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Eddy Current Testing of a Steam Generator with a Support Plate

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INTRODUCTION & AIM

Steam generators play an important role in a variety of industries, including chemical and petrochemical production, engineering and nuclear applications. Steam generator tubes are subjected to high pressures, making them prone to corrosion and vibration; as a result, they are held in place with supports named tube support plates (TSPs). However, TSPs are regarded as disturbing signals for , nondestructive testing (NDT) techniques. In this study, the influence of the support plates on eddy current testing (ECT) of a steam generator tube made of Inconel 600 with a defect is explored. The modeling of eddy current testing is based on solving a 2D axisymmetric finite element formulation under steady-state conditions via Comsol Multiphysics Software. The impedance of the differential coil is calculated using the direct method, and the difference impedance signal is obtained from two simulations: with flaw and without flaw.

METHOD

Nondestructive problem modelling using eddy current testing

$$\boldsymbol{rot}\left(\left(\frac{1}{\mu}\right)\boldsymbol{rot}(\boldsymbol{A})\right)+\sigma\left(\frac{\partial(\boldsymbol{A})}{\partial t}\right)=\boldsymbol{J_e} \quad (1)$$

In harmonic analysis, the time derivative $\frac{\partial(A)}{\partial t}$ is replaced by the complex expression $j\omega\boldsymbol{A}$ $(j^2=-1)$

$$\boldsymbol{rot}\left(\left(\frac{1}{\mu}\right)rot(\boldsymbol{A})\right)+\sigma(j\omega\boldsymbol{A})=\boldsymbol{J_e} \quad (2)$$

In an axisymmetric problem, the components of the current density **J** and the vector potential **A** are:: **J** $(0, J_\varphi, 0)$ and **A** $(0, A_\varphi, 0)$
Equation (2) becomes [1]:

$$-\frac{\partial}{\partial r}\left(\frac{1}{r\mu_r}\cdot\frac{\partial(\boldsymbol{A})}{\partial r}\right)-\frac{\partial}{\partial z}\left(\frac{1}{r\mu_r}\cdot\frac{\partial(\boldsymbol{A})}{\partial z}\right)+j\frac{\omega.\sigma.\mu_0}{r}\cdot(\boldsymbol{A})=\mu_0.\boldsymbol{J_\varphi} \quad (3)$$

The 2D axisymmetric frequency-domain equation (3) is solved through the finite element method via COMSOL Multiphysics Software.

Impedance evaluation of a differential coil via the finite element modelling

Consider two coils with Ns turns, connected in a differential configuration and carrying equal and opposite currents. An axisymmetric finite element analysis allows to calculate the impedance according to expression [2]:

$$Z_{bobine}=\frac{j\omega\,.\,2\pi\,.\,J_s}{I_s^2}\cdot\left(\sum_{1}^{n_a} r_{ci}\,.\,A_{ci}\,.\,\Delta_i-\sum_{1}^{n_b} r_{ci}\,.\,A_{ci}\,.\,\Delta_i\right) \quad (4)$$

Δ_i : is the area of the element under consideration.
A_I, A_J et A_K : are the values of the vector potential A at nodes I, J, and K
.r_I, r_J et r_K : are the values of the radius r of nodes I, J, and K with respect to the axis of symmetry.

The modeling of the system to be inspected is carried out in the case of the existence of the defect and with the absence of the defect; the differences in impedance, reactance, and resistance are given by the following equations:

$$\Delta Z=\sqrt{\Delta R^2+\Delta X^2}$$

$$\Delta X=Xd-X0$$

$$\Delta R=Rd-R0$$

Xd : Sensor reactance with defected piece[Ω].

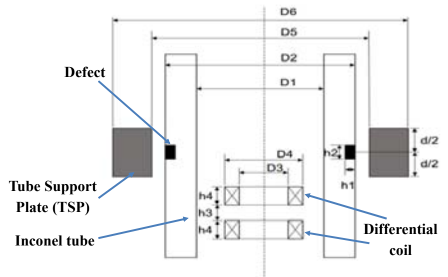
$X0$: Sensor reactance of a defect free piece[Ω].

Rd : Sensor resistance with defected piece [Ω].

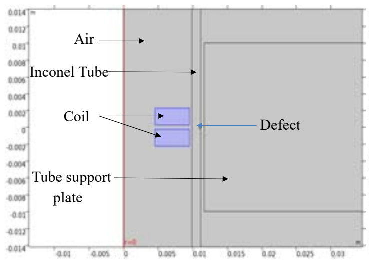
$R0$: Sensor resistance of a defect free piece [Ω]

RESULTS & DISCUSSION

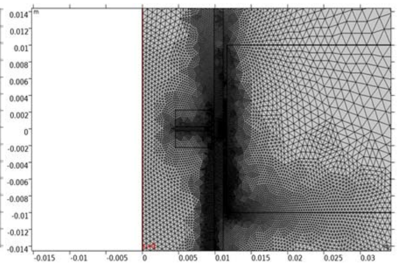
Simulated Steam Generator



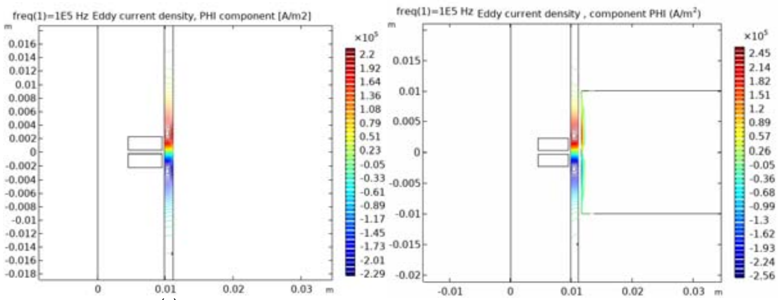
Eddy current reference problem of a steam generator proposed by WFNDEC [3]



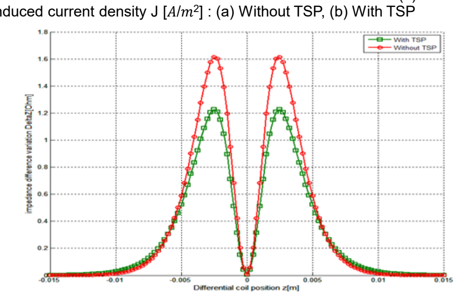
Axisymmetric representation of the simulated device



Geometry discretization using comsol



Induced current density J [A/m^2] : (a) Without TSP, (b) With TSP



Variation of the impedance difference as a function of the position of the differential coil sensor

CONCLUSION

The presence of a support plate alters the eddy current distribution and therefore the measured impedance. Fault detection is visible at the scan point corresponding to z=0. The results obtained have proven that the support plate is a disturbing element that influences the fault detection signal.

FUTURE WORK / REFERENCES

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