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Nanotechnology for upgrading erosion protective coatings

Jorge Rituerto, Sergio Armada, Shawn Wilson, Astrid Bjørgum,
SINTEF Materials and Chemistry

Emil André Valaker,
NTNU

Thia Simonsen and
Christina Tønset,
HIST

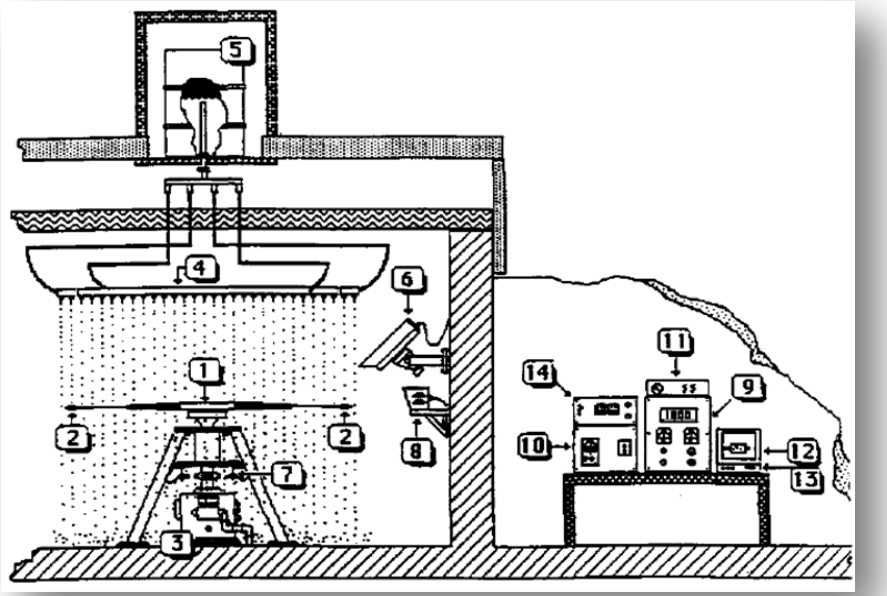
Introduction

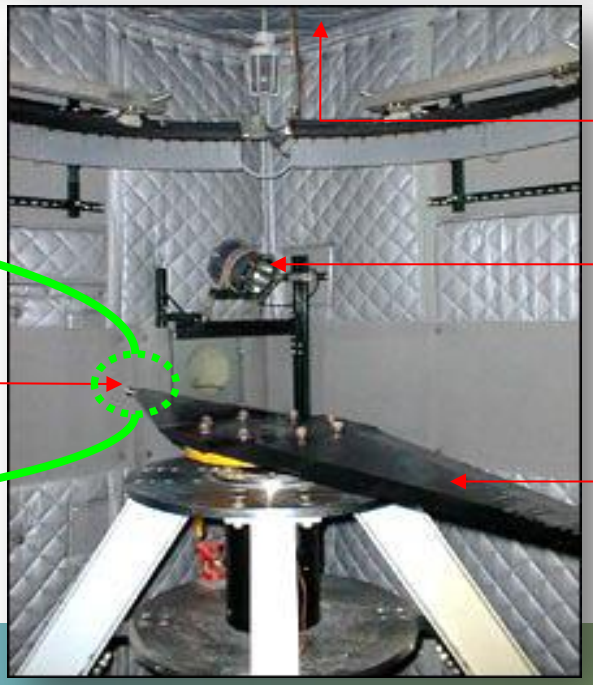
- Water droplets impact high speed rotating blades causing erosion of the leading edge
- Erosion increases blade roughness resulting in decreased turbine efficiency
- New coatings with improved erosion resistance are needed - but
  - How can they be tested at lab scale?
  - Is there any relationship between the lab tests and reality?

Classic Test Facility:

Dayton's Research Institute

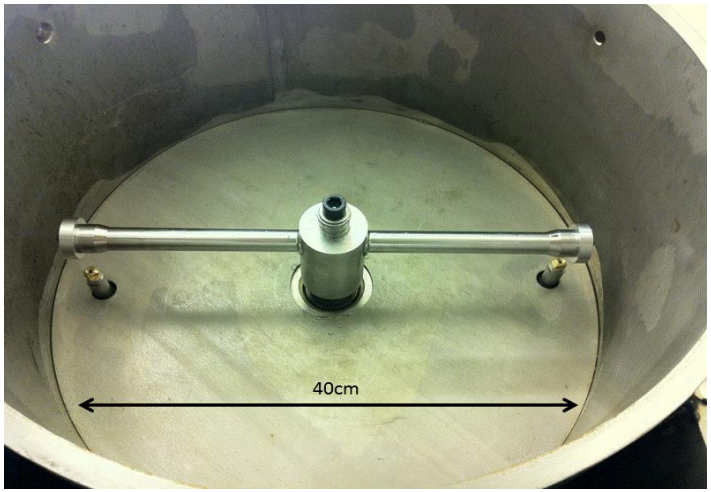
1. DOUBLE-ARM BLADE
2. MATED TEST SPECIMENS
3. VERTICAL DRIVE GEARBOX AND SHAFT
4. CURVED-MANIFOLD QUADRANT
5. WATER STORAGE TANK FOR RAIN SIMULATION
6. REMOTE-CONTROLLED CAMERAS
7. MAGNETIC PICKUPS FOR FIRING STROBE LIGHTS
8. HIGH-INTENSITY STROBE LIGHT FOR STOP-MOTION VIEWING
9. VARIABLE SPEED READOUT AND CONTROL
10. STROBE CONTROL
11. REMOTE COLOR CAMERA CONTROLS
12. COLOR MONITORS FOR SPECIMEN VIEWING
13. RAIN SIMULATION CONTROL
14. VCRs FOR VIDEOTAPING TESTS

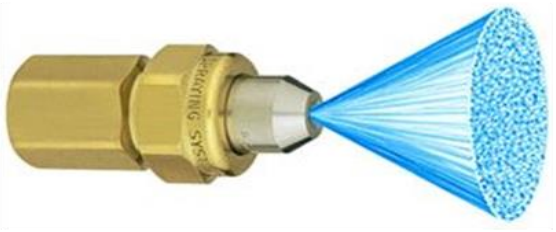




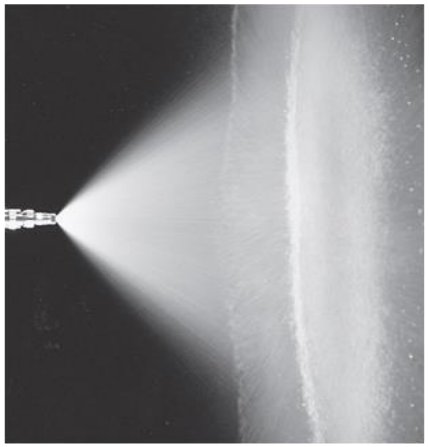
Droplet Erosion Test at SINTEF –

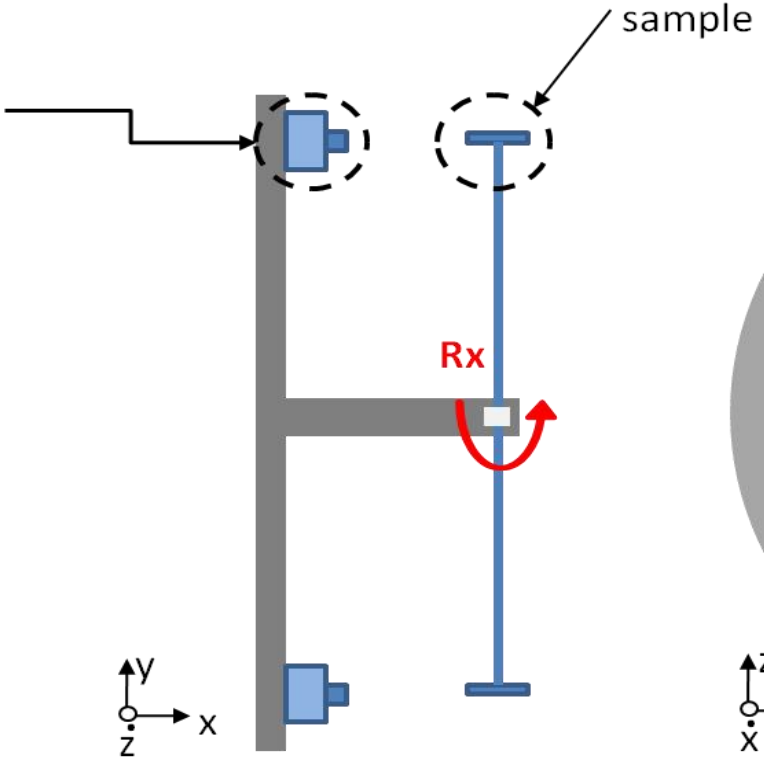
Principles

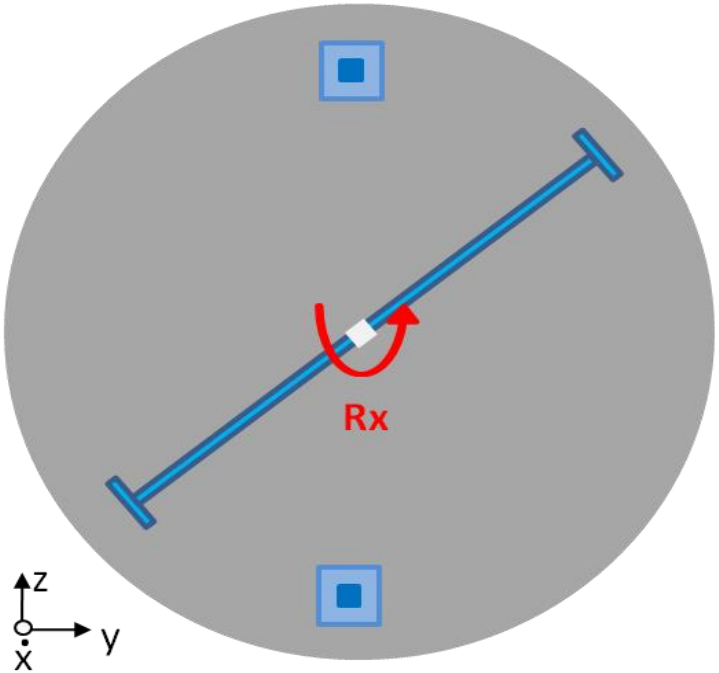




Water Spray

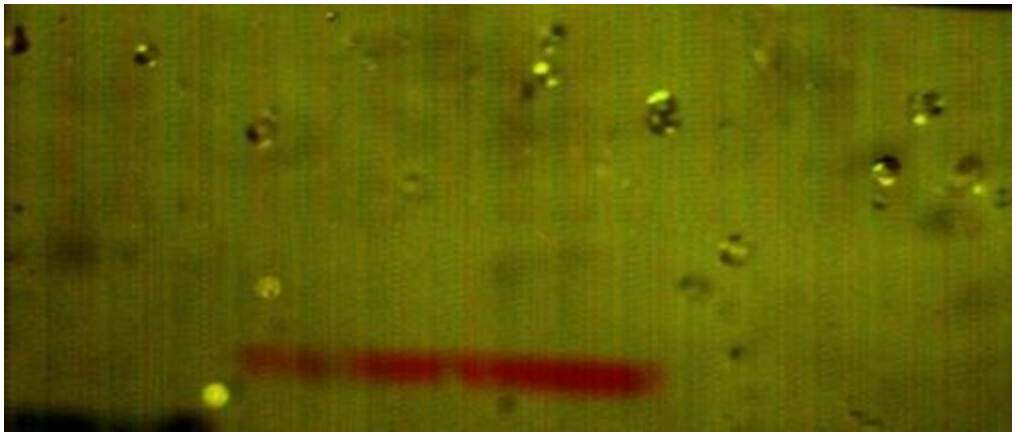






Characterization of water droplets

Phantom Multi Camera (160 000 HZ)



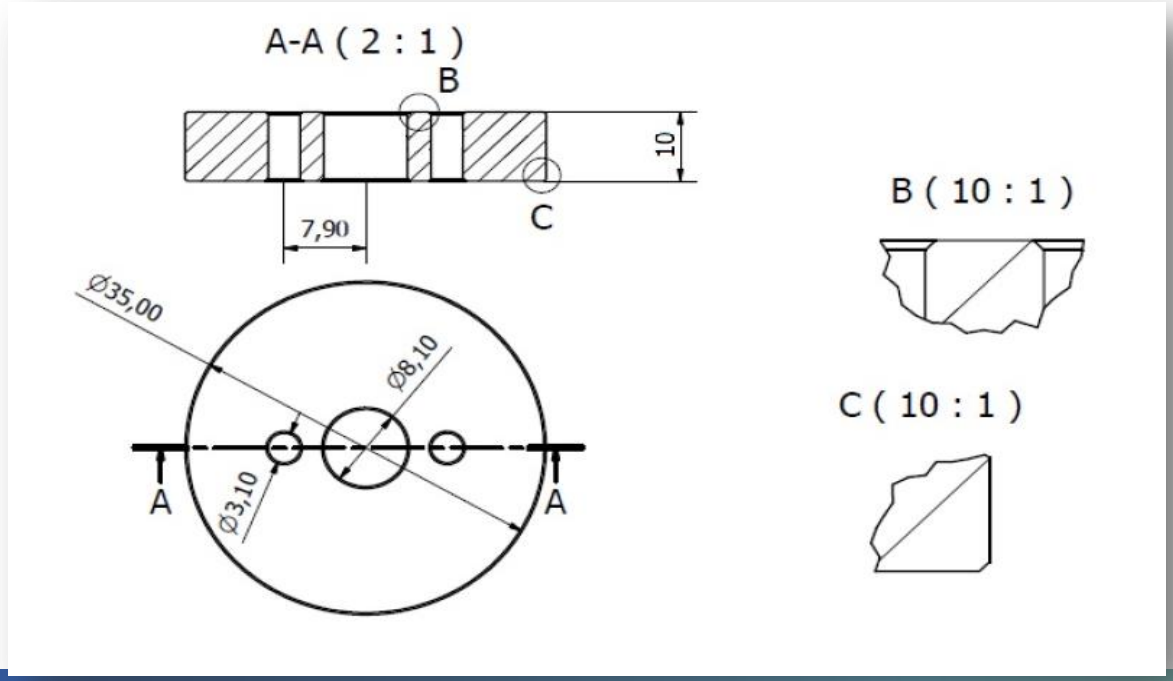
Droplets

- Shape: Round
- Size: ≈ 2 mm
- Distribution: Evenly

Test samples

Substrates tested

- Steel
- Aluminum
- Epoxy



Advantages and disadvantages of the test method

Advantages

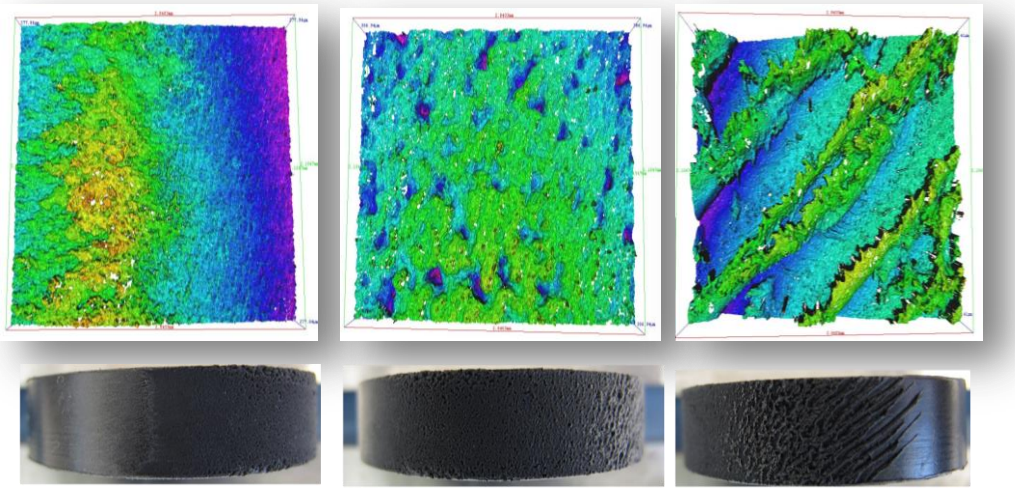
- Simple, compact and robust
- Full control of parameters
- High rotation speeds - Max speed 180 m/s
- Very cost efficient
- Highly adaptable

Disadvantages

- Small samples,
  - Edge-effects can play an important role on test results
- Samples are discs
  - Different shape compared with real turbine blades

Materials and coatings investigated

- *Dummy samples for erosion test facility*
  - HDPE
  - PVC
- *Protective coatings*
  - Commercial wind protection
    - Tape
    - Coatings
  - Polyurethane composite coatings
    - 100% PUR
    - Modified PUR type #1
    - Modified PUR type #2

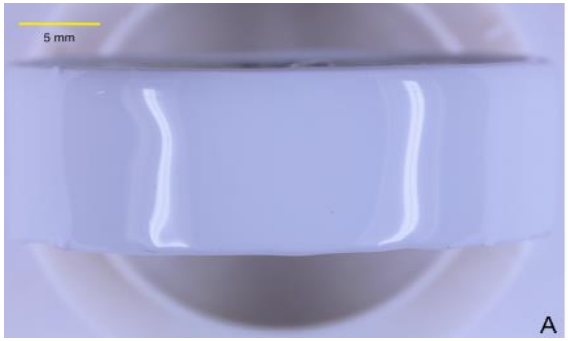


Erosion pattern observed on dummy samples in HDPE after impact testing at 180 m/s for 180 min

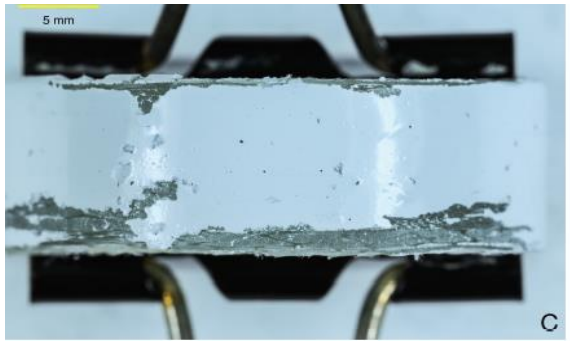
Characterisation of erosion protective coatings –
Substrate: glass fibre reinforced polymer

Erosion protection coating

Before test

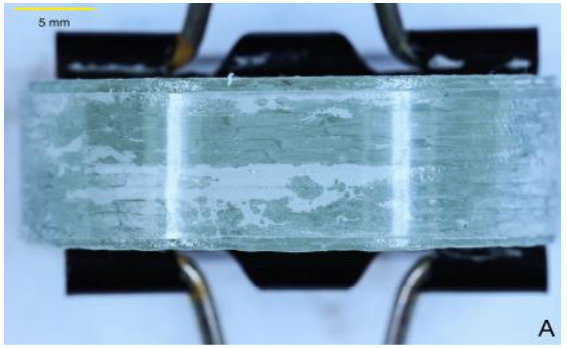


After test
100 m/min for 60 min

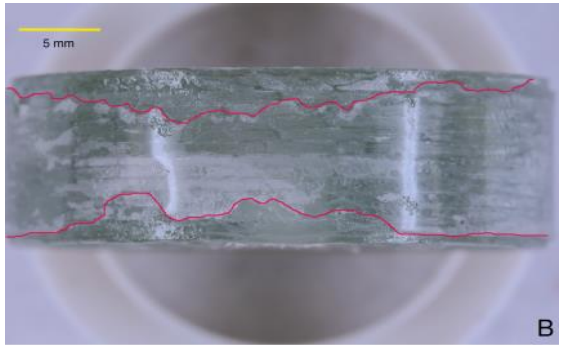


Erosion protection tape

Before test

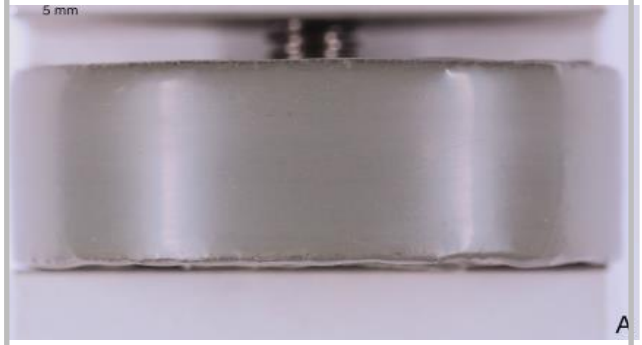


After test
100 m/min for 20 min

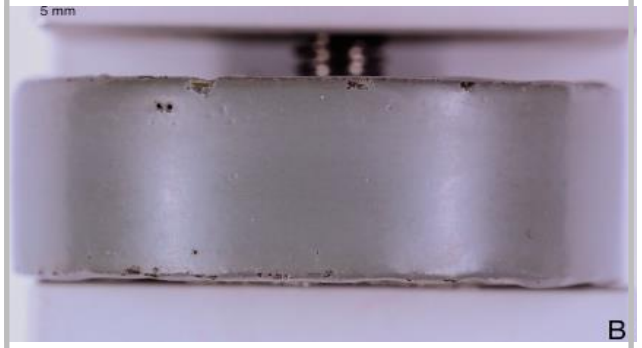


Reinforced polyurethane

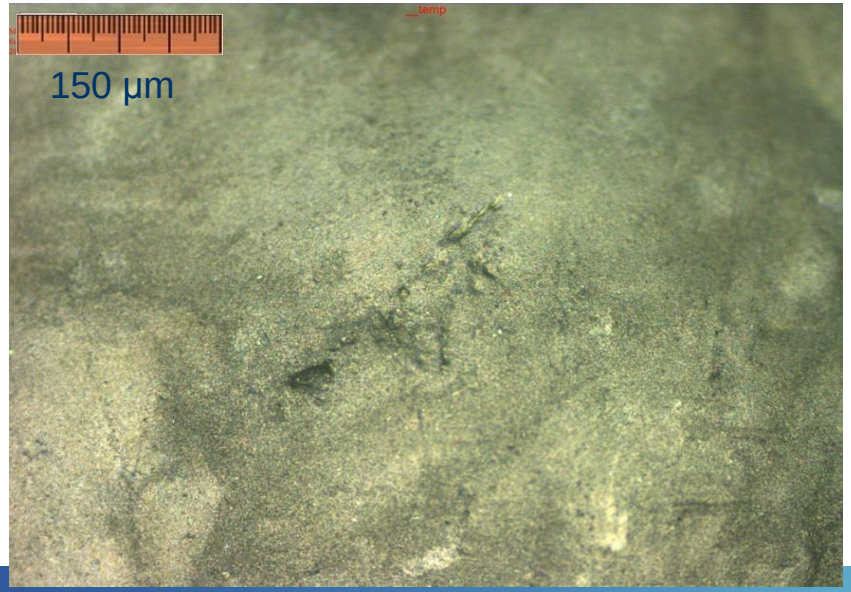
Before test



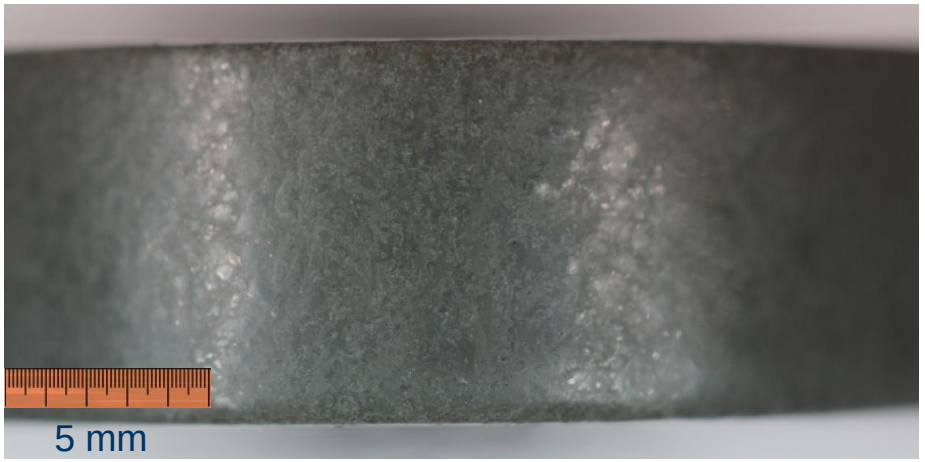
After test
120 m/min for 180 min

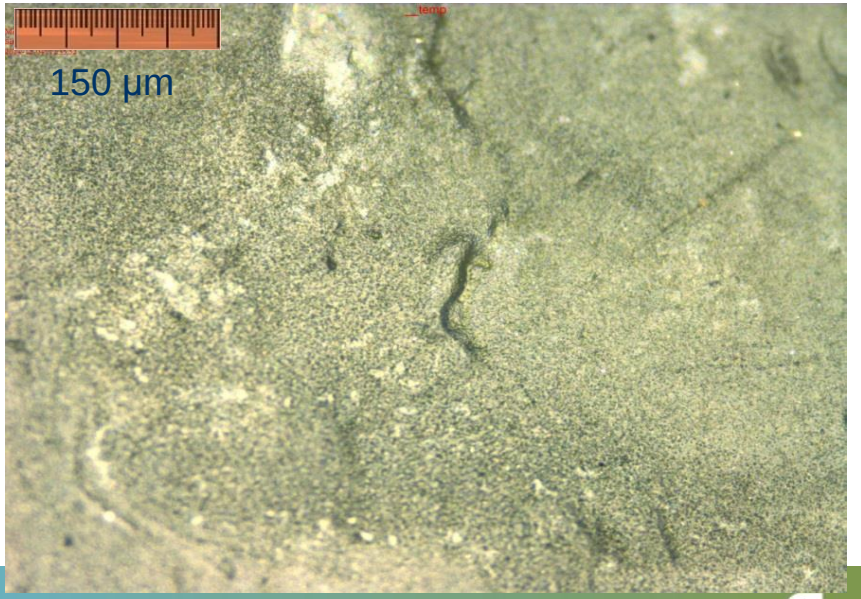


#30, 100 m/s, 40 min
SINTEF modified, type #1

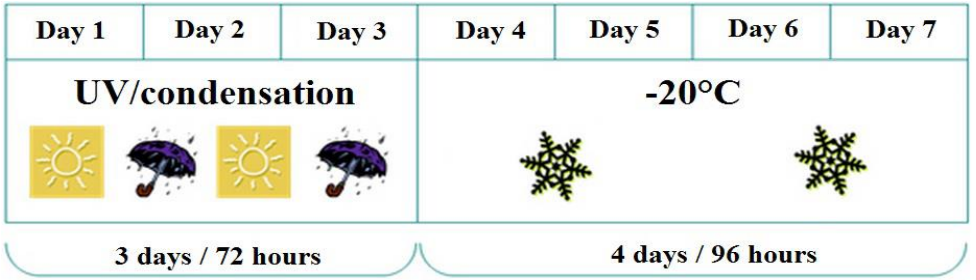


#21, 100 m/s, 120 min
SINTEF modified, type #2





Environmental Factors



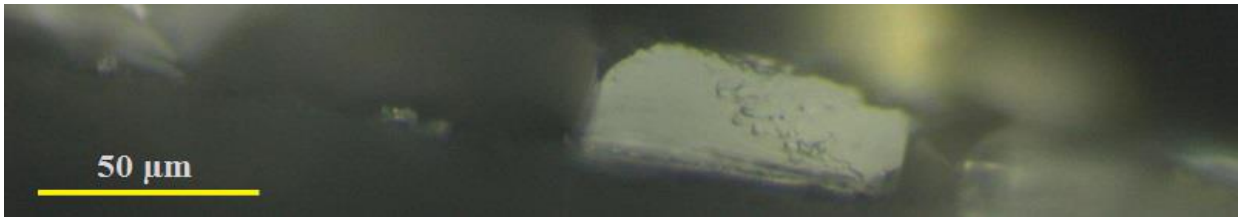
UV - exposure

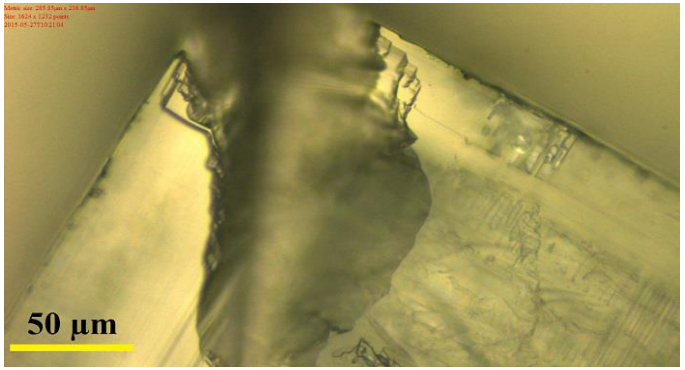
- Reference materials were exposed to cyclic UV / condensation and freezing
- No aging observed after 8 weeks exposure (tested by micro-indentation)

Saline environments

- Samples where submerged in a NaCl solution to highlight the effect of salt settled at the coating surface
- Salt grains and sharp edges may be possible initiation points of cracking and blade erosion

Droplet erosion testing not performed





Summary

- The droplet erosion equipment used is very versatile
  - Different nozzles can be selected to obtain different rain drop shapes and sizes
  - Rotating speed can be controlled from 0 to 180m/s
- Modified coatings produced at SINTEF performed better than commersial coatings available in the project
  - Commercial coatings failed at 100 m/s speed
  - SINTEF coated samples could withstand up to 140 m/s
- All coatings started to fail at samples edge
- Thicker samples and/or a new sample geometry should be tested.
- Effect of environmental conditions may affect lifetime –

  More research is needed…

Thank you for your attention!

Any QUESTIONS???