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Parametric simulation of Induction Thermography for optimal cracks detection and characterization

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Parametric simulation of Induction Thermography for optimal cracks detection and characterization

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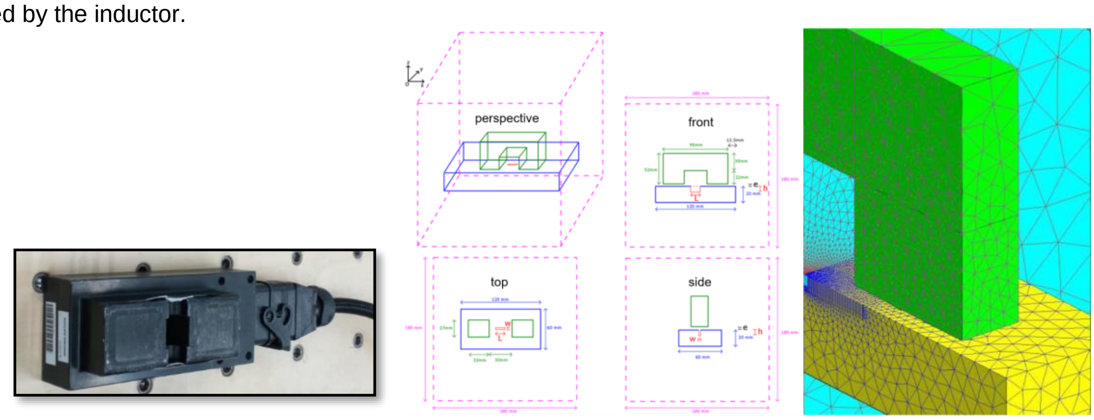
Abstract

In the last few years, induction thermography has been identified as a non-destructive testing method for detecting and characterizing surface cracks in metals. The sample to be inspected is heated with a short induced electrical current pulse, and the infrared camera records the temperature distribution and transient temporal behavior at the surface during and after the heating pulse. In this work, 3D Finite element simulations, performed with the software FLUX©, were carried out to investigate how the thermal contrast depends on parameters such as excitation frequency, pulse duration, material parameters, crack depth and length.

1. Simulation description

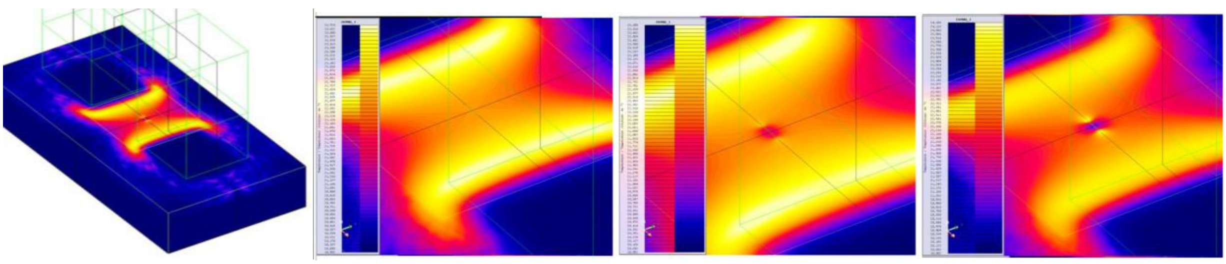
To compare the simulations with the experimental results, the modeled inductor is a realistic U-ferritic yoke surmounted by a copper winding. The two block samples involve two materials massively used in aeronautics: the first one is paramagnetic (nickel based superalloy INCONEL 718), the second one is ferromagnetic (low carbon steel 16CND13), which implies very different skin depths. The magnetic excitation frequency varies between 10 kHz and 600 kHz, and the step heating duration between 10 to 100 ms. Also, the length of the notch varies between 0.2 mm to 5 mm and the depth between 0.1 to 5 mm. A total of 360 configurations have been simulated.

The multiphysical simulations take into account the non-linearity of the sample magnetic permeabilities, which makes it possible to calculate finely the total impedance of the inductor at each magnetic frequency. For a current imposed excitation through the inductor, this allows to normalize the observations with respect to the active and reactive power consumed by the inductor.



(a) (b) (c)

Fig. 1. *(a)* ***:*** *Real inductor from Edevis©. (b) : schematic view of the problem : in green the ferrite of the inductor, in blue the plate sample, in red the defect (notch). (c) cross section of the mesh problem.*



(a) (b) (c) (d)

Fig. 2. *(a)* ***:*** *Simulation results : temperature distribution on the surface of Inconel sample at t=100 ms and f_{mag}=100 kHz. (b) : without defect. (c) defect height=0.5 mm and length=2.5 mm. (d) : defect height=2 mm and length=2.5 mm.*

2. Signal analysis

From the temperature distributions at each time step, the analysis of the differential thermal contrast between a defect situation and a defect-free situation, emphasizes the detectability of the defect as a function of the introduced parametric variations. The thermal-temporal extractions provided are used firstly to find the optimal excitation parameters (frequency of the induced currents, heating duration) which maximizes the thermal contrast, and on the other hand to define a methodology for sizing defects according to their lengths and depths. The optimum contrast calculated on the phase of the Fourier Transform (Pulse Phase Thermography PPT) provides credible but sensitive information related to the excitation parameters and the geometric parameters of the defects. In the final paper, two methods of analysis will be compared: the PPT and the wavelet pulsed phased thermography.

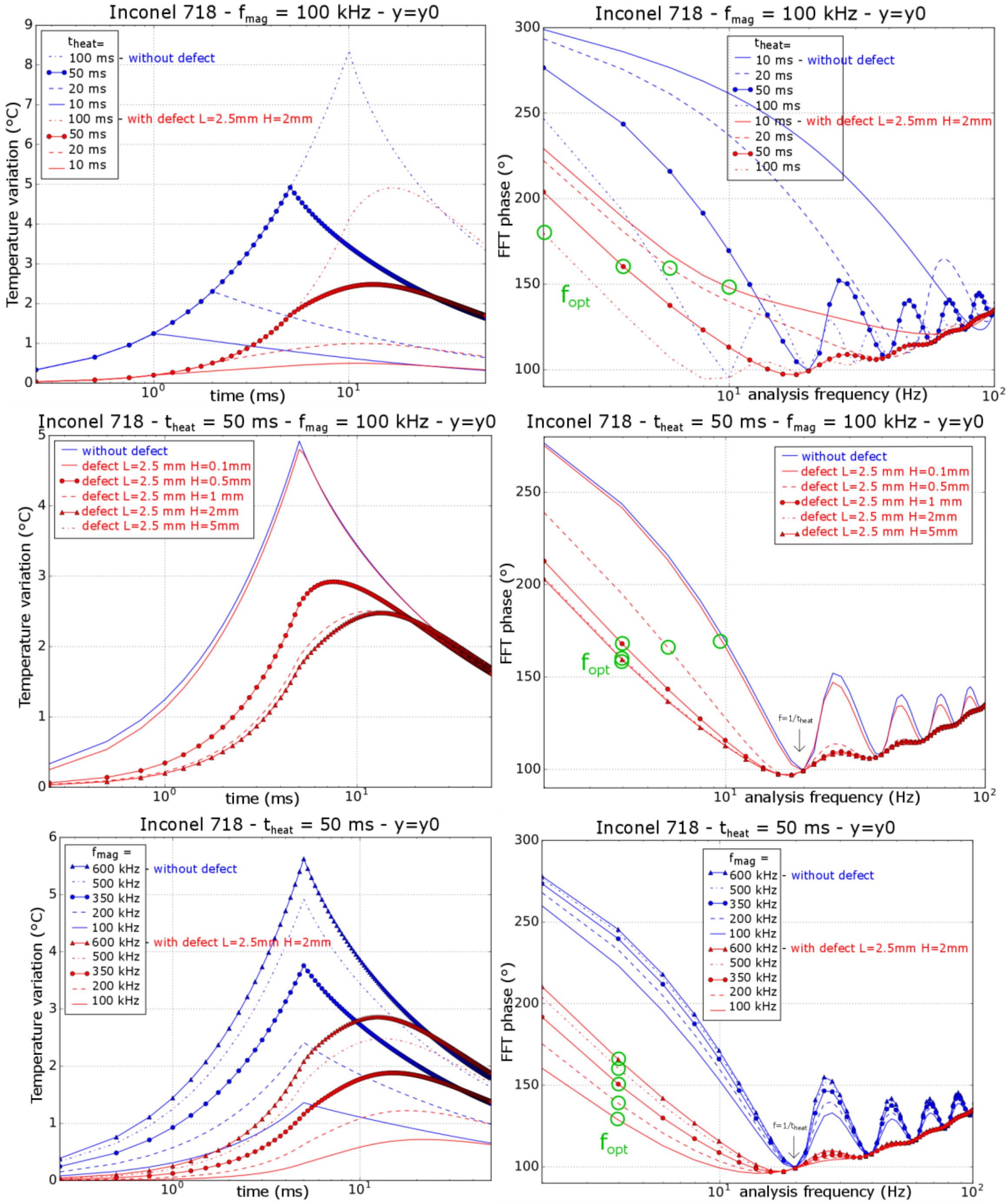


Fig. 3. Temporal variation and phase of the Fast Fourier Transform for different excitation and defects parameters. The data are computed on a point localized at the surface nearby the orthogonal axis of the defect. The optimal analysis frequency of the FFT f_{opt} wich maximize the differential contrast, varies with the step heating duration and the size of the defect.