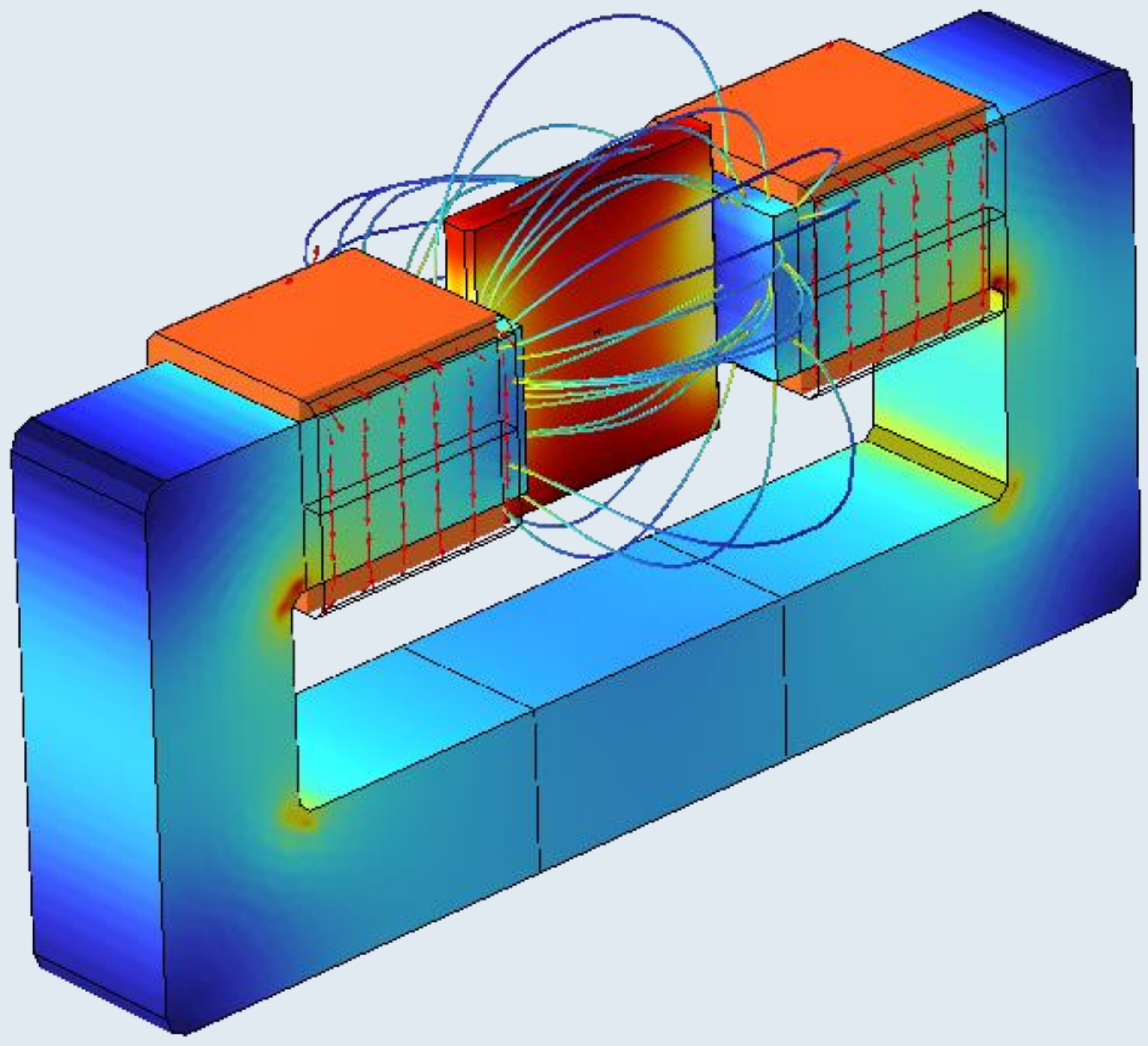

Eddy Current Thermography Study Using COMSOL Multiphysics®

An eddy current thermography (ECT) feasibility study was performed by developing a COMSOL Multiphysics® model for defect detection in a conductive sample using electromagnetic induction and thermal imaging. Different orientations for single and multiple cracks (connected as bridge or parallel) were simulated and an algorithm was developed to maximize the detection.

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Introduction

This paper explores the use of ECT as a non-destructive, contact-free method for detecting single or multiple connected defects in conductive materials. We simulate the interaction of eddy currents and thermal imaging to identify challenging cracks based on their orientation using COMSOL Multiphysics®. A nonlinear magnetic core with current carrying coils induces eddy currents in a test object, where electromagnetic losses are converted into heat.

The temperature gradients around defects are analyzed for detectability, with a focus on crack orientation relative to the applied magnetic field[1]. We find cracks aligned with the induced current flow are more detectable, while "bridge cracks" show distinct thermal signatures. The research highlights the importance of optimizing the gap between the core and test sample for effective detection, guiding the design and scanning protocols for practical ECT applications.

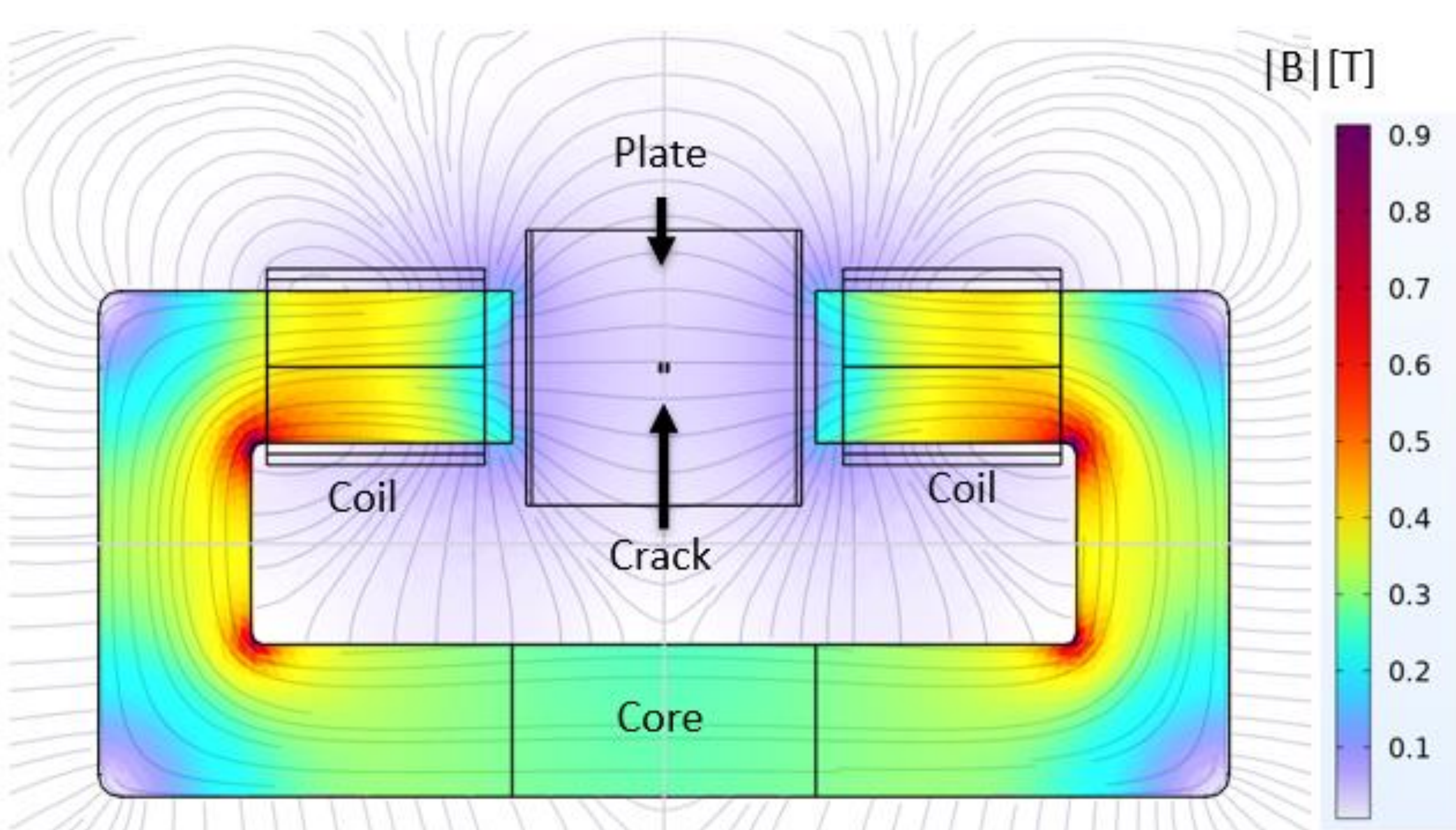

FIGURE 1. ECT setup with two coils, core and sample with cracks. Streamlines indicate the magnetic flux density flux lines.

Methodology

A three-dimensional electro-thermal model is developed in COMSOL® using the AC/DC and Heat Transfer modules. A 20kHz square wave through the coil generates heat loss in the sample. For efficient modeling we used the Fourier Transformed frequency and amplitude for the first 10 components of the square wave[2] and performed a *Frequency Domain* study using *Magnetic Fields* physics. The total electromagnetic loss from these ten components is a heat source in the Heat Transfer physics, solved in the time domain and turned on/off at 8Hz frequency. We compare the temperature gradient near the crack vs the reference model (without crack) using pixel size discretized surface probes. We simulated multiple cases with half-moon cracks and bridge cracks for magnetic fields parallel and perpendicular to the crack. We analyzed the effect of the critical gap between the inductor and sample.

Results

We demonstrated that cracks are more detectable when crack orientation is parallel to the magnetic field than when perpendicular. The bridge crack creates less current distribution than an equally sized half-moon crack. Bridge cracks near the plate surface will show up as local hot spots in the temperature distribution but will appear with smaller phase delays. The gap between the core and the test sample is critical to designing the optimal system. Hence, either the test sample or core should be moved/rotated to fully scan the sample for cracks.

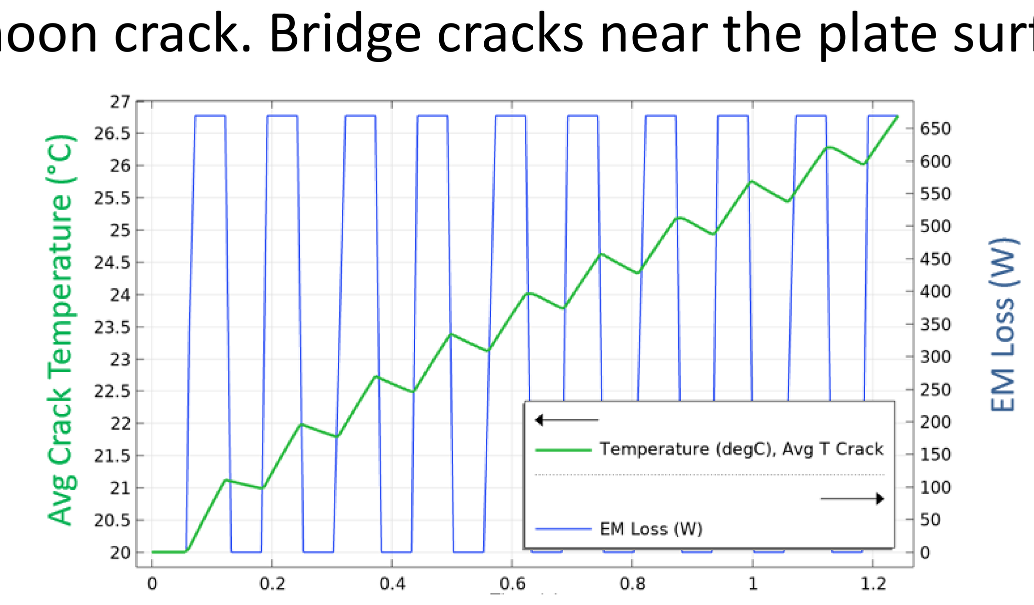

FIGURE 2. Applied power source is turned on/off at 8Hz (blue) and average temperature along crack surface vs time (green).

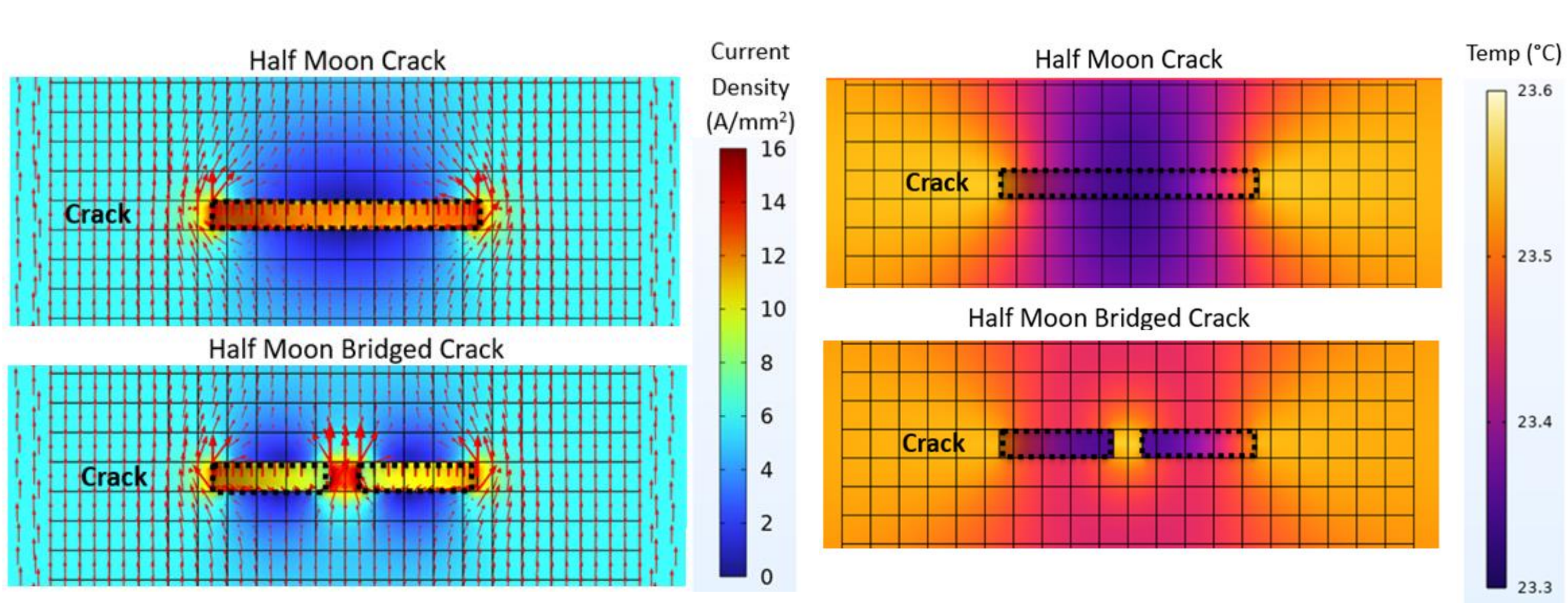

FIGURE 3. Left: Induced eddy current around a half-moon crack (top) and half-moon bridged crack (bottom). Right: Temperature on grid surface for half-moon crack (top) and half-moon bridged crack (bottom).

REFERENCES

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