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Hybrid NDT for Complex Aerospace Structures

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Statement of the problem

PROBLEM:

- Increasing emissions of the carbon dioxide due to growth of the transport sector.

SOLUTION:

- Material substitution for weight reduction of the vehicles;
- The development of light hybrid structures joining two or more lightweight dissimilar materials.

CHALLENGE:

- The hybrid structures made out of dissimilar materials can only be reliable if the joint is effective.
- New or existing NDT techniques need to be adopted for control of adhesion of the dissimilar joints.

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Objective

The objective of this work was to develop hybrid NDT techniques, suitable for defect detection in complex aerospace structures made from hybrid metal-composite joints.

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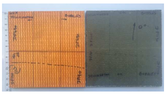
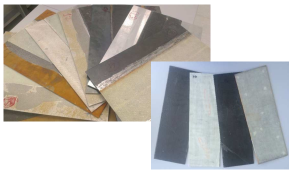
Samples

- 2 steel plates with 4 layers of a glass-carbon fibre epoxy resin composite applied provided by Walker Technical Resources.

- 2 samples of the CFRP/metal with pins provided by Swerea SICOMP AB
- 2 Samples of composite-metal provided by ITA.





- 15+4 samples of the composite-metal provided by AP&M.

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Investigation of the dissimilar joints
(measurement side alternatives)

	Metal side (steel)	Composite path side (CFRP)
Wave transition into the structure	12%	72%
Reflection from interface to transducer	1%	34%
Possibility to detect defects in composite structure	No	Good
Non parallel surfaces of sample	Same on both sides	
Material surface roughness	Low	Rough
Thickness variations	Low	High
Signal reflection overlapping	Yes	No

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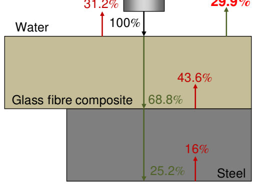
Challenges

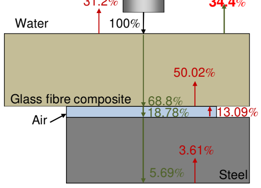
- No damage:

Energy back to transducer from the 1st composite-steel interface 29.9%



- Delamination:

Energy back to transducer from the 1st composite-steel interface 34.4%



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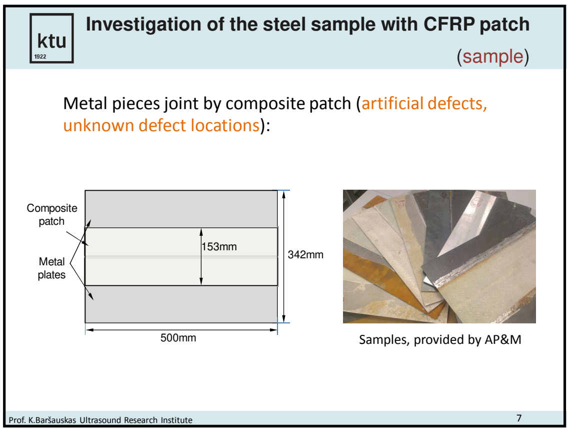
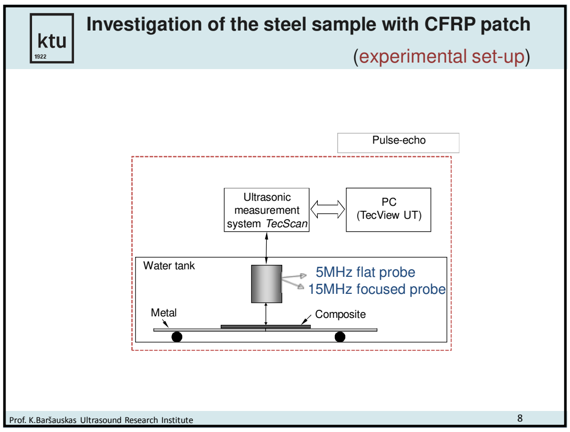
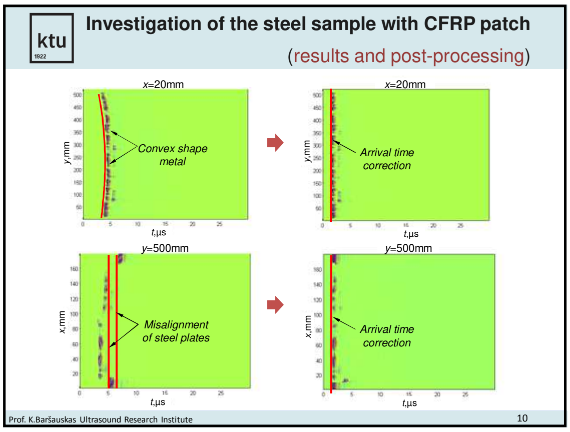
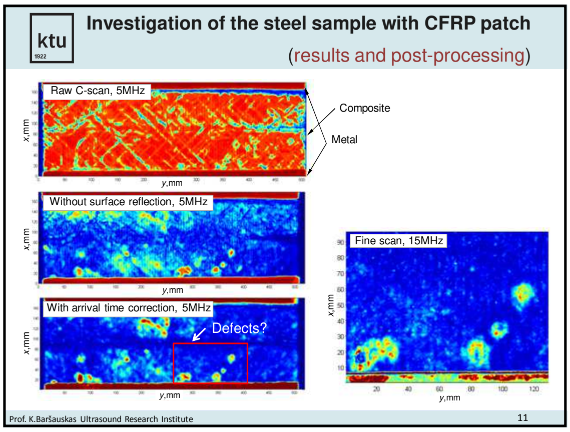
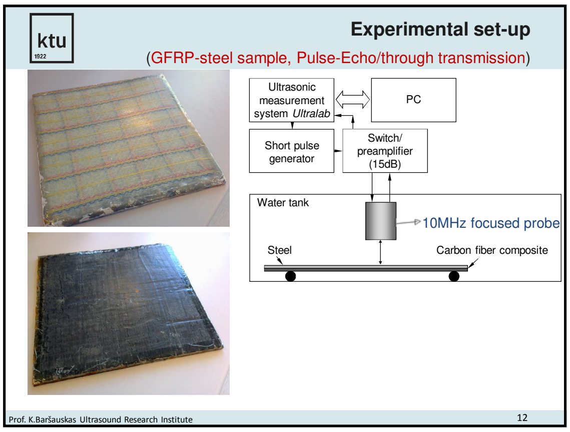
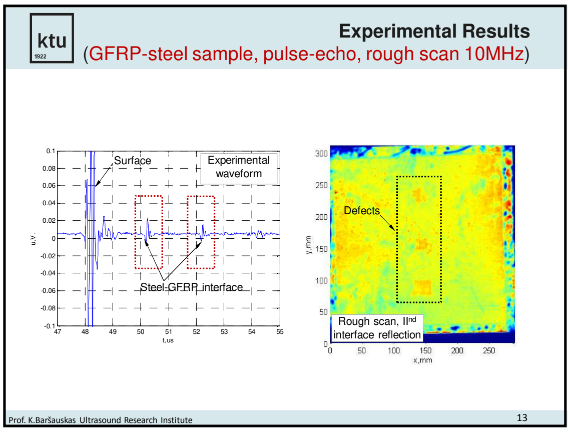




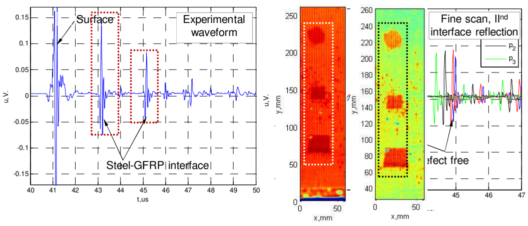






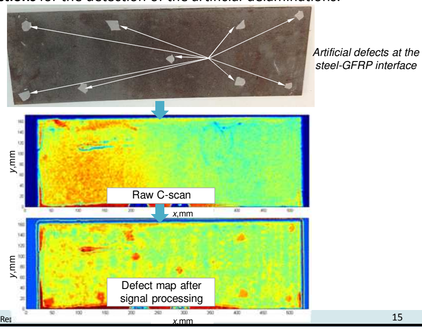


Experimental Results
(GFRP-steel sample, pulse-echo, fine scan 10MHz)



Ultrasonic NDT of dissimilar metal/composite joints using analysis of repeated reflections

An application of pulse-echo measurement method with the **analysis of repeated reflections** for the detection of the artificial delaminations.

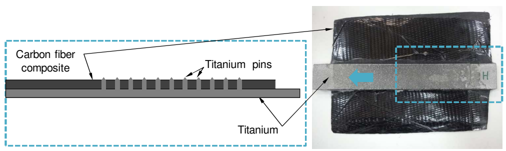


Samples representing complex aerospace strutures

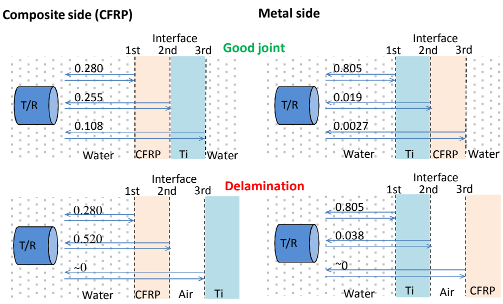
- CFRP/metal with pins

Investigation of the CFRP-Ti sample with pins
(sample)

CFRP/titanium sample with pins (artificial defects, known defect locations):

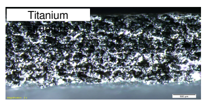


Possible inspection set-ups

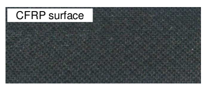


Investigation of the CFRP-Ti sample with pins
(challenges)

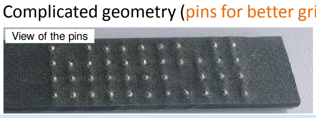
- Rough inhomogeneous structure:
  - Titanium part is manufactured using electron beam melting technique;



  - Woven CFRP;

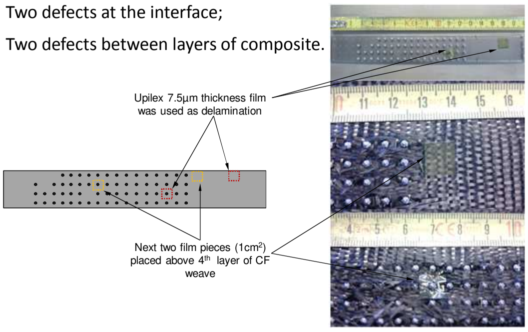


- Complicated geometry (pins for better grip).

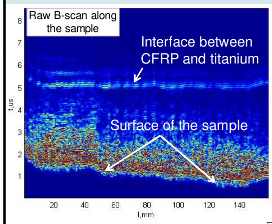


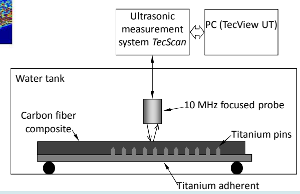
Investigation of the CFRP-Ti sample with pins (defect map)

- Two defects at the interface;
- Two defects between layers of composite.



Investigation of the CFRP-Ti sample with pins (experimental set-up)

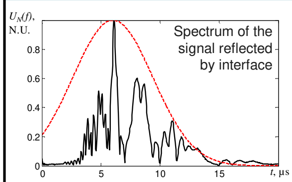




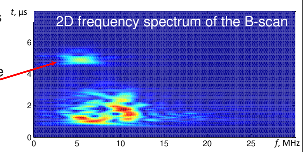
Signal processing algorithm

- Each signal is filtered using Gaussian filter in order to reduce the structural noise;
- The arrival time of the signal reflected by the interface is estimated;
- As the result of this step the set of the arrival times of interface reflections along B-scan is obtained;
- The B-scan aligned with respect to interface is obtained by shifting each of the signals in the time domain according to estimated arrival time;
- In order to reduce the structural noise in the front of the interface, reflected signals are filtered using Gaussian time domain filter;
- The envelope of each signal in B-scan is calculated;
- The data for 3D imaging are prepared by calculating maximum value for each signal.

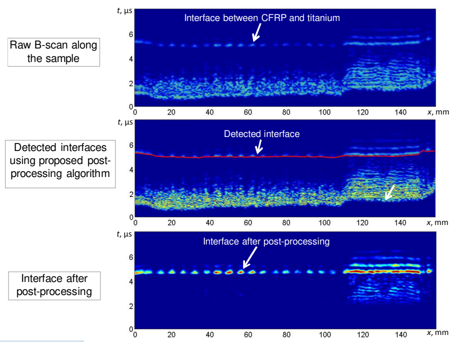
Time frequency analysis



- the frequency of the signal decreases going deeper into the sample;
- reflection from interface (at 4,5 µs) possesses lower frequencies than the surface reflection.



Investigation of the CFRP-Ti sample with pins (results and post-processing)



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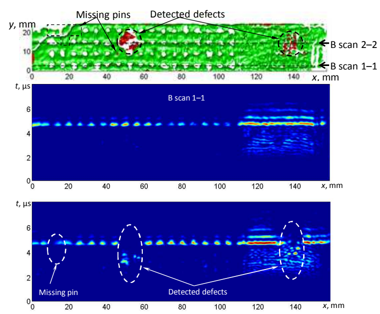

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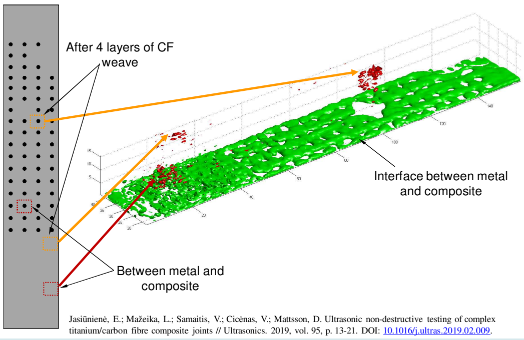
Investigation of the CFRP-Ti sample with pins

(results and post-processing)



Jasiūnienė, E.; Mažeika, L.; Samaitis, V.; Cicėnas, V.; Mattsson, D. Ultrasonic non-destructive testing of complex titanium/carbon fibre composite joints // Ultrasonics. 2019, vol. 95, p. 13-21. DOI: 10.1016/j.ultras.2019.02.009.

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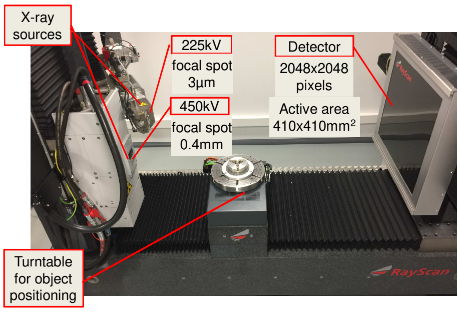
Rayscan 250 computer tomograph



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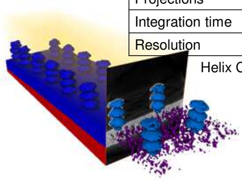
Computed tomography

The objective – to investigate the structure of titanium pin array produced using additive manufacturing technology using computerized X-ray tomography

Measurement parameters:

Voltage	180 kV
Current	150 µA
Projections	800
Integration time	2s
Resolution	55µm



Helix CT

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Conclusions

1. The investigation of the different type of joints demonstrated, that the main challenges determining the quality of the joint are due to uneven surfaces, inhomogeneous structures, complicated geometries, relatively thin thicknesses and minor amplitude differences between defected and defect free areas.
2. It was determined, that the influence of these factors can be reduced by applying a special post-processing techniques, such as arrival time correction and automatic interface detection.
3. Delamination's can be detected in different layers (between metal and composite and between composite layers) and in different positions – even between the pins in samples with complicated geometry.
4. Use of X-ray computed tomography can help to visualize porosity content in the additively manufactured titanium part.

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Acknowledgement

The research leading to these results has received funding from the European Union Seventh Framework Programme under grant agreement n° 310498

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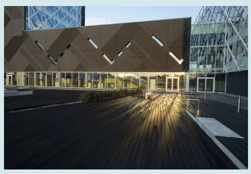
Thank you for attention



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