# IN-LINE MECHANICAL PRODUCTION TEST EQUIPMENT FOR CRACK DETECTION IN PERMANENT MAGNETS AND MAGNET BLANKS

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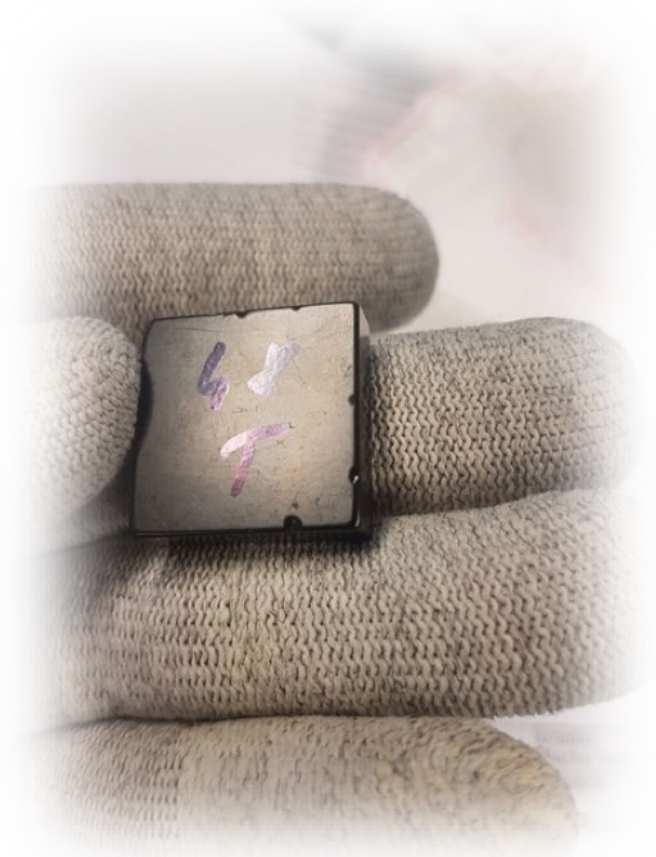

MAGNETICS 2020

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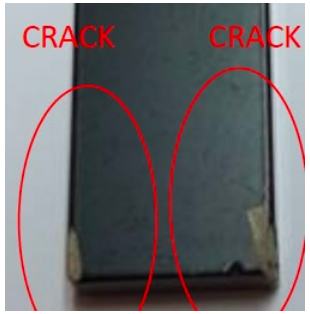
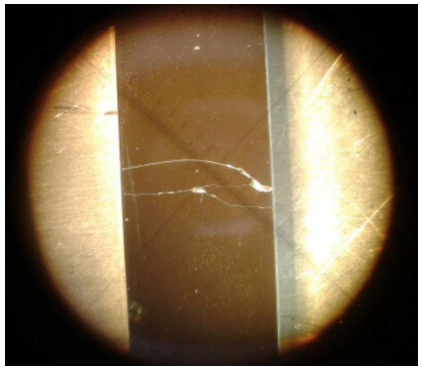
# CRACKS CAUSE COSTS!

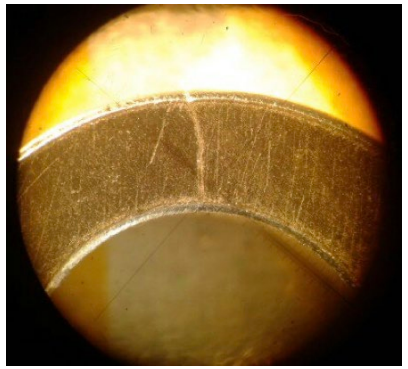
- Magnets with cracks or defects on surface or inside inhomogeneities can break during magnetizing, processing, assembly or in operation.
- Crack induced failure inside the magnet system can be dangerous, e.g. high continuous torque motor
- It might be costly to replace the complete assembled magnet system, such as motor/rotor, sensor systems
- Detection of cracks during the production process can improves the yield and reduces the maintenance costs.

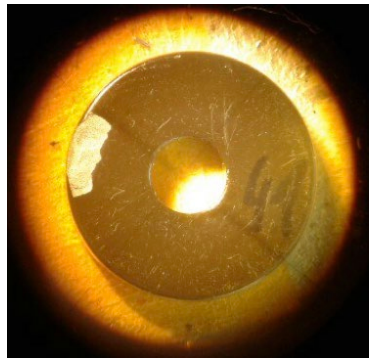
# HOW DO CRACKS LOOK LIKE?



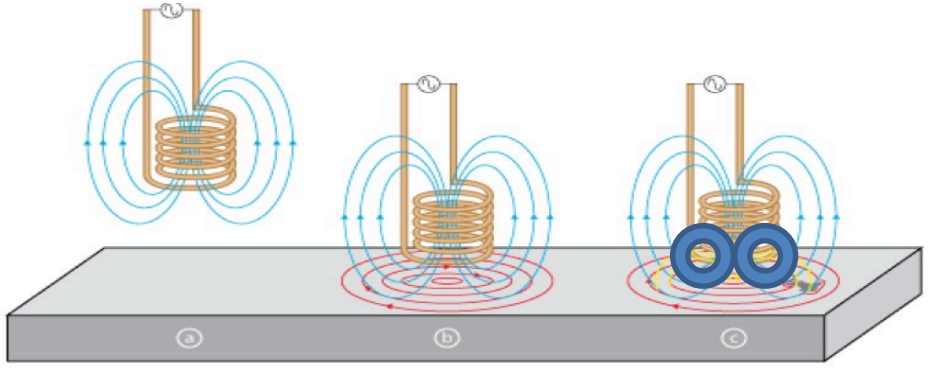







# EDDY CURRENT - CRACK DETECTION

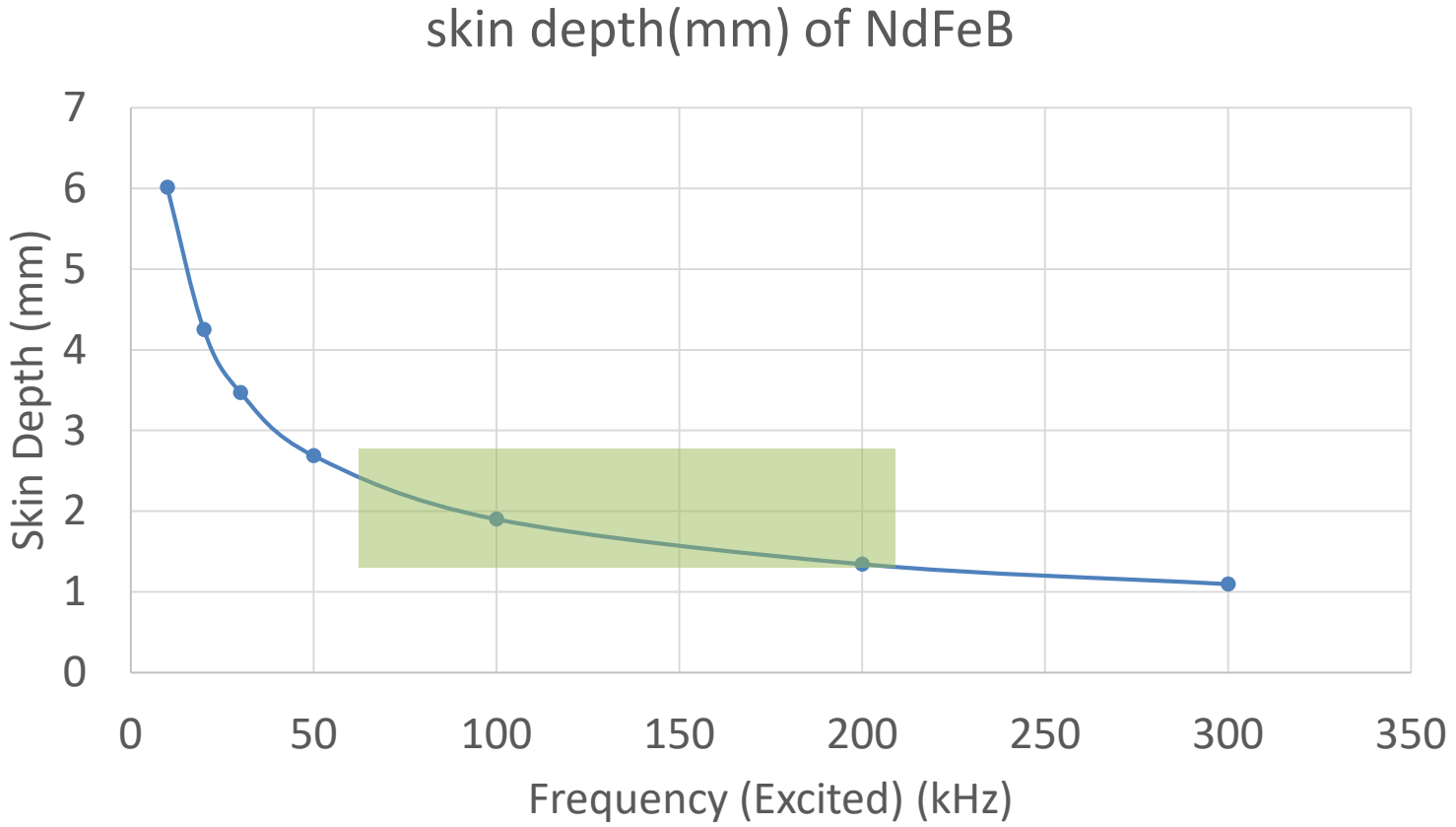
- Alternating current injected into a coil creates a magnetic field.
- When the coil is placed over a conductive part, opposed alternating currents are generated.
- Defects in the part disturb the path of the eddy currents.
- This disturbance can be measured by pickup coils, either through single coil or differential pick coils.



# INFLUENCING FACTORS

- Conductivity of the target plate
- Permeability of the target plate
- Temperature of the target plate
- Coil geometry
- Operating frequency (excitation)

# Probe Design and Simulation




$$J = J_S\, e^{-(1+j)d/\delta}$$

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

d: Distance relative to sample surface

$J_S$: Surface density

Properties if NdFeB:

Conductivity: 6.67E+05 S/m

Relative permeability: 1.05

Sensor Configurations: 20kHz to 220kHz in the steps of 10kHz

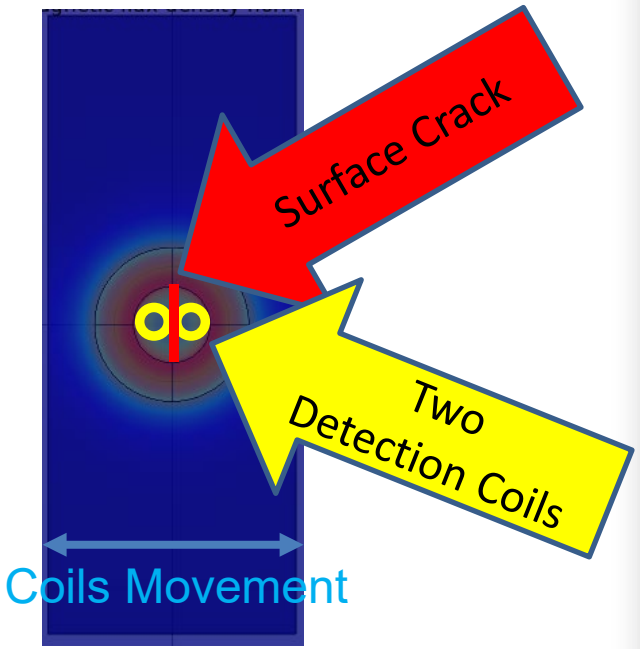
# Simulation Example

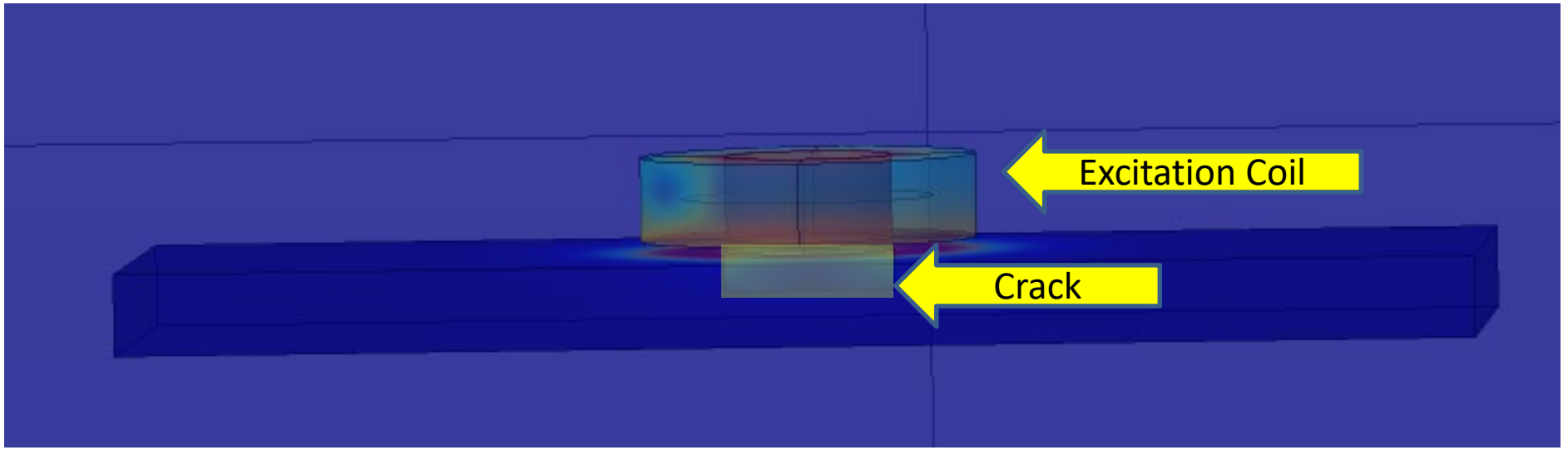
Sample Size: 100mm*40mm

Parameters

| Name | Expression | Value | Description |
|---|---|---|---|
| a2 | 6.15[mm] | 0.00615 m | Inner Radius of Coil |
| a1 | 12.4[mm] | 0.0124 m | Outer Radius of Coil |
| b | 6.15[mm] | 0.00615 m | Length of Coil |
| N | 3790 | 3790 | Number of Turns |
| l | 0.88[mm] | 8.8E-4 m | Lift-Off |
| Sigma_Test | 6.67e5[S/m] | 6.67E5 S/m | Conductivity of Test Spec... |
| Thickness_Test | 6[mm] | 0.006 m | Thickness of Test Specim... |
| Height_Defect | 3[mm] | 0.003 m | Height of Defect |
| Depth_Defect | 12.6[mm] | 0.0126 m | Depth of Defect |
| Width_Defect | 0.28[mm] | 2.8E-4 m | Width of Defect |
| Freq | 200000[Hz] | 2E5 Hz | Frequency |
| Position | 0[mm] | 0 m | Initial Position of Coil |

Top View




Side View

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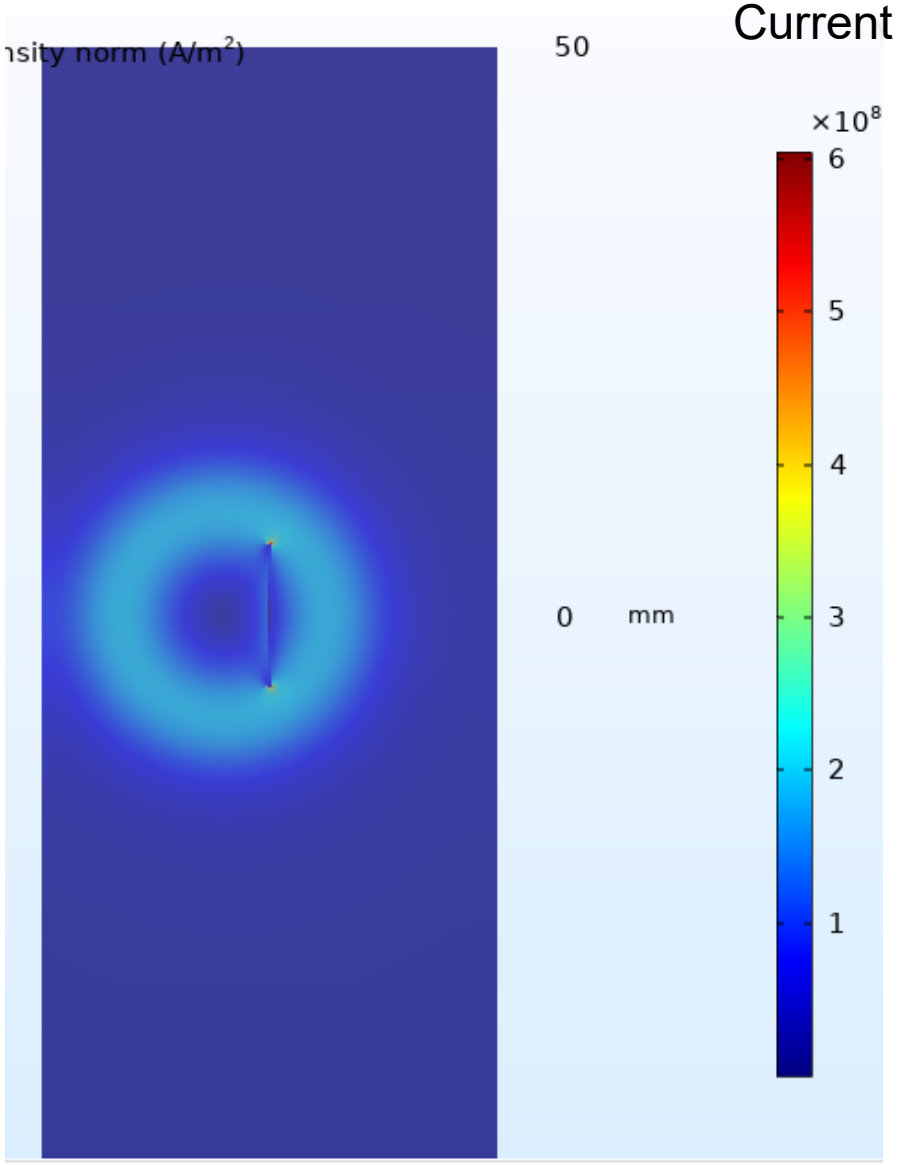
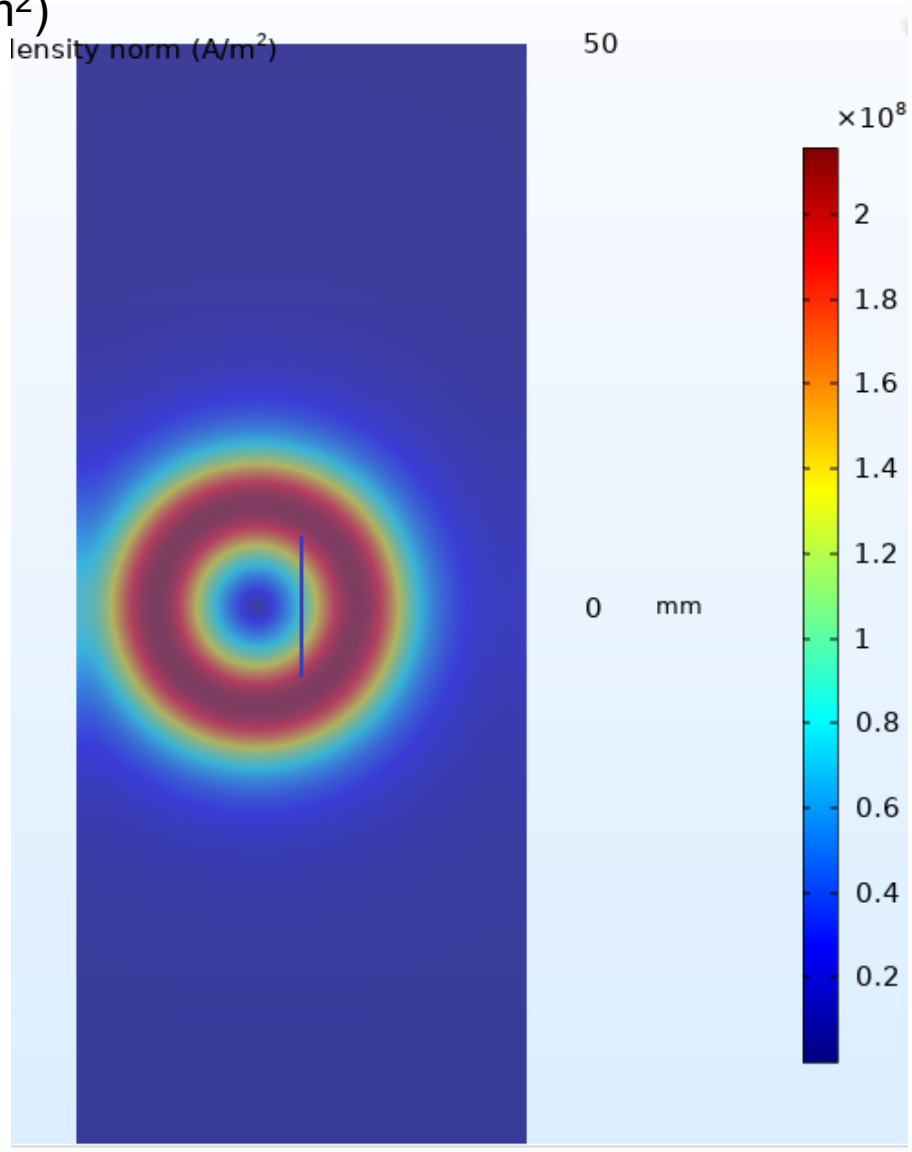
# Current Density Distribution

Position: -4mm

Current Density ($A/m^2$)




Crack



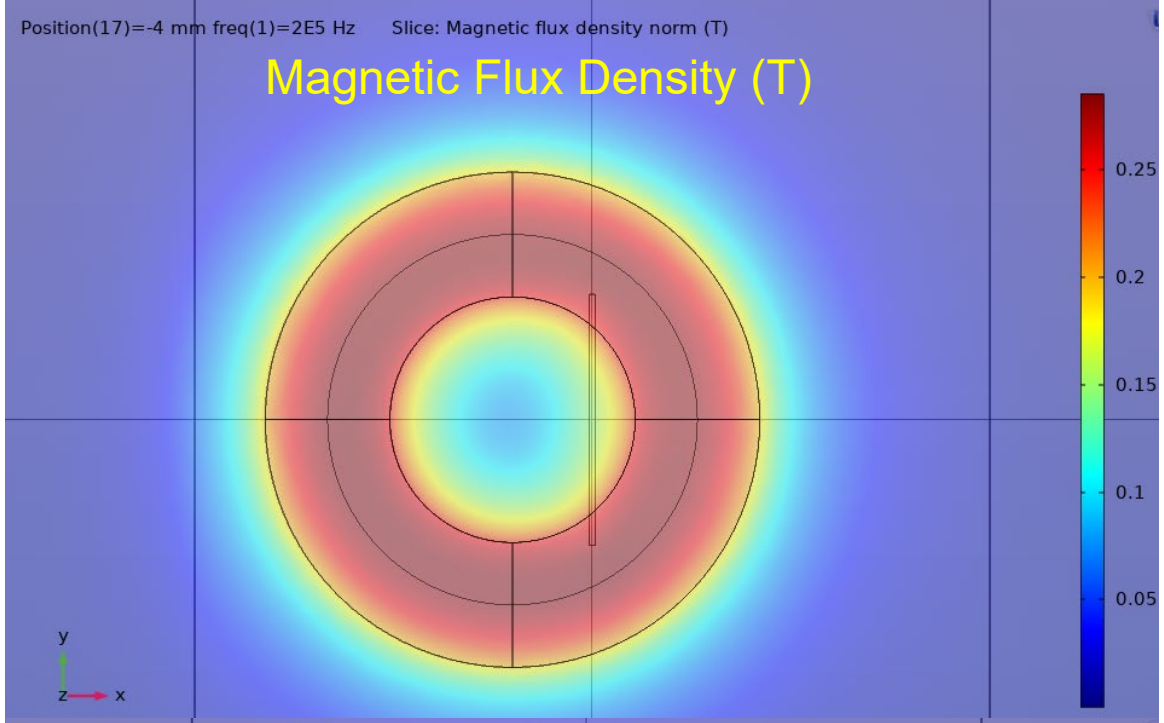

No Crack

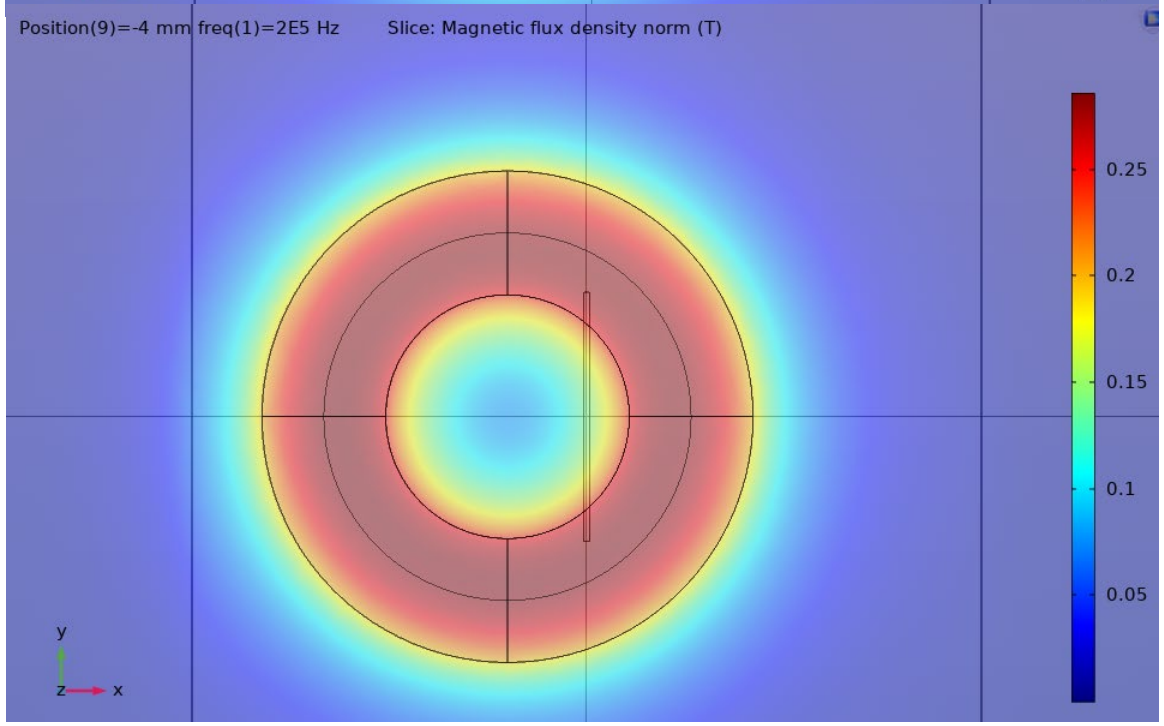
# Magnetic Flux Density on sample surface

Crack

Position: -4mm

No Crack

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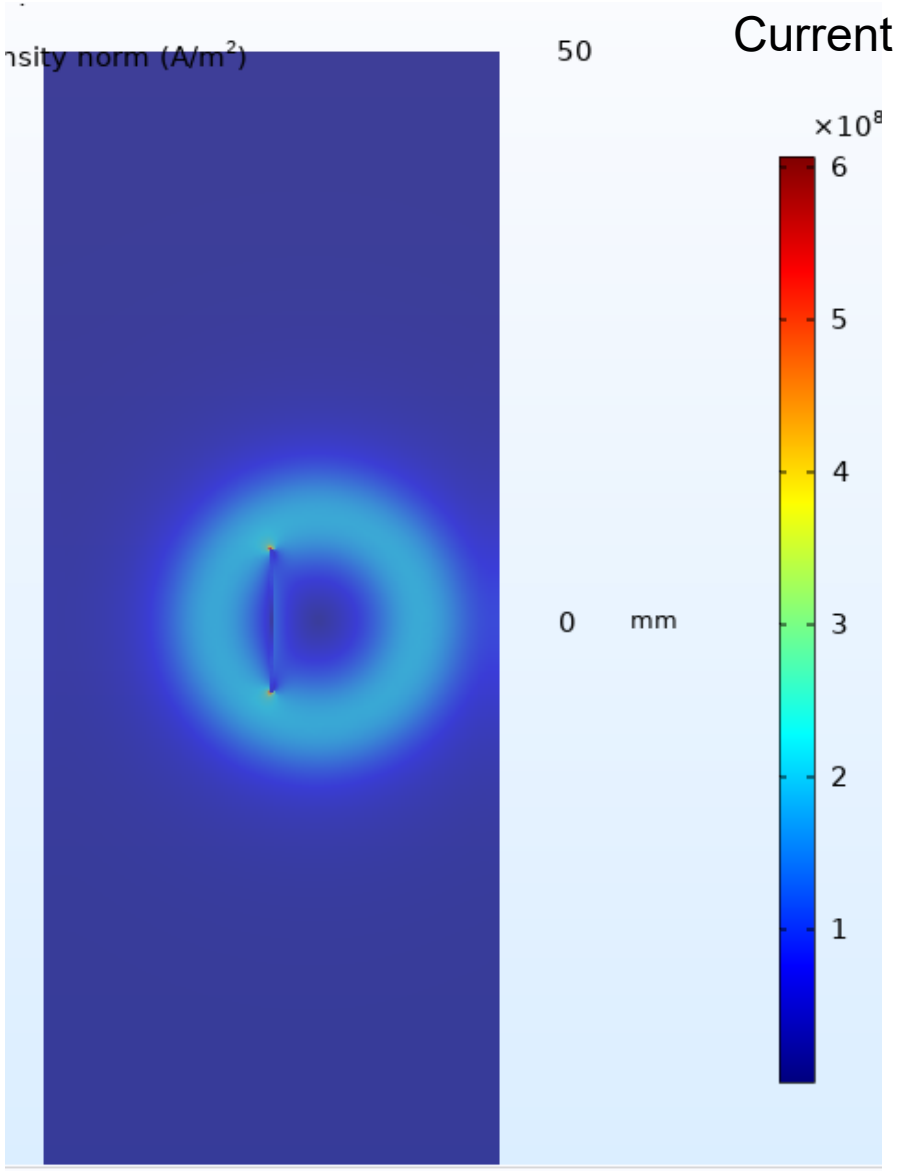
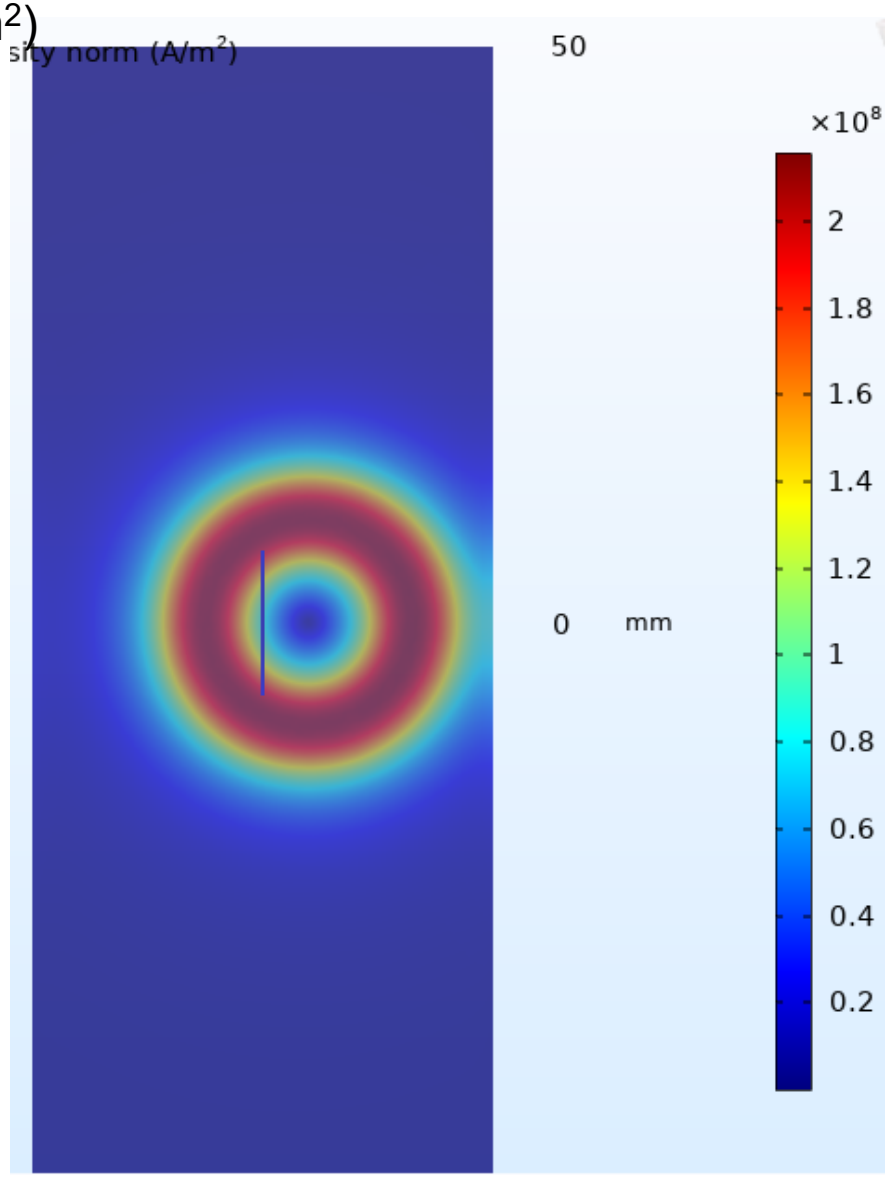
# Current Density Distribution

Position: 4mm




Crack

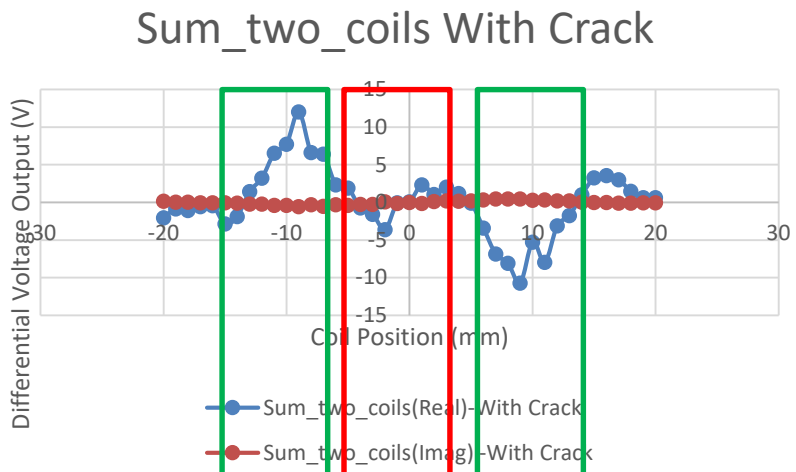



No Crack

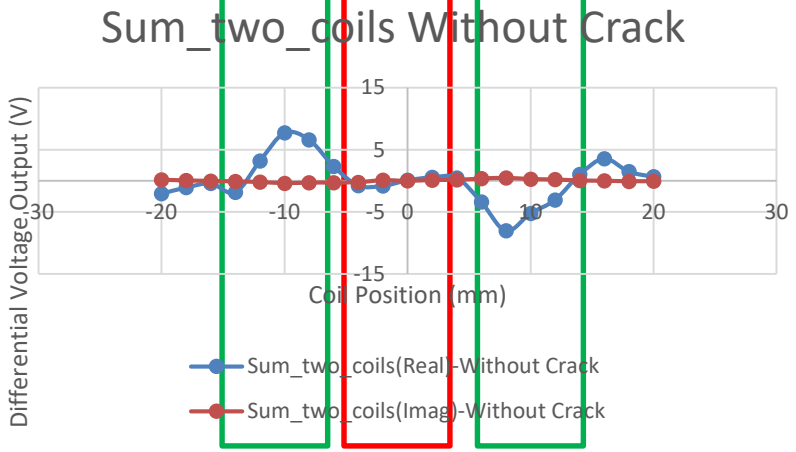
# Crack & No Crack

$$V = -\frac{d\varphi}{dt} = -\frac{d(N \cdot \vec{B} \cdot \vec{S})}{dt} = -N \cdot f \cdot \vec{B} \cdot \vec{S}$$

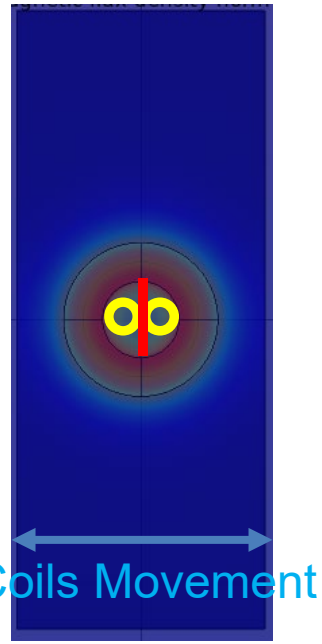
**Crack Influences**



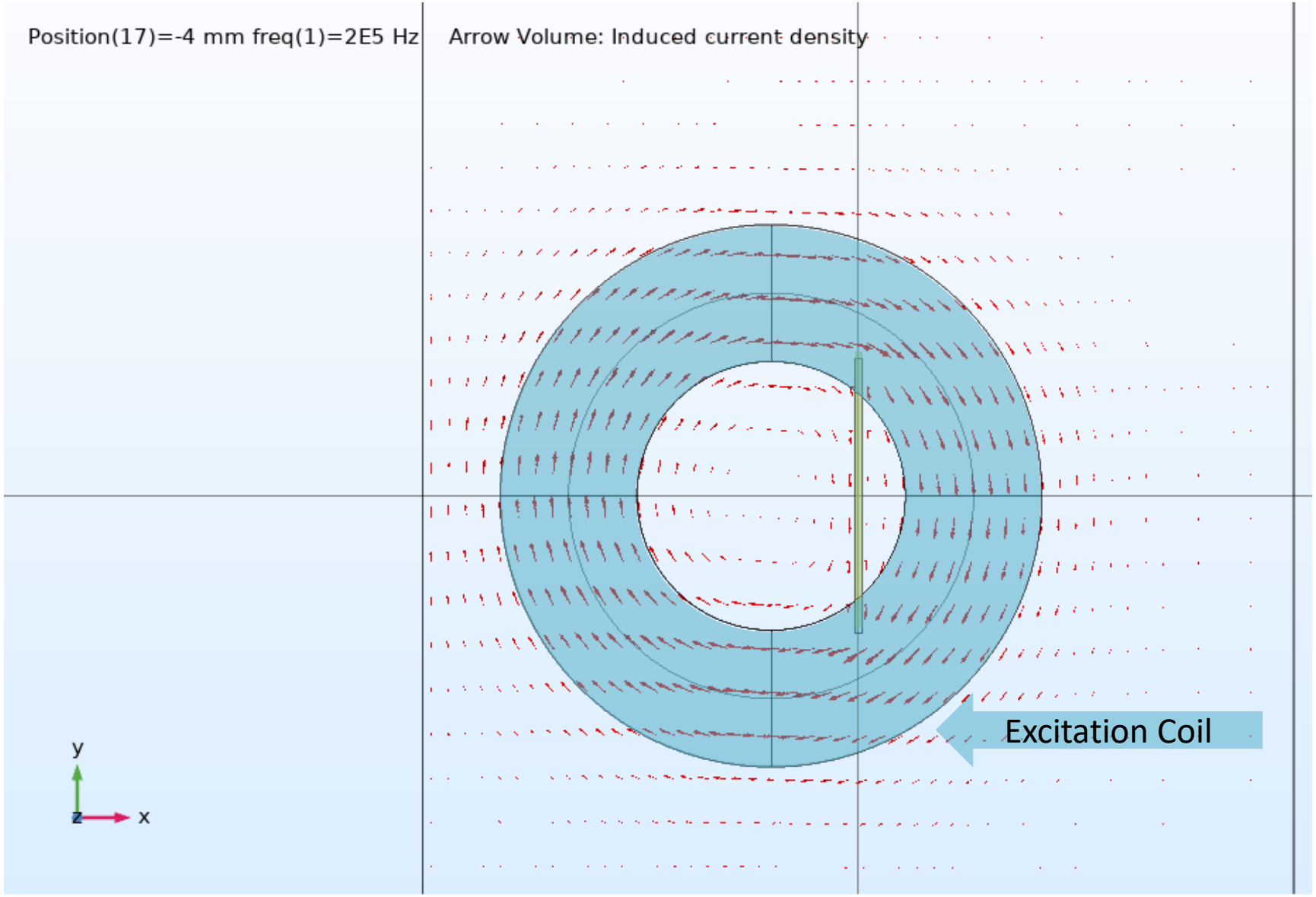

**Sample Edge Influences**



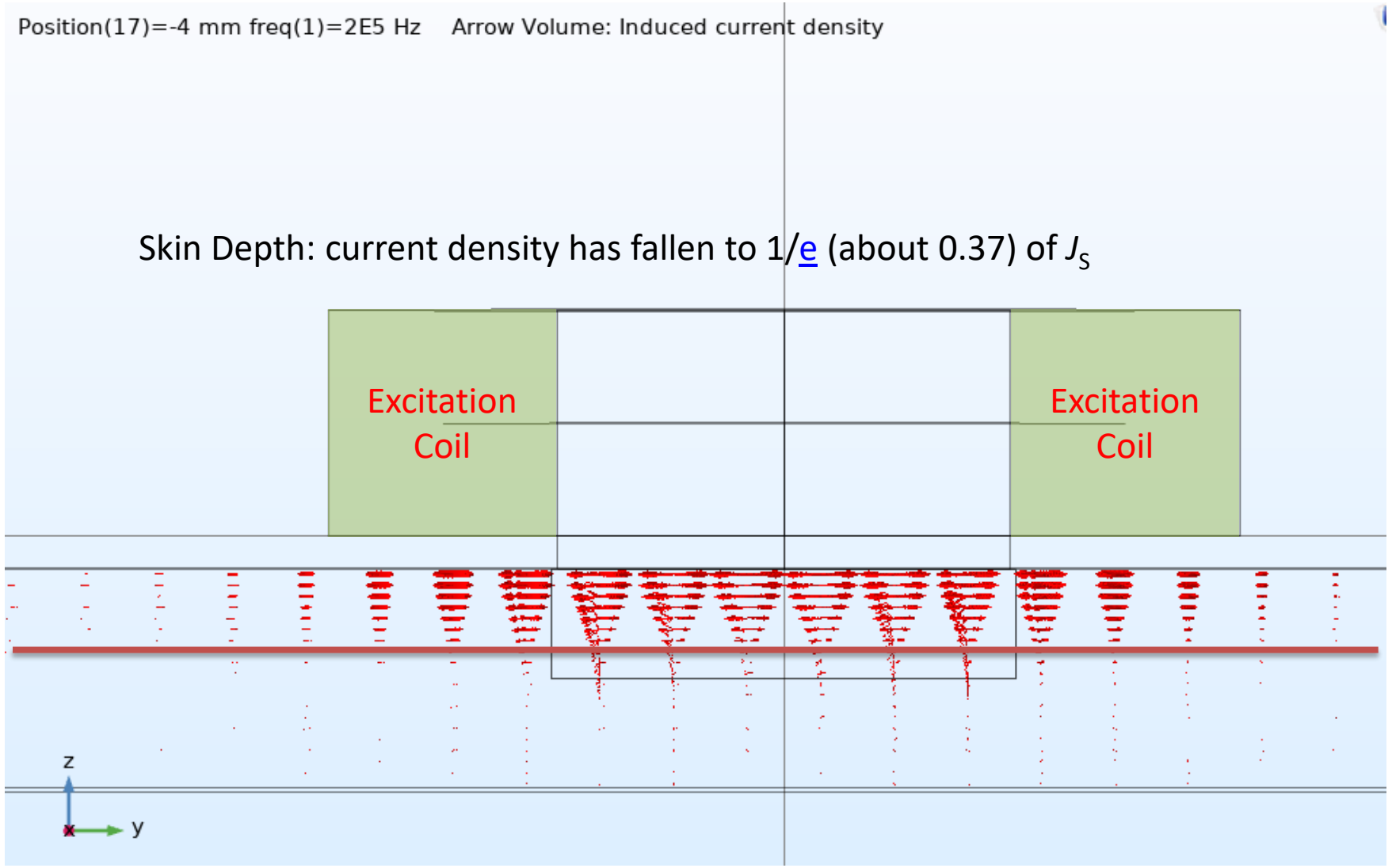

Sample Size
100mm*40mm



# Current Density Distribution (XY)

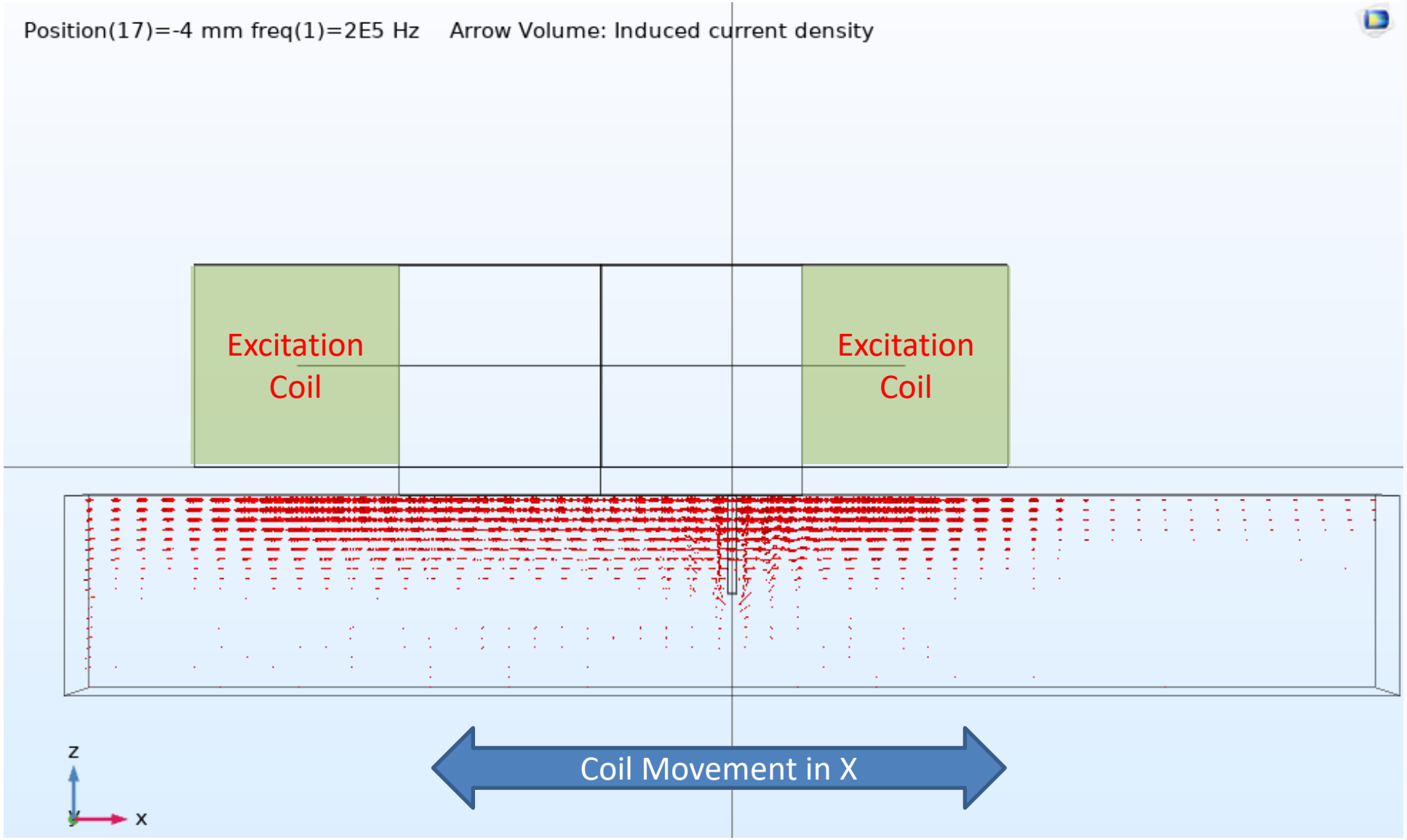


# Current Density Distribution (YZ)

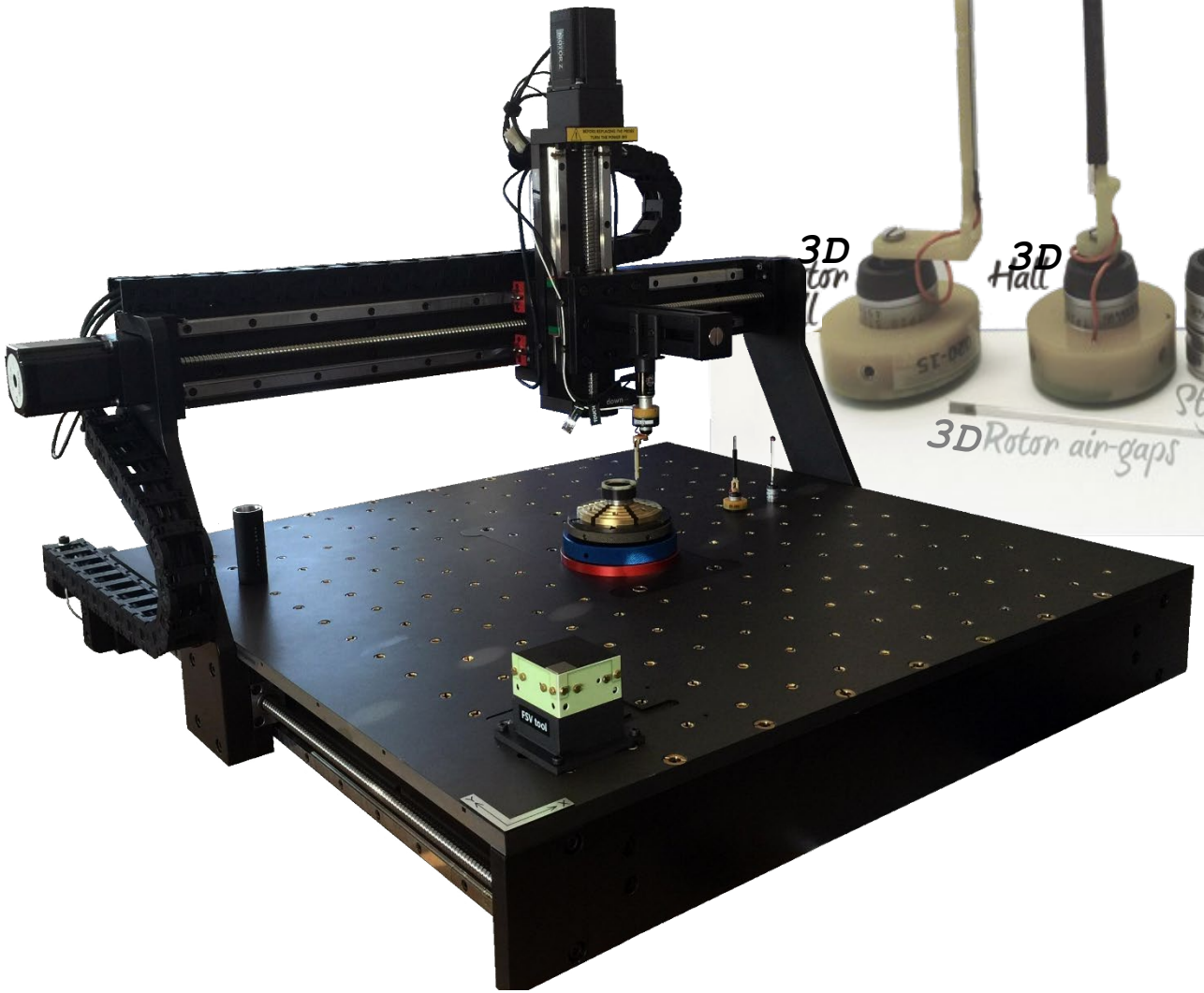


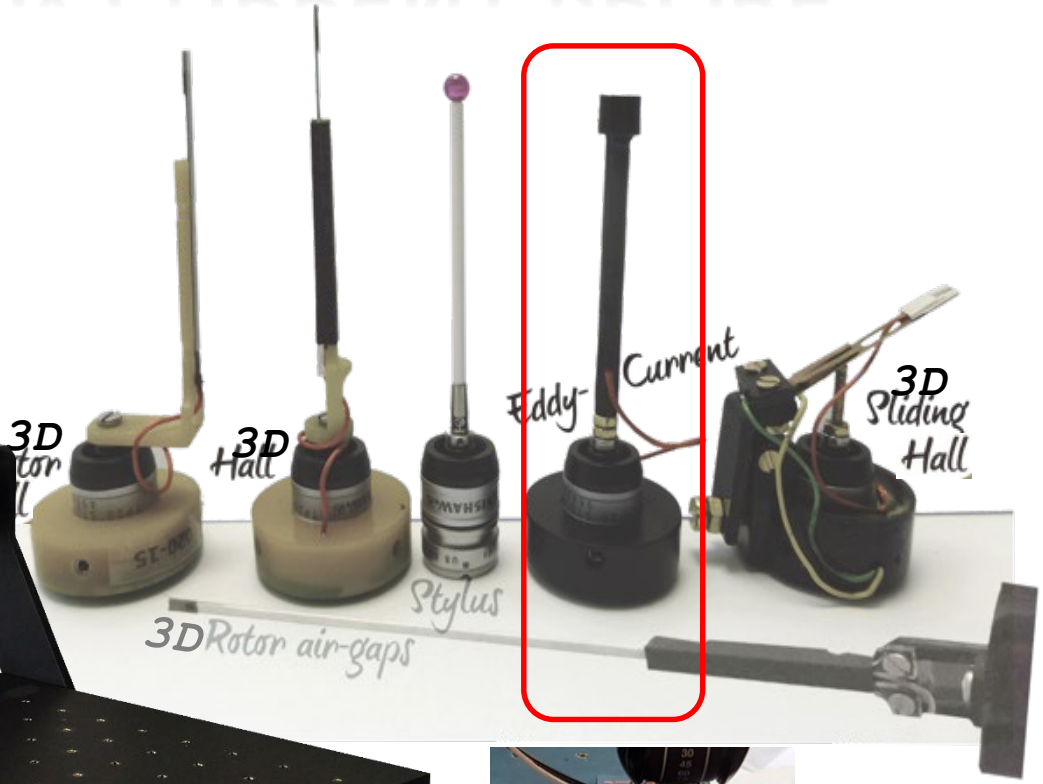

Skin Depth ~ 2mm (Total Sample Thickness 6mm)

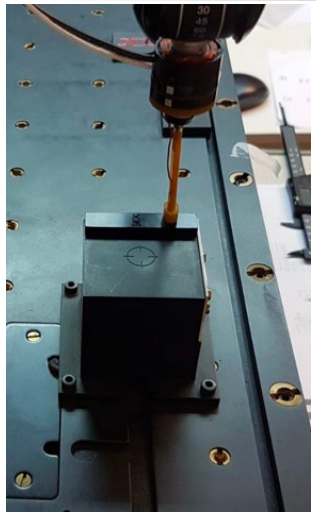
# Current Density Distribution (XZ)



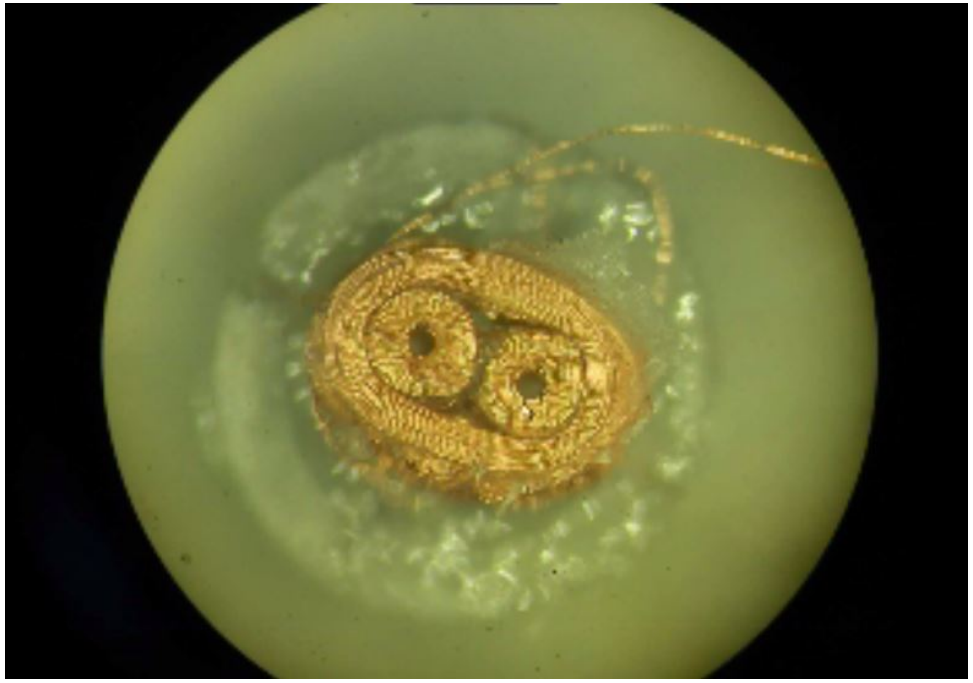
# MAPPER + EDDY-CURRENT PROBE

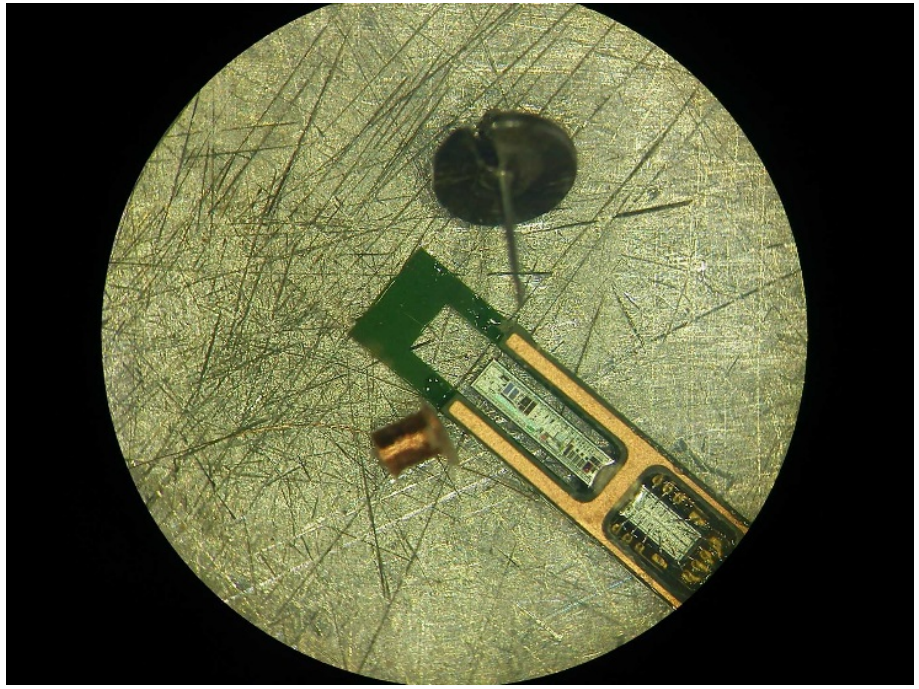


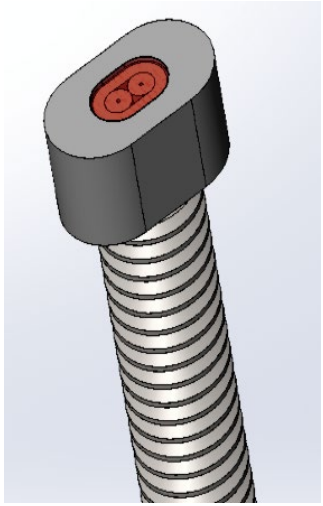


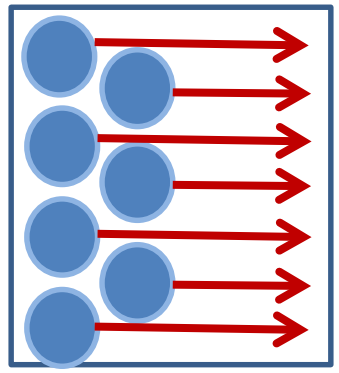



# SENIS EDDY-CURRENT PROBES

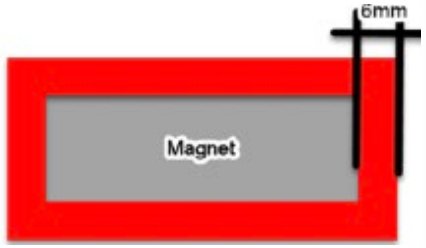




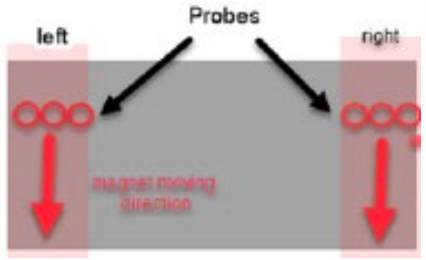


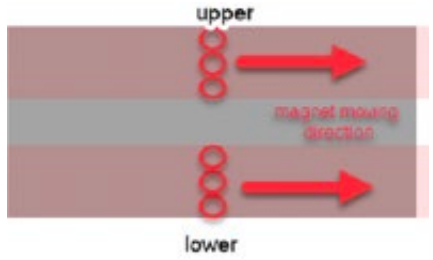


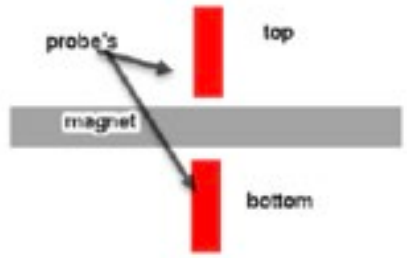
# NEW PROJECT REQUIREMENTS




- Non-magnetised and epoxy  coated magnet blanks of different sizes need to be separated from each other  and put on the linear transport system
- Only the edge part of magnet need to be measured (6mm area on all four edges from both sides of the magnet blanks, i.e. length and width)
- The magnet thickness will be measured to adjust the distance (air-gap) between magnets and eddy current probe arrays
- An operator interface software for entering the magnet and test data, such as Article, Date, Op. Name, Lot number…
- GOOD / BAD decision will be made based on a SENIS proprietary algorithm for crack detection
- A calibration software using 5 golden parts to periodical compensate offset
- 100% in-line production test – test duration: <7sec per magnet

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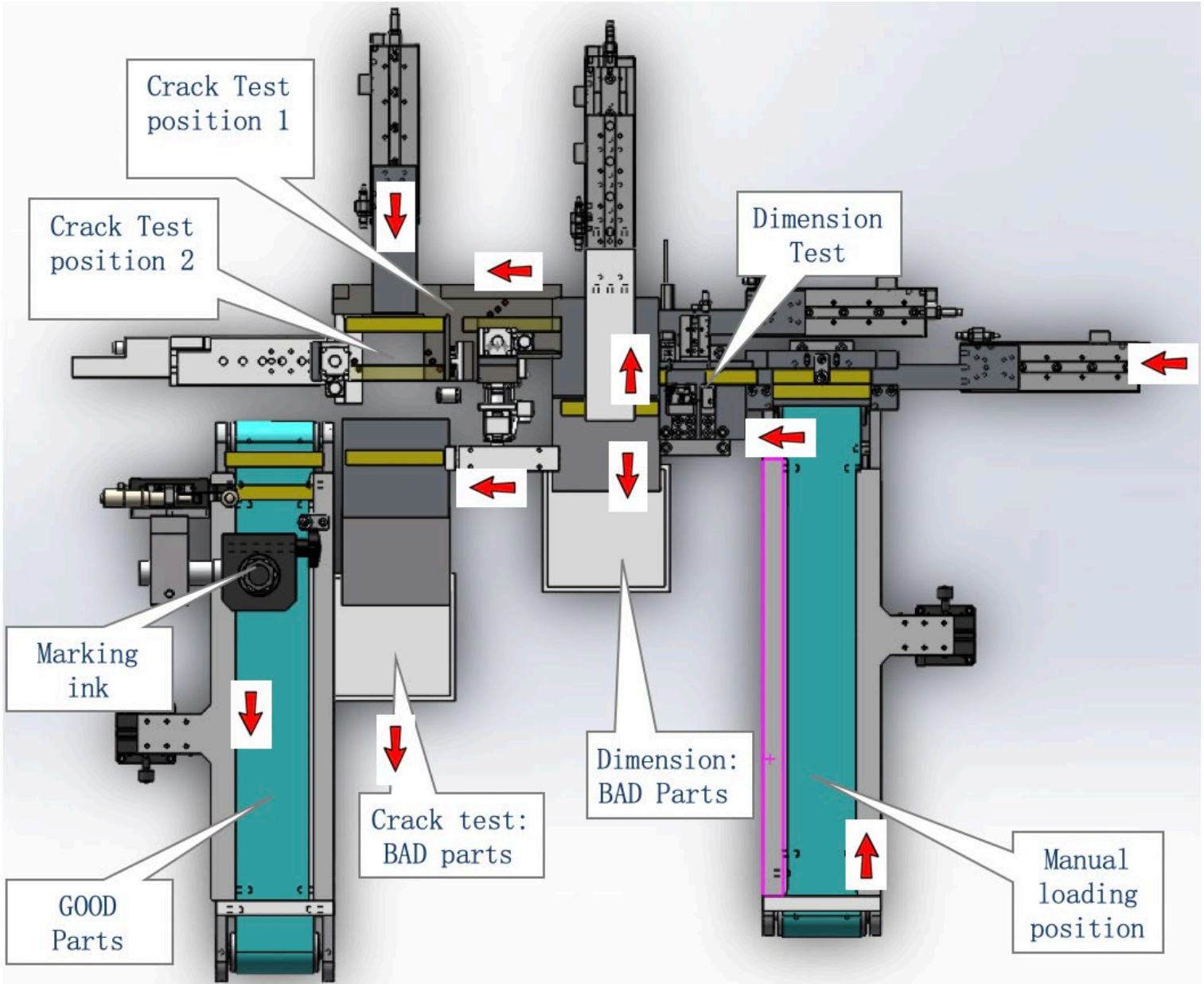
# PARTS FLOW

optical position sensors detect the magnet on the transportation system with encoders

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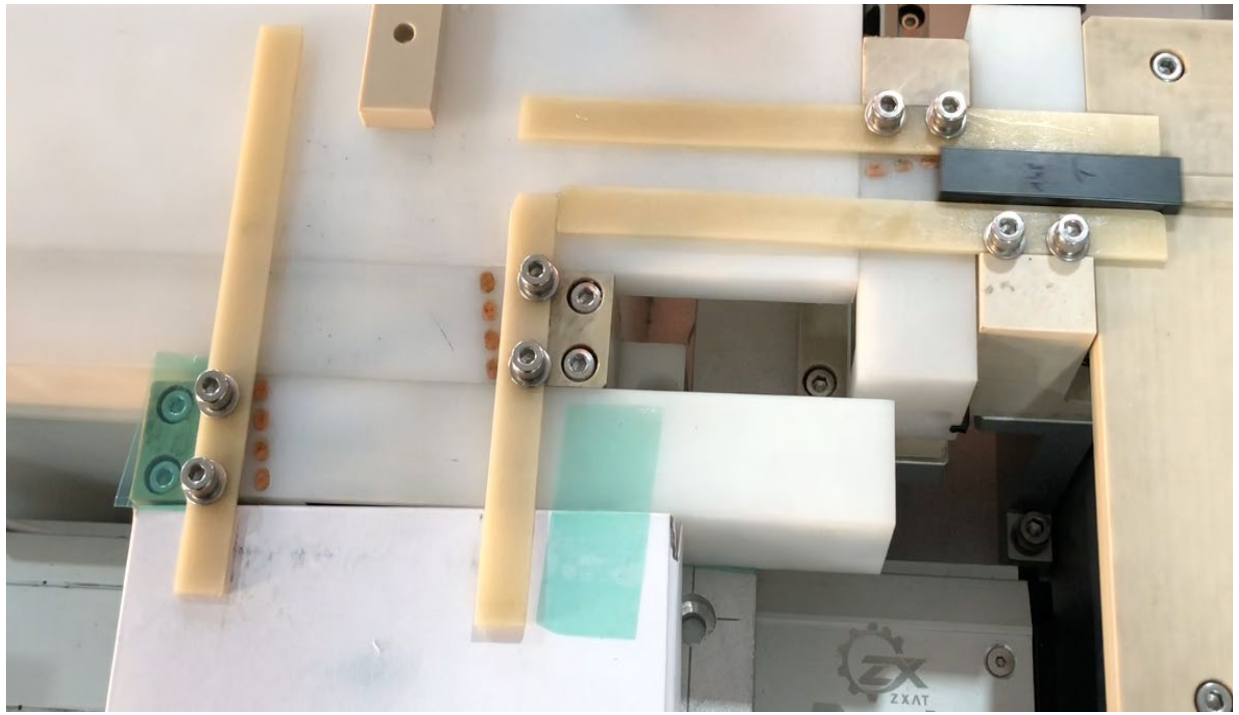
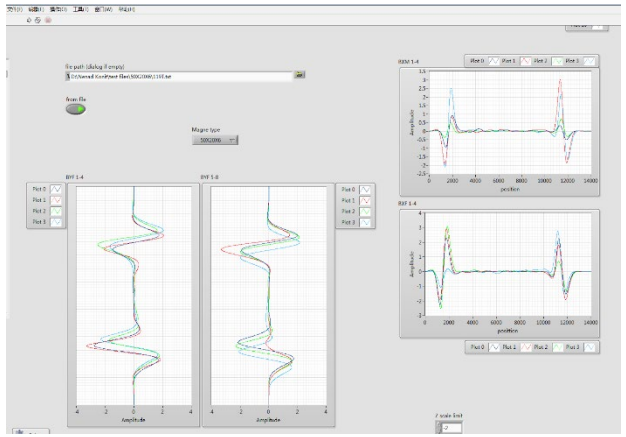
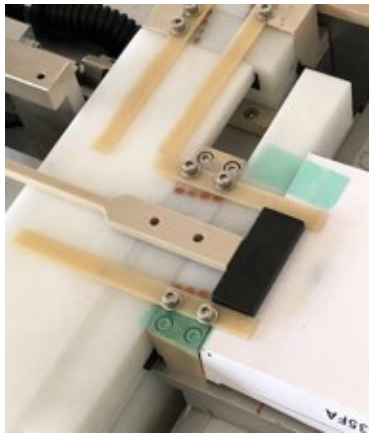
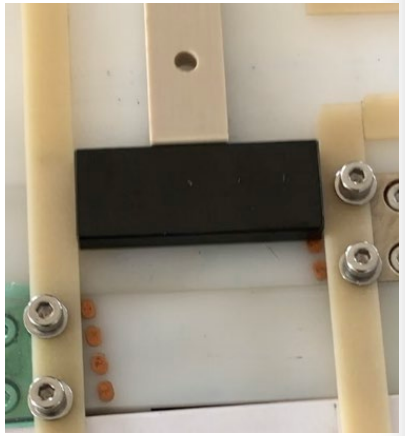
# IMPLEMENTATION

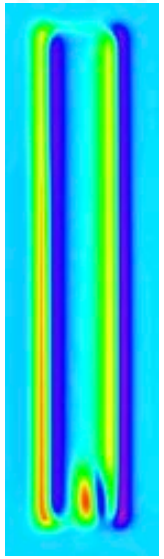


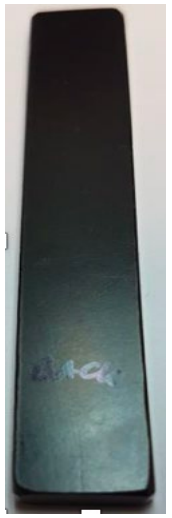


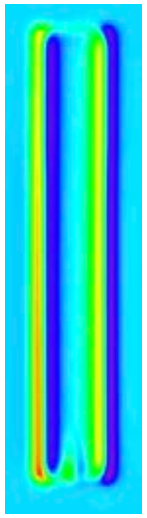




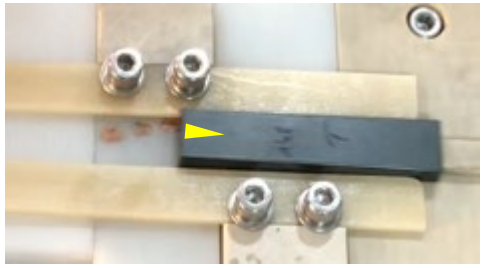
# RESULT – CRACK DETECTION

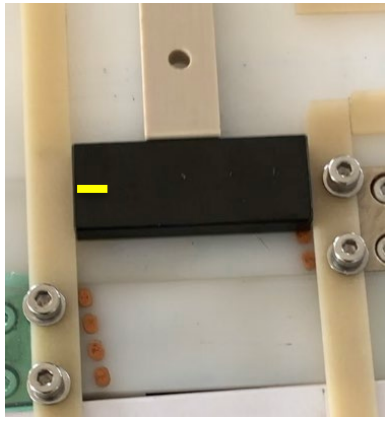


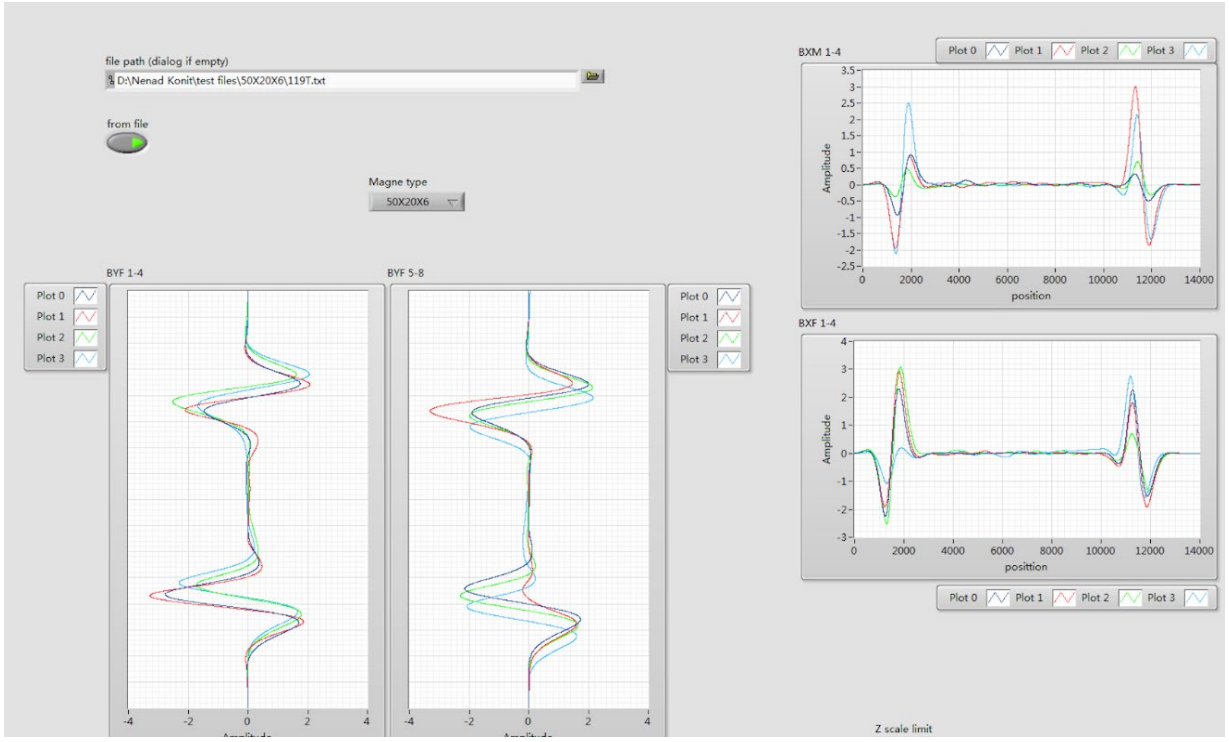




- The contrast reflects the voltage difference between two coils.
- Compared with cracks, magnet edges shows higher color contrast.







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