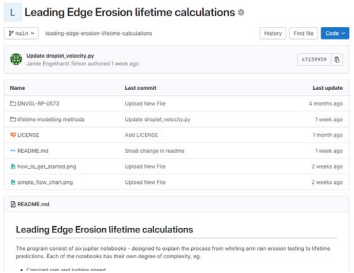
WP 4 deliverable 3

Fitting VN data from rain erosion test data and the potential effects on predicted lifetime

Nicolai Frost-Jensen Johansen
Ph.D, Development engineer, DTU Wind

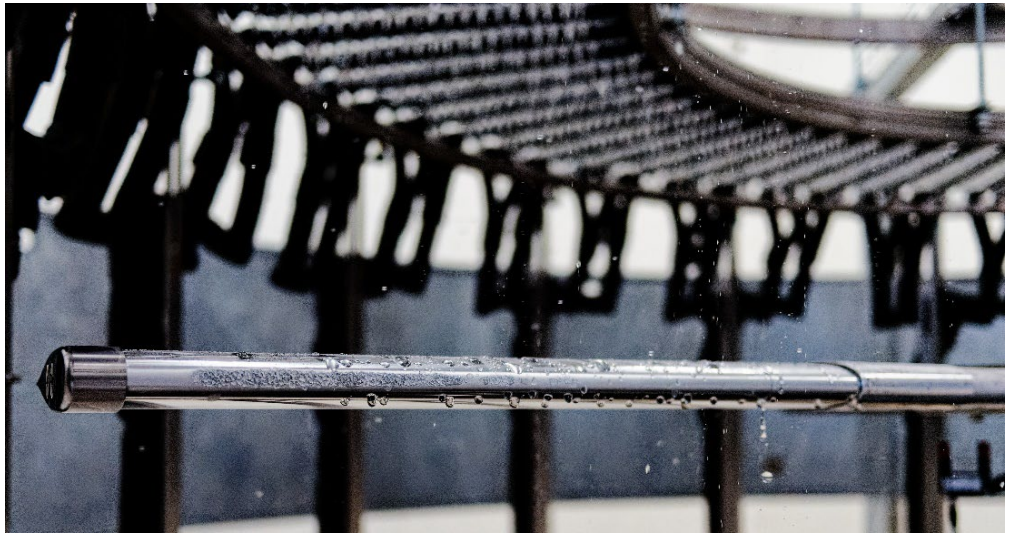
- Python-Jupityr notebook implementation of DNV-GL RP 0573
- Pure VN data driven
- With and Without covariance of wind and rain
- Base implementation of Springer model
- Improved and transparent fitting V or N dependent
- https://gitlab.windenergy.dtu.dk/jaensi1/leading-edge-erosion-lifetime-calculations
- Report on the way
- Code is on gitlab.



Whirling arm RET is the SoTA LAB test for erosion

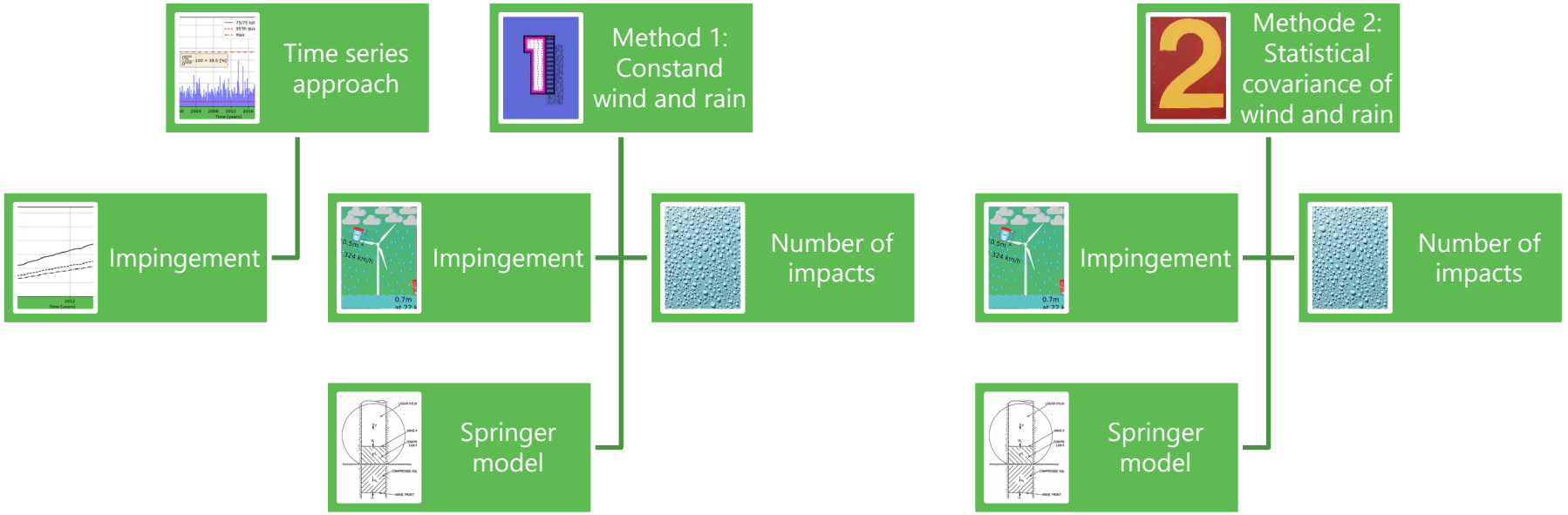
IEA Wind TCP

- Our machine at DTU installed this year 2024 is machine nr 15
- At least 2 more where install this year



Current extend of the models

IEA Wind TCP



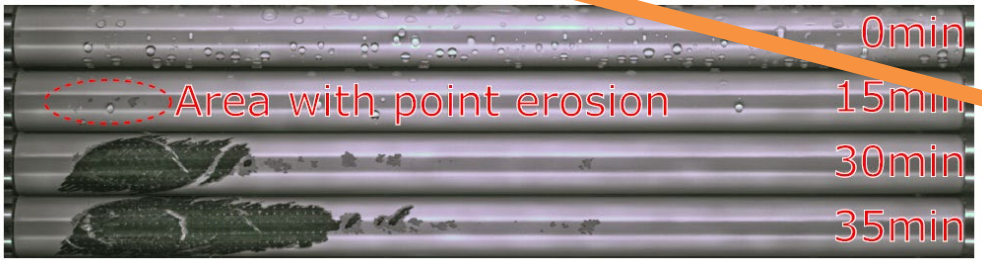
Example data from commercially analysed RET data following DNV-GL RP 0171

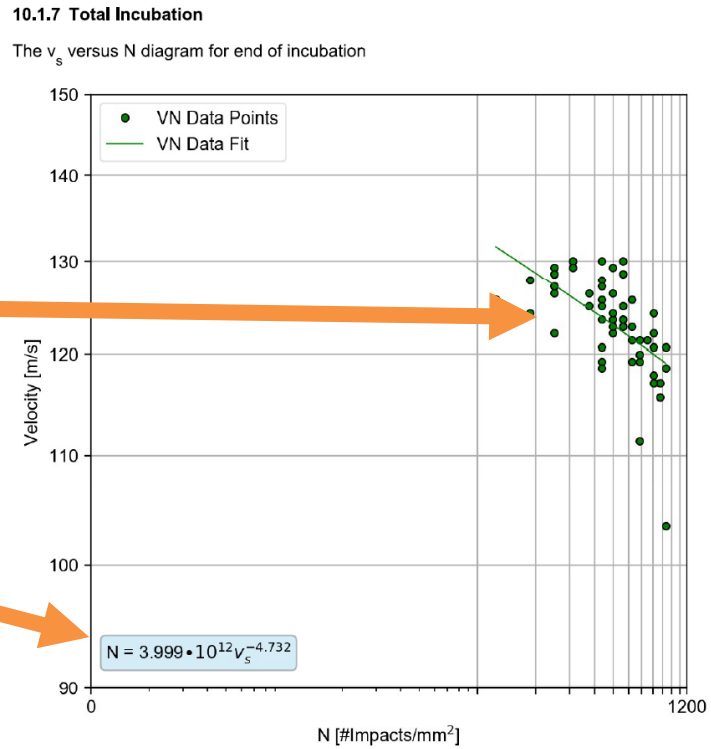
IEA Wind TCP

- RET is expensive
  - Single test cost starting at about 3-4000€
    - Accelerated speed single run for initial screening not uncommon

- Line is V dependent
  - $N = 717 * 10^{40} * v^{-19}$

- Equation is N dependent
  - $N = 4 * 10^{12} * v^{-4.73}$





Standards for fitting data

IEA Wind TCP

- ASTM E739-10
  - Statistical Analysis of Linear or Linearized Stress-Life (S-N)
- DNV-GL RP-0171
  - Testing of rotor blade erosion protection systems
- DNV-GL RP-0573
  - Evaluation of erosion and delamination for leading edge protection systems of rotor blades

As often used for traditional fatigue S/N curves, the equation may be specified with *N* as the dependent parameter:

DNV-GL-RP-0171

$$N(v_s) = k \cdot v_s^m \left[\frac{\#Impacts}{m^2}\right]$$

- test results in the form of a VN curve for one mean droplet diameter d
- N drops per unit area should be the dependent variable
- linear regression in a logarithmic- logarithmic representation, resulting in the VN curve above which 50% of the population is expected to lie
- slope -m of the VN curve from linear regression
- statistical treatment to obtain the characteristic VN curve above which 95% of the population is expected to lie with a 95% confidence according to /3/ or ASTM E739
- compute the modified strength, S_{ec}, by choosing a point from the fit 95%/95% VN log-log equation and equating the chosen value N, to the same value of N in the Springer equation calculated using the chosen value of v:

DNV-GL-RP-0573

$$N = N_s\left(\mathrm{v}, d\right) = \frac{8.9}{d^2} \cdot \left(\frac{S_{ec}}{\sigma_0}\right)^m$$

3. Terminology

3.1 The terms used in this practice shall be used as defined in Definitions E206 and E513. In addition, the following terminology is used:

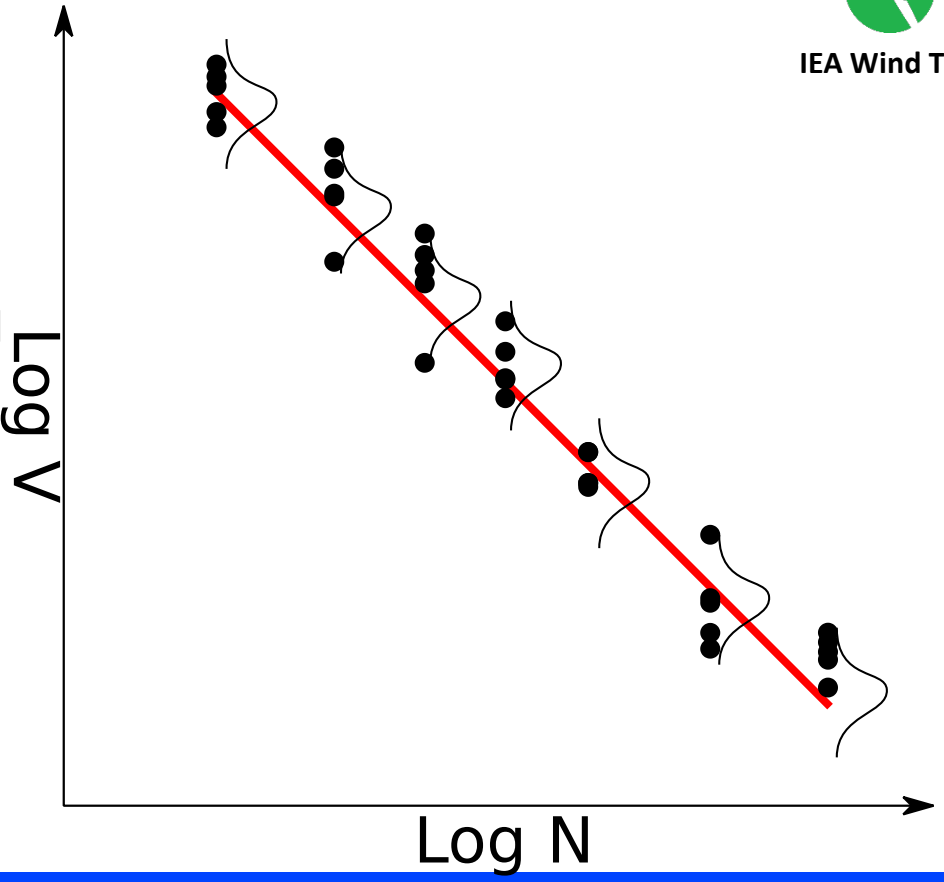
3.1.1 *dependent variable*—the fatigue life N (or the logarithm of the fatigue life).

3.1.1.1 *Discussion*—Log (N) is denoted Y in this practice.

3.1.2 *independent variable*—the selected and controlled variable (namely, stress or strain). It is denoted X in this practice when plotted on appropriate coordinates.

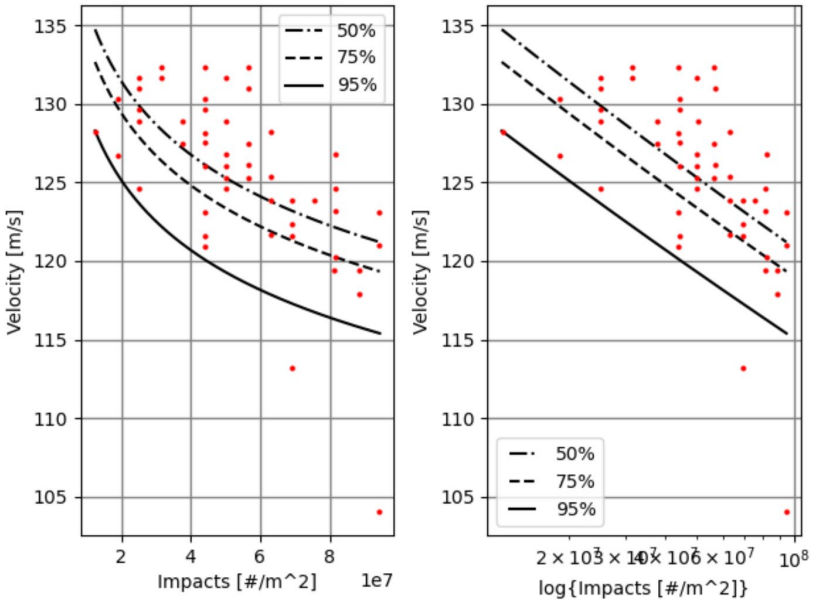
ASTM-E739-10

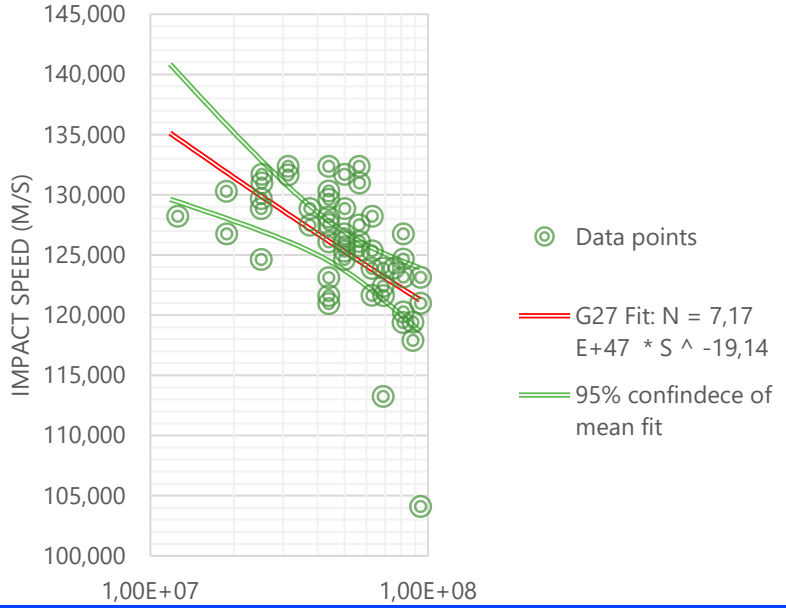
- S is the **Dependent** variable
  - S is is observed at failure position
- N is the **Independent** variable
  - N is know from the inspection interval
- Data is vertically distributed
  - Discreet sampling interval
  - 3 blades
  - Repeated test
  - Distribution is vertical



- New data driven method
- 95% are above the line

ASTM E739-10

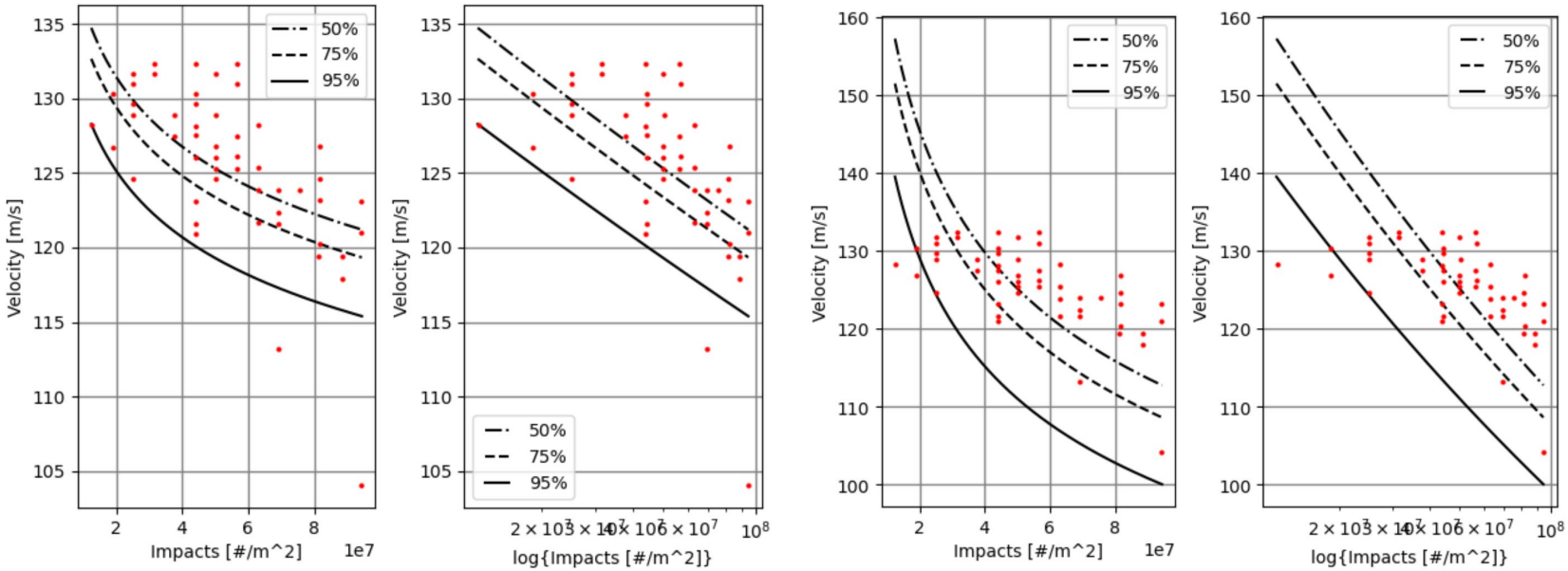




N AS PER DNV-GL

Fitting 95/95 confidence intervals

IEA Wind TCP

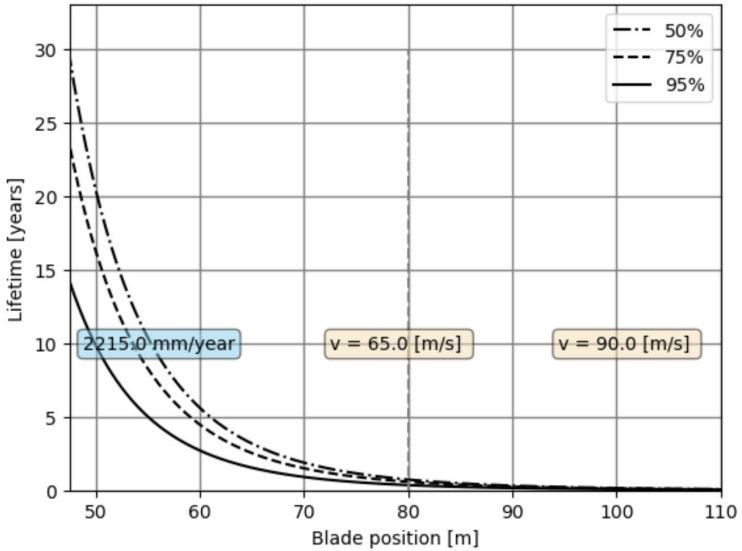


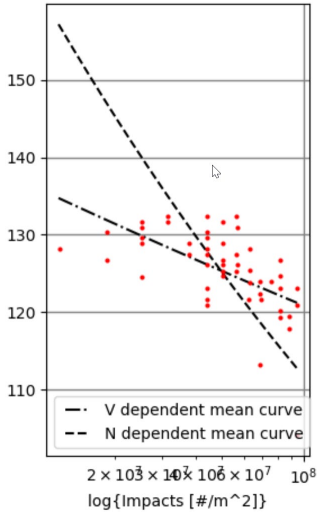
The influence on predicted lifetime

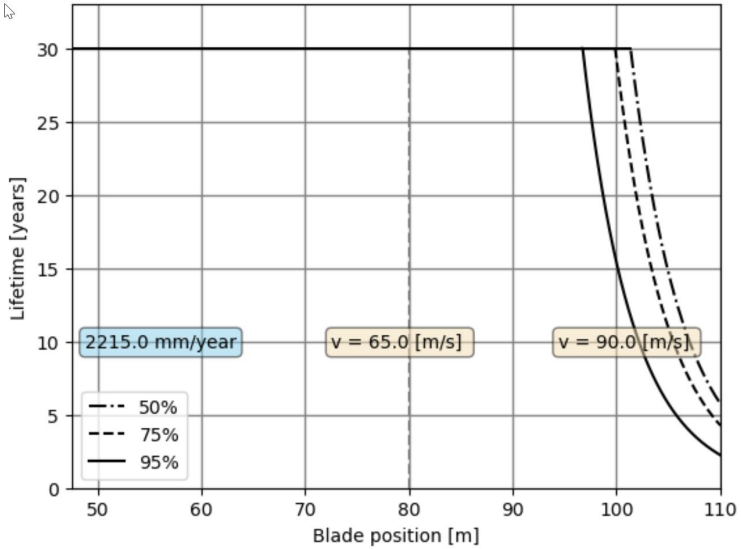
IEA Wind TCP

- N – dependent fitting lifetime
  lifetime

V- depended







Phase 2 WP4

IEA Wind TCP

- 4.1 Large-scale comparison and round-robin
- 4.2 RETs under different climatic conditions and effect of droplet size and impact rate on coating lifetime.
- 4.3 Impact of microplastics emissions from erosion.
- 4.4 Incorporation of weathering into RET protocol.
- 4.5 Design of specimens with predefined defects. Objective: Develop a standard method for introducing predefined defects into RET specimens,