Degradation of Blade Coatings due to Rain Erosion & Weathering

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Introduction

The issue of wind turbine blade coating degradation is yet to be fully understood. This poster presents current research of coating degradation mechanisms and influences.

Wind turbine blades are coated to prevent damage to the materials of the blade structure and to ensure the blades have a smooth, efficient surface. Blade coatings are polymeric, typically polyurethane. A coating is applied over the whole blade, with an additional coating applied to the leading edge. The leading edge experiences the most destructive environmental conditions due to impacting rain droplets and weathering.

Research purpose

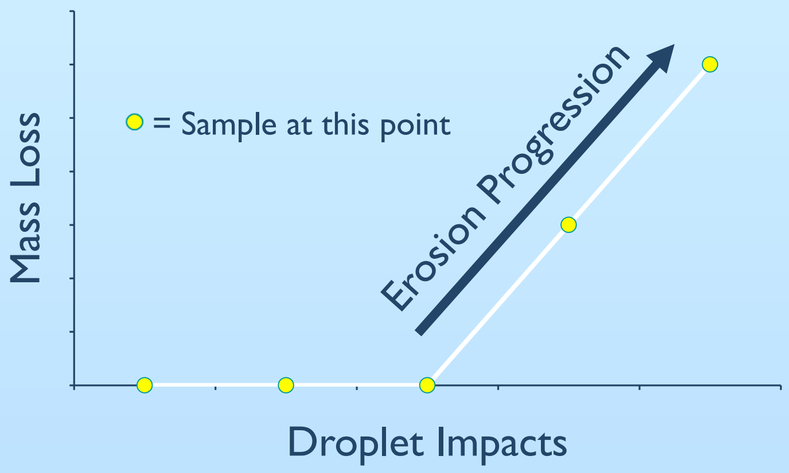
To investigate changes in material properties and chemical composition of blade coating materials due to erosion and weathering. How does weathering and rain influence the degradation mechanism(s)?

Known degradation mechanisms will allow for comprehensive testing of coatings and development of more resistant coatings. Thus, coatings will have a longer operational life, leading to less required maintenance, resulting in a lower overall LCoE for the turbine.

Experiment Construction

Three stages of experimental work were identified from current gaps in knowledge. Each stage has a different degradation mechanism, based on environmental factors.

Sample points were chosen at periods through the progression of erosion. Beginning with no erosion, a sample within the incubation period and then samples of a mildly eroded surface and a very eroded surface.



Rain Impacts

UV Radiation

Thermal Cycling

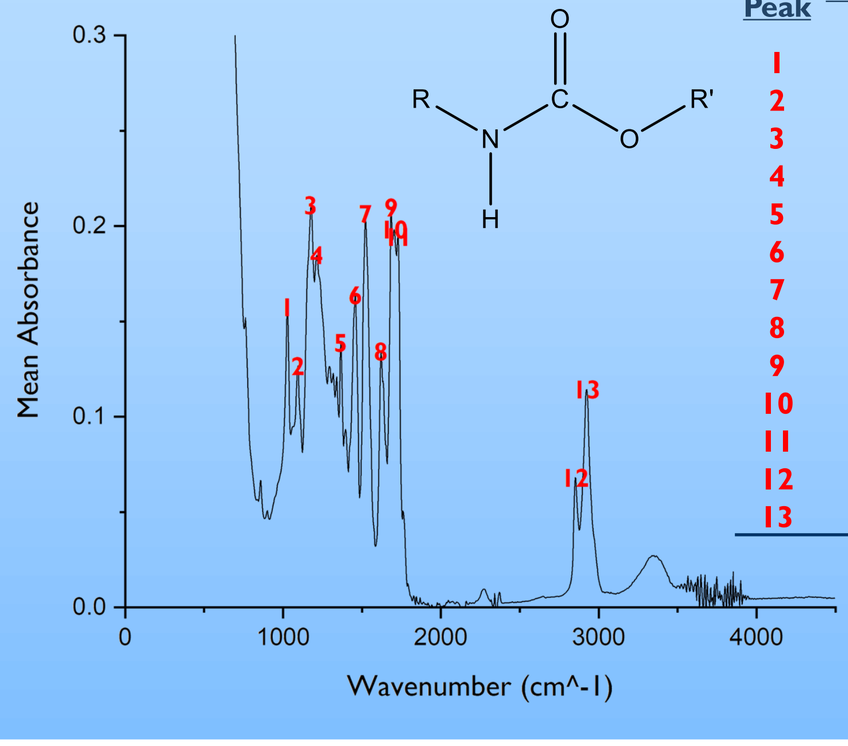
Humidity

Stage 1 – Rain
Stage 2 – Weathering
Stage 3 – Rain + Weathering

A thorough laboratory analysis will take place at each sample point assessing mass & volume loss, material properties and chemical composition. This will allow for a quantitative assessment of the progression of erosion and degradation.

Chemical Analysis

FTIR was used to generate infra-red absorbance spectra for blade coatings. The spectrum has various peaks which link to chemical functional groups of the analysed coating. Analysis will be conducted at each sample point to track chemical changes as erosion progresses. The exact chemistry of the coating was unknown at the time of analysis, it was presumed to be of a polyurethane base. The molecule shown below is a generic polyurethane monomer (repeating unit).



Peak	Functional Group	Compound
1	C-N	Amine
2	C-N	Amine
3	C-O	Ester / Tertiary Alcohol
4	C-O	Vinyl Ether
5	N-O	Nitro Compound
6	C-H	Alkane
7	N-O	Nitro Compound
8	N-H	Amine
9	C=O	Conjugated Acid/Aldehyde
10	C=O	Conjugated Acid/Aldehyde
11	C=O	Aldehyde
12	C-H	Alkane / Aldehyde
13	C-H	Alkane

What is erosion?

Erosion is defined as the gradual destruction of a material by physical or chemical action.

The main cause of erosion on wind turbine blades is rain droplets impacting the blade, causing repeated stresses which leads to surface fatigue. The influence of weathering from UV radiation, humidity and thermal cycling, on the blade erosion process is yet unknown.

Images: H. M. Slot, E. R. Gelinck, C. Rentrop, and E. Van der Heide, "Leading edge erosion of coated wind turbine blades: Review of coating life models," *Renewable Energy*

Erosion Progression

Experiment Description

Stage 1 – Focused solely on rain impact erosion. Aim to generate a baseline of material changes due to droplet impacts. Quantify changes in mass/volume, internal structure(cracks), moduli & chemistry.

Stage 2 – Looking at weathering aspects, not including rain impacts. Weathering is a combination of UV radiation with temperature and humidity changes. Quantify changes in mass/volume, internal structure(cracks), moduli, crystallisation percentage, thermal reactions & chemistry.

Stage 3 – Combine both stage 1 and stage 2 to create a realistic degradation cycle which uses both weathering and rain impacts. Quantify changes in mass/volume, internal structure(cracks), moduli, crystallisation percentage, thermal reactions & chemistry. Compare to stage 1 and stage 2, quantify how much weathering affects erosion and identify changes/degradation mechanism(s).

Lab Analysis

Various analytical lab techniques will be used to assess the state of the coating at each sample point.

Each technique will provide a quantitative measure to assess the degradation and erosion at each sample point.

As erosion progresses along each sample point, a timeline of degradation data will be generated. Data including material properties and chemical composition will be used to link specific stages to changes within the coating.

This will allow for any effects that weathering has on the erosion process to be identified.

- 3D Optical Microscope (3DOM)
- Atomic Force Microscopy (AFM)
- Differential Scanning Calorimetry (DSC)
- Dynamic Mechanical Analysis (DMA)
- Fourier Transform IR Spectroscopy (FTIR)
- Scanning Election Microscope (SEM)
- Thermo-gravimetric Analysis (TGA)
- Ultrasonic Thickness Gauge (UTG)
- X-ray Computed Tomography (XCT)

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