Stress Monitoring of Ferromagnetic Steel using Magnetic Barkhausen Noise

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Background - What is MBN?

Magnetic Barkhausen Noise (MBN) is the discontinuous magnetization changes within ferromagnetic steel.
Background - What is MBN?

Correlated with:

- Microstructure and texture.
- Residual and applied stresses.
Background - MBN set-up

- BN frequency > 1 kHz
- Excitation frequency << 1 kHz
- MBN can be isolated by filtering.
- Typical penetration depth: 0.01 to 0.5 mm.
Background - MBN Signal

• Energy

\[ BN_E = \int (BN_{env})^2 \cdot d\phi_F \]

• Peak height

• Position
Advantages and Capabilities of MBN

- High resolution local scans.
- Greater depth of sampling than X-ray.
- Rapid measurements. (3 sec at 50 Hz)
- Relatively low cost.
Flux-Controlled Method

Magnetic circuit: Electromagnet + sample + air gap
Flux-Controlled Method

- Current/voltage control of the excitation magnet.
  - Sensitive to lift-off variations and permeability changes.
  - Distorted wave forms.
Flux-Controlled Method

New method

Flux-controlled measurements.
Flux-Controlled Method

MBN Probe
Flux-Controlled Method

Characteristics

(i) Controls flux within magnetic circuit.

(ii) Compensates for lift-off variations and provides more comparable data between samples.

(iii) Reduces distortions in the periodic magnetic flux waveforms compared to voltage/current controlled systems.
Applications

Applied Magnetics Group (AMG) at Queen’s University in collaboration with Royal Military College of Canada (RMC) have been developing MBN technique for more than 25 years for evaluation of stress and microstructure in various ferromagnetic steels including:

✓ Submarine hull (HY-80)
✓ Oil & Gas Pipelines
✓ Transformer and electric motor steel (Si-Fe laminates)
✓ CANDU feeder pipes
✓ Low-high carbon steels
Applications

Microstructure effects
- carbon content
- grain size
- texture
- core loss

Stress effects
- elastic & plastic deformation
Microstructure Effects
(Carbon Content)

Peak height/position and shape of envelope changes with carbon content.
Microstructure Effects
(Carbon Content)
Microstructure Effects
(Grain Size)

Transformer steel
(cm grain diameter)

Electric motor steel
(micron grain diameter)
Transformer steel has a strong anisotropy in RD direction due to \{110\}(001) Goss texture.
Microstructure Effects
(Core Loss in Transformer Steel)
Stress Effects
(Magnetic Texture)

Uniaxial tensile stress along RD in a transformer steel.
Stress Effects
(Plastic Deformation)

Uniaxial tensile stress along RD in submarine hull and mild steel.
Stress Effects
(Low and High Carbon Steel)

Uniaxial tensile stress along RD in low and high carbon steel.
Magnetic Circuit Measurements
(microstructure)

Flux density measured at the pole
Magnetic Circuit Measurements (microstructure)
Magnetic Circuit Measurements (Stress)

Uniaxial tensile stress along RD.
Conclusion

- Magnetic Barkhausen Noise (MBN) technique exploits changes in magnetic properties to monitor the stress state of ferromagnetic steels.

- MBN is capable of detecting residual stresses, which may develop flaws in the long term such as stress corrosion cracking and fatigue-cycle cracks.

- The AMG in-house designed flux controller provides consistent Barkhausen measurement capability for monitoring stress and microstructural changes in various ferromagnetic steels.