Analysis of Impedance Signal on Eddy Current Testing using FEM simulation

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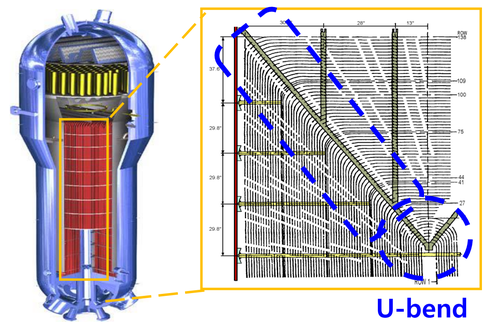
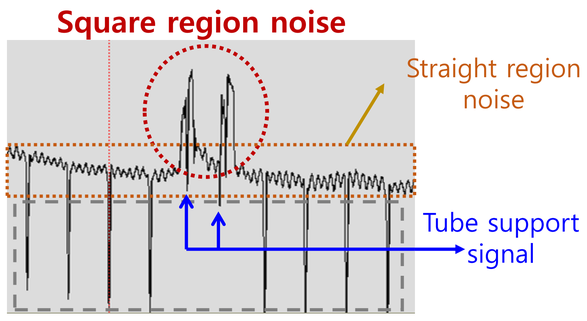
Background

- Steam generator (SG) tubes in nuclear power plants (NPPs) have U-bend regions of various radii. However, the defect detection in the U-bend region is difficult due to a large background noise signal from geometric distortions.



U-bend



<Strip chart>

⇒ Significant background noise (structural noise in square type tube)

- The bending may cause the variation in tube dimensions of wall thickness, ovality and may also affect the trajectory of the probe motion which can be tilted and lift-off.

➡ **Noise signals**

Experiments

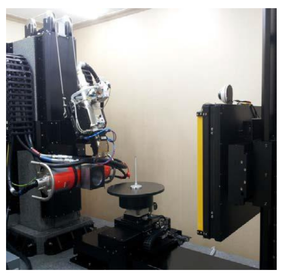
❖ Instrument

- CT(Computed Tomography) instruments

  : High power X-ray tube

  (Tube voltage 450 kV/ Tube power 700 W)

  : VG studio max 3D (Analysis software)



<CT>

- ECT instruments

  : MIZ-70 Digital Data Acquisition Unit,

  Eddynet Data Analysis System

  : Bobbin(absolute) probe

<ECT>

❖ Simulation

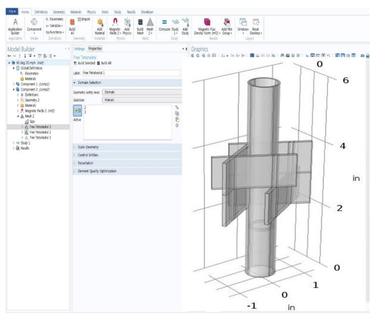
- COMSOL Multiphysics 5.4

  (AC/DC module)

- Electromagnetic numerical analysis

  - Maxwell-Ampere's Law formula

$$\Delta \cdot \boldsymbol{H} = \boldsymbol{J}$$



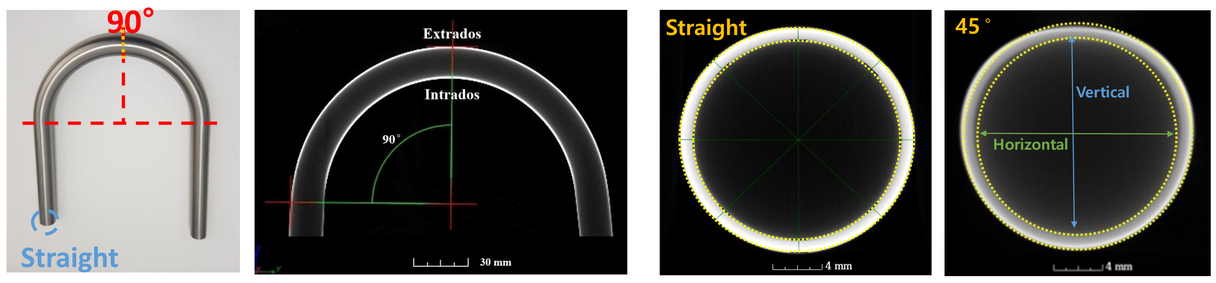
<COMSOL S/W>

❖ Material properties

	Relative permeability	Relative permittivity	Electrical Conductivity [S/m]
Air	1.00000037	1.000536	$3x10^{-15}$
Coil (Copper)	0.999994	0.9999996	$5.96x10^{7}$
Tube (Inconel 690)	1.01	1	$6.7567x10^{6}$

Results

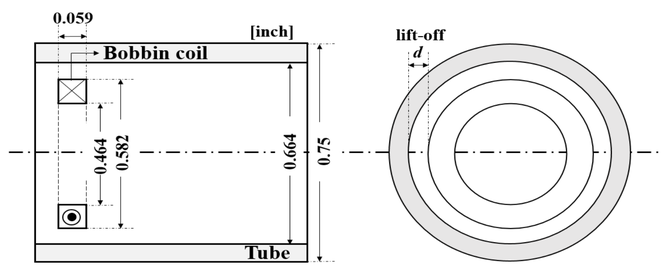
❖ Results from CT



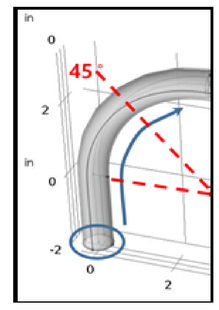
<Cross sectional area result of U-bend tube >

❖ Simulation Modeling

- The schematic diagram of SG tube

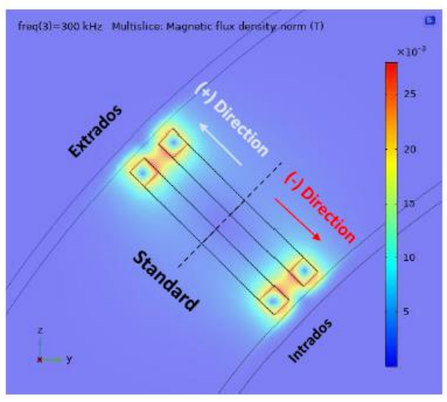


- Extraction structure design

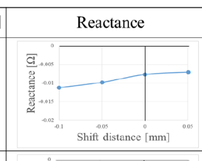
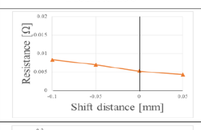
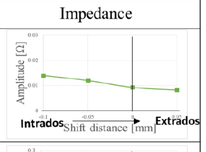
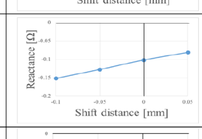
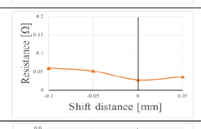
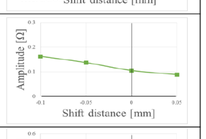
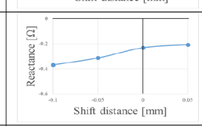
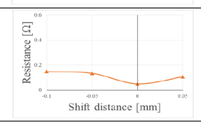
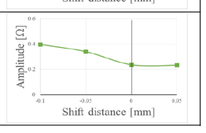


❖ Results from Simulation

- Coil lift-off



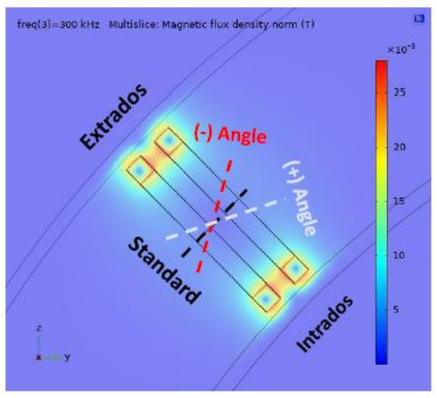
< Strip chart >

F [kHz]	Reactance	Resistance	Impedance
20			
150			
300			

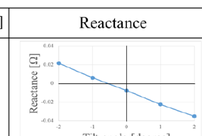
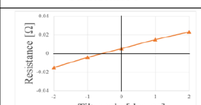
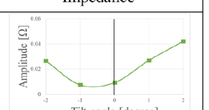
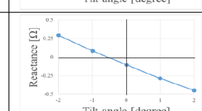
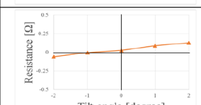
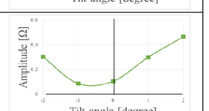
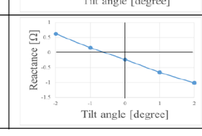
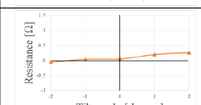
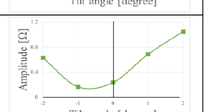
Reactance [Ω] / Resistance [Ω] / Amplitude [Ω] — Shift distance [mm] (Intrados … Extrados)

➢ (+) Direction is the coil lift-off to extrados of the pipe, (-) Direction is the coil lift-off to intrados of the pipe.

- Coil tilt



< Strip chart >

F [kHz]	Reactance	Resistance	Impedance
20			
150			
300			

Reactance [Ω] / Resistance [Ω] / Amplitude [Ω] — Tilt angle [degree]

➢ (+) Angle is the front coil tilted to intrados of the pipe, (-) Angle is the front coil tilted to extrados of the pipe.

⇒ The variation between reaction and resistance occurs depending on the coil position inside the pipe surface based on the center of the pipe.

⇒ The value of Impedance varies with the degree to which each of the two coils approaches the surface inside the pipe.

Summary

- The noise signal is generated during eddy current inspection due to the effect of the change in the ovality of the steam generator heat pipe.
- It is expected that the noise level will rise due to the tilting of the coil in the bent part, and verified using simulation.
- At a position with high ovality (45 degrees), the effect of lift-off and tilted the coil was applied to analysis the noise signal level.
- The change in the noise signal depends on the coil position inside the pipe.
- Analyzing noise signals using the simulations used in this study could be useful for high-precision defects detection.