Erosion of Wind Turbine Blade Coatings

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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 erosion mechanisms and influences.

Wind turbine blades are coated to prevent damage to the core materials of the blade structure and to ensure the blades have a smooth, efficient surface. The blade coating is polymeric, typically polyurethane or polyuria based, and applied as a paint over the whole blade. The efficiency of the blade is effected when the blade coating begins to degrade, mostly at the leading edge.

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 and causing repeated stresses leading to surface fatigue. The erosion process starts as small pin-holes which then expand and merge to develop into larger patches. The larger patches then further collate, expanding into sections where the core matrix material of the blade is visible and exposed to further damage. The larger collated sections of eroded surface have an effect of the aerodynamic performance of the blade, reducing the coefficient of lift and increasing the coefficient of drag.

[1]

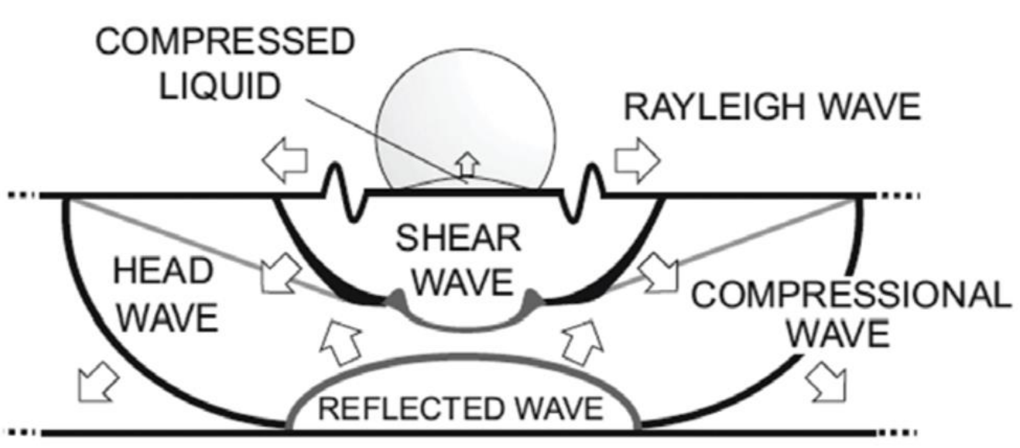
Coating Purpose

The coating provides an efficient surface for the blade and acts as a barrier, preventing damage. Blade coatings should withstand damage from: rain erosion, water/ice, UV radiation, chemical attack, blood (insects), excrement (birds), temperature cycling , sand, salt, mechanical impact and lightning.

Erosion Mechanism

A rain droplet impact causes a depression on the coating material of the blade, therefore applying stresses around the impact zone. Repeated impacts produce repeated stresses which can lead to crack formation due to fatigue.

Once a crack has formed, the repeated impacts lead to crack propagation and ultimately failure where the coating fractures and is removed from the substrate.



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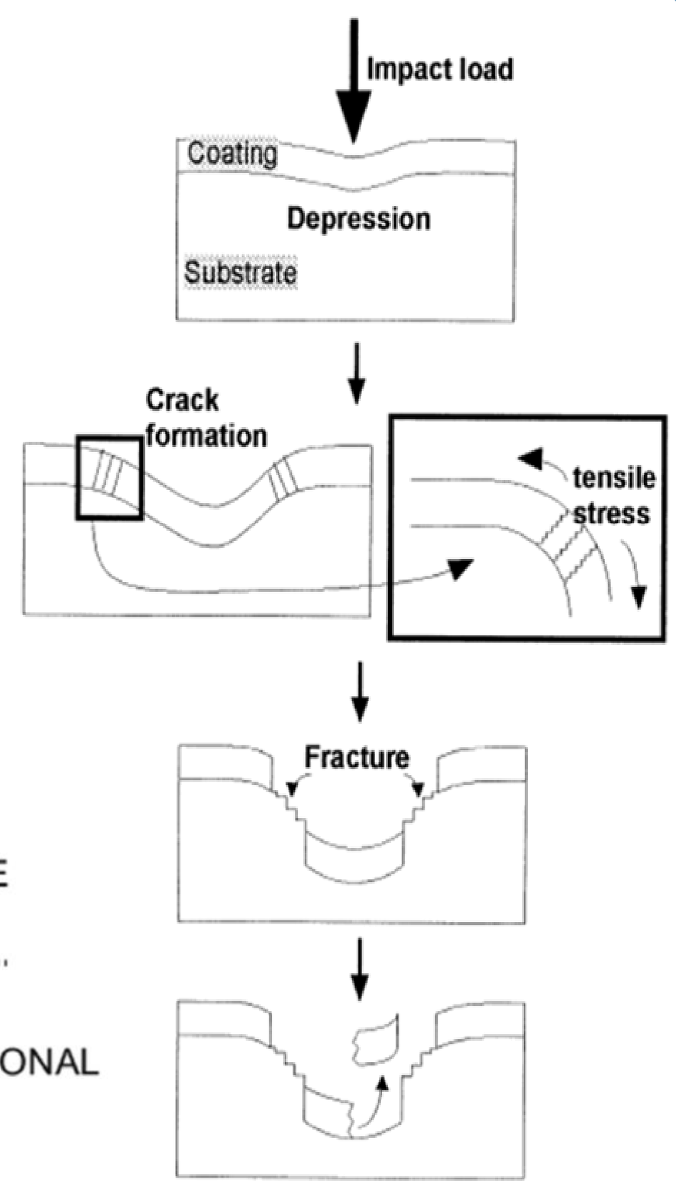
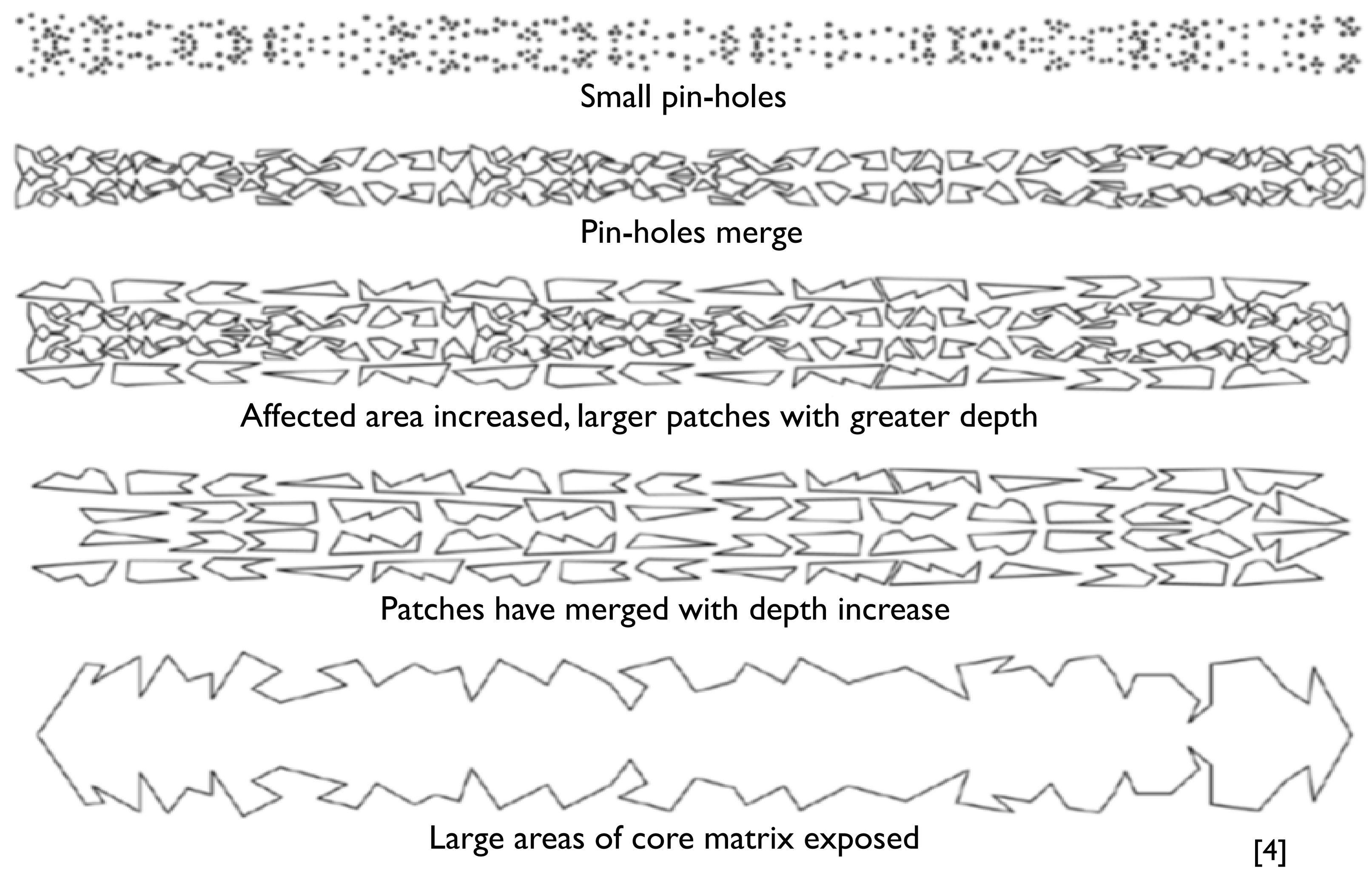


[3]

Each rain droplet impact causes several stresses within the blade, albeit of low magnitude. Firstly, a compressional wave is radiated throughout the coating in a longitudinal direction, some of which is reflected upon contact with the substrate. The compressional wave is followed by a shear wave, which acts in a transverse direction. Thirdly, a Rayleigh wave is produced along the coating surface and travels radially from the point of impact.

Erosion Stages

A study by Vestas [4] looking at the patterns in erosion of wind turbine blades at different stages of operational life.



[4]

Five defined stages were identified, with each stage reducing the coefficient of lift and increasing the coefficient of drag of the blade. At stage five the C_L is reduced by approximately 6% and the C_D is increased by approximately 86%

Key Physical Factors

Liquid:

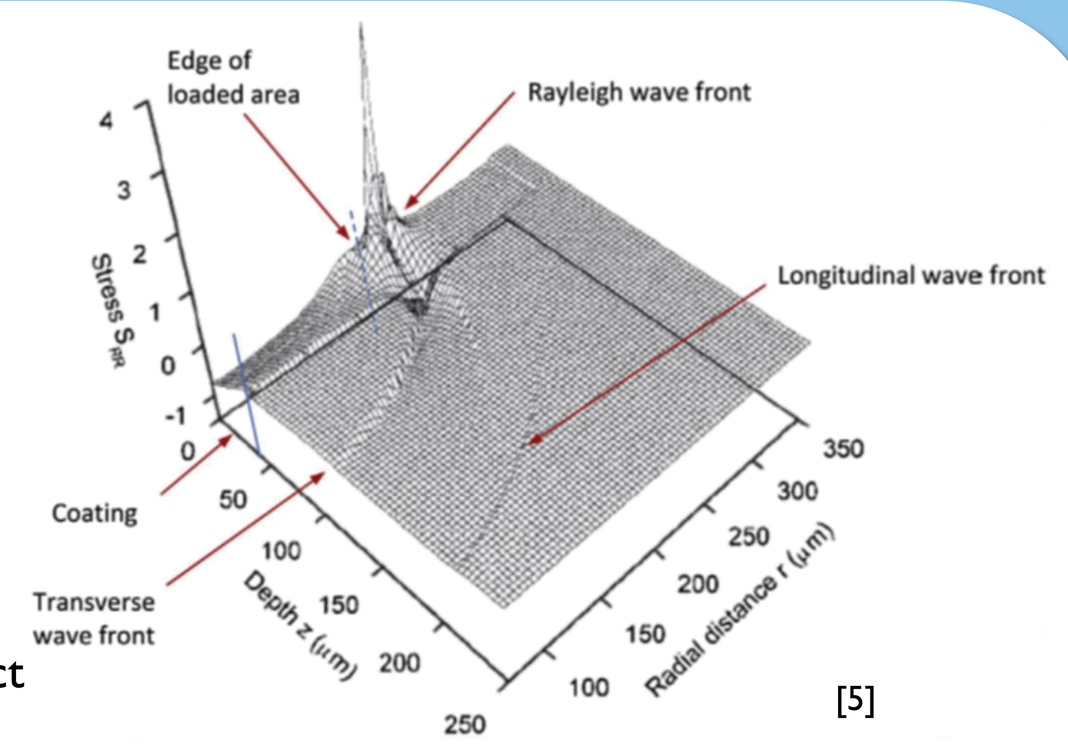
- Impact Velocity
- Impact Angle
- Droplet Size

Surface:

- Hardness/Elasticity
- Blade Velocity

Brittle Surface: good impact resistance at low droplet impact angles

Ductile Surface: good impact resistance at high droplet impact angles



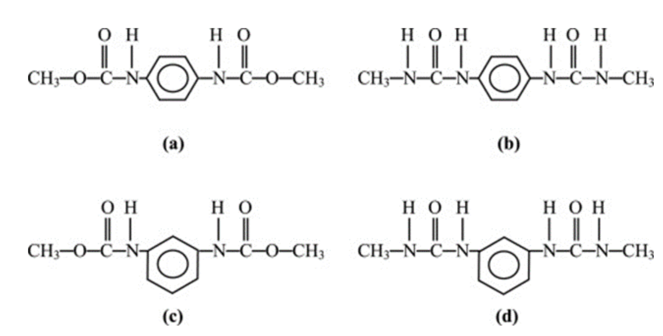
[5]

Magnitude of stresses vary depending on the key factors. A higher impact velocity or droplet size will increase the magnitude of the stresses.

What's next?

- Investigate the chemical factors of erosion
- Investigate forces of bonds (bond energy) holding polymers and layers together - Intermolecular (Hydrogen bonding, Van der Waals forces) & Chemical (Covalent, Ionic)
- Relate droplet impact stresses to bonding forces of material
- Investigate polymers and polymer composites to determine desired properties
- Investigate composite polymer coatings where chain extenders are employed between repeating units to boost the desired coating properties.

Chemical structures of model urethane and urea compounds. (a) PPDI-urethane, (b) PPDI-urea, (c) MPDI-urethane and (d) MPDI-urea.



[6]

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