CRACK WIDTH DETERMINATION FROM EDDY CURRENT NON DESTRUCTIVE TESTING SIGNAL BY USING THE FVM METHOD

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Abstract: This paper demonstrates a new field of application of the finite volume method (FVM). Due to its simplicity and efficiency in several electromagnetic problems, in this paper the FVM is adapted for solution of inverse eddy current non destructive testing (EC NDT) problems. A computer code involving crack size determination is developed and tested by a JSAEM benchmark problem.

Keywords: EC NDT, Finite volume method, Inverse problem.

1. INTRODUCTION

Crack size determination represents an important task in EC NDT analysis. Information about the flaw size can be extracted from the probe coil response. This response is strongly related to the distribution of eddy currents in the controlled specimen. The way to find this information is associated to solve an inverse problem. At this stage, the finite element method (FEM) is the most used method with the aid of other identification and optimization techniques [1], [2].

In some previous works we have demonstrated that the finite volume method (FVM) is a promising method in solving electromagnetic problems such as magnetostatic ones. The FVM is particularly attractive because its small required storage memory, reduced CPU time and simplicity of implementation [3]. Here, the FVM is adapted to solve the inverse EC NDT problems, where the inversion method is operated by using the forward problem. By using the *A-V* formulation, the governing equations of the forward EC NDT problems are:

$$\nabla \times \nu \nabla \times A - \nabla \nu \nabla \cdot A + \sigma(\partial_t A + \nabla V) = J_s \quad (1)$$

$$\nabla \cdot [-\sigma(\partial_t A + \nabla V)] = 0 \quad (2)$$

where A is the magnetic vector potential, V is the electric scalar potential and J_s is the exciting current density.

2. INVERSION METHOD

To start the inversion process an initial shape of the crack is considered [4]. Then, the system constructed by (1) and (2) is solved for two cases as follows:

- Case 1: Specimen without crack (unflawed),
- Case 2: Specimen with crack (flawed).

Then, the impedance variation of the probe coil (ΔZ) due to the crack is calculated by:

$$\Delta Z = Z^u - Z^f \quad (3)$$

Z^u : is the probe coil impedance obtained in case 1.
Z^f : is the probe coil impedance obtained in case 2.

In both cases, the impedance is given by using electromagnetic the energy formula [5]. Once the impedance variation of the probe coil is given by equation (3), we compute the difference ∂Z as:

$$\partial Z = |\Delta Z_m - \Delta Z| \quad (4)$$

ΔZ_m is the measured impedance variation of the probe coil. The real crack size to be found is that correspond to the minimum value of ∂Z. The minimum values of the difference ∂Z can be reached by adjusting the crack size.

3. NUMERICAL EXAMPLE

Making use of the proposed method, we have developed a computer code under Matlab program. This numerical tool permits easily to determine the crack size from the measured value of the impedance variation of the probe coil. In order to test its numerical behavior and its efficiency, the benchmark problem JSAEM#6 (Fig.1) is used. This problem deals with a pancake coil, placed above a conductive plate with a rectangular crack of 10mm length, 0.22mm width and 0.75mm depth [6]. The coil is made of 140 turns, supplied with a current of 8mA and 150kHz. The plate has an electric conductivity σ=10E6S/m and a relative magnetic permeability μ_r=1.

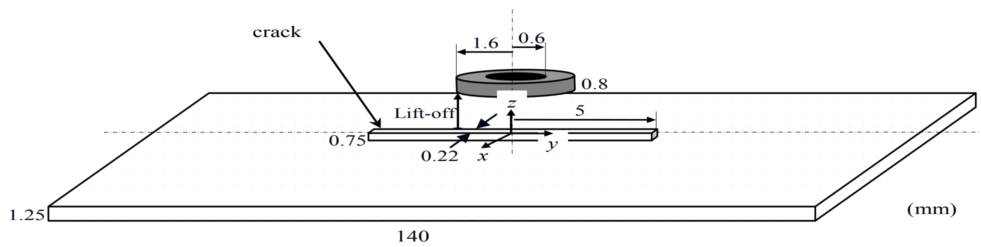


Fig.1. Description of JSAEM#6

The solution of this problem requires the determination of the crack width from the measured impedance variation of the probe coil (ΔZ_m) due to the presence of the crack:

$$\Delta Z_m = 0.19\Omega \tag{5}$$

4. RESULTS

For each forward iteration (No. Iter) we calculate the difference ∂Z and the estimated crack width (Table.I). Note that for the iteration number 6 the difference ∂Z is small enough, and hence the iteration process is stoped. The crack width obtained is 0.235mm, with accuracy of 6.38%.

Table I: Some computational data

No. Iter	∂Z (Ω)	Crack width (mm)
1	0.0153	0.175
2	0.0065	0.262
3	0.0041	0.218
4	0.0012	0.240
5	0.0014	0.229
6	0.0001	0.235

The computer code based on the finite volume method illustrates stable and rapid convergence as shown in the convergence curve (Fig.2).

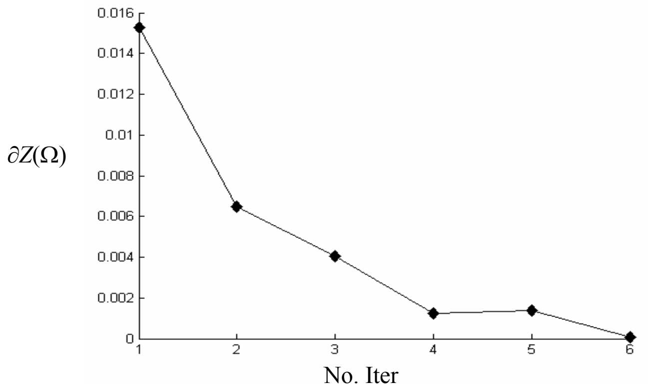
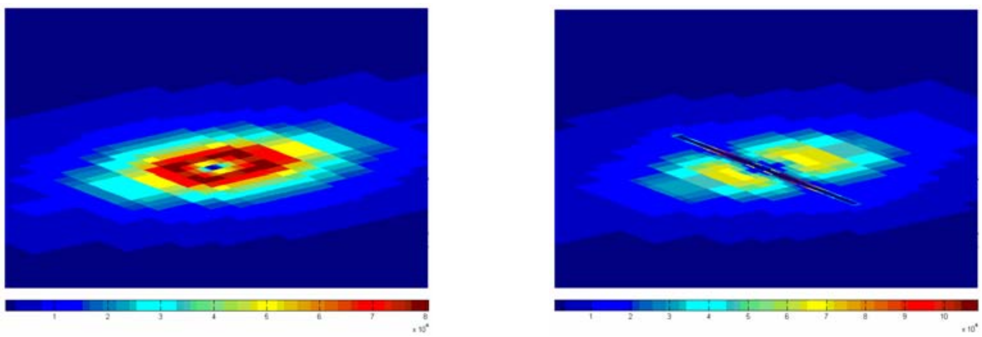


Fig.2. Convergence curve

Fig.3.a and Fig.3.b shows respectively, the distribution of eddy currents density on the top surface of the conductive plate for both cases: without crack and with crack.

5. CONCLUSION

In this paper, the finite volume method has been applied to solve an inverse problem in eddy current non destructive testing. The benchmark problem JSAEM#6 is used to test the numerical behaviour of the developed computer code. Agreement between calculated and measured values of the crack width, confirms the efficiently of the finite volume method in solving such problems.



(a). plate without crack (b). plate with crack (crack width=0.235mm)

Fig.3. Eddy currents density colormap on the top surface of the conductive plate of JSAEM#6 problem

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