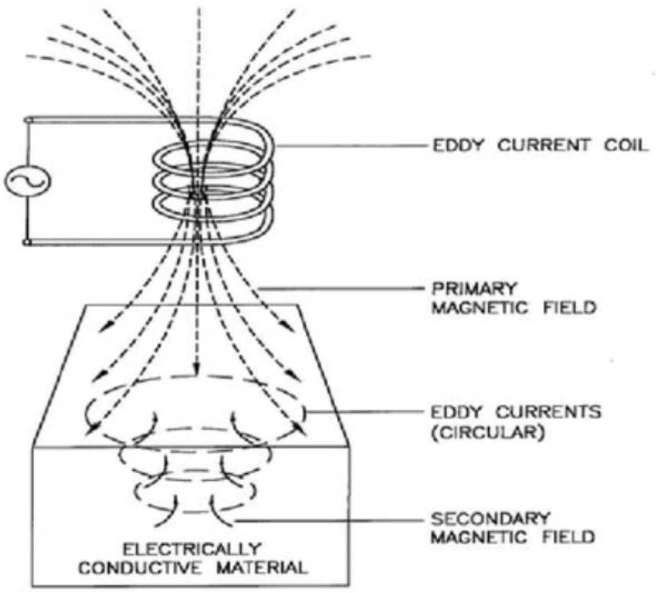
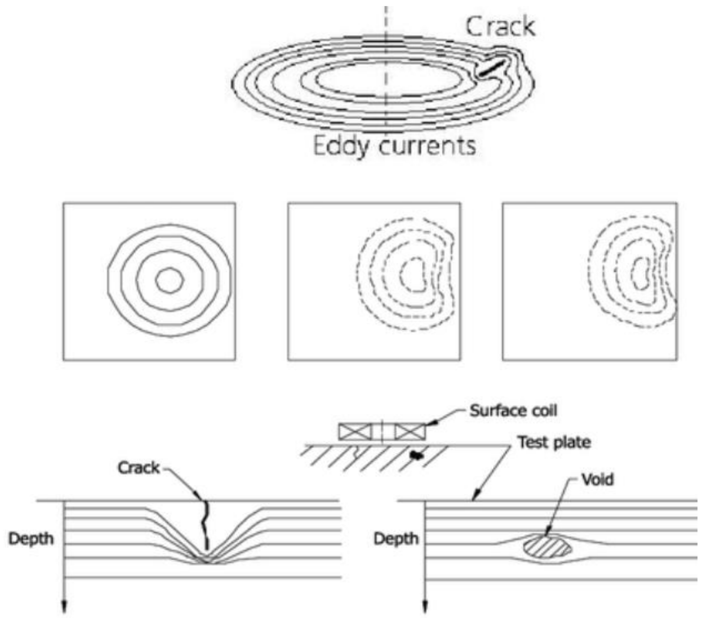
Eddy Current Testing for Crack Detection





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Project Overview:

In this project, I have used MatLab to simulate the Eddy Current Testing (ECT) method to detect surface cracks in conductive materials. The project involved modeling the electromagnetic field, introducing a crack in the material, and analyzing the change in impedance to detect surface anomalies. By visualizing the interaction between eddy currents and the crack, I demonstrated how this NDT method can be applied to real-world situations.

Introduction

Eddy Current Testing (ECT) is a non-destructive testing (NDT) technique used to detect cracks, corrosion, and other defects in conductive materials. It works by inducing an alternating current into the material using a coil. This creates circulating currents, called **eddy currents**, within the material. When the material has a crack or flaw, it disrupts the flow of these currents, causing a change in the impedance (resistance) of the system.

By measuring the impedance changes, ECT can identify surface and near-surface defects, making it a valuable method for inspecting materials like metals without causing damage. It is commonly used in industries such as aerospace, automotive, and manufacturing for inspecting components like aircraft parts, pipes, and tanks.

This project simulates an **Eddy Current Testing system** using MatLab to detect cracks in conductive materials. The simulation focuses on:

1. Generating an eddy current in a material.
2. Introducing a surface crack.
3. Visualizing the interaction between the eddy current and the crack.
4. Analyzing the impedance change to detect the crack.

Technical parameters used in the Eddy Current simulation:

The tables below summarise the key parameters and values used in the simulation. The material properties, geometry, crack dimensions, and impedance changes are defined to model real-world NDT conditions.

Material Properties of Copper:

Parameter	Value	Description
Conductivity (sigma)	5.8e7 S/m	Electrical conductivity of copper
Permeability (mu)	4*π*1e-7 H/m	Permeability of free space (constant)
Frequency (f)	1e4 Hz	Frequency of alternating current applied
Angular frequency (omega)	2*pi*f	Angular frequency calculated from the applied frequency
Current amplitude (A)	1e-3 A	Amplitude of the alternating current

Geometry of Material (Cylinder):

Parameter	Value	Description
Material radius	1e-3 m	Radius of the material (1 mm)
Material length	0.1 m	Length of the material (10 cm)

Crack Dimensions:

Parameter	Value	Description
Crack length	5e-3 m	Length of the simulated crack (5 mm)
Crack depth	0.2e-3 m	Depth of the simulated crack (0.2 mm)

Eddy Current Model:

Parameter	Value	Description
Skin depth (penetration depth)	sqrt(2/(omega*mu*sigma))	Eddy current penetration depth into the material based on frequency and conductivity

Mesh Grid Dimensions:

Parameter	Value	Description
Grid size	100	Number of grid points in each dimension (X and Y axes)
X-axis range	[-radius, radius]	Range for X-axis value (-1 mm to 1 mm)
Y-axis range	[-radius, radius]	Range for Y-axis value (-1 mm to 1 mm)

Crack region modeling:

Parameter	Value	Description
Crack region (conductivity)	1 (simulated crack)	Area of the material where conductivity is reduced to simulate the crack

Impedance:

Parameter	Value	Description
Baseline impedance (no crack)	50 Ohms	Example impedance value when no crack is present
Impedance with crack	52 Ohms	Impedance with simulated crack (increase by 2 Ohms)

Results and Visualization

Below are the visualizations generated by the MATLAB simulation:

1. Surface with and without Crack (2D Visualization)

The first two plots show the surface of the material both with and without the crack. The crack is represented as a region where the material properties (conductivity) are altered. The **crack region** is highlighted in red in the first image. Picture of the surface cracks in the real world is also provided

Figure 1: *Surface with Crack (Material)*
The crack in the material is highlighted, showing the region where eddy currents are disrupted.

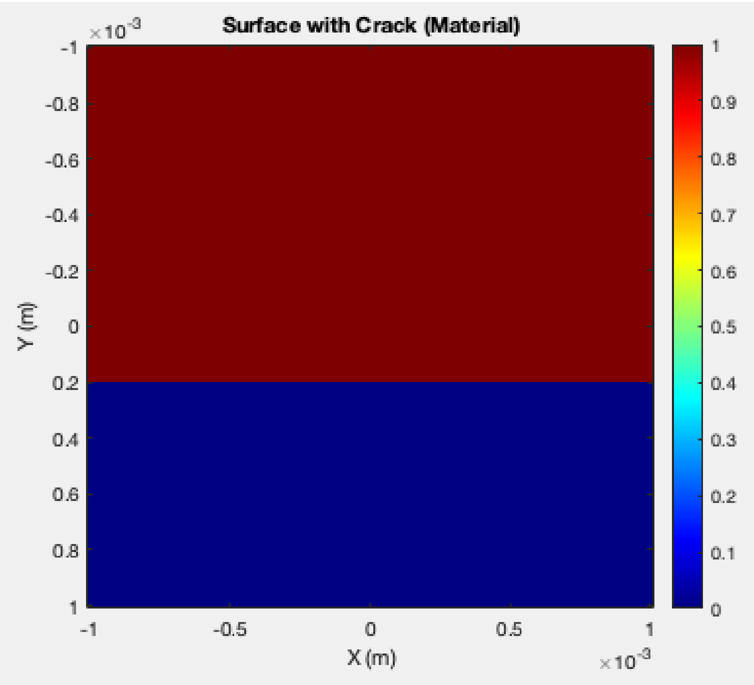


Figure 2: *Surface without Crack (Material)*
The second image represents the same material without a crack, showing a uniform conductivity region.

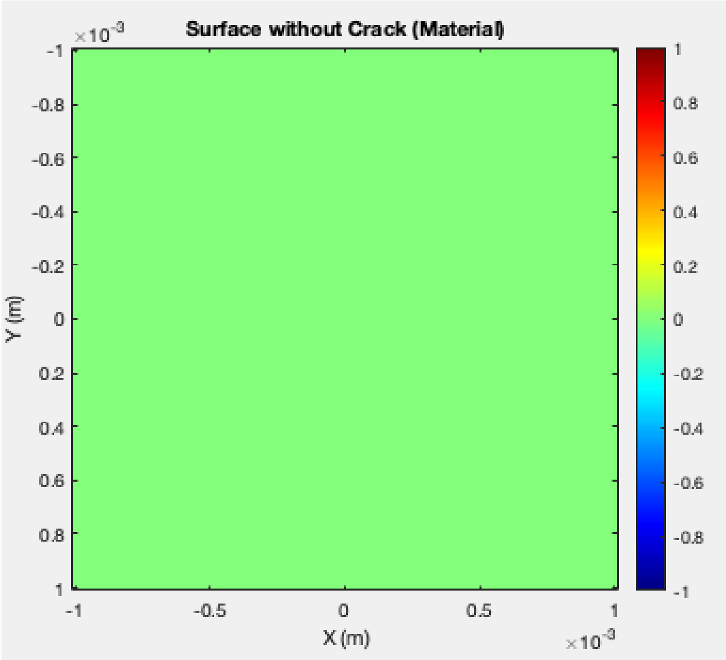
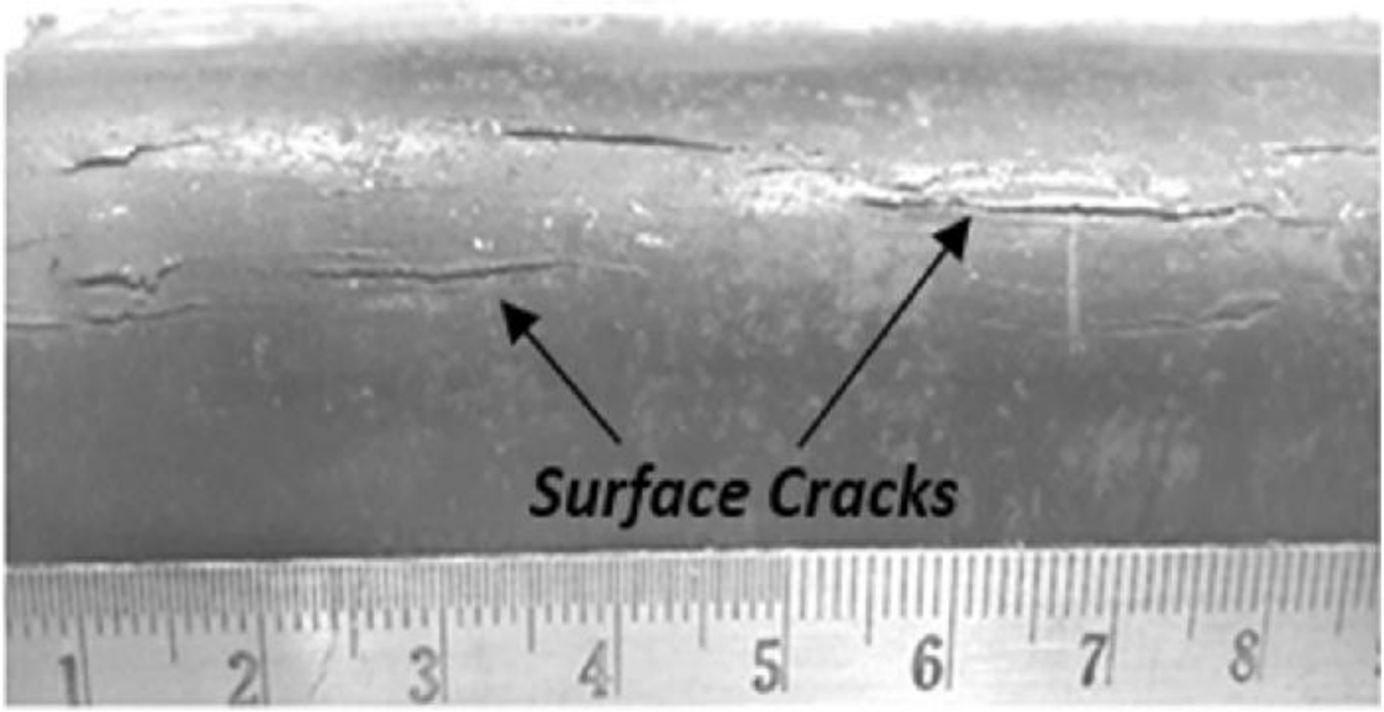


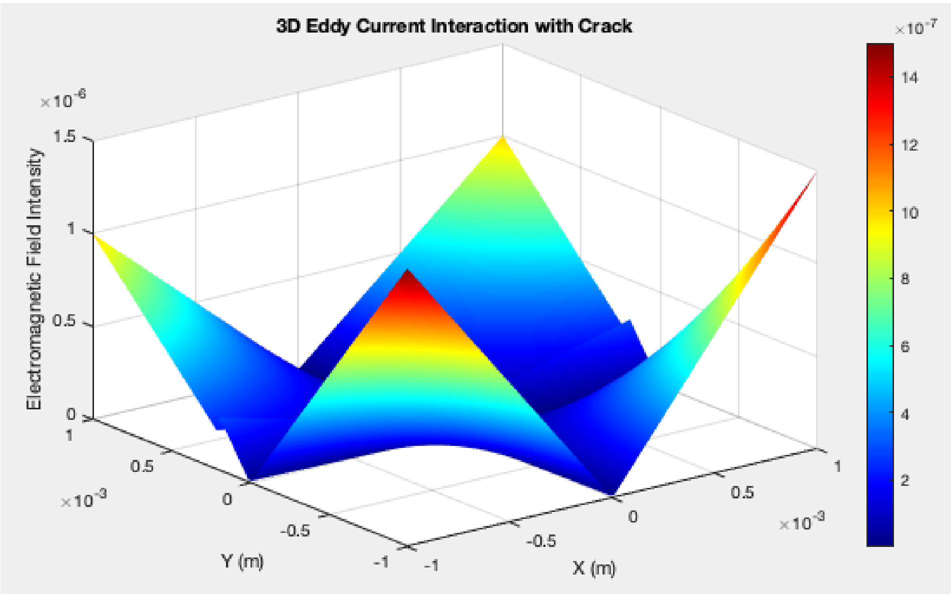
Figure 3: *Material with surface cracks in the real world.*

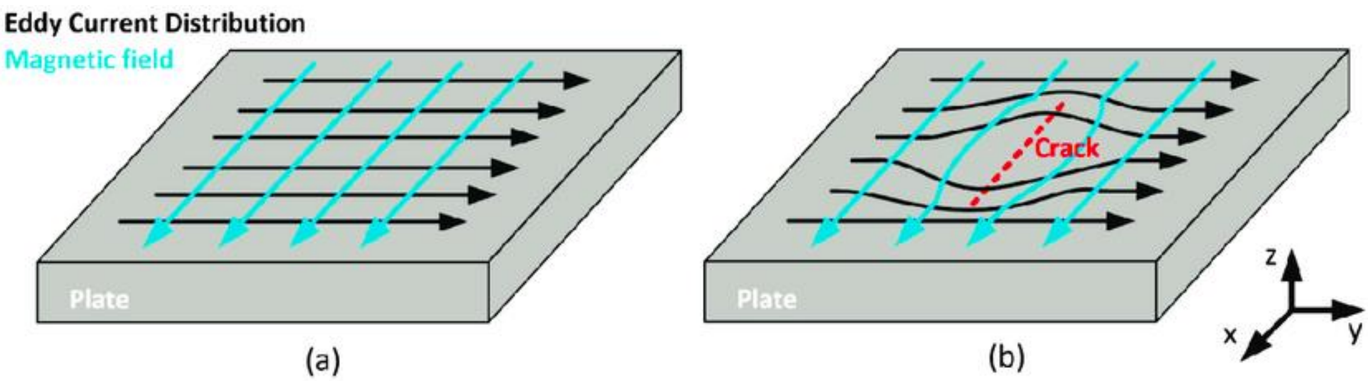


2. 3D Eddy Current Interaction with Crack

The third plot is a **3D surface plot** showing how the eddy current interacts with the crack. The color intensity represents the strength of the electromagnetic field, and you can see how the crack area disturbs the eddy current flow, increasing the field intensity around it. Additional illustration is provided for better understanding

Figure 4: *3D Eddy Current Interaction with Crack*
This plot demonstrates the change in electromagnetic field intensity when eddy currents interact with the crack.

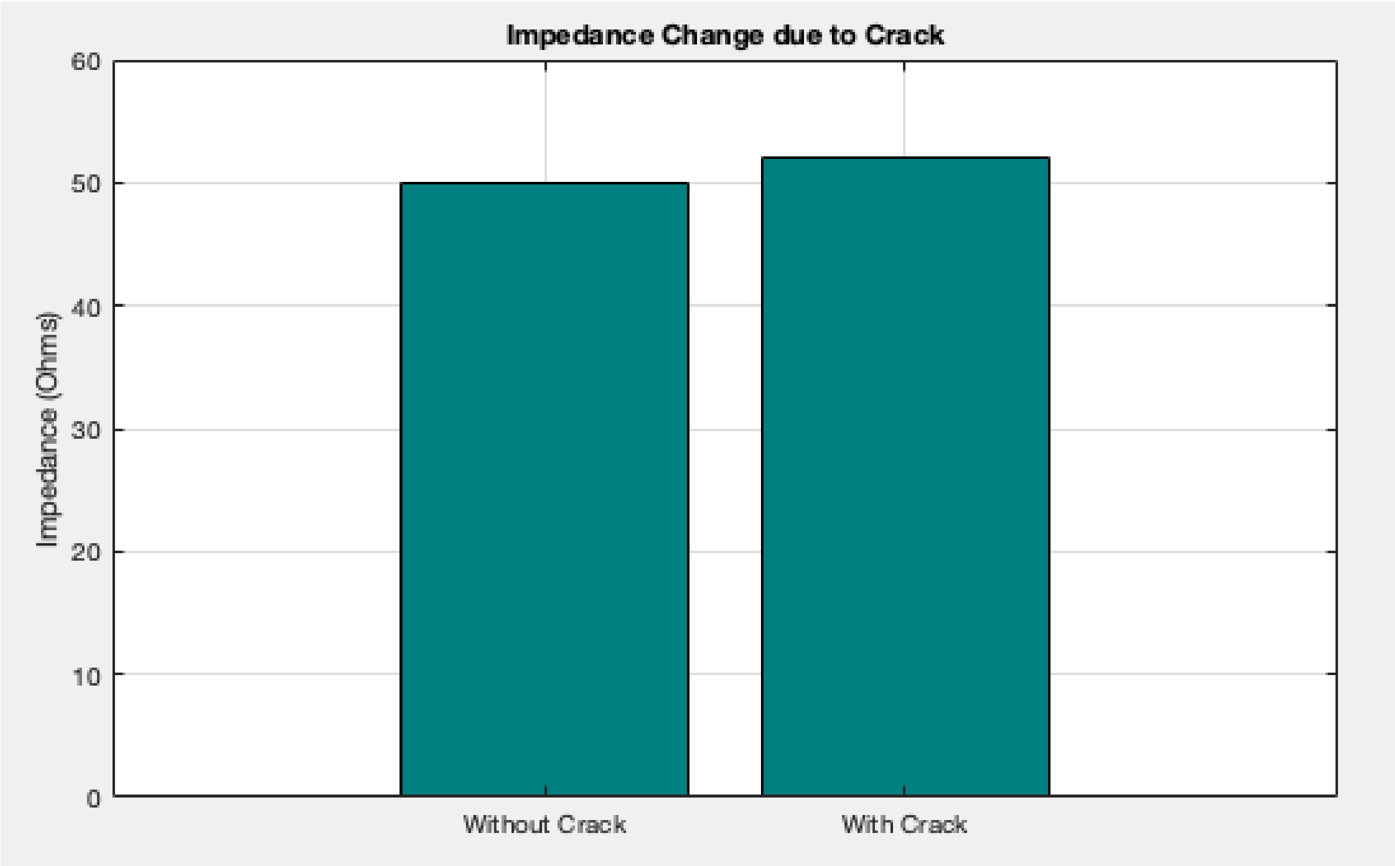




3. Impedance Change Bar Graph

The fourth plot presents a **bar graph** comparing the impedance of the material with and without the crack. As expected, the impedance increases when the crack is present, indicating a disruption in the eddy current flow.

Figure 5: *Impedance Change due to Crack*
The impedance is measured with and without a crack, showing a clear increase in impedance when the crack is present.



Conclusion

The results demonstrate how **Eddy Current Testing (ECT)** can effectively detect surface cracks in conductive materials. Through simulation, it was observed that the crack caused an **increase in impedance**, which is a common indicator of defect presence in NDT methods. The **3D visualization** of the eddy current interaction with the crack further reinforces the significance of this technique for detecting surface-level defects.

Key Findings:

- **Impedance without crack**: 50 Ohms
- **Impedance with crack**: 52 Ohms
- **Impedance change**: 2 Ohms (indicating the presence of a crack)

This project highlights how simulation-based methods can be used to visualize and understand the underlying principles of NDT techniques, especially **Eddy Current Testing**, and can serve as a useful tool for learning and experimentation in the field of material science and non-destructive testing.

Additional Notes

- **Tools Used**: MATLAB for simulation and visualization.
- **Challenges**: Understanding the theoretical concepts of electromagnetic field interactions with defects, and translating them into a computational model.