Barkhausen Noise Correlation with Stress in SA-106 Grade B Piping

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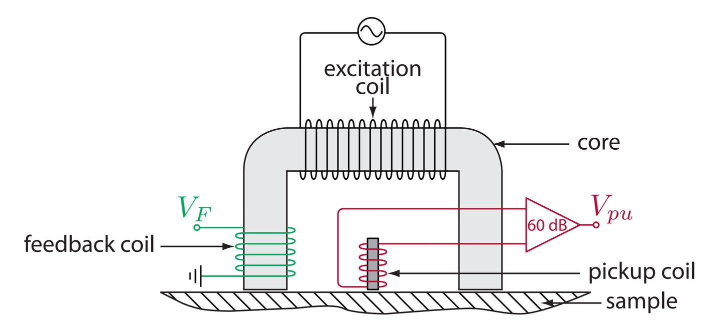
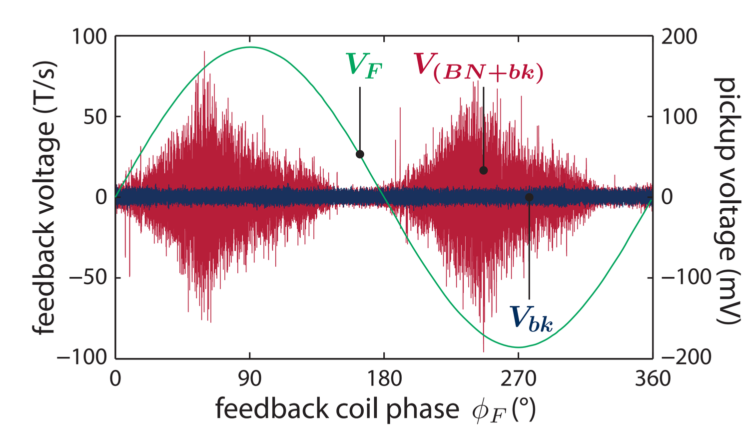
1 Introduction

The Barkhausen noise (BN) response from ferromagnetic materials, such as carbon steel, is sensitive to elastic stress. In 2004, a project was launched at Queen's University to develop a BN testing system to investigate residual stresses in CANDU feeder pipes. This resulted in the development of a state-of-the-art approach to BN measurement, which is capable of measuring axial and hoop stresses in feeders with an estimated sensing depth of 100 μm.

Correlations between BN and stress in SA-106 grade B piping were demonstrated using a three-point bending rig. Precision for stress estimation in feeder pipes was found to be between ±7 MPa and ±9 MPa in tension, depending on the excitation field configuration, and negligible in compression. Positional BN scans were performed on a feeder bend manufactured using the compression boost technique. The scans indicate elevated BN in the bend cheeks and near the start of the bend, in agreement with observed increases in residual tensile stress in this region.

2 Barkhausen Noise Basics





BN is generated when the magnetization of a ferromagnetic material is varied.

A BN probe consists of a flux-controlled electromagnet and a pickup coil.

Flux control is achieved by supplying an alternating current to the excitation coil which produces the desired voltage across the feedback coil (V_F).

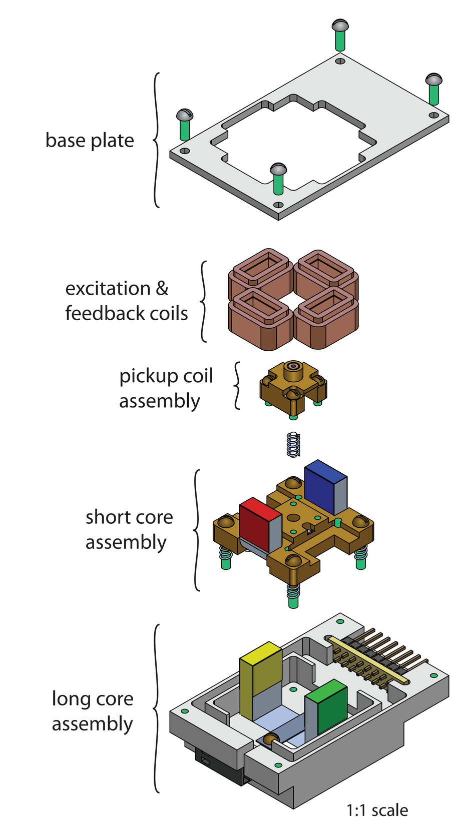
Abrupt changes in the sample magnetization are detected as increased noise in the voltage across the pickup coil (V_{pu})

BN is identified by comparing V_{pu} during a measurement ($V_{(BN+bk)}$) with V_{pu} when V_F is zero (V_{bk}).

Integrating the BN over 1 cycle produces the BN energy (BN_E).

data from [1]

3 S$_{pring}$L$_{oaded}$4P$_{ole}$P$_{rototype}$ BN Probe



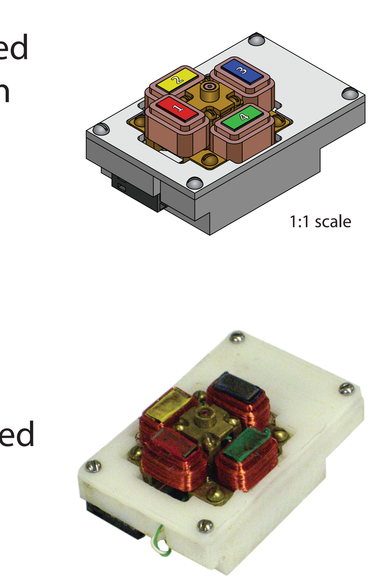
Short and long cores are nested to form a 2D magnetisation yoke.

The flux through each pole is controlled independently, allowing the excitation field orientation to be varied using superposition.

Comparing the BN from multiple field orientations can be used to identify multiple components of stress.

The pickup coil sensing area is restricted to the superposition region by core design & shielding.

The pickup coil and short core are spring-loaded to ensure contact with the feeder curvature.

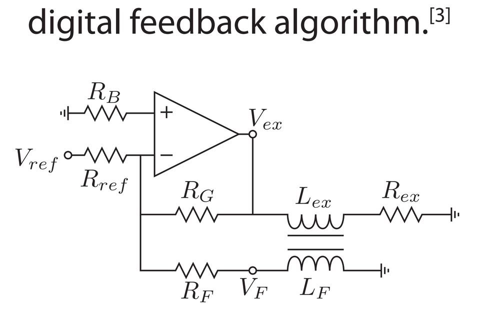


figures from [1]

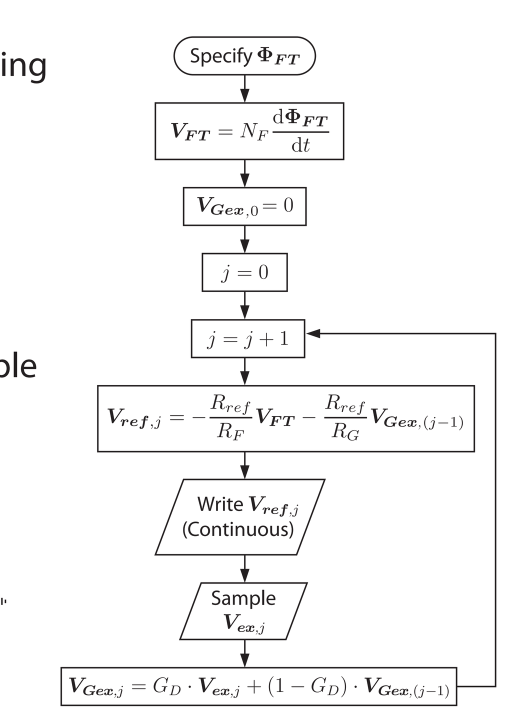
4 Multi-Channel Flux Control

Flux control was achieved using a combination of an analog feedback circuit with digital error correction.

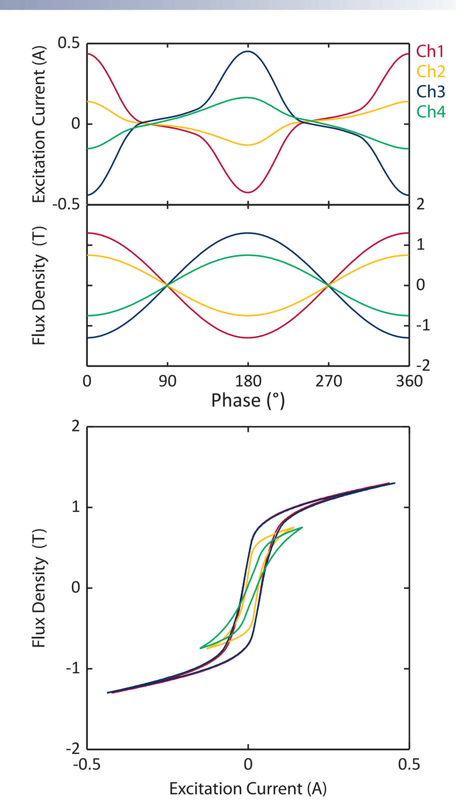
The system converges 95% faster and 10 times more accurately[2] than a comparable digital feedback algorithm.[3]



analog circuit



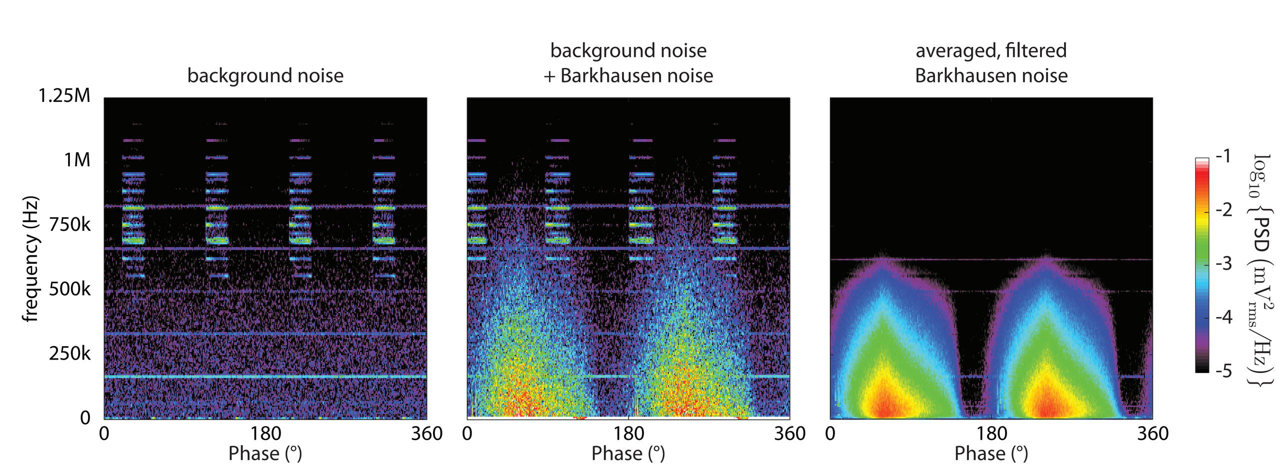
error correction algorithm



typical output

figures & data from [2]

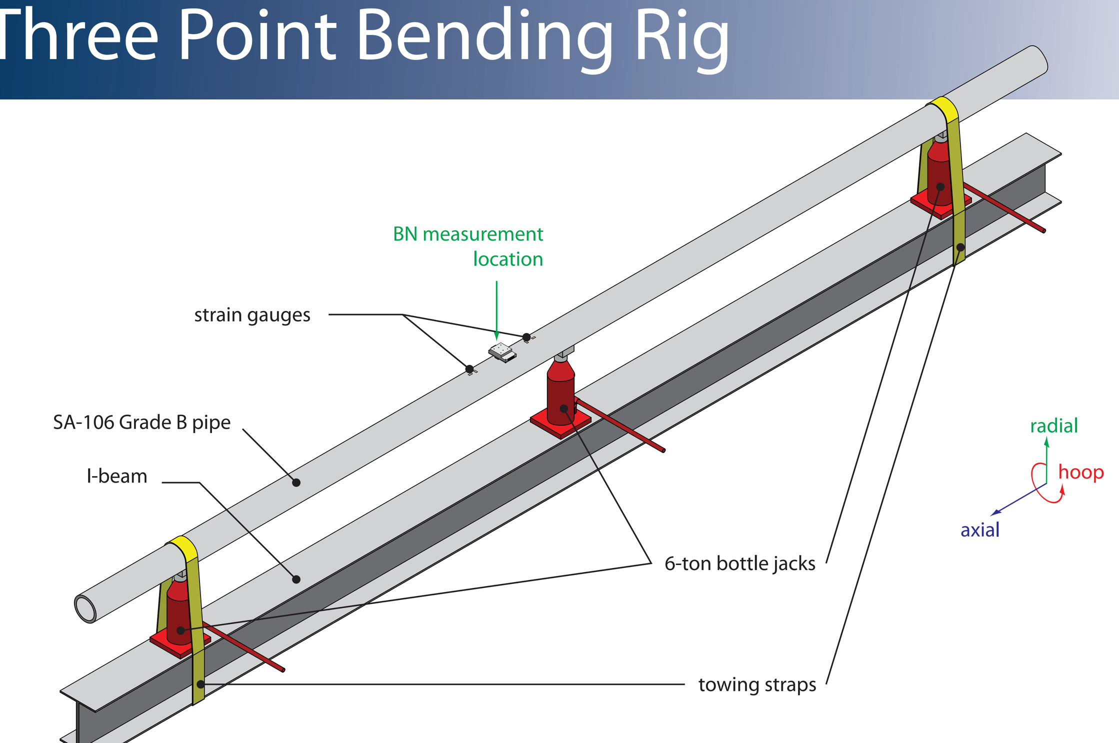
5 Data Analysis



New BN analysis procedures were developed using digital filtering and dynamic power spectral averaging. This provides effective isolation of BN power from background noise, without a need for user-defined thresholds.

figures & data from [1]

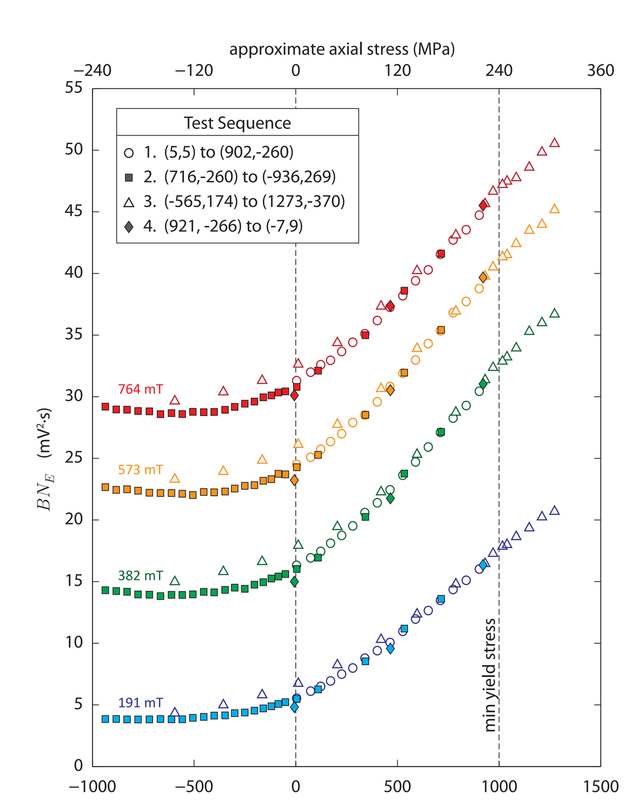
6 Three Point Bending Rig



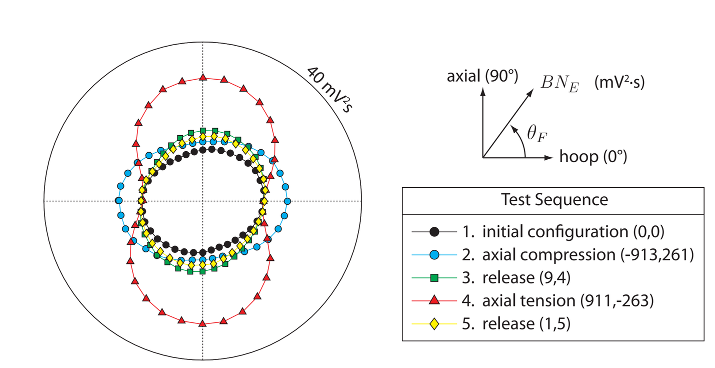
The bending rig was used to estimate BN correlation with stress & strain.

Increasing the field amplitude has little effect on the slope or range of the BN_E variation with stress. Thus, the BN correlation with stress is associated with low excitation fields.

BN anisotropy measurements demonstrate Poisson's effect, and the capability to measure both axial and hoop components of stress under an approximately uniaxial load.



correlation between BN and stress



BN_E anisotropy with stress at 382 mT

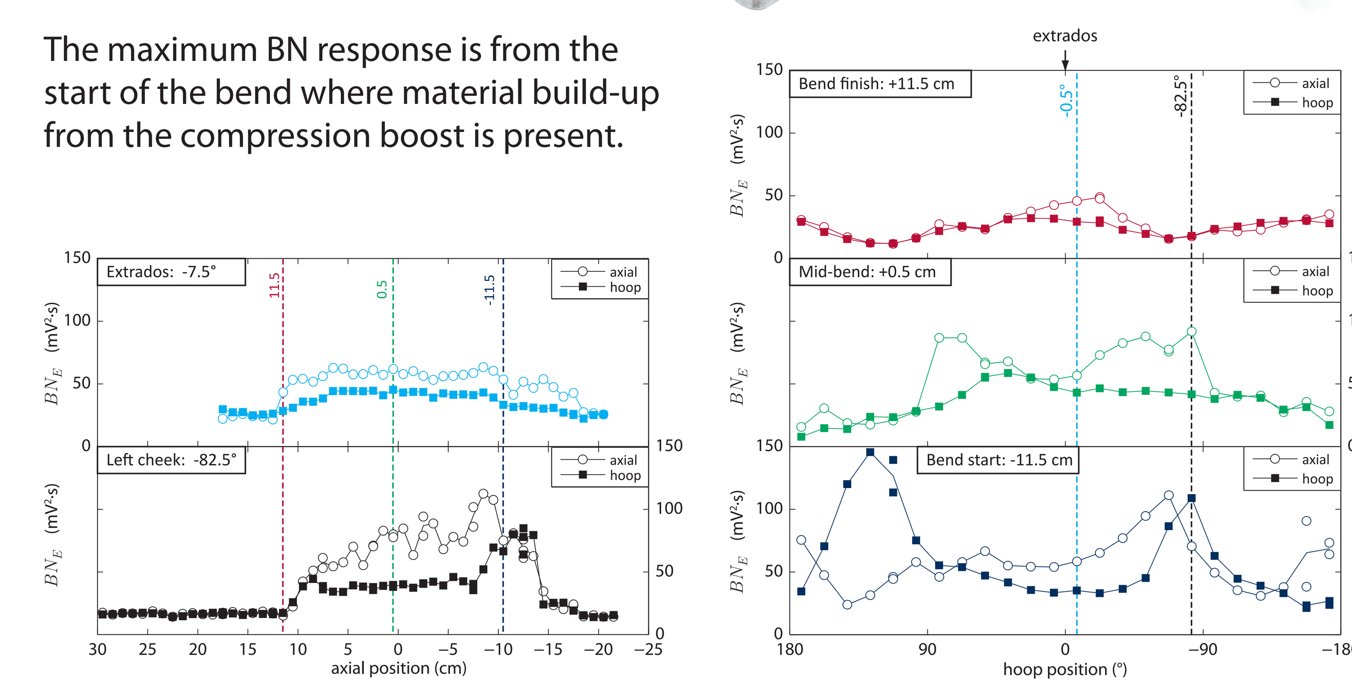
figures & data from [1]

7 T01-5 Feeder Bend Scans

Axial scans show a flat BN response outside the bend.

The scans show increased BN anisotropy in the cheeks compared to the extrados and intrados.

The maximum BN response is from the start of the bend where material build-up from the compression boost is present.



axial scans

hoop scans

figures & data from [1]

8 Conclusions

BN measurements of SA-106 grade B pipes have demonstrated sensitivity to tensile stress under elastic loads, and strong BN variations have been demonstrated in a sample bent using the compression boost technique.

BN testing is capable of providing near-surface estimates of axial and hoop stresses in feeder piping, and could likely be adapted for *in situ* feeder pipe inspection or quality assurance of stress relief during manufacture.

References

[1] S. White, *A Barkhausen Noise Testing System for CANDU Feeder Pipes*, Ph.D. Thesis, Queen's University, 2009.

[2] S. White, T.W. Krause, L. Clapham, *A multi-channel magnetic flux controller for periodic magnetizing conditions*, submitted to *IEEE Transactions on Magnetics*, Sept, 2009. ID: TMAG-09-09-0464

[3] S. Zurek et al., *IEEE Transactions on Magnetics* vol. 41, no. 11., pp. 4242-4249, 2005.

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