Comparison of 2D and 3D FEM Models of Eddy Current Pressure Tube to Calandria Tube Gap Measurement

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INTRODUCTION & MOTIVATION

CANDU® PT-CT Gap

- CANDU® reactor fuel channels consist of a 6 m long pressure tube (PT) at ~300°C, held within a larger diameter calandria tube (CT) at ~50°C [1]
- Pressure, heat, fuel bundle weight and irradiation effects can cause the PT to sag and come into contact the with CT, potentially leading to the formation of hydride blisters on the PT
- Hydride blisters can crack and cause PT failure
- Reactor operators are required to have fuel channels inspected periodically to ensure that PT-CT contact is not imminent
- Inspection is performed by measuring the PT-CT gap using a send-receive eddy current based system
- The eddy current system uses one drive coil and a pick-up coil at some liftoff (LO), as shown below

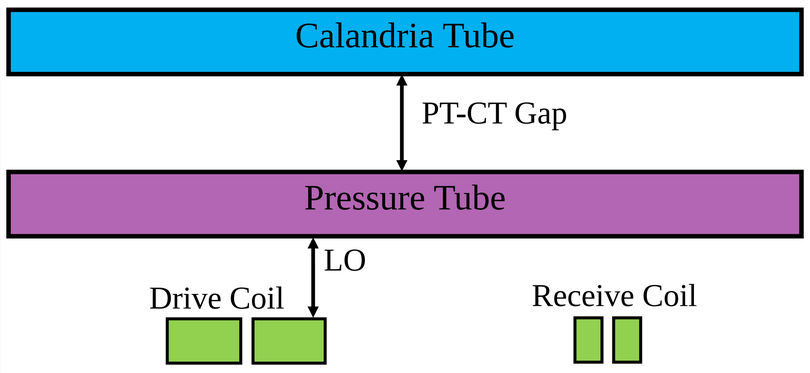

Figure 1: 2D representation of PT-CT gap system

Objective

- Using COMSOL® construct both a flat-plate and curved FEM model to determine if the flat-plate approximation [4], as shown above, can accurately represent the curved geometry of the PT-CT gap measurement system
- Investigate how varying in-reactor parameters affect PT-CT gap measurements, using each model
- Validate the selected models against experimental measurements

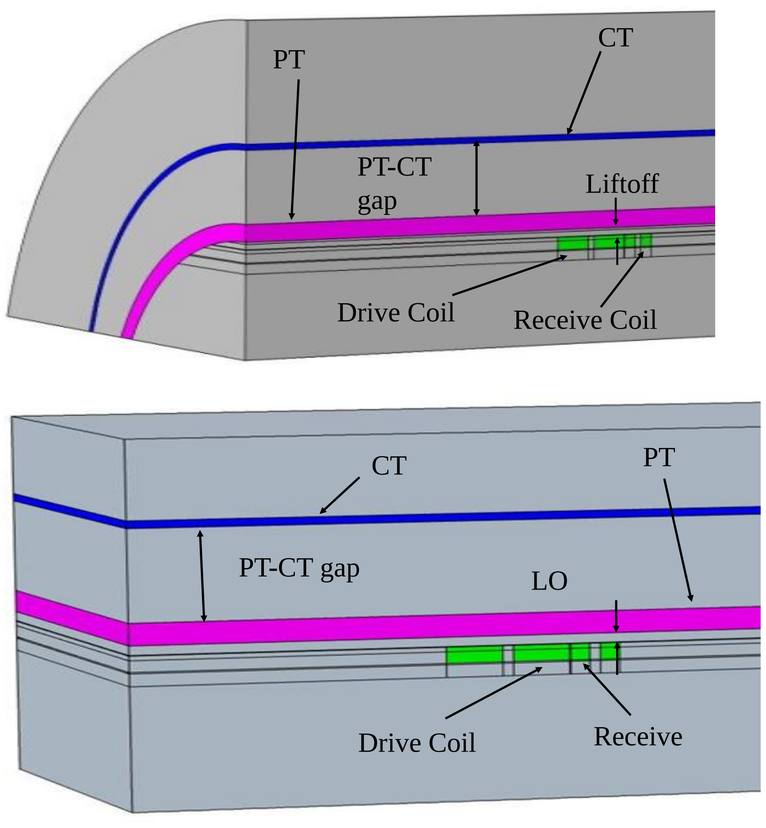

Figure 2: Curved model (top) and flat plate model (bottom).

Flat Plate vs Curved

Modelled Receive Coil Response

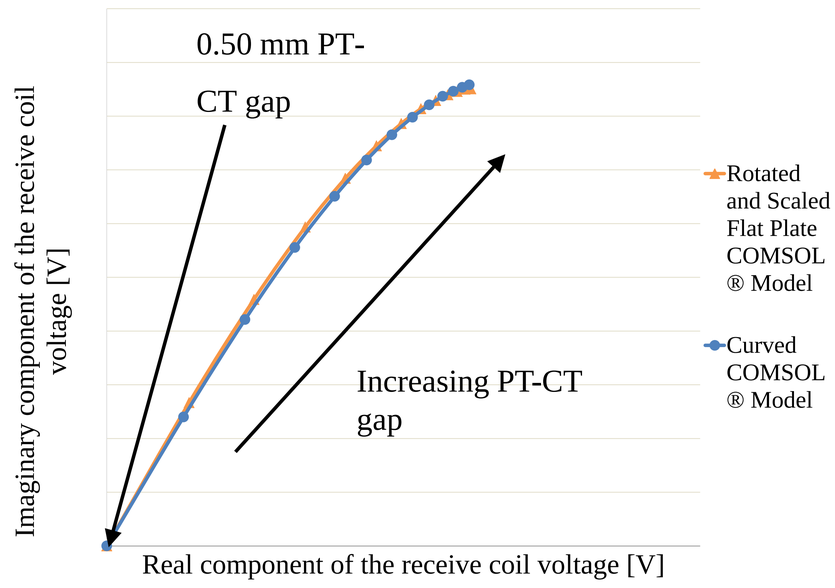

Figure 3: Receive coil responses for PT-CT gap variation

Experimental Probe

- A MS5800 data acquisition eddy current instrument excites the drive coil with a 1 V, 4 kHz sinusoidal signal
- The experimental eddy current probe used is show below

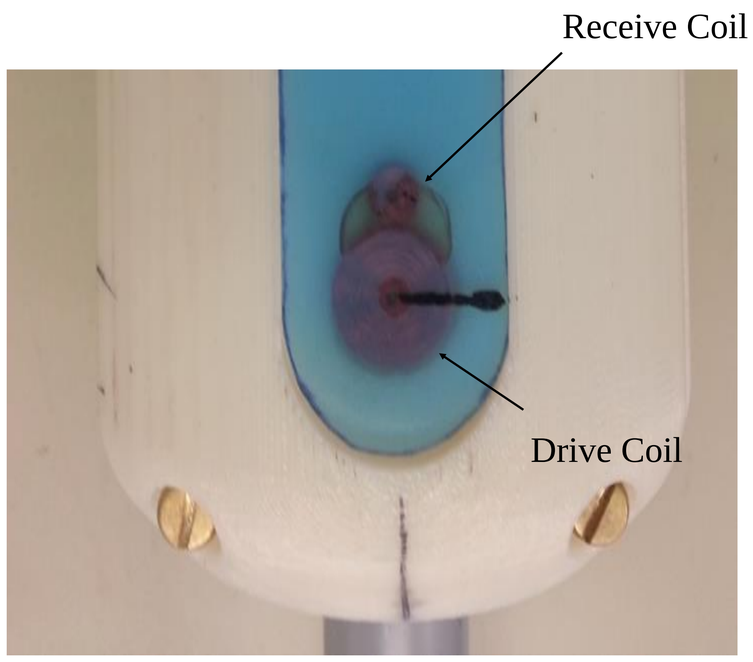

Figure 4: Eddy current probe for experimental measurements.

Wall Thickness Variation Results

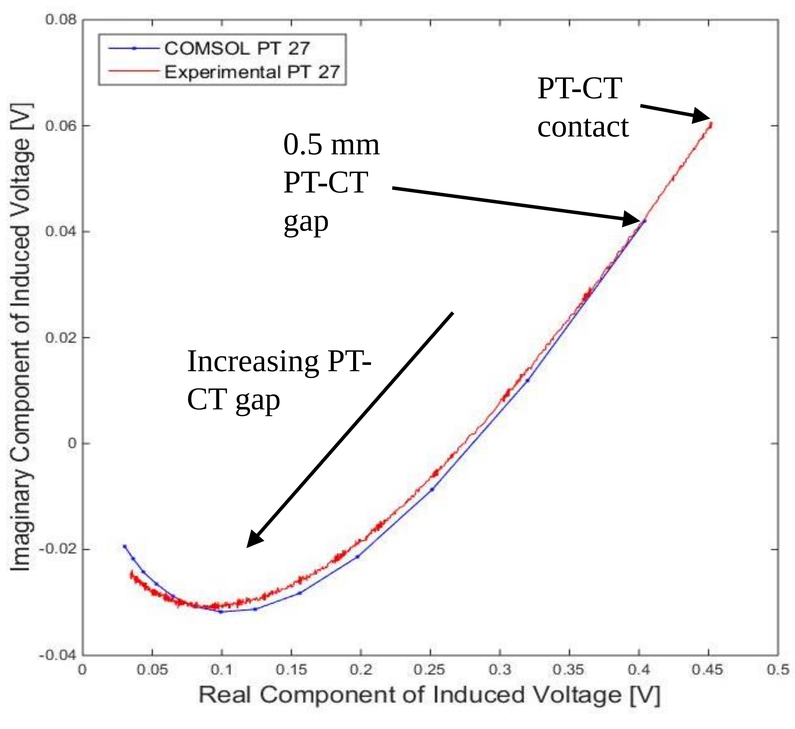

Figure 5: Comparison between calibrated curved FEM results and experimental data for 4.38 mm PT WT.

- PT wall thickness (WT) variation comparison between models and experiment
- The model results were compared to the experimental measurements based on a calibration data set at 4.40 mm WT
- Calibration accounts for amplification and phase differences between models and experiment

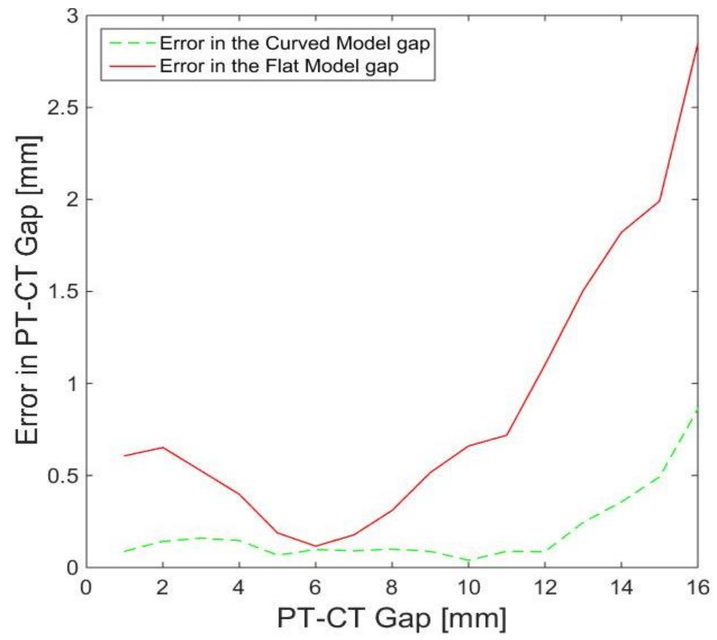

Figure 6: Errors in the modelled PT-CT gaps for the flat plate and curved FEM models .

Wall Thickness [mm]	PT-CT Gap Error [mm]			
	1 mm Gap	5 mm Gap	10 mm Gap	16 mm Gap
4.38	0.09	0.07	0.04	0.9
4.36	0.06	0.12	0.05	1.4
4.34	0.07	0.25	0.15	1.3
4.28	0.18	0.22	0.17	0.9
4.26	0.26	0.18	0.14	1.4
Average	0.12	0.15	0.12	1.4

Table 1: Error in the modeled PT-CT gap for the curved model.

Conclusion

- The curved model is in better agreement with experimental results than the flat plate model
- The error in the calibrated PT-CT gap response is ~0.1 mm for the curved model and ~0.5 mm for the flat plate model at gaps less than 10 mm
- For gaps greater than 10 mm error grows far faster for the flat plate than the curved model
- The curved FEM model is able to accurately show how nominal variations in PT WT affect PT-CT gap measurements

References

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[3]	S. Shokralla and T. W. Krause, "Methods for Evaluation of Accuracy with Multiple Essential Parameters for Eddy Current Measurement of Pressure Tube to Calandria Tube Gap in CANDU® Reactors," CINDE, vol. 35, no. 1, pp. 5-8, 2014.
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