Estimation of a Hidden Crack Position Using the FVM Skin Effect Analysis

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Abstract. In this paper the finite volume method is used to analyze an eddy current non destructive testing problem. The aim of this work consists to evaluate the position of a hidden crack from the surface of the workpiece.

1 Introduction

To avoid danger from hidden cracks in metallic structures, usually a control of quality is strongly required. The eddy current non destructive testing (EC-NDT) is one of lucrative methods; it is extensively used to detect cracks in metallic structures such as steam-tube. To solve and analyze an EC-NDT problem several numerical methods can be used. The finite volume method (FVM) has shown its efficiency to solve EC-NDT problems [1]. In shch problems, several reasearch works are interested to estimate crack properties as crack depth [2]. This work is aimed to estimate the position of a hidden crack when inspecting the surface of the workpiece using the FVM skin effect analysis.

2 Formulation

Let us consider the 2D axisymmetric case, hence the governing equation is:

$$\frac{\partial}{\partial r}\left(\frac{\upsilon}{r}\frac{\partial A^*}{\partial r}\right)+\frac{\partial}{\partial z}\left(\frac{\upsilon}{r}\frac{\partial A^*}{\partial z}\right)-\frac{\sigma}{r}j\omega A^* = -J_{s\varphi} \tag{1}$$

A^* is the modified magnetic vector potential ($A^* = rA_\varphi$). $J_{s\varphi}$ is the impressed current density. Solving the partial differential equation (1) using the finite volume method is realized in two steps as follows. The first step is the mesh generating where the geometrical model of the problem is subdivided into a large number of control volumes [4]. In 2D axisymmetric case, each control volume is delimited by four faces: *e*, *w*, *n* and *s*. Then equation (1) has to be integrated over a sample control volume as:

$$\int_w^e\int_s^n \frac{\partial}{\partial r}\frac{\upsilon}{r}\frac{\partial(A^*)}{\partial r}drdz+\int_w^e\int_s^n \frac{\partial}{\partial z}\frac{\upsilon}{r}\frac{\partial(A^*)}{\partial z}drdz-\int_w^e\int_s^n \frac{\sigma}{r}\frac{\partial(A^*)}{\partial t}drdz=-\int_w^e\int_s^n J_S\,drdz \tag{2}$$

In order to estimate the crack position a multi-frequencies mode of excitation of the sensor is carried out. For each frequency we evaluate the penetration coefficient δ:

$$\delta = \sqrt{\frac{2}{\mu\omega\sigma}} \tag{3}$$

3 Results

The test problem (Figure 1) is an Inconel 600 tube, with an outer diameter of 22.47mm, an inner diameter of 16.47mm and a thickness of 3mm. The sensor has an outer diameter of 15.45mm, an inner diameter of 12.45mm, a thickness of 1.50mm and a width of 1.50mm [3]. The crack position is 2mm which has to be estimated using the FVM model.

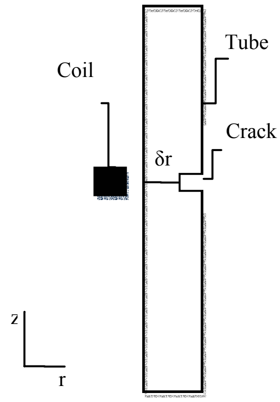

Figure 1: Problem Description.

Table 1: Summary of results

f (kHz)	δ(mm)	Z0(Ω)	Zd(Ω)	ΔZ(Ω)
200	1.12	249.99	249.90	0.09
100	1.59	133.67	133.60	0.07
90	1.68	121.52	121.47	0.05
80	1.78	109.22	109.19	0.03
70	1.90	96.81	96.81	0
60	2.05	84.29	84.32	-0.03
50	2.25	71.65	71.70	-0.05

Table 1 shows the summary of results. For each frequency we give the impedance variation (ΔZ) due to the crack and the penetration coefficient. The crack position is obtained when ΔZ changes the sign. Hence the calculated crack position is 1.90mm with 5% of accuracy.

4 Conclusion

In this paper the finite volume method is applied to analyze an EC-NDT problem. By making use of the skin effect of the examined material, the crack position value is calculated with accuracy of 5%.

References

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