Comparison of Magnetic Barkhausen Noise Tetrapole and Dipole Probe Designs

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Introduction: Magnetic Barkhausen Noise (MBN) is emitted as magnetic domain walls abruptly move in ferromagnetic materials. It is sensitive to stress and so is useful for studying residual stress in steels. Classically, the directional properties of MBN have been studied by manually rotating a dipole electromagnet (Figure 1 left). Rather than manually rotating the electromagnet, a tetrapole electromagnet (Figure 1 right) can be used and the magnetic field rotated by vector superposition. Unfortunately, the two approaches are not equivalent as expected (see Figure 2) [1,2]. COMSOL is used to understand the differences in these two approaches.

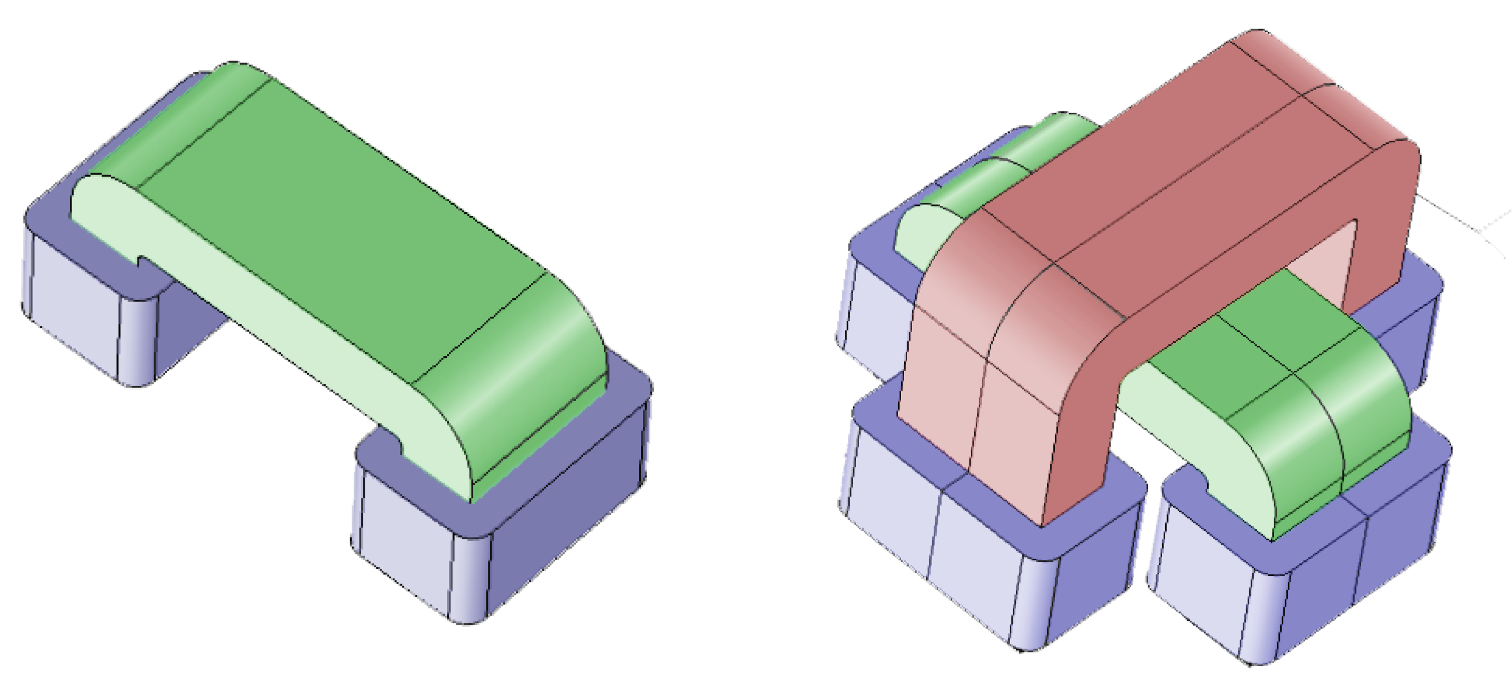

Figure 1. MBN dipole probe (left) and tetrapole probe (right). Drive coils are in blue

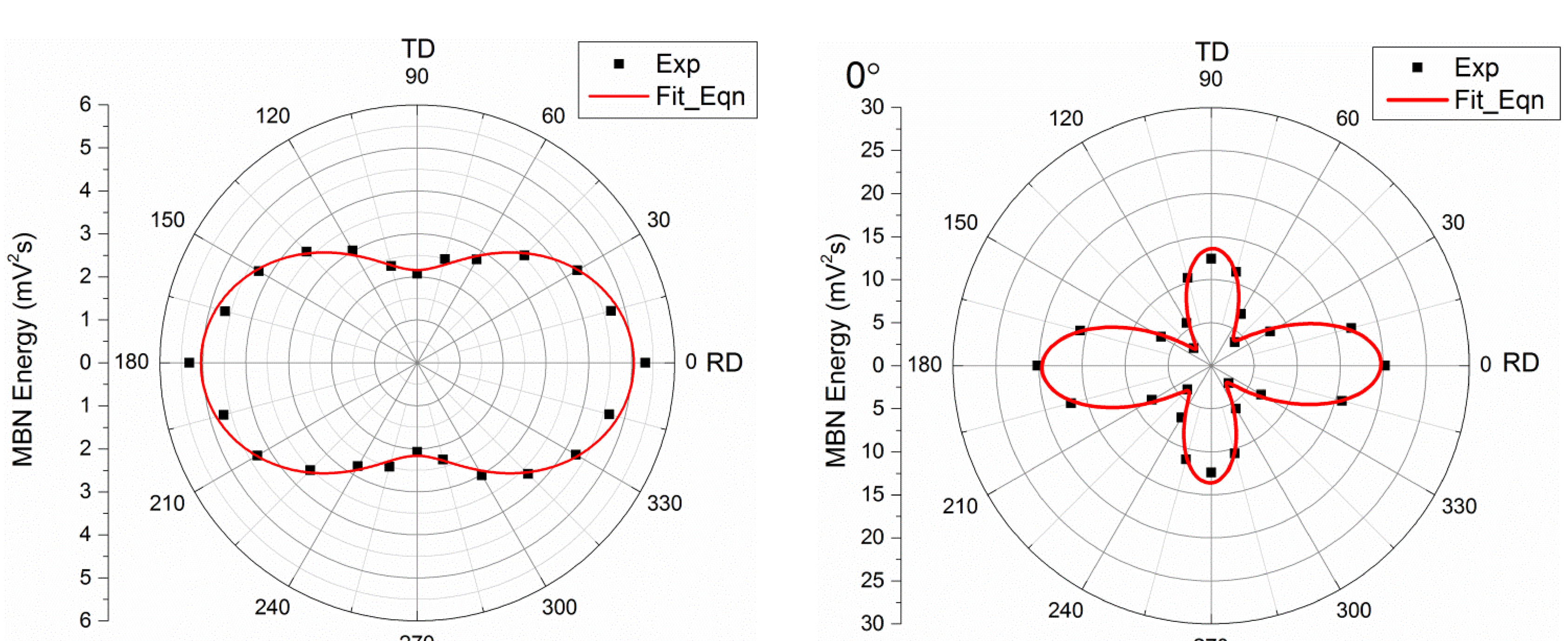

Figure 2. MBN distribution relative to the rolling direction for a dipole probe (left) and tetrapole probe (right)

Computational Methods: The AC/DC module was used for the simulations. The laminated Supermendur electromagnets used a diagonal conductivity matrix and an Ampere's law node to rotate the local co-ordinate system to align the conductivity with the laminate, preventing induced current flow between layers. The steel substrate used a diagonal permeability matrix to reflect the magnetic easy axis in the rolling direction. An Ampere's law node was used to rotate the local co-ordinate system in the steel so that the easy axis could be rotated relative to the tetrapole. The tetrapole phase angle was varied using a parametric sweep of a 50Hz time harmonic calculation

Results: Figures 3 and 4 show the magnetic field just inside the steel substrate obtained from a dipole probe and a tetrapole operating at 0°. In the centre of the probe, the fields are very similar. The tetrapole shows some flux leakage through the extra set of poles resulting in slightly less field intensity in the center.

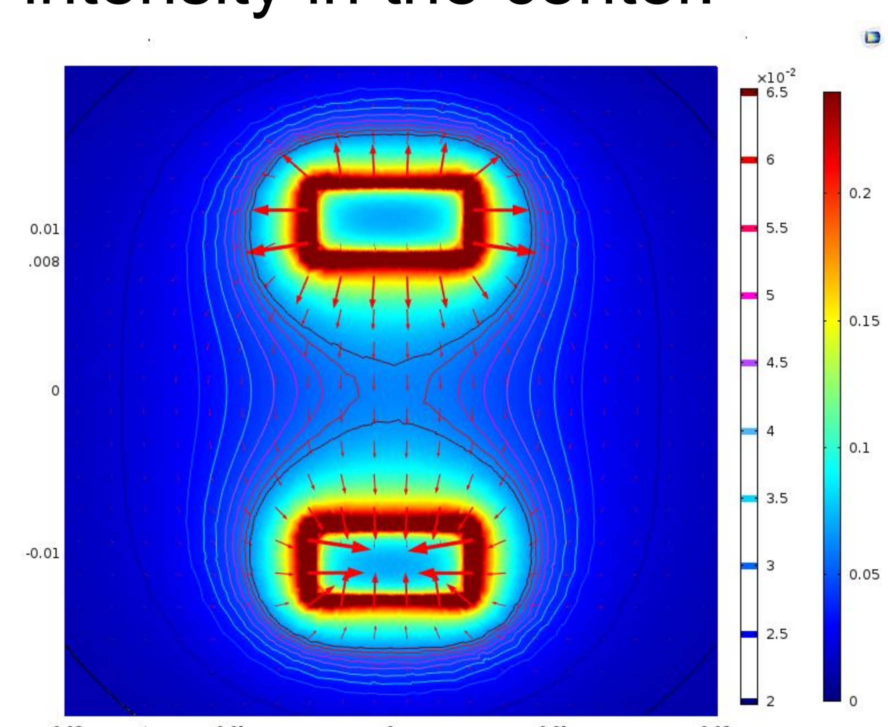

Figure 3. Magnetic field, **B**, of dipole inside substrate

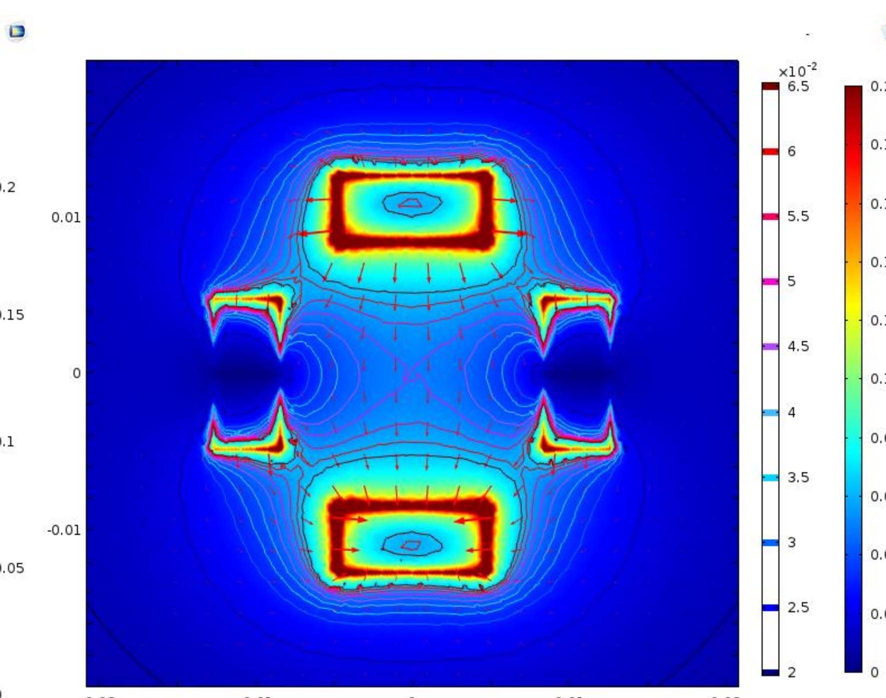

Figure 4. Magnetic field, **B**, of tetrapole operating at 0°

Figure 5 shows the tetrapole operating at a superposition of 45°. In this case the field intensity profile has rotated one way but the flux lines have rotated the other so that the flux direction and the line of maximum field intensity are 90° to each other. Since the magnetic domains grow from the region of strongest field, this can be expected to effect the production of MBN. This condition does not arise with a dipole probe

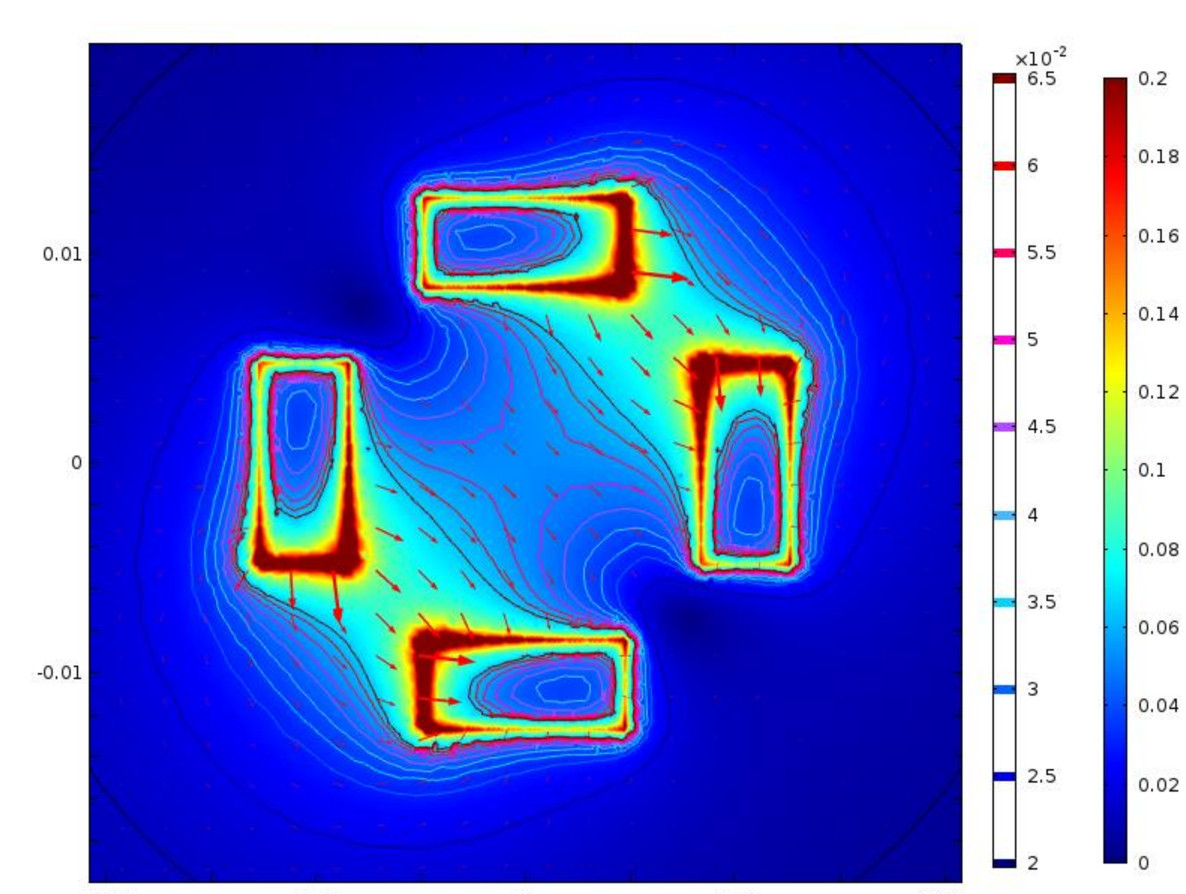

Figure 5. Magnetic field, **B**, of tetrapole operating at 45°

Conclusions: While superposition works, the field gradients produced by a tetrapole probe are oriented very differently from those produced by a dipole probe potentially causing different MBN response.

References:

1. S. A. White. A Barkhausen noise testing system for CANDU R feeder pipes, Queen's University, 2009.
2. P. McNairnay. Magnetic Barkhausen noise measurements using tetrapole probe designs. Queen's University, 2014