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October 28, 2021

Host: Flynn Spears

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Eddy Current Inspection of Stainless Steel Welds

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Global Product Application Leader

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Stainless Steel Weld Inspection

Introduction

Depending on the method used, NDT inspection of stainless steel welds presents a variety of challenges. For example, penetrant testing (PT), a method that involves noxious chemicals and can require extensive surface preparation, was commonly used for this application for decades. Today, eddy current array (ECA) technology makes these inspections easier, safer, and more reliable. During this presentation, I will review the advantages and limitations of using eddy current inspection techniques on stainless steel welds.

Agenda

- Stainless Steel Weld Inspection Challenges
- Advantages of Eddy Current Testing (ECT)
- Eddy Current Liftoff
- Eddy Current Results
- Eddy Current Array
- Depth Sizing

Stainless Steel Weld Inspection Challenges

Surface Condition

Painted Surfaces

Paint or coating on stainless steel welds may need to be removed when using some NDT inspection methods. Eddy currents, however, pass through paint and coatings unaffected, offering a way to inspect parts without the time-consuming paint/coating removal process. Inspectors can also use the results to evaluate the paint thickness. That said, the paint thickness can influence the sensitivity of the method if not controlled.

Surface Condition

Dirty Surfaces

Eddy current testing (ECT) is an efficient and practical solution for inspecting parts in the field. No time or effort is required to clean the parts. Dirt, mud, grease, and dust can be compared to air when using eddy current inspection—they have no effect on defect detection or measurement.

Surface Condition

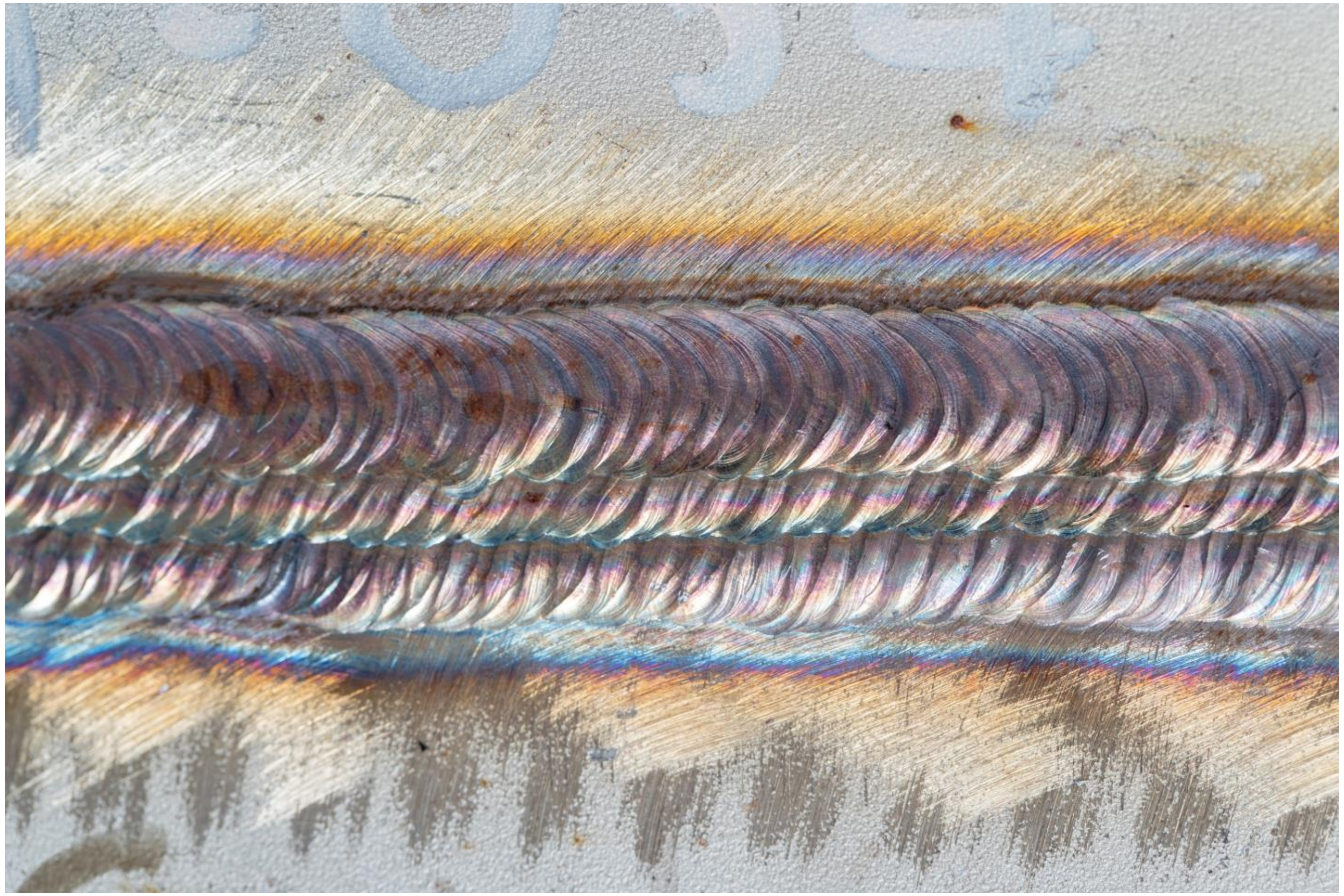
Weather Conditions

In the field, welded structures are constantly exposed to the elements. In-service inspections of stainless steel welds may need to be performed in the rain or in extreme temperatures. These conditions can affect the inspection performance of some NDT methods. ECT, however, can be performed on wet, cold, and hot surfaces with reliable results.

Surface Condition

Rough Surfaces

ECT can be used to inspect rough weld surfaces. Sand-blasted and corroded surfaces can also be inspected. Specialized probes are available to avoid the liftoff signal caused by uneven surfaces.



Stainless Steel Welds

Advantages of Eddy Current Testing (ECT)

Eddy Current Advantages

Environment Friendly

Eddy current inspection is a safe solution for the environment. The method does not require any chemicals, so it's odorless and avoids the risks associated with using and storing chemicals, as well as the costs of waste management. The eddy current technique is also silent, so noise pollution is not a concern.

Eddy Current Advantages

No Contact Required

ECT is a noncontact inspection method. The probe type and configuration can be selected to minimize the liftoff effect when the part's surface integrity needs to be preserved or, conversely, to protect the probe from a rough surface.

Eddy Current Advantages

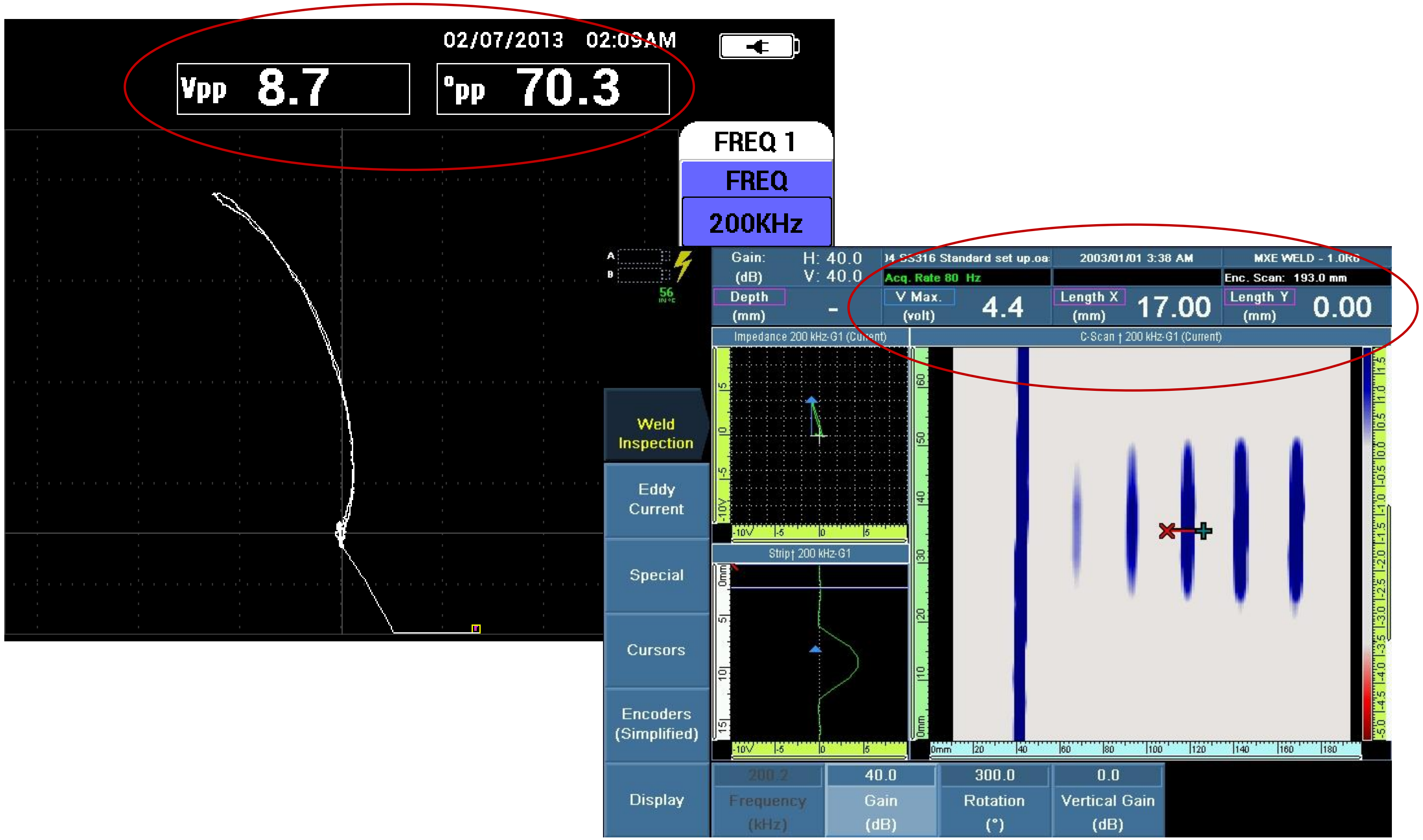
Depth Evaluation

The depth of open-to-surface defects can be evaluated using ECT and ECA. The amplitude and phase of the signal can be compared to a calibration sample to evaluate the depth of flaws.

Eddy Current Advantages

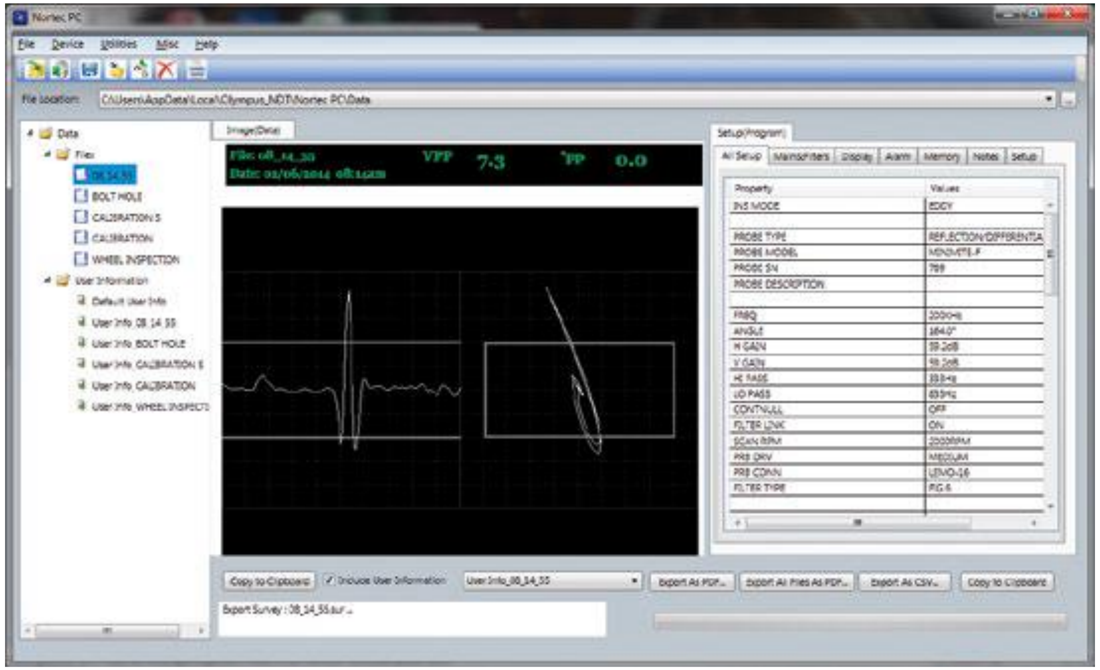
Data Analysis

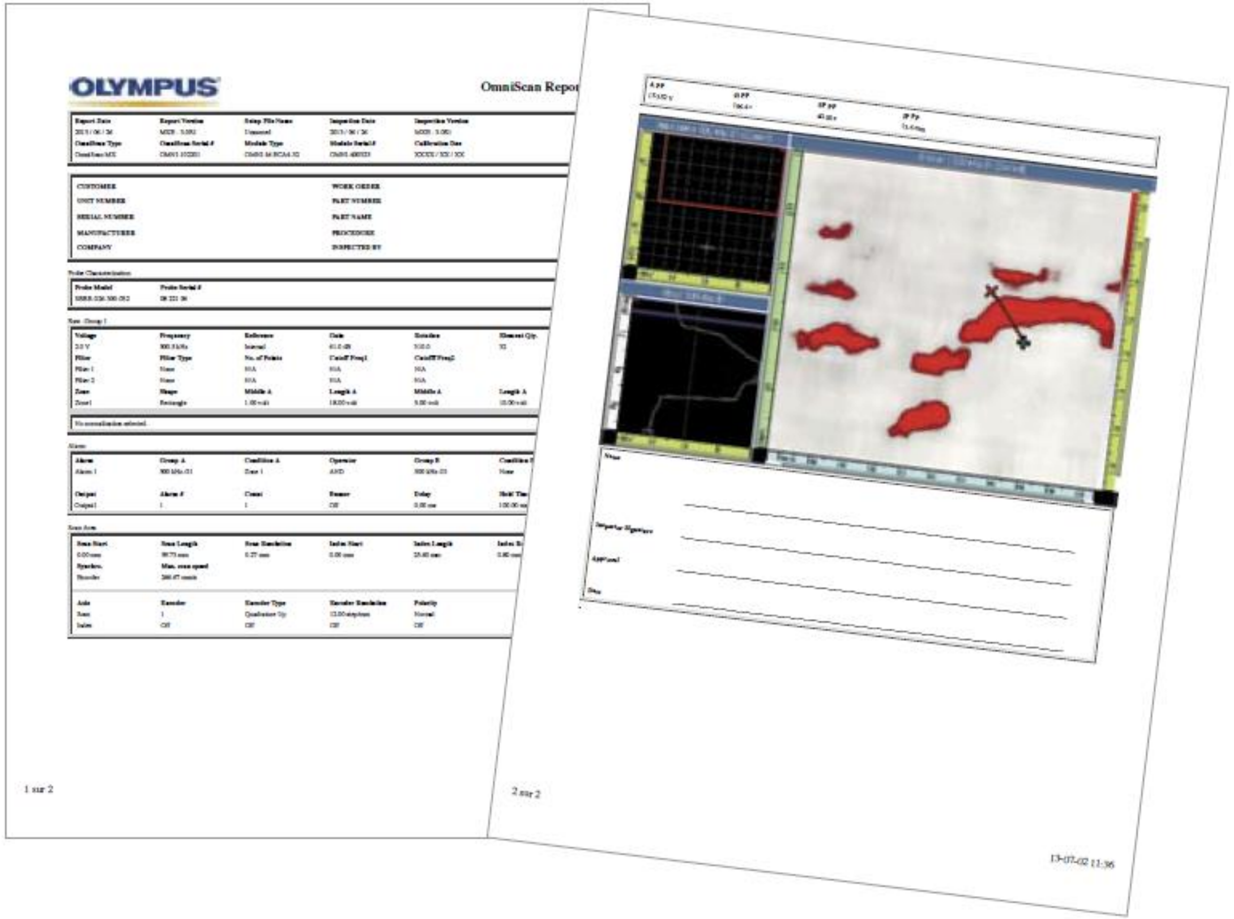
Eddy current readings: signal amplitude and phase angle can be used to analyze the inspection results.



Eddy Current Advantages

Reporting and Archiving





Eddy Current Advantages

Inspection Speed

Eddy current technology is versatile. When speed is a critical inspection requirement, eddy current inspection is a good option. Eddy current probes vary from very small to large, providing the required resolution. Custom probes with the required sensitivity can easily be made for areas with limited access. For high-speed inspections, different kinds of scanners can help increase the speed without missing a spot.

Eddy Current Advantages

Automated Integration

Eddy current technology easily integrates into manufacturing shops. Eddy current probes can be fixed on existing or dedicated machines, such as robots. Eddy current probes can be manipulated at high speed with or without contact with the parts to be inspected. Since eddy current equipment is compact, relatively silent, and safe for workers in the vicinity, it can become a component of the shop workflow. These advantages make eddy current testing an optimal solution for integration into production lines.

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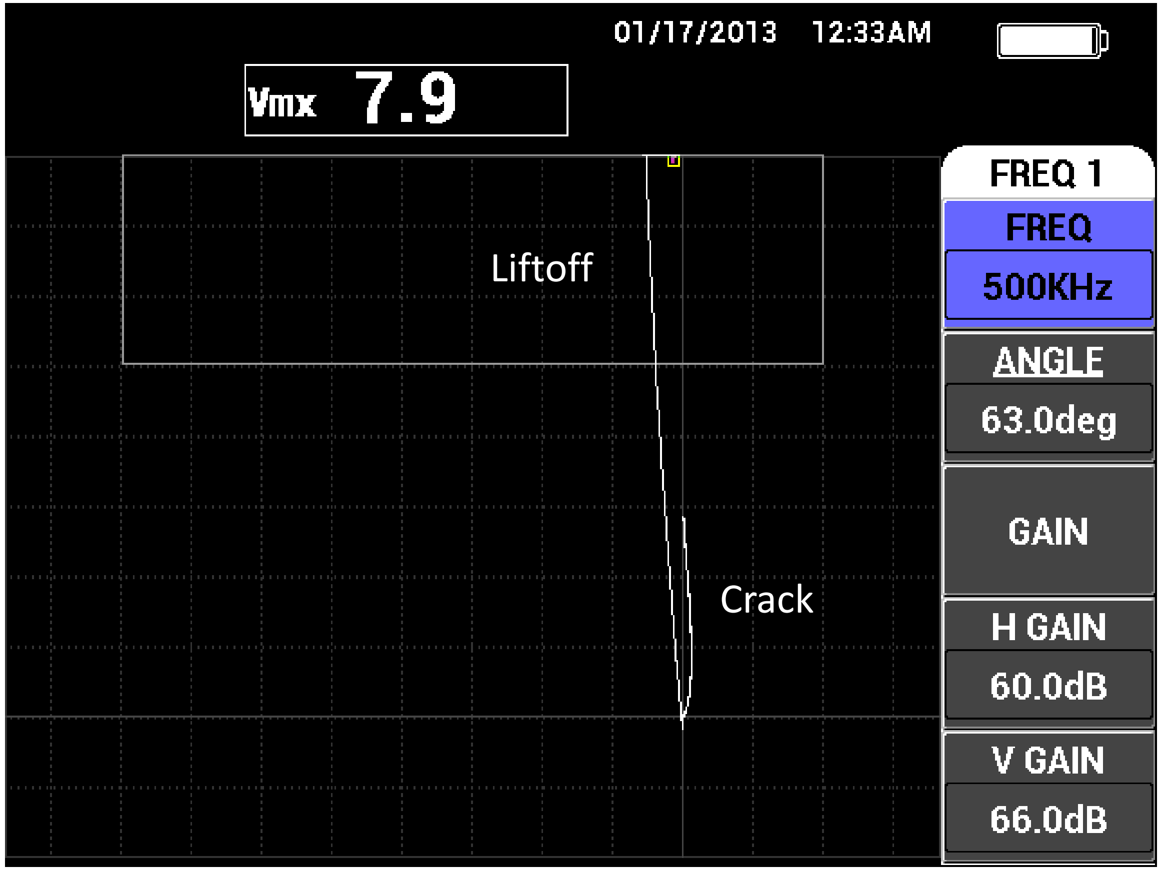
Stainless Steel Welds
Eddy Current Liftoff

Liftoff

Phase Angle Problem

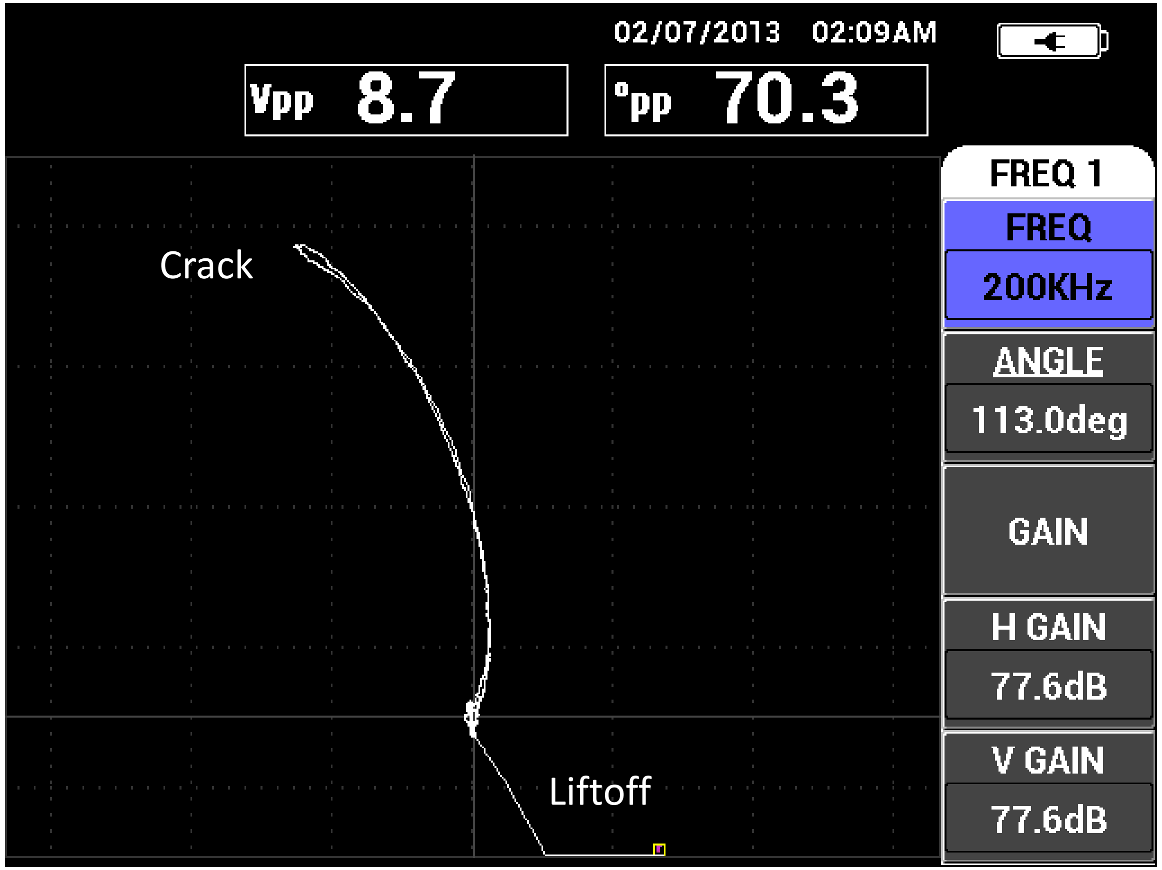
The liftoff phase angle is important when inspecting austenitic stainless steel. Low phase lag can cause high liftoff sensitivity.
A phase lag of about 90° or more in between the liftoff signal and the crack signal is suitable for a good detection performance.



Liftoff

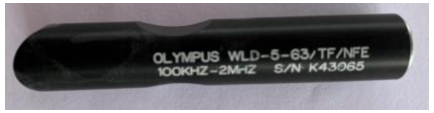
Phase Angle Solution

Option #1:
One option to resolve this issue is to use the WLD-5-63 or WLD-8-55 probe, depending on the profile of the weld to be inspected.
These probes have cross-wound coils that provide a phase lag of about 180°, which is more than enough to get a reliable reading.

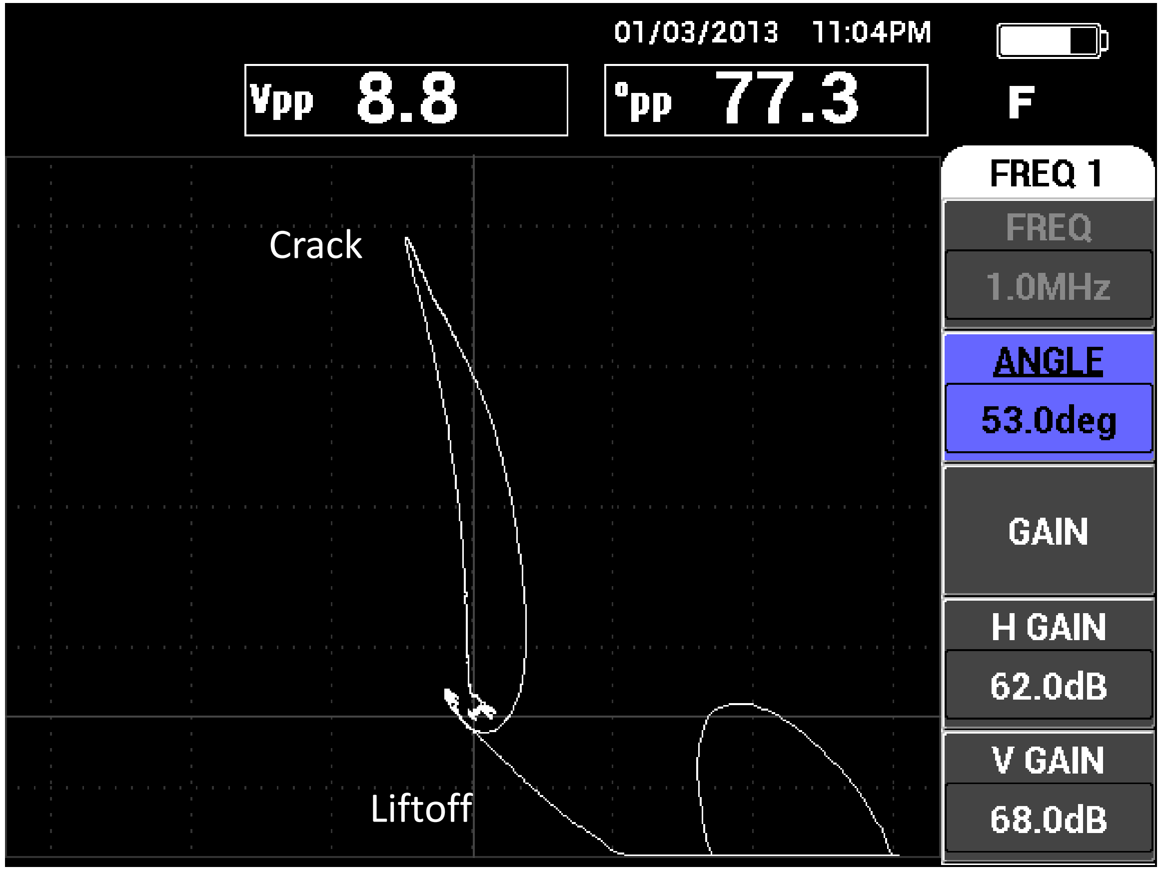


Liftoff

Phase Angle Solution



Option #2:
Another option is to use the WLD-5-63-TF-NFE or the WLD-8-55-TF-NFE probe, depending on the weld profile. These reflection coil probes provide a phase lag of about 120°, which is also sufficient to obtain a reliable reading.



Stainless Steel Welds

Eddy Current Results

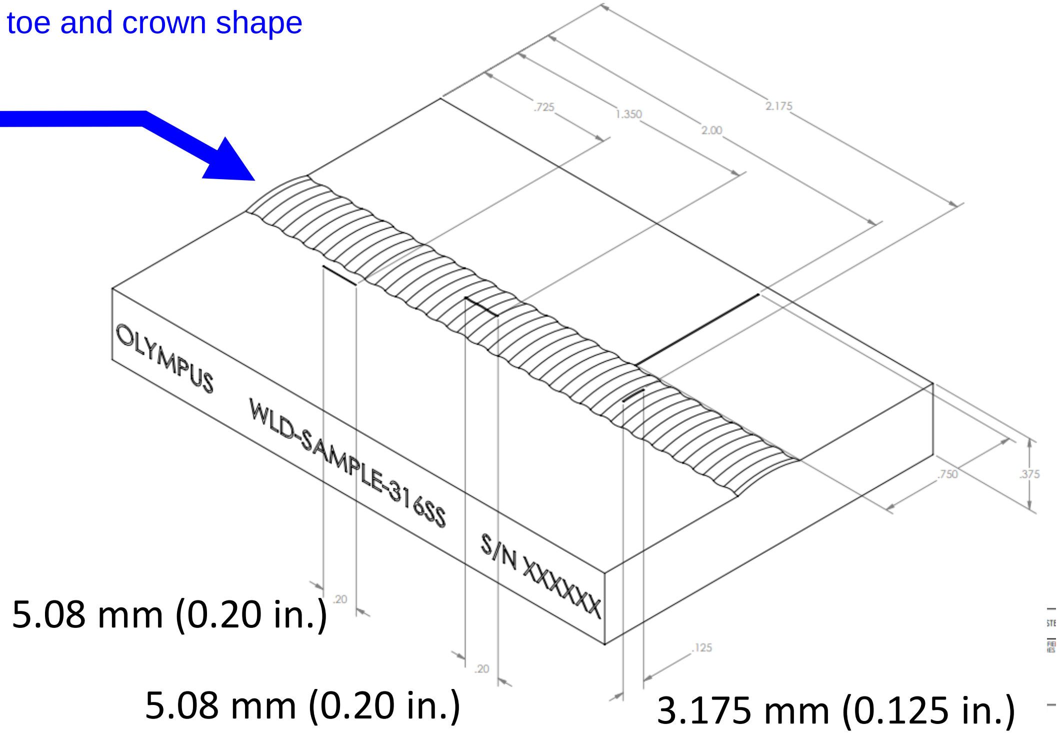
Results–Equipment Used

Weld Kit Q2502240 NEC-8196-NFE

Stainless steel weld inspection kit contains:

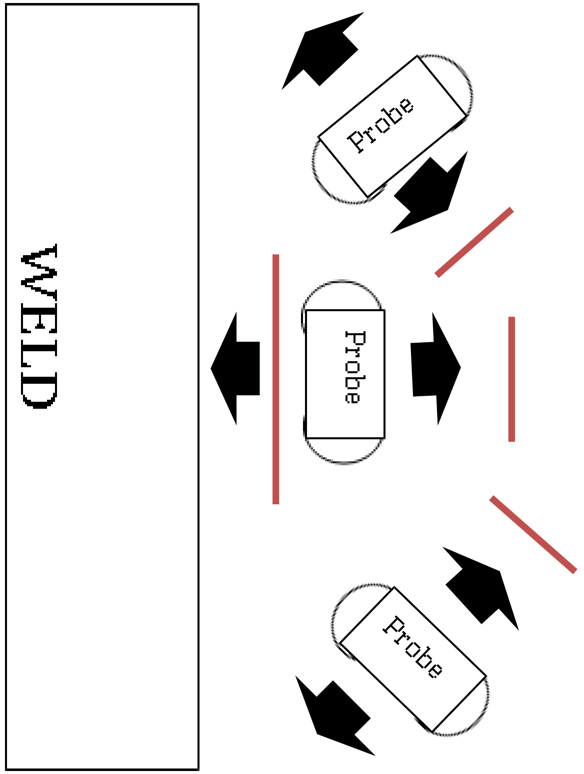
- WLD-5-63-TF-NFE
  or
- WLD-8-55-TF-NFE
- WLD-SAMPLE-316SS
- SPO-6687 cable

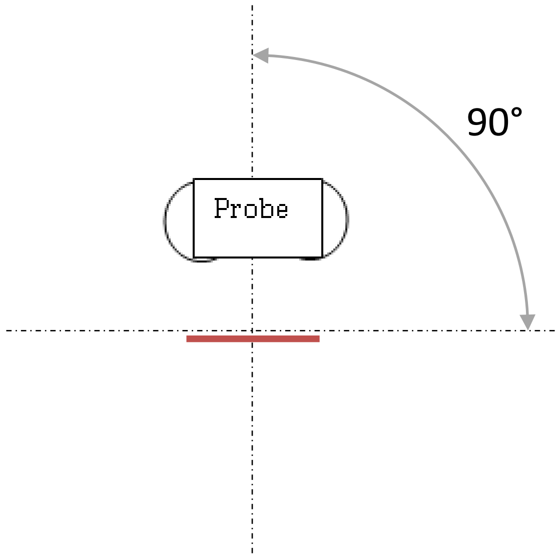
Depending on weld toe and crown shape

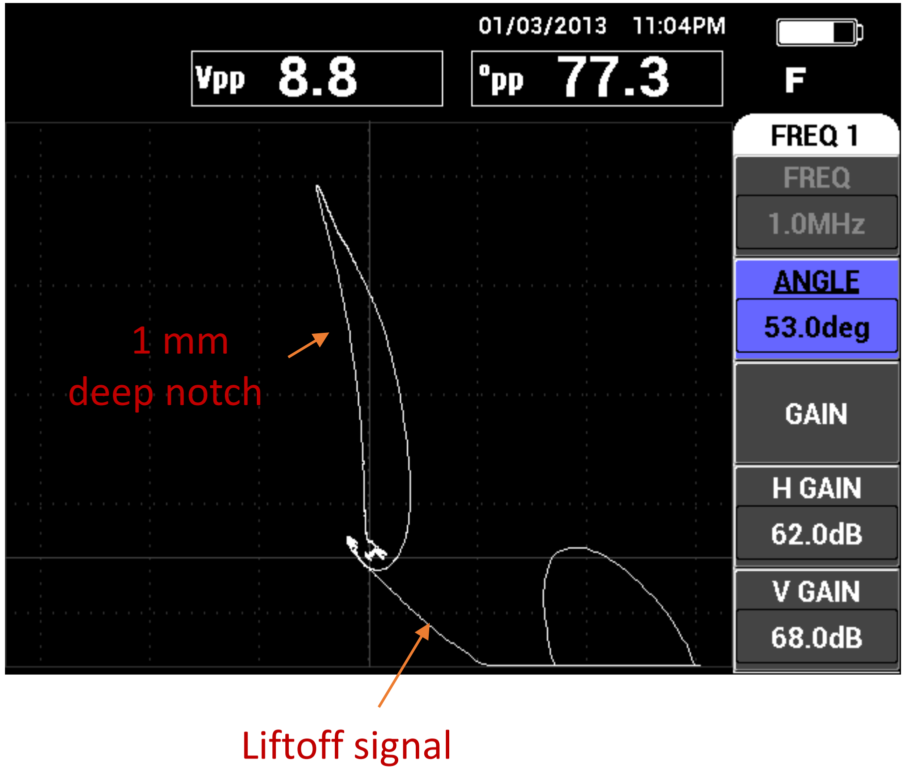


Results–Stainless Steel Weld Calibration

Parent Material and Near Weld Zone Testing

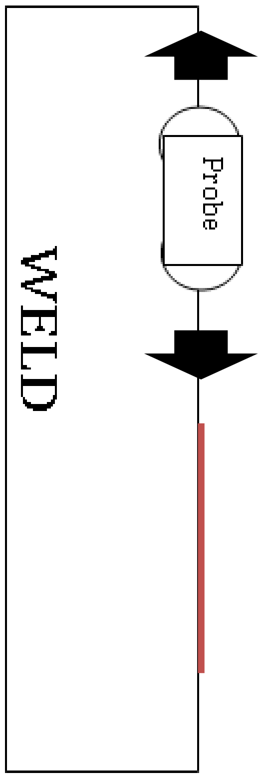


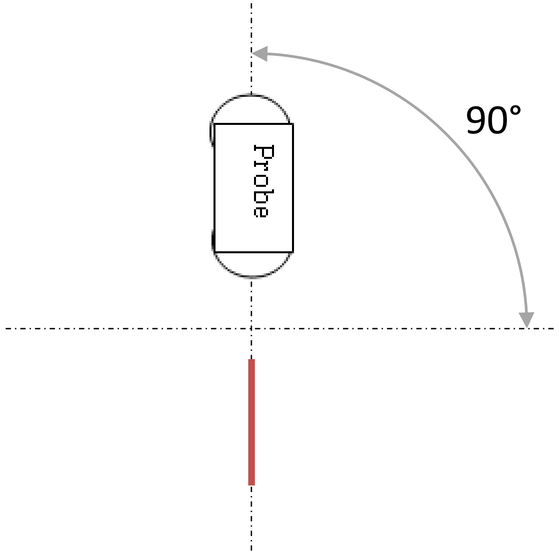


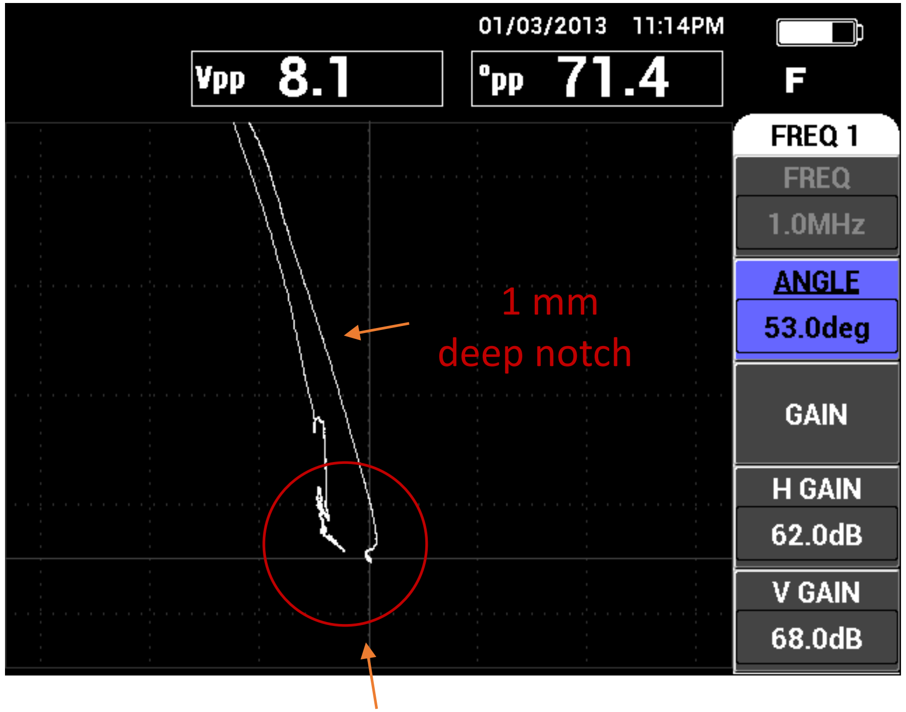


Results–Stainless Steel Weld Calibration

Single Pass in Toe of the Weld Zone



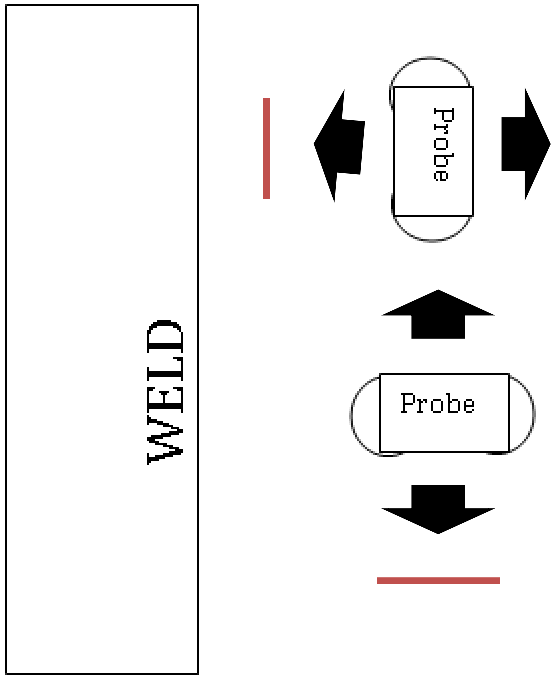


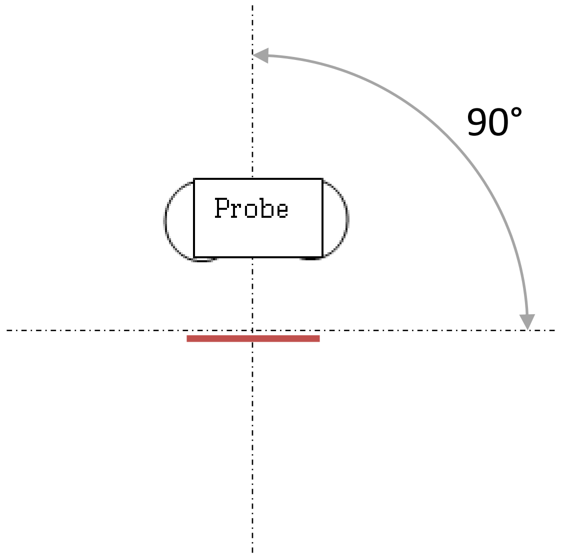


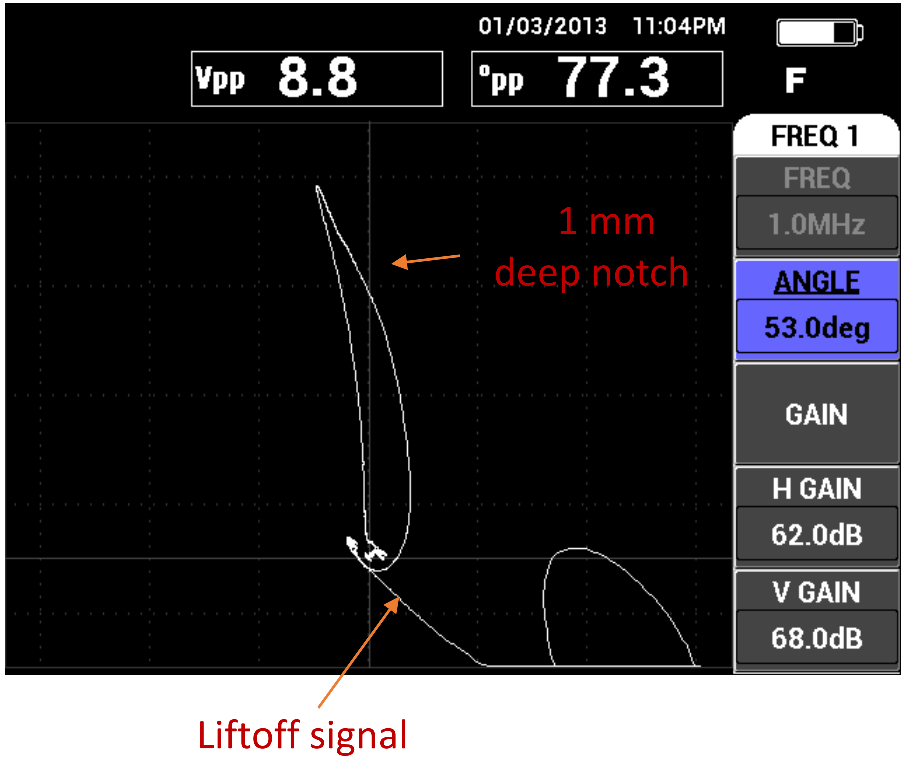
Noise caused by weld roughness

Results–Stainless Steel Weld Calibration

Additional Scan in the Near Weld Zone

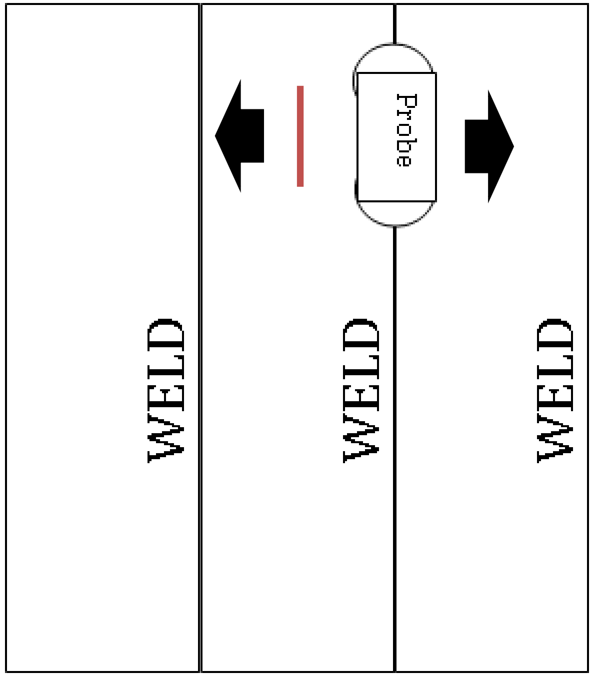


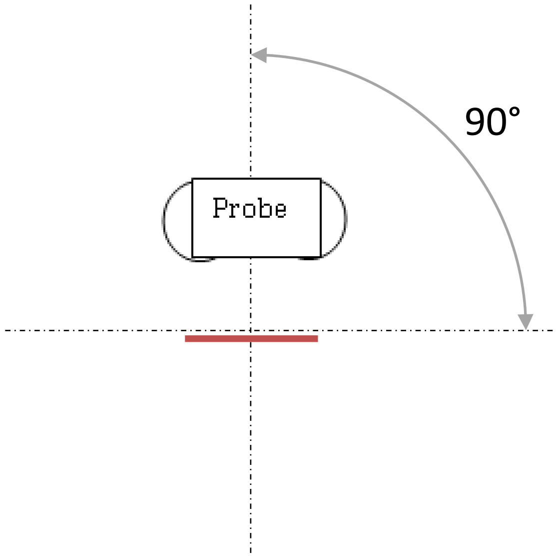


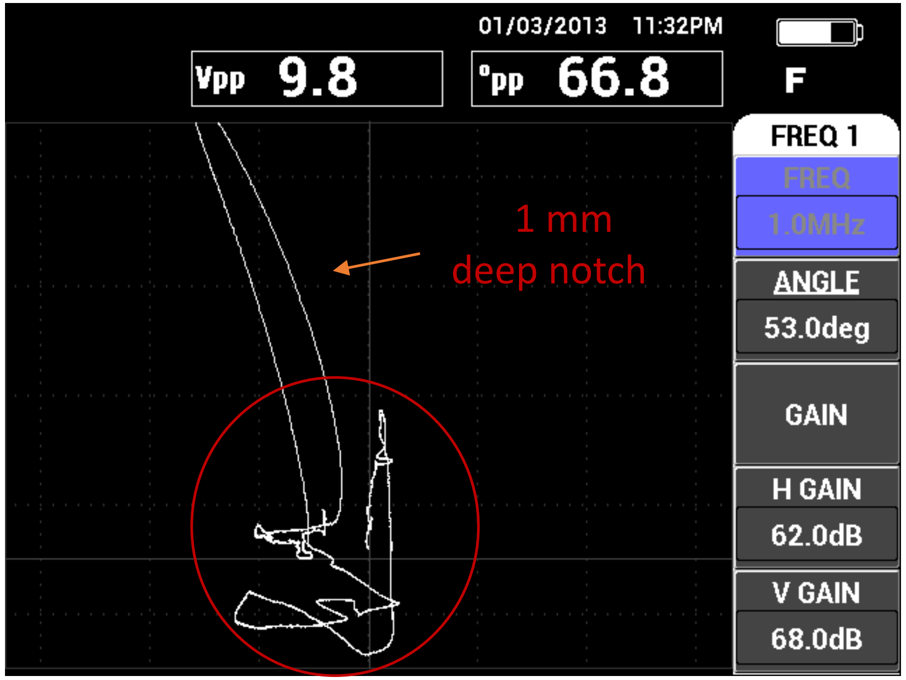


Results–Stainless Steel Weld Calibration

Scanning Procedure for Weld Cap Testing



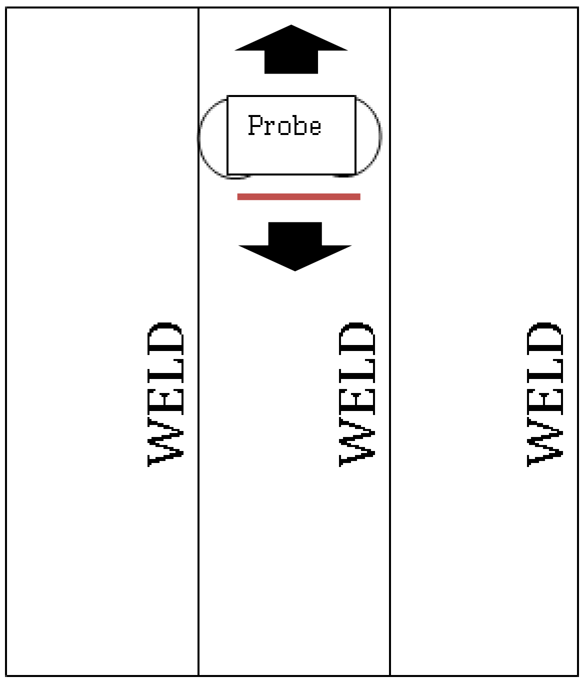


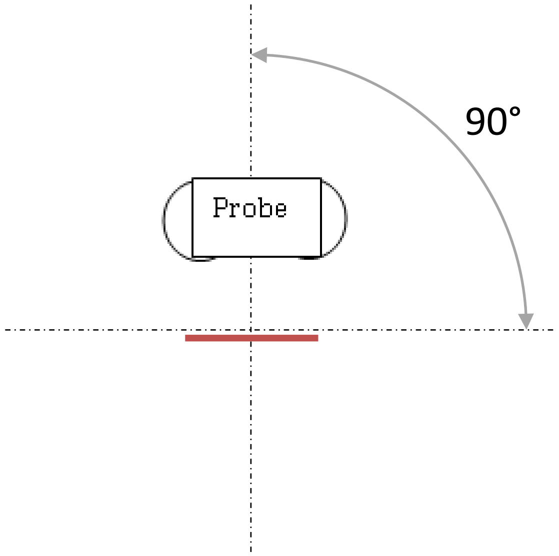


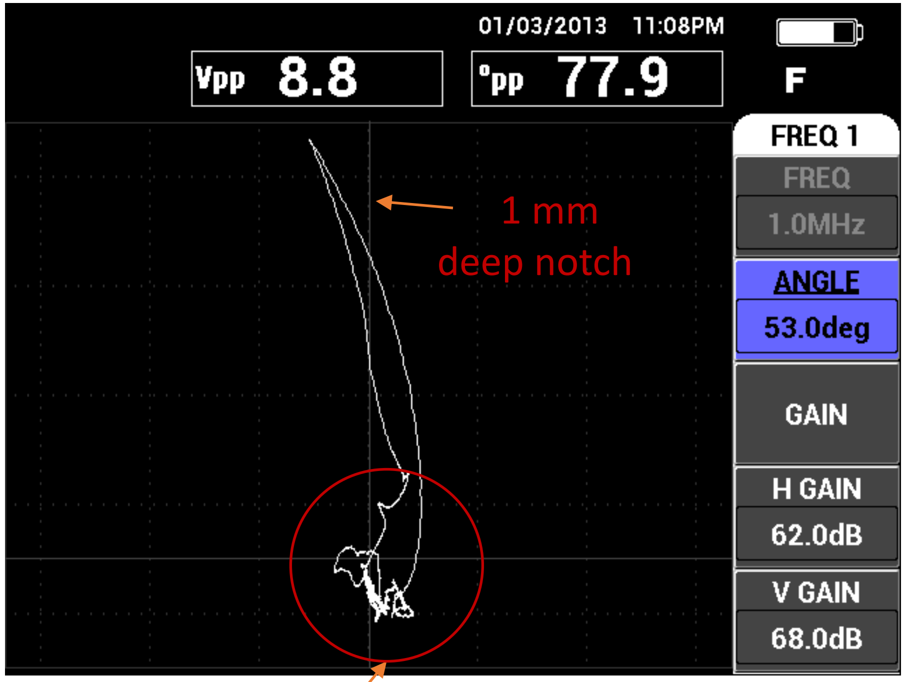
Noise caused by weld roughness

Results–Stainless Steel Weld Calibration

Scanning Procedure for Weld Cap Testing



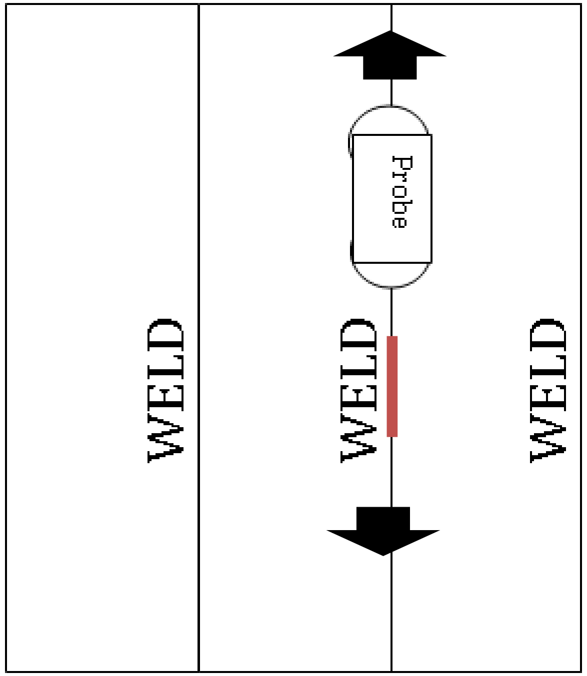


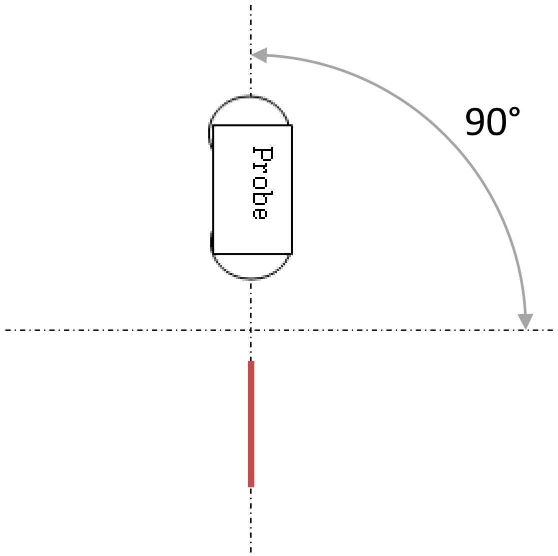


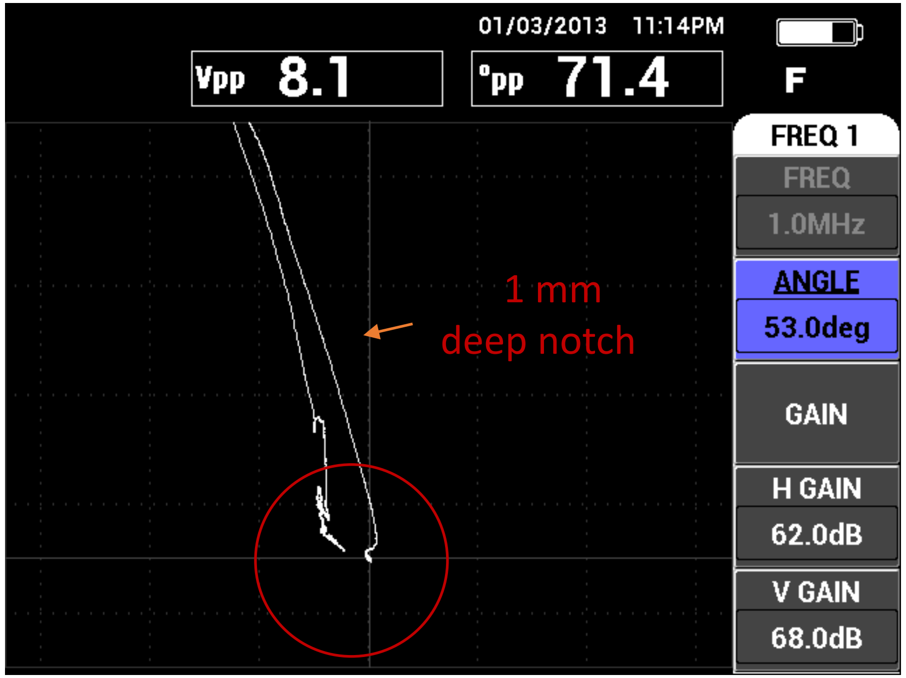
Noise caused by weld roughness

Results–Stainless Steel Weld Calibration

Scanning Procedure for Weld Cap Testing



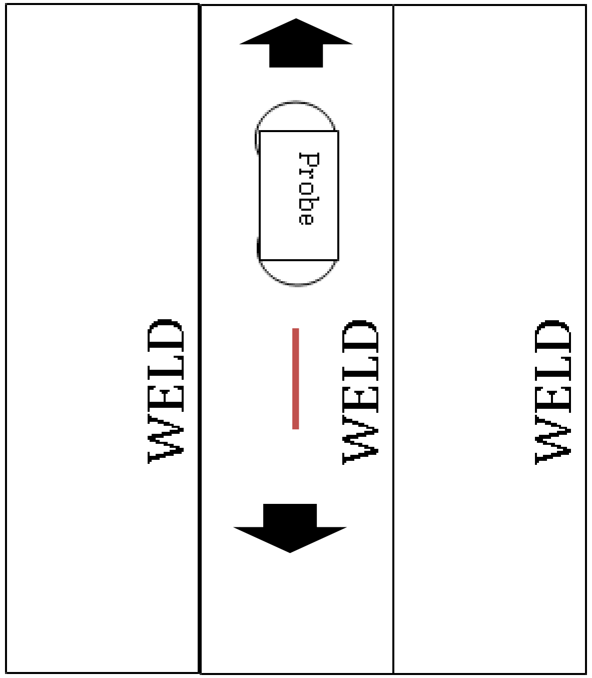


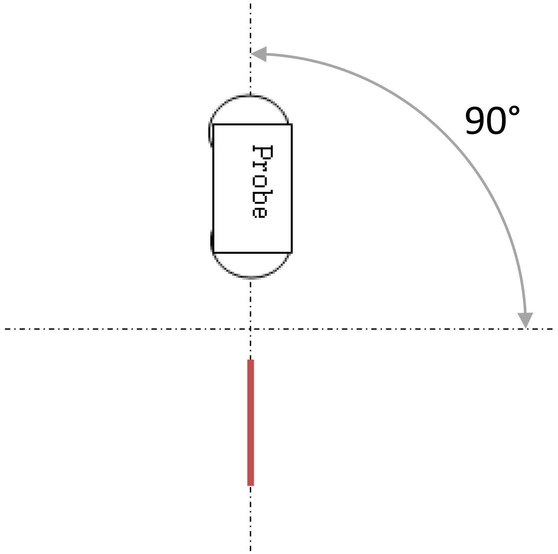


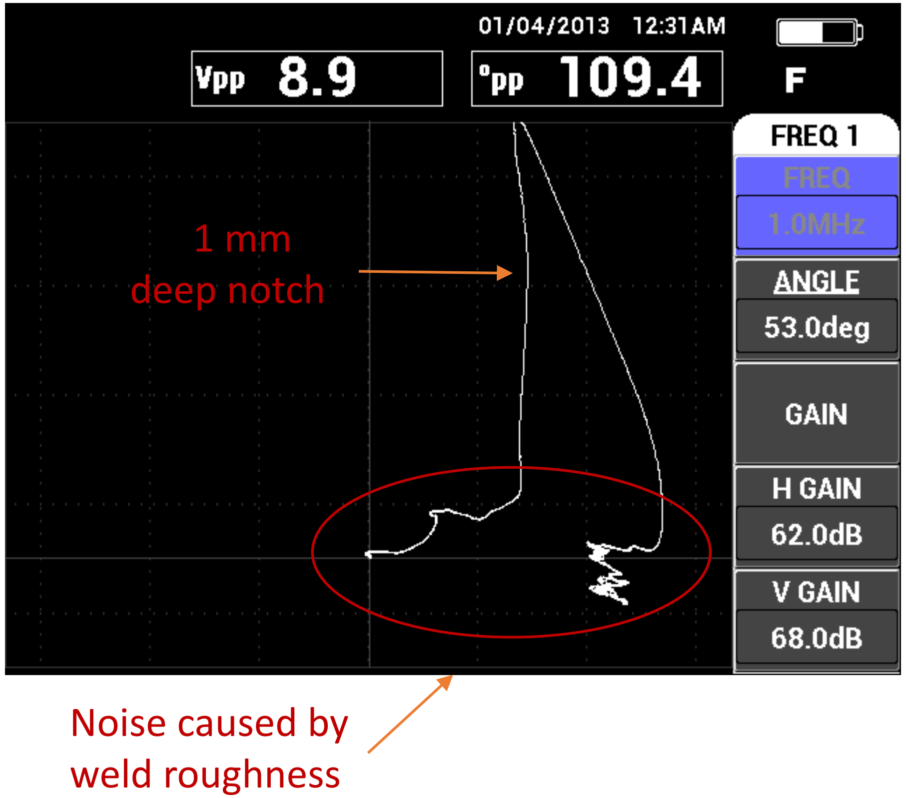
Noise caused by weld roughness

Results–Stainless Steel Weld Calibration

Scanning Procedure for Weld Cap Testing



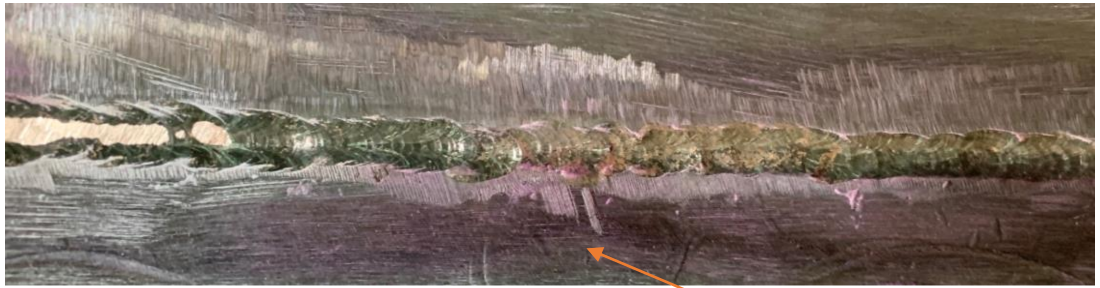


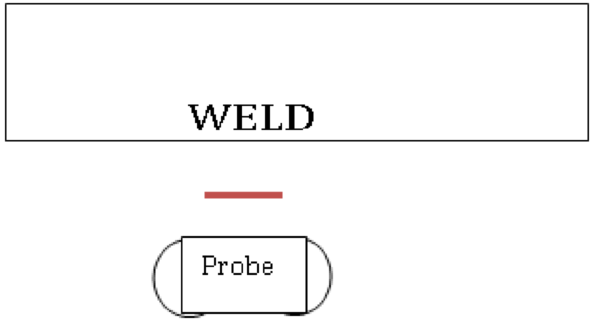


Results–Stainless Steel Weld Calibration

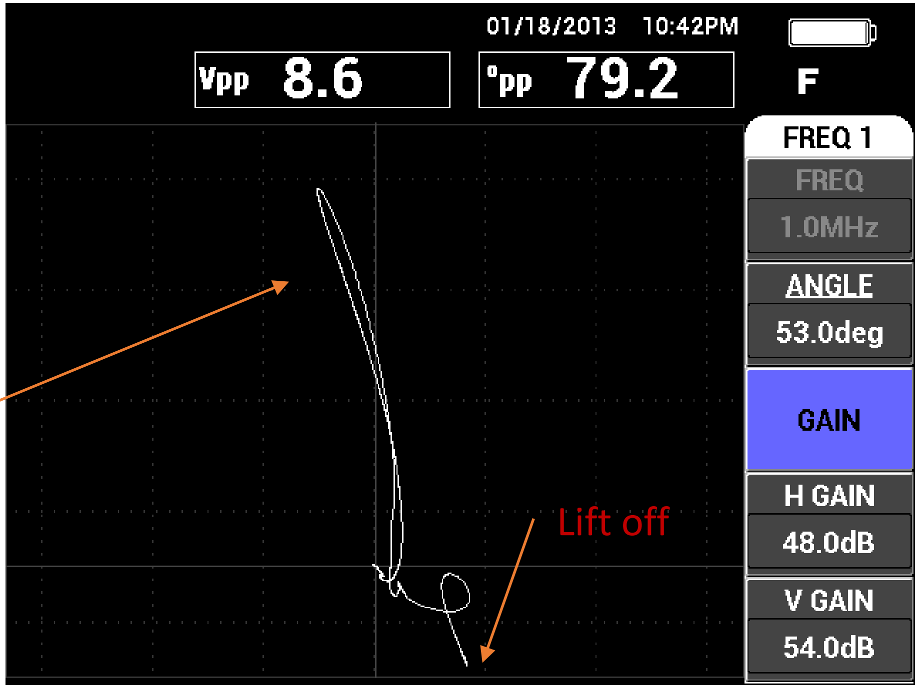
Transversal Scan on the Parent Material

Real crack deeper than the 0.040 in. (1 mm) calibration notch





Crack signal



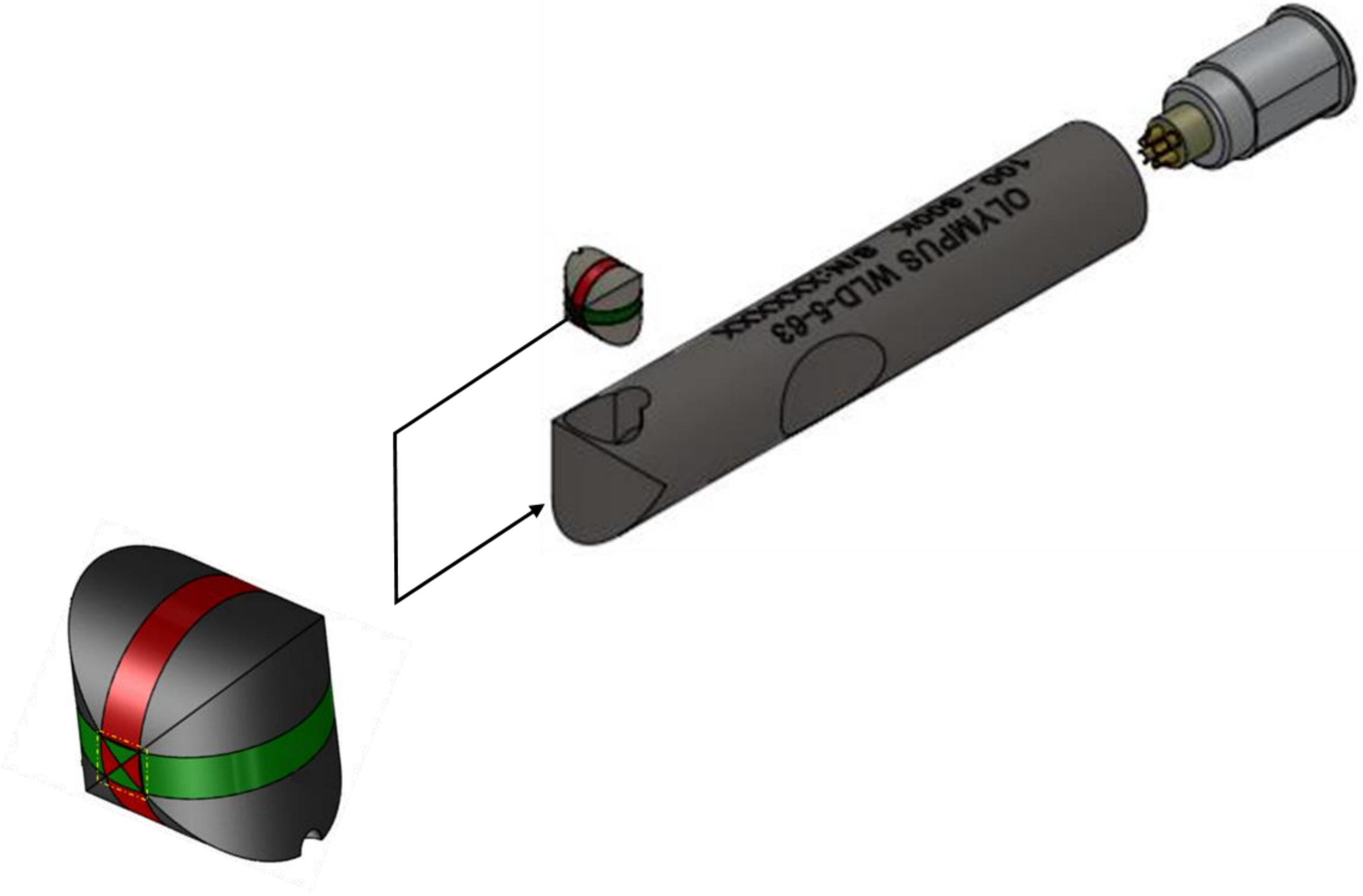
The gain was reduced by 14 dB to be able to see the entire crack signal on the screen.

Stainless Steel Welds
Eddy Current Array (ECA)

Coil Arrangement

Cross-Wound Coil

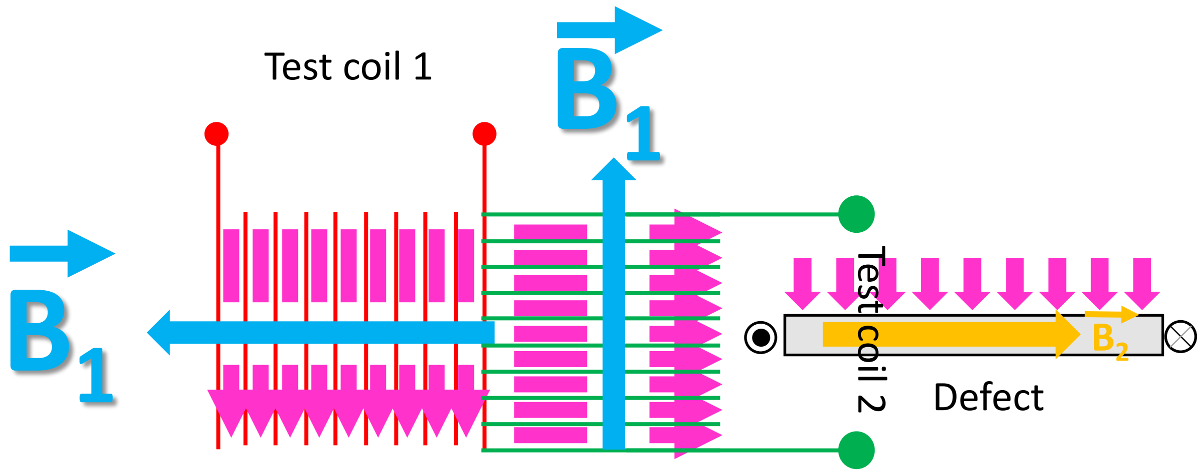
An eddy currant array (ECA) probe is practical when large areas need to be covered. Using an ECA probe with cross-wound coil technology is a good option to avoid noise caused by liftoff.

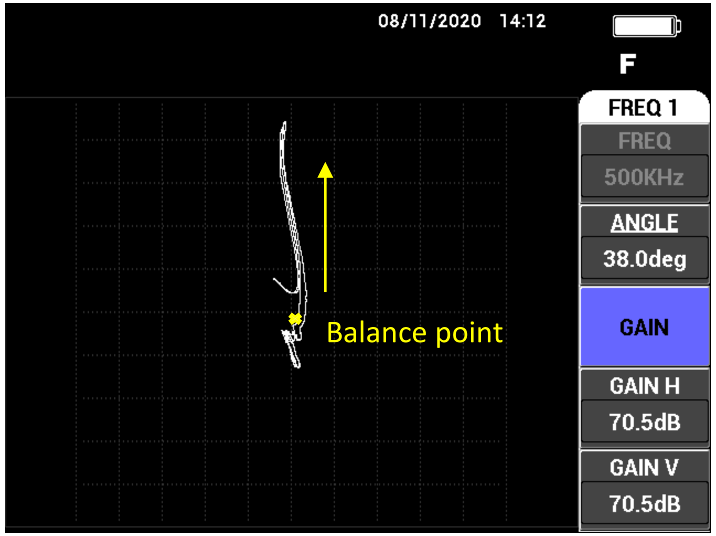


Signal Analysis

Signal analysis is based on the EC's modification between test coils 1 and 2. The eddy current is modified by a perpendicular defect orientation.

Induced magnetic field B1 is generated on test coil 1. The eddy current perturbation is maximized on test coil 1 and doesn't affect test coil 2.





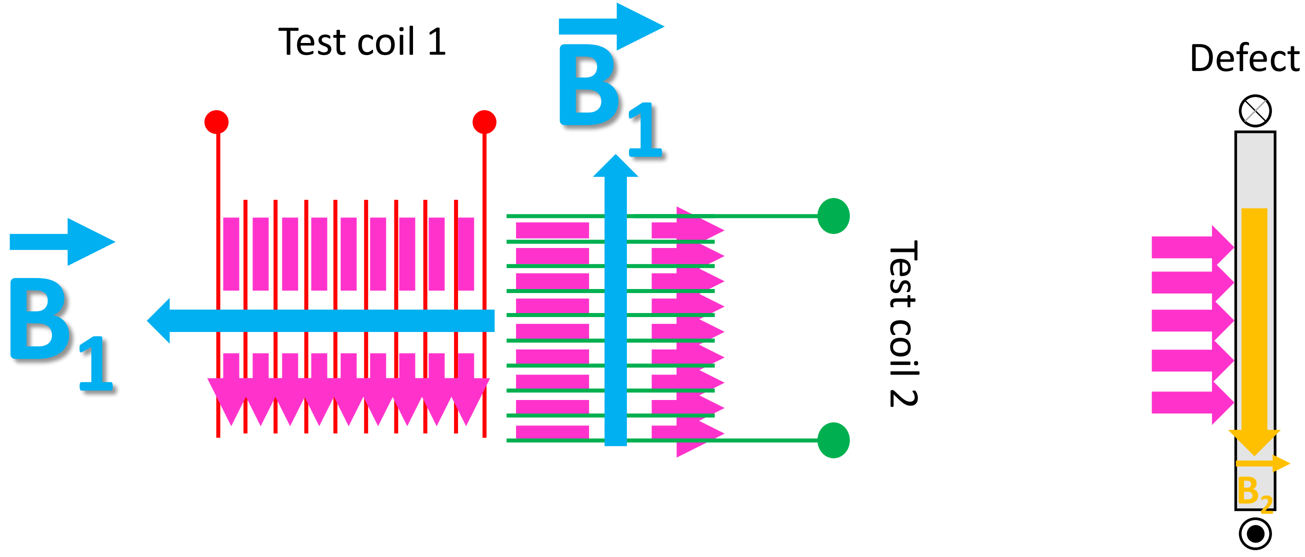
The impedance plane is unbalanced compared to the flawless area. The signal tends to move upward.

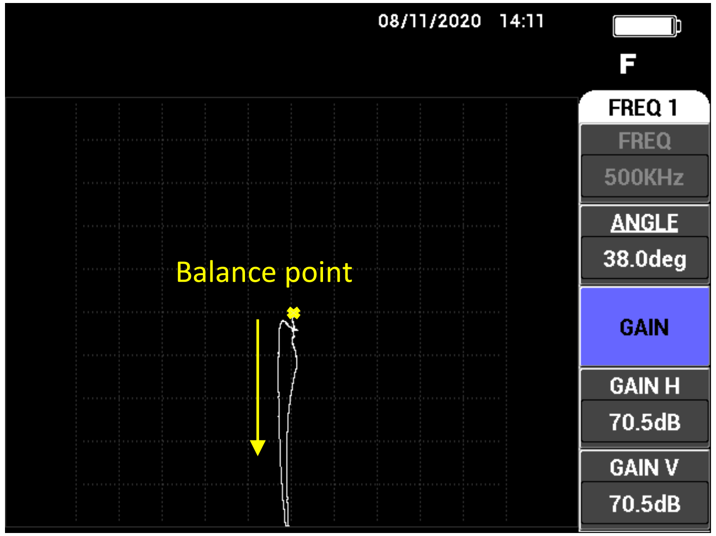
Signal Analysis

Defect perpendicular to test coil 2

Induced magnetic field B1 is generated on test coil 2.

The eddy current perturbation is maximized on test coil 2 and doesn't affect test coil 1.





The impedance plane is unbalanced compared to the flawless area. The signal tends to move downward.

Eddy Current Array

Conventional cross-wound sensors, which are composed of two orthogonal coils, can now be fabricated using printed-circuit board (PCB) technology, enabling them to have multiple layers.

Eddy current array sensors:

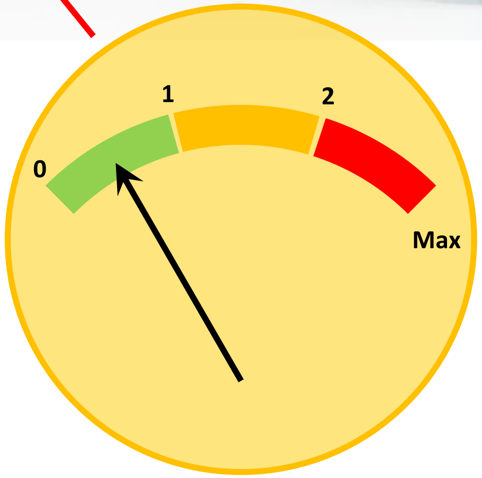
Multilayer PCB etched coils

Eddy Current Array

Multilayer Etched Coils Containing Two Types of Sensors

Eddy Current Array

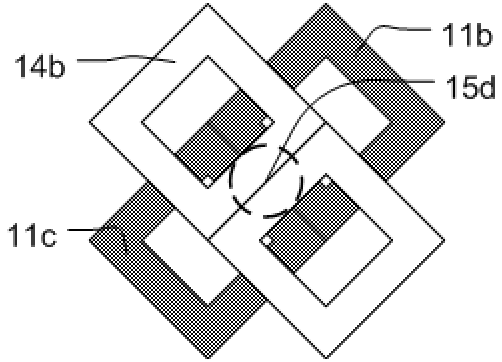
Type 1
Crack detector



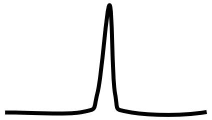
Type 2
Liftoff gauge

Eddy Current Array

Type 1 Crack Detector

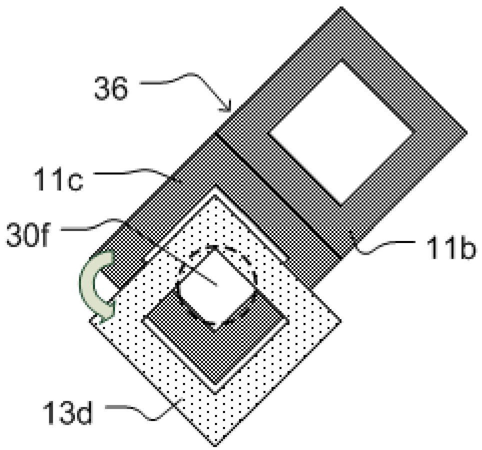


Cross-wound coil



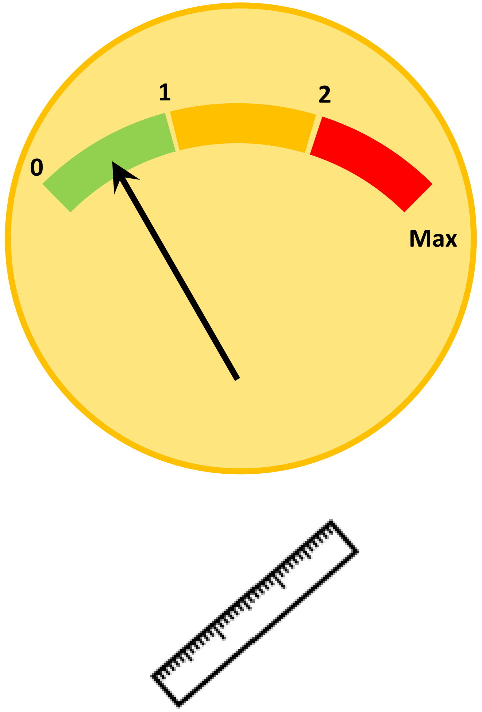
Crack
signal

Eddy Current Array



Reflection coil

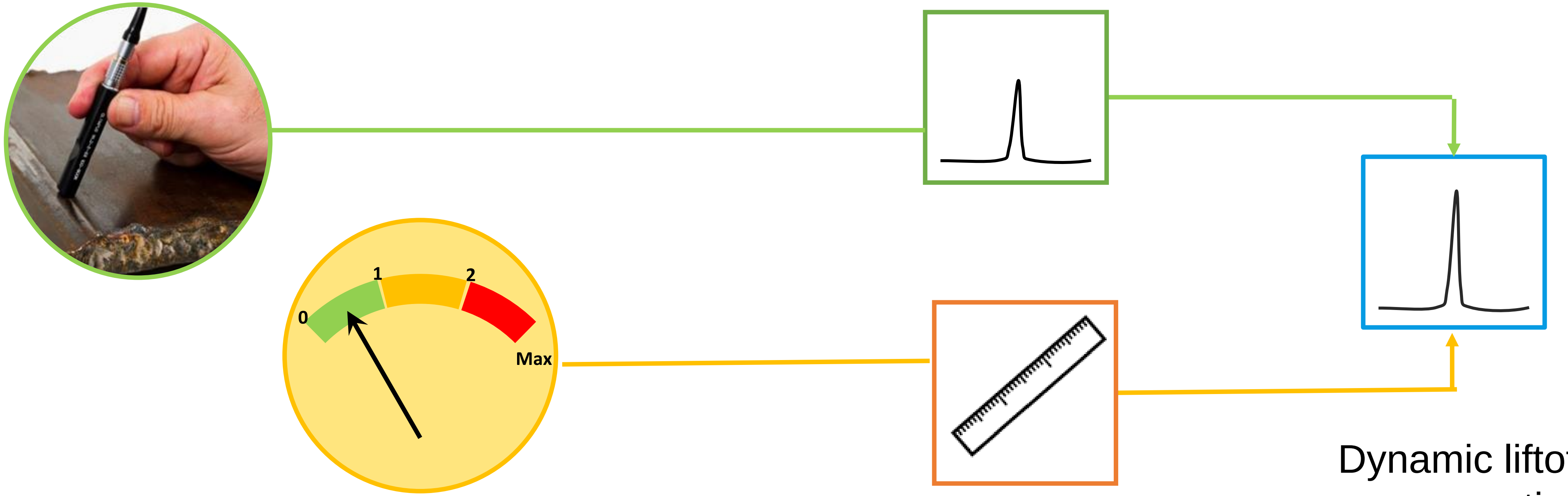
=



Liftoff measurement

Eddy Current Array

Cross-Wound Coil/Reflection Coil Combination



Dynamic liftoff compensation

Eddy Current Array

Independent Sensors

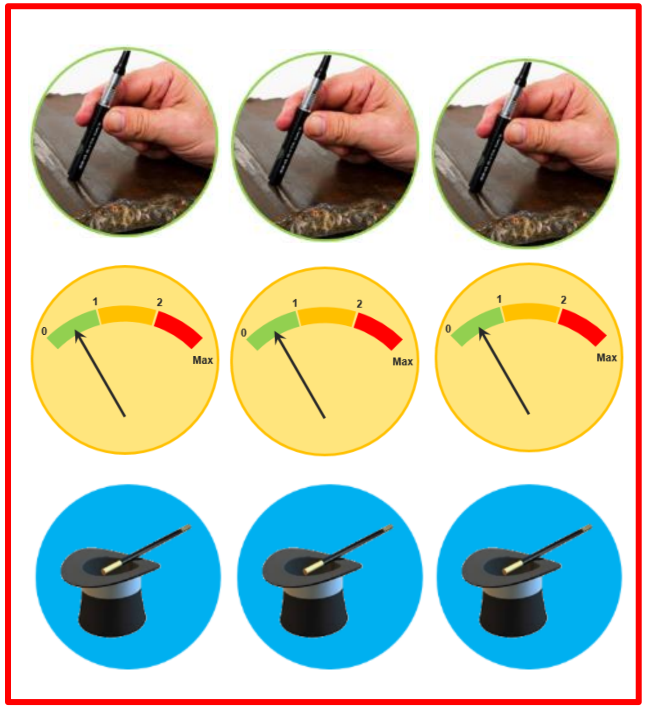
16 independent crack detectors

+

16 independent liftoff gauges

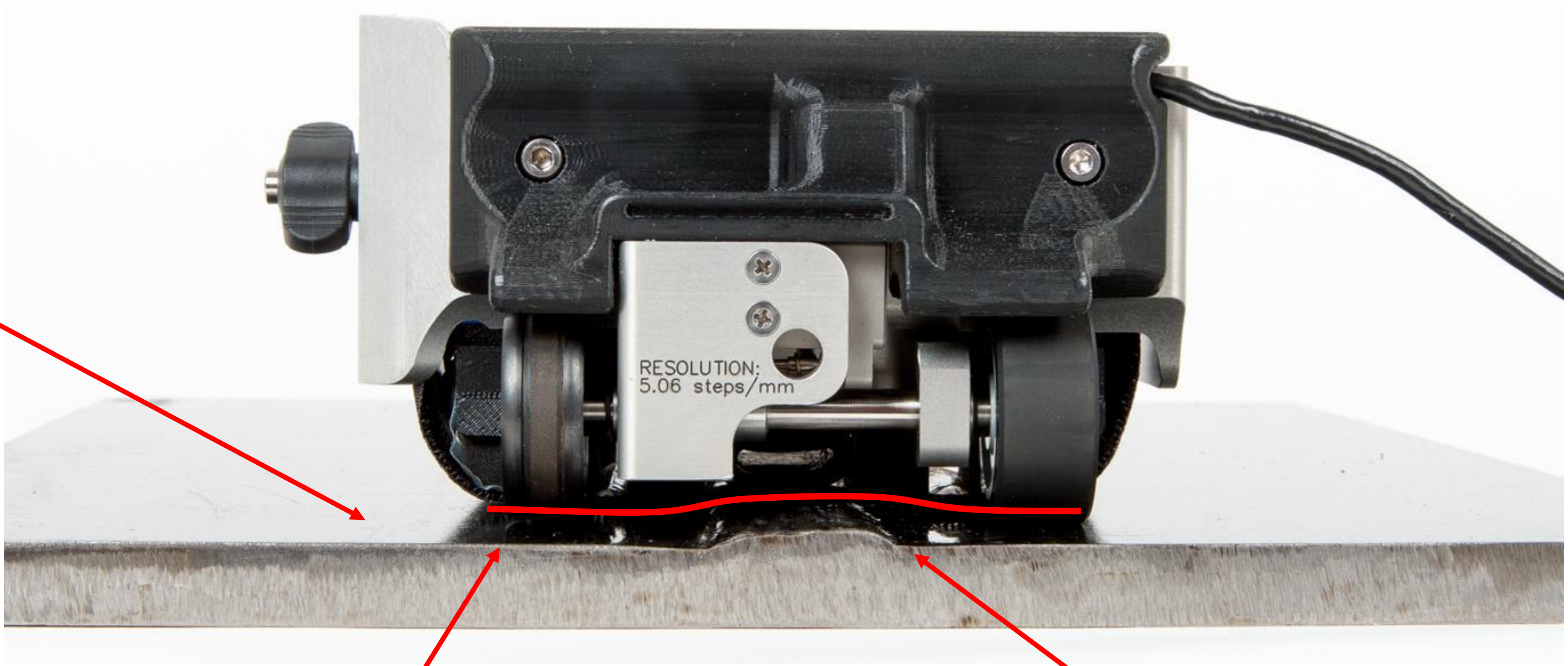
=

16 independent dynamic liftoff compensated channels



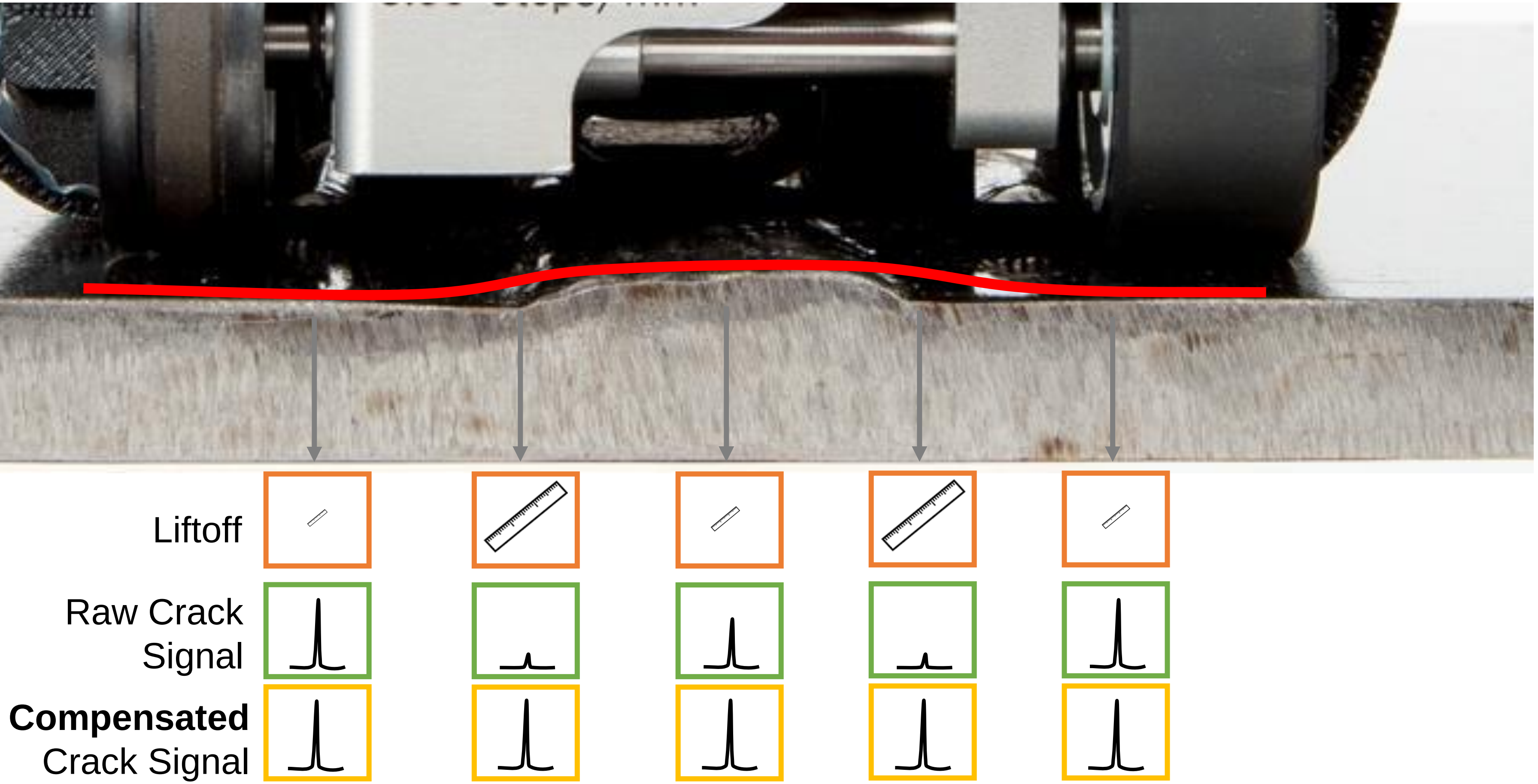
Eddy Current Array

Flexible ECA



Eddy Current Array

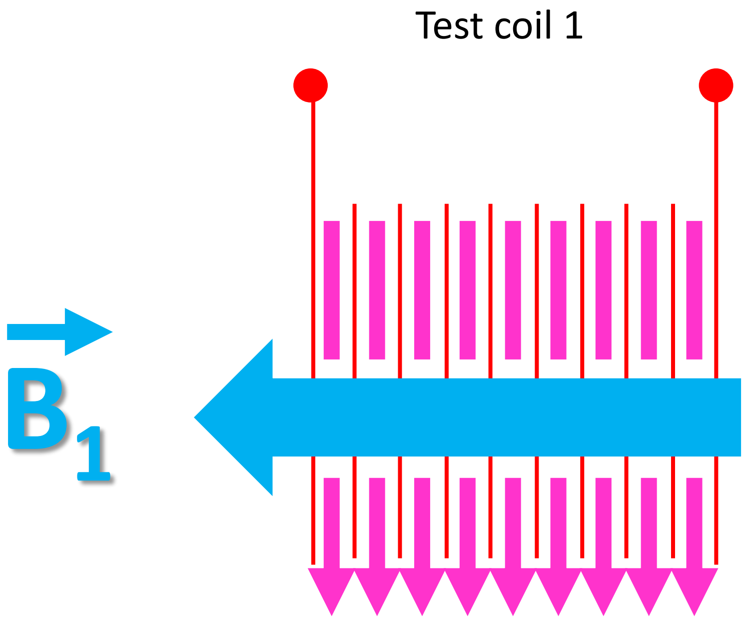
Liftoff Compensation

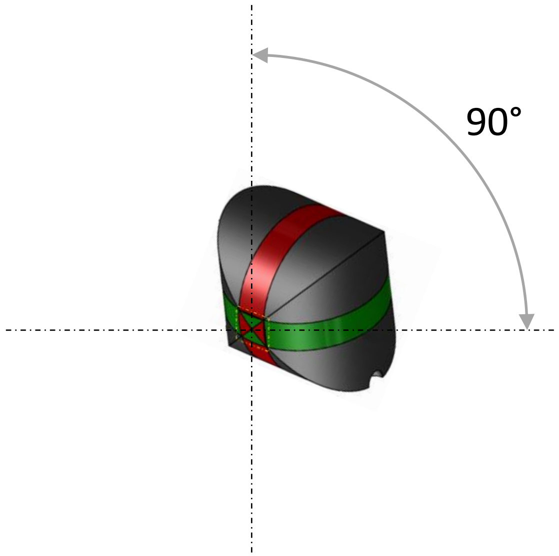


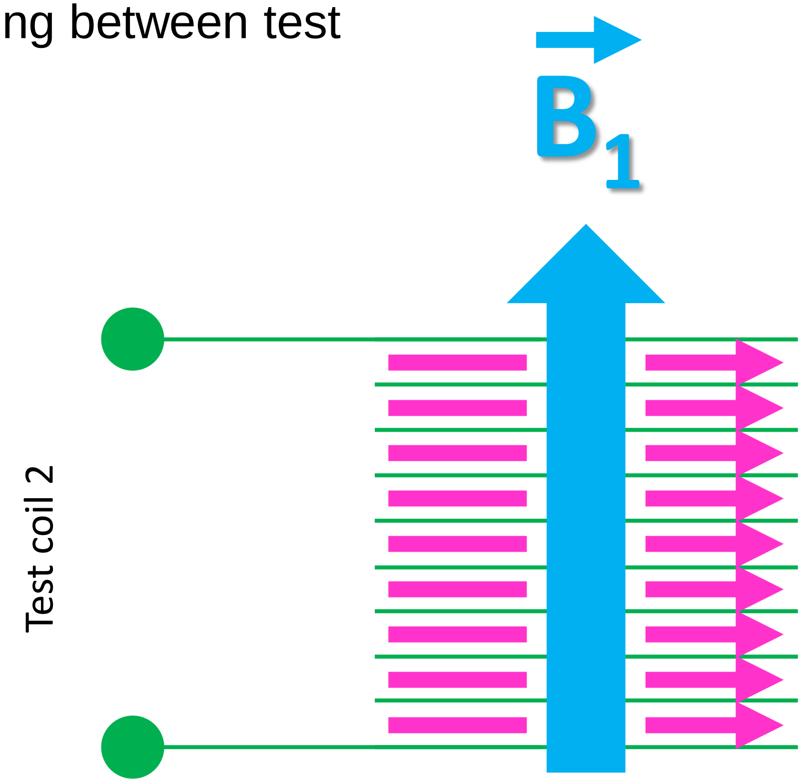
Signal Analysis

The two test coils are crossed by the same inductive current and generate two inductive magnetic fields in a 90° orientation because of their orthogonal positioning.

Because of the orthogonal concept (90°), there is no magnetic coupling between test coil 1 and test coil 2.

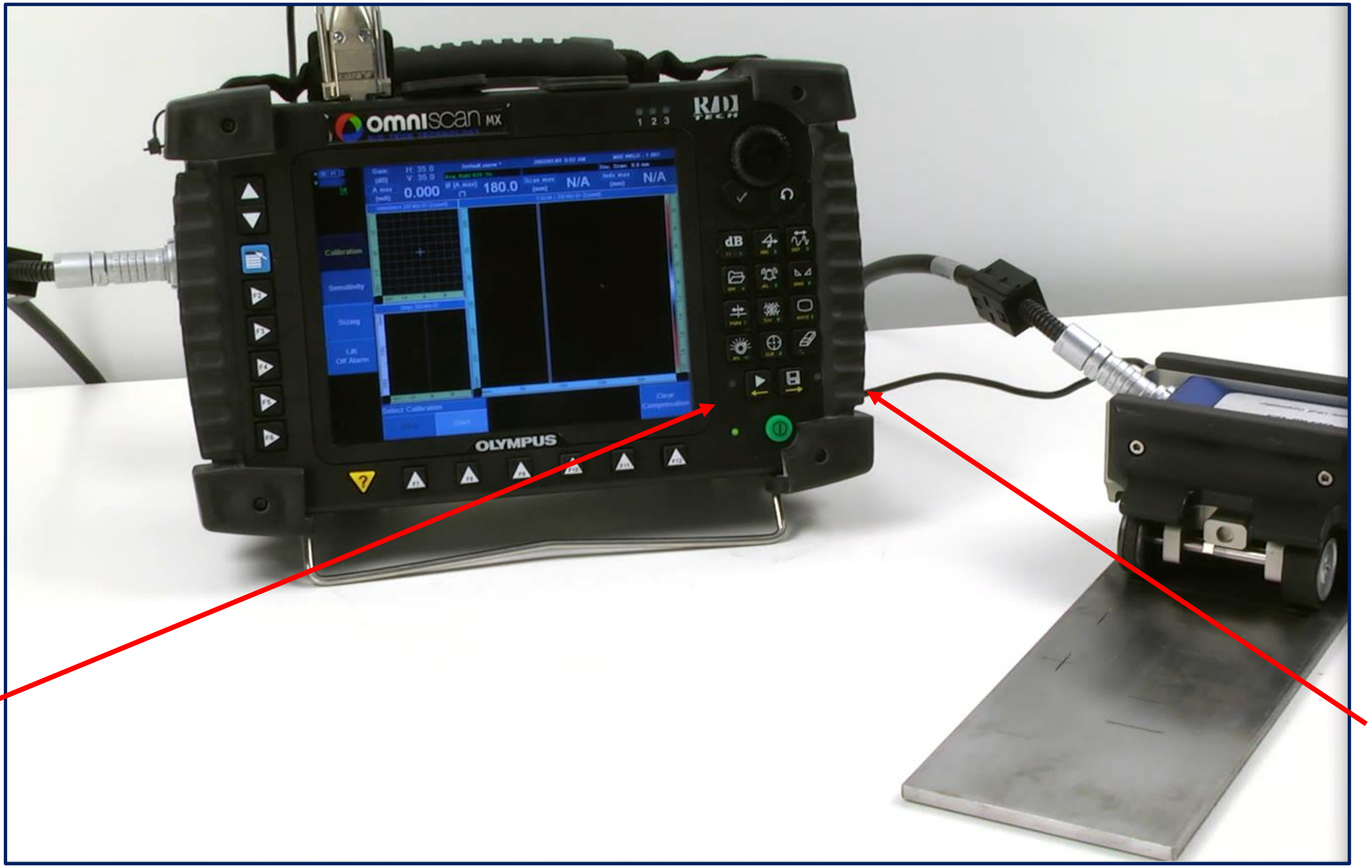






Eddy Current Array

Liftoff Compensation on Steel



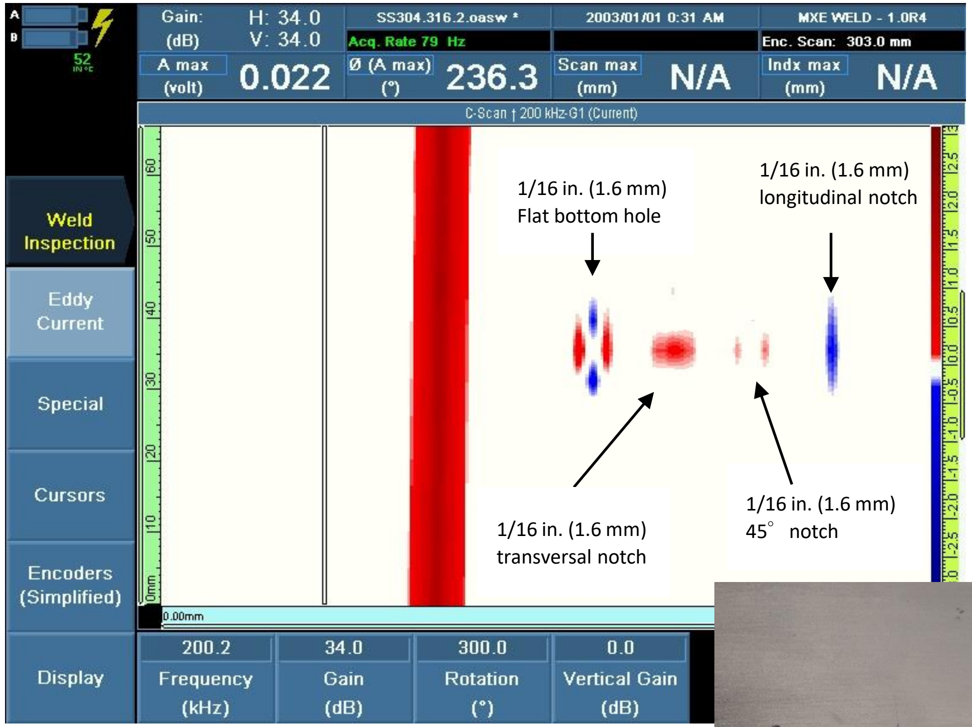
Before
No liftoff

After
1/8 in. (3 mm)
liftoff

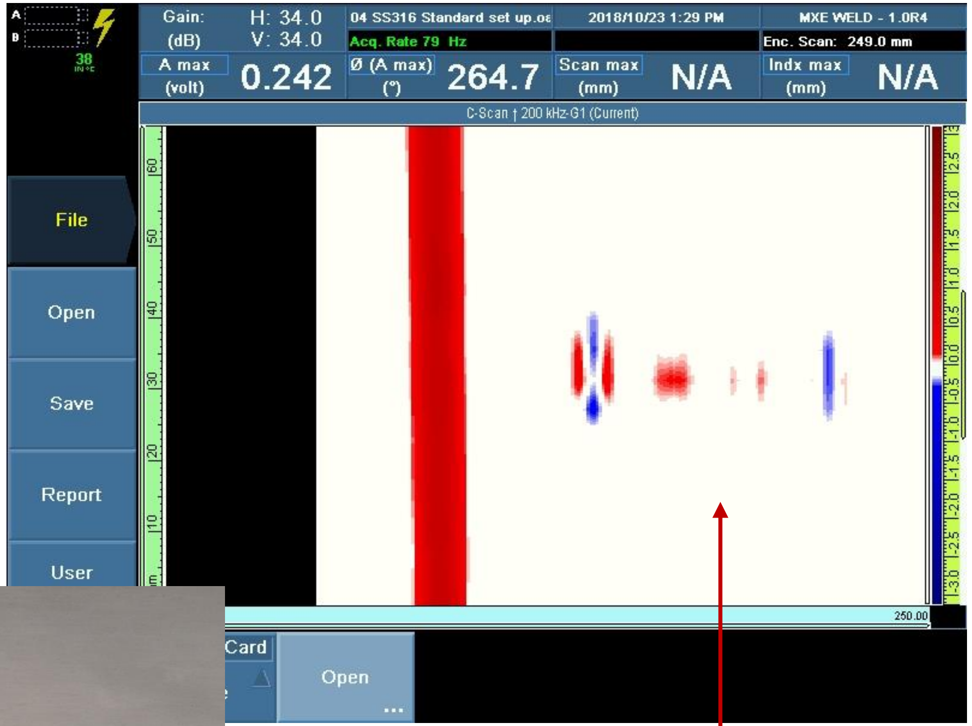
Eddy Current Array

Liftoff Compensation on Stainless Steel

Stainless steel 304, C-scan image with 0 mm of liftoff



Stainless steel 304, C-scan image with 3 mm of liftoff

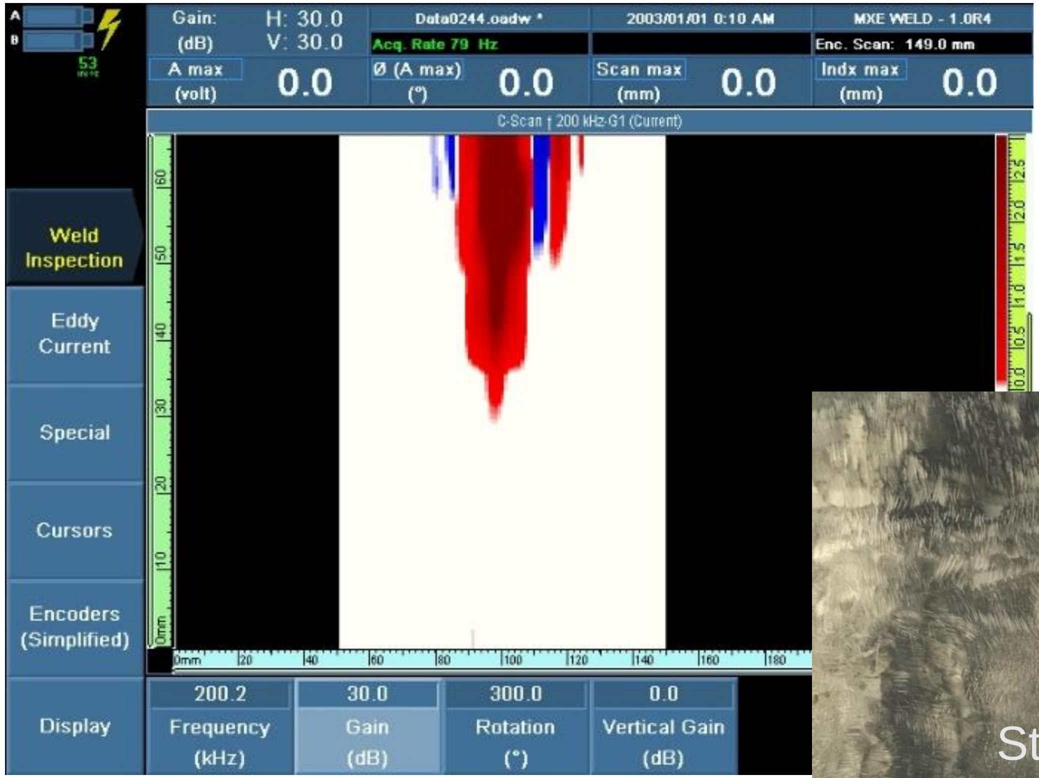


No noise caused by liftoff

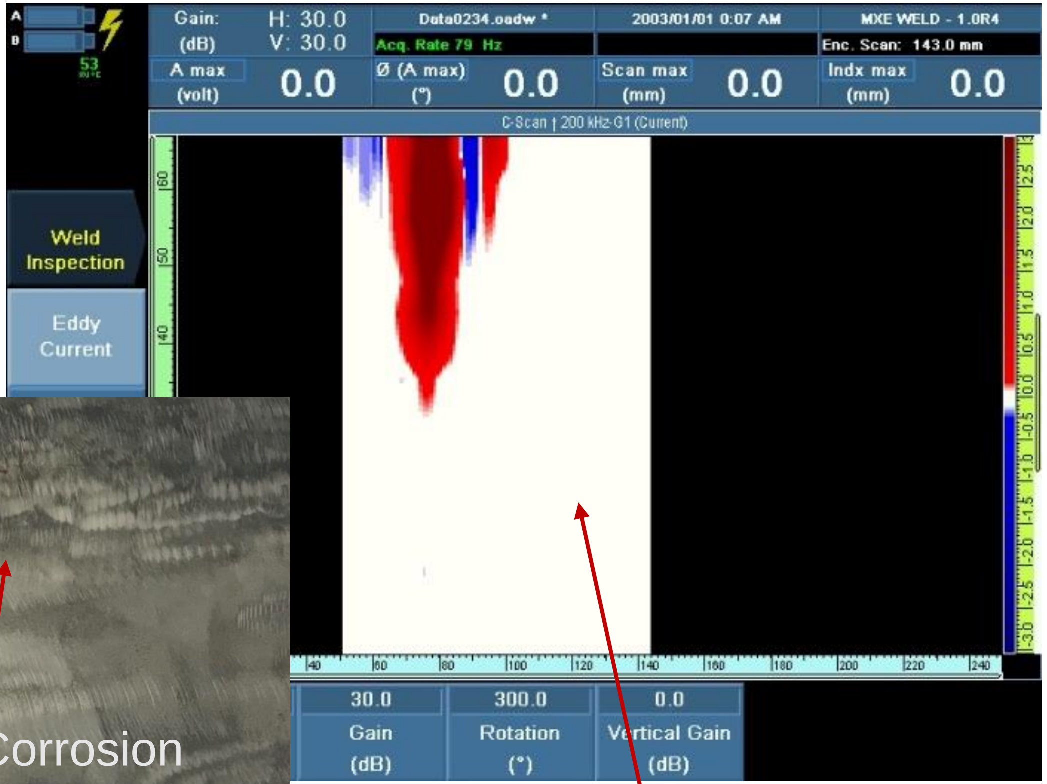
Eddy Current Array

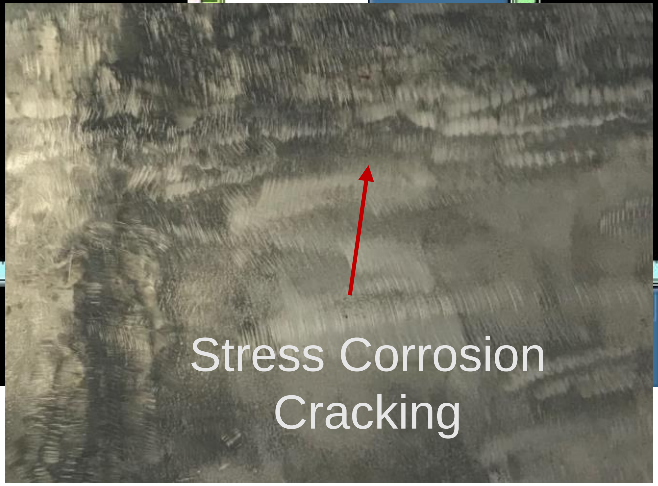
Liftoff Compensation on Stress Corrosion Cracking (SCC)

Stainless steel 304 C-scan image with no liftoff



Stainless steel 304 C-scan image with 1/8 in. (3 mm) liftoff





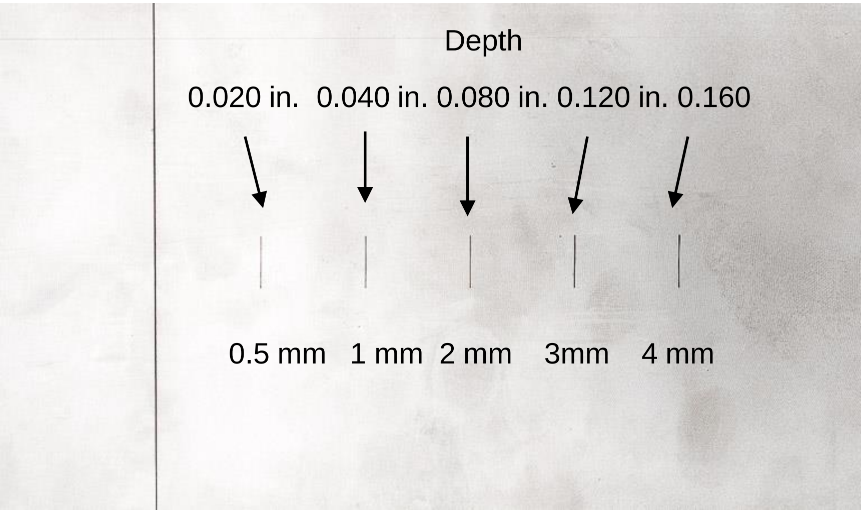
No noise caused by liftoff

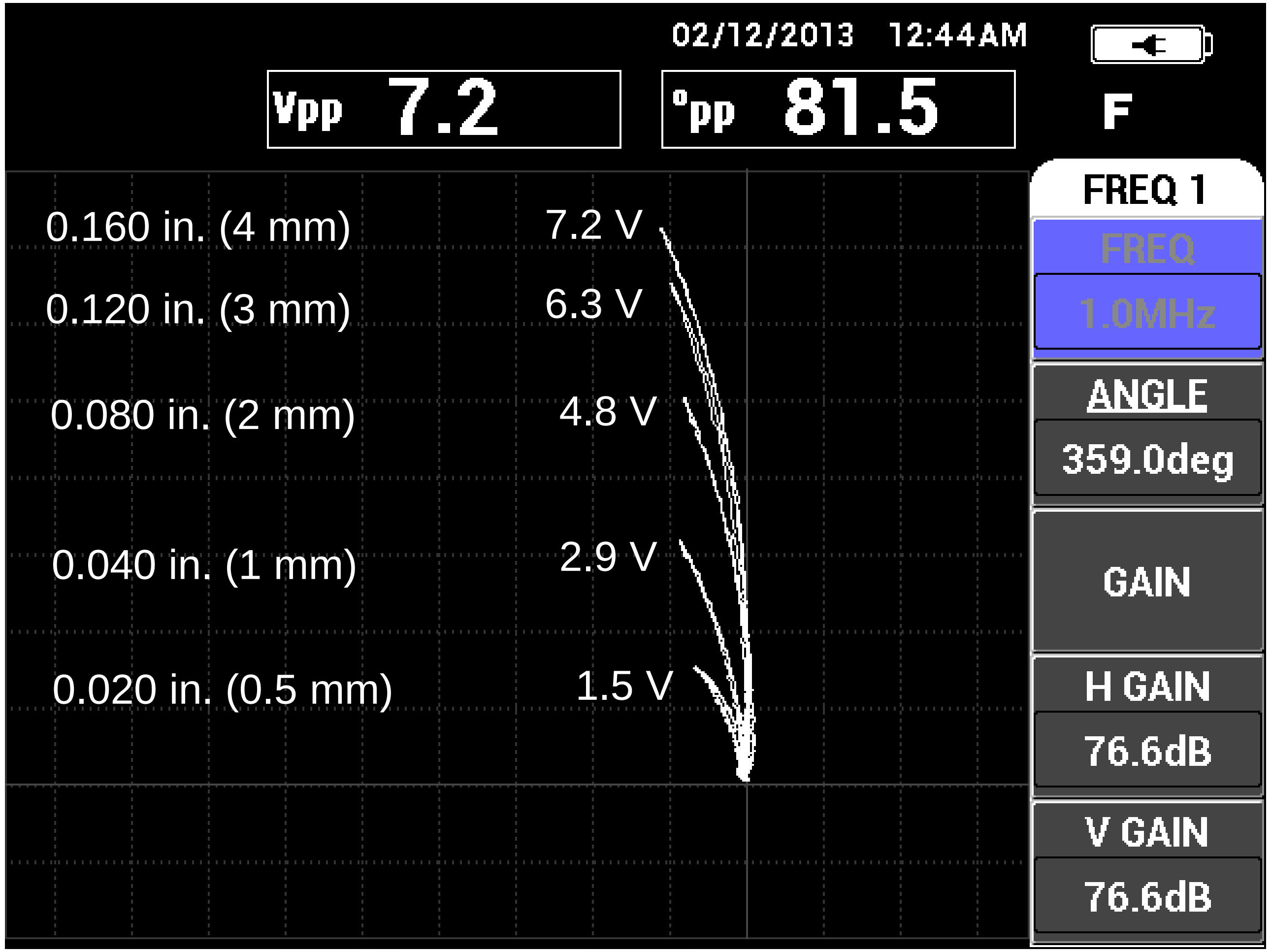
Stainless Steel Weld Depth Sizing

Depth Sizing

Conventional Eddy Current

The detection amplitude is directly related to the flaw depth. Therefore, the depth can be evaluated by comparing indication amplitudes to those of calibrated notches.

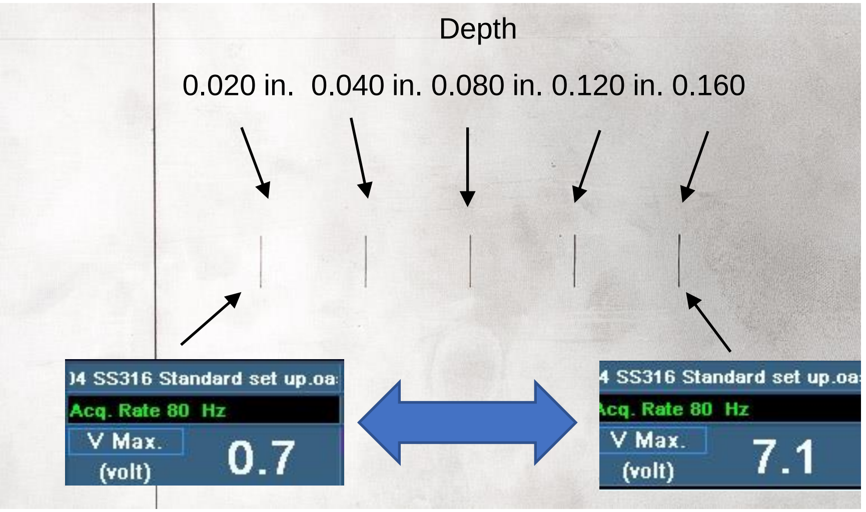


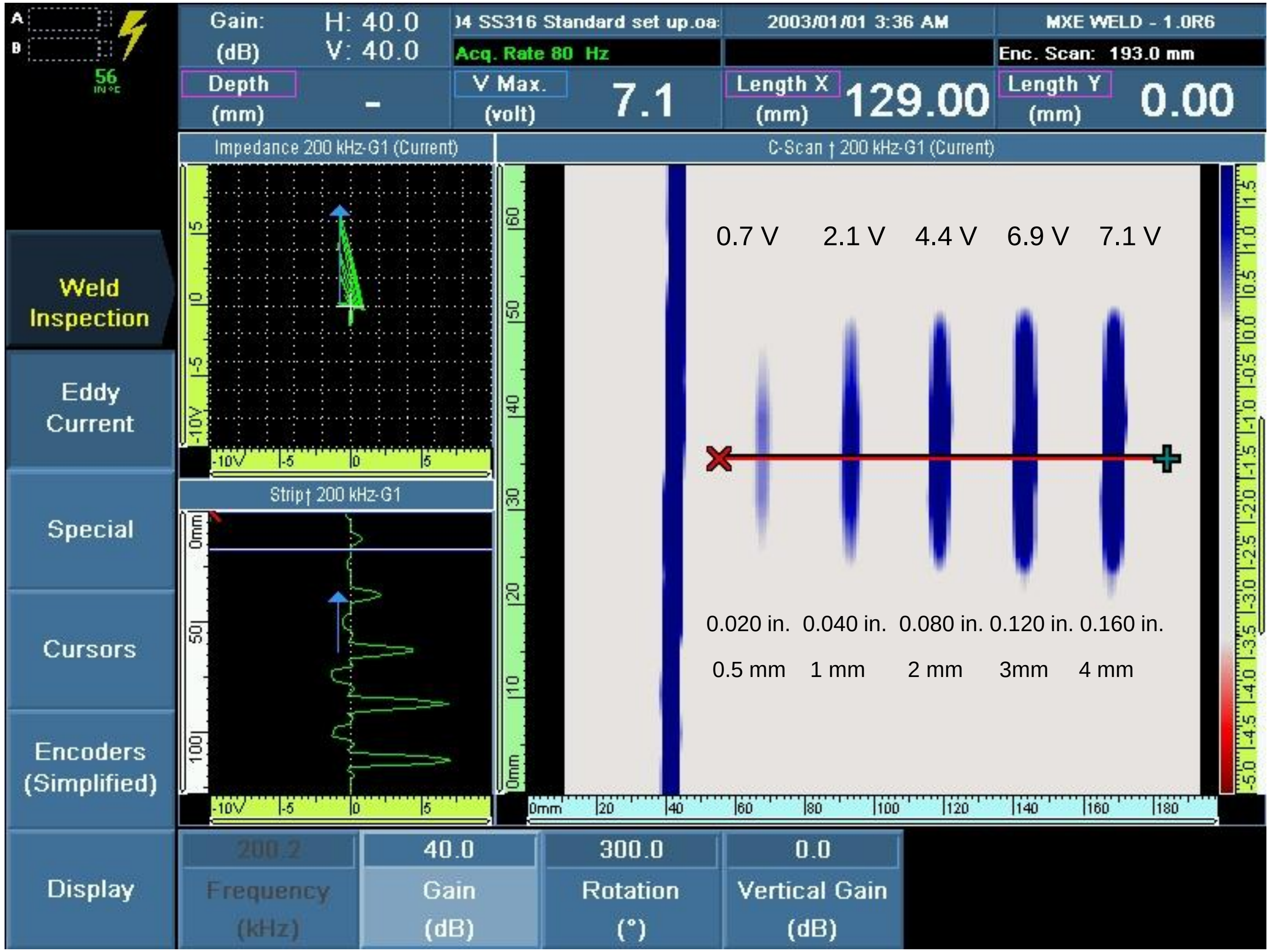


Depth Sizing

Eddy Current Array

When using an ECA probe, the detection amplitude can also be used to evaluate the depth of flaws. Like with ECT, depth can be evaluated by comparing indication amplitudes to those of calibrated notches.





Conclusion

How Eddy Current Solves These Challenges

- Coated surfaces: Eddy current testing can be used to inspect and evaluate depth through paint and coatings.
- Dirty surfaces: Eddy current testing can be performed directly on surfaces that haven’t been cleaned.
- Rough surfaces: Eddy current inspection is a reliable method to inspect rough surfaces.

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Conclusion

Eddy Current Advantages

- Environment friendly: No chemicals, powders, or gels are required when using ECT and ECA.
- No contact required: Liftoff between probes and parts can be managed with the proper coil configuration.
- Depth evaluation: Depth of flaws can be evaluated using ECT and ECA.
- Inspection speed: Large probes can be used with scanners to speed up the inspection.
- Data analysis: Signal amplitude and phase angle can be used in the results analysis.
- Reporting and archiving: Reporting tools are available, and data can be archived.
- Digitalization: Eddy current data can be digitalized.
- Automated integration: Eddy current probes can be integrated to robotic and automated systems.

THANK YOU

Additional Questions?

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Thank you for participating!

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