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Title: Calculation of Eddy Current and Temperature Change in Clamping Plate
of Pressure Cell

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Calculation of Eddy Current and Temperature Change in Clamping Plate of Pressure Cell

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21 June 2018

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Motivation

- Pressure is important parameter to tune materials in our high pulsed magnetic fields
- Pressure cells usually use high strength metal plates to squeeze diamond anvils to create high pressure on a sample (several GPa or above, higher is better)
- Under a transient magnetic field, there will be a temperature rise in metal plate => disturb the experiment
- What is that temperature rise and how to minimize that thermal instability?

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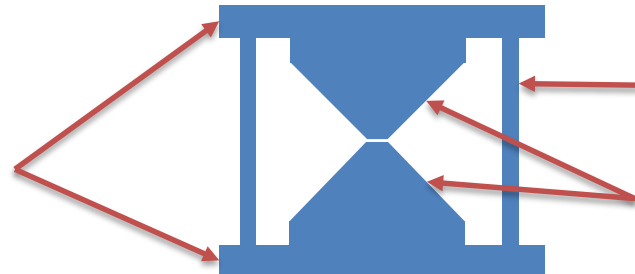
Introduction

Pressure Cell

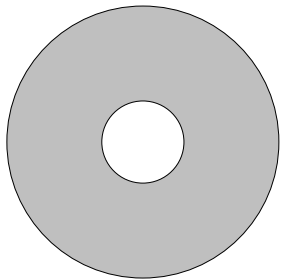
High Strength
metal Plate

Metal Rod

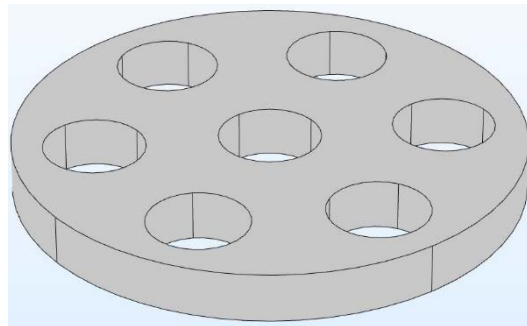
Diamond Anvil



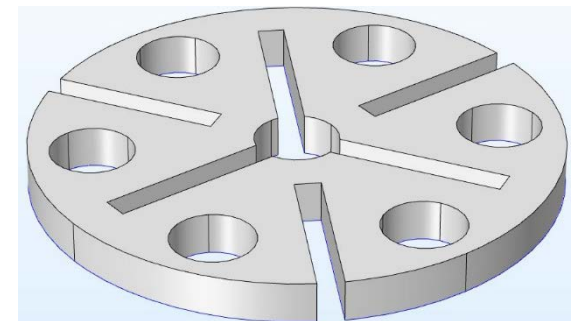
Clamping Plate With
Center Hole



Clamping Plate Without Slot
Original Design



Clamping Plate With Slot



Materials:

- Titanium

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65 Tesla Magnet

Diagram of Field Profile

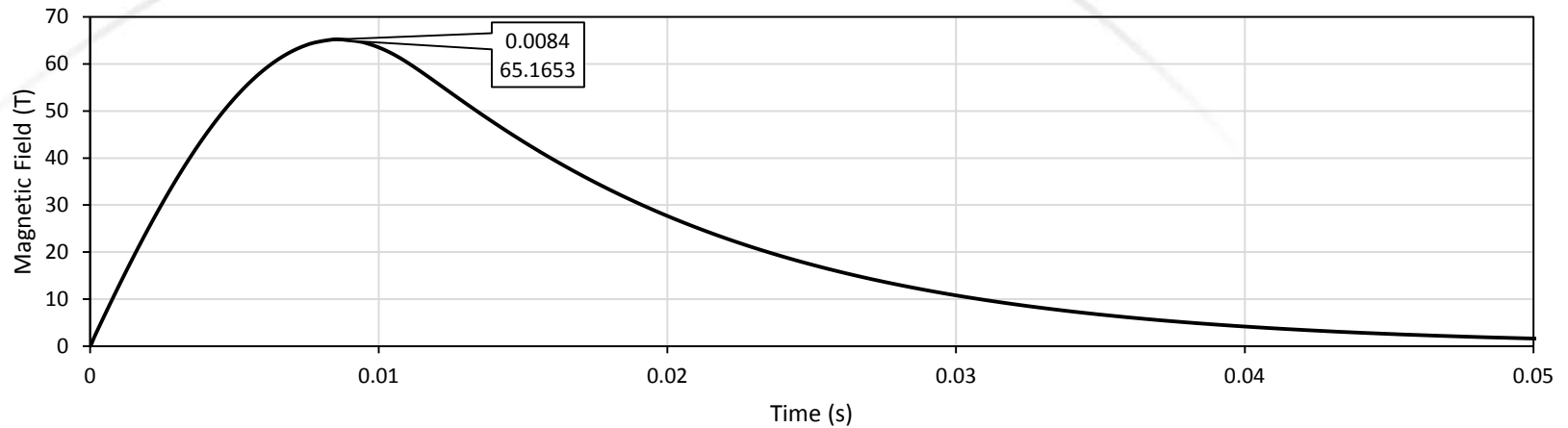
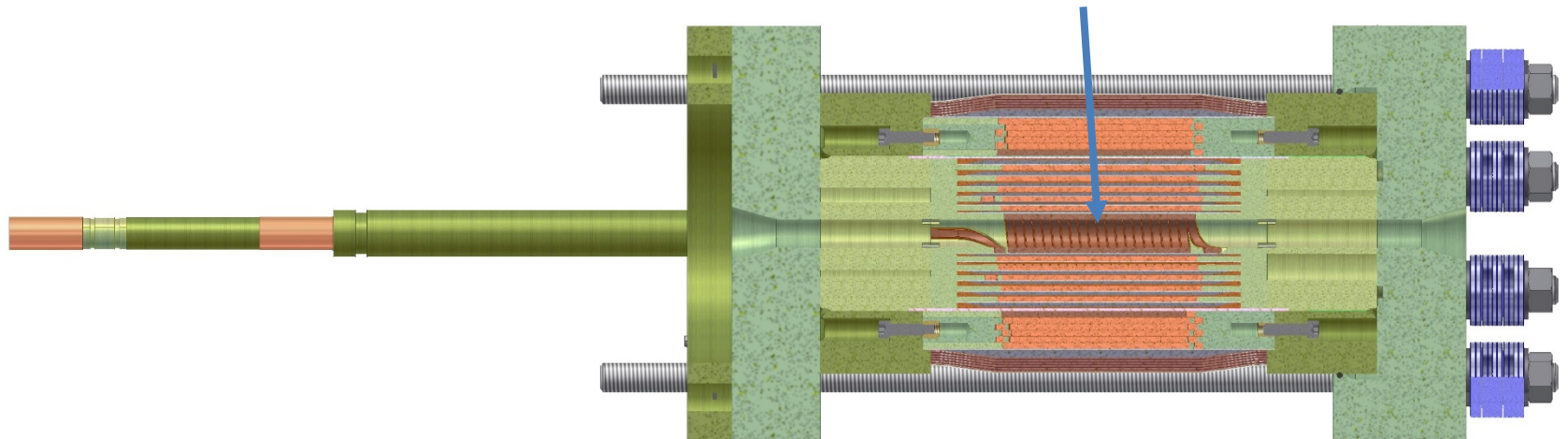


Diagram of Magnet

Magnet bore 15.5 mm



Computational Approach

INPUTS

- Field Profile
- Geometry of Dimension
- Material



COMSOL 3D Multiphysics

AC/DC Magnetic Field Module



Heat Transfer in Solids

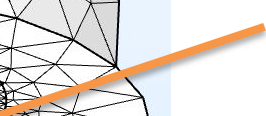


OUTPUTS

- Induced Current Density (Eddy Current)
- Temperature

Note: Temperature Dependence of electrical conductivity is taken into account

Clamping Plate

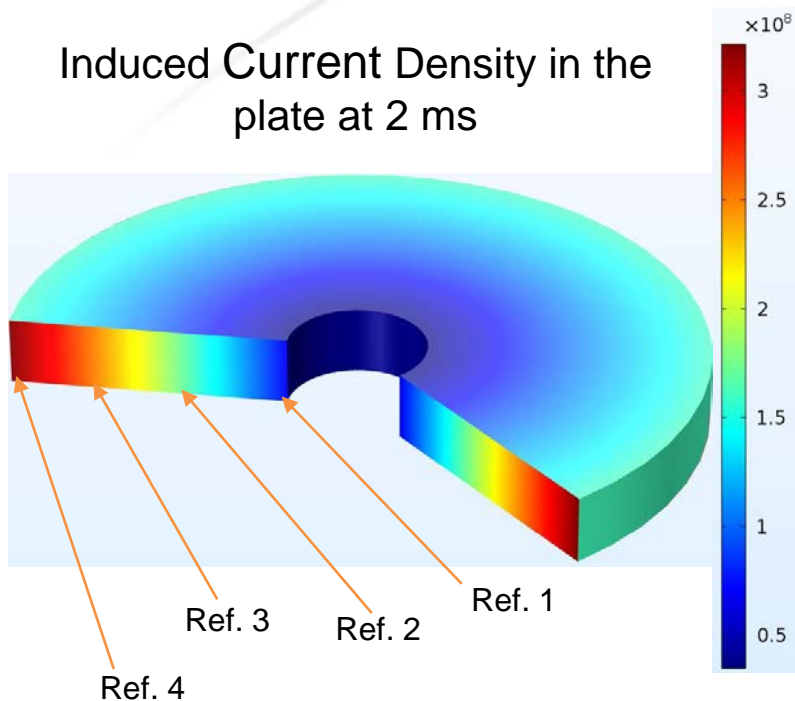


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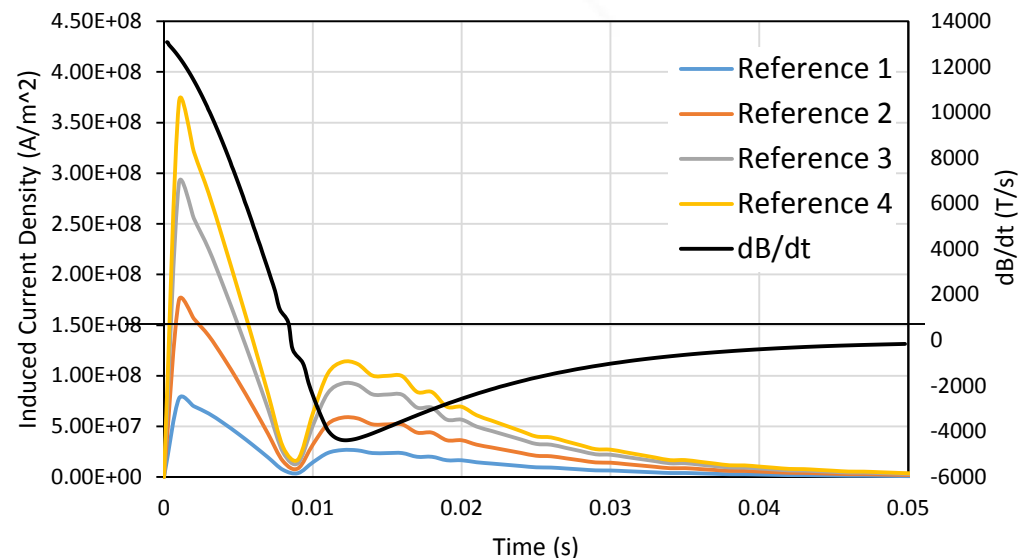
Induced current density in plate with only center hole

Current density (A/m^2)

Induced Current Density in the plate at 2 ms



Induced Current Density in Respect to Time at Specific Reference Points

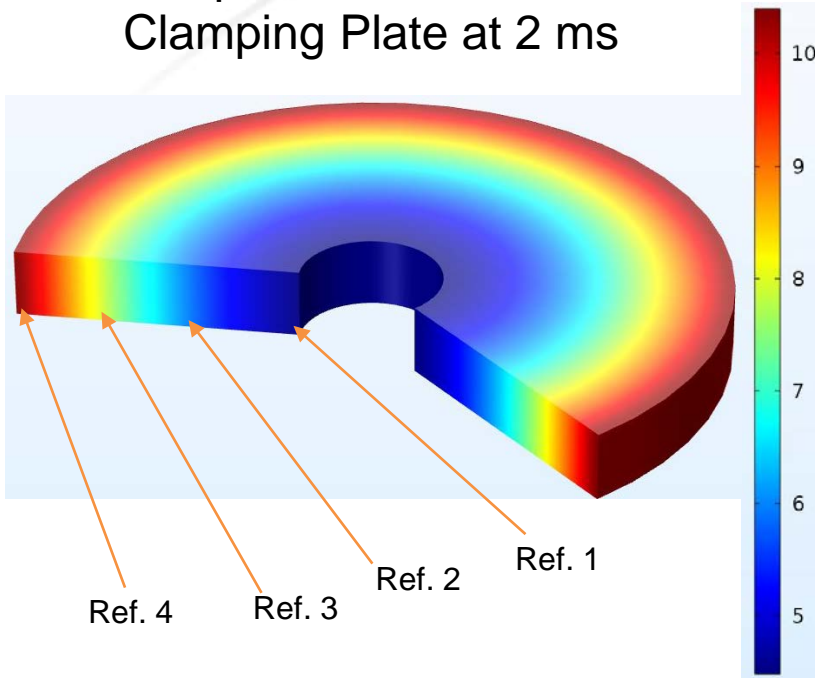


- Induced Current Density proportional to $|\text{dB/dt}|$
 - Current Density at its lowest when dB/dt is 0 (peak field)

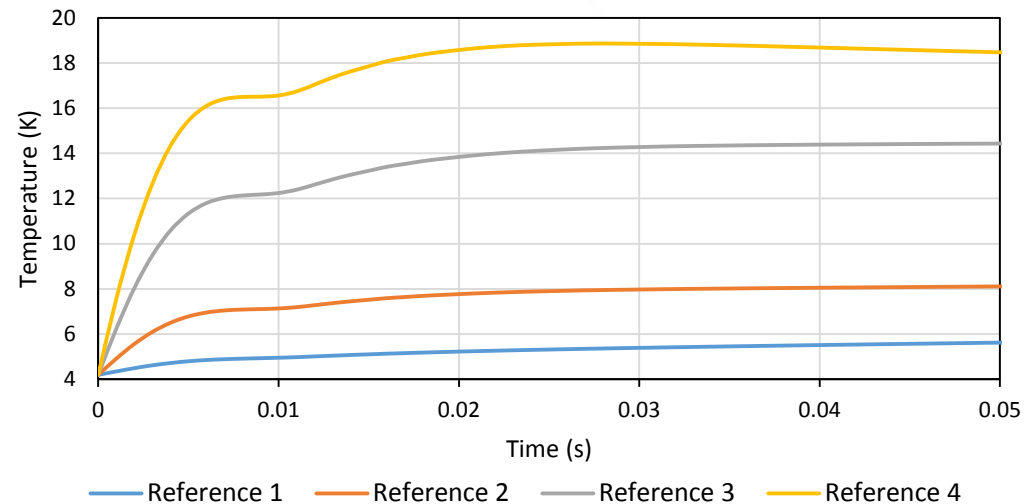
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Temperature in plate with only center hole

Temperature Profile of Clamping Plate at 2 ms



Temperature in Respect to Time at Specific Reference Point

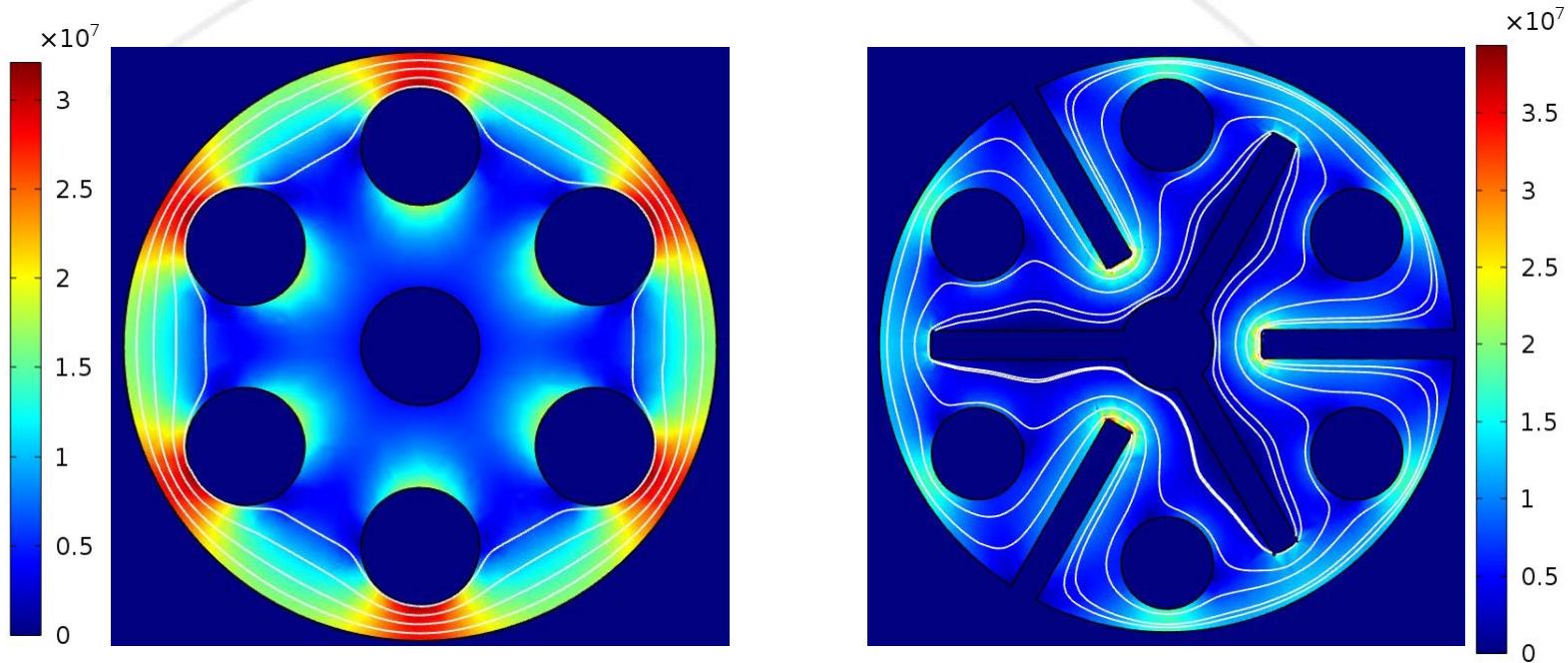


- Uniform temperature distribution across the plate thickness
- Temperature increases as radial distance increases
- High Temperature at the edge of plate

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Induced Current Density in Plates

Induced Current Density Profile of the Clamping Plate at 2 ms

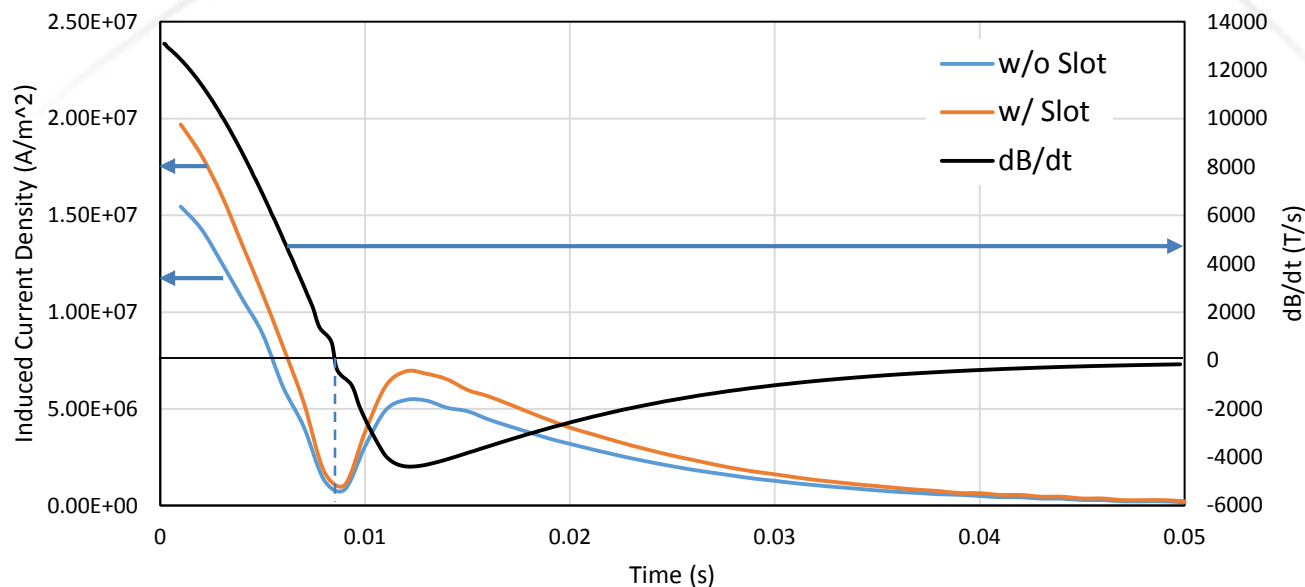


- 2 ms is when change of Magnetic field over change in time is the greatest
- Change in Magnetic field over change in time is directly proportional to Eddy current

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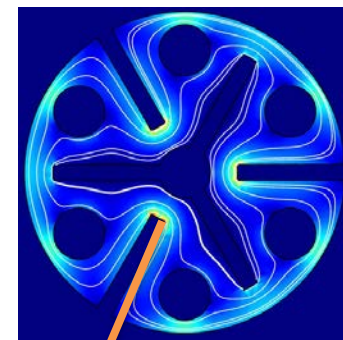
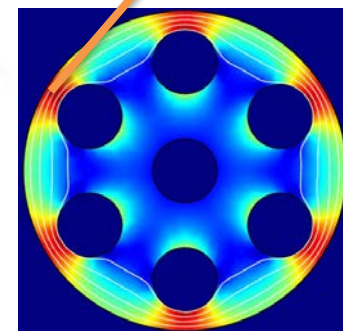
Induced Current Density in Plates

Induced Current Density in Respect to Time



- Induced Current Density proportional to $|dB/dt|$
 - Current Density at its lowest when dB/dt is 0

Reference point

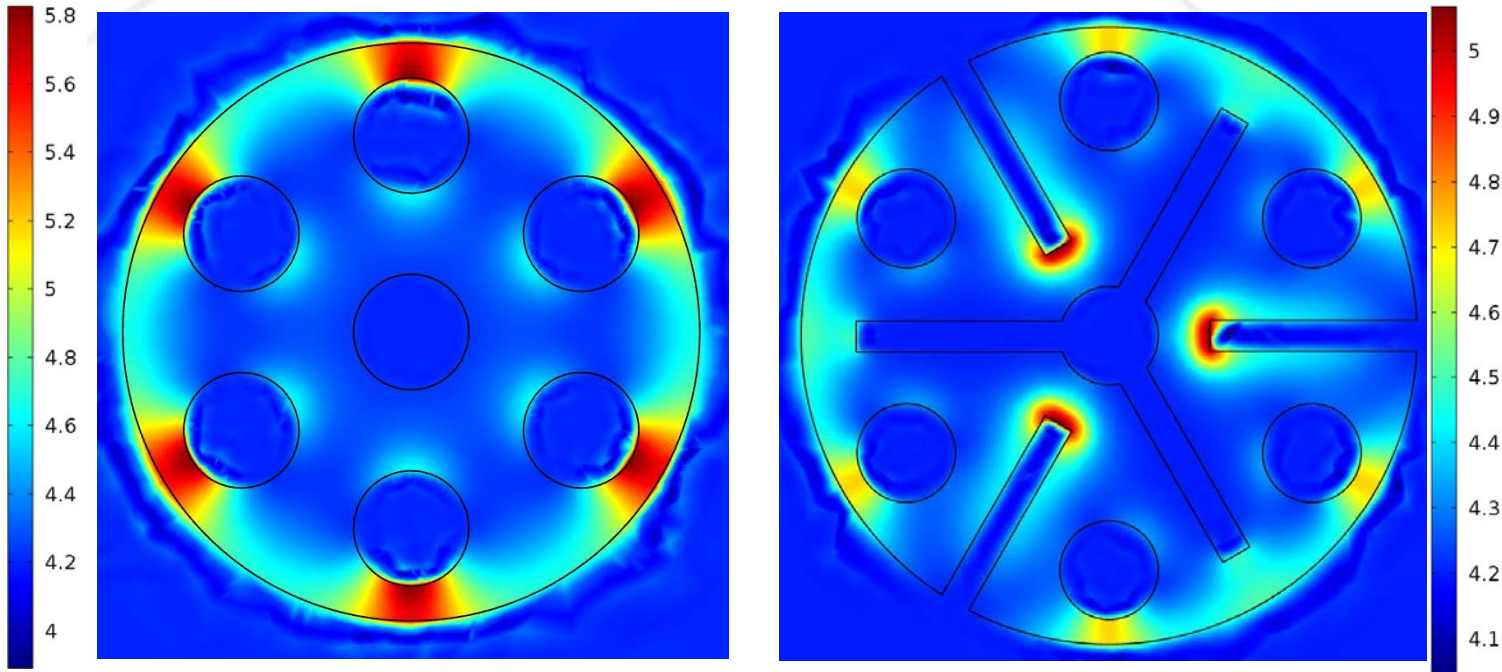


Reference point

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Temperature in Plates

Temperature Profile of Clamping Plate at 2 ms

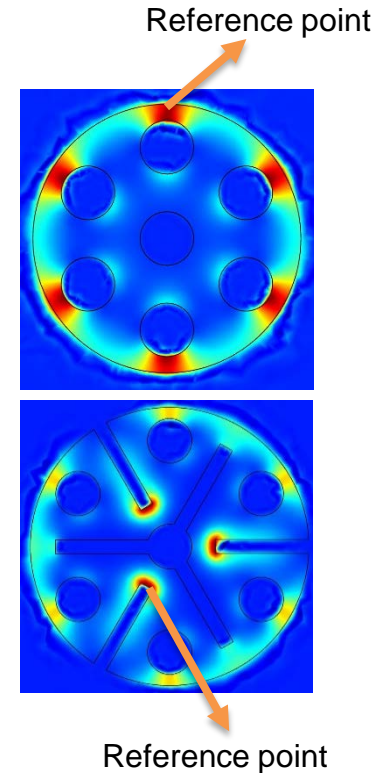
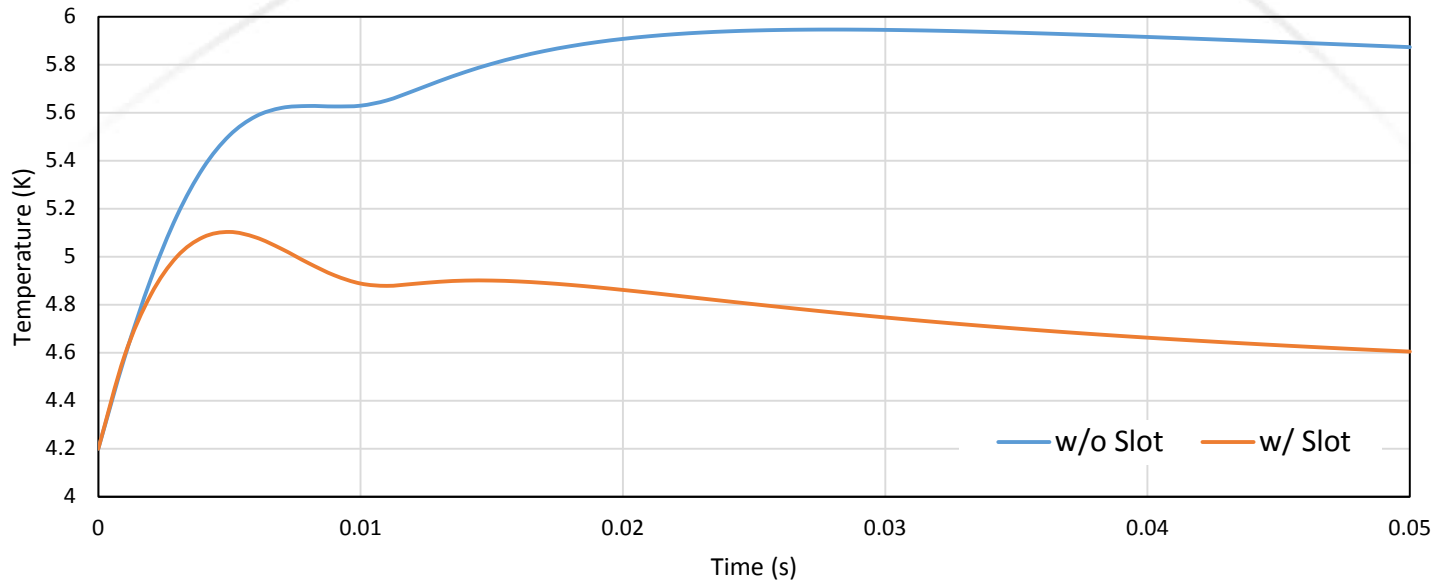


- More concentrated heat in the design without slots
- Uniform temperature throughout the design with slots

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Temperature in Plates

Temperature Change in Respect to Time



- At the beginning, temperature increases due to high dB/dt
- Near the peak field, heat generated by low eddy current (due to low dB/dt) is lower than the transferred heat, temperature decreases

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Conclusion

- Computational Approach
 - COMSOL multi-physics software
- Provide understanding of temperature change during pulses
- Optimization of clamping plate design (with Slot)
 - Decreases temperature by 30%
 - Decrease in Induced Current Density
- Further optimization is needed. The code can be applied for any shapes of metal pieces

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