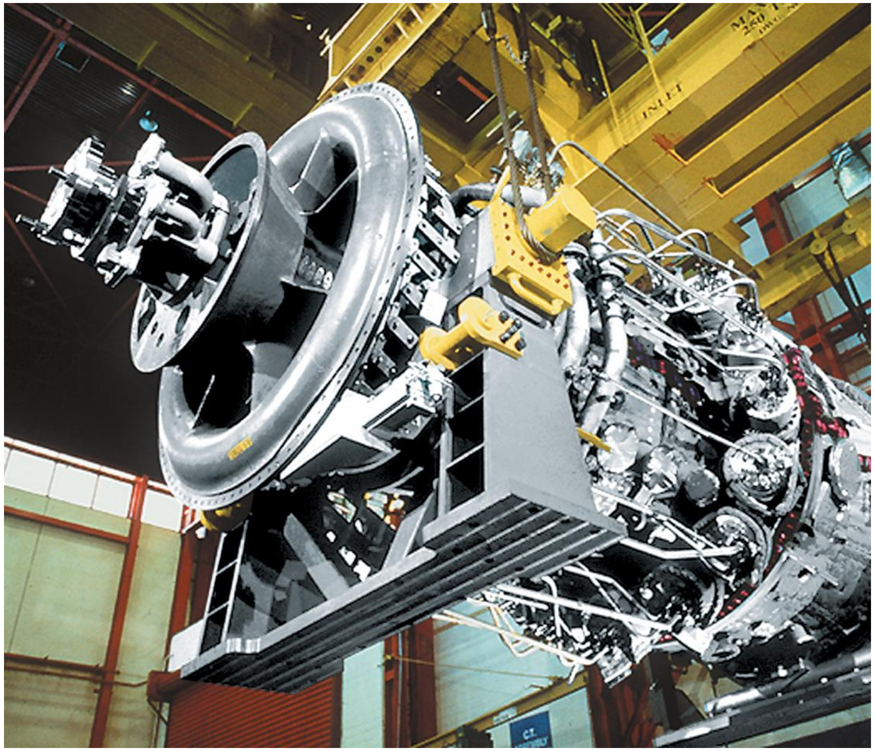


Validation of Multi-Frequency Eddy Current MWM® Sensors and MWM-Arrays for Coating Production Quality and Refurbishment Assessment

Vladimir Zilberstein, Ian Shay, Robert Lyons, Neil Goldfine

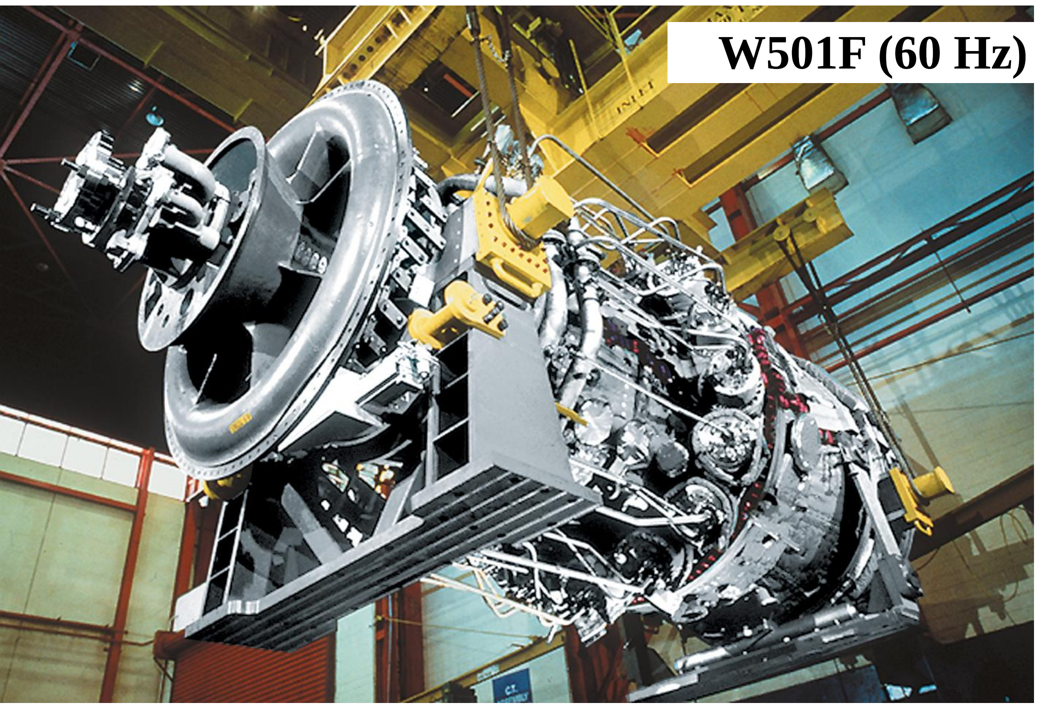
JENTEK Sensors, Inc.

Thomas Malow, Ralph Reiche

Siemens Power Generation

June 16-19, 2003

Siemens Power Generation Gas Turbine Models

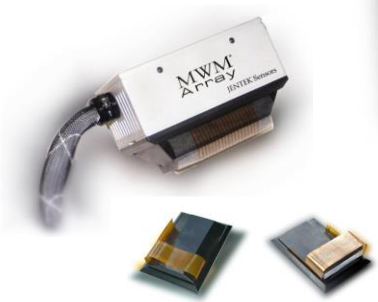


Uncoated turbine blade (rotating component) and vane (stationary component)

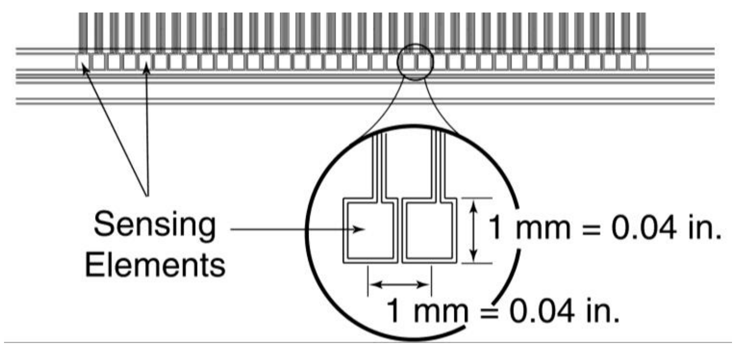
JENTEK Instrumentation, Software, MWM Sensors and MWM-Arrays

- Conformable sensors and MWM-Arrays
- Multi-frequency measurements (1 kHz to 40 MHz)
- Bi-directional measurements (anisotropy)
- Multi-Channel Instrumentation
- Multiple unknown algorithms
- GridStation® software

MWM-Array Probe & Interchangeable MWM-Array Tips

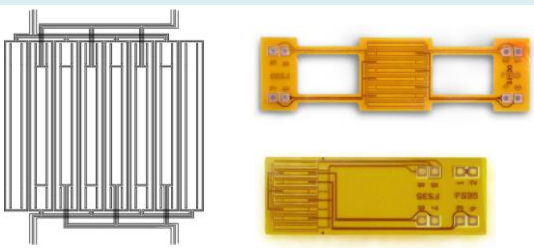


7-Channel System; Available up to 39 channels

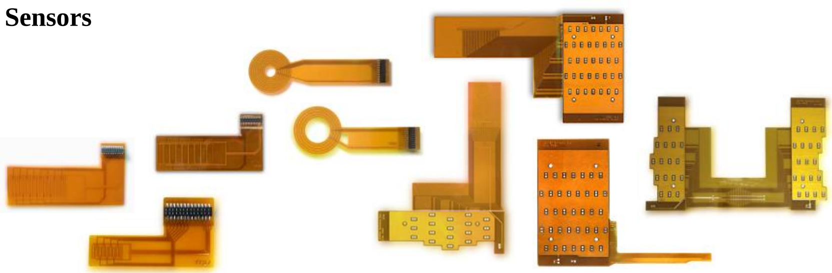


Interchangeable Tips

Single Channel MWM Probe

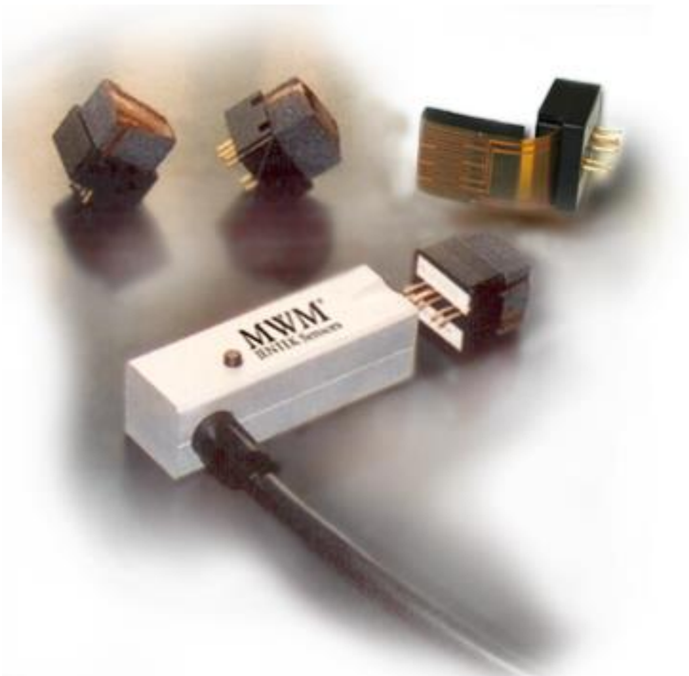


Single Sensing MWM Sensors



...

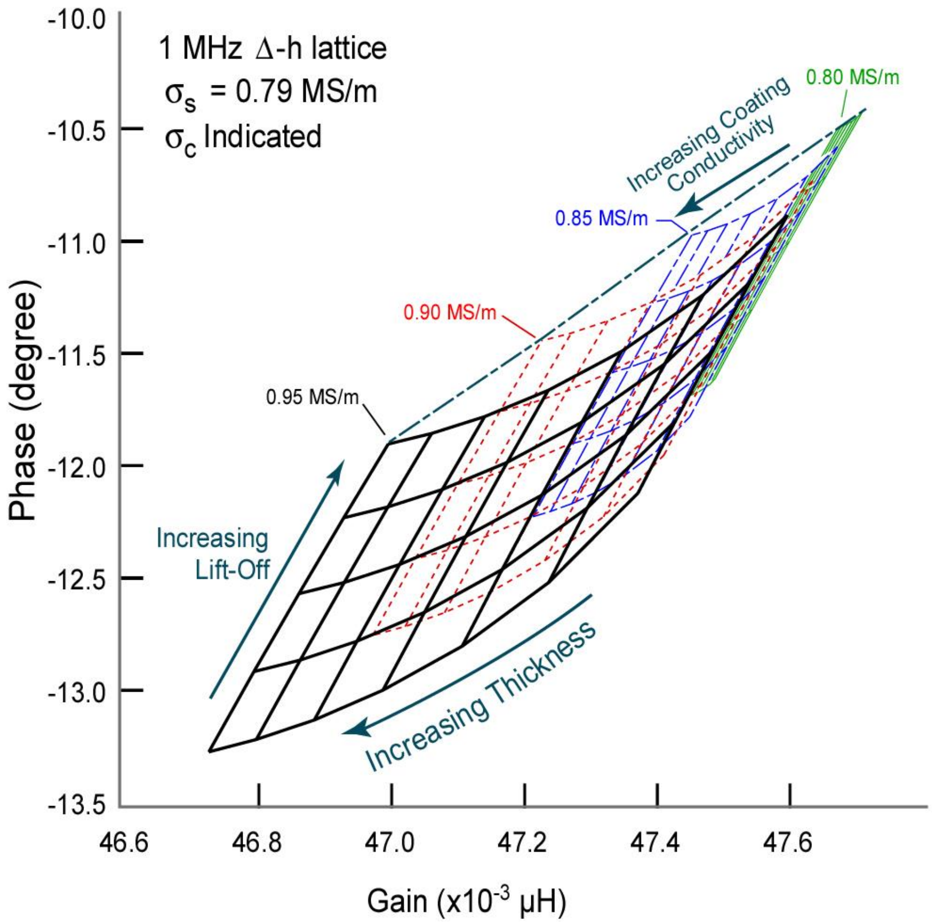
Example MWM-Arrays

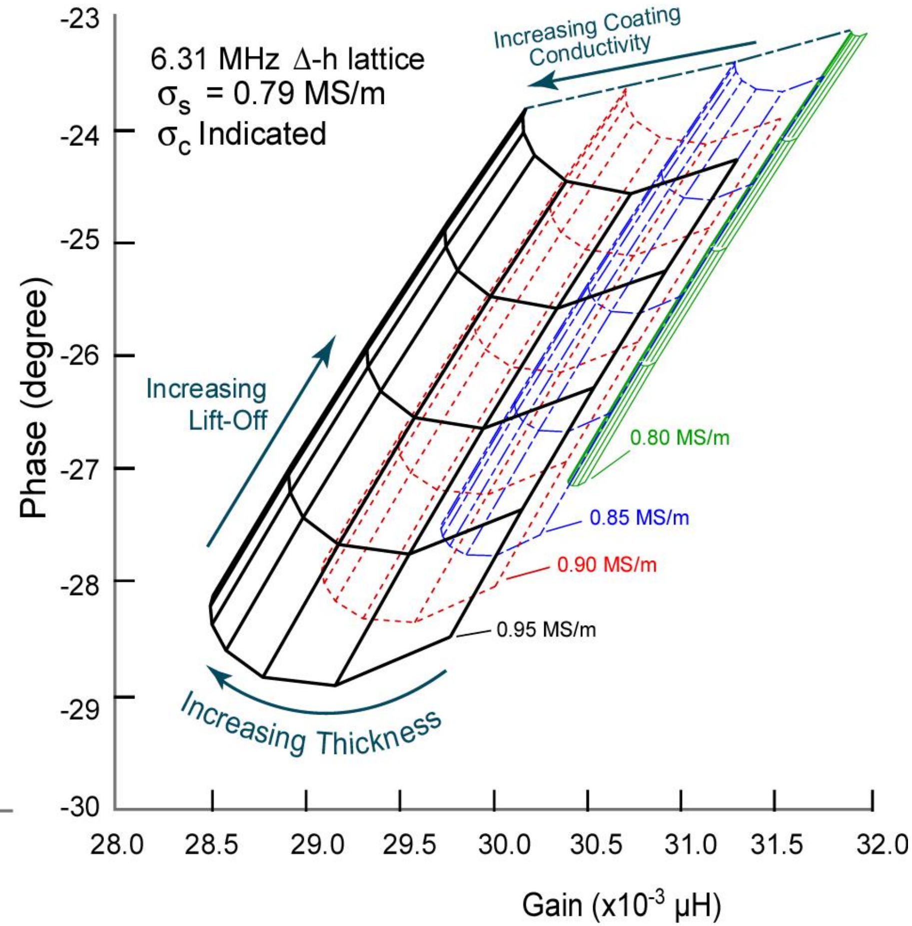


MWM Single-Channel Probe and Interchangeable Probe Tips

MWM-Array Probe

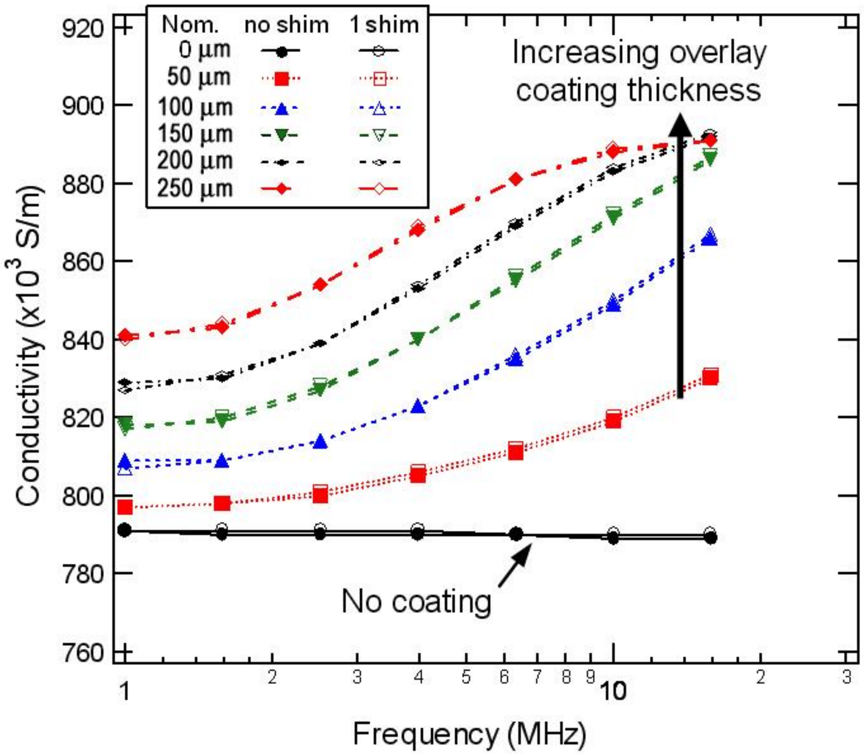
Coating Thickness - Lift-off Grid Lattices for MCrAlY Coating Family

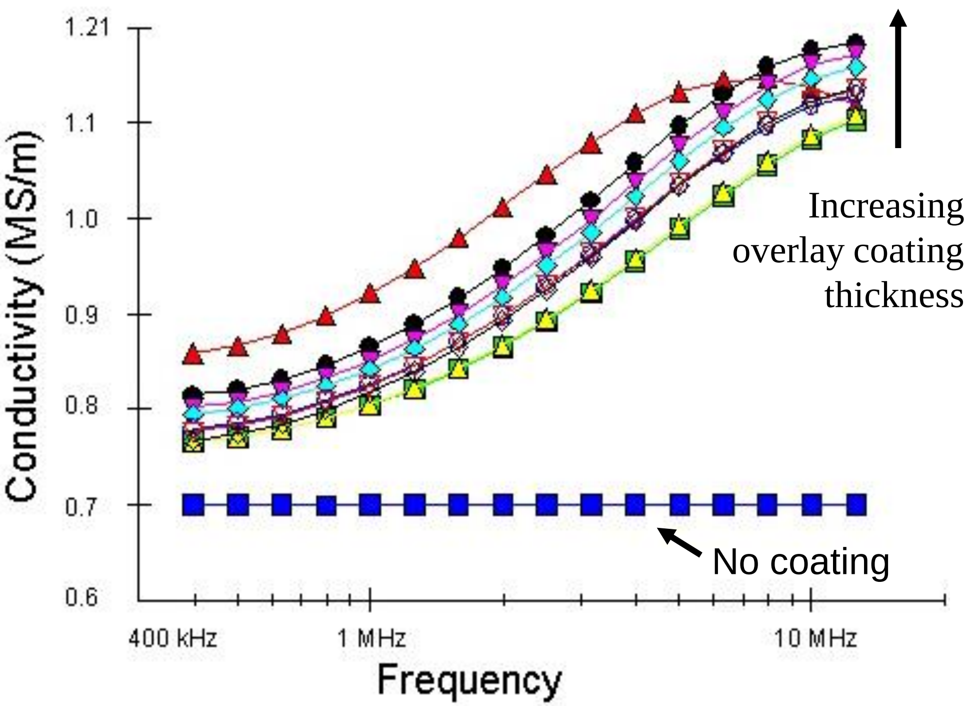




Effective Conductivity as a Function of Frequency for Uncoated and Coated Material

(Left) Results from an earlier study; (Right) results for coated alloy 1





Note that the results are essentially not affected by increasing lift-off, i.e., by adding a 25-µm thick shim between the sensor and part.

Motivation, Objective, and Scope

Motivation

- Thickness measurements of MCrAlY coatings after diffusion heat treatment pose an especially tough problem for conventional eddy current technology
- MWM sensors with grid methods provide a potential solution

Objective

- Evaluate and qualify MWM with grid methods for characterization of MCrAlY coatings

Scope

- Three different superalloy substrates
- Nickel-based and cobalt-based
- All of the examined MCrAlY coatings had gone through the diffusion heat treatment

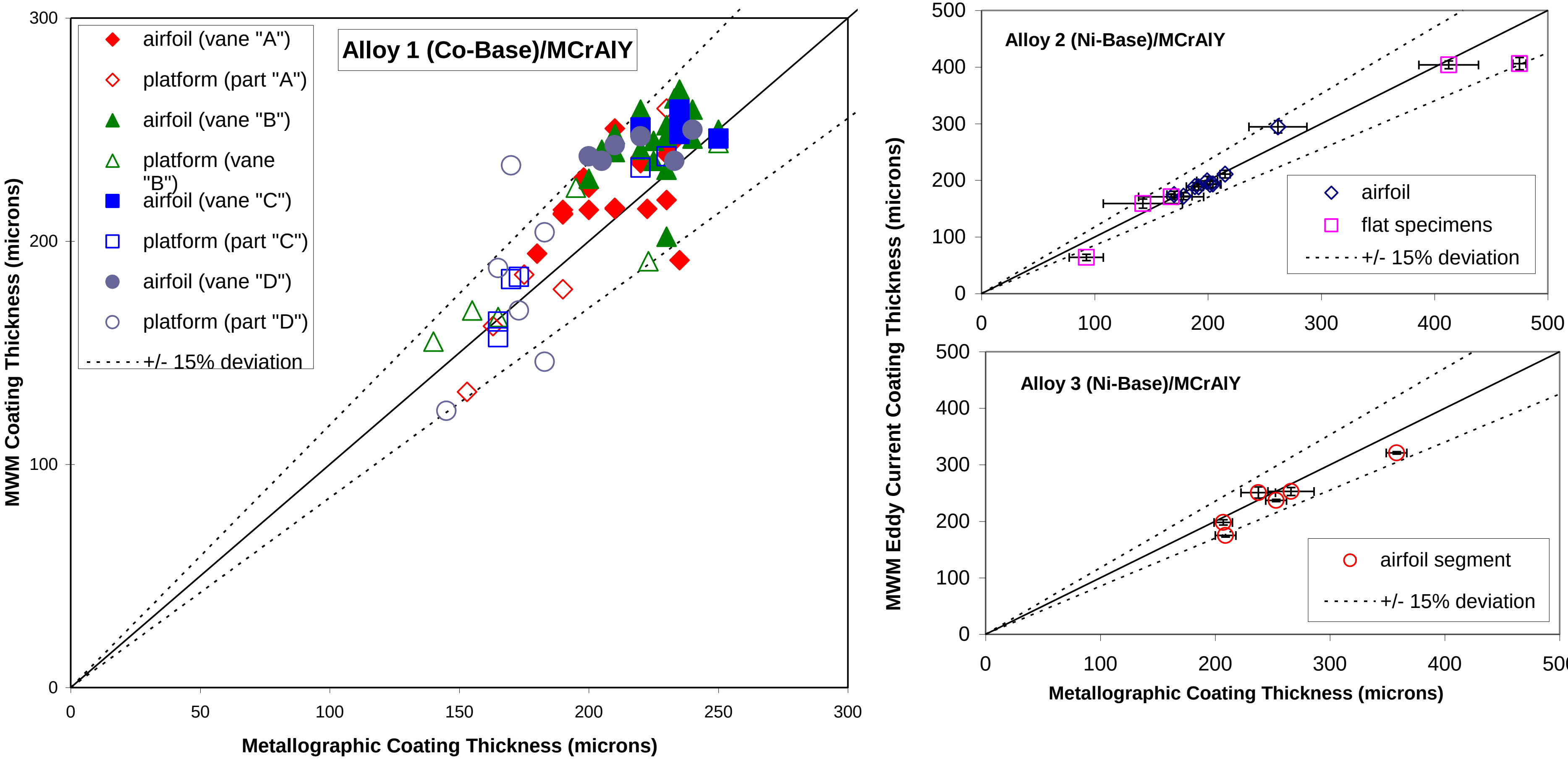
MWM Characterization of MCrAlY Coatings

Evaluation of MWM with Grid Methods for Production Quality Control

- The superalloy substrates, investigated with their respective MCrAlY coatings, were:
  Alloy 1 (Co-base alloy)
  Alloy 2 (Ni-base alloy)
  Alloy 3 (Ni-base alloy)

- Measurements were performed over a wide range of frequencies
  (Typically 400 kHz to 16 MHz)

Comparison of MWM with Metallographic MCrAlY Coating Thickness Measurements for Three Different Substrate/Coating Combinations



JENTEK Sensors

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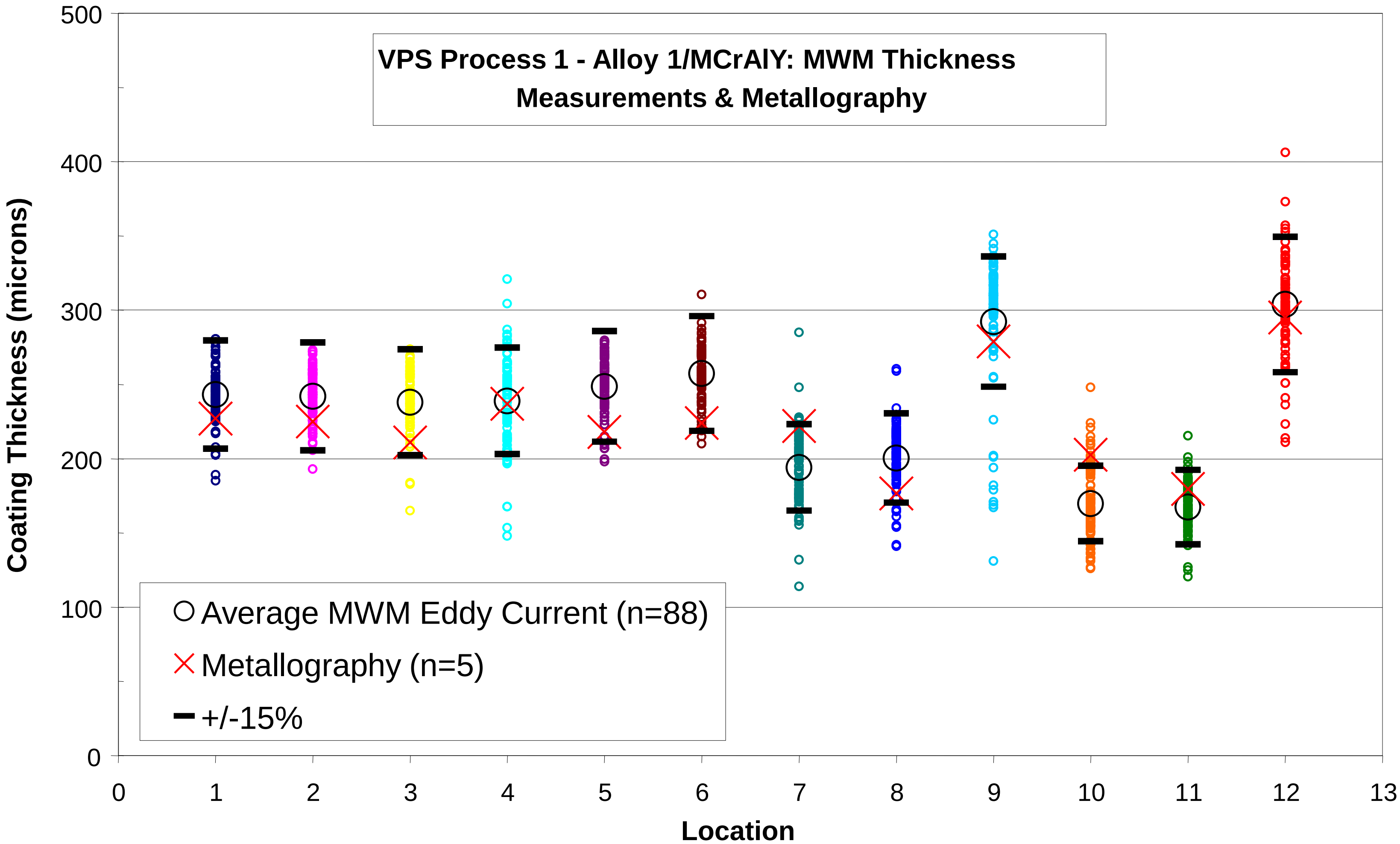
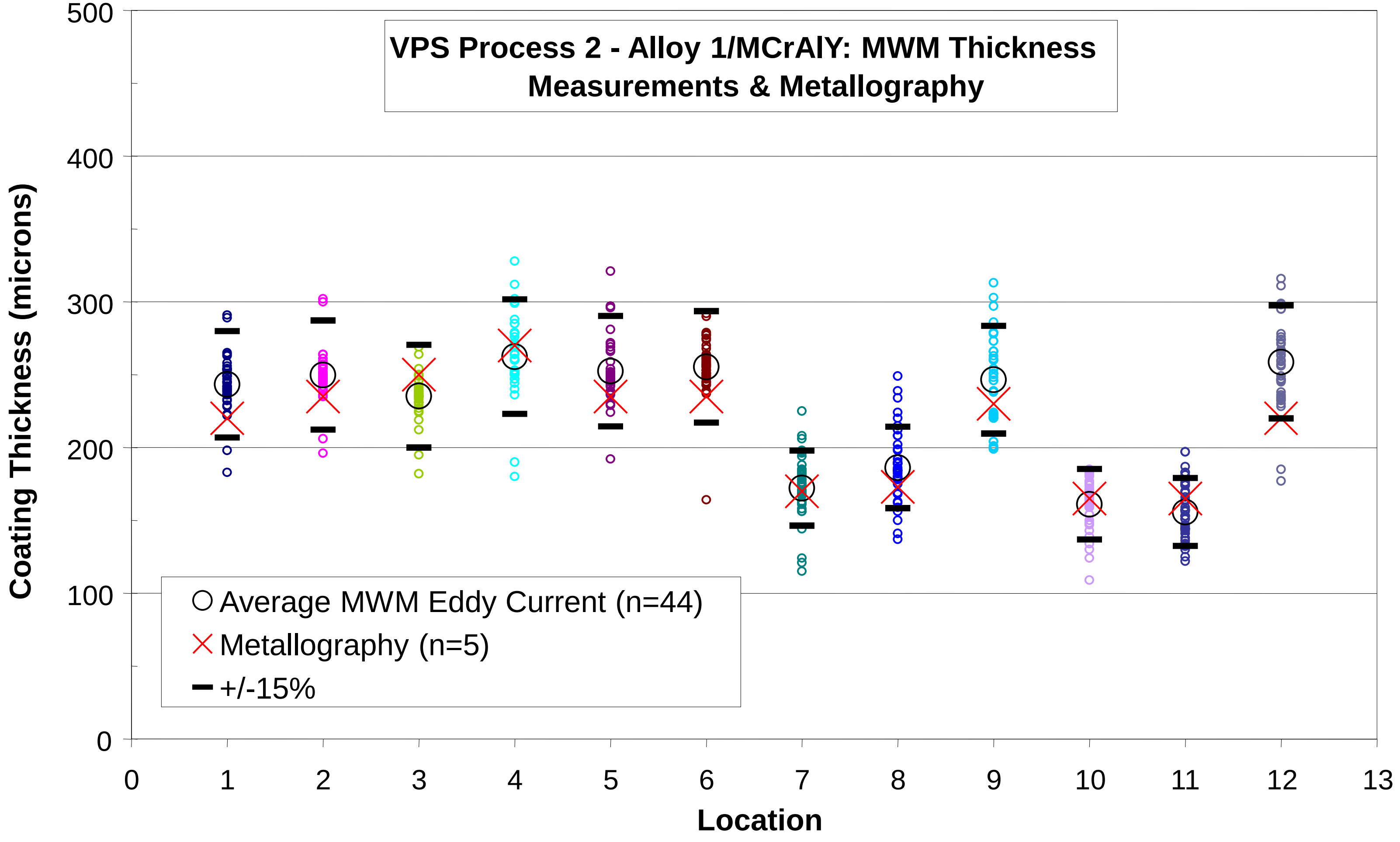
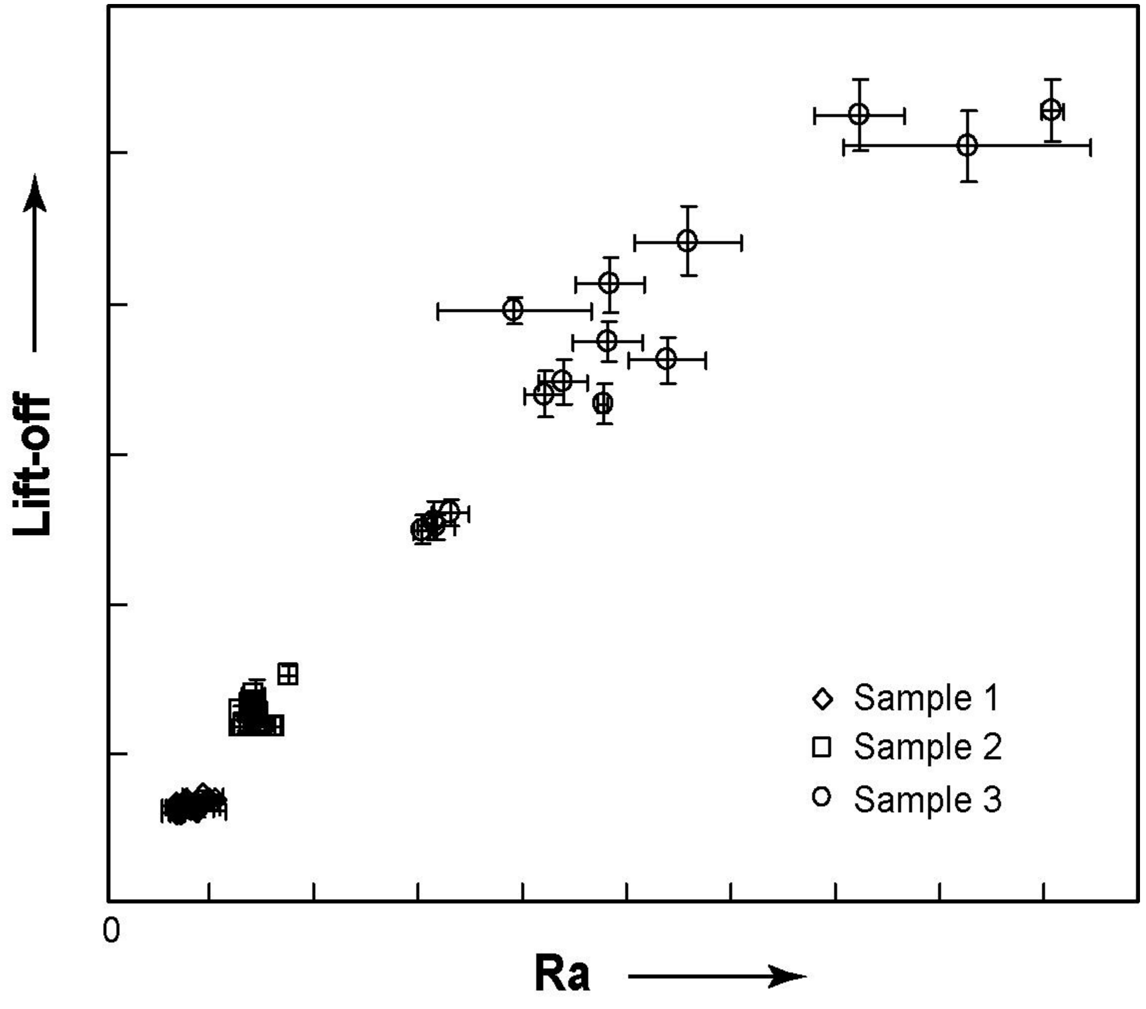
MWM Results of 10% production MCrAlY Coating Thickness Measurements for Process 1



MWM Results of 10% Production MCrAlY Coating Thickness Measurements for Process 2

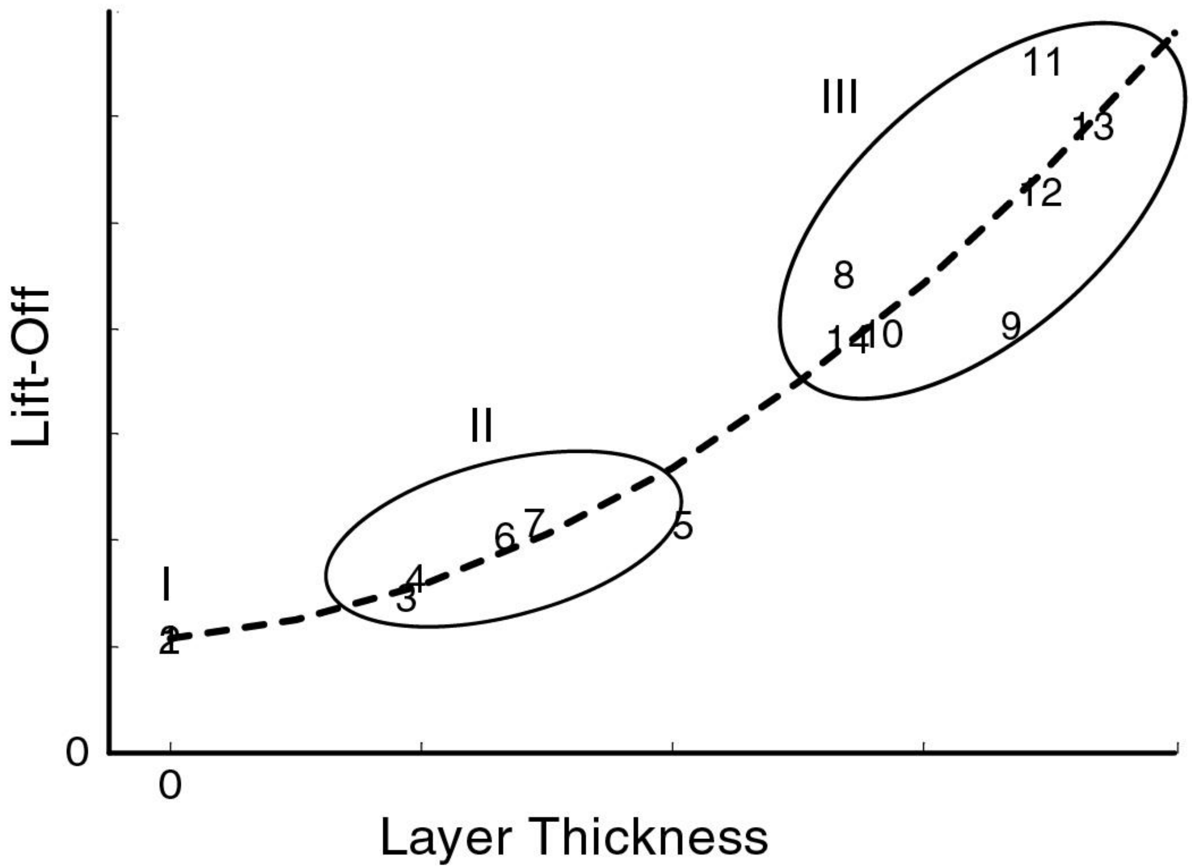


Correlation Between Surface Roughness and Lift-off for Three Samples

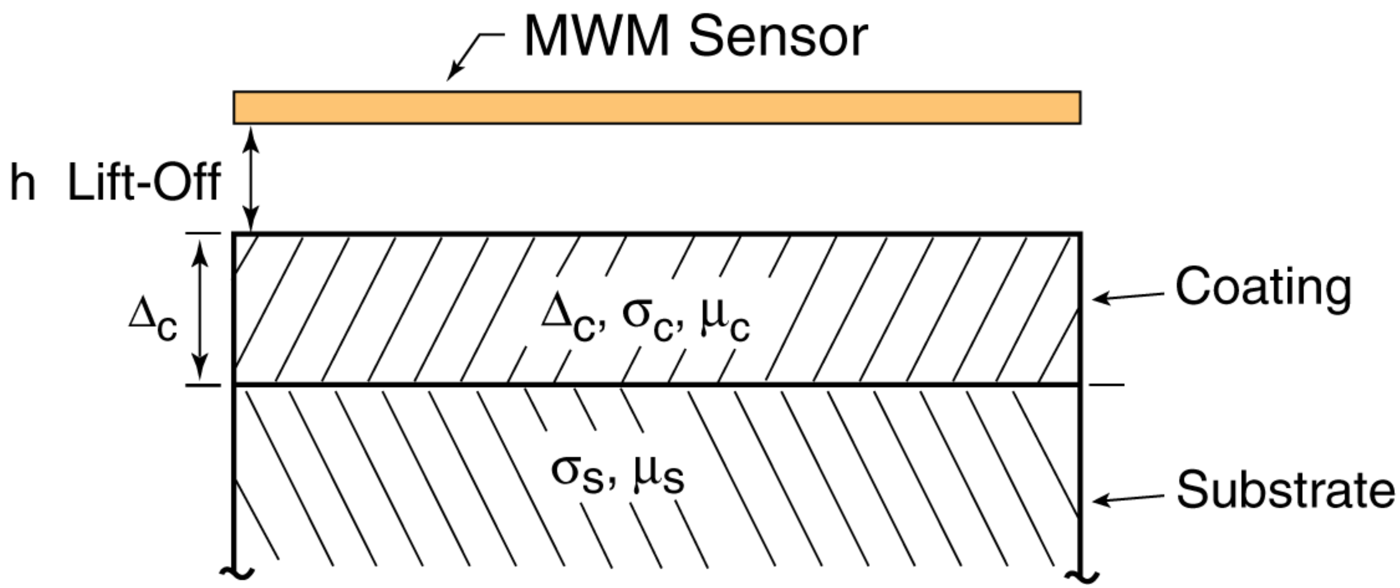


MWM Measured Lift-off vs. Effective Thickness using a Three-unknown Model

B, C, and D are the three corrosion damage states identified in the study

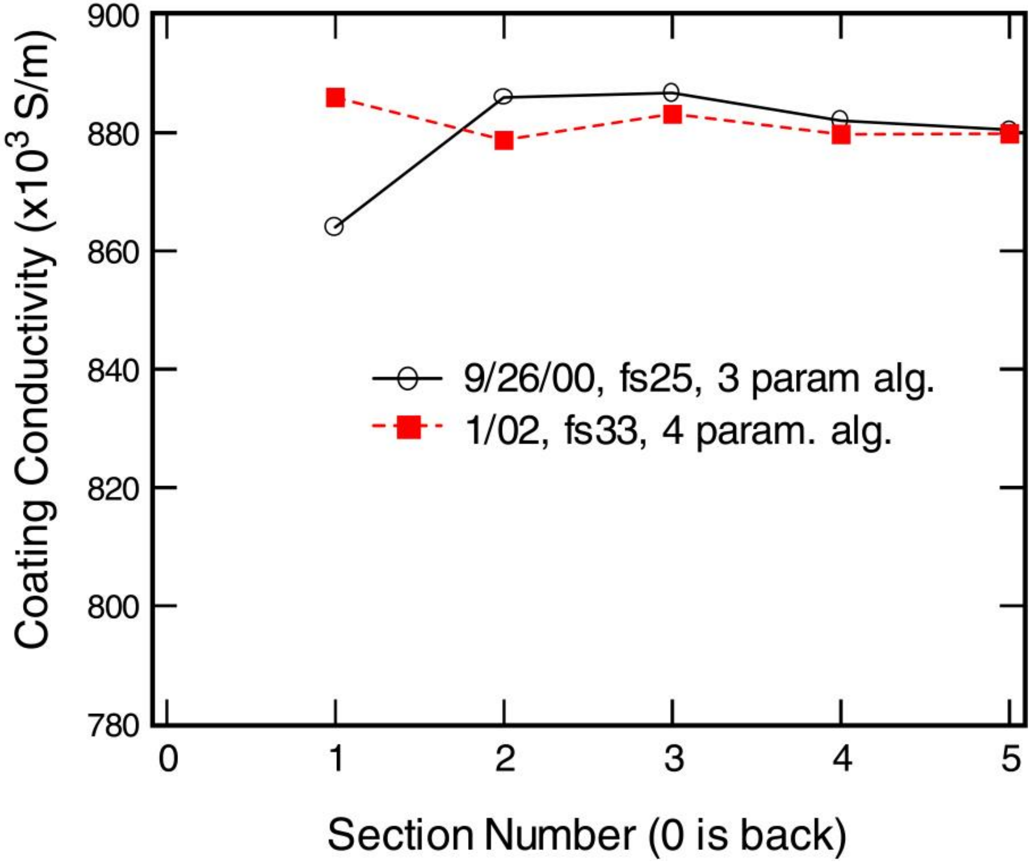


Four-Unknown Coating Problem Examples

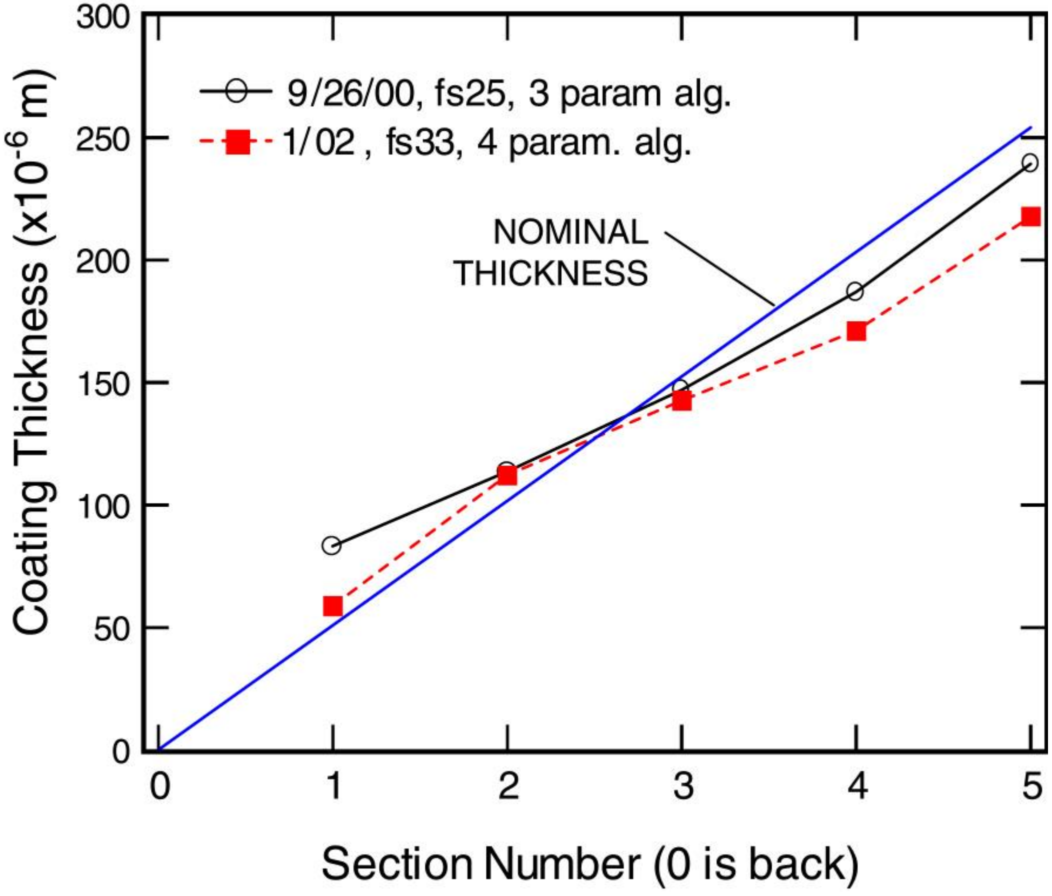


	4 Unknowns:	Knowns:
Case 1	h, Δ_C, σ_C, μ_C	σ_S , μ_S
Case 2	h, Δ_C, σ_C, μ_S	μ_C, σ_S
Case 3	h, Δ_C, σ_C, σ_S	μ_C, μ_S
Etc.	...	...

Comparison of MWM measured coating conductivity determined with a 4-unknown algorithm vs. 3-unknown algorithm



Comparison of MWM measured coating thickness determined with a 4-unknown algorithm vs. 3-unknown algorithm



Additional MWM Capabilities

- The MWM results are based on a three-unknown algorithm. For magnetic coatings and/or substrates as well as for substrates with spatially variable properties, an algorithm that can handle four or more unknowns can be used.

- The results presented today were obtained using an MWM sensor with a single sensing element. Imaging MWM-Arrays provide additional powerful capabilities for inspection of coated turbine components.

- MWM-Arrays with multiple sensing elements have the ability to generate images that reveal cracks, microstructural or chemical variations, as well as hidden geometric features.

Conclusions

- The agreement between the MWM coating thickness results and metallography is remarkably good
- MWM has significant advantages over metallography since it can provide coating thickness measurements nondestructively at any number of selected locations on actual parts in production
- MWM can also provide information on coating porosity variations and TBC thickness

Conclusions

- Correlation of MWM lift-off measurements with surface roughness has been demonstrated. This provides a fast alternative to other profilometry methods even for complex surfaces.

- A study of hot corrosion yielded promising results. Semi-quantitative measurements of corrosion severity using a three-unknown algorithm were shown to be possible. MWM technology can thus be used as a screening method.