Accelerating the future of aerospace

Use of CIVA to determine optimal settings for the inspection of bonded 1.6 mm aluminum plates, comparing different excitation techniques, like Flash or Halogen lamps.

Patrick Jansen, 4th April 2025, Civa Users Community Event

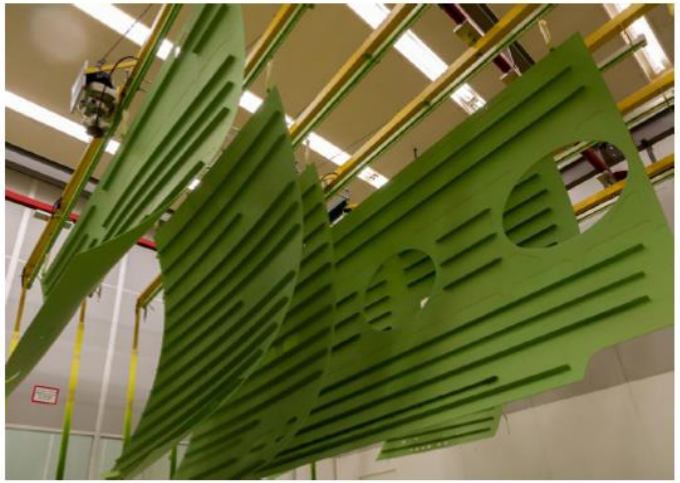
Rijksdienst voor Ondernemend Nederland

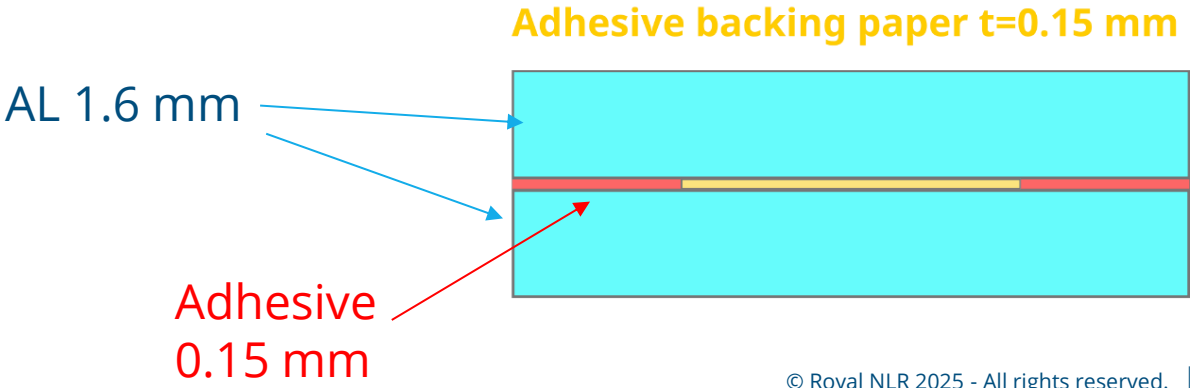
TSH21005
Advanced-alloy Sustainable Structure Enabling Technologies (ASSET)

GKN AEROSPACE

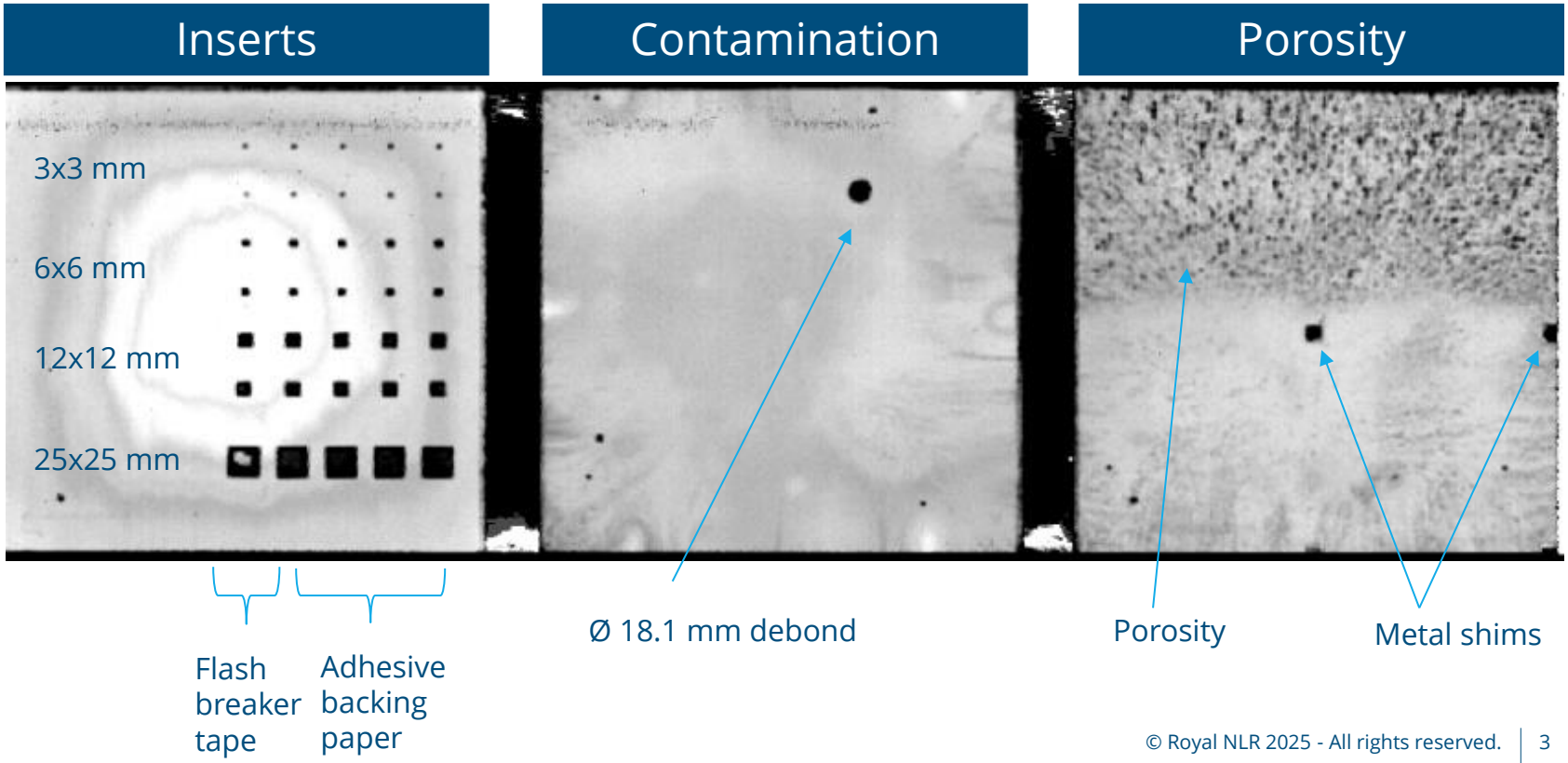
Usercase

- Try to find an NDI technique that can quickly inspect for Bonded / non-bonded adhesively joined metal sheets





C-scan images TT @ 5MHz



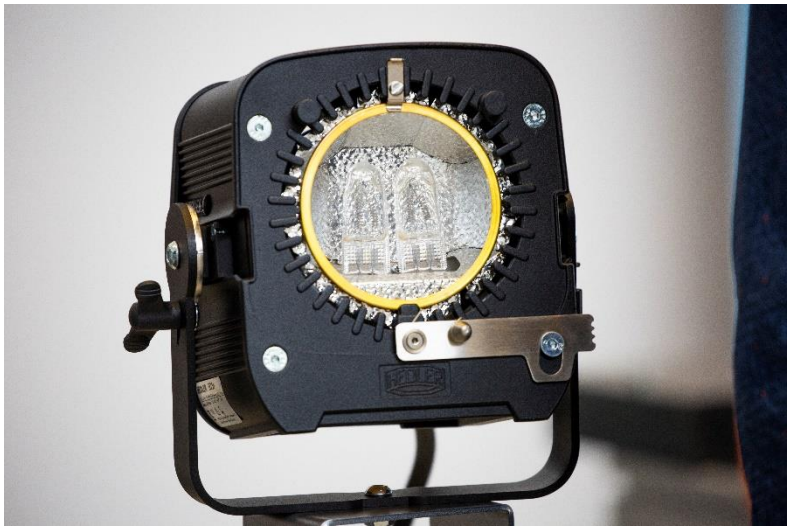
Thermography

- Fast large area in short amount of inspection time
- Challenge with supplying enough heat?
- Problems with low emissivity of sample?

- First initial experiments did not show any results

Excitation Techniques

Halogen



2 lamps, 4 filaments, total Power 4kW

Flash

6000 Joule

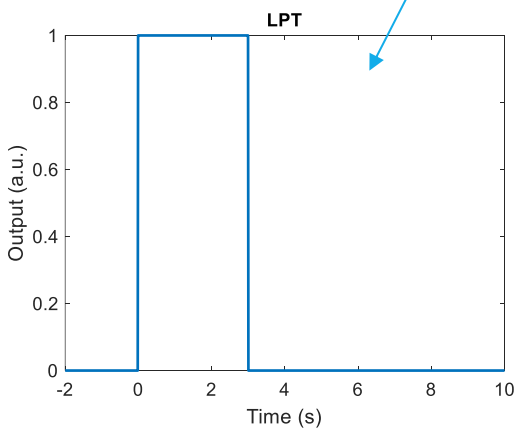
Excitation Techniques

Halogen

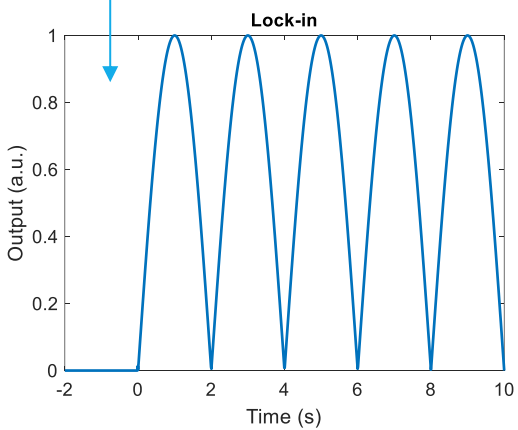
Flash

Long pulse thermography (LPT)

Lock-in

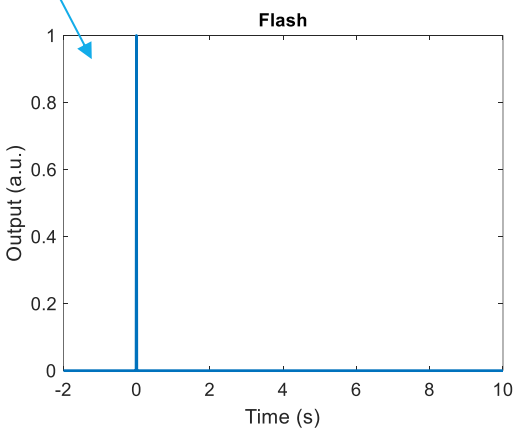


Amplitude, pulse length

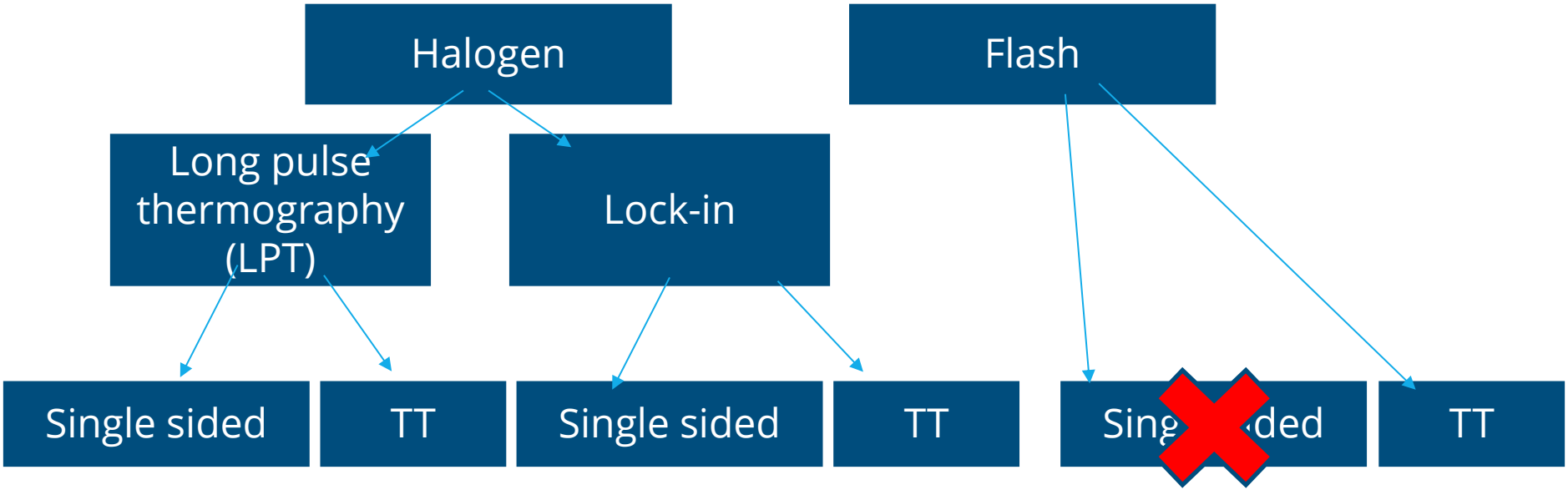


Amplitude, frequency

Amplitude

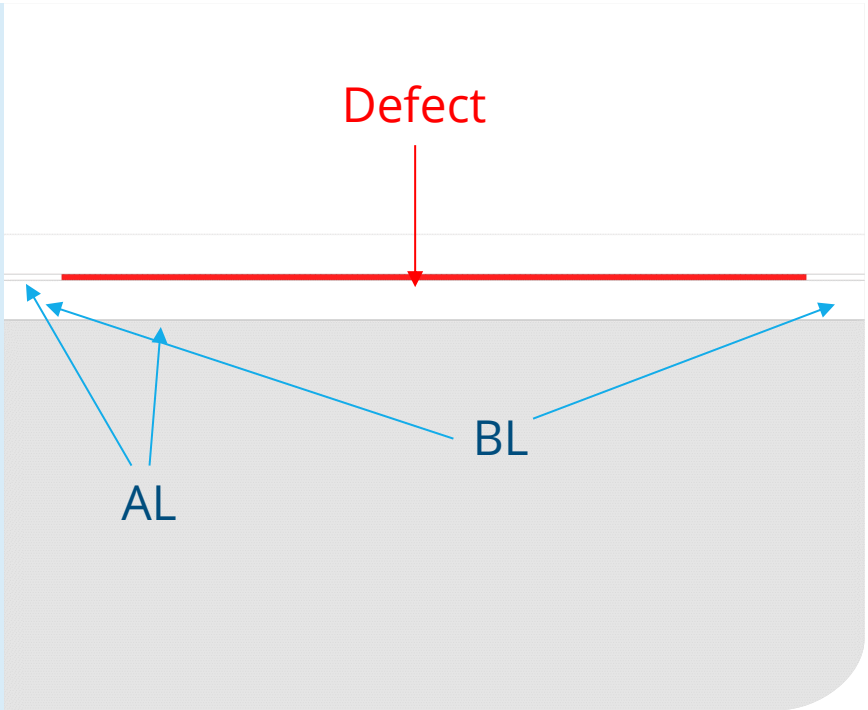


Excitation Techniques



Civa simulations thermography

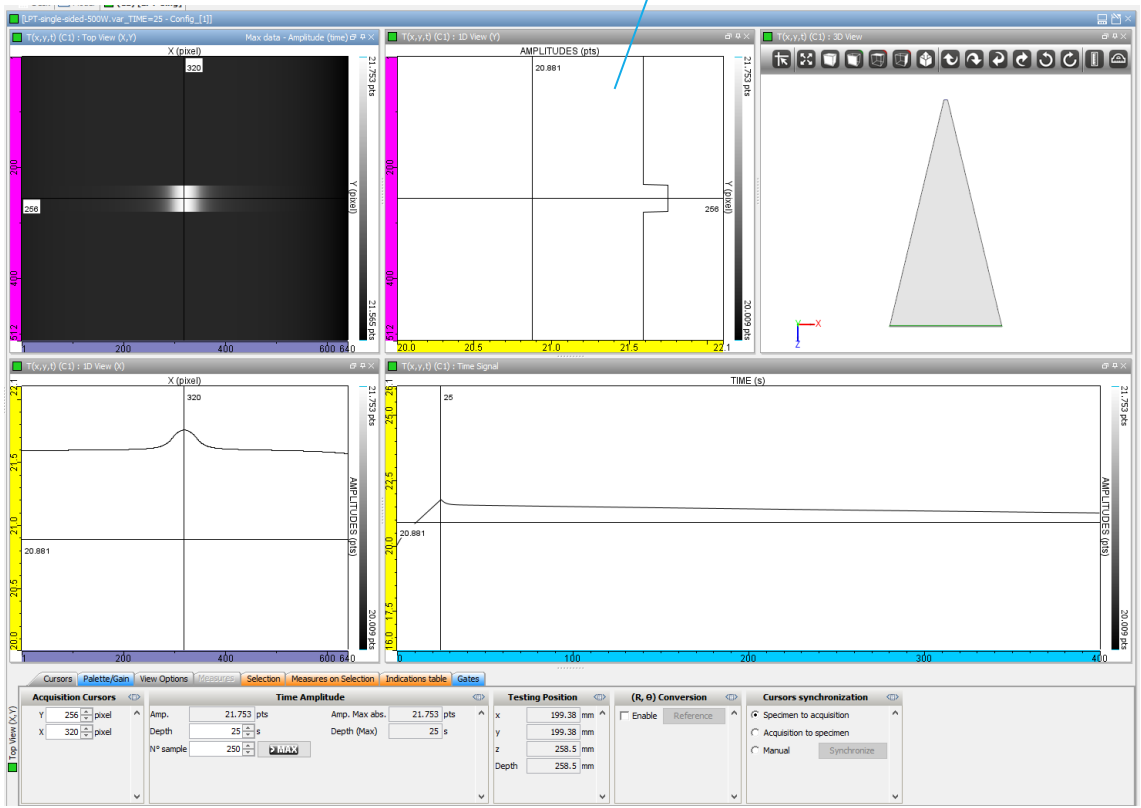
- Civa program is used to model thermography on the panels
- Heat-transfer is modelled in two directions and not in 3 directions.
- Emissivity of the sample is not taken into account during simulations.
- Panel has been inserted with a bondline, with a part of 30x30 mm of missing bondline -> air



LPT single sided 25 second pulse

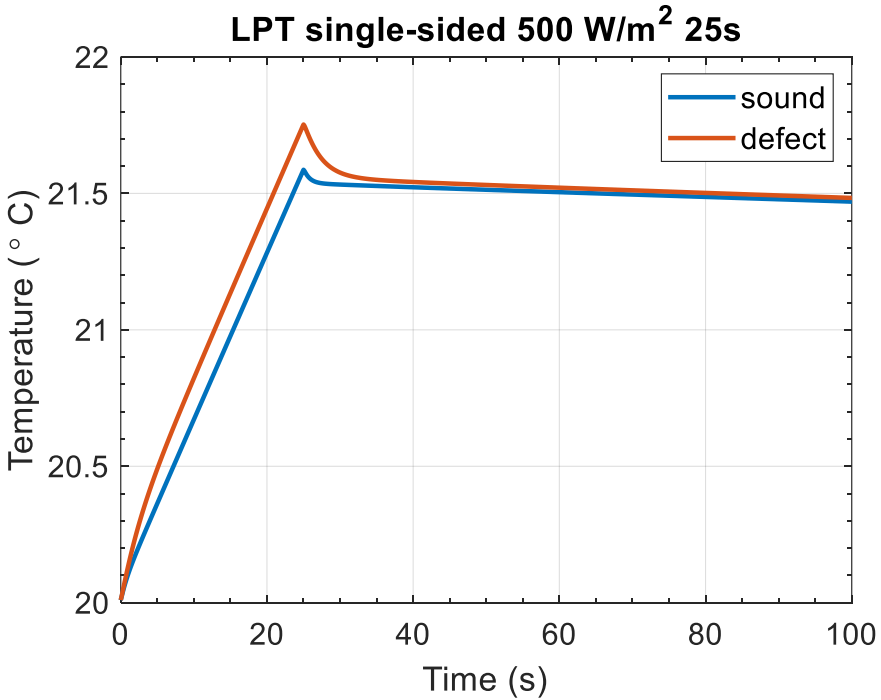
- Difference in temperature at maximum 0.16°C @ 25 seconds
- 500W/m^2

- Reality to be even lower due to 3-dimensional heat transfer



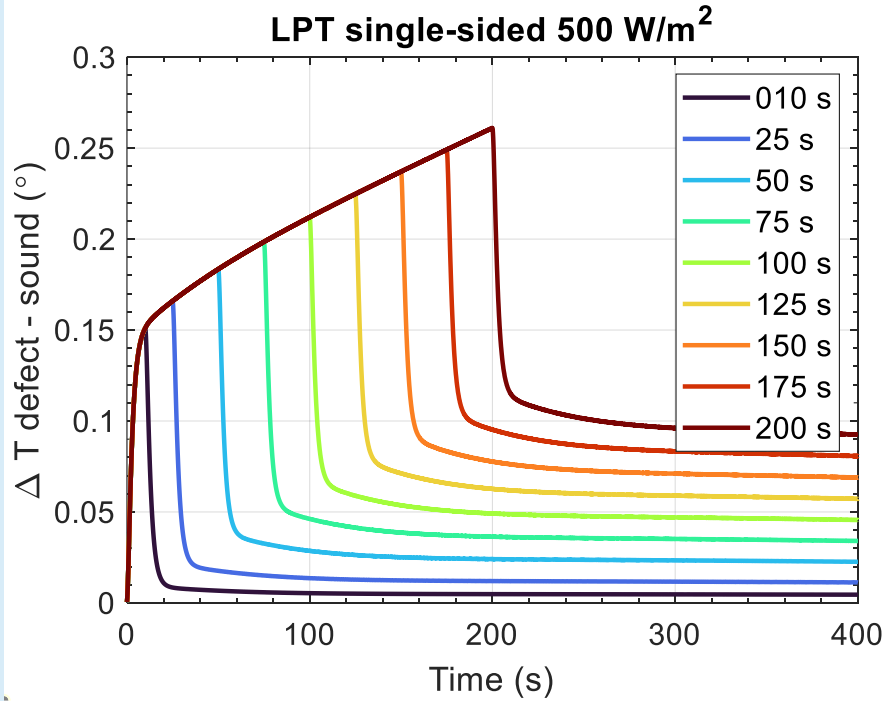
LPT single sided 25 second pulse

- Defect warms up faster as compared to sound material
- Maximum temperature of defect larger than that of sound material.
- Cooldown is faster



Civa simulations thermography – LPT single sided

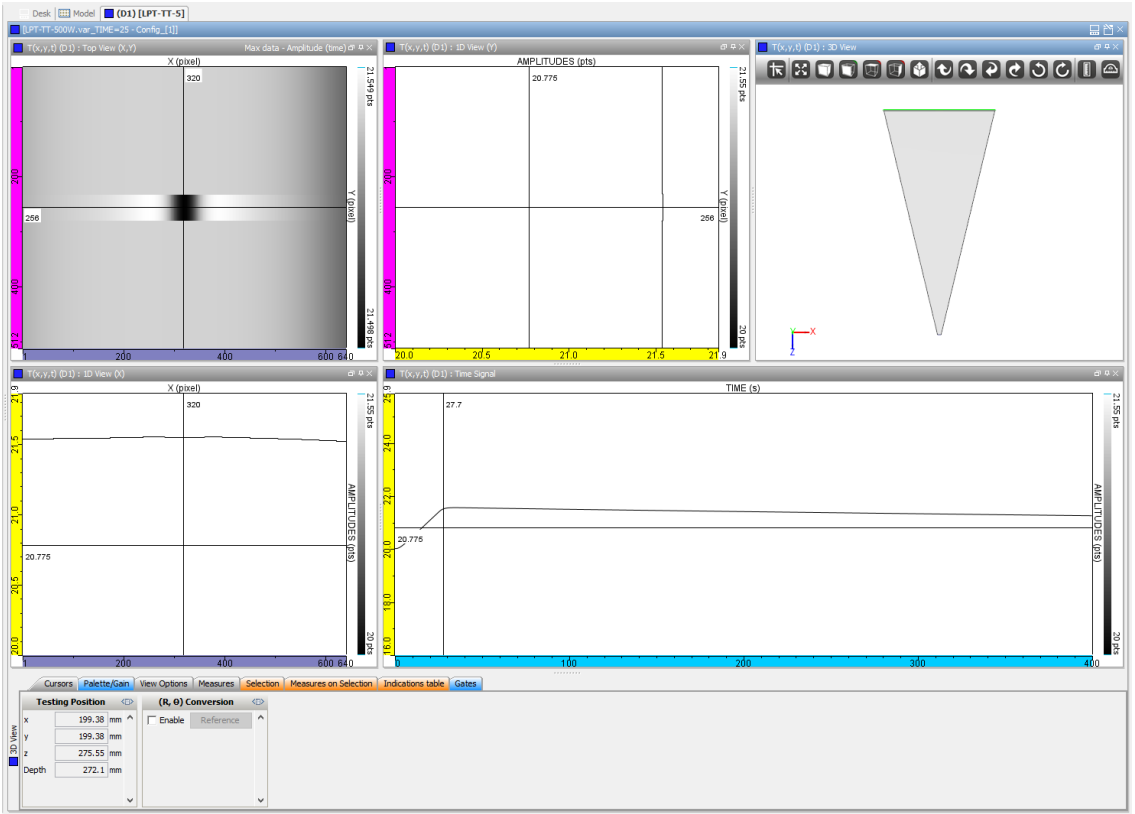
- Long pulsed Thermography single sided.
- Length of pulse is varied.
- Longer pulses provide higher temperature.
- Little difference between sound material and defect both in temperature and time.



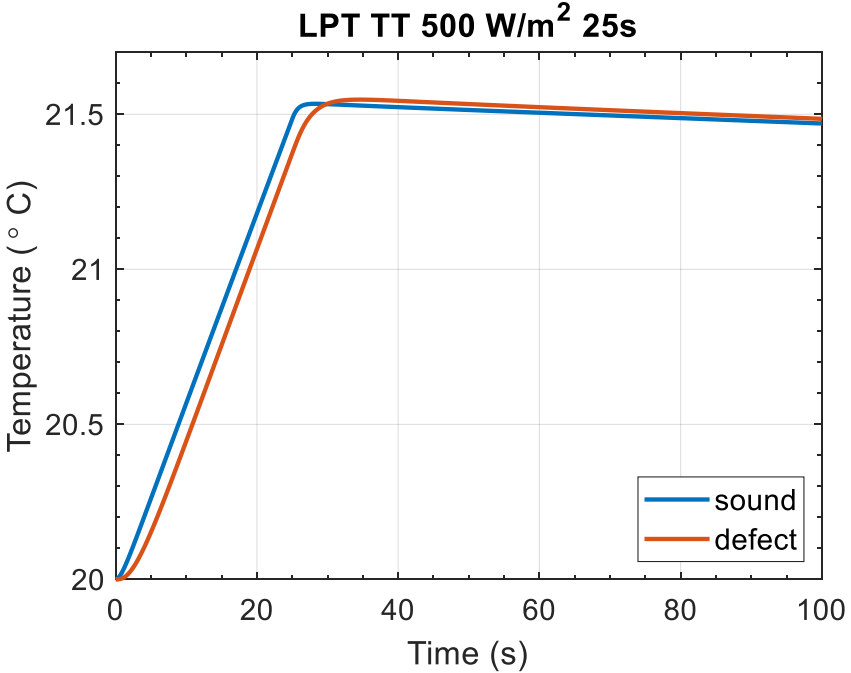
LPT TT 25 second pulse

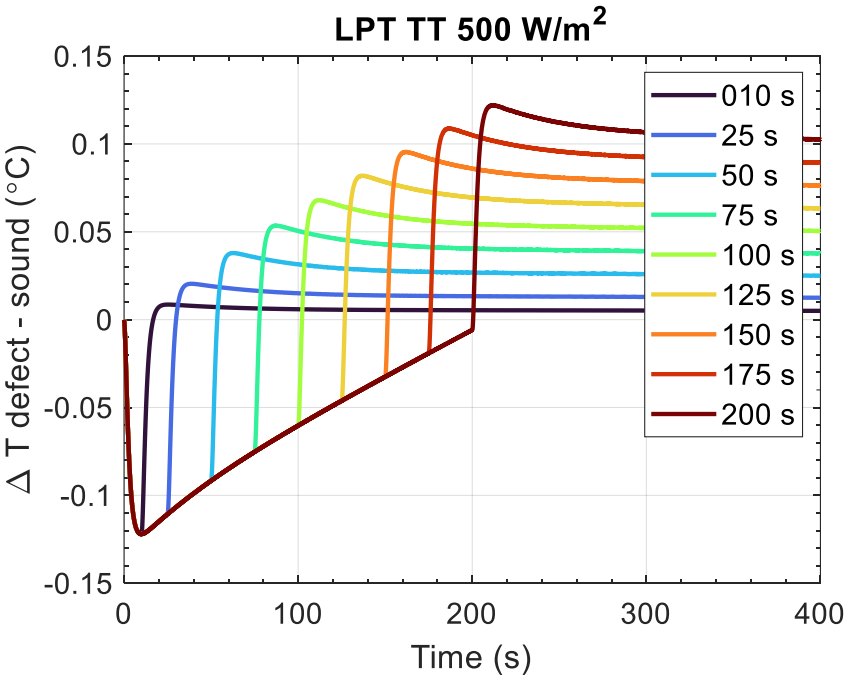
- Difference in temperature at maximum 0.12°C @ 25 seconds
- 500W/m^2

- Reality to be even lower due to 3-dimensional heat transfer



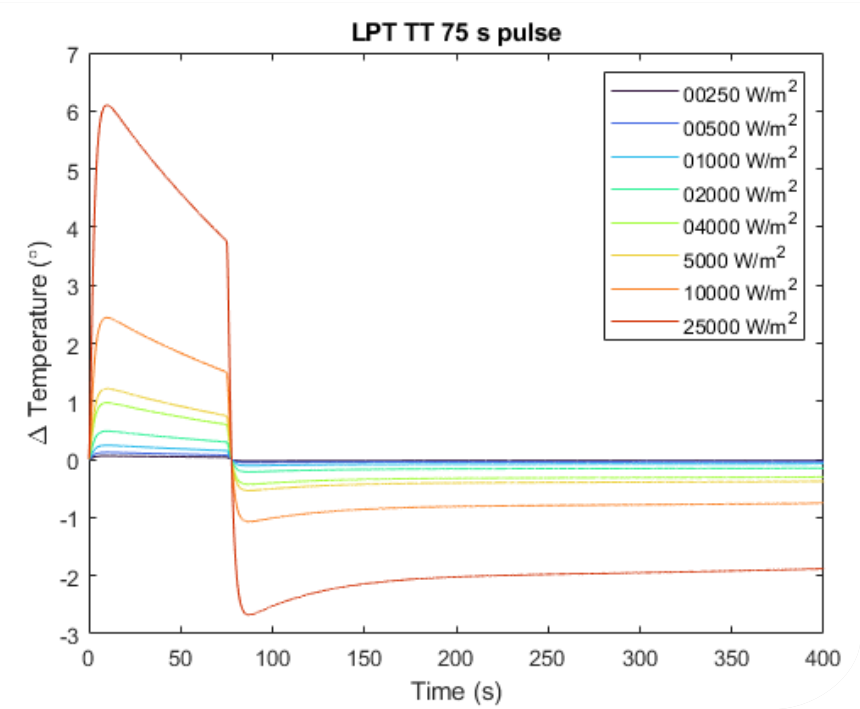
Civa simulations thermography – LPT TT





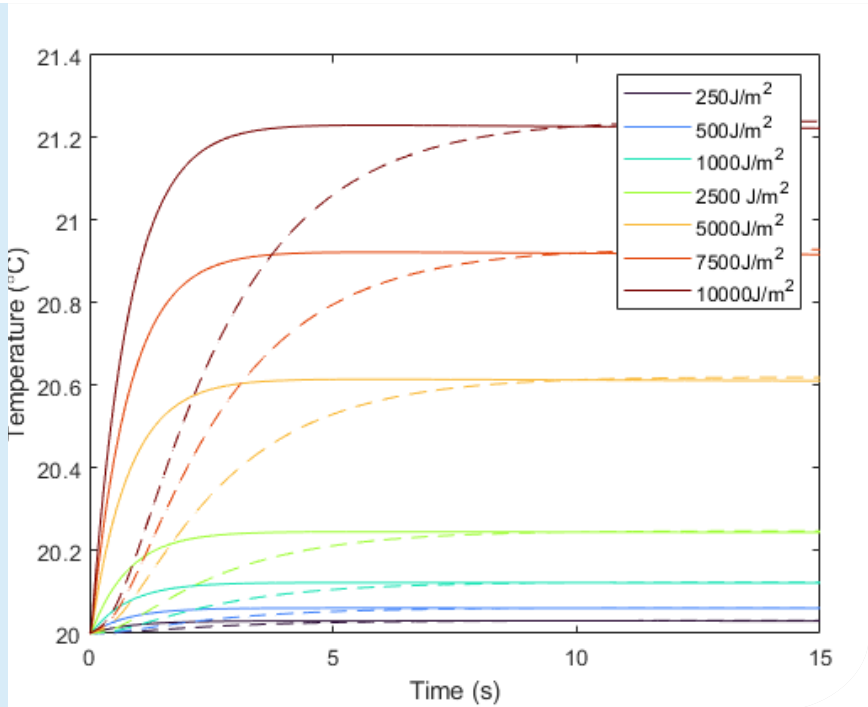
Civa simulations thermography – LPT TT

- Effect of excitation power.
- Higher power shows steeper slopes
- Temperature differences increases as power increases.
- Very high power densities needed, making LPT unsuited, both in single sided operation as in through transmission.

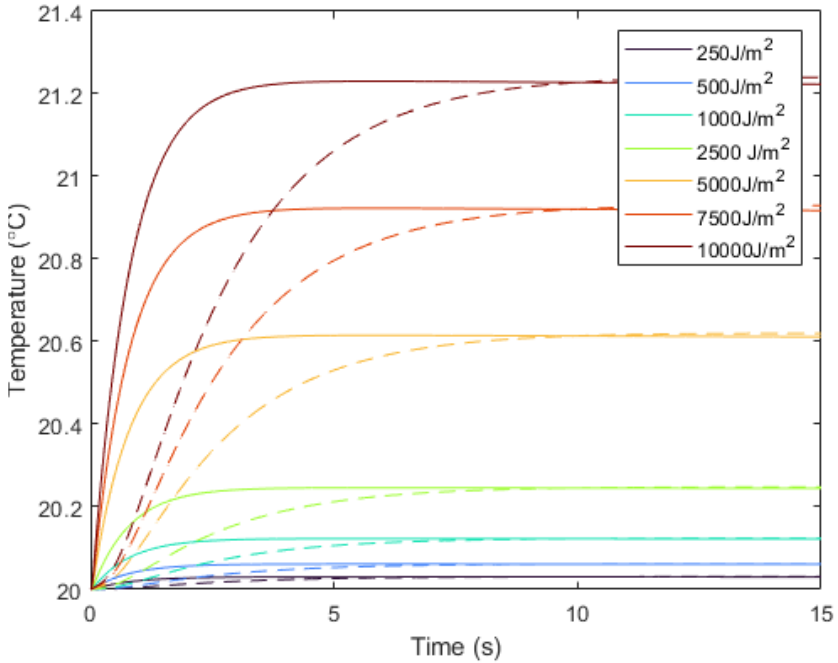


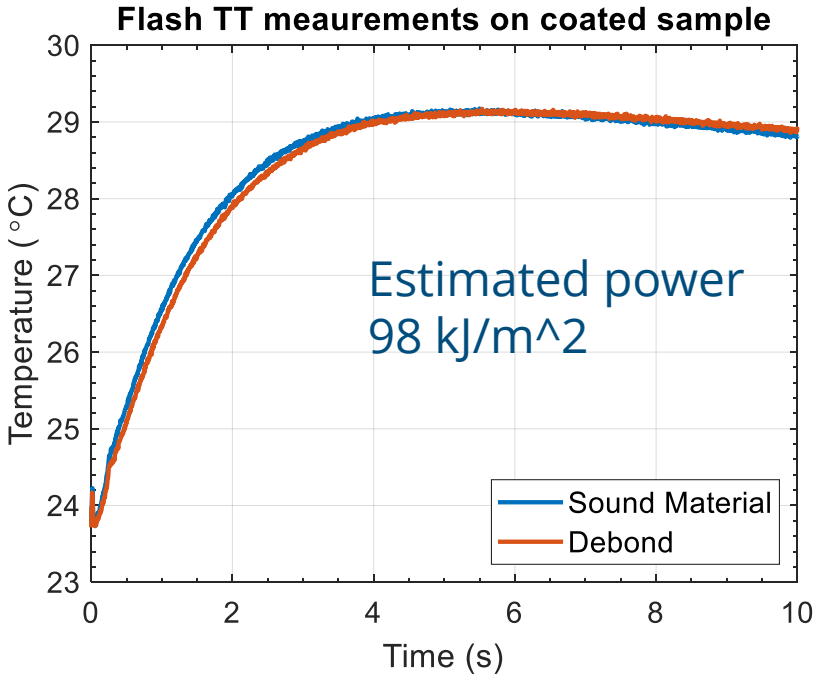
Civa simulations thermography – Flash TT

- Flash excitation, in through transmission
- Good separation in temperature and time, enabling better detection.
- Solid line, sound material
- Dashed line, defect



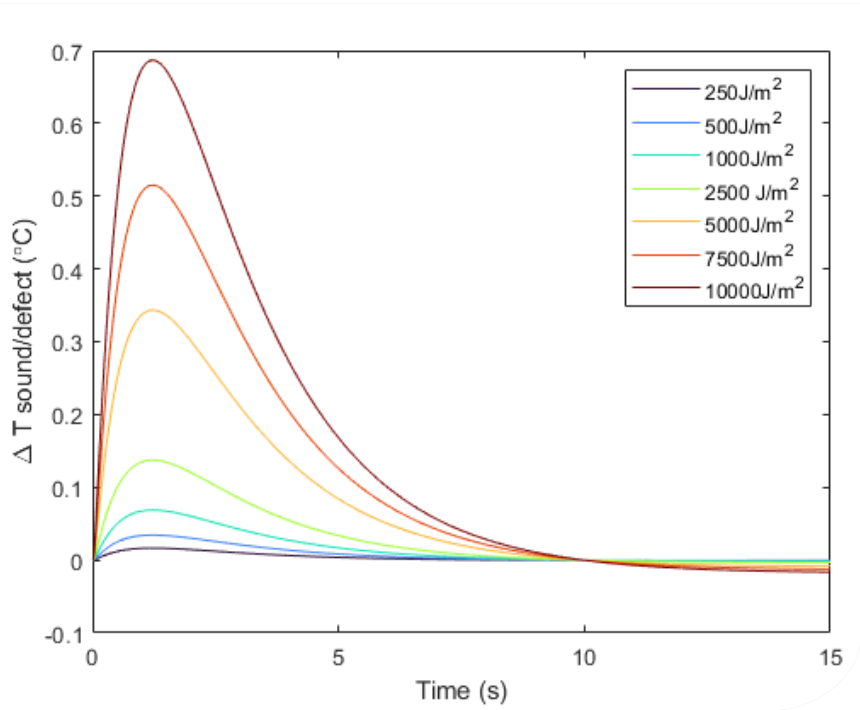
Flash TT experiment vs simulation





Civa simulations thermography – Flash TT

- Flash excitation, in through transmission
- Good separation in temperature and time, enabling better detection.
- To do simulation for single sided, even better separation expected.
- Try flash excitation at Edevis Stuttgart

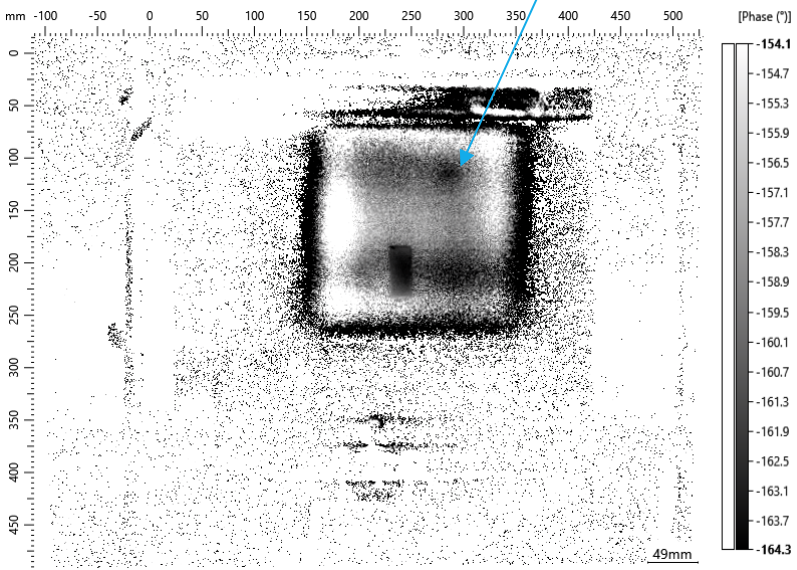


Uncoated sample, KB1 Flash

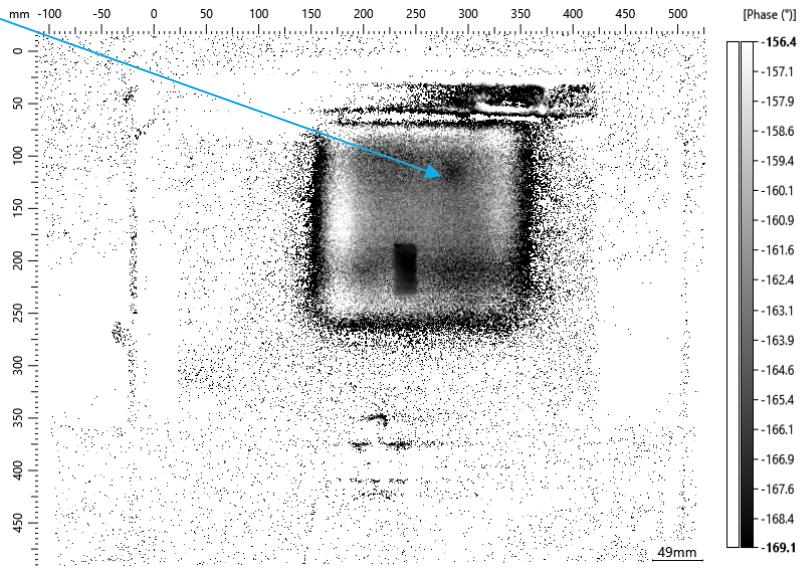
0.300 Hz
Ref -158.617, 1.553
Defect -163.127, 0.638
Delta phase 4.51, SNR **2.9**
0.400 Hz
Ref -163.025, 1.881
Defect -167.277, 0.54
Delta phase 4.202, SNR **2.2**

debond

0.300 Hz



0.400 Hz

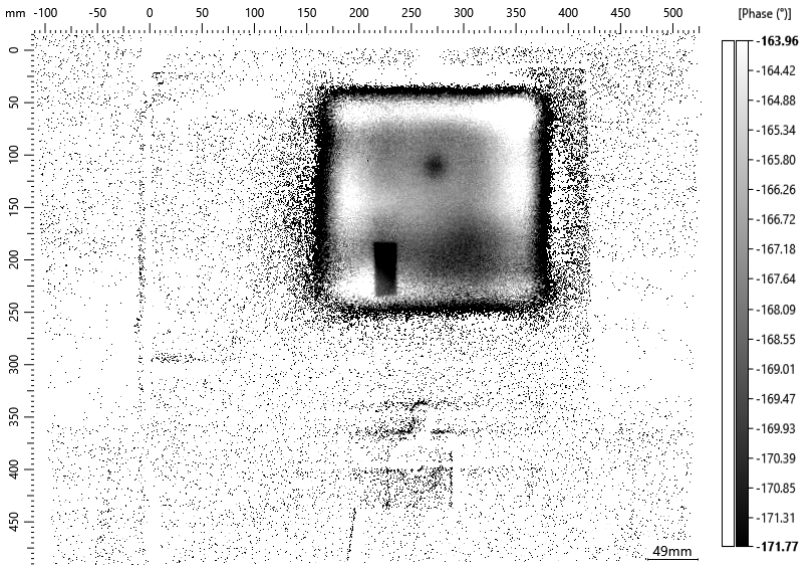


Imgir40, 50 Hz, 4153 µs, binning, 10s
TAS-WP3-NDT-KB1.di

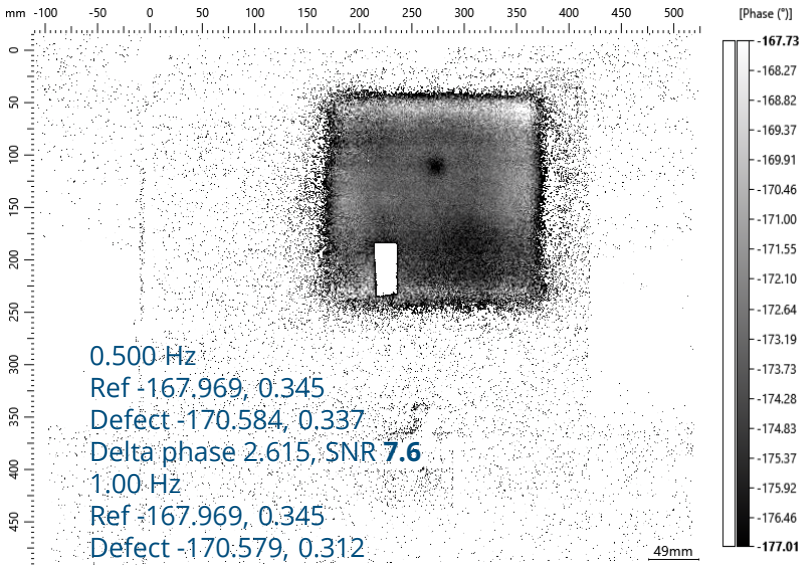
Coated, KB-1 best settings Flash

Developer ε from 0.16 to 0.3

0.500 Hz



1.000 Hz



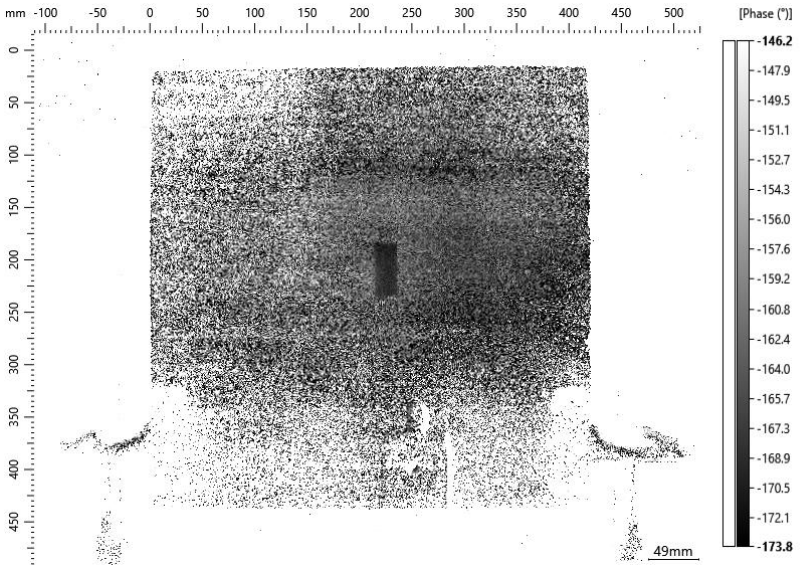
0.500 Hz
Ref -167.969, 0.345
Defect -170.584, 0.337
Delta phase 2.615, SNR **7.6**
1.00 Hz
Ref -167.969, 0.345
Defect -170.579, 0.312
Delta phase 2.61, SNR **7.6**

Imgir40, 227 Hz, 4153 µs, binning, 4s
TAS-WP3-NDT-KB1 close (1).di

Coated, KB-1 larger area

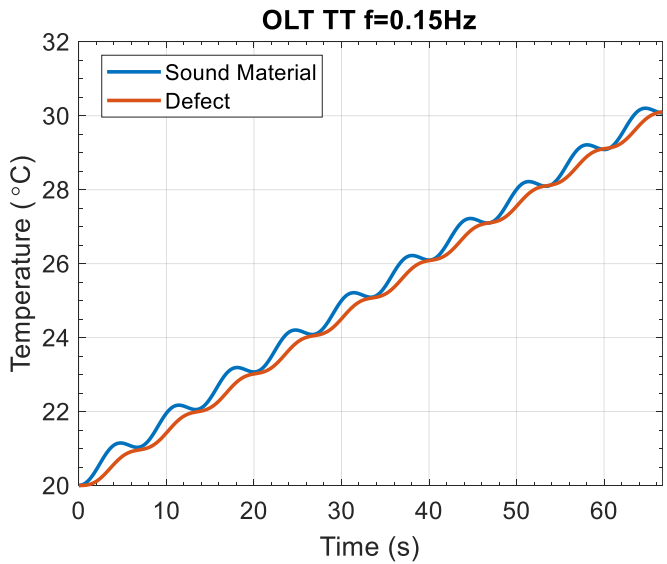
- Positioned flash lamp farther away, in order to excite a larger area.
- Debond not detected anymore, due to small temperature differences

0.300Hz



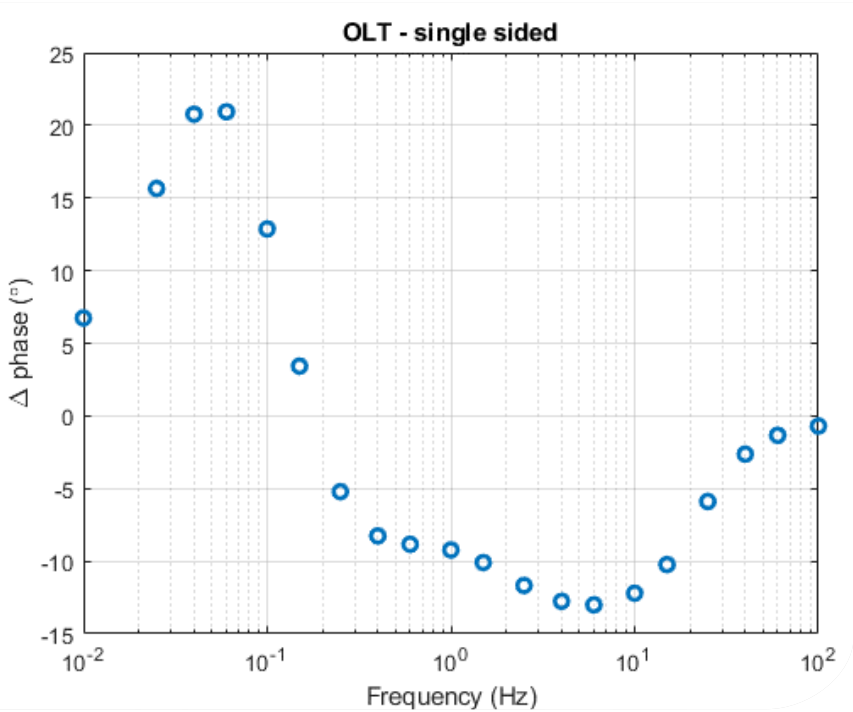
Lock-in Thermography

- Civa gives time trace.
- Phase values are calculated in Matlab (with new update also available in Civa).
- Phase difference is a function of applied frequency.



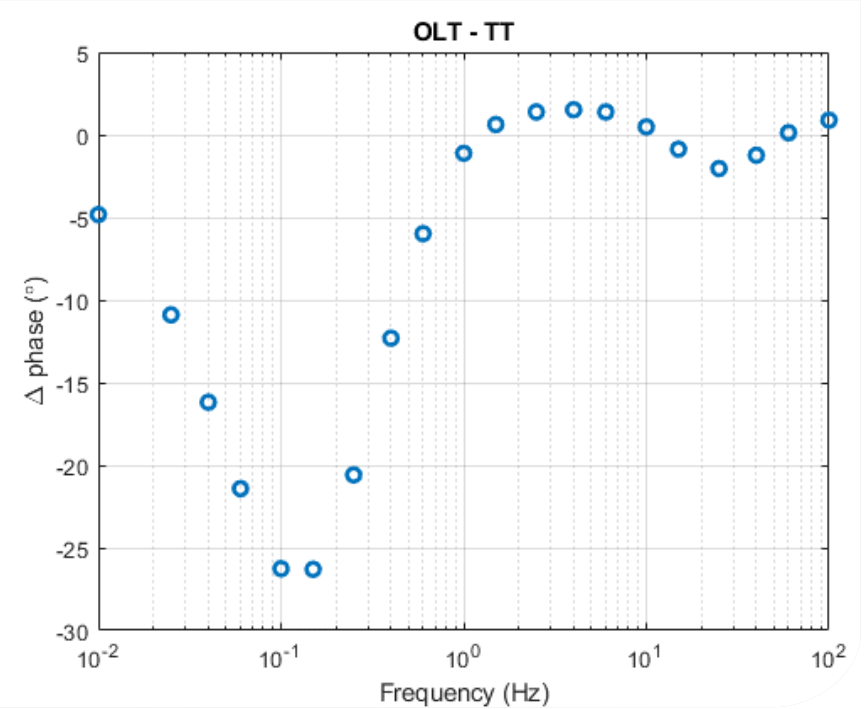
Civa simulation – Lock in thermography single sided

- Simulations with lock-in thermography single sided over a broad frequency range.
- Simulations done at 3 different power intensities
- Delta phase between sound and defect material is not dependent on the power intensity.
- Best frequency for inspection at 6 Hz

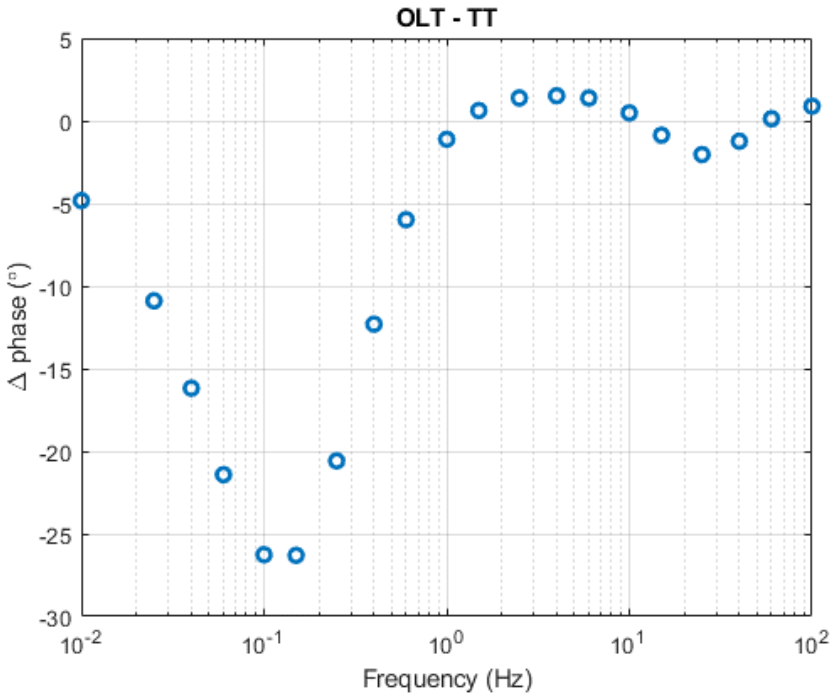


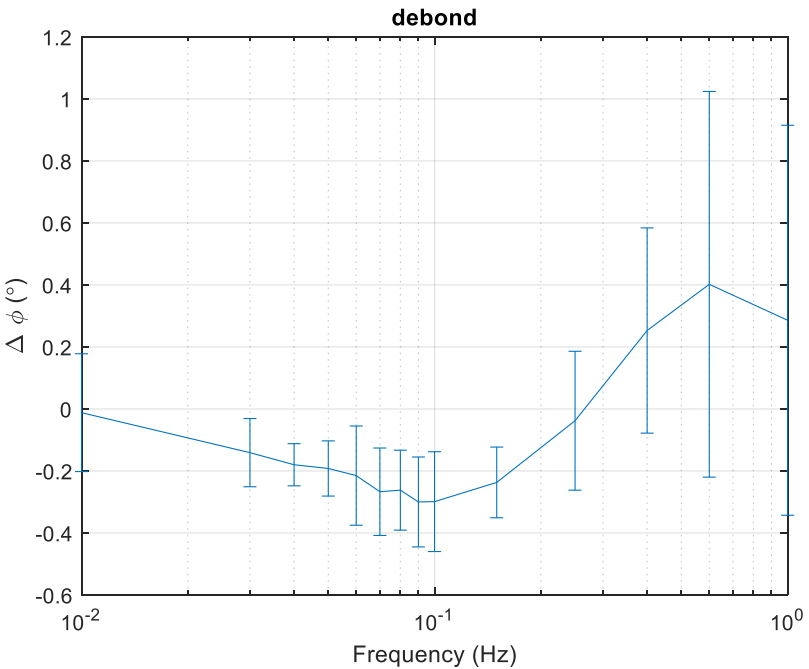
Civa simulation – Lock-in thermography TT

- Doing OLT in TT mode shifts the curve to lower frequencies.
- Delta phase almost factor 2 as compared to single sided OLT inspection.



Experiment vs simulation

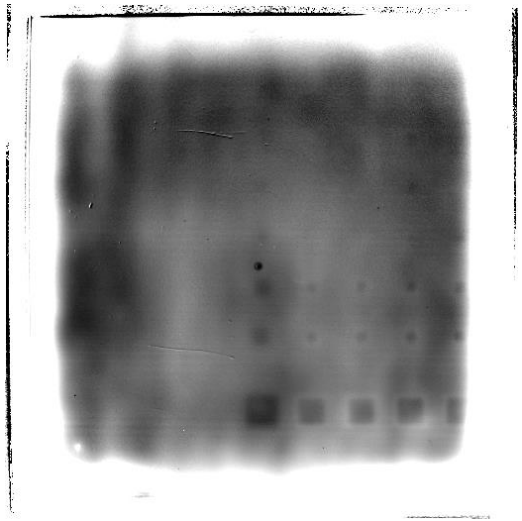


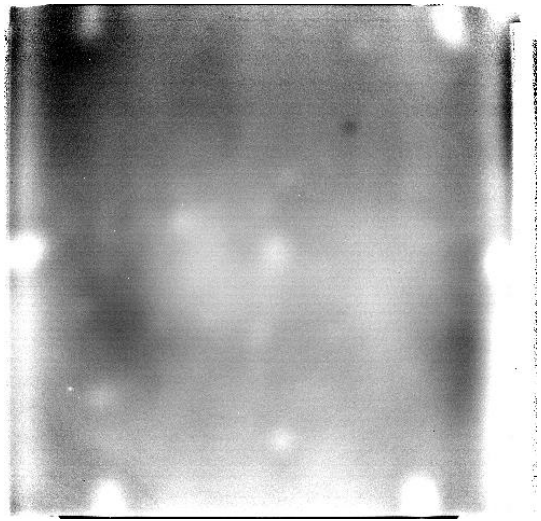


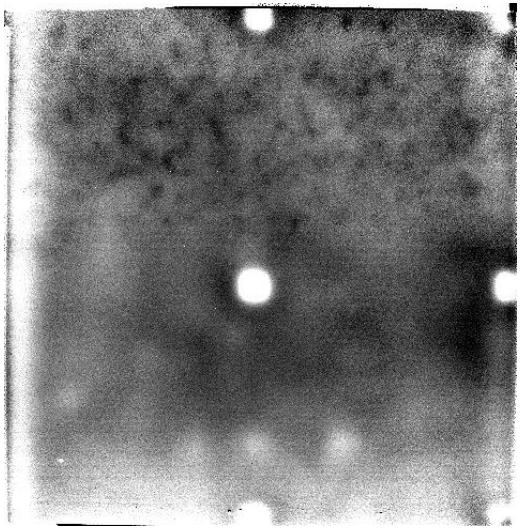
Experimental results Lock-in TT

Frequency 0.15 Hz
Able to capture entire panel

Inserts	Contamination	Porosity







Conclusions

- Using Civa, it was possible to find proper experimental settings to detect defects in adhesively bonded material.
- Simulations gave a good estimate about the power densities needed.
- Difference in absolute values, due to 2D heat transfer, but still useful.
- For lock-in, correct inspection frequencies could be found.

Thank you for your attention!

Accelerating the future of aerospace

Royal NLR - Netherlands Aerospace Centre

Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands
+31 88 511 31 13

info@nlr.nl www.nlr.org

Voorsterweg 31
8316 PR Marknesse
The Netherlands
+31 88 511 44 44

Dr. H.P. (Patrick) Jansen
Senior Scientist – non-destructive inspection

+31 88 511 4333
Patrick.jansen@nlr.nl