EDDY CURRENT ARRAY (ECA)-ENABLED INSPECTION OF ORBITAL WELDS AND JET ENGINE COMPONENTS

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September 19th, 2023

A4A NDT Forum
Denver, Colorado

AGENDA

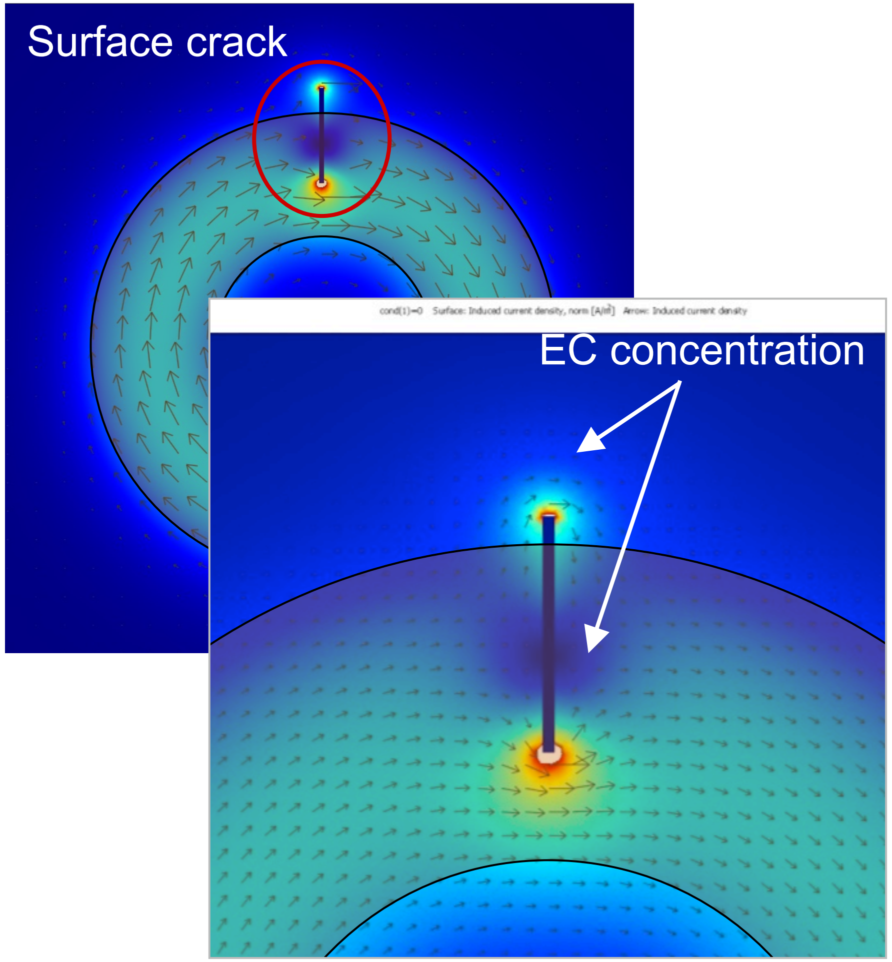
- Introduction to eddy current array (ECA)
- Orbital weld inspection using ECA
- Customization process of ECA
- ECA for aviation and aerospace
- Conclusion

INTRODUCTION TO EDDY CURRENT ARRAY (ECA)

EDDY CURRENT ARRAY (ECA)

ECT - The fundamentals

- An alternating current flowing in a wire will produce a magnetic field around it.
- When the wire is shaped into a coil, the field generated by each turn interacts to create a global field.
- When the coil is placed over a conductive part, the magnetic field generated will induce ***eddy currents*** in the surface.
- Cracks and surface-breaking flaws will disturb the flow of eddy currents, affecting the ***impedance*** of the coil.



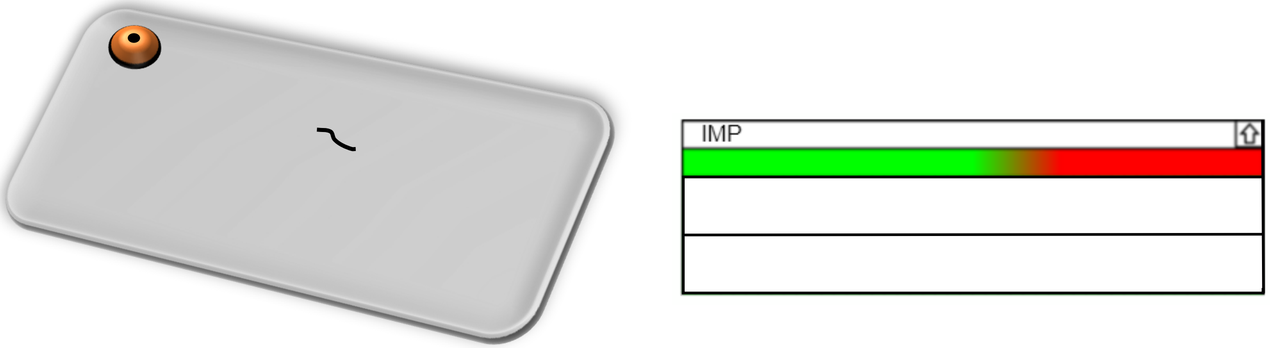
Top view:
Eddy current path and density

EDDY CURRENT ARRAY (ECA)

Eddy current array (ECA) uses multiplexed coil sensors, allowing the inspection of large surfaces in a single linear scan.

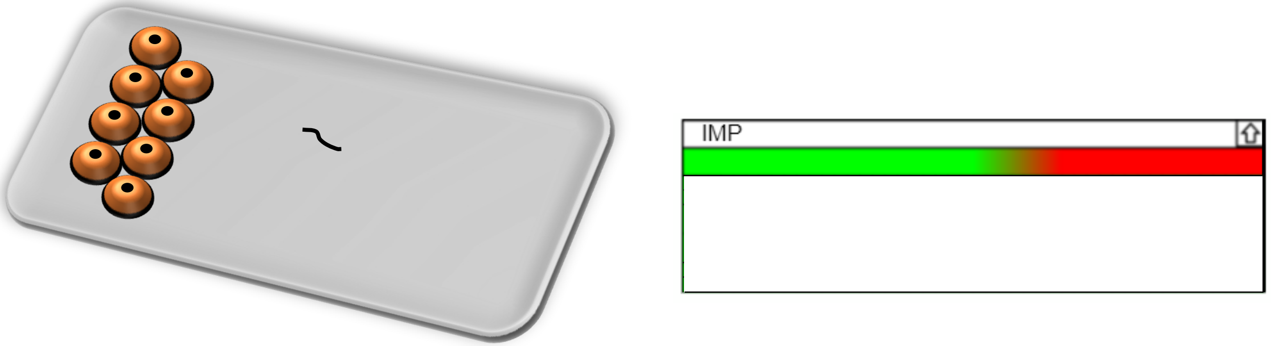
Single-element ECT on large surfaces:

- High operator dependency due to coil instability and positioning
- Slow inspection process
- Post-inspection analysis difficult



Eddy current array:

- Low operator dependency
- Faster inspection
- Intuitive surface visualization and post-inspection data analysis



EDDY CURRENT ARRAY (ECA)

Two technologies of ECA sensors:

- Copper “pancake” coils
- Higher impedance, lower frequency
- Allows deeper penetration in non-ferrous materials

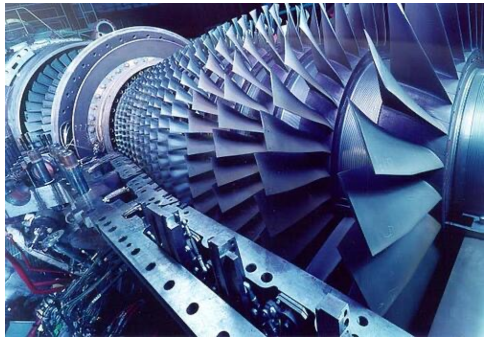
- Printed coils embedded in flexible boards
- Lower impedance, higher frequency
- Allows more flexibility to inspection the most complex geometries

EDDY CURRENT ARRAY (ECA)

Eddyfi Technologies

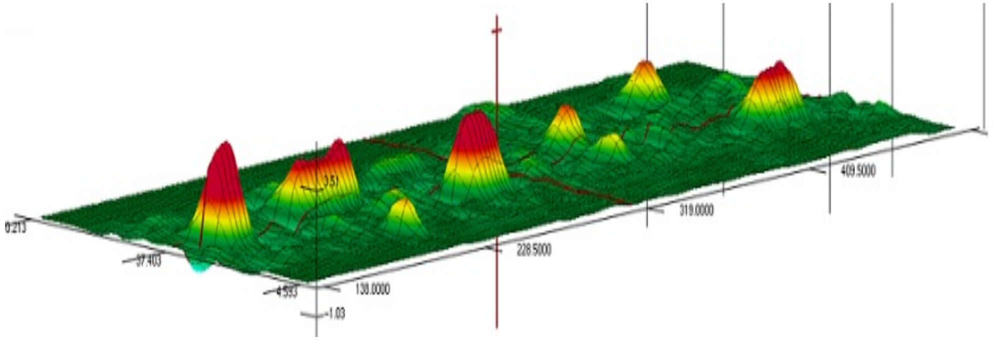
What can be detected with ECA?

- Cracks
- Porosities
- Weld flaws (LoF, LoP, etc.)
- Corrosion
- Variation of properties (conductivity, hardness, etc.)



How is it different from penetrant testing?

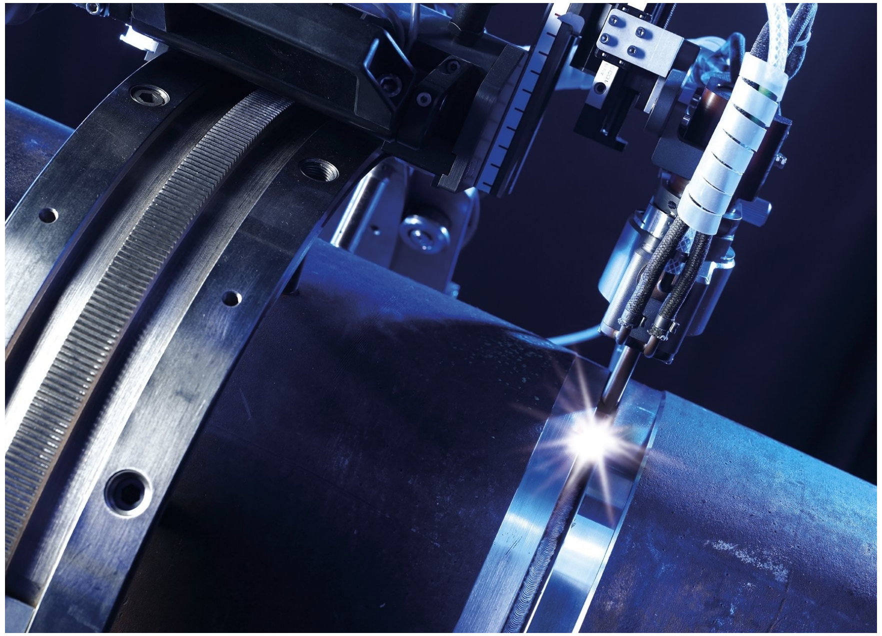
- Faster inspection process
- Allows inspection through coating
- Penetration of non-ferrous materials
- Digital data archiving (2D and 3D C-scans)
- Easier access to complex geometries
- No consumable chemicals

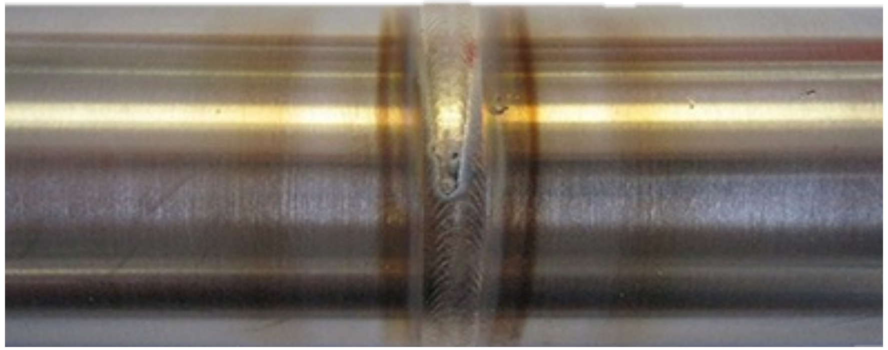


ORBITAL WELD INSPECTION USING EDDY CURRENT ARRAY

ORBITAL WELD INSPECTION

- Orbital welding: automated rotation of an arc around a static tube
- Widely used in aerospace for fuel lines and hydraulic lines
- Welding process susceptible to clusters of porosities and development of small cracks
- Combination of radiography and penetrant testing is often the procedure of choice to inspect orbital welds

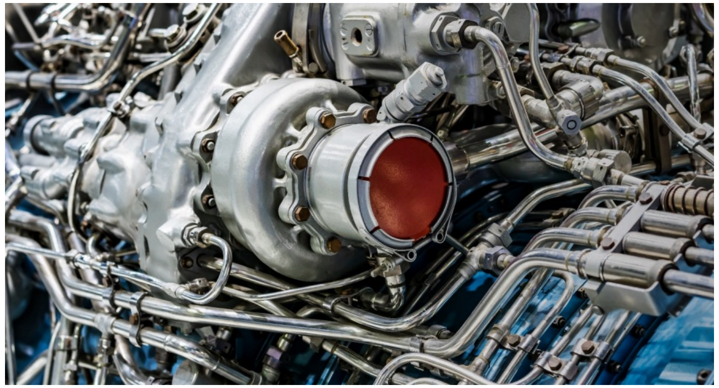




ORBITAL WELD INSPECTION

Technical requirements for ECA development:

- Weld material: titanium, stainless steel, Inconel
- Tube diameter: 6 mm to 50 mm (¼” to 2”)
- Wall thickness: 0.5 mm to 2.0 mm (0.020” to 0.080”)
- Access: inspection from the outside, 1 inch from elbow
- Target defects: cracks and clusters of porosities
- Minimum defect depth: 40% wall thickness
- Minimum defect length: 2 mm (0.080”)
- Defect position: internal, external, mid-wall

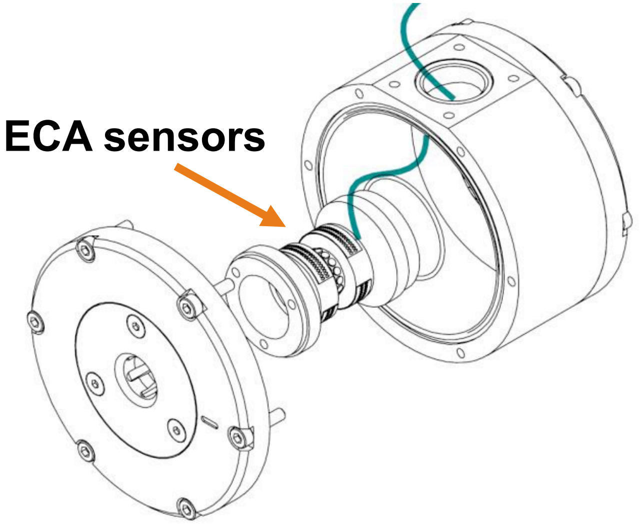


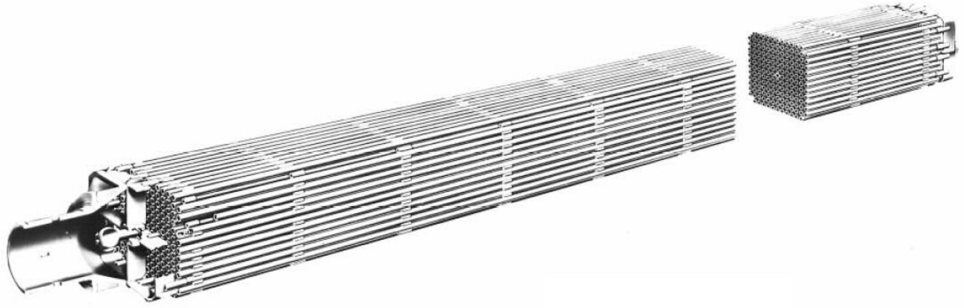
ECA SOLUTION DEVELOPMENT

Preliminary probe design based on nuclear components inspection:

Thin tubes containing nuclear fuel (*fuel rods*):

- Similar diameters and material electrical properties
- Similar defect type and size
- ECA probe covering 360° in a single pass
- Coils of 2 mm penetrating a wall of 2 mm
- Frequency: 500 to 1200 kHz

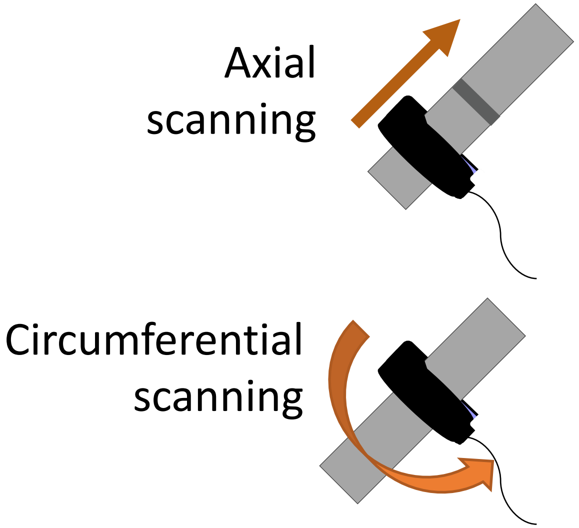


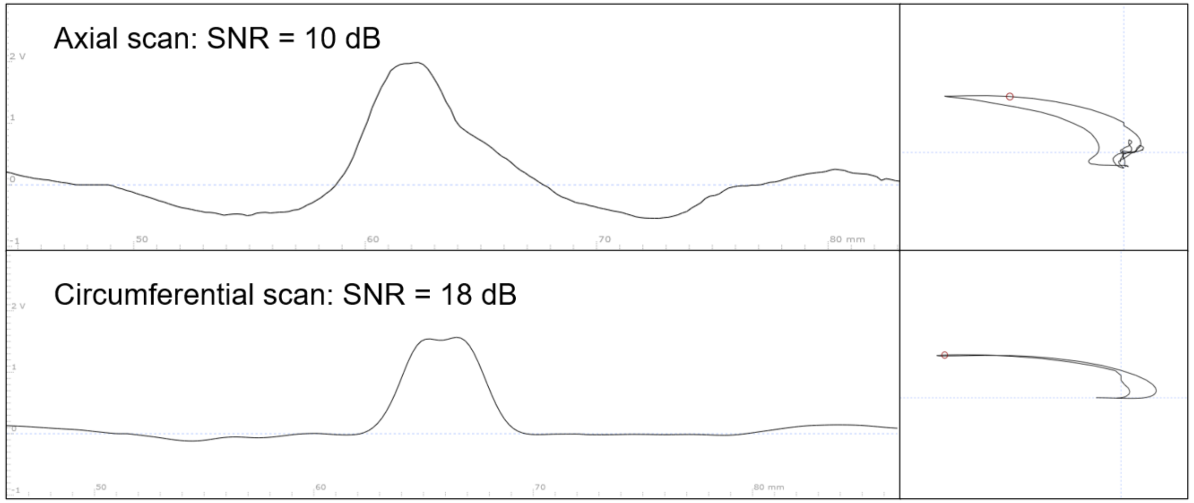


ECA SOLUTION DEVELOPMENT

Validation #1 – Scan axis:

- Change of electrical properties and geometry at the weld induces additional noise when scanning the tube axially
- Circumferential scanning allows nulling the sensors directly on the orbital weld

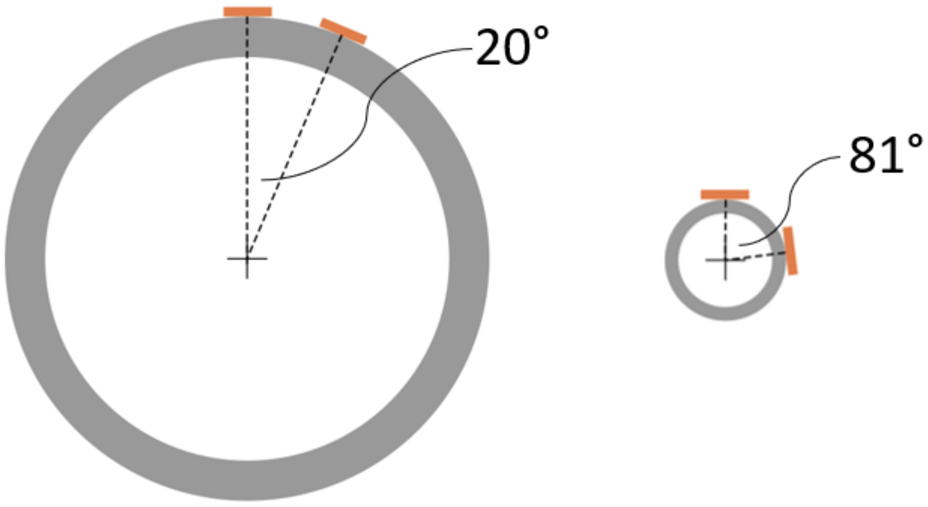




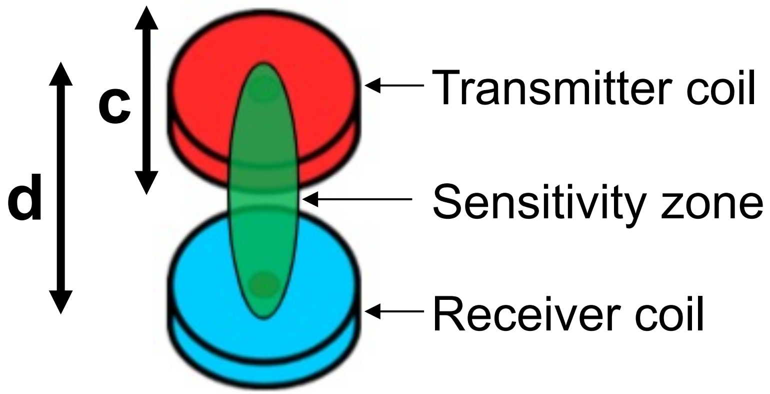
ECA SOLUTION DEVELOPMENT

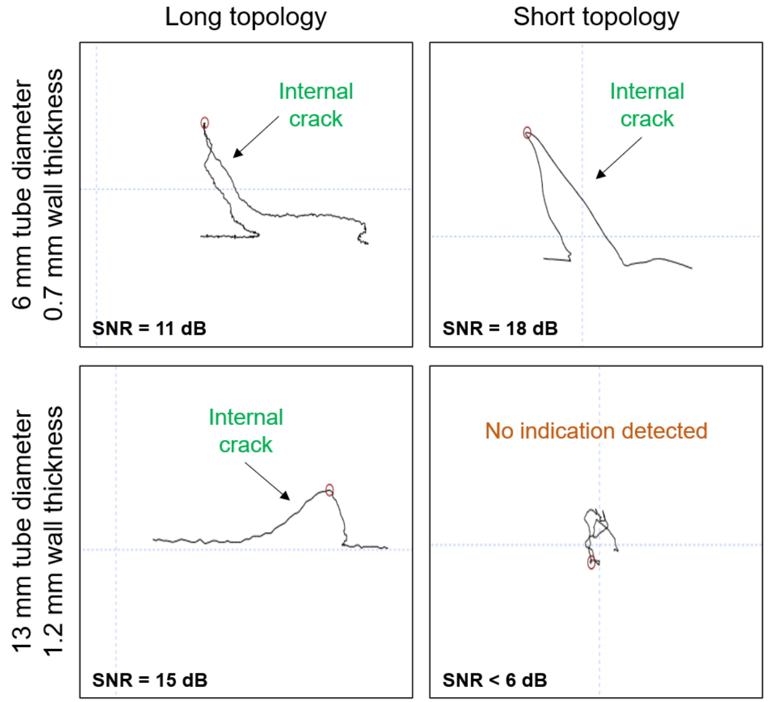
Validation #2 – ECA topology:

- Short topology ($d \approx c$): higher resolution
- Long topology: ($d \approx 2c$): higher penetration



Diameter = 25 mm Diameter = 6 mm

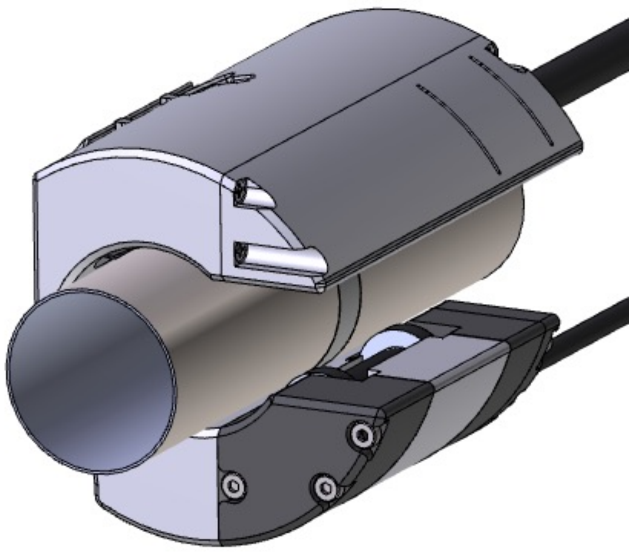


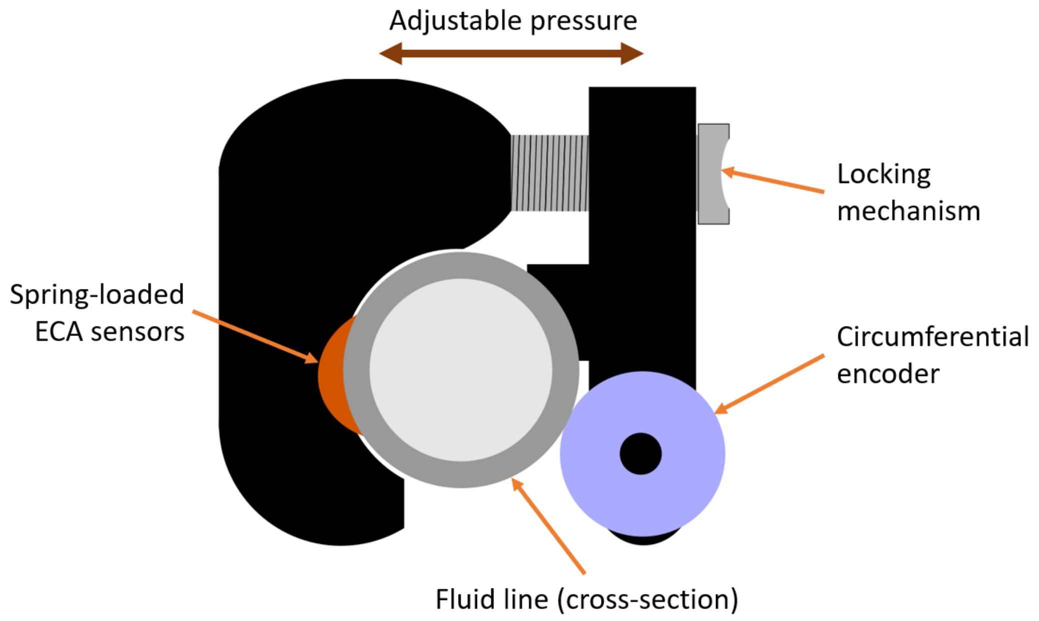


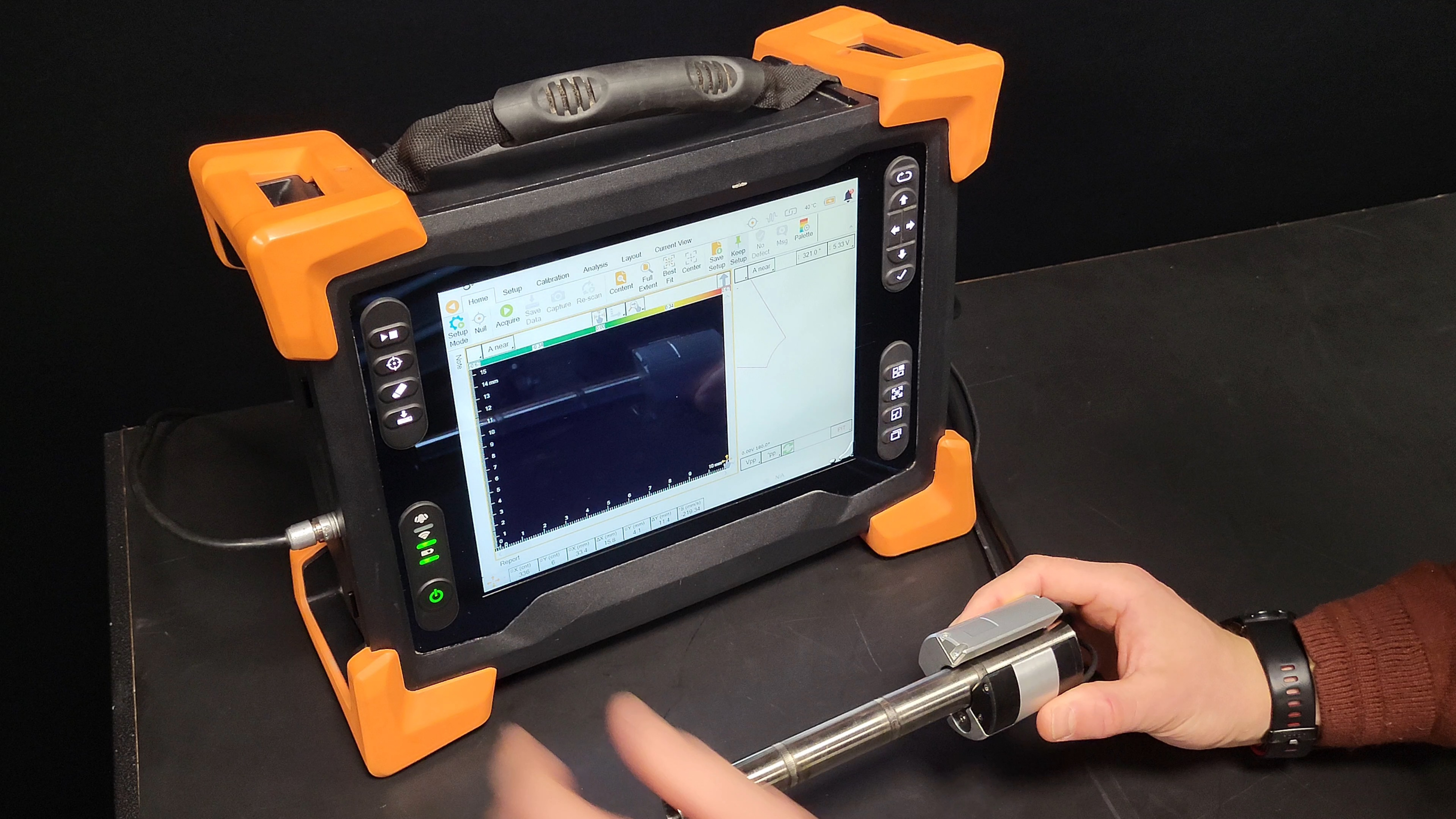
ECA SOLUTION DEVELOPMENT

Validation #3 – Size, frequency and depth of penetration:

- Copper coils of 2 mm (0.080”) optimized at 1050 kHz to fully penetrate the wall thickness and remain away from resonance effects
- Array of sensors spring-loaded to minimize lift-off



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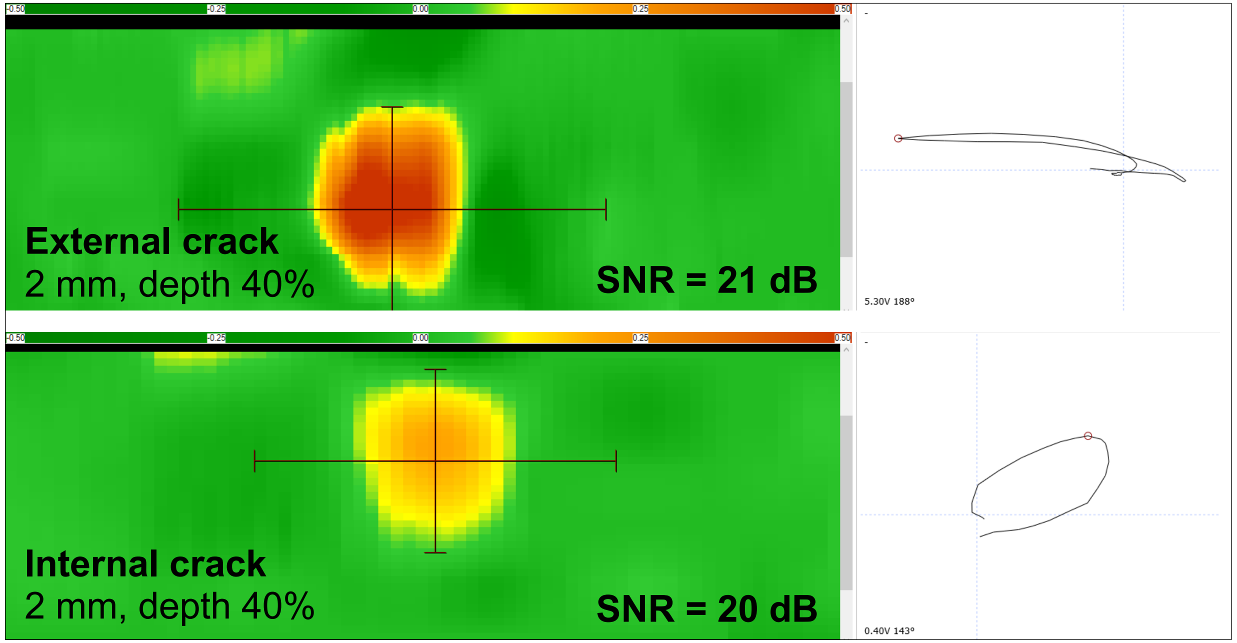
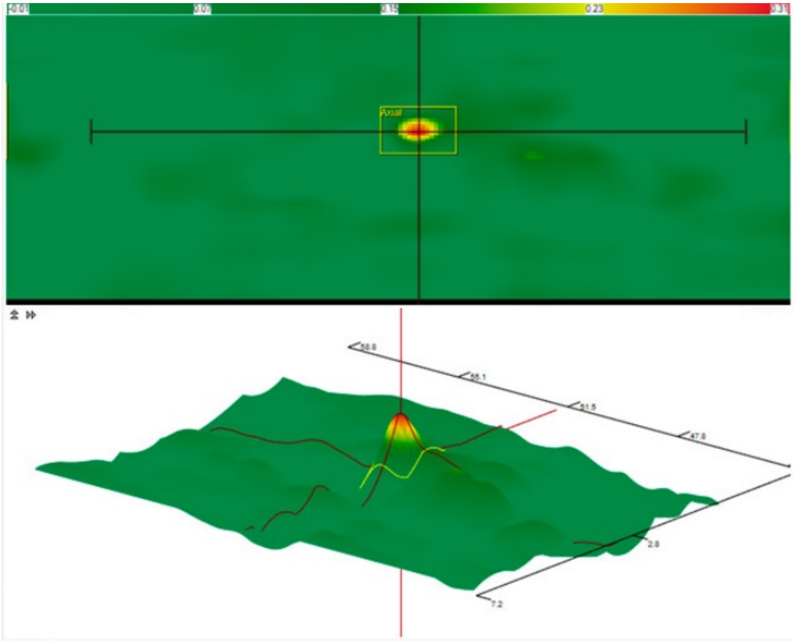
ECA RESULTS ON ORBITAL WELD

Results on orbital welds with natural defects:

Cracks:



Clusters of porosities:

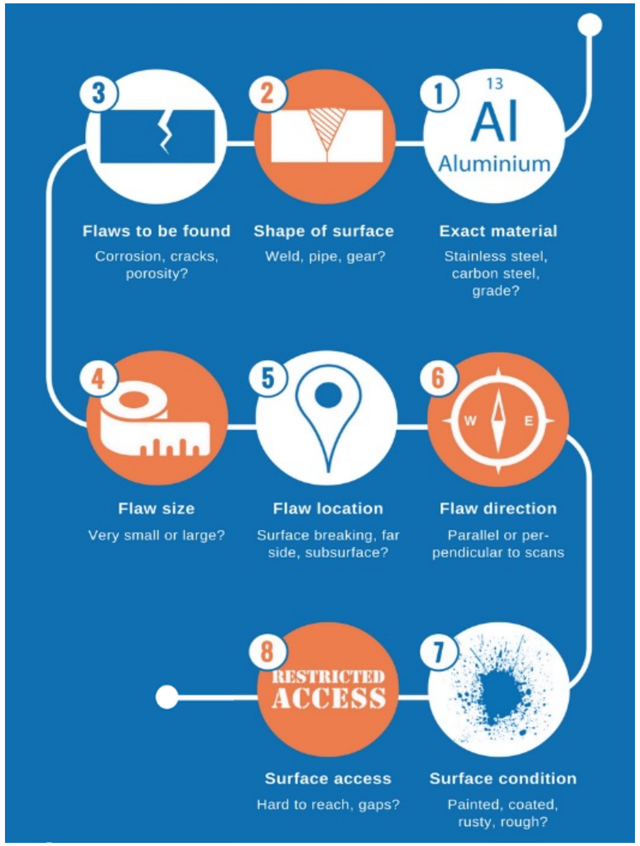


ECA CUSTOMIZATION FOR AVIATION AND AEROSPACE

ECA CUSTOMIZATION FOR AVIATION

ISO-certified design process developed for the customization of ECA solutions:

- Performance validated through feasibility studies
- Coil sensors, topology and array size optimized for each application
- Weighted advantages of pancake coils and printed coils (depth of penetration and flexibility)
- Probe body tailored to the component to inspect

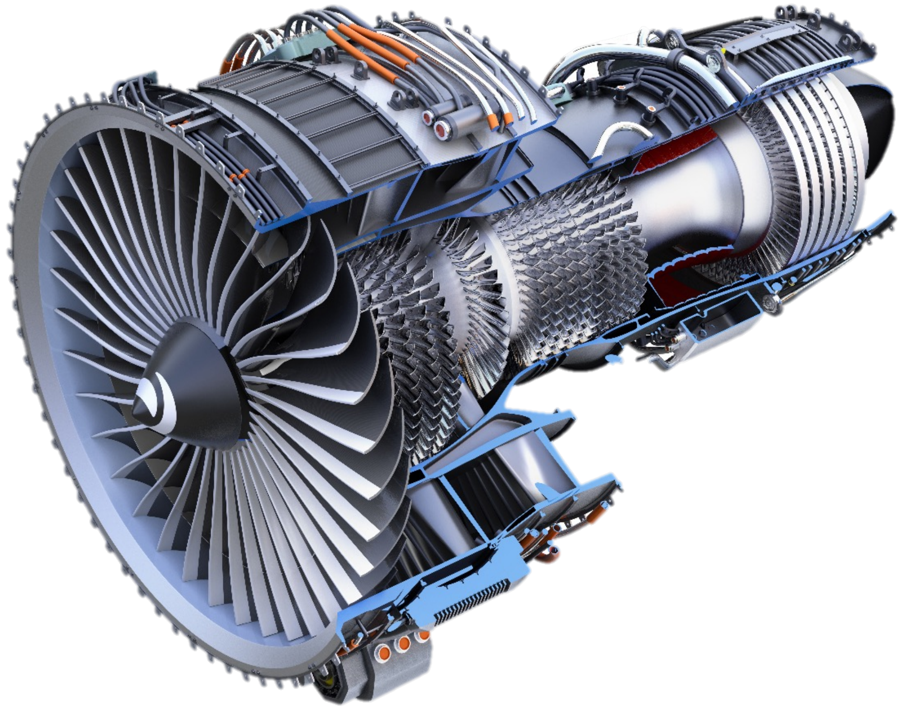


ECA CUSTOMIZATION FOR AVIATION

Eddyfi Technologies

Custom ECA design process used to inspect several parts of the engine:

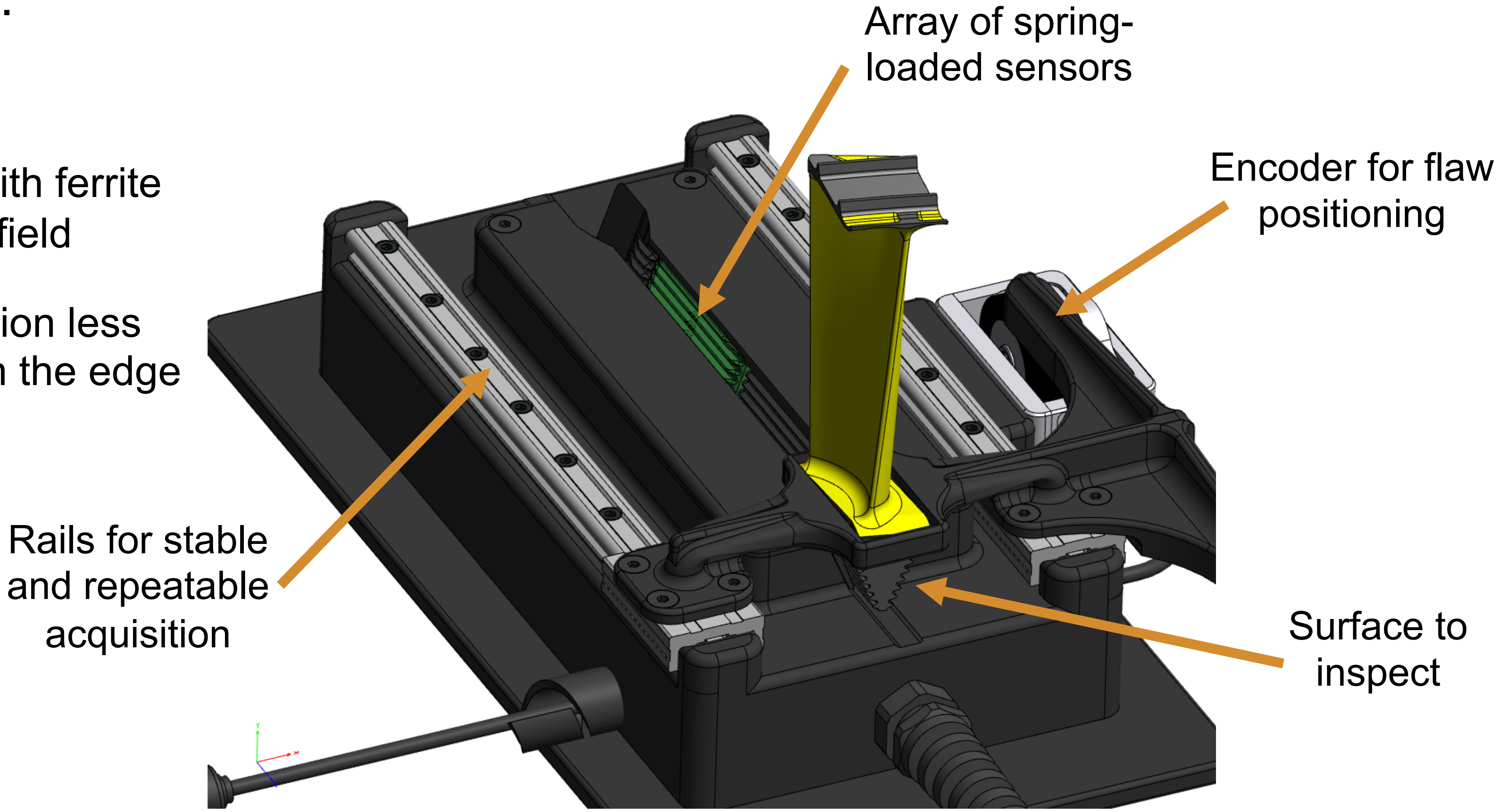
- ✓ Fuel lines (orbital welds)
- ✓ Turbine spools
- ✓ Blade surfaces
- ✓ Blade roots
- ✓ Fir-tree serrations
- ✓ Cooling holes
- ✓ Bore hole



ECA CUSTOMIZATION FOR AVIATION

Blade root inspection:

- 1-mm coils at 1 MHz
- Topology: Differential, with ferrite core to concentrate the field
- Detection of crack initiation less than 1 mm (0.040") from the edge

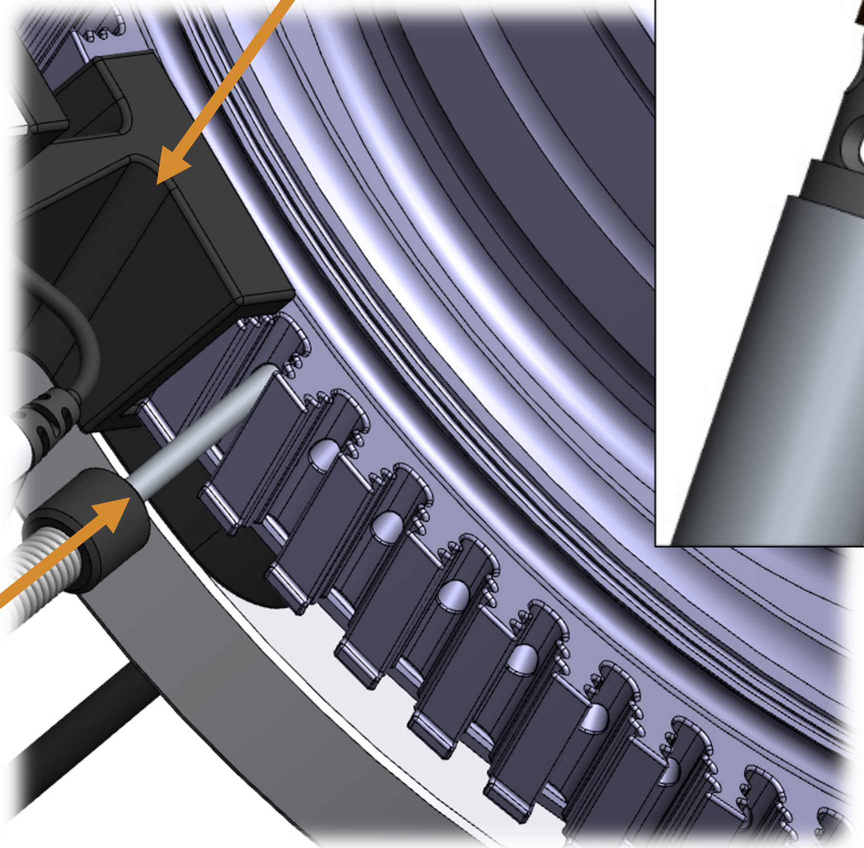


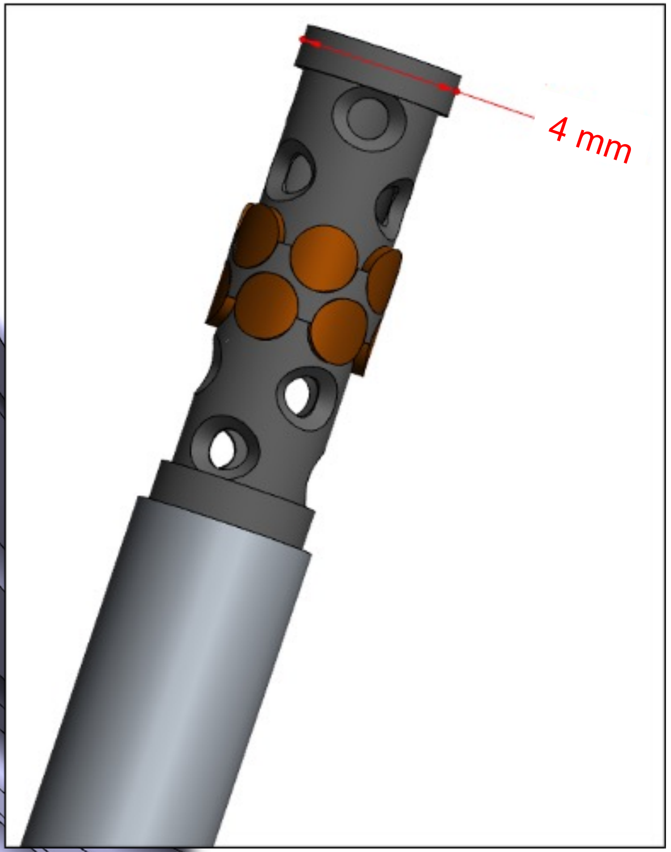
ECA CUSTOMIZATION FOR AVIATION

Eddyfi Technologies

Cooling hole inspection:

- Hole diameter = 4 mm (0.160”)
- Circular array of 12 coils
- Detection of crack initiation less than 1 mm (0.040”) from the edge
- Encoded scans for crack length measurement

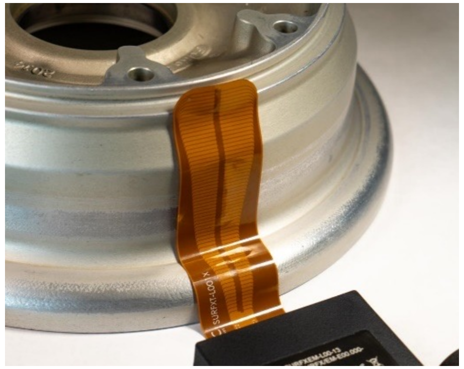




ECA CUSTOMIZATION FOR AVIATION

Aircraft wheel rim inspection:

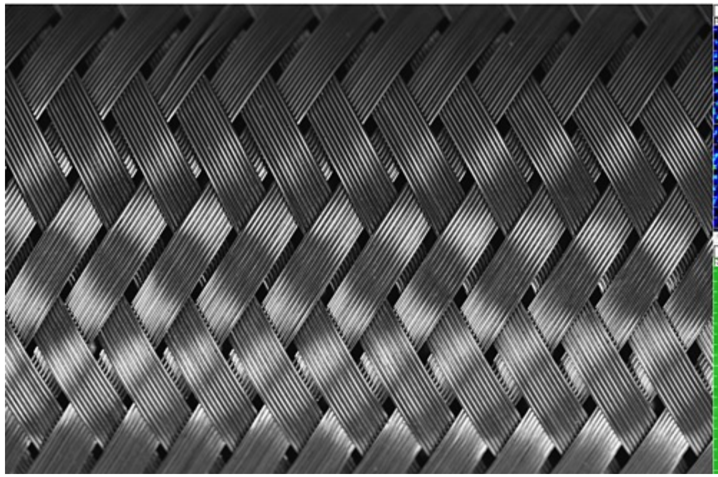
- Detection of cracks in the radius
- Flexible printed coils for optimized surface contact
- Array probe compatible with various holders for inspection of wheel diameters between 120 mm (4.7 in) and 600 mm (24 in)
- Multiple other applications possible with the same equipment

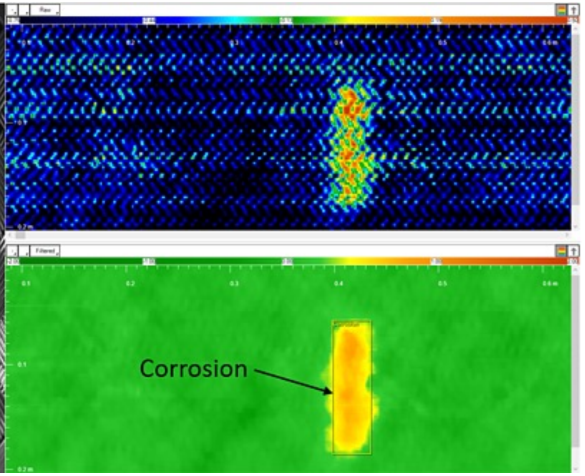


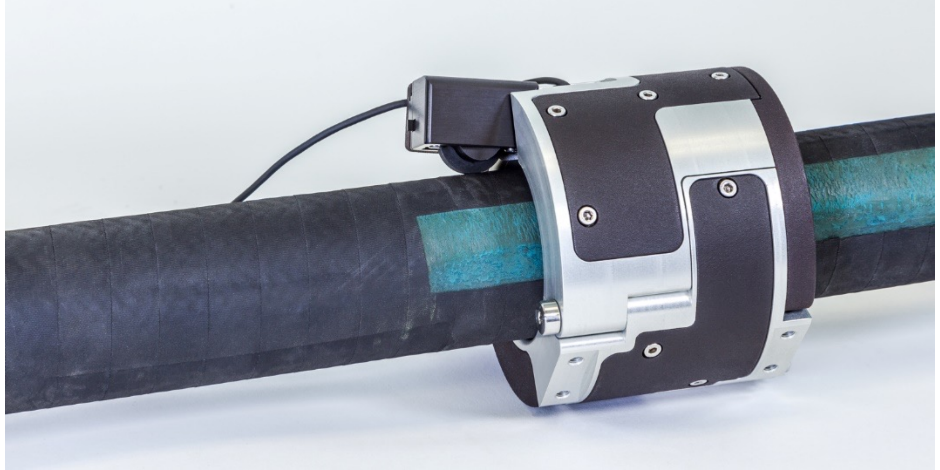
ECA CUSTOMIZATION FOR AVIATION

In-flight refueling hoses:

- Detection of corrosion in the carbon steel braid
- Full 360° coverage in one pass, scan speed up to 2 ft/s (600 mm/s)
- Automated corrosion detection with go/no-go criteria







CONCLUSION

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- ✓ Eddy current array (ECA) provides a faster alternative to penetrant testing for inspecting orbital welds.
- ✓ The nature of ECA goes against a “one size fits all” solution – a probe customization process is preferred to meet specific application requirements.
- ✓ Flexibility on sensor type, size, frequency and topology allows testing complex surface geometries in various aircraft components.
- ✓ ECA shows potential to boost efficiency, minimize human error, and elevate safety standards in aviation inspection procedures.

THANK YOU!

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