

Magnetization mechanisms for the non-destructive evaluation of early-stage thermal oxidation (corrosion) in low-carbon steels

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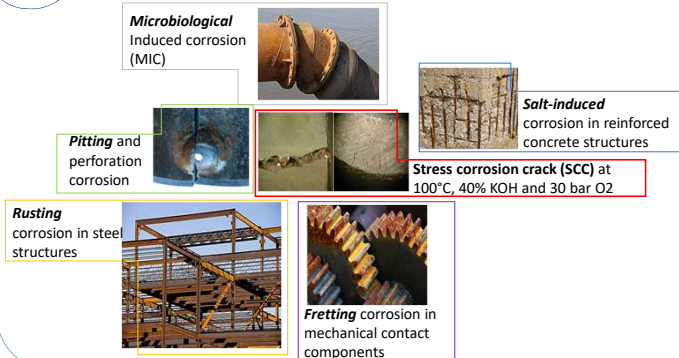
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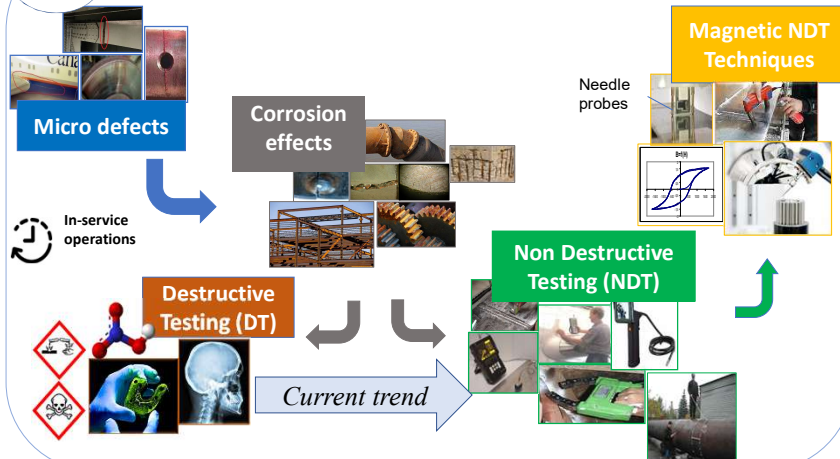
Summary

Low-carbon steel undergoes corrosion during its service life, bringing about failures and substantial financial losses. Magnetic non-destructive testing techniques have been used in assessing the changes that occur on the surface and subsurface when subjected to highly corrosive environments, and their viability has been established. However, limited work has been conducted to detect changes in micro-structural properties due to early-stage corrosion, corresponding to a corrosion level hardly detectable with conventional methods. In this work, an investigation is done to identify the magnetic non-destructive testing technique and associated indicators that present the most distinguishable response to changes in steel properties due to the onset and evolution of starting corrosion. This is found by measuring magnetic responses, including the magnetic hysteresis cycle (MHC), Magnetic Barkhausen Noise (MBN), and Magnetic Incremental Permeability (MIP) at the early stage of corrosion. The most responsive indicators are established through linear Pearson's correlation coefficient comparing them with weight change and corrosion destructive observations.

1 The Impact of Metal Corrosion



2 Metal Corrosion Detection Technics



4 Sample Preparation



6 Indicators Correlation Analysis

Magnetization Mechanism	Indicators	$B_a(H_{surf})$	$MBN_e(H_{surf})$	$ Z _{MIP}(H_{surf})$
• Domain Wall's Irreversible Motions Coercivity - DWIM		0.7754	0.5452	0.6612
• Macroscopic Eddy Currents - MEC	Remanence	0.5364	0.7177	0.0723
• Magnetic Hysteresis Area - MHA	Hysteresis area	0.7554	0.6772	0.3206
• Magnetization Rotation - MR	$\mu_{r(sat)} - B_a(H_{surf})$	0.4614	-	-
• Domain Wall Dynamic Answer - DWDA	$\max(MBN_e)$	-	0.7258	-
• Domain Wall Bulging - DWB	$\Delta Z _{MIP}$	-	-	0.163

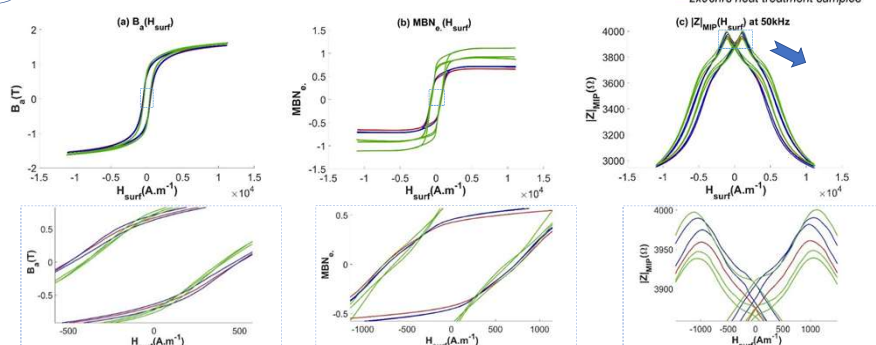
Pearson's (r) grading

$r < 0.5$
$0.5 \leq r < 0.6$
$0.6 \leq r < 0.7$
$0.7 \leq r < 0.75$
$0.75 \leq r < 0.8$
$0.8 \leq r$

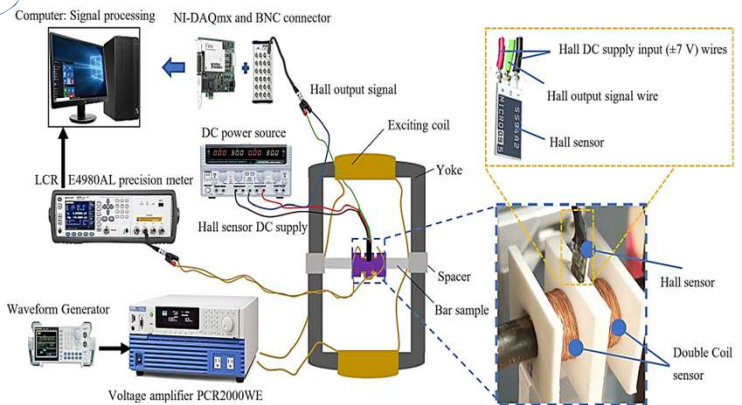
Key:

— Control sample
— 1x96hrs heat treatment samples
— 2x96hrs heat treatment samples

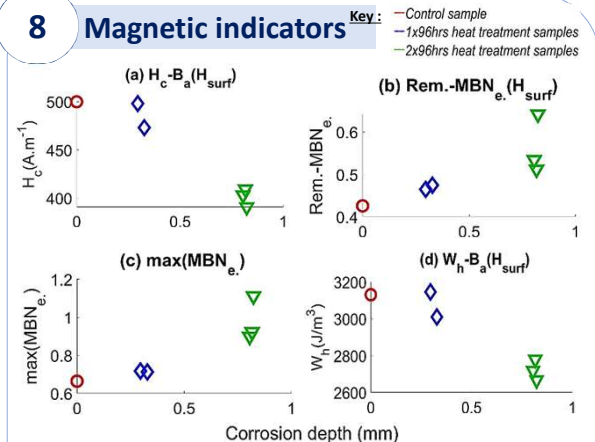
5 Magnetic characterization results



3 Experimental Set-up for NDT measurement



8 Magnetic indicators



Perspectives:

- Investigation of NDT magnetic mechanisms on moisture induced corrosion effects
- Mathematical modelling of Magnetic systems.