Ph.D. Defense Presentation

By

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A COMPUTATIONAL INVESTIGATION FOR TWO-DIMENSIONAL EDDY CURRENT TESTING PROBLEMS USING SUBREGION FINITE ELEMENT METHOD

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Abstract

Eddy Current Testing (ECT) plays a key role in detecting cracks and defects in conductors. This thesis examined for the first time how subregion method as an effective mathematical and computational technique can be used admixed with Finite Element Method (FEM) to study multiple defects parameters for ECT issues. Separating defect region from the entire domain in any computational technique will save both time and storage space. The idea of minimizing processing time and saving memory especially for large-scale problems is one of the major challenges that researches and engineers are facing. This will lead to tangibly computational cost minimization. The entire domain is separated to multiple domains containing an isolated defect region. Then Finite Element solution has been developed to each region separately, next, to the
affected region alone by using an elastic mesh generation technique that improved in this thesis to apply mathematical inverse problem techniques on the selected affected region alone, and then recombine all solutions of the existing problem. A flexible and elastic mesh generating scheme is derived and improved to change the defect preselected design parameters each iteration. This meshing technique adds the specialty for using subregion method in such inverse FEM problems where the presented mesh generation process will go through this elastic algorithm, so element numbering is saved inside and outside defect region. Examples for different types of defects are presented in this thesis and a tangible result of processing time reduction by 90% have been achieved which lead to consider subregion FEM as an effective method in solving different Non Destructive Evaluation (NDE) problems. In addition, Subregion FEM is developed to handle more complicated design problems in characterizing two-dimensional defects in metals. To characterize hidden cracks, both of Genetic Algorithm and Simulated Annealing optimization techniques are used to get the best shape of the defect that is closer to the original one. The presented Subregion FEM results were verified computationally using COMSOL and classical FEM. Excellent results of minimizing processing time with a factor of 90% with an accuracy 98% was achieved which lead to use this technique in online and in field practical testing problems. In addition, the presented Subregion FEM algorithm was verified experimentally by testing a mild steel plate (0.15 - 0.30% carbon and Fe) and Aluminum (T6061-T6) samples with defects. Tunneling Magnetoresistive (TMR) sensor was used to measure the component of the magnetic field normal to the sample top surface. We used these magnetic flux density values as an input to our inverse characterization model to reconstruct the shape of the defect. An excellent agreement between our results and others using classical Finite
Element Method (FEM) and COMSOL. The major part of minimizing processing time was achieved which can lead to use this technique in online and in field testing problems.

- **Journals**

- **Conferences, Presentations and Symposiums**
  - M. R. Rawashdeh, N. Dib and S. Ratnajeewan Hoole “Full Wave Graphical Processing Unit (GPU) Analysis of Circular Guiding Structures Using One and Two Dimensional Finite Difference Frequency Domain Method (FDFD)”. *Engineering*
Graduate Research Symposium, Michigan State University, East Lansing, Michigan, USA, 2014.


**Conference Proceedings**


**Talks**


**Awards and Prizes**

- Winning a scholarship to get the PhD study in Michigan State University from Yarmouk University in Jordan (2012-2016).
- Graduate School Fellowship, Spring Semester 2017, Michigan State University.
- Honored from King of Jordan, King Abdullah II bin Al-Hussein, regarding his distinguished academic performance in supervising undergraduate graduation projects in 2011.
- Electrical Engineering Shield Award from Jordan Engineers Association, Irbid, Jordan 2005.