# Ultrasonic Inspection of Wind Turbine Blades

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# Contents



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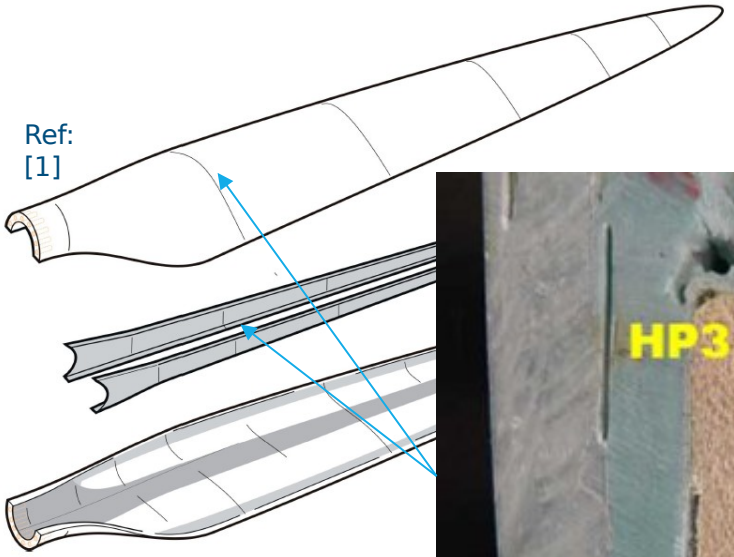
# Highlights from the Literature Study

# Highlights from the AIRTuB literature study

| Type |
| --- |
| **delamination in outer skin-core bond of sandwich** |
| **bondline tunneling or disbond cracks** |

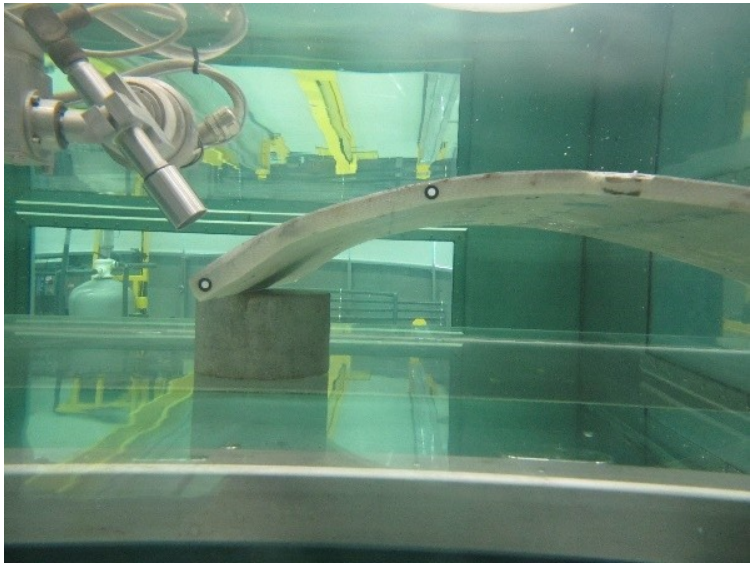
Ref: [1]

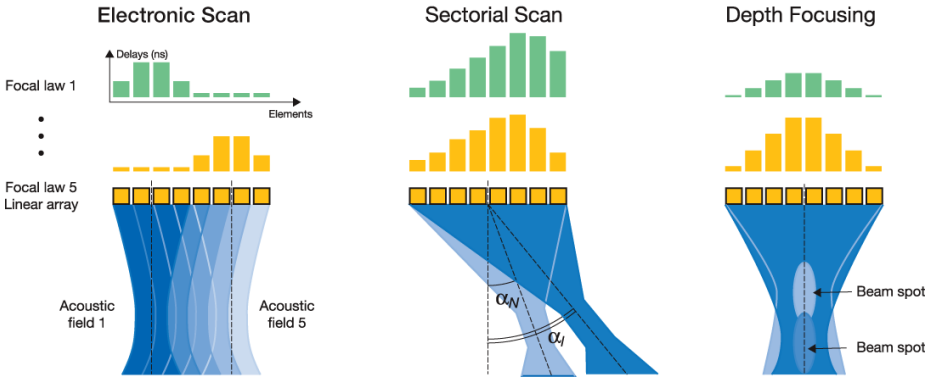



Ref: [2]

Viable methods: ultrasonic inspection

# Ultrasonic Inspection







Ref: Olympus

# Targets and Challenges

- Developing ultrasonic inspection package to be able to:

**Requirements**

- Operate in offshore
- Be carried by drone and crawler
- Perform with remote control
- wide range of thickness 10-70 mm
- Inspect different kind of damages

**Limitations**

- Resisting environmental condition (IP rated)
- 10kg, to minimize dimension
- Lack of operational control, 200m
- Probe and frequency selection
- Type of damage & location of inspection

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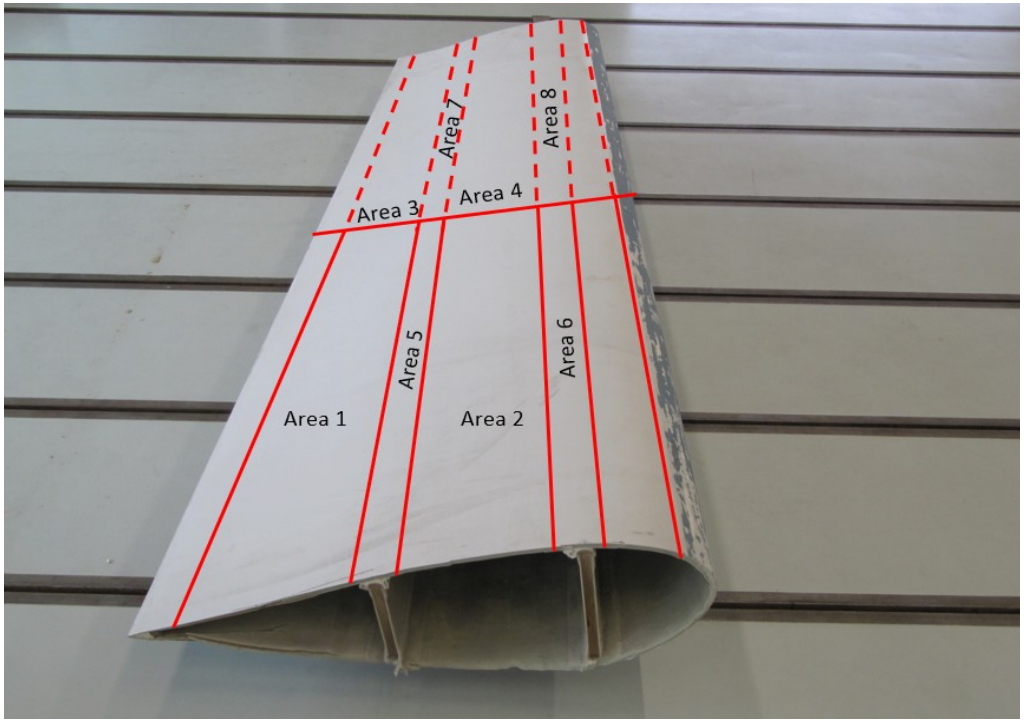
# Reference Specimen

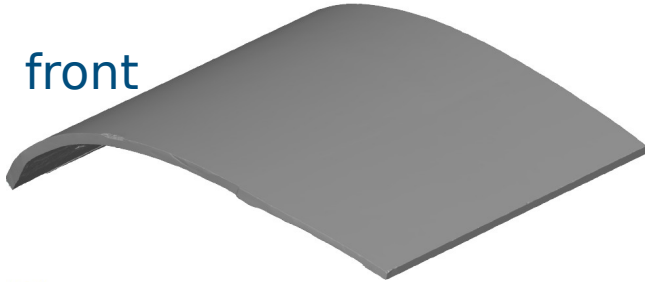
# Reference Specimens



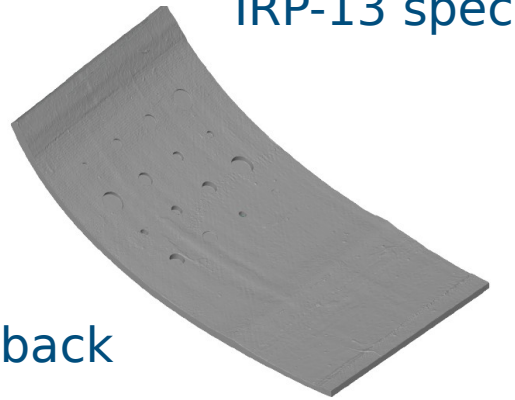

- NedWind 40/500, 20+ yrs
- Reference specimens were cut out
- Section of 3 meters can be used for sensor-crawler integration

# Reference Specimens

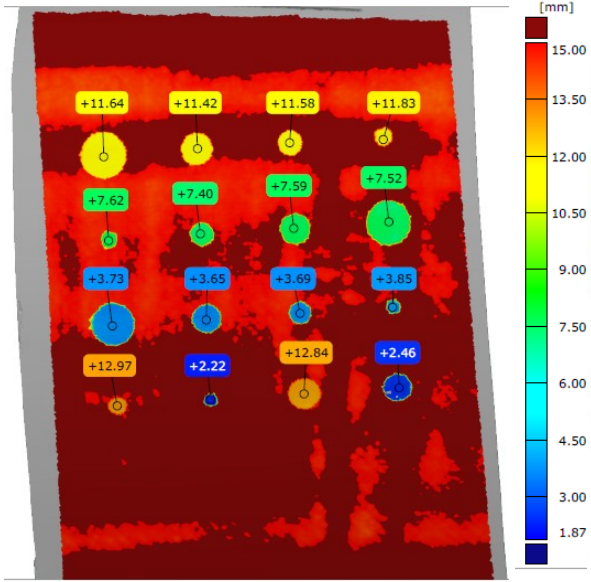
front



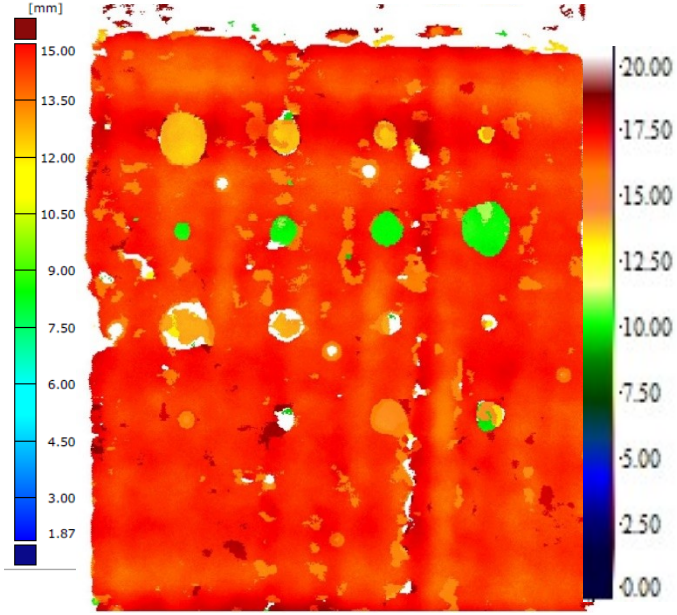
IRP-13 specimen



back

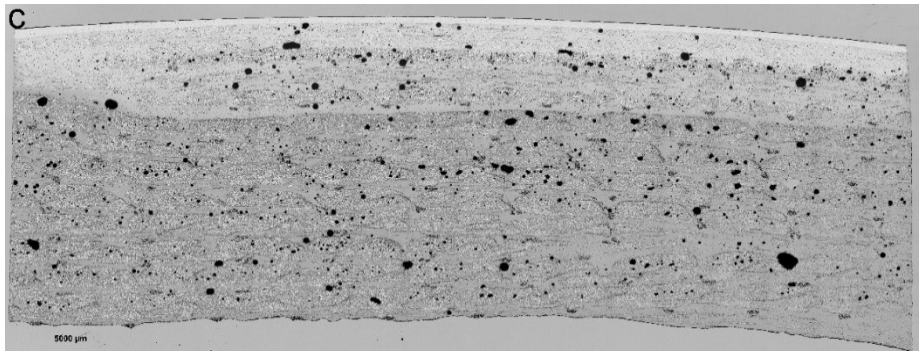


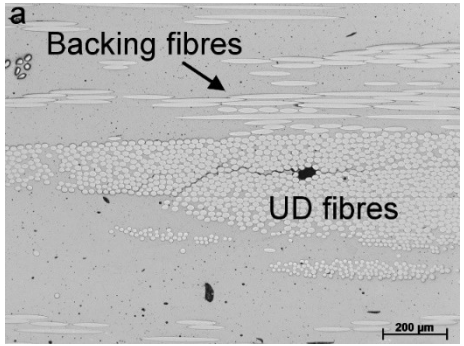

Actual remaining material

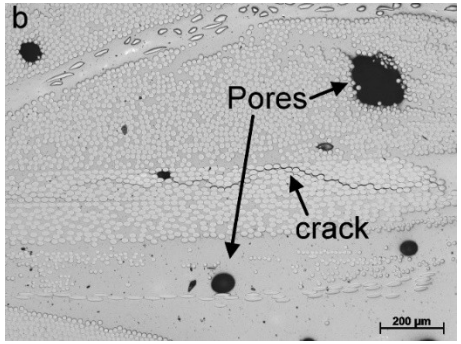


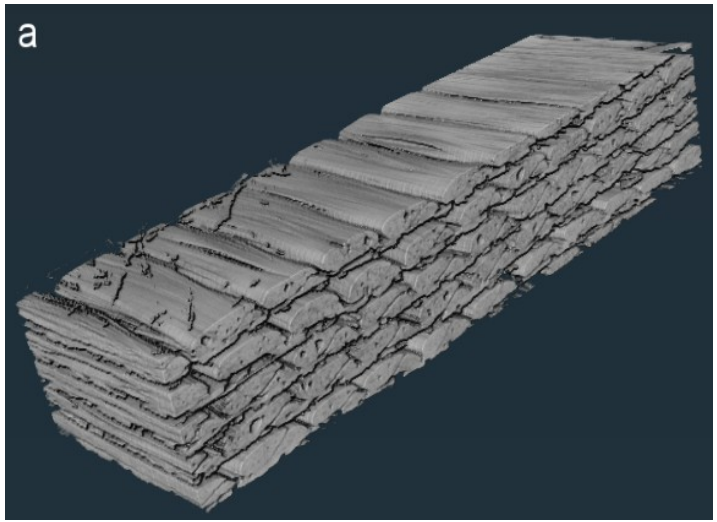

TOF C-scan

# Reference Specimens

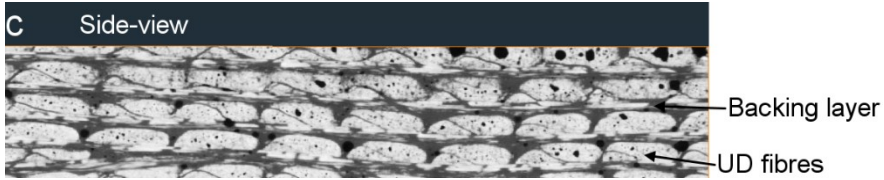






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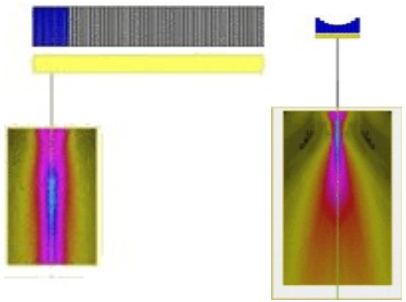
# Hardware Design

# Probe Selection

**UT probes**

**Electrically instead of mechanical scanning**

**electronically control inspection parameters**



**PAUT probes**

**Material & thickness**

**Inspection target**

**Frequency & size selection**

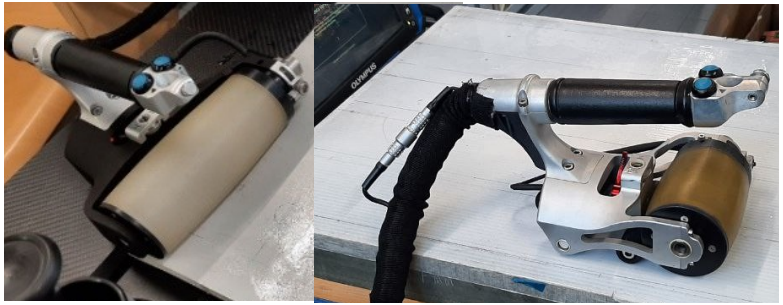
**0.5MHz or 1MHz probes**

**Lack of operator**

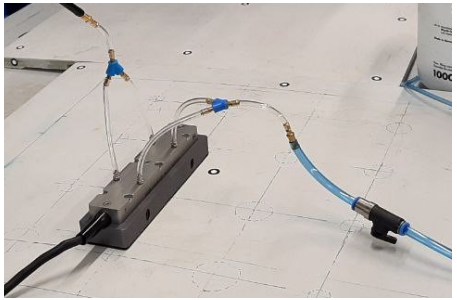
**Coupling material**

**Roller probe**

**0.5 MHz Roller probe**



**1 MHz Roller probe**

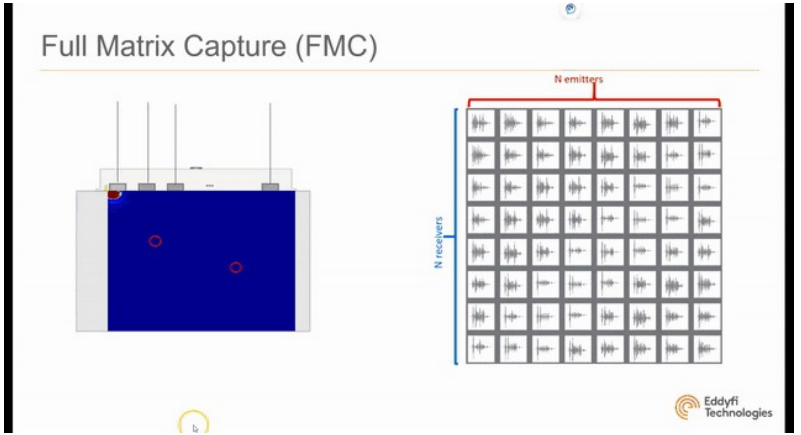


**0.5 MHz conventional prob**

# Analyser Selection

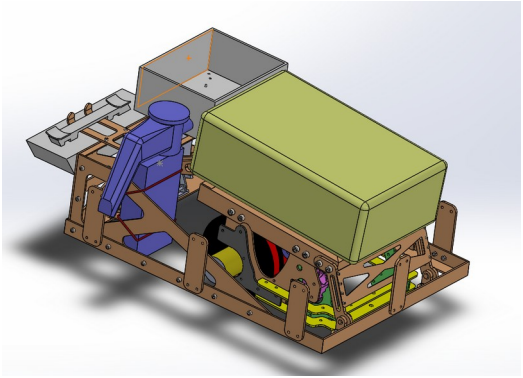
**PAUT Analyser**

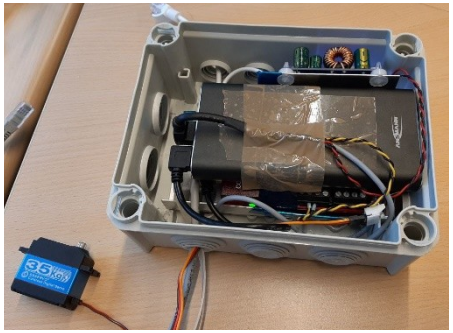
- Remote control capability
- FMC data generation
- IP66 Rating
- Multi scanning capability
- Minimum weight

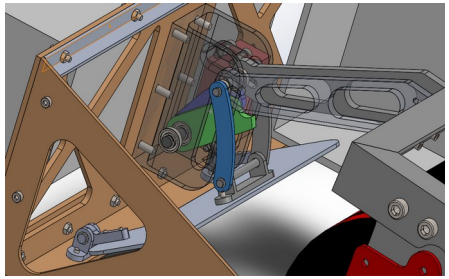


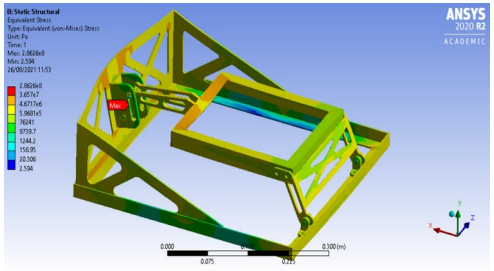

Ref: [3]

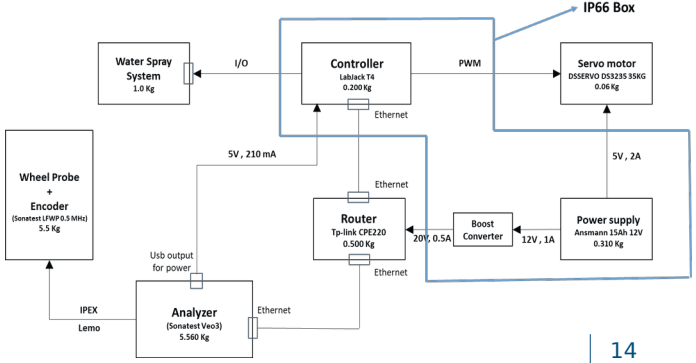
# Design of Sensor Package









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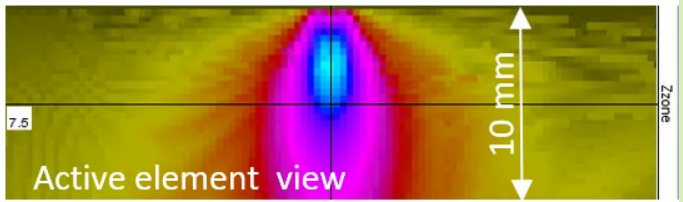
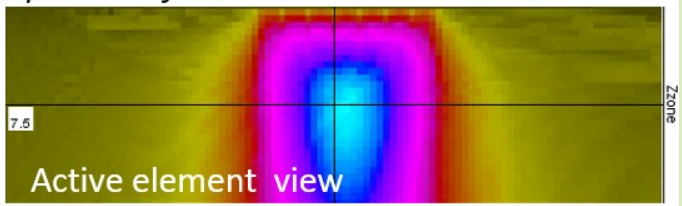
# Simulation

# Simulation

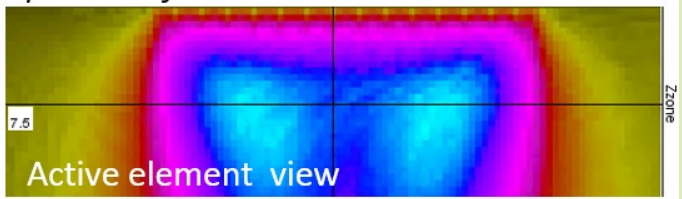
## 10 mm GFRP panel




*Aperture of 4 elements*

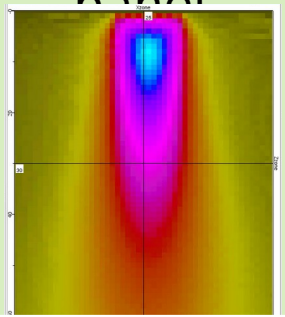



*Aperture of 8 elements*

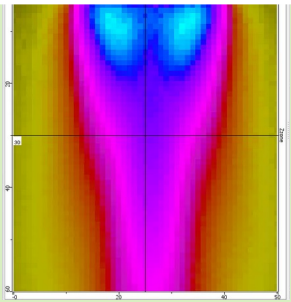



*Aperture of 16 elements*

## 60 mm GFRP panel



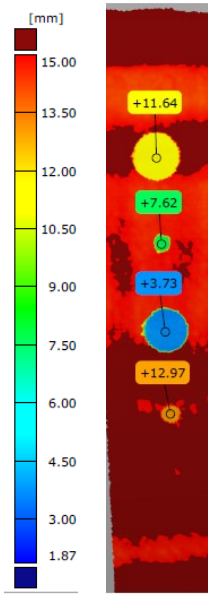
*Aperture of 8 elements*



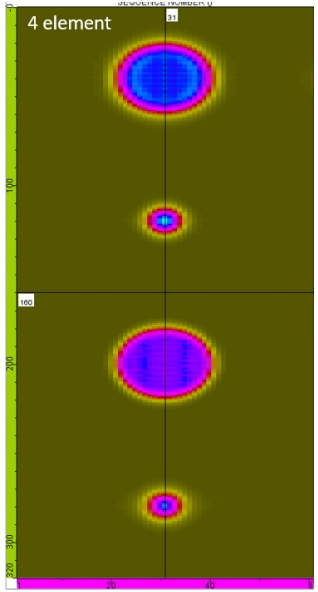
*Aperture of 16 elements*

# Simulation

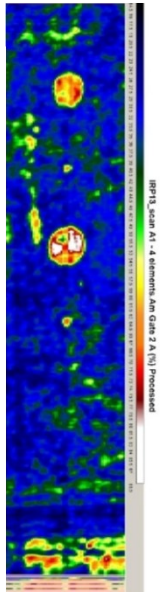
## 4-Element PAUT




Actual remaining material 3D measurement

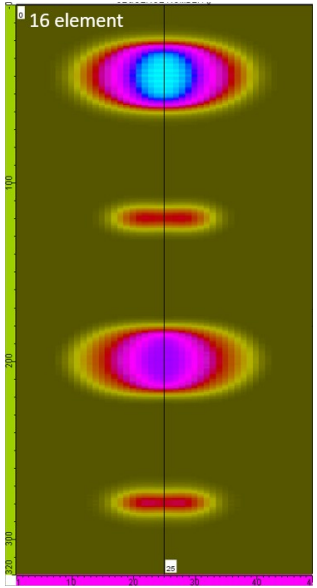



simulation

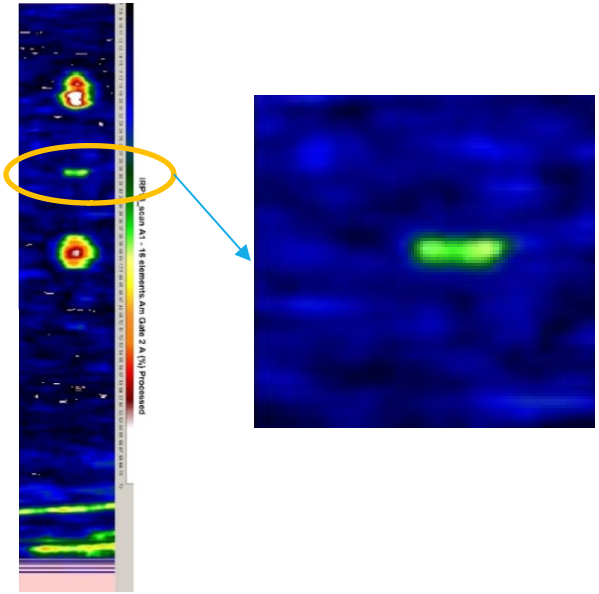


experimental

## 16-Element PAUT



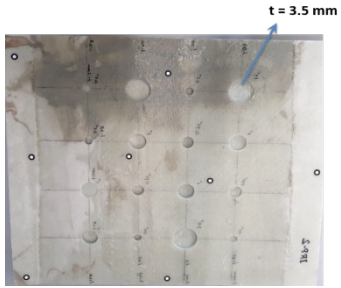

simulation

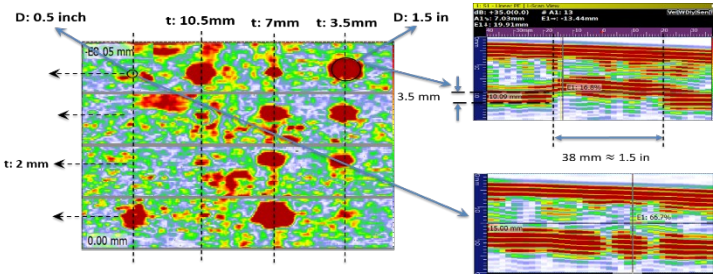


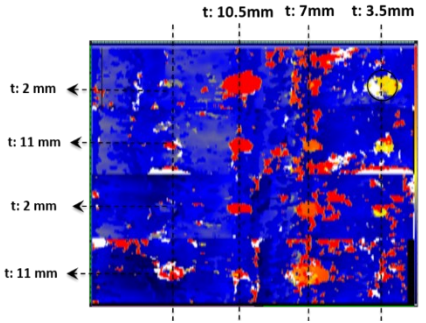
experimental

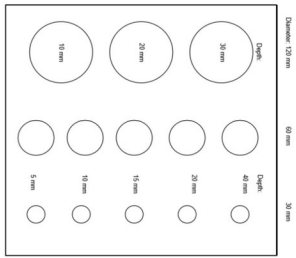
# Experimental Results

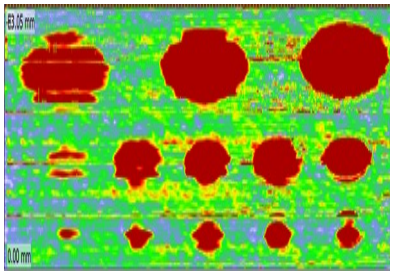
# Linear Phased Array Scanning

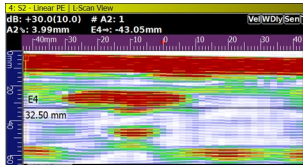


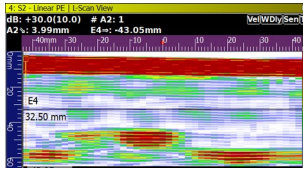



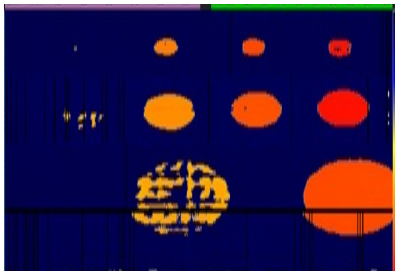





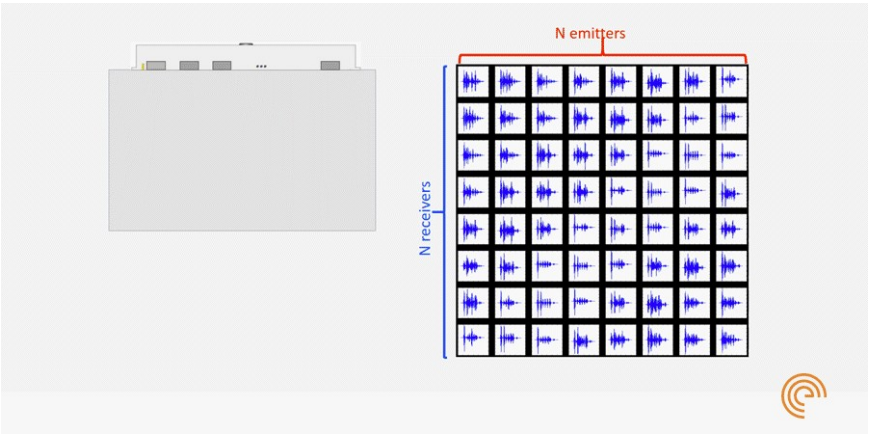


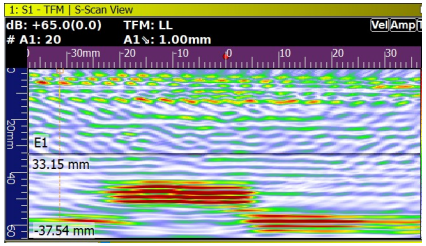



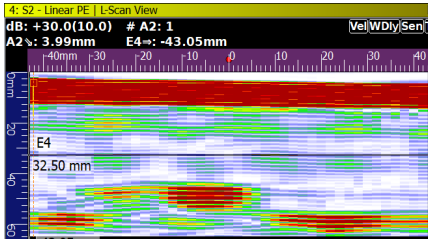
# Full Matrix Capturing Results

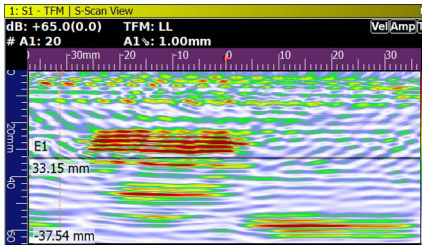
- Full Matrix Capturing (FMC) and TFM method

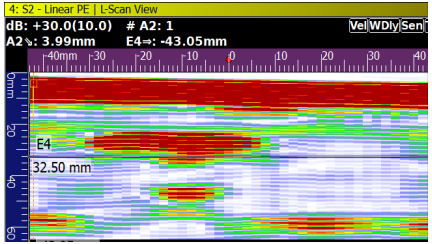


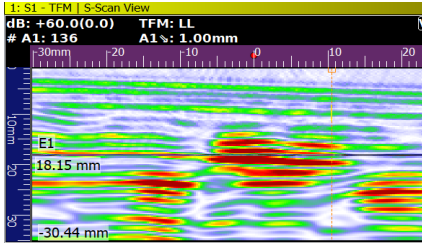

Ref: [4]

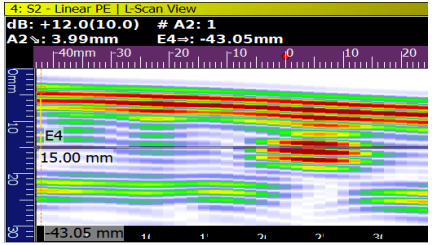


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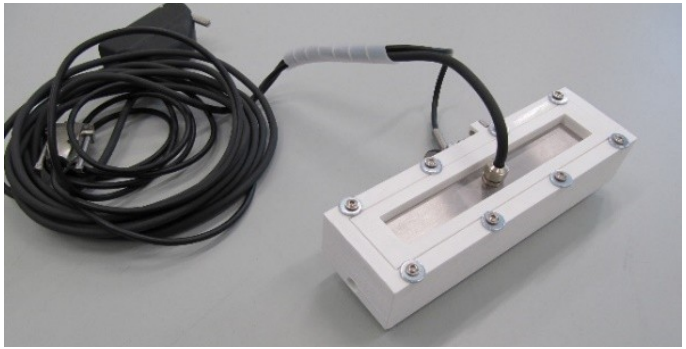
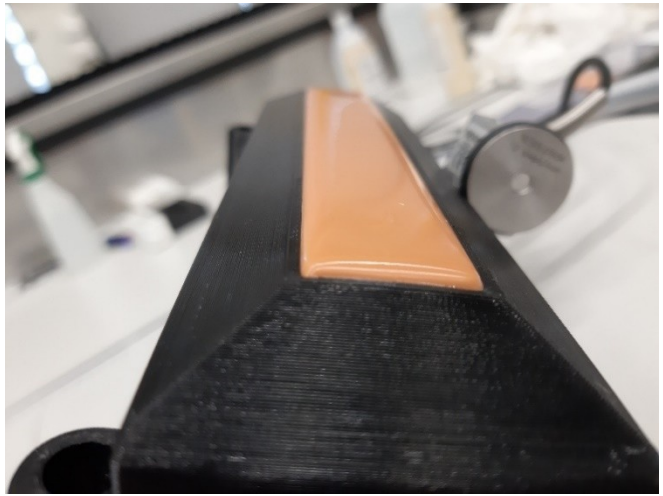
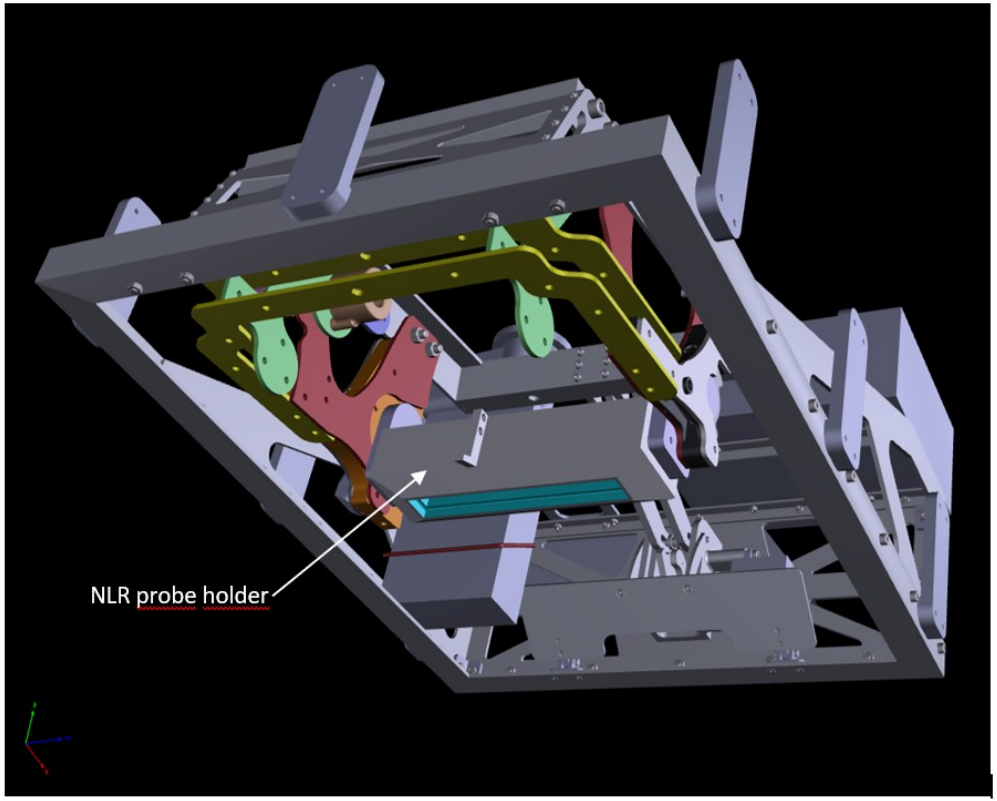
# Current Activities

# Probe Holder Design for Crawler

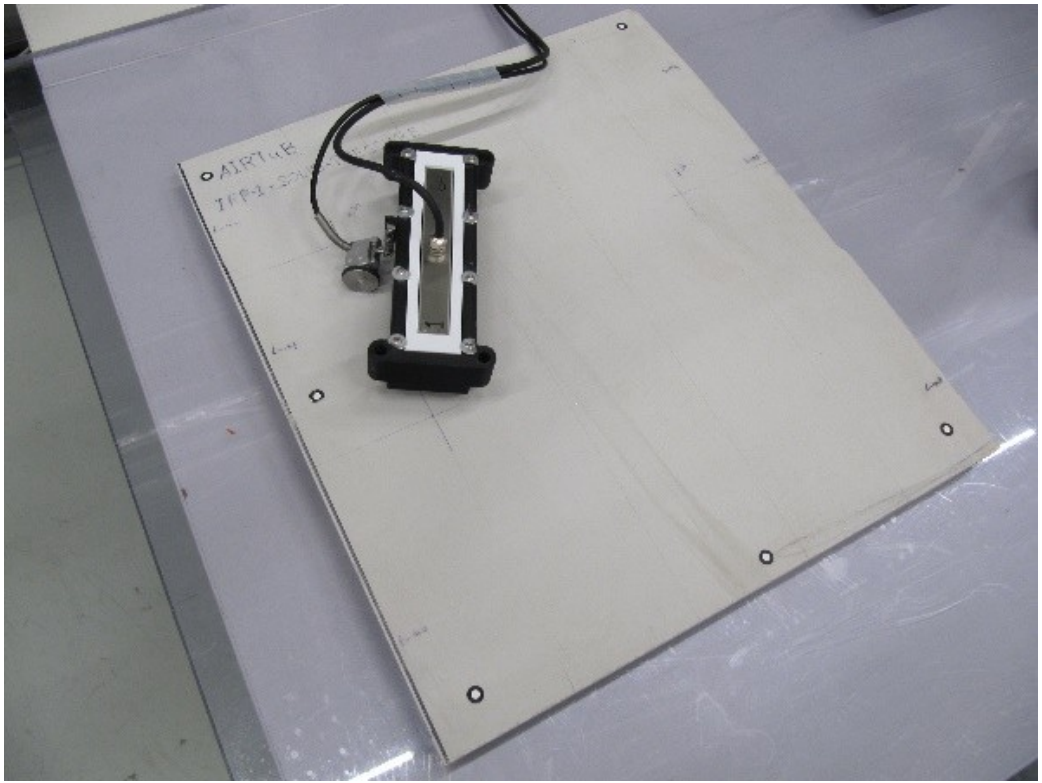




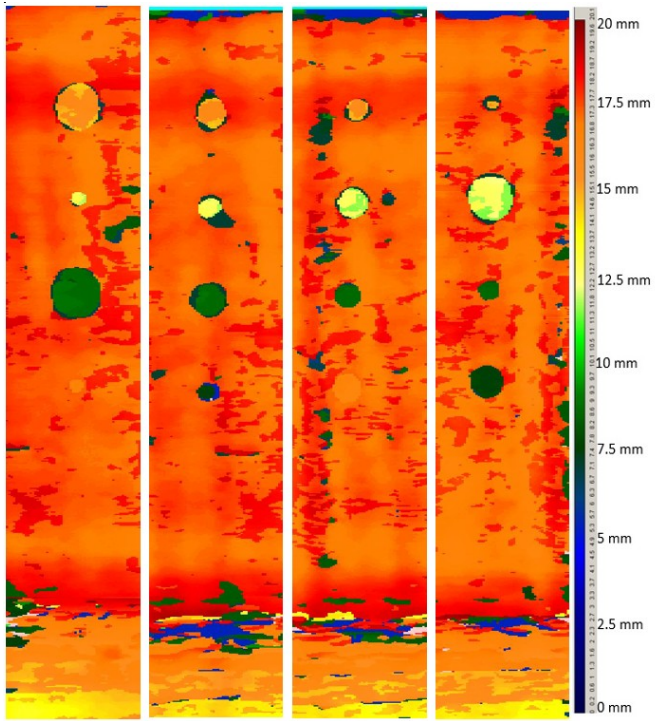


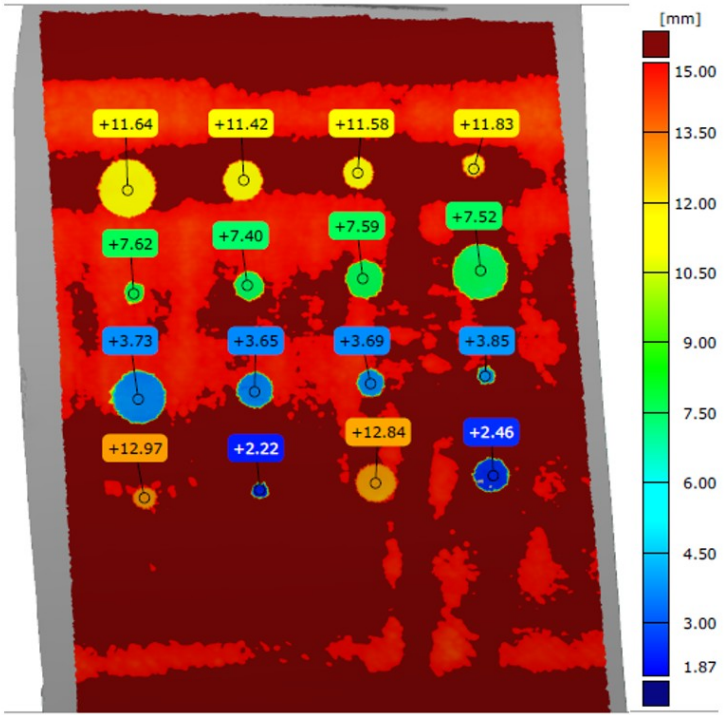
# Experimental Setup – New Concept Design

- PAUT with miniaturized probe holder design
- Time Corrected Gain (TCG) is used to optimize Signal-to-Noise Ratio (SNR)
- 4 paths needed to cover the area
- Payload of sensor < 1 kg



# Experiments Results – New Concept Design



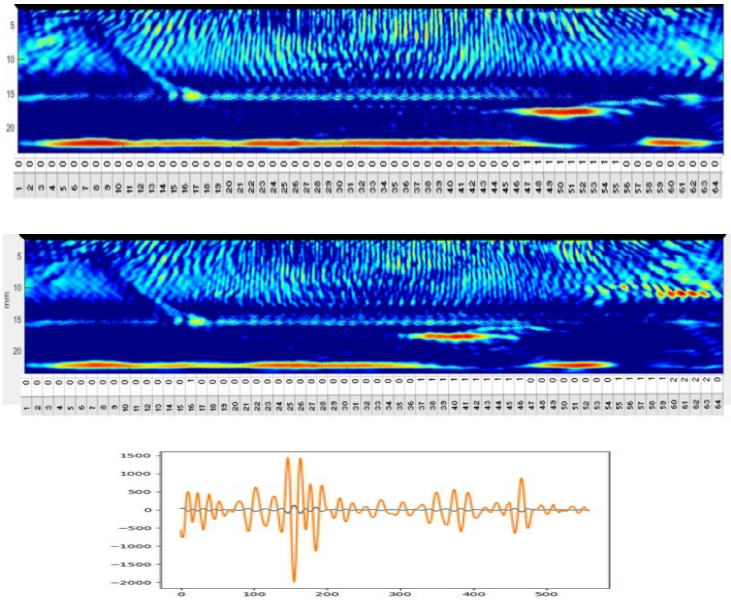




TOF C-scan on IRP-13 Panel

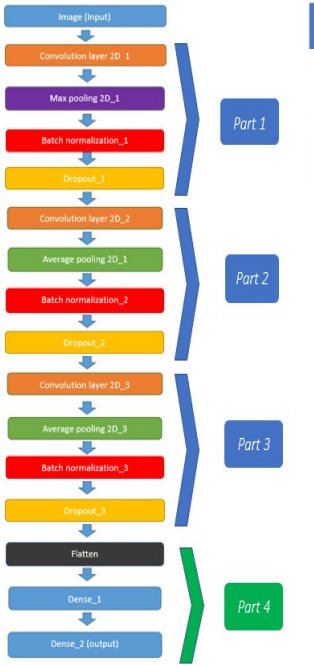
# Data Processing

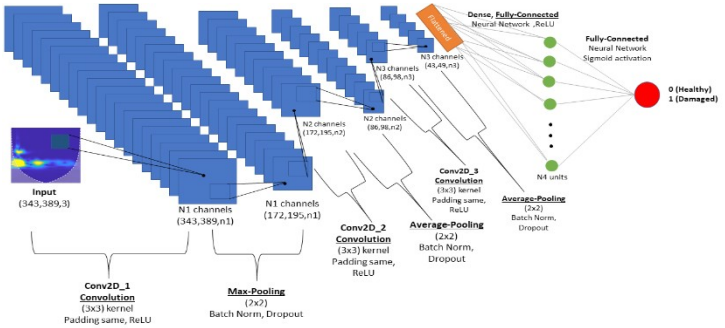
## FMC and AI methods (Supervised and Unsupervised)

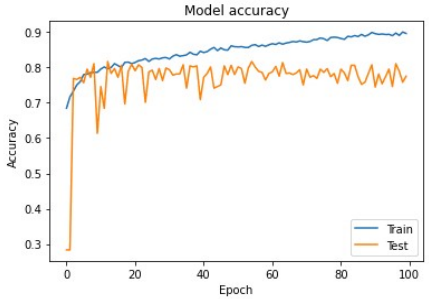
### Unsupervised K-means



### Supervised deep learning



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# Conclusions Conclusion & Planned Activities

# Conclusions

- Literature study showed that ultrasonic inspection method is feasible for detecting bonding and delamination in the solid skin parts
- Reference specimens were prepared for the internal damage inspection
- Conceptual and detailed design and manufacturing of internal damage sensor package

# Planned Activities

- Finalize the sensor package
- Integration of sensor package into the crawler and performing test on a blade
- Design optimization for reducing the weight and price
  - Structural design optimization
  - Designing a new probe holder
- Working on data processing as the first step to develop customized analyzer
- Planned to perform Eneco Wind blade inspection in Lelystad (full scale up to 60mm thickness)

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