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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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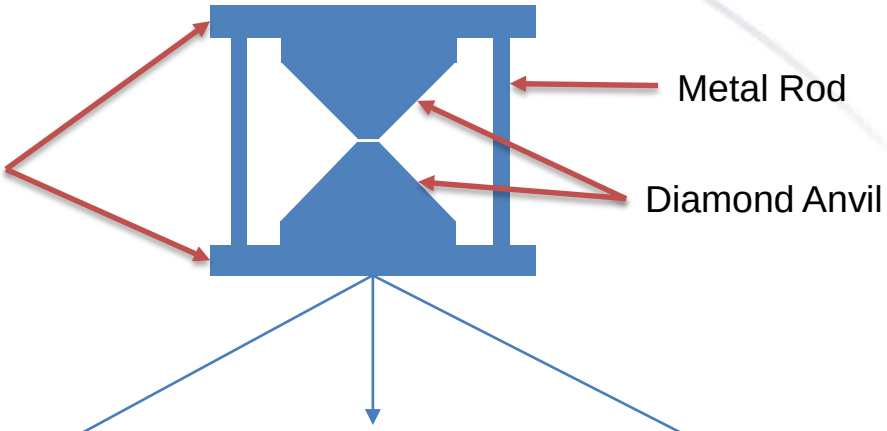
Motivation

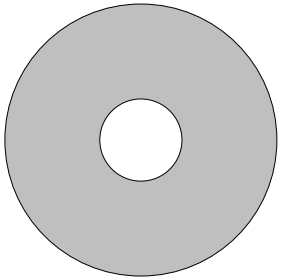
- Pressure is important parameter to tune materials in our high pulsed magnetic fields
- Pressure cells usually use high strength metal plates to squeeze diamond anvils to create high pressure on a sample (several GPa or above, higher is better)
- Under a transient magnetic field, there will be a temperature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

Introduction

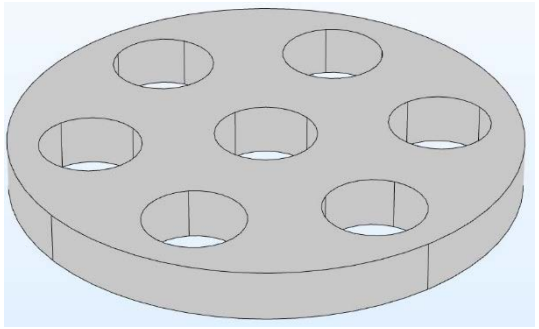
Pressure Cell



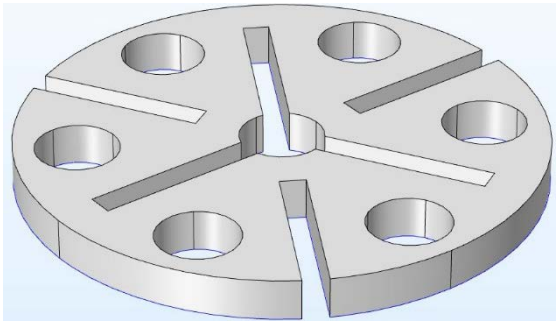
Clamping Plate With Center Hole



Clamping Plate Without Slot
Original Design



Clamping Plate With Slot



Materials:

- Titanium

65 Tesla Magnet

Diagram of Field Profile

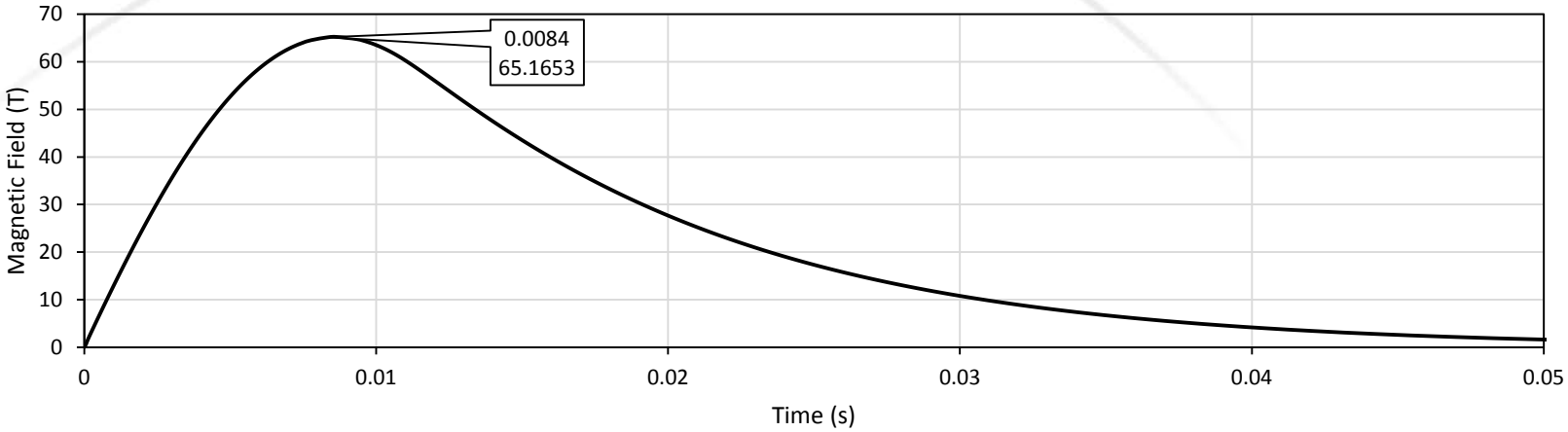
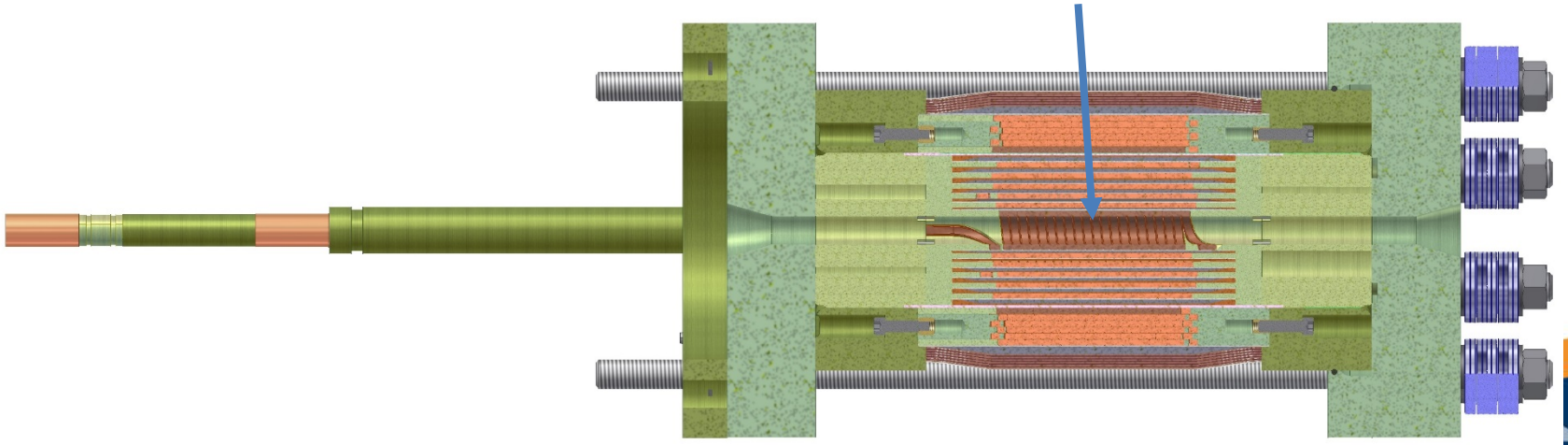


Diagram of Magnet



Computational Approach

INPUTS

- Field Profile
- Geometry of Dimension
- Material

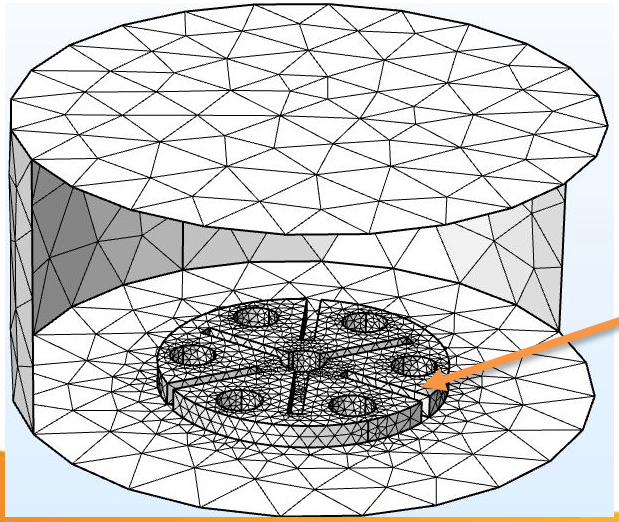
COMSOL 3D Multiphysics

AC/DC Magnetic Field Module

Heat Transfer in Solids

OUTPUTS

- Induced Current Density (Eddy Current)
- Temperature

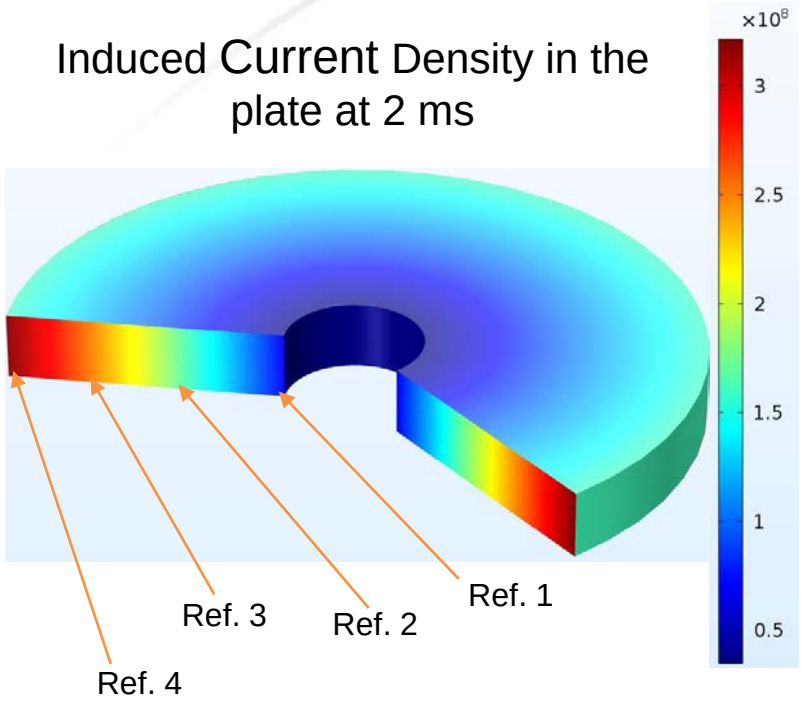


Note: Temperature Dependence of electrical conductivity is taken into account

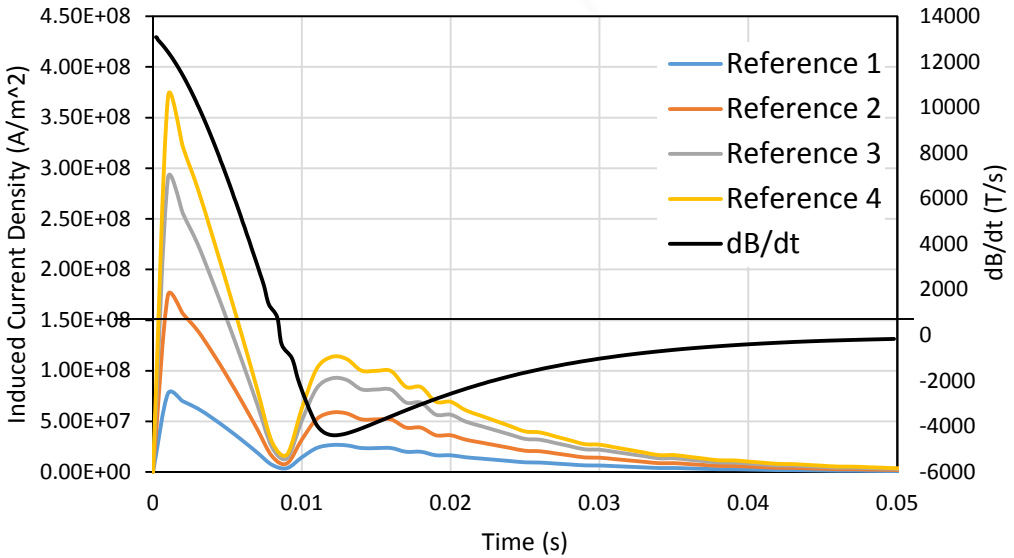
Induced current density in plate with only center hole

Current density (A/m^2)

Induced Current Density in the plate at 2 ms



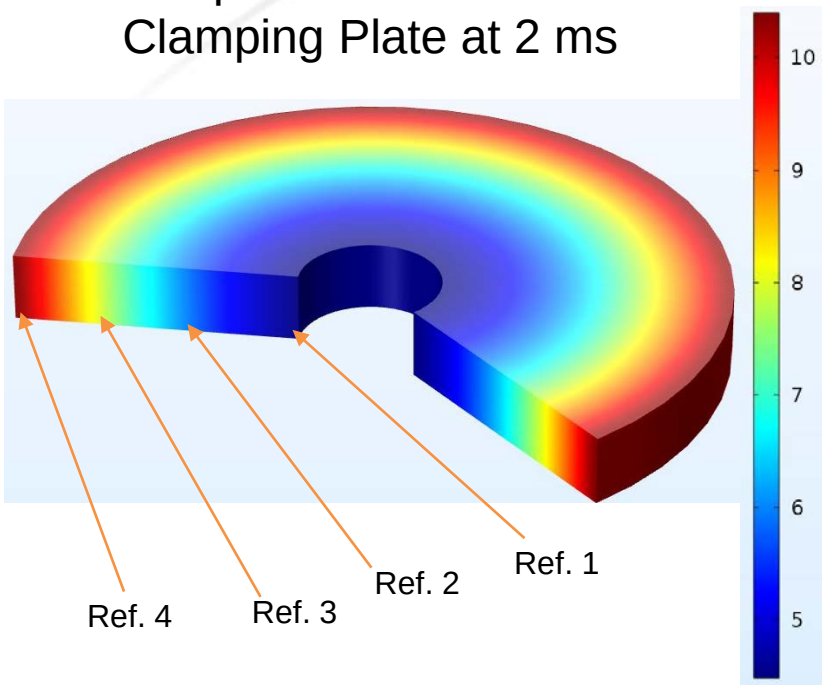
Induced Current Density in Respect to Time at Specific Reference Points



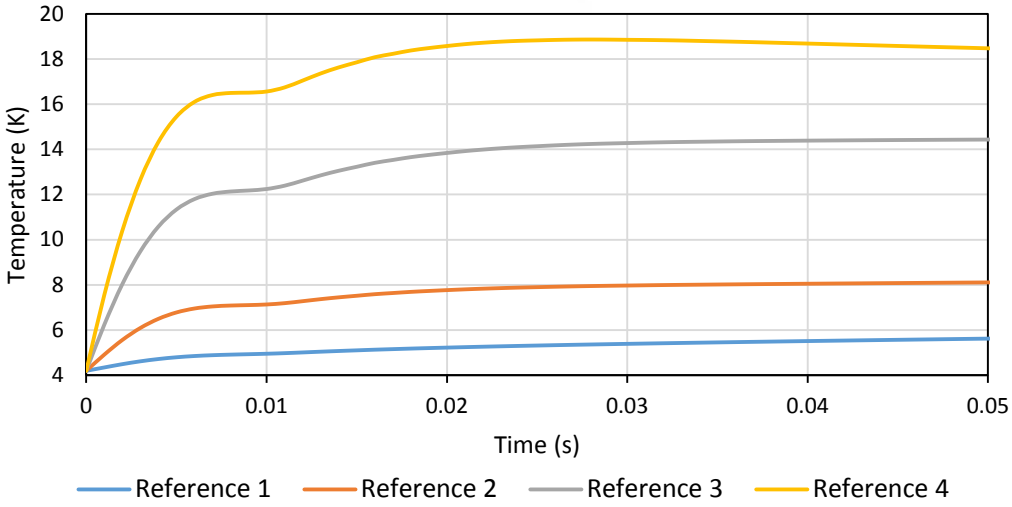
- Induced Current Density proportional to |dB/dt|
  - Current Density at its lowest when dB/dt is 0 (peak field)

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

Induced Current Density in Plates

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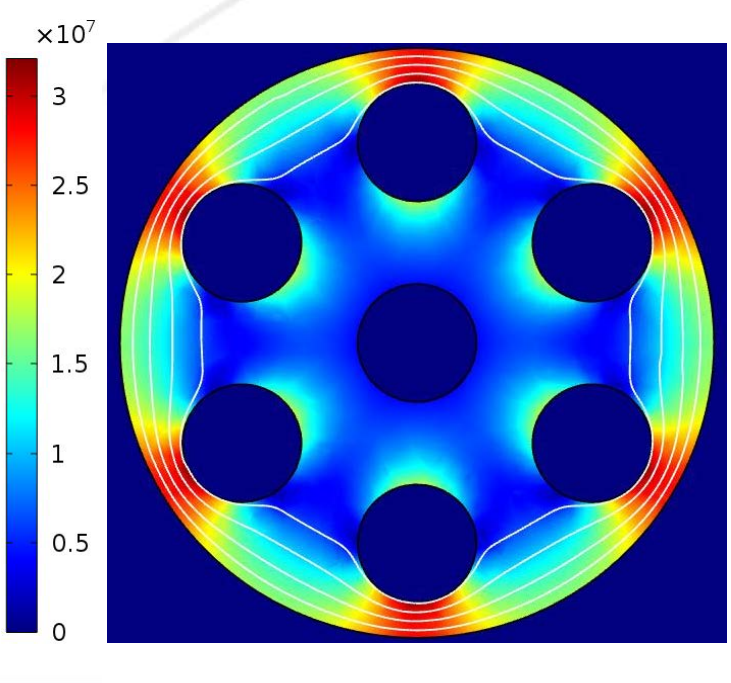
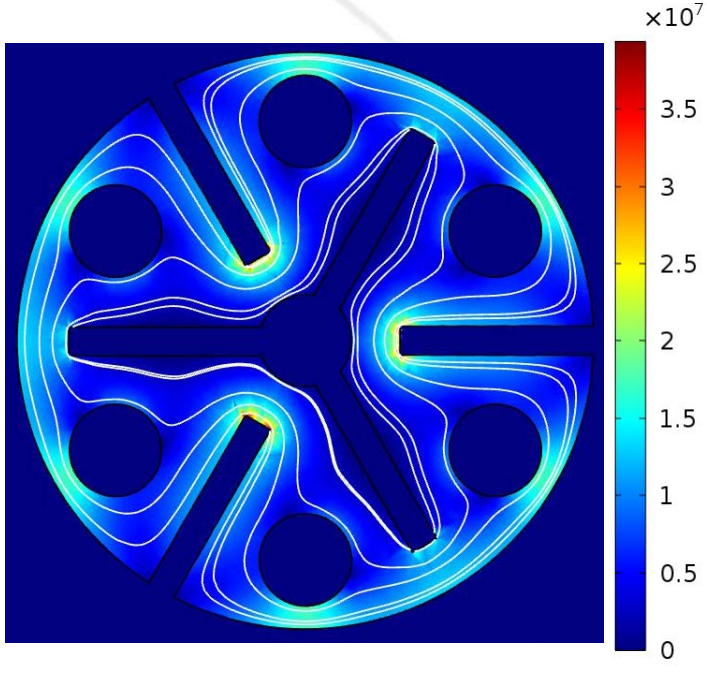
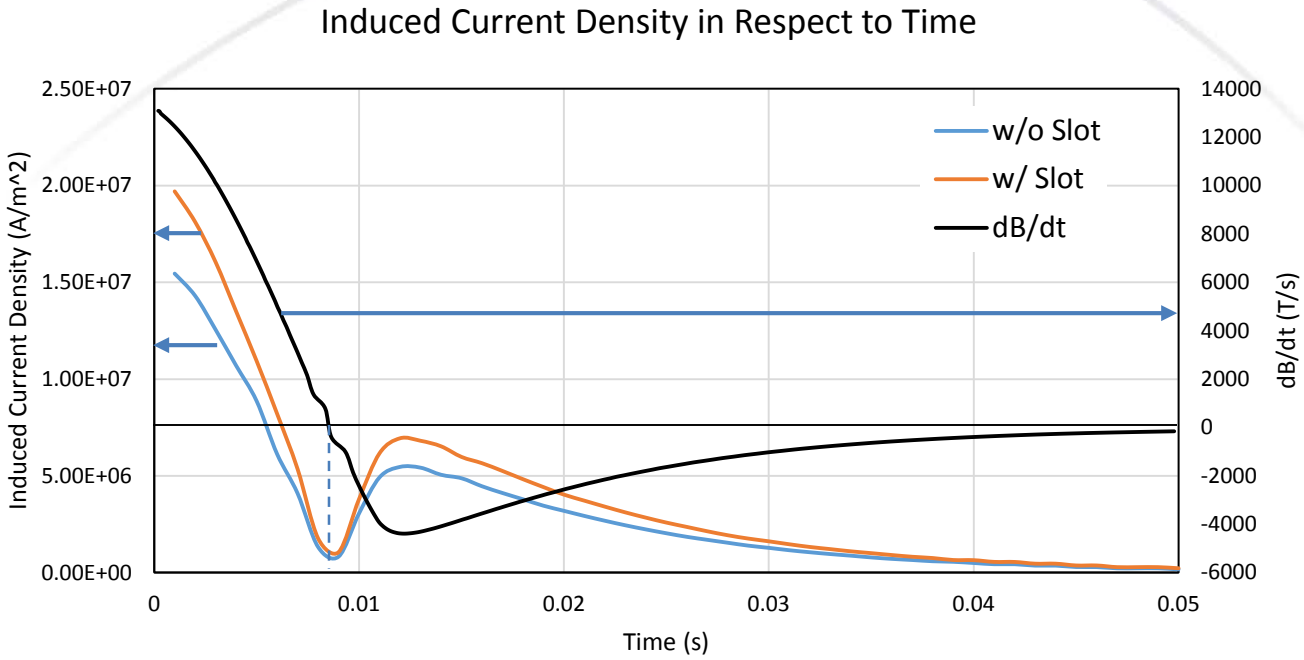
Induced Current Density Profile of the Clamping Plate at 2 ms

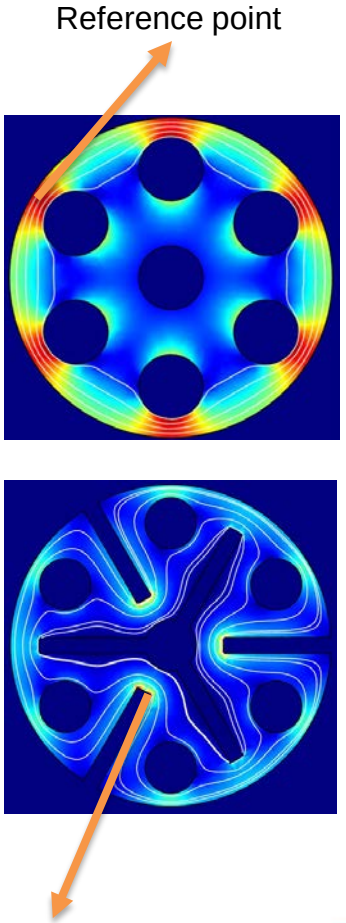




- 2 ms is when change of Magnetic field over change in time is the greatest
- Change in Magnetic field over change in time is directly proportional to Eddy current

Induced Current Density in Plates

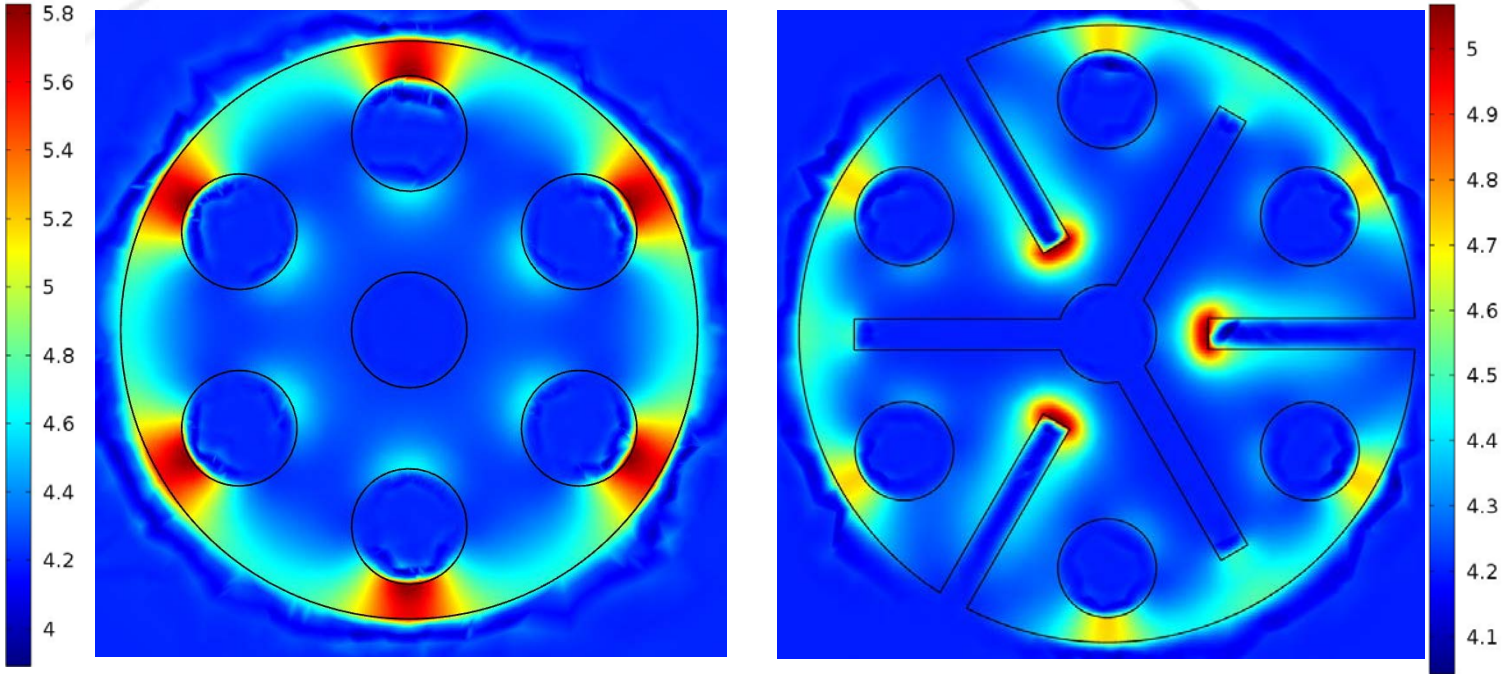




- Induced Current Density proportional to |dB/dt|
  - Current Density at its lowest when dB/dt is 0

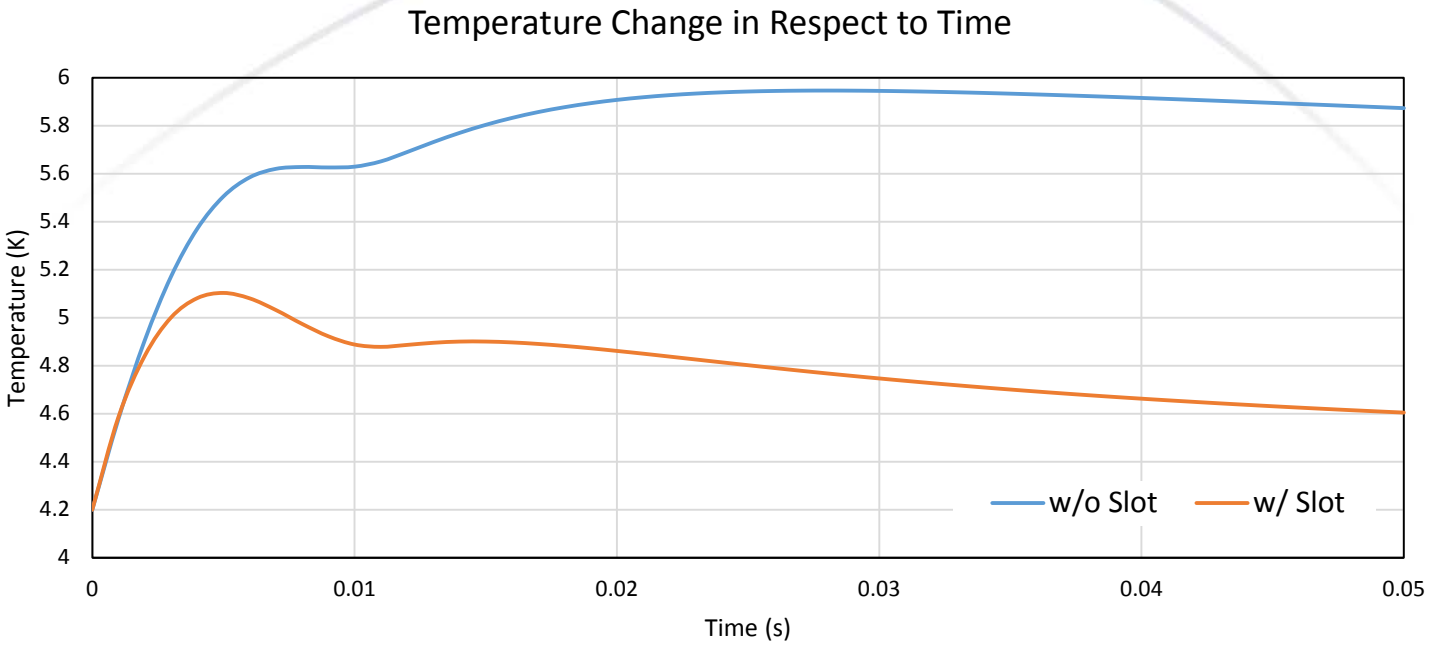
Temperature in Plates

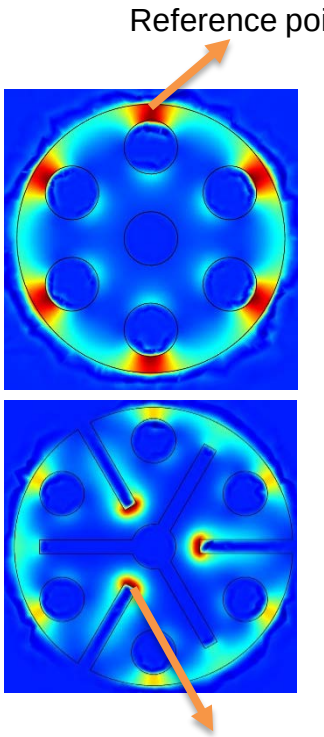
Temperature Profile of Clamping Plate at 2 ms



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

Temperature in Plates





- 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

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