

Master Thesis Proposal

Numerical Modeling of Electromagnetic Fields with Applications to Eddy Current Imaging

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Introduction The aim in this master thesis is to investigate numerical modeling and optimization techniques enabling the eddy current imaging of electrically conducting media. Examples of application of this non-destructive testing technique include the detection of corrosion spots in gas pipelines and of cracks in sheet metal. The thesis is to be carried out in the context of a collaboration between the Delft Institute of Applied Mathematics (DIAM) and the Instrumentation Oil and Gas Division of TNO Science and Industry (TNO). DIAM will provide support in mathematical modeling and numerical methods (partial differential equations, discretization methods, non-linear, linear system solvers and optimization methods) while TNO will bring in its expertise in the application of imaging using electromagnetic sources and provide a bench mark model with measurement data.

Problem Formulation In the context described above we formulated two master thesis proposals in which we distinguish between solving the so-called *direct* and *inverse* problem. In this thesis we concentrate on solving the former. It consists of solving a (set of) partial differential equation(s) derived from the Maxwell equations supplied with boundary conditions [2]. The frequency of the electromagnetic field excitation depends on the typical dimensions of the objects one wishes to visualize, and it is not a-priori clear whether a formulation of the electromagnetic problem exists that is appropriate for all length scales. Another issue to be investigated is the computational effort of the finite element solution process within the iterative inversion procedure. An alternative to be considered here is to resort to the so-called *space-mapping* method [1]. In this method an approximate coarse model is iteratively improved by extracting information from the fine model.

Roadmap To successfully carry out the project, we distinguish the following steps:

- perform a literature study on existing methods for the modelling of quasi-stationary magnetic fields taking the eddy currents and frequency dependent skin depth into account; this study should lead to a motivated selection of one or a few strategies to solve the direct problem.
- implement the methods of choice in a software environment;
- validate the results of the numerical modeling by comparison with measurements performed by TNO on an experimental set-up;
- write master thesis.

Deliverables As deliverables in the project we foresee

- a documented perspective on existing formulations and discretization methods for quasi-stationary electromagnetic fields for electromagnetic imaging purposes in the form of a literature report;
- an implementation of the most promising methods on a scale of problems of increasing difficulty in two and three dimensions and different frequency ranges;
- a validation of the afore mentioned implementation through comparison with experimental results;
- master thesis report



Figure 1: Finite element simulation of eddy current imaging of a rectangular plate with two corrosion zones.

References

- [1] D. Echeverría, D. Lahaye, and P.W. Hemker. Space mapping and defect correction. In W. Schilders, H. van der Vorst, and J. Rommes, editors, *Model Order Reduction: Theory, Research Aspects and Applications*, volume 13 of *Mathematics in Industry*, 1008.
- [2] J. Jin. *The Finite Element Method in Electromagnetics*. John Wiley & Sons, New York, USA, 1993.