AIRTuB
Laser line scanning for leading-edge erosion inspection

Andrei G. Anisimov
a.g.anisimov@tudelft.nl

Anisimov, et. al, "AIRTuB: towards automated inspection of leading-edge erosion of wind turbine blades by shape analysis", Proc. SPIE 11785, Multimodal Sensing and Artificial Intelligence: Technologies and Applications II, 117850W

AIRTuB
Laser line scanning for leading-edge erosion inspection

Andrei G. Anisimov
a.g.anisimov@tudelft.nl

Anisimov, et. al, "AIRTuB: towards automated inspection of leading-edge erosion of wind turbine blades by shape analysis", Proc. SPIE 11785, Multimodal Sensing and Artificial Intelligence: Technologies and Applications II, 117850W

AIRTuB
Laser line scanning for leading-edge erosion inspection

Andrei G. Anisimov
a.g.anisimov@tudelft.nl

Anisimov, et. al, "AIRTuB: towards automated inspection of leading-edge erosion of wind turbine blades by shape analysis", Proc. SPIE 11785, Multimodal Sensing and Artificial Intelligence: Technologies and Applications II, 117850W

Requirements

Type of Damage	Erosion Depth (mm)	Erosion Diameter (mm)	Decrease in AEP expected	Number of features
Pit	0.3	2	3% - 5%	400 over a 2.5m span

AIRTuB open deliverables:

- A Literature Survey on Remote Inspection of Offshore Wind Turbine Blades: Automated Inspection and Repair of Turbine Blades (AIRTuB) - WP1
  Hwang, J.S., et. al. Netherlands Aerospace Centre NLR 2021-05 http://hdl.handle.net/10921/1559

- Nijssen, R. and Manrique, E. “Literature Review of Structural and Non-Structural Wind Turbine Blade Damage”, TNO report, August 2020

https://www.worldclassmaintenance.com/project/fieldlab-zephyros/
https://www.worldclassmaintenance.com/sub-project/airtub-automatische-inspectie-reparatie-van-turbinebladen/

TU Delft AeroNDT

What is now?

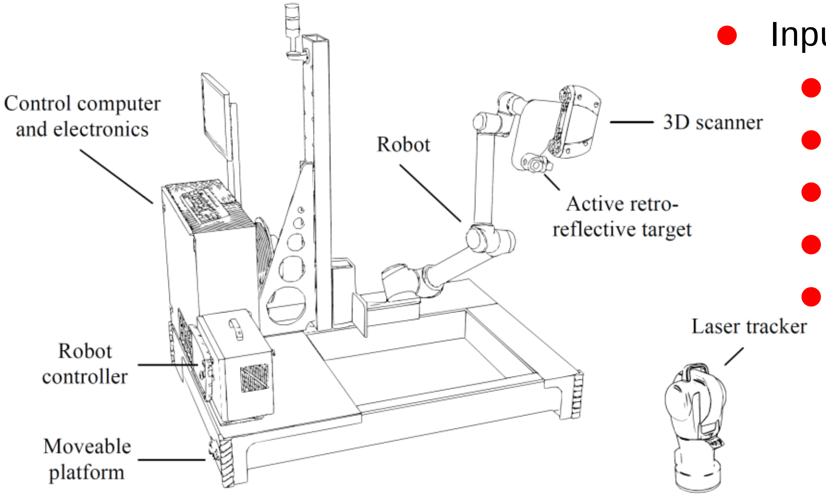
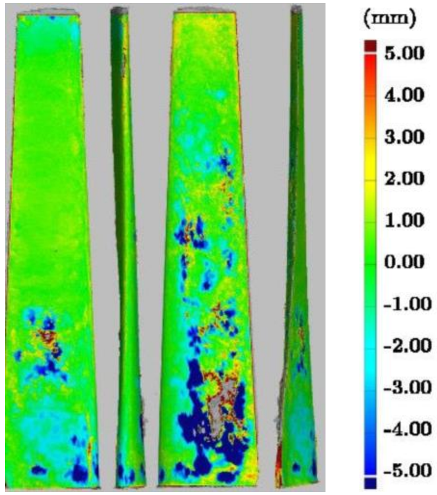


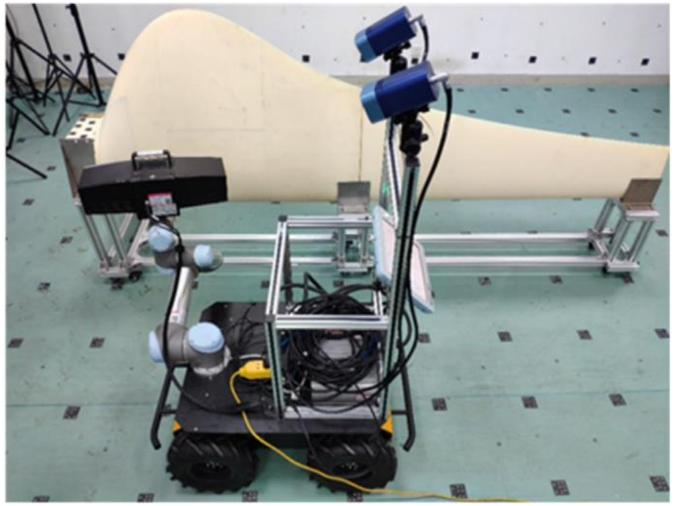
Figure 1. Sketch of the inspection system.

- Inputs:
  - High TRL
  - Available now
  - Robust (IP65)
  - Resolution ≈ 0.1-0.2 mm
  - Distance 1.5+ m



- Error: 0.5 mm (3 STD)

- Error: 5+ mm (3 STD)

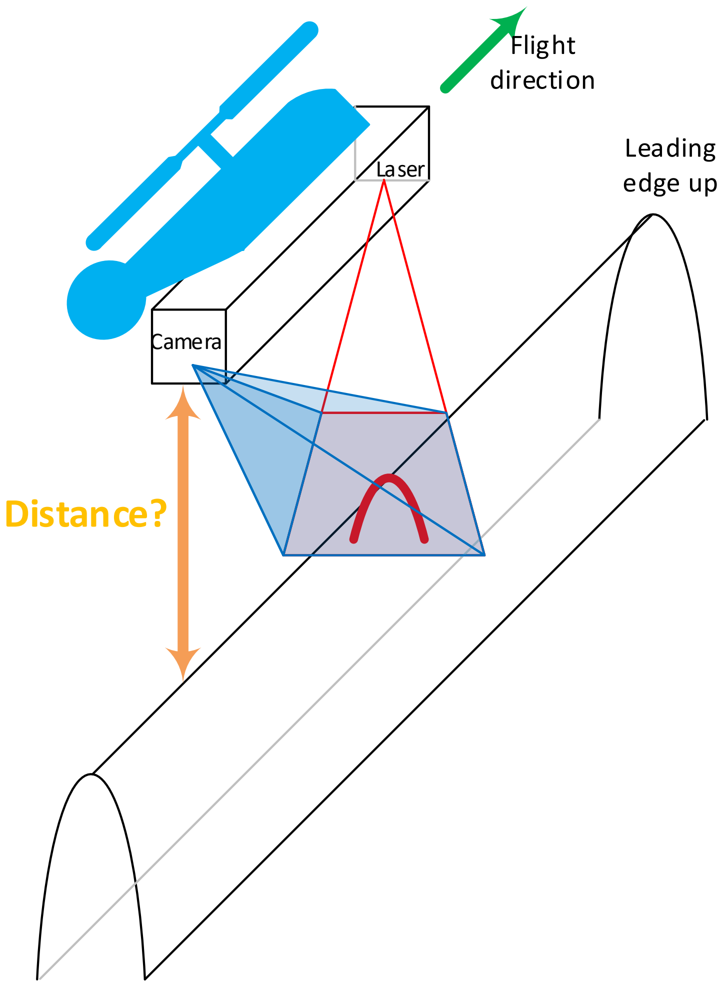


- Error: 0.3 mm (3 STD)

- Market: multiple options for visual inspection
  - Lidar
  - *Photogrammetry is coming*

Lyngby, R. A., Development and metrological validation of a new automated scanner system for freeform measurements on wind turbine blades in the production. 2019
Wang, J., A mobile robotic measurement system for large-scale complex components based on optical scanning and visual tracking. 2021
Zhang, D. Remote inspection of wind turbine blades using UAV with photogrammetry payload. 2017

Measurement approach



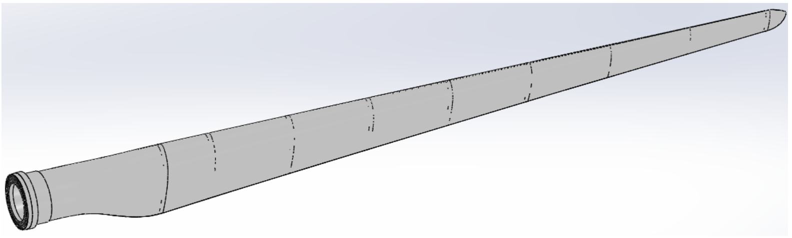
- Inputs:
  - High TRL
  - Available now
  - Robust (IP65)
  - Resolution ≈ 0.1-0.2 mm
  - Distance 1.5+ m

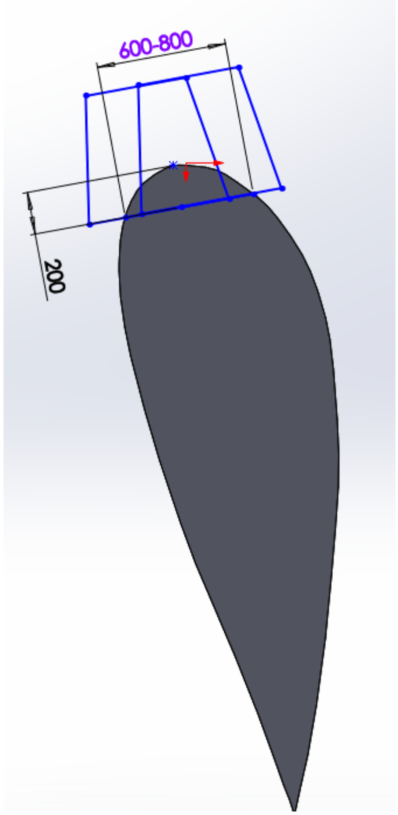
- Drone issues:
  - Safe flight
  - Coordinates?
    - orientation
  - Vibrations
  - Mass/power
  - Autonomous
  - Weather

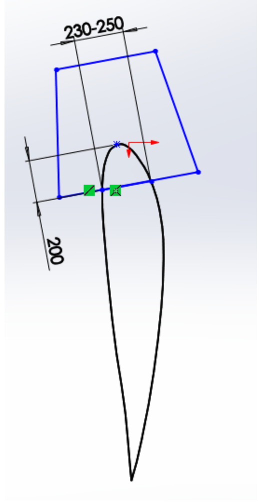
RF629
Riftek

Measuring range	490 mm @1310 mm 680 mm @1900 mm
Resolution	
X @ midrange [mm]	0.2
Error Z	0.05% of the distance (0.8 mm @ 1600 mm)
Number of points	1280 (2560)
Frequency [Hz]	2000
Weight [kg]	4.0
Dimensions [mm]	
Width	64
Height	125
Length	680

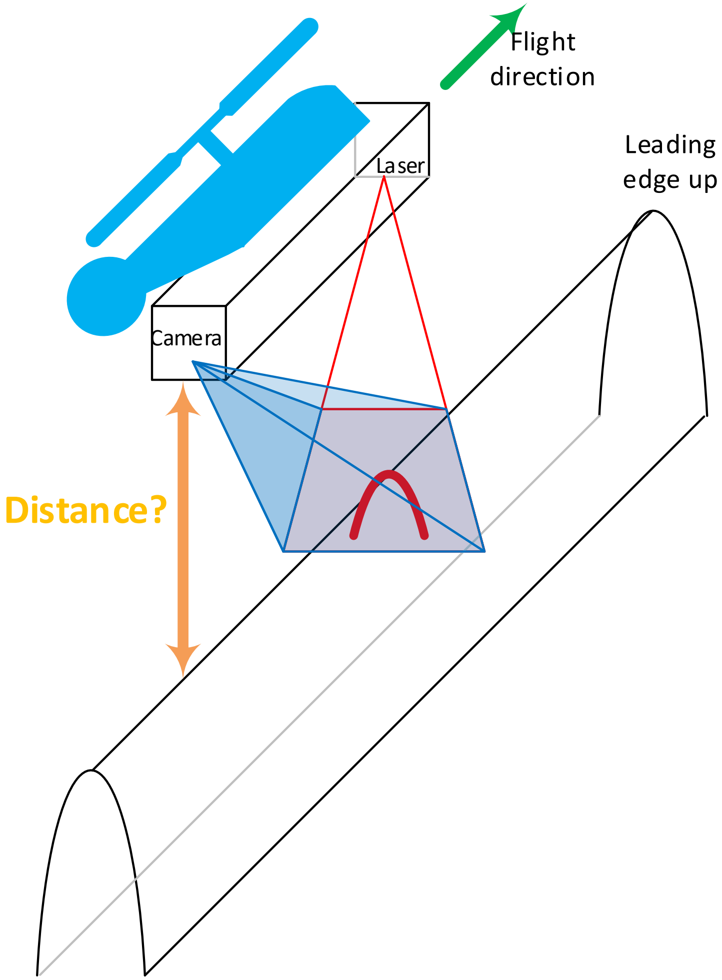
≈40 m long







Measurement approach



- Inputs:
  - High TRL
  - Available now
  - Robust (IP65)
  - Resolution ≈ 0.1-0.2 mm
  - Distance 1.5+ m

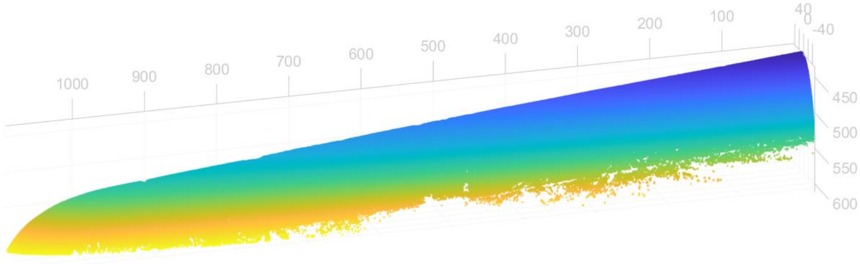
- Drone issues:
  - Safe flight
  - Coordinates?
    - orientation
  - Vibrations
  - Mass/power
  - Autonomous
  - Weather

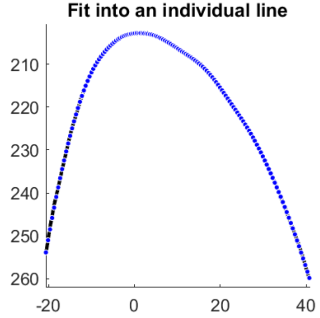
	RF629 Riftek
Measuring range	490 mm @1310 mm 680 mm @1900 mm
Resolution	
X @ midrange [mm]	0.2
Error Z	0.05% of the distance (0.8 mm @ 1600 mm)
Number of points	1280 (2560)
Frequency [Hz]	2000
Weight [kg]	4.0
Dimensions [mm]	
Width	64
Height	125
Length	680

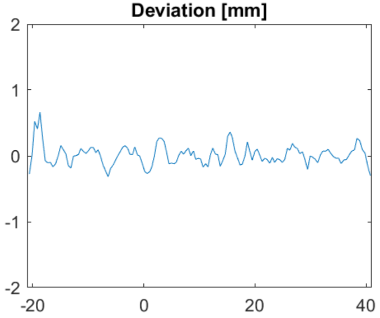
TU Delft AeroNDT

Erosion map

(a)







Point cloud

2D: individual profiles

- Deterministic "Line by line":
  - Search for a deviation
  - Fitting/smoothing
  - Segmentation

- Simple
- Robust
- Fast (parallel)

- Statistical vs. parametric

3D: point cloud

GOM proprietary defect detection

NLR

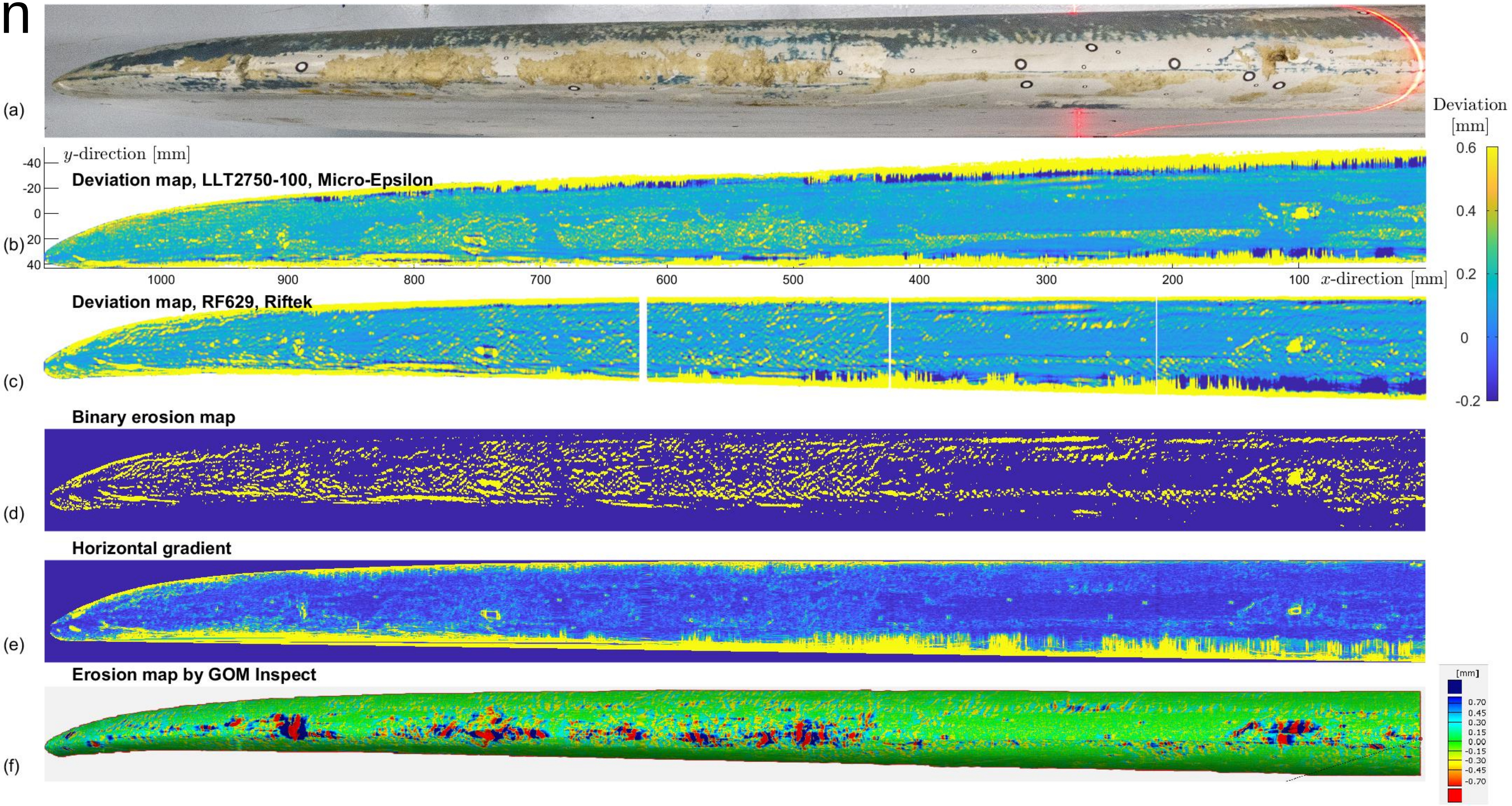
2D: surface plots

Machine learning (e.g. conv3D)

***HZ** University of Applied Sciences*

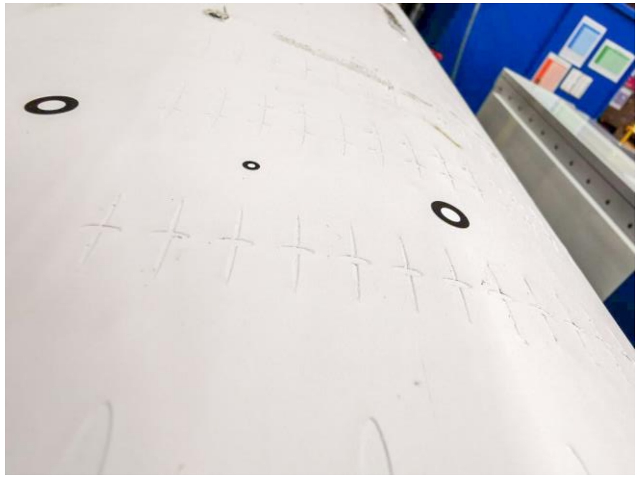
Relevant erosion database

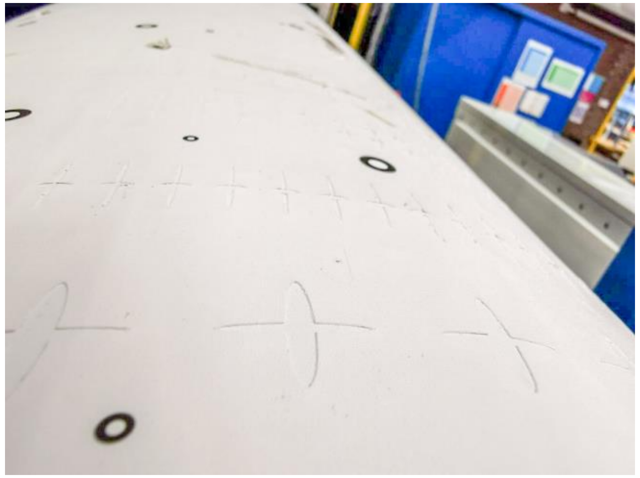
Erosion map

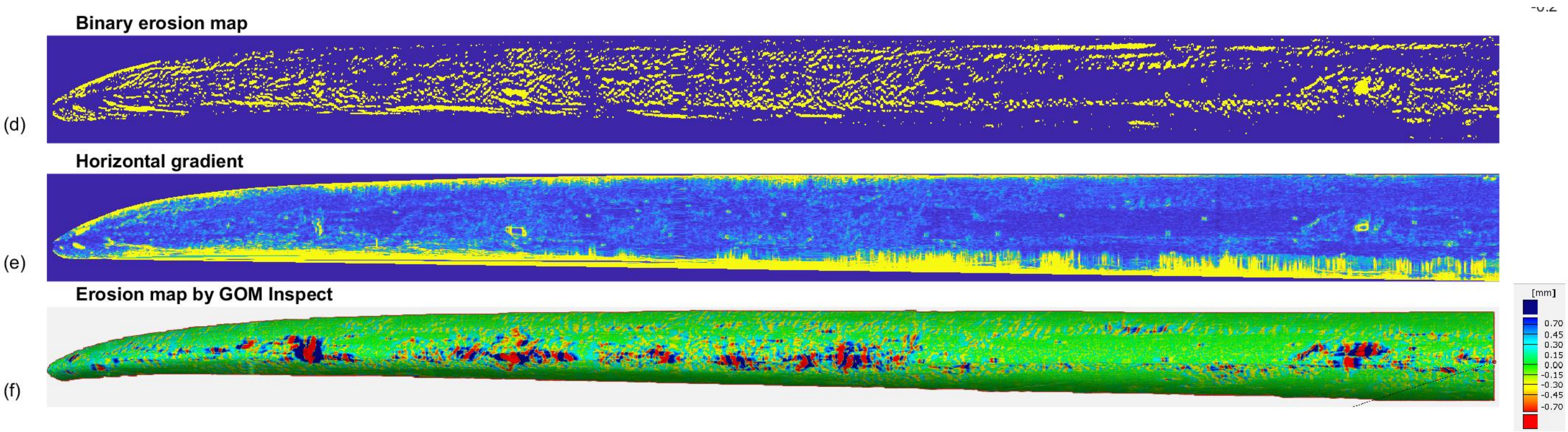


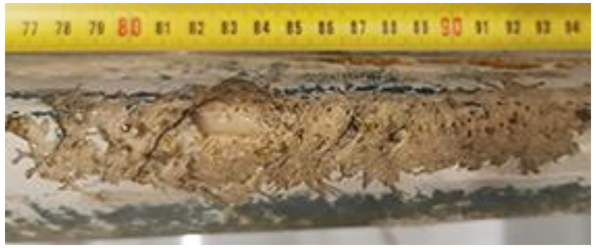
(a)
(b)
y-direction [mm]
-40
-20
0
20
40
Deviation map, LLT2750-100, Micro-Epsilon
1000
900
800
700
600
500
400
300
200
100
x-direction [mm]
Deviation [mm]
0.6
0.4
0.2
0
-0.2
(c)
Deviation map, RF629, Riftek
(d)
Binary erosion map
(e)
Horizontal gradient
(f)
Erosion map by GOM Inspect
[mm]
0.70
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.70

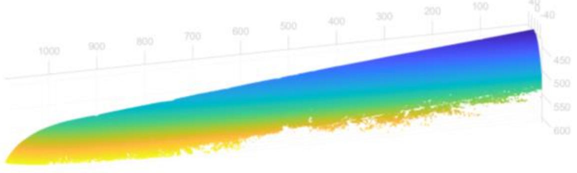
Reference?

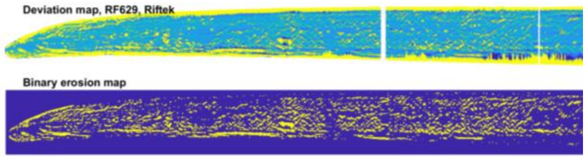


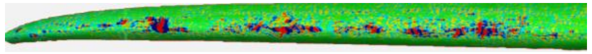



Binary erosion map
(d)
Horizontal gradient
(e)
Erosion map by GOM Inspect
(f)
[mm]
0.70
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.70









Discussion

- Quantitative erosion inspection?
  - Feasible with laser line scanners
  - mm and sub-mm range
- Drone-based
  - testing now
- AI/ML
  - Relevant reliable dataset

- Drone *issues*

Safe flight:	1.3..1.9 m
Coordinates	Point cloud reconstruction = orientation the main challenge *Oversampling* at low speed
Mass/power	Engineering and collaborating
Integration	On the way
Vibrations	Preliminary tests: clear effect, detection possible
Weather	To be tested
Drone	6 kg

AIRTuB
Laser line scanning for leading-edge erosion inspection

Andrei G. Anisimov
a.g.anisimov@tudelft.nl

Anisimov, et. al, "AIRTuB: towards automated inspection of leading-edge erosion of wind turbine blades by shape analysis", Proc. SPIE 11785, Multimodal Sensing and Artificial Intelligence: Technologies and Applications II, 117850W

TU Delft · AeroNDT · WORLD CLASS MAINTENANCE