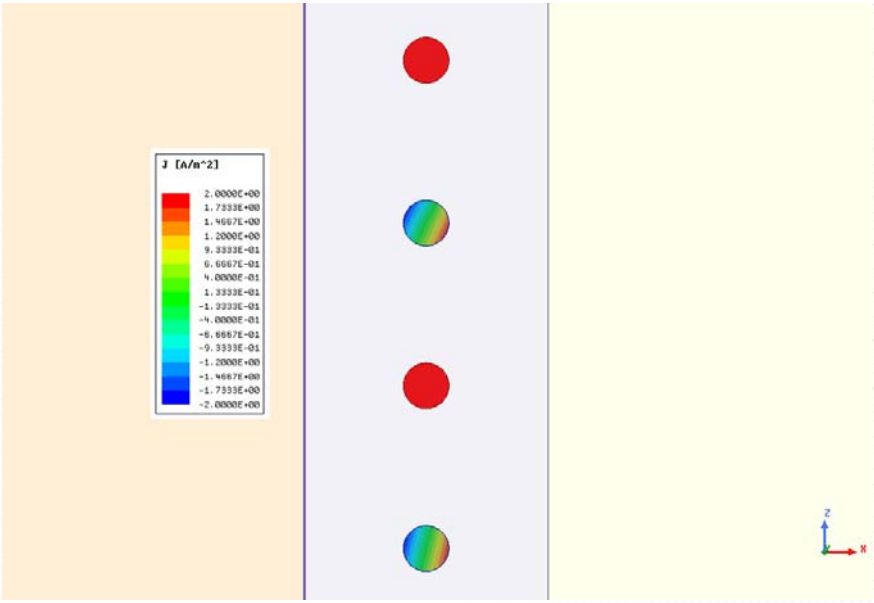
Liquid Na	No Liquid Na
	

Results

❖ Pitch = 4 mm

H Vector	Current Density @ Coils

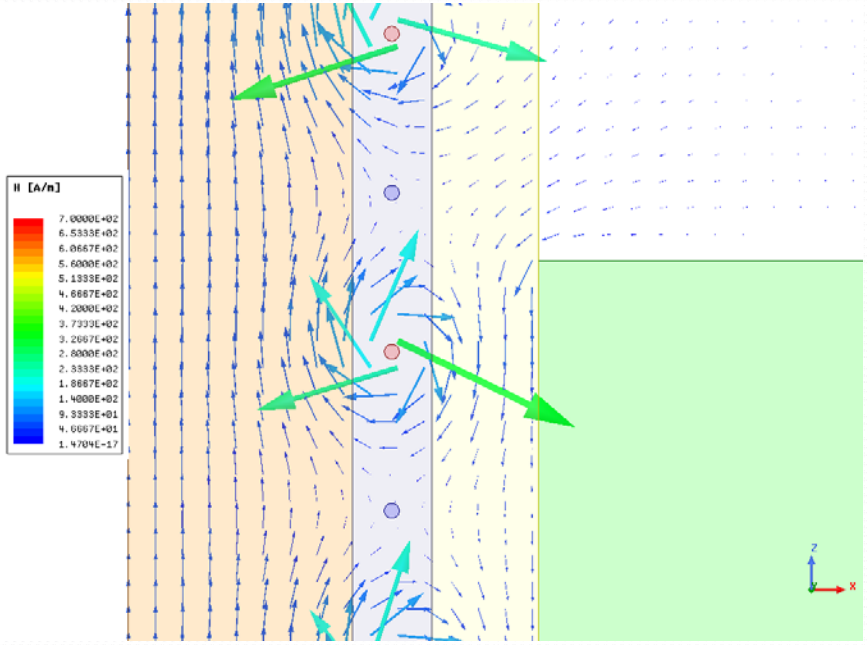


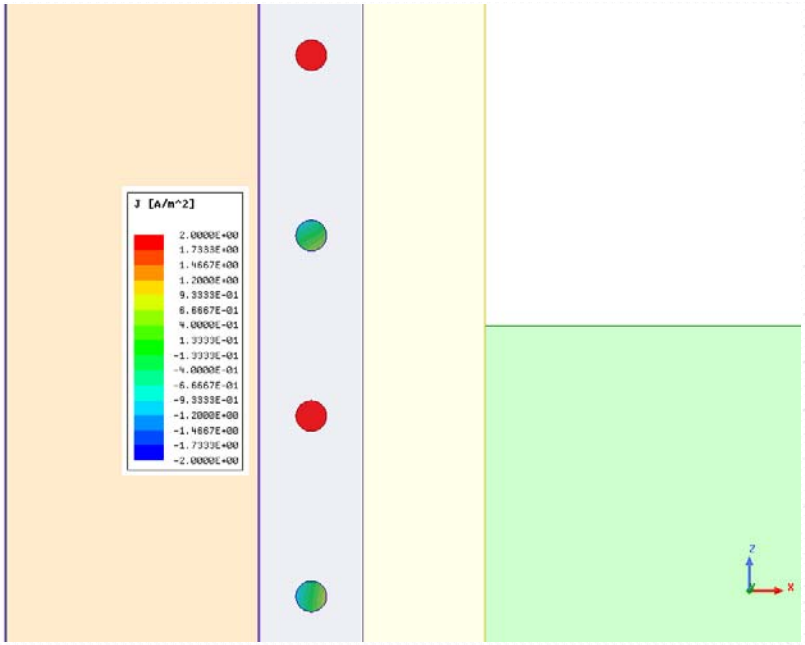


Results

❖ Pitch = 12 mm

H Vector	Current Density @ Coils

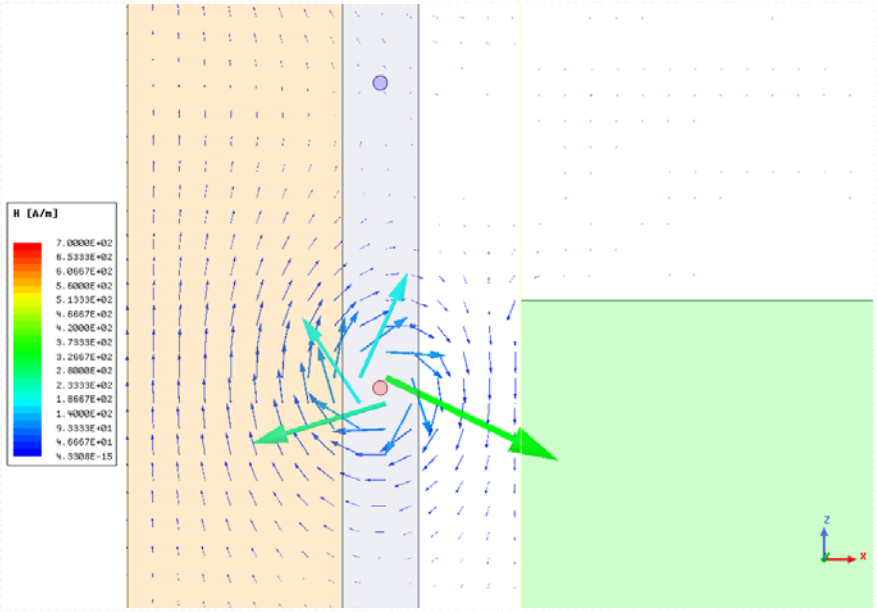




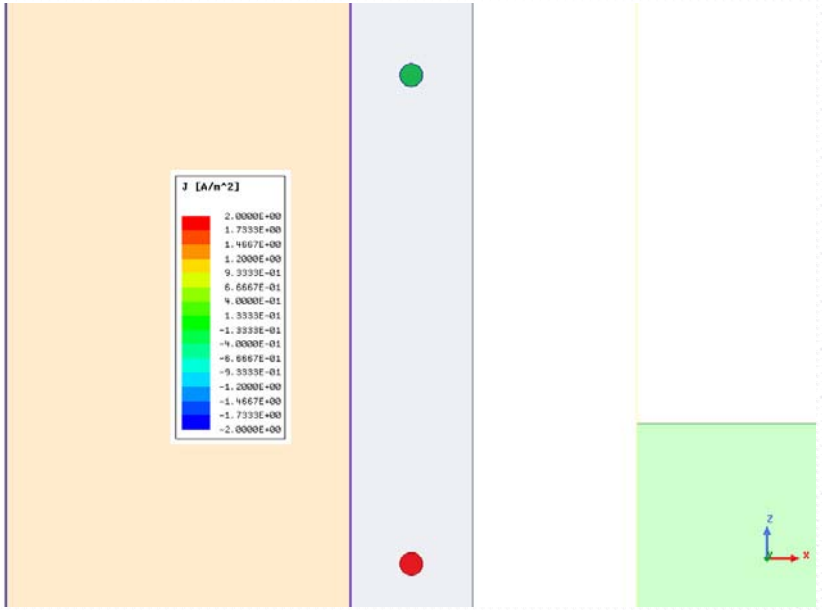
Results

❖ Pitch = 24 mm

H Vector

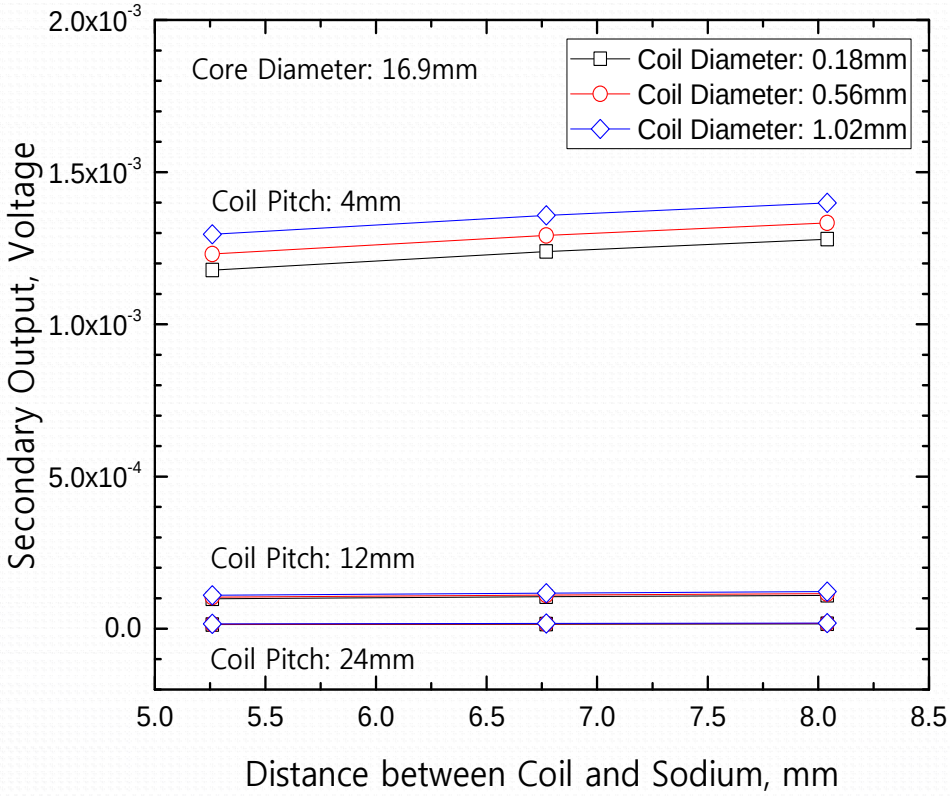


Current Density @ Coils



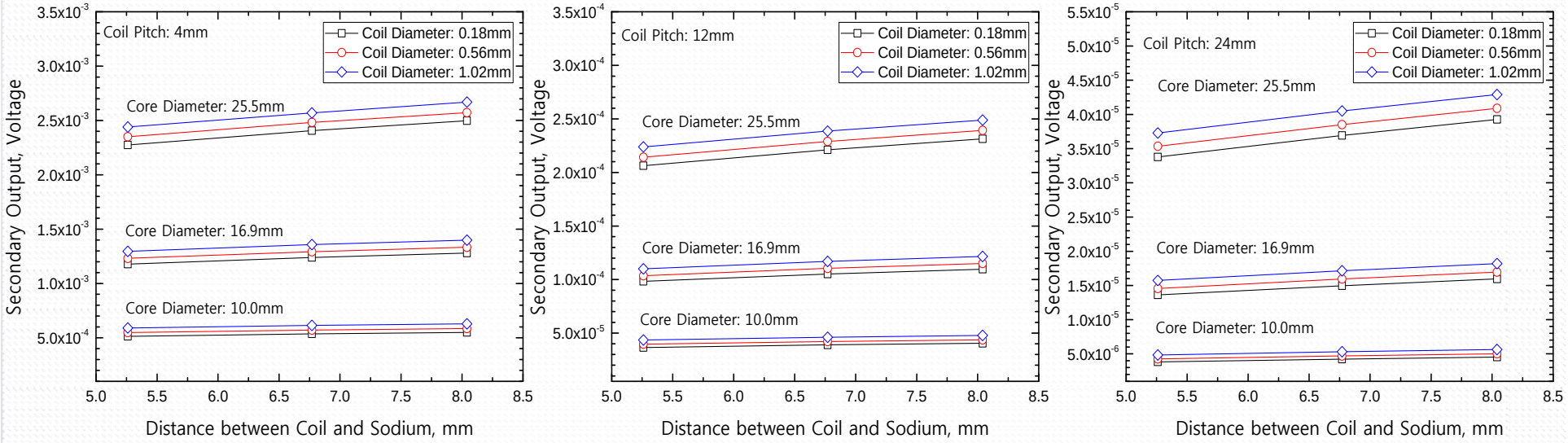
Results

❖ Effect of coil diameter and pitch



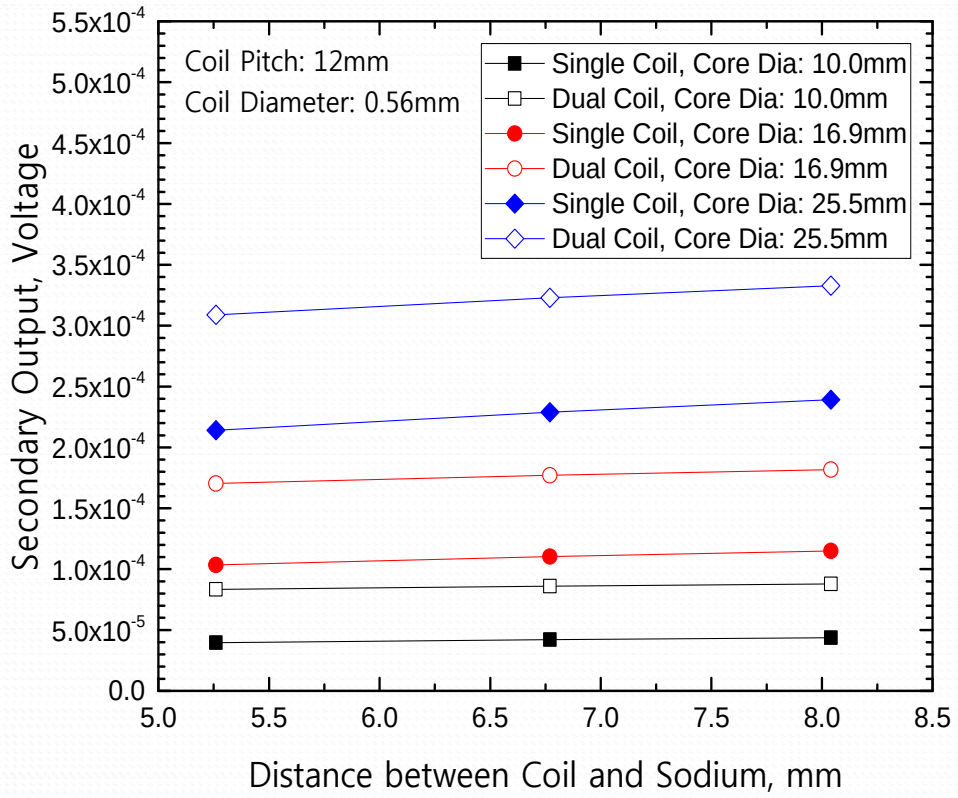
Results

❖ Effect of coil diameter and core diameter



Results

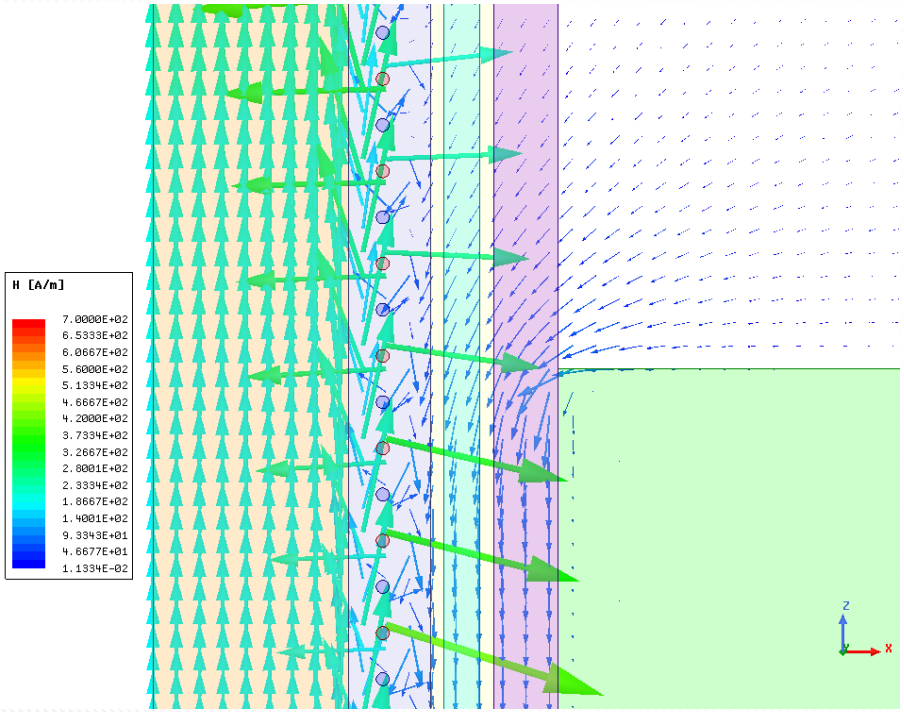
❖ Effect of coil winding method



Results

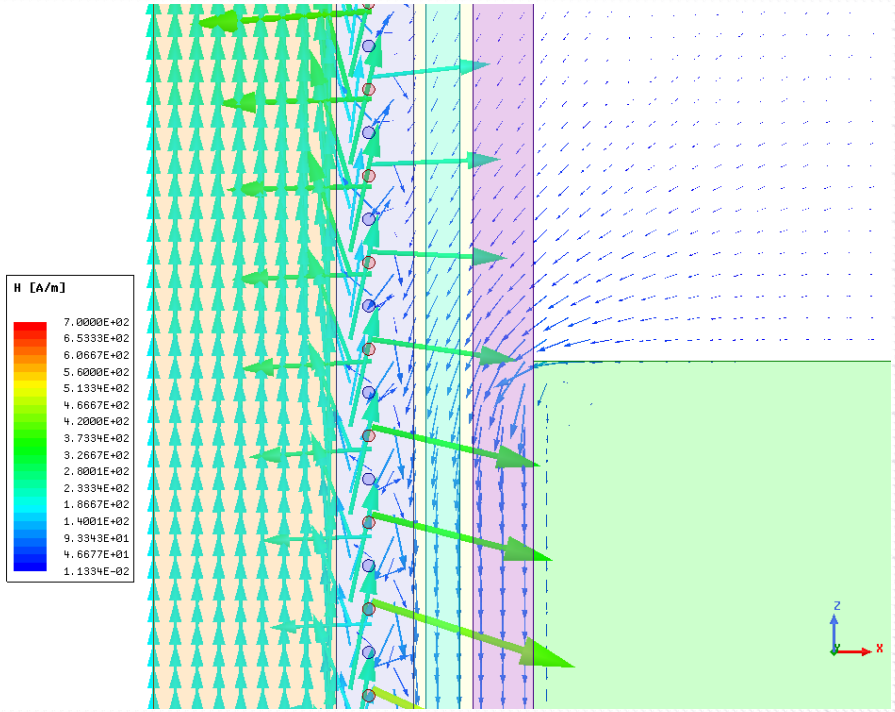
❖ Effect of guide tube

w_ Na & w_Guide



mag(InducedVoltage(2nd)) [mV] Setup1 : LastAdaptive
1.311359

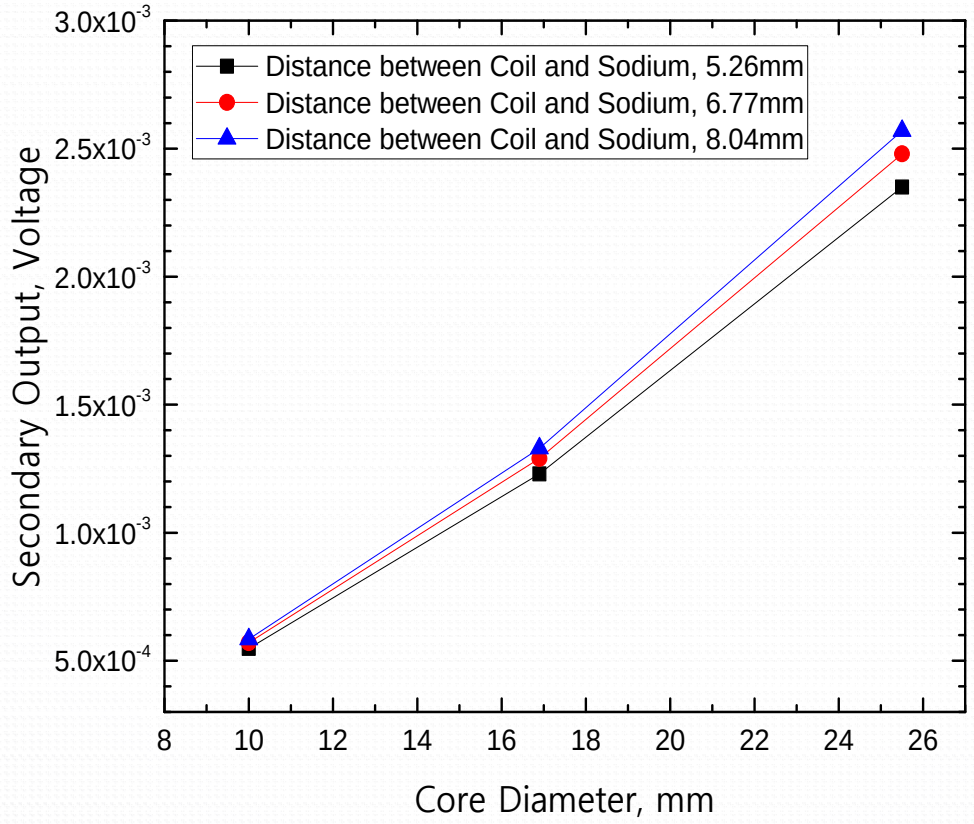
w_ Na & wo_Guide



mag(InducedVoltage(2nd)) [mV] Setup1 : LastAdaptive
1.311359

Results

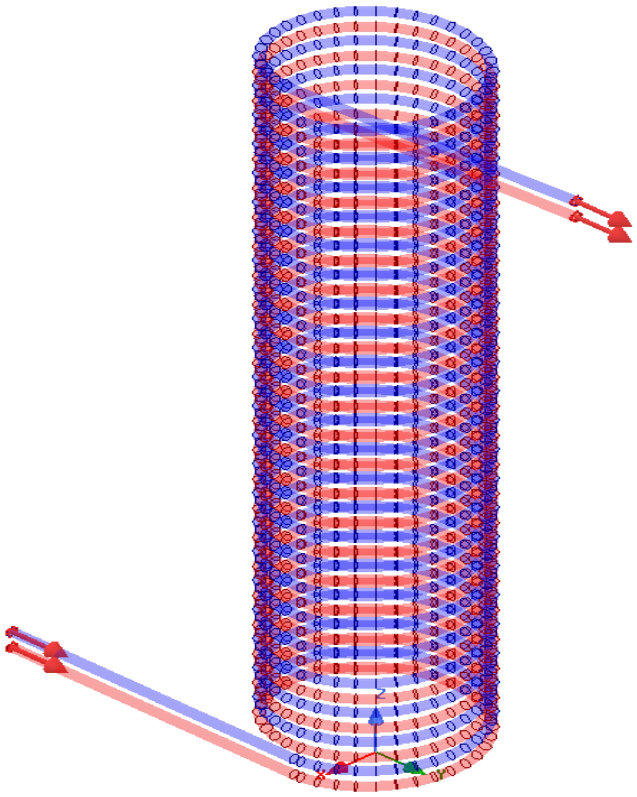
❖ Effect of distance between coil and sodium (+ core diameter)

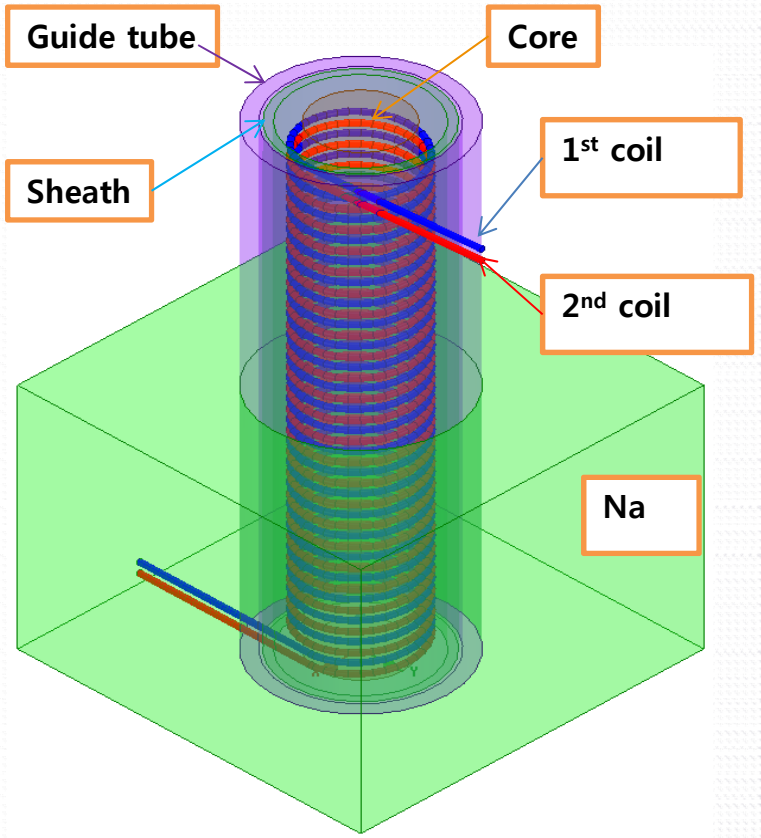


Summary

- ❖ Effect of coil diameter
  - ✓ Negligible
- ❖ Effect of coil pitch
  - ✓ Important design parameter
  - ✓ Optimization needs considering the proximity effect and the eddy current of coil itself
- ❖ Effect of coil winding method
  - ✓ Rather than winding method, the distance between coil-Na is more direct effect
- ❖ Effect of guide tube
  - ✓ No effect or very small (it is negligible)
- ❖ Effect of core diameter and distance between coil-Na
  - ✓ Sensitive to core diameter and not sensitive to the distance

Appendix - 3D Model

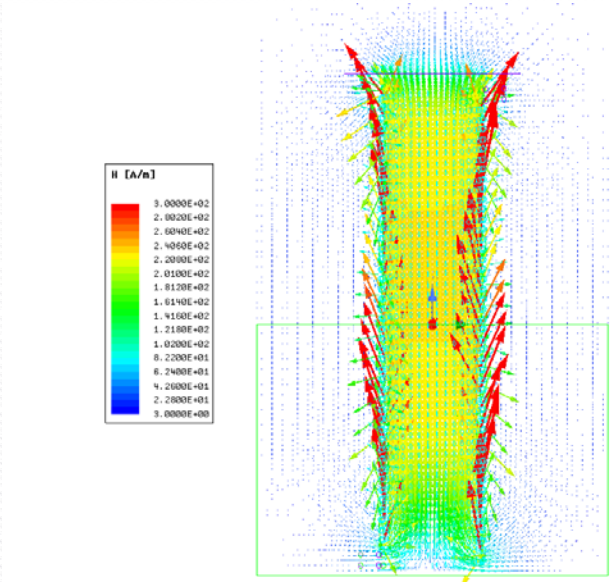




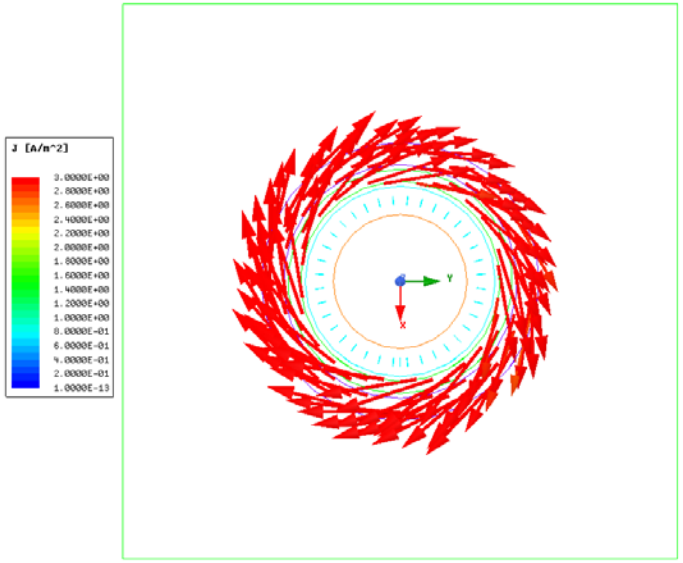
Appendix - 3D Analysis Result

❖ Without Sodium

H vector @ YZ plane



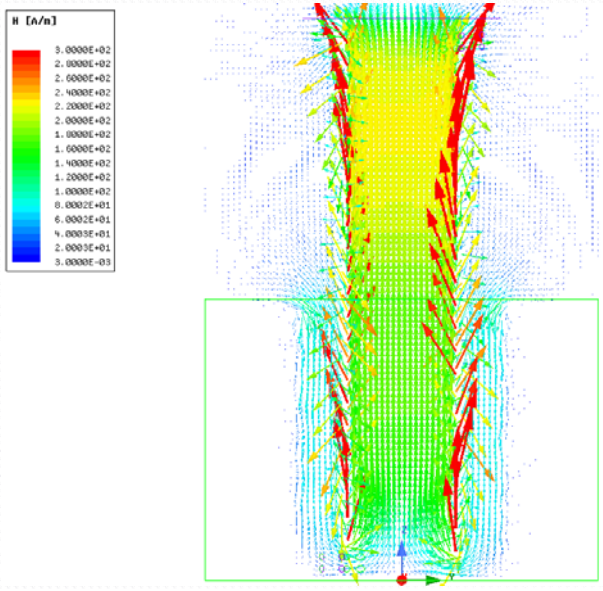
J Vector @ XY Plane - (Na, Guide) Top



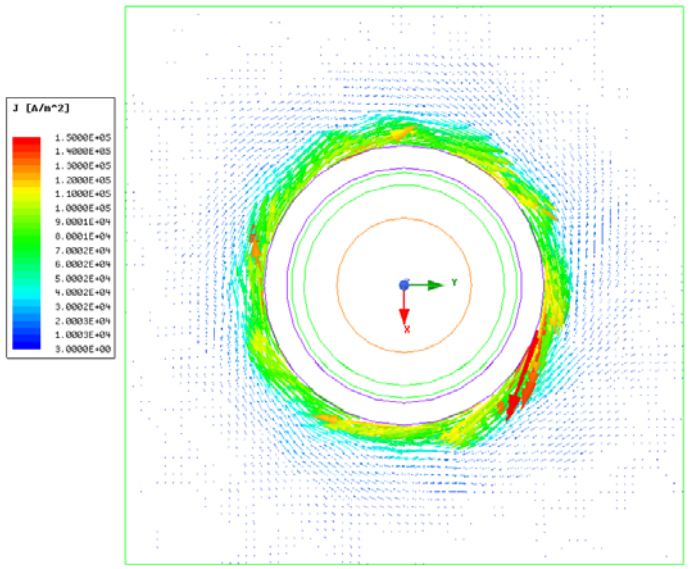
Appendix - 3D Analysis Result

❖ With Sodium

H vector @ YZ plane



J Vector @ XY Plane - (Na, Guide) Top

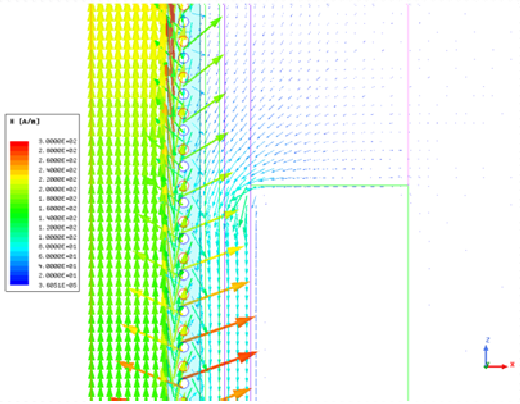


Appendix - 3D Analysis Result

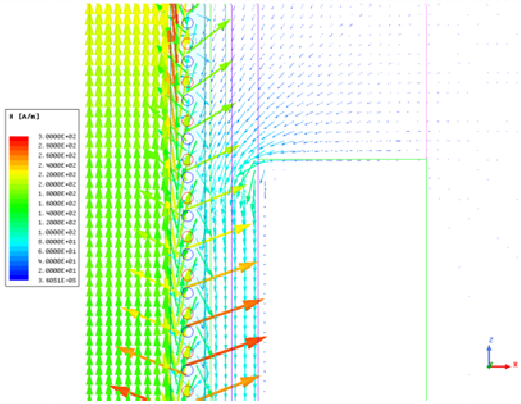
❖ Comparison between 3D & 2D

	2D		3D
	Induced V, μV	Difference, %	Induced V, μV
Na without guide tube	613.68	102.3%	600.01
Na with guide tube	613.57	102.3%	599.93
No Na with guide tube	767.45	108.1%	710.00

w_Na & wo_Guide



w_Na & w_Guide



wo_Na & w_Guide