Detection of Grinding Stresses Nondestructively with Magnetic Barkhausen Noise

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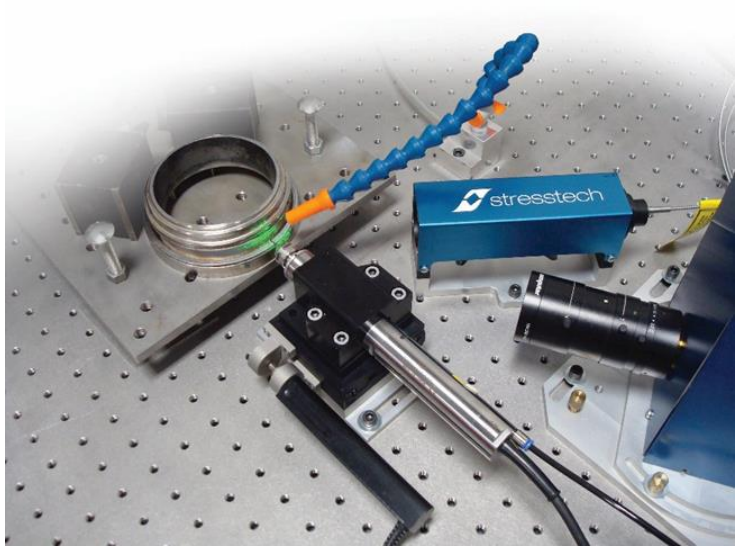
Introduction – MBN Method

X-Ray Diffraction

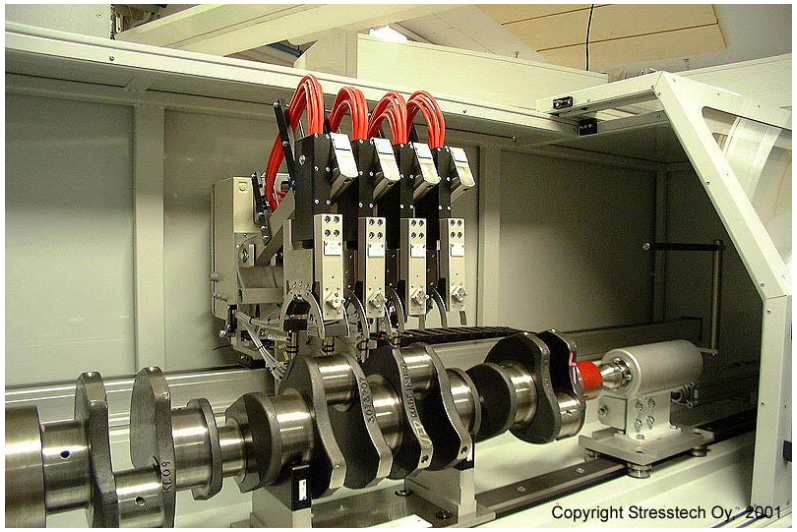


ESPI Hole Drilling

Magnetic Barkhausen Noise Analysis

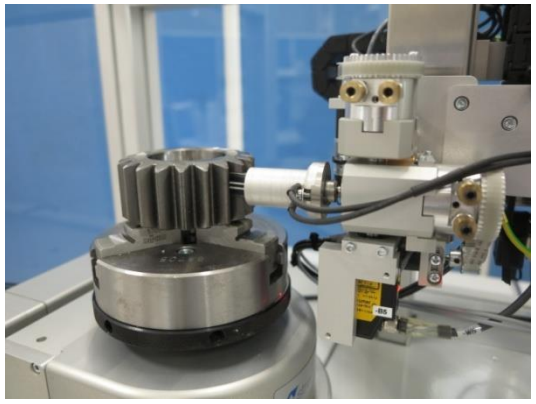
Introduction – MBN Application Examples

bearings

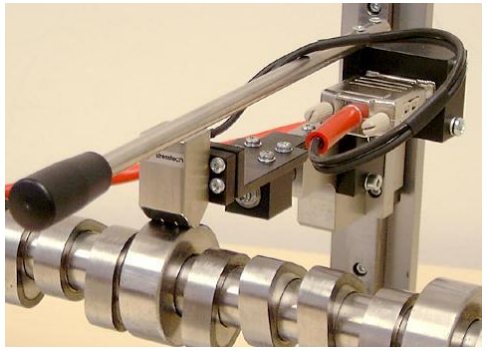


crankshafts

hand testing of gears



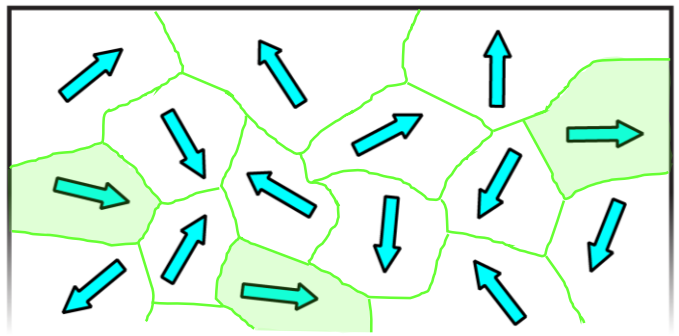
automated gear inspection



camshafts

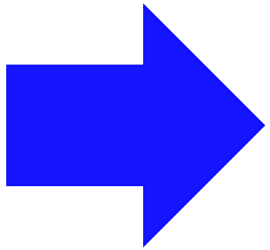
Introduction – Magnetic Barkhausen Noise

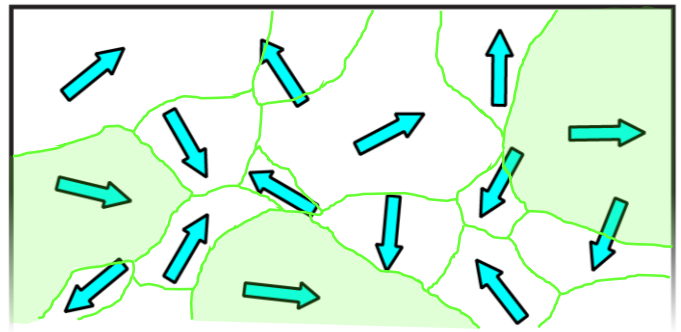
magnetic moments in ferromagnetic material



domain walls

APPLIED FIELD



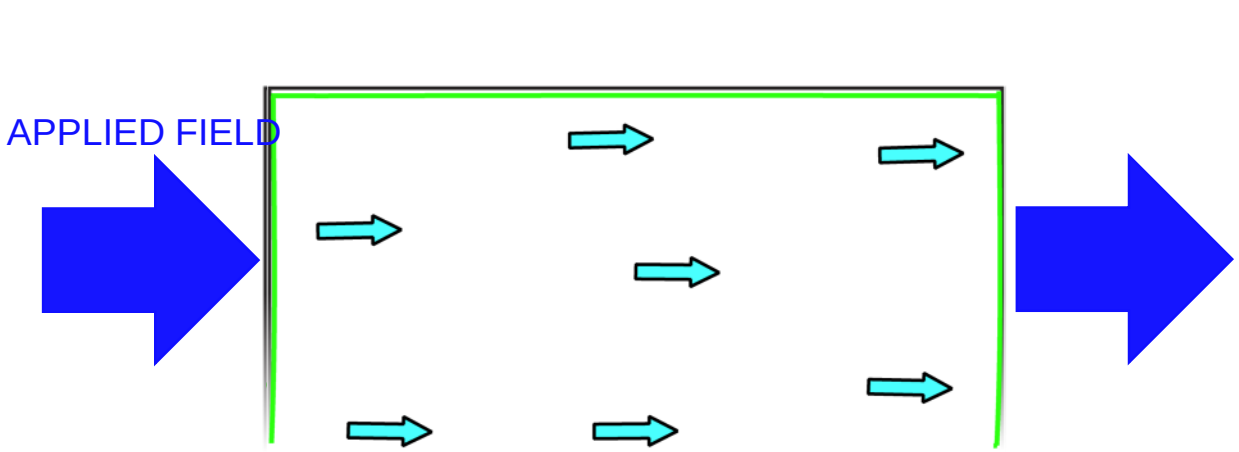


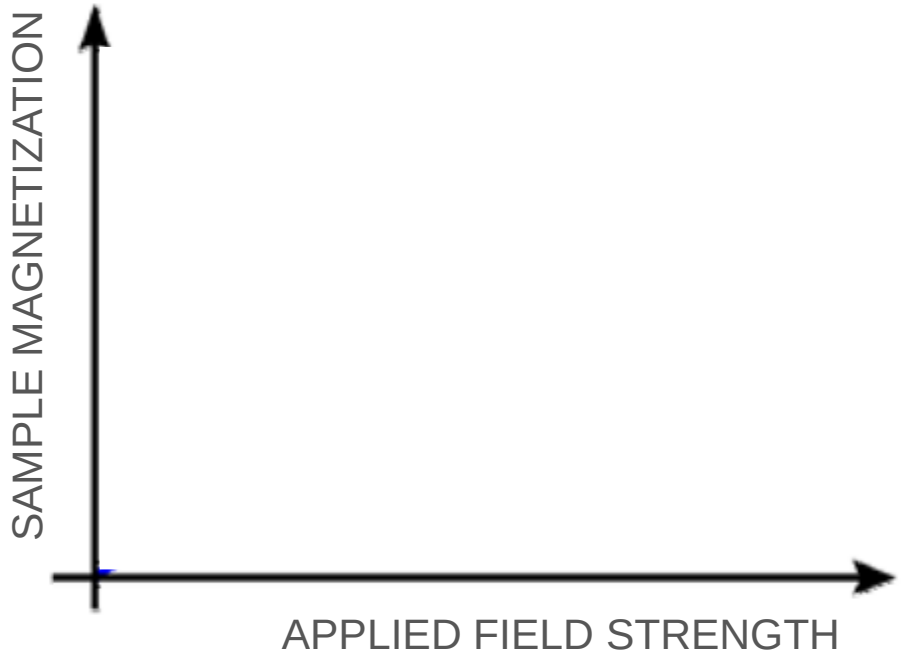
“non-magnetic”:
net zero magnetic field

in a magnetic field:
domain walls move, unfavorably oriented domains shrink

Introduction – Magnetic Barkhausen Noise

As the applied field increases domain walls grow/shrink and net magnetization increases





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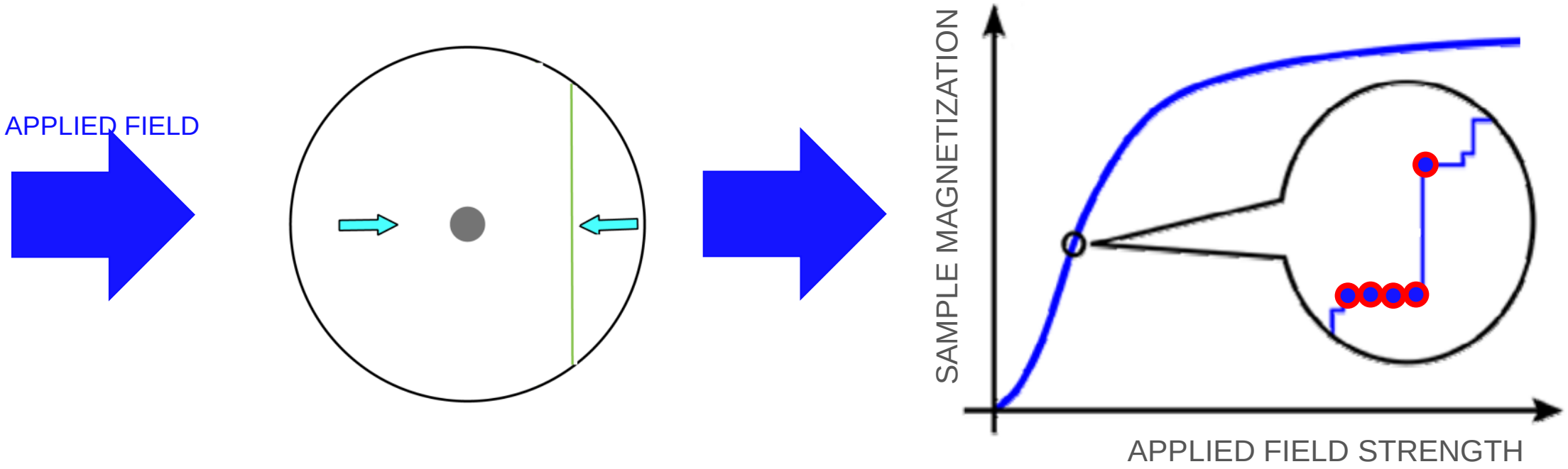
Introduction – Magnetic Barkhausen Noise

As domains grow/shrink they are pinned by obstacles, resulting in steps or “jumps”



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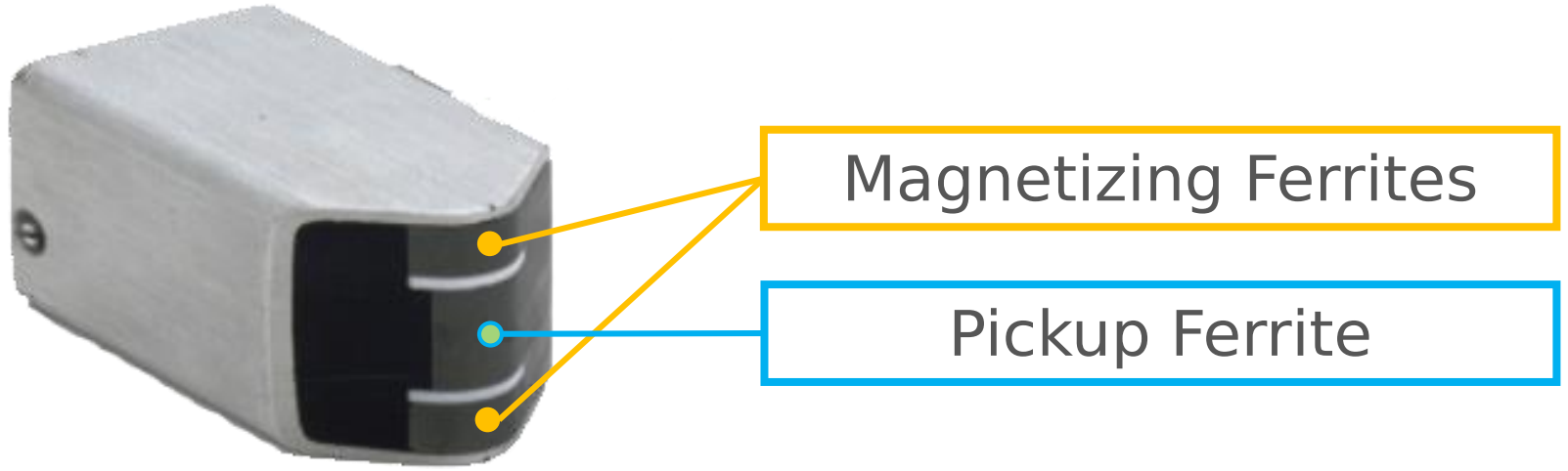
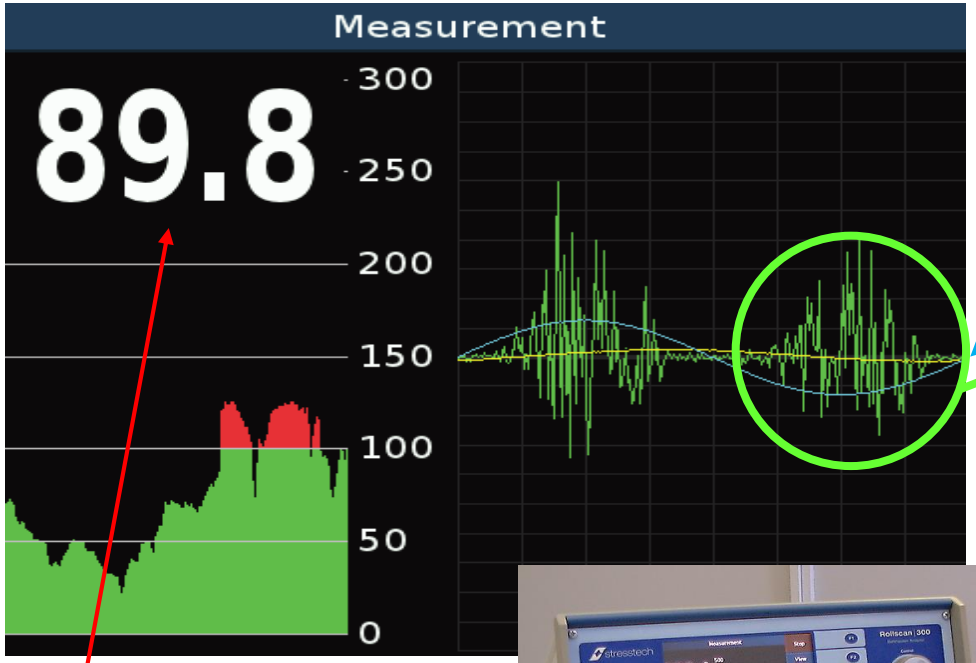
MBN Technique – Sensor



Sensors

- apply an alternating magnetic field to the part
- measure the response of the material (pickup)

MBN Technique – Signal Analysis



alternating external field

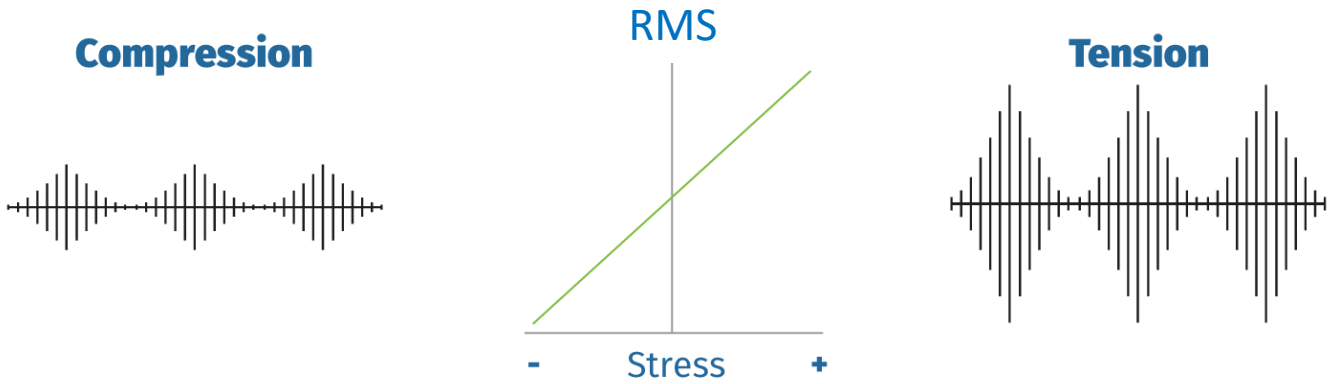
Barkhausen burst

RMS value

- signal filtered and amplified
- root mean square (RMS) is calculated in real-time

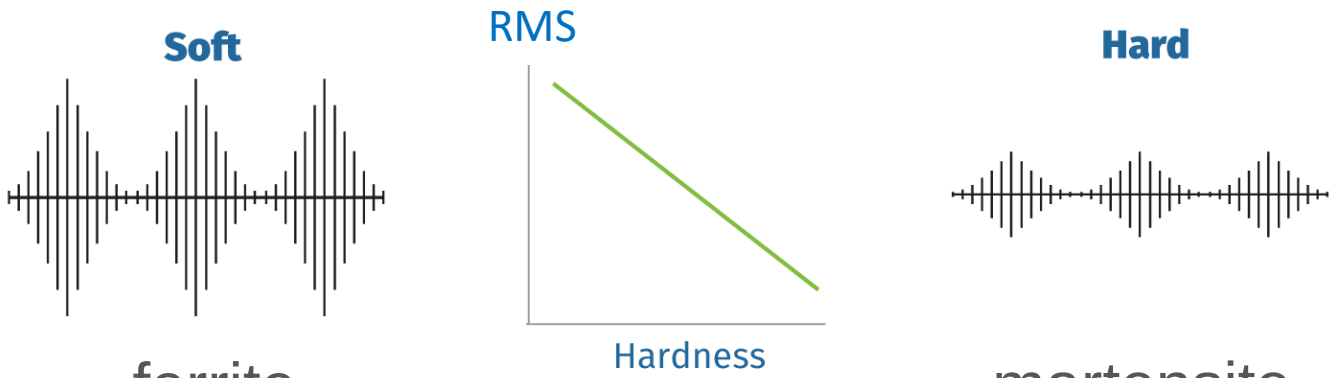
MBN Technique – Barkhausen Noise Factors

stress



hardness

(% martensite, % C, less temper)



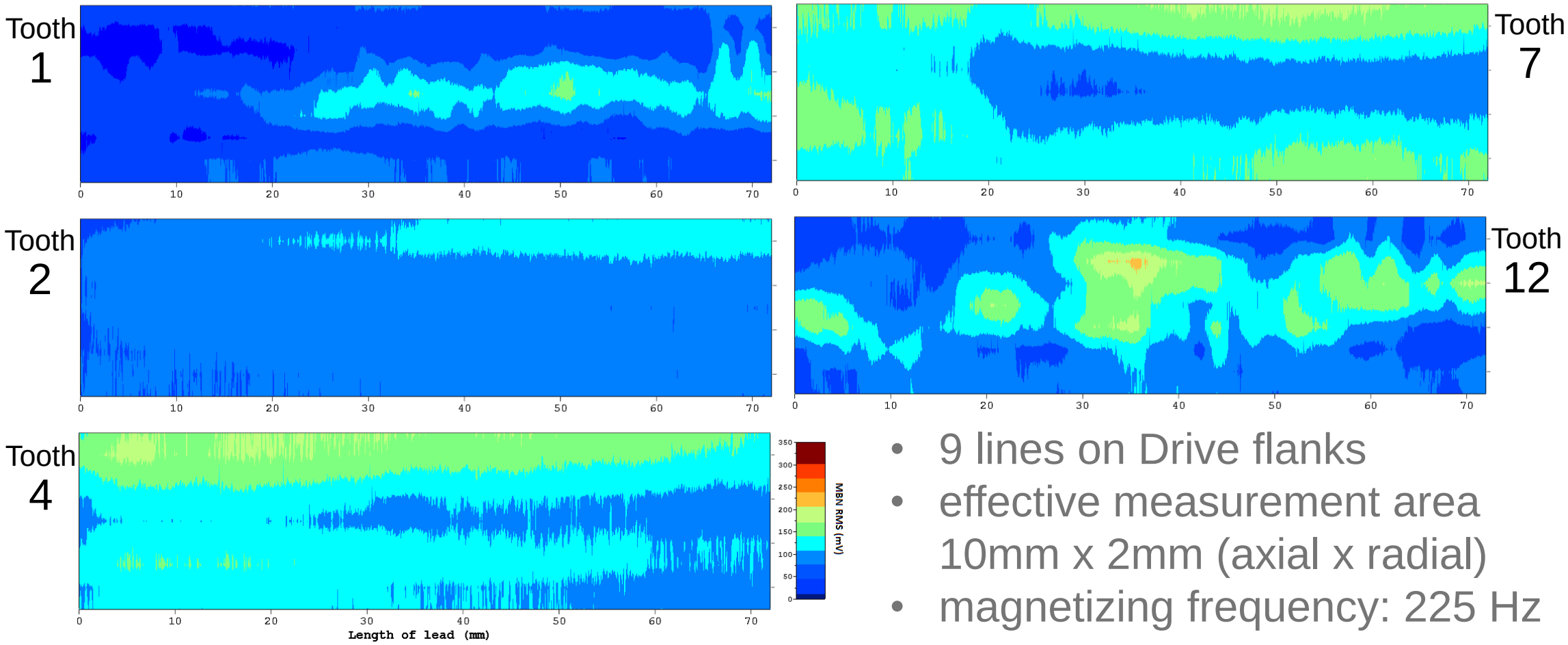
ferrite

martensite

Grind Temper Study - Experimental

- ground AISI 3310 gears; no peening
- single wheel; single pass per space, no dressing; progressively increasing friction (gear temperature)
- Barkhausen noise analysis; residual stress measurement by X-ray Diffraction

Grind Temper Study - MBN Measurement (RMS)



- 9 lines on Drive flanks
- effective measurement area 10mm x 2mm (axial x radial)
- magnetizing frequency: 225 Hz

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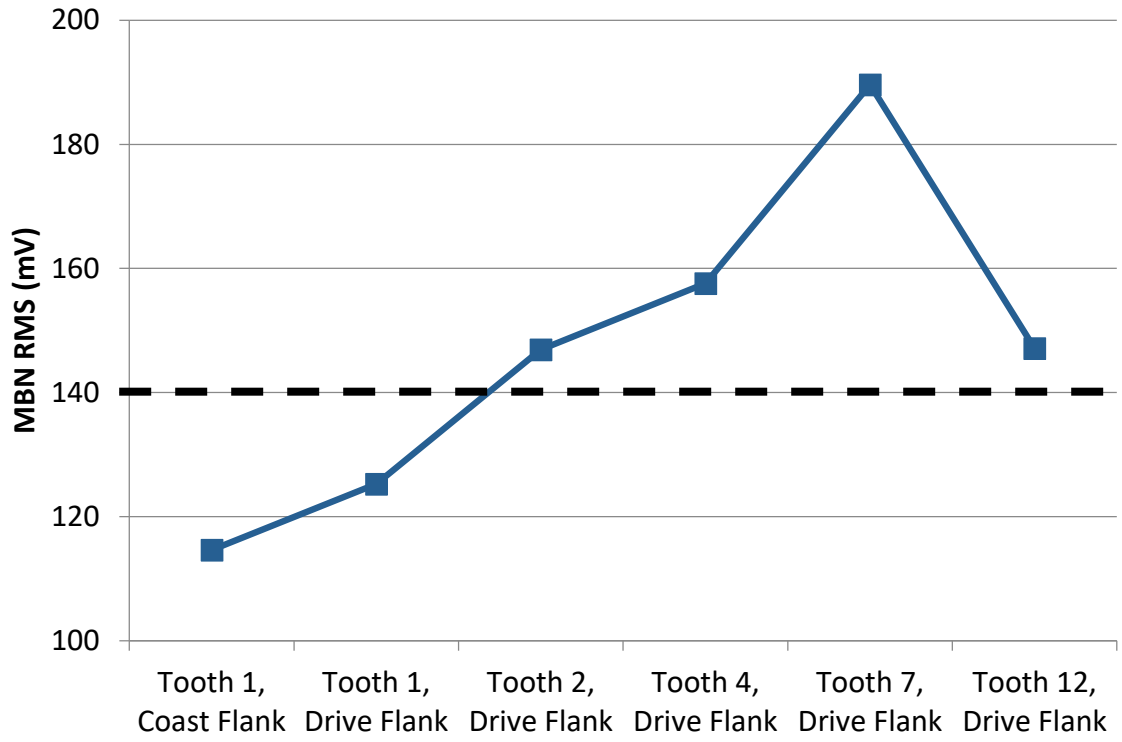
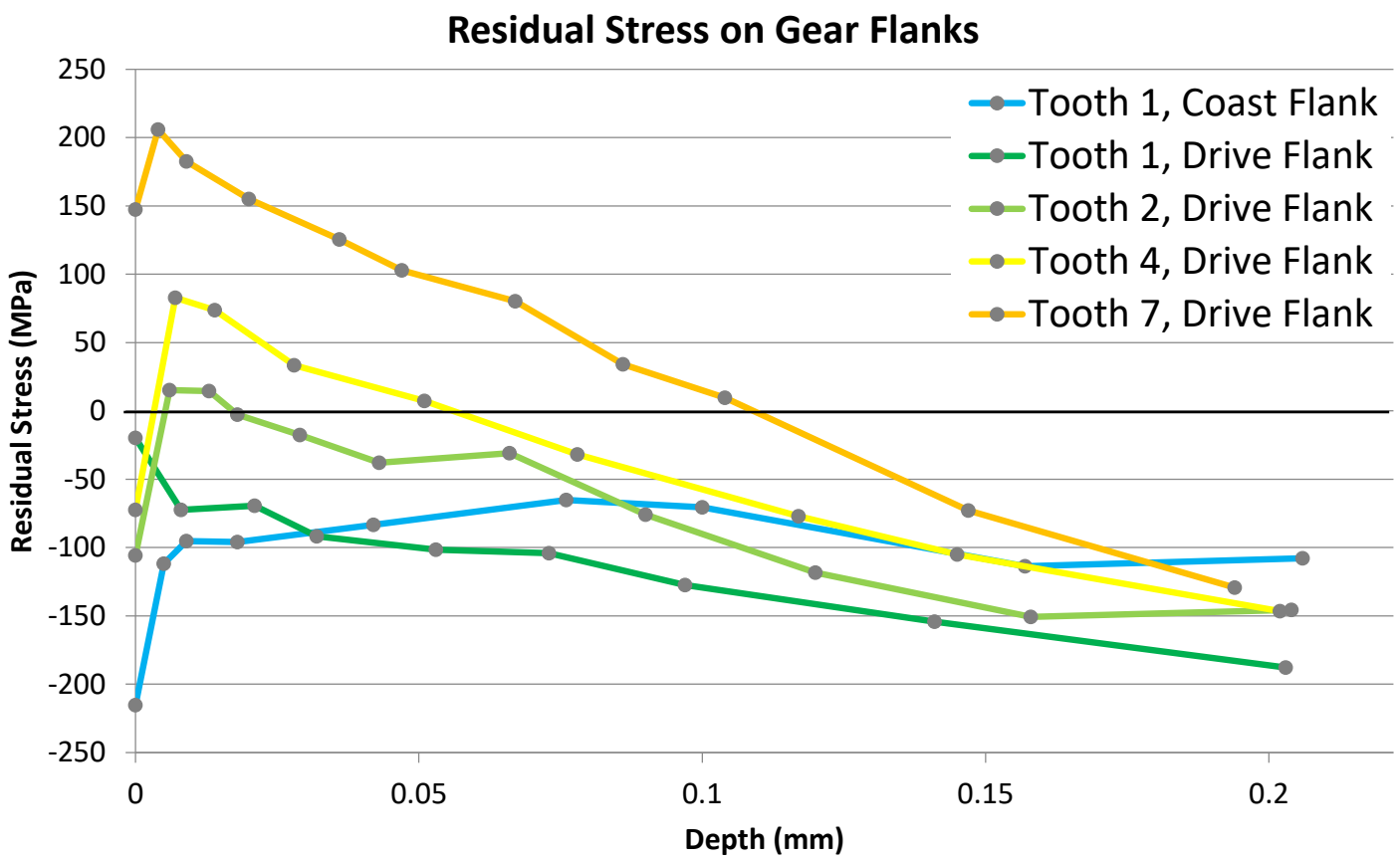
Grind Temper Study - MBN Measurement



- data for single location at the pitch diameter on each of 6 flanks (to be measured by XRD)
- progressively increasing RMS value – up to Tooth 12
- Tooth 12 breaks the trend, but RMS value is higher than the established limit (140 mV)

Grind Temper Study - XRD Results



- residual stress increases from tooth to tooth during grinding process
- typical core stresses retained from about 0.2 mm
- tensile stresses below the surface (grind temper) starting with Tooth 2

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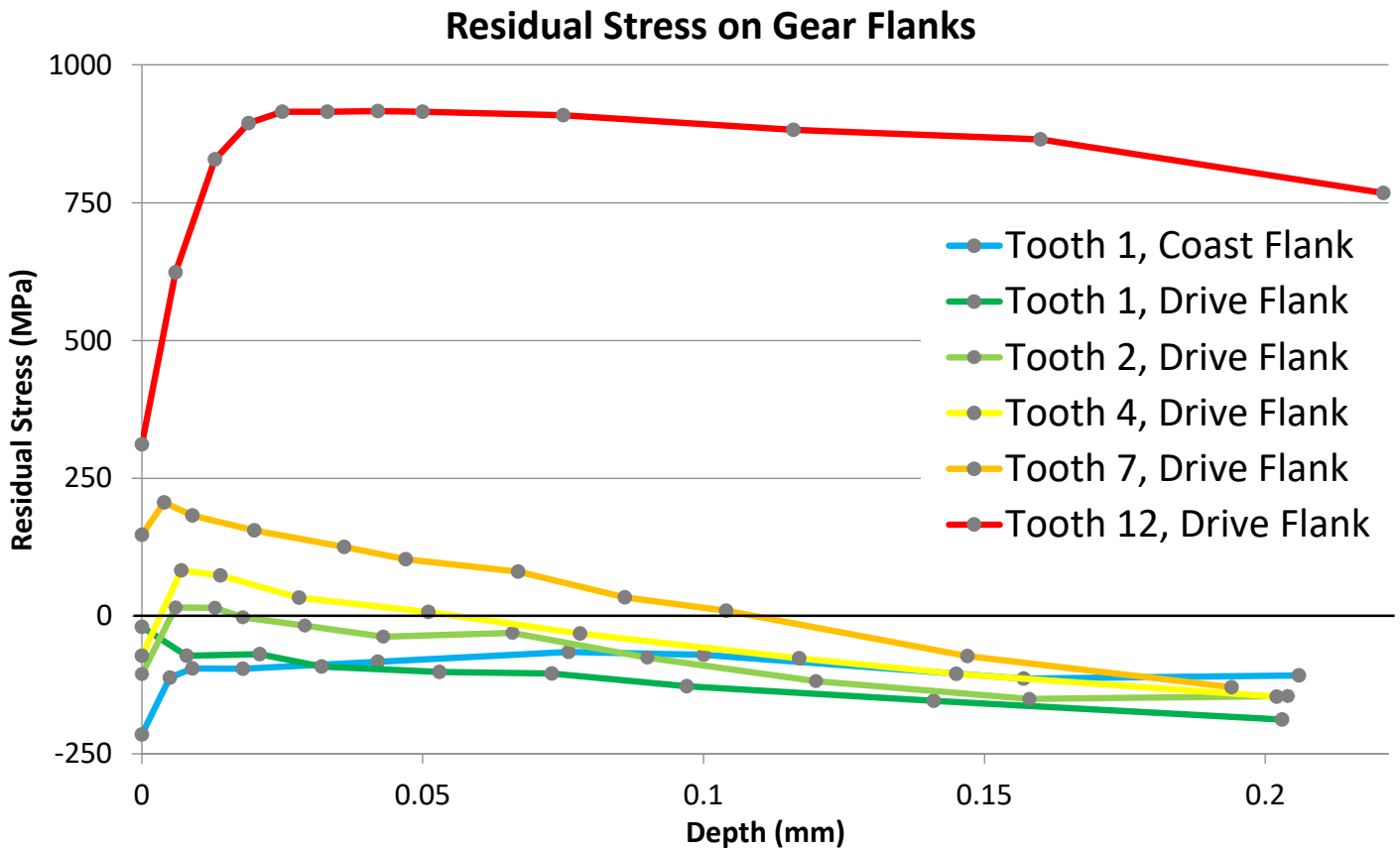
Grind Temper Study - XRD Results



Tooth 12

- extremely large tensile stresses
- grinding produced a lot of deformation and heating
- heat results in tempered martensite

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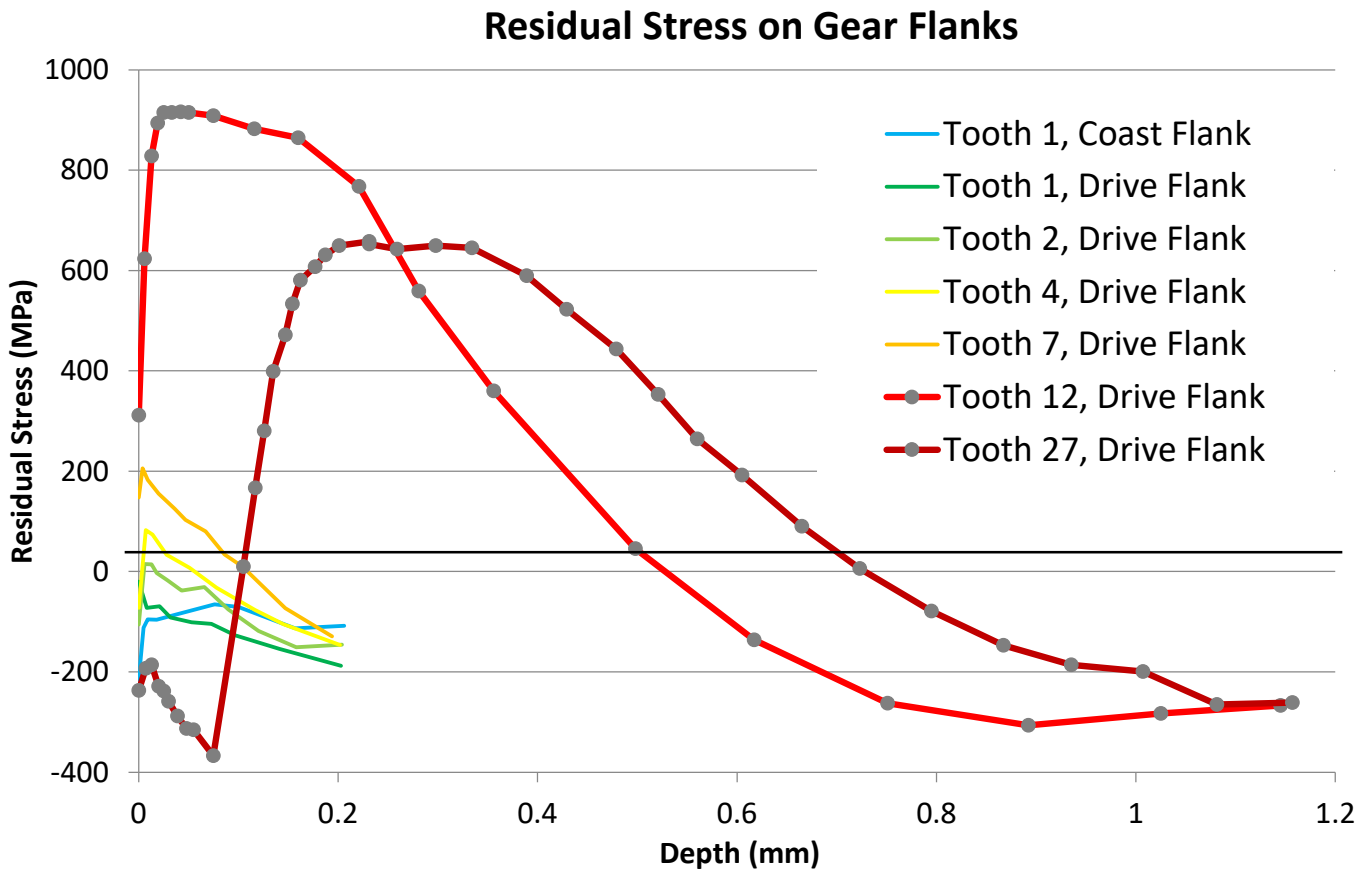
Grind Temper Study - XRD Results



Tooth 27

- quite compressive surface stresses
- high tensile stresses below, over a large depth range (grind temper)

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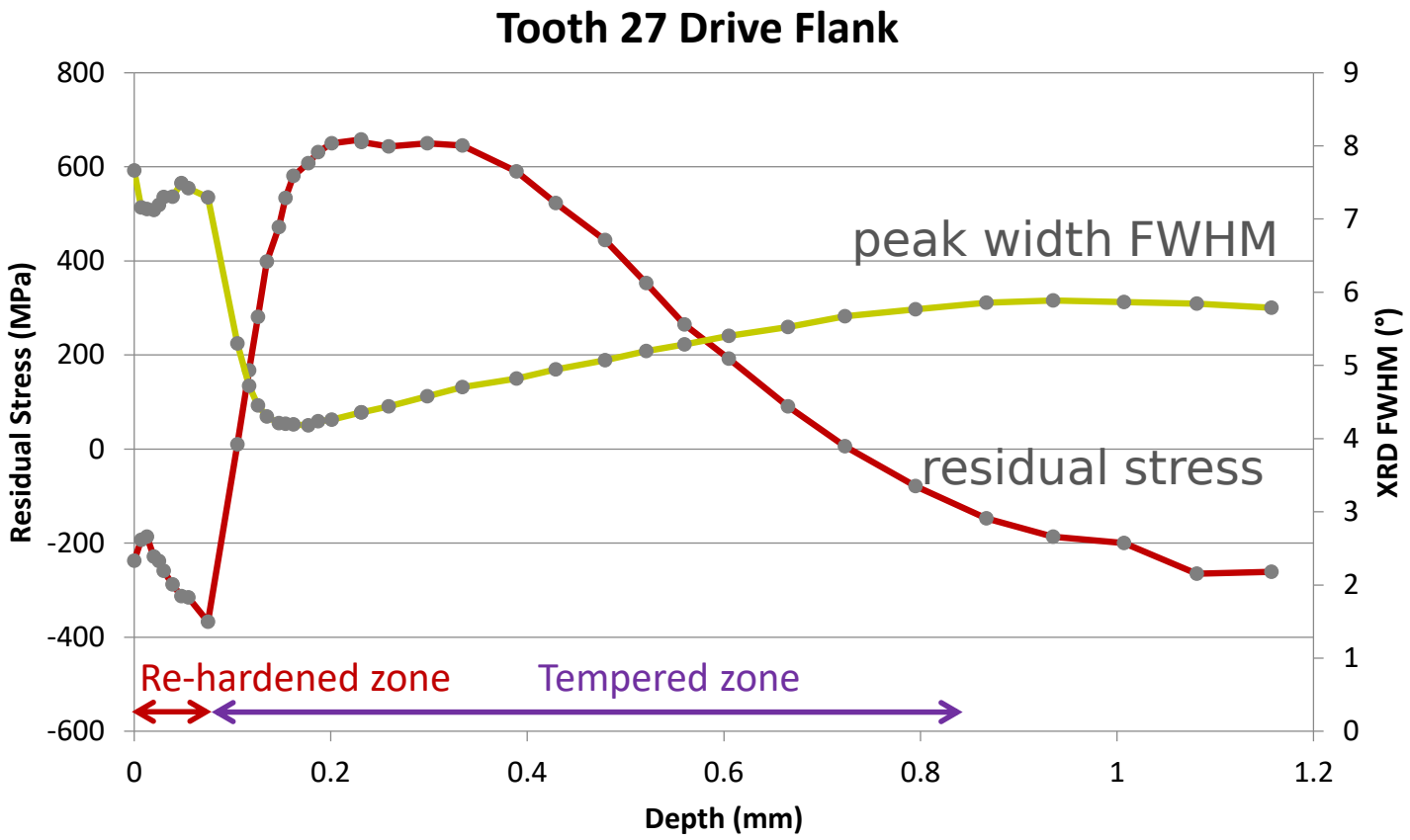
Grind Temper Study - XRD Results



Tooth 27

- peak width is high near surface, then drops sharply, then increases gradually
- re-hardening: grinding heats the surface (austenitizing), the coolant quenches it

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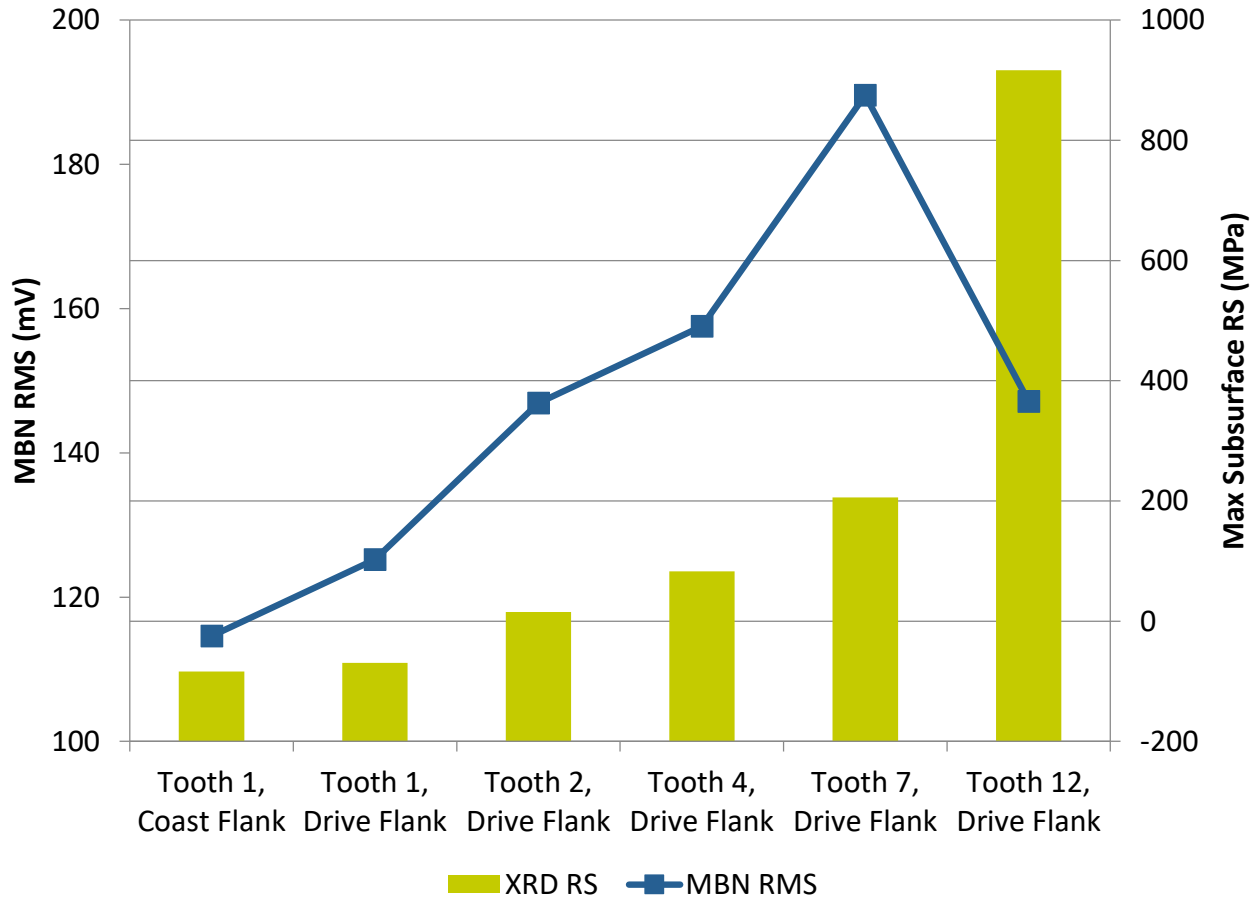
Grind Temper Study – Comparison MBN - XRD



- residual stresses increase steadily with continued grinding
- RMS values increase up to Tooth 12, but then drop
- suggests change in microstructure (higher hardness)

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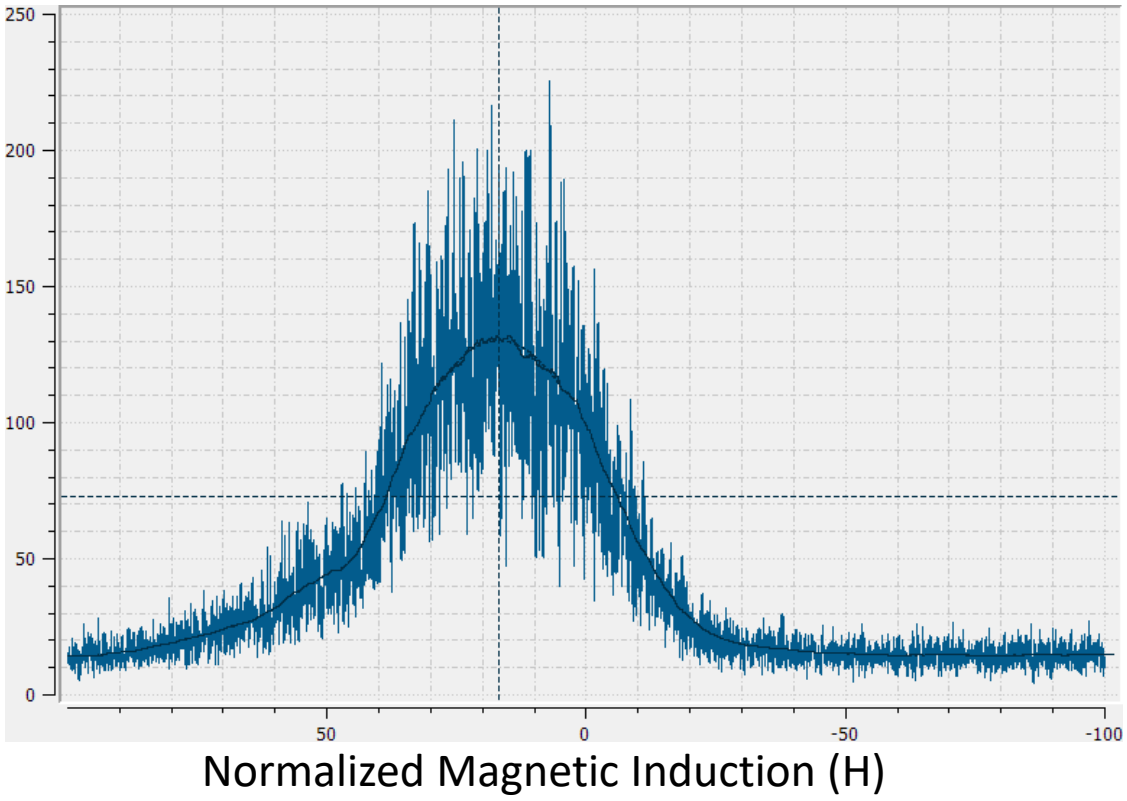
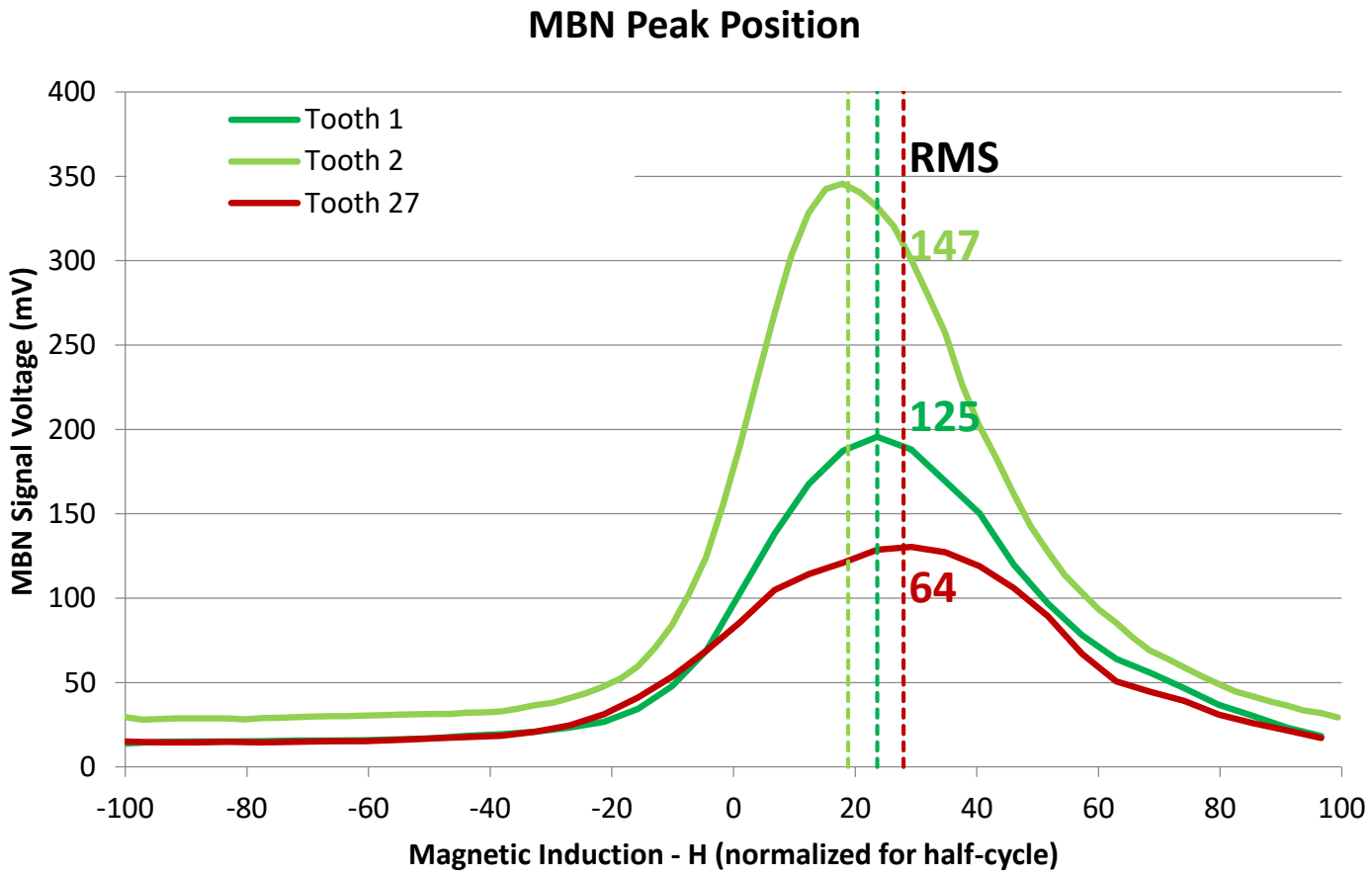
Grind Temper Study – MBN Analysis

Example of rectified BN signal Burst



- RMS (root mean square) is the traditional measure used for Barkhausen noise analysis
- MBN Peak Position is correlated with coercivity and characteristic for the microstructure (sensitive to microstructural changes)

Grind Temper Study – MBN Peak Position



- more-tensile stresses and grind temper move the peak to lower values (lower coercivity)
- re-hardening moves the peak up

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Summary - MBN Applications

analysis of RMS for

- general detection of grinding burn
- detection of heat treat defects

analysis of MBN Peak Position for

- identifying re-hardening

further analysis of the MBN Signal for

- measuring case depth