Thermographic detection and AI-evaluation of leading-edge erosion

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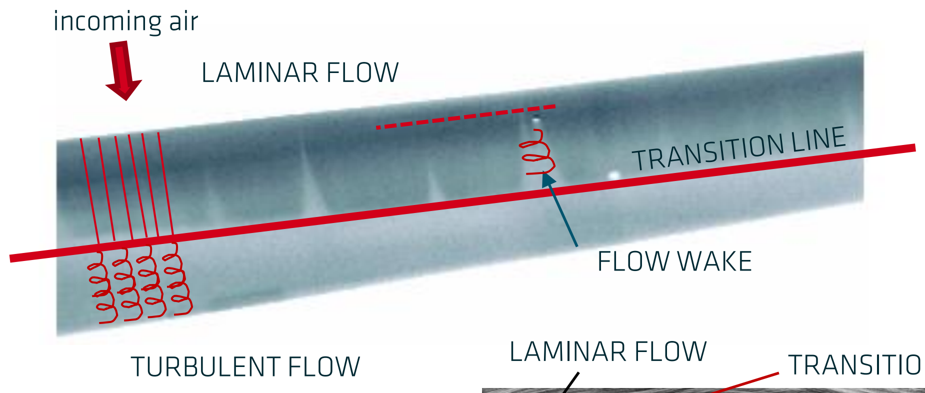
Thermal signature of erosion damage on the leading edge

- Thermographic imaging can visualize the transition from laminar to turbulent flow of a wind turbine blades (WTB)
- Additionally, erosion damage at or near the leading edge causes formation of turbulent wakes, that have characteristic thermal signatures
- Such turbulent wakes increase the drag of the blade, thus decreasing the efficiency of the blade



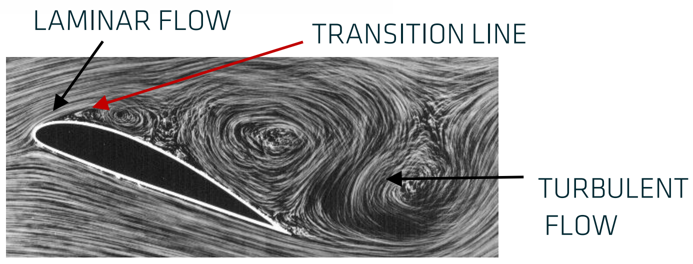


Fig 1. Thermographic image of a blade (up) and an illustration of flow transition around a 2D airfoil cross-section (right)

Ground-based thermal and visual inspection of WTBs in operation

Inspection method:

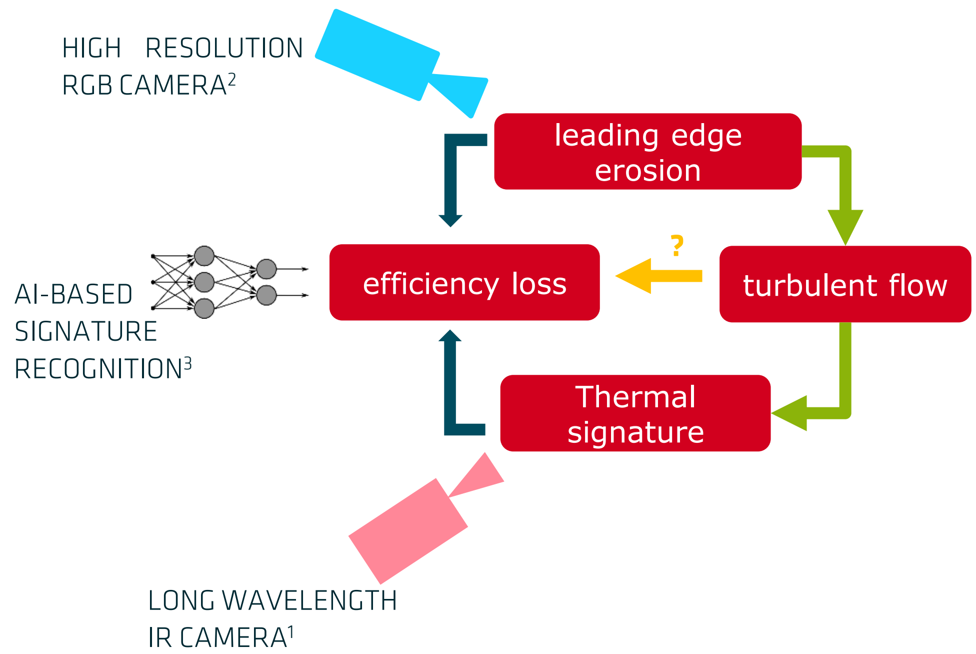
High-speed long-wavelength IR camera (200 mm objective) mounted on a pan-tilt unit and a RGB camera in tandem to obtain images of a blade while turbine is in operation.

AI-based algorithm recognizes and evaluates the characteristic thermal effect of erosion damage.

Goal:

Early detection of the erosion damage and estimation of efficiency loss due to change of blade aerodynamics.

Fig 2. Thermal camera (front) and RGB- camera (back) in operation

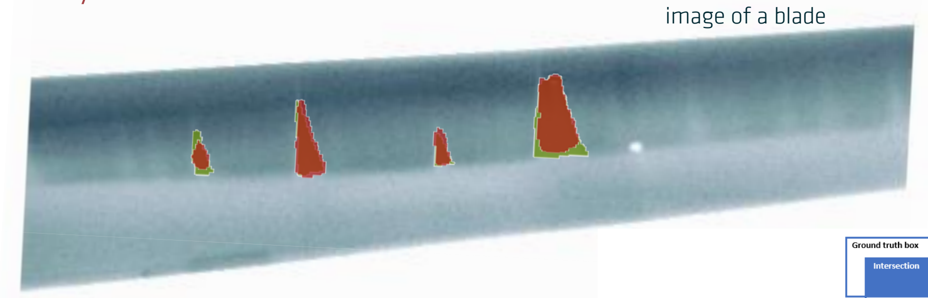


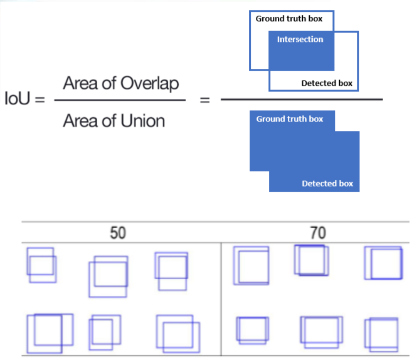
Phase I: Model training

Human annotation = ground truth

Fully Convolutional Network Prediction

Fig 3. Thermographic image of a blade





Proof-of-concept study:

1500 evaluated images

50% images w/o thermal signatures

80/20 % training/testing images

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Intersection over Union (IoU) = ~ 50

Phase II: Vis- & thermal image integration

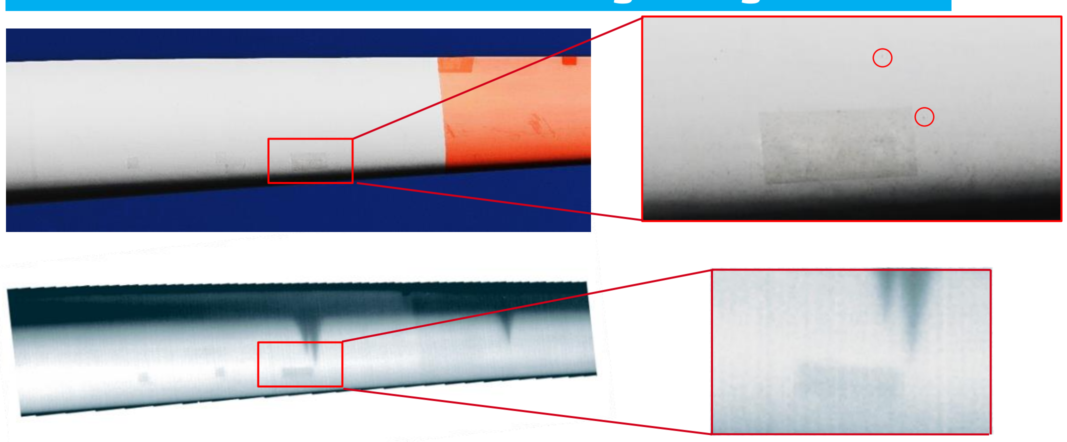

Fig 4. Visual image (above) and thermal image (below) of the same blade. On the right is a zoomed section showing two potential defects with turbulent flow wakes.

When to repair?

A visually small defect can have big effect in disturbance of laminar flow!
But also a visually bigger defect might have small laminar flow disturbance and does not need to be repaired!

Open question:

What is the link between the size and shape of the thermal signature and the efficiency loss?

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