Working Towards Magnetic Barkhausen Noise Detection on Curved Surfaces

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INTRODUCTION:

- Inspecting critical HY-80 steel components with curved surfaces for residual stress (see Fig. 1) can be costly and time-consuming.

Figure 1. Cylindrical sample of HY-80 steel to be tested using MBN techniques. Radius of curvature: 50 mm.

- Magnetic Barkhausen noise (MBN) can be used to non-destructively evaluate materials for residual surface stress [1,2]. MBN is also a function of flux density in a magnetic circuit.
- Flux density B is related to the magnetic reluctance $\mathcal{R}$ of a given flux path by the following equation:

$$B = \frac{\mathcal{F}}{\mathcal{R}S}$$

- where $\mathcal{F}$ is magneto-motive force, and S is cross-sectional area of the circuit [3].
- MBN is sensitive to lift-off between test probe and sample, making measurement reproducibility a challenge, especially on curved surfaces.
- Analytical and FEM models using COMSOL (Fig.4) were developed for a dual-pole probe (Fig.1) and lift-off effects were studied for flat (Fig.2(a)) and convex (Fig.2(b)) sample geometries.

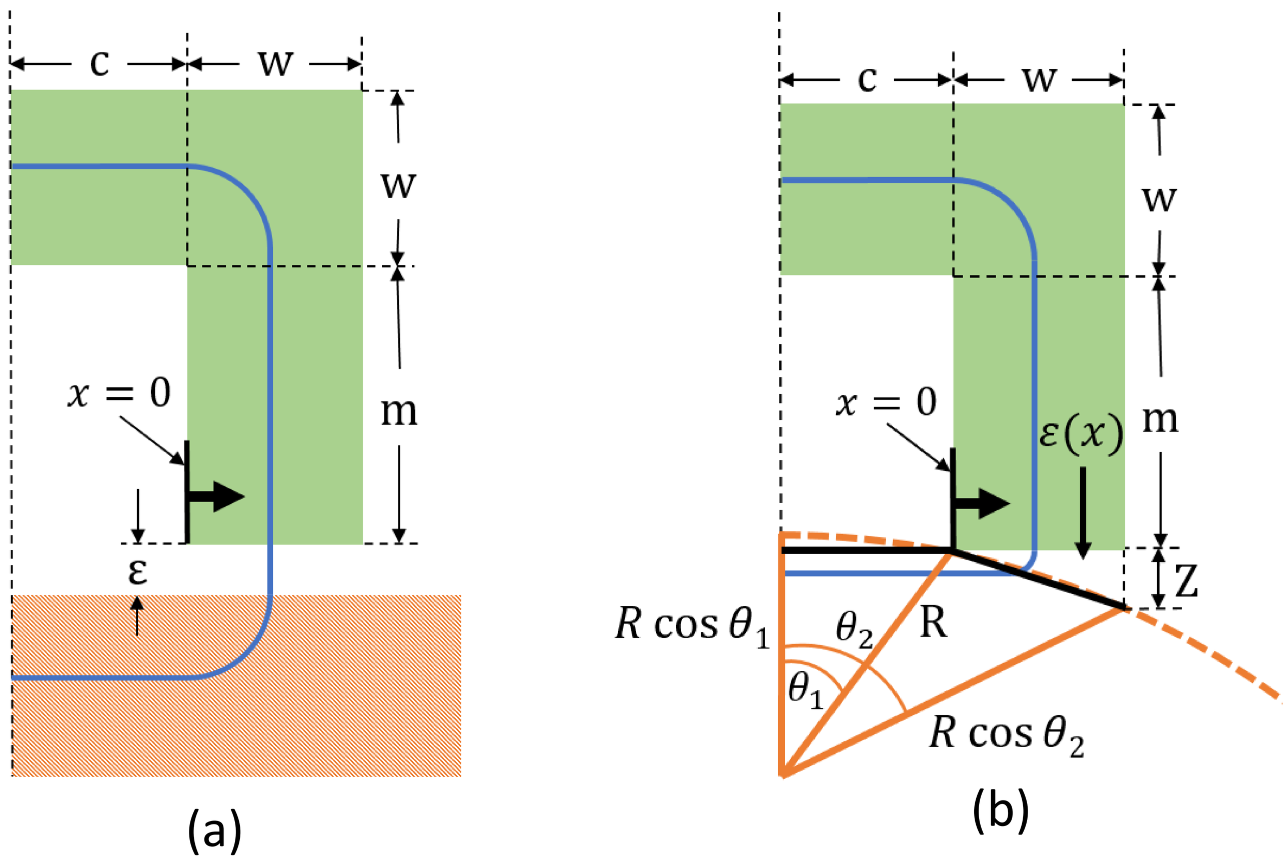

Figure 2. Magnetic probe core mounted on flat (a) and curved (b) surfaces. Curved surface is approximated as a straight line.

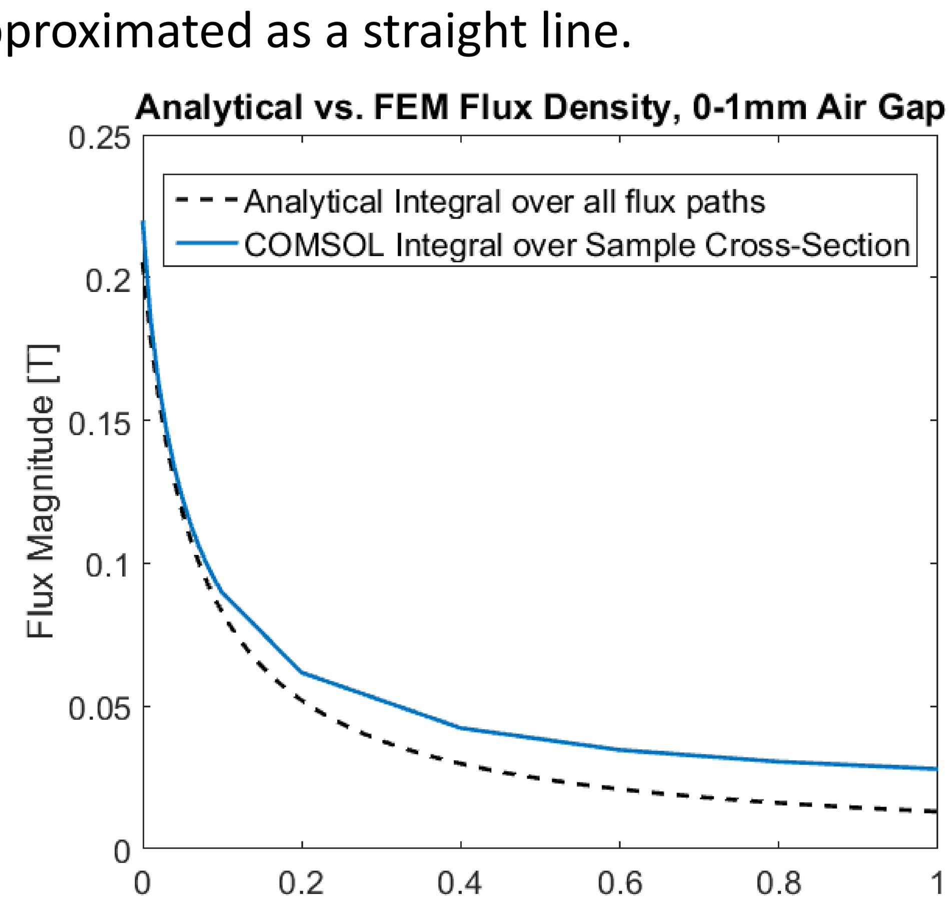

Figure 3. Analytical model results showing the decreasing trend in flux density with increased air gap between core and sample.

COMPUTATIONAL METHODS: Using the AC/DC Module, a model was developed based on previous work [4]. DC current through coils was simulated and resulting flux density in the magnetic circuit was simulated (Fig.5).

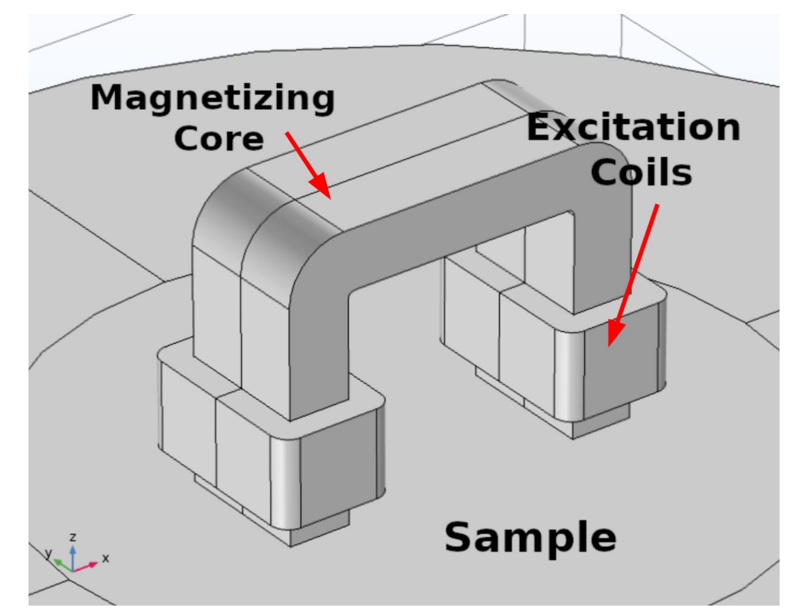

Figure 4. Dual pole MBN probe design.

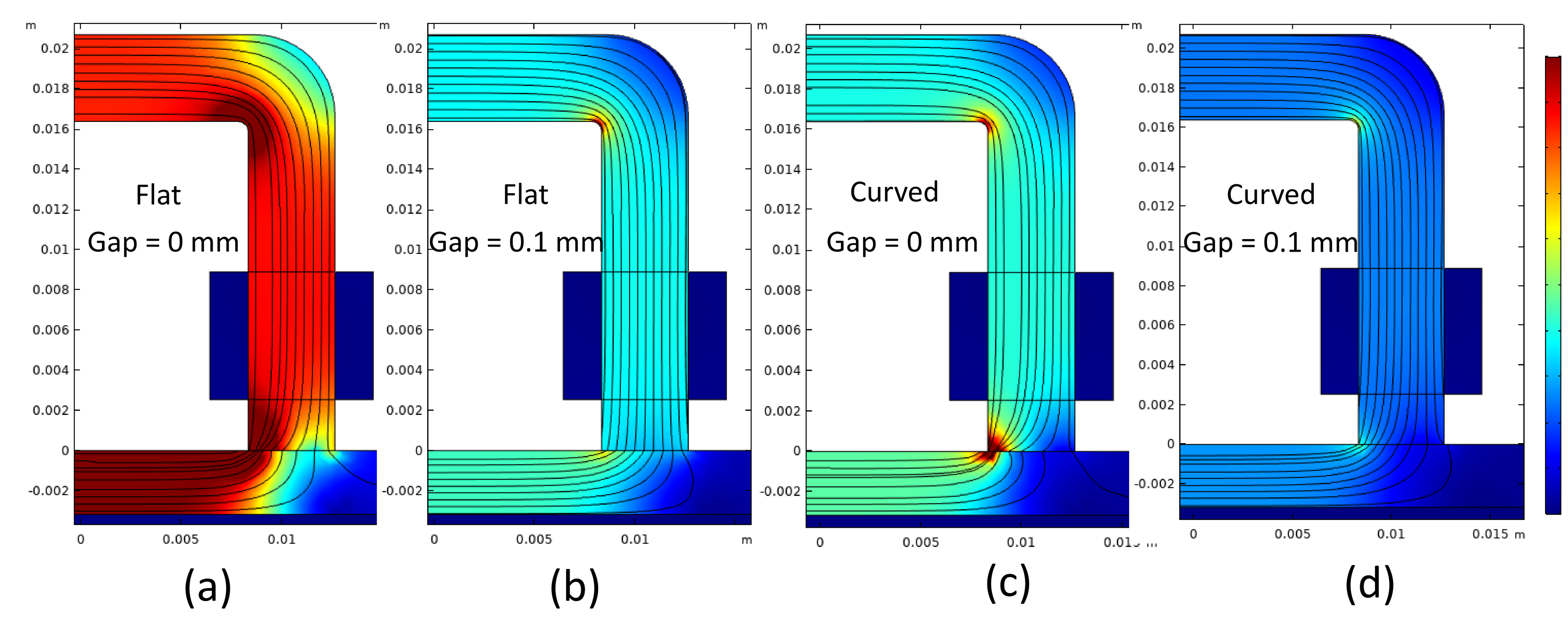

Figure 5. COMSOL simulations showing magnetizing core in contact with a flat and approximately curved samples with 0 and 0.1 mm gap.

RESULTS: As predicted analytically, flux densities in the FEM model for the flat geometry drop off at the expected rate. Curved analytical model requires further work to compare with FEM, but FEM model shows expected behavior. Differences could be attributed to the 2D analytic vs 3D FEM nature of each model. Both models require experimental validation.

CONCLUSIONS:

- A consistent trend between the simple magnetic circuit and FEM are observed, with good qualitative agreement (Fig. 3).
- An FEM model for the curved surface showed the expected behavior of flux concentration at the pole's contact point with the sample.
- This provides a tool towards the design of MBN probes for application on curved surfaces.

FUTURE WORK:

- Account for full curvature of the sample in both analytical and FEM models.
- Validate models with experimental work.
- AC current sources should be modeled to account for skin depth effects and eddy current losses.

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Excerpt from the Proceedings of the 2019 COMSOL Conference in Boston