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3-D Movement Simulation Technique in FVM Method Application to Eddy Current Non-Destructive Testing

Abstract. *This paper presents the finite volume method FVM in modeling eddy current non-destructive testing EC NDT problems. In such problems, the probe movement has to be simulated. The nonconforming mesh technique already developed is extended to handle the probe displacement. A workshop problem proposed by JSAEM is used as reference to test the proposed method.*

Keywords: FVM – EC NDT – movement – nonconforming mesh.

Introduction

There are few papers which report analysis of eddy current problems by the finite volume methods such as in [1]. In this paper, the FVM method is adapted to model EC NDT problems. Moreover, the movement simulation is carried out by extending the nonconforming mesh technique already developed in [2]. A JSAEM problem has been used to examine the efficiently of the proposed method.

Governing equations

Using the A-V formulation (A: magnetic vector potential, V: electric scalar potential), the governing equations for eddy current NDT problems are:

(1) $$\nabla\times\nu\nabla\times A-\nabla\nu\nabla\cdot A+\sigma\left(\frac{\partial A}{\partial t}+\nabla V\right)=J_s$$

(2) $$\nabla\cdot\left\{-\sigma\left(\frac{\partial A}{\partial t}+\nabla V\right)\right\}=0$$

Where: J_s – exciting current density, ν – magnetic reluctivity, σ – electric conductivity. Here, the Coulomb gauge is imposed for the uniqueness of the solution. Applying the FVM method, means integrate (1) and (2) on each control volume constructed by the meshing process of the method. Then, an algebraic form is obtained:

(3) $$[K]\cdot\begin{bmatrix}A\\V\end{bmatrix}=[J_s]$$

where K is the global FVM matrix.

Movement simulation

By applying the nonconforming technique, meshes of the exciting coil with its surrounding air (Ω1) and the inspected conductive plate with its surrounding air (Ω2) are generated separately, so called respectively, moved and fixed meshes (Fig.1). Therefore, the first mesh can be moved freely without being restricted by the positions of nodes of the fixed one at the nonconforming (N-C) region.

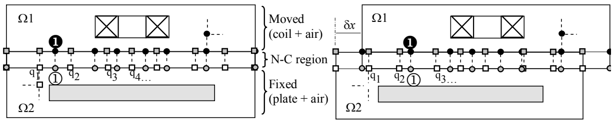

Fig.1. Movement simulation using nonconforming mesh technique
(a). Moved and fixed meshes connection: initial position
(b). Displacement of the moved mesh with δx

Results

The benchmark problem JSAEM#6 (Fig.2) is used to test the proposed method. This problem deals with a pancake coil, placed above a conductive plate with rectangular crack of 10mm length and 0.22mm width [3].

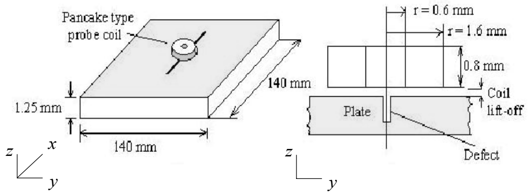

Fig.2. Description of JSAEM#6 problem

The impedance change due to the presence of the crack is represented by its real part (ΔR) and its imaginary part (ΔX) in Fig.3. Therein, the calculated impedance changes versus the position of the coil are similar to the measured data.

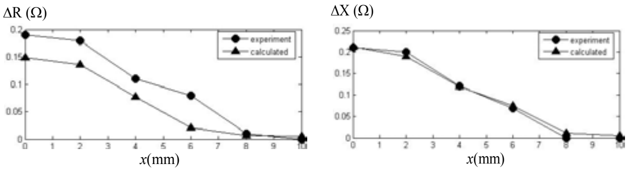

Fig.3. Impedance change due to the presence of crack versus the displacement of the coil.

The present work is realized within an Algerian-French cooperation PAI-Tassili program.

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