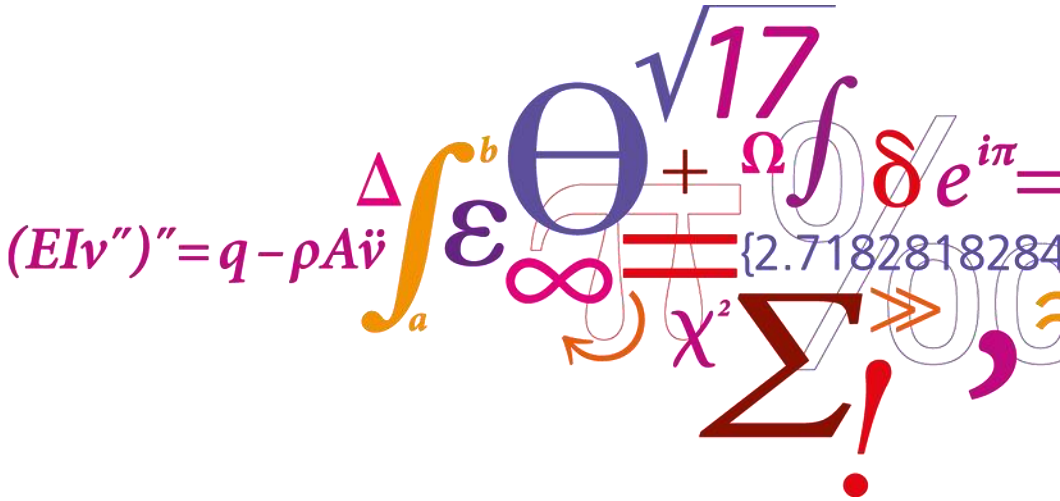
SPIFT

New approaches to coating and surface development, by the use of new testing and evaluation methods.



DTU Mechanical Engineering
Department of Mechanical Engineering

Presenter

- Nicolai Frost-Jensen Johansen
  - Msc. Material and Manufacturing
  - Bsc. Physics and nanotechnology

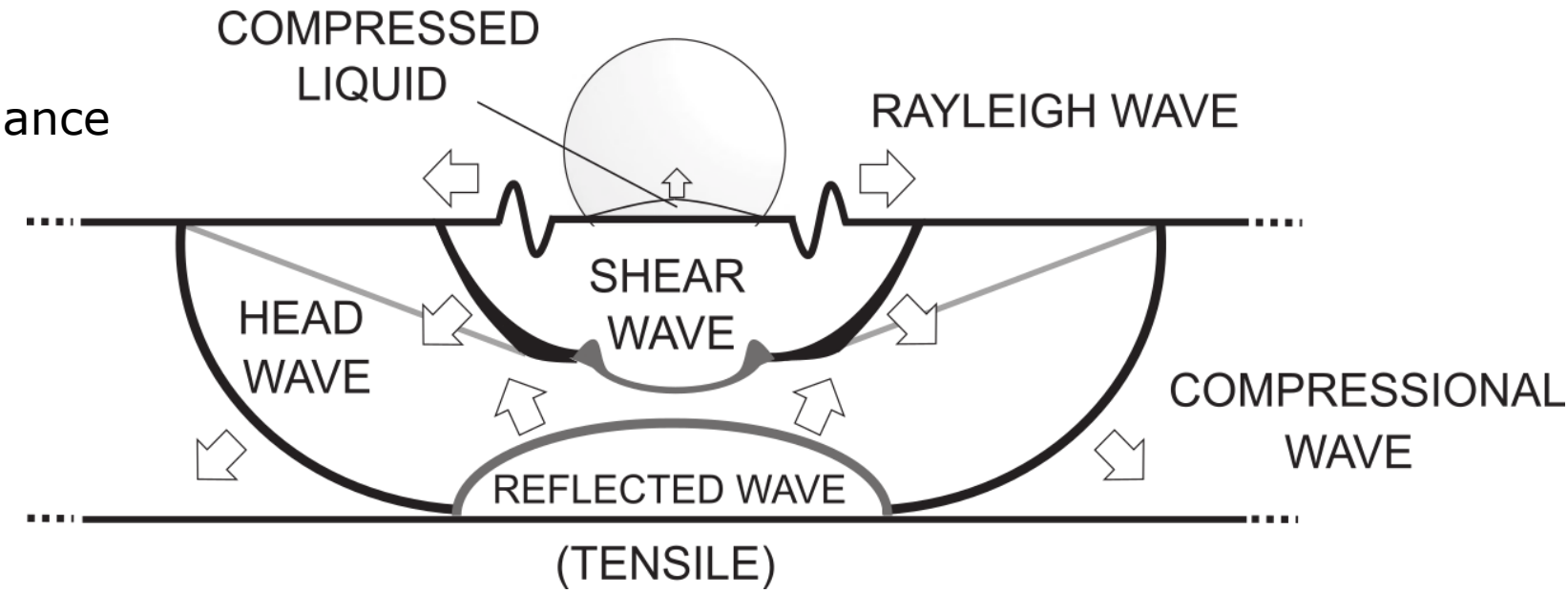
- Ph.D student DTU MEK
  - Societal partnership supported by Innovation Fund Denmark
    - Fast Track
  - Supervisor
    - professor Per Møller DTU MEK
  - Co. supervisor
    - Senior development engineer Jakob Ilsted Bech DTU WIND ENERGY Risø

State of art in rain erosion testing

- Whirling arm tester
  - Strengths
    - Close to reality
    - Proven
    - Recognizable damage
    - Can test small scale system
  - Weaknesses
    - Corse time steps
    - No way to isolate impacts
    - Rain control
    - Difficult insiut monitoring
      - Water mist
      - No on sample sensors
    - Sample price

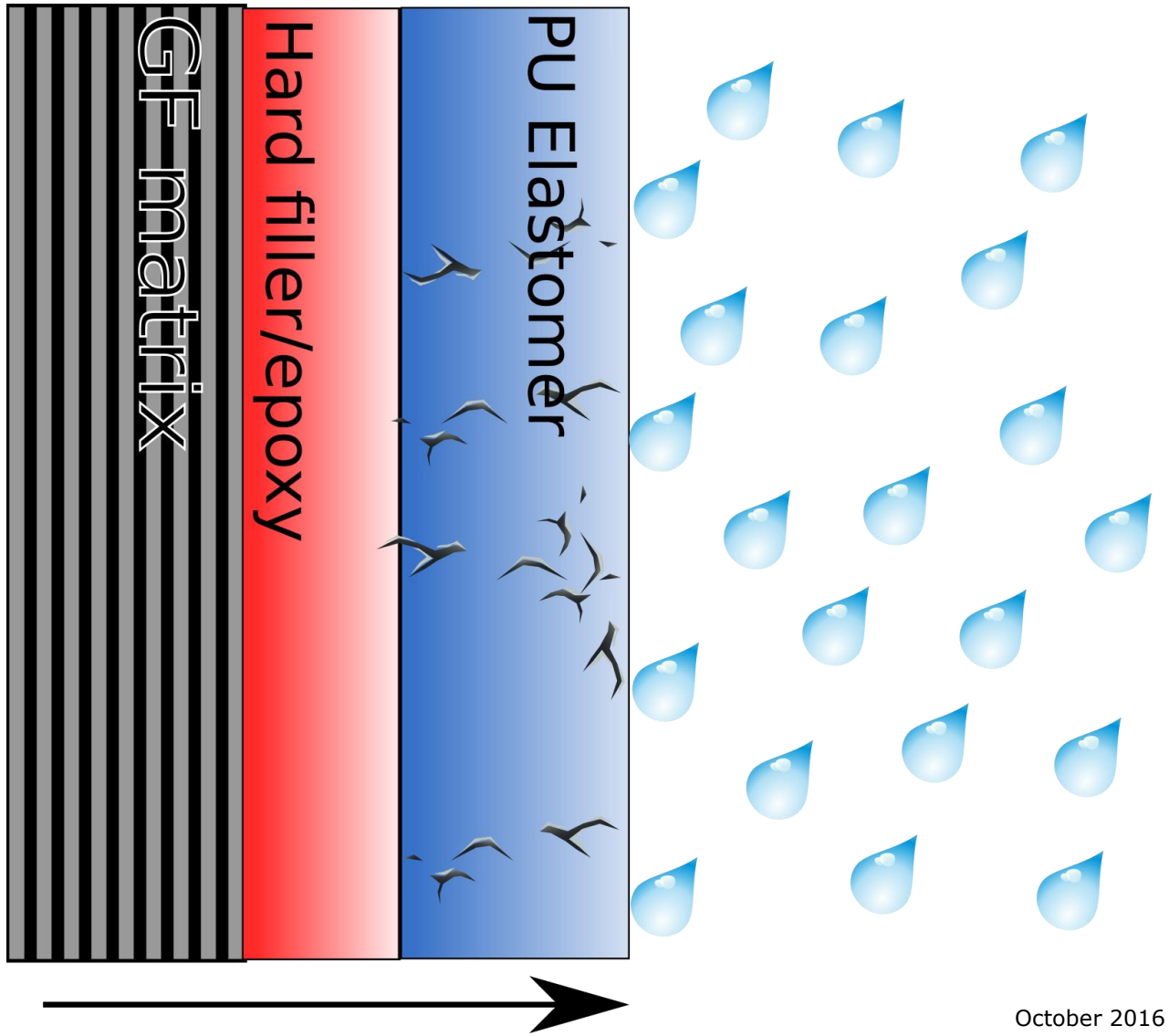
What does a good coating need to do?

- Distribute impact energy
  - Thicker layers
    - Expanding shockwave= lower pressure
- Absorbing energy
  - Viscoelastic effects
- High cycle fatigue resistance
- Good adhesion
- Appropriate impact rate compliance
  - Storage Vs. loss modulus
- Environmental stability
  - Temperature
  - Moisture
  - UV
  - Some chemical resistance



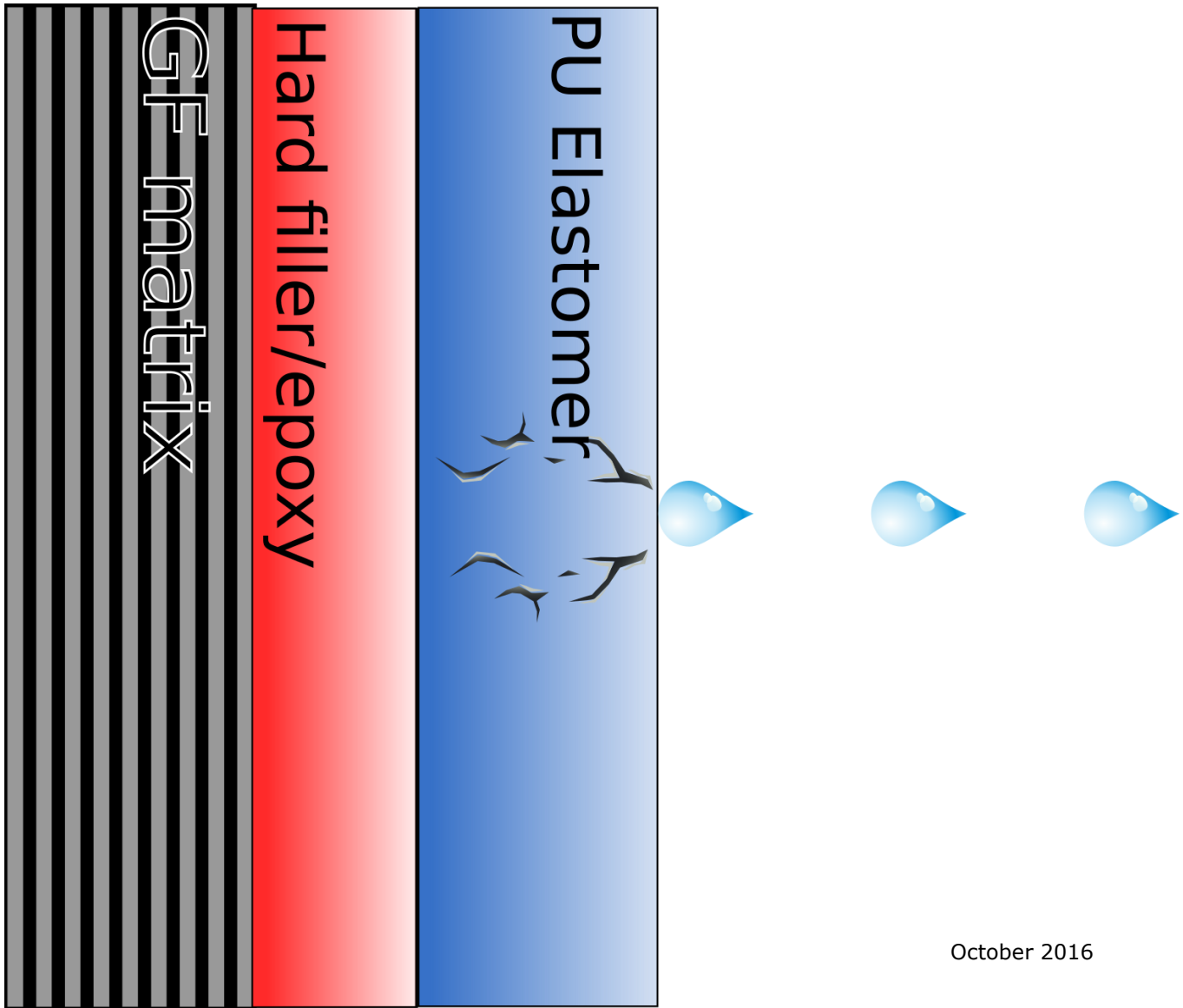
Multipel droplet impact

- Moving target
  - V_ving >> V_drop
- Distributed impacts
- No knowledge about each impact
- Time to damage
-



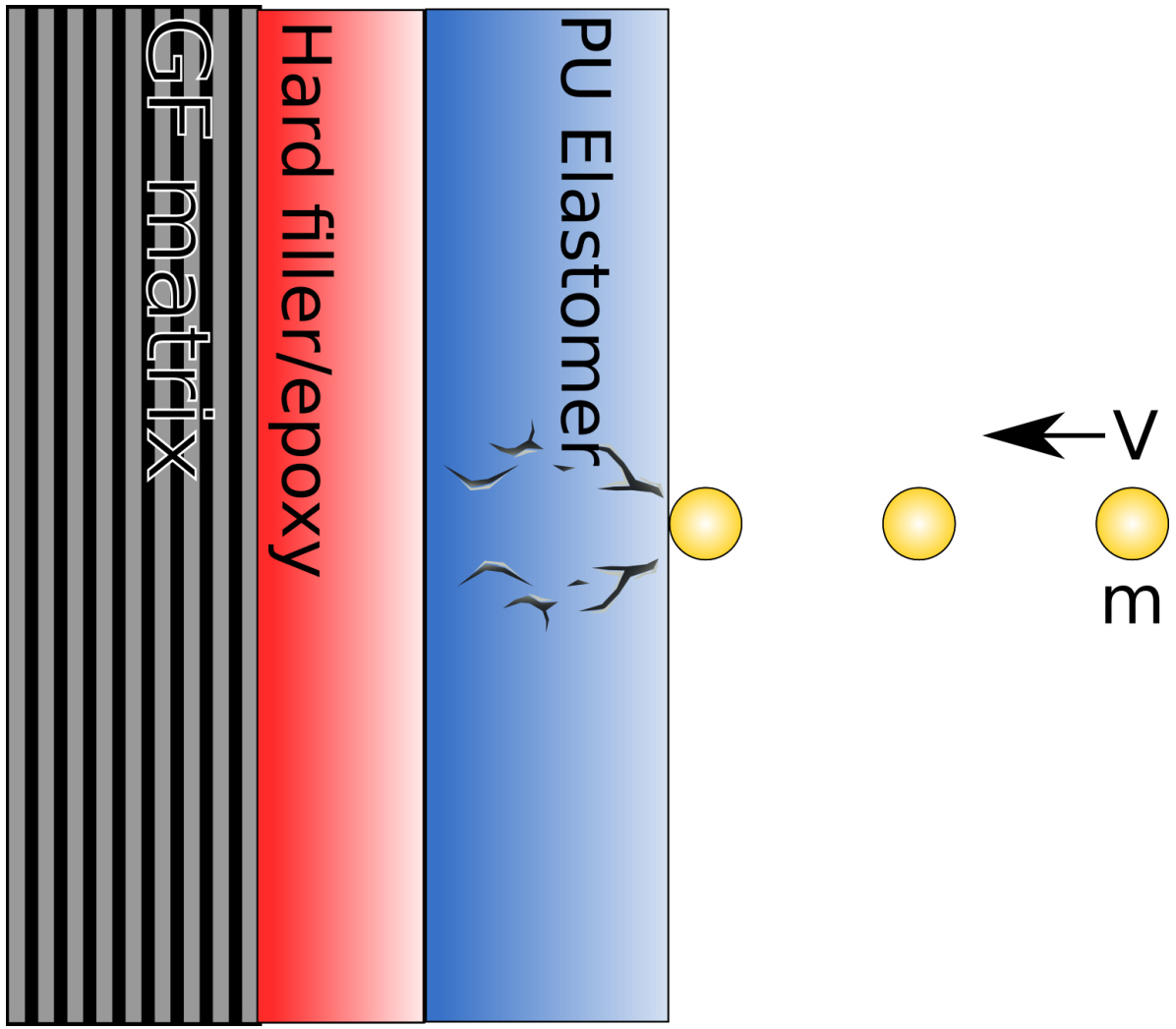
Single drop impact

- Ideal situation
  - Accelerated single droplets
- Difficult to realize
  - Accelerating a droplet
  - Misting
  -



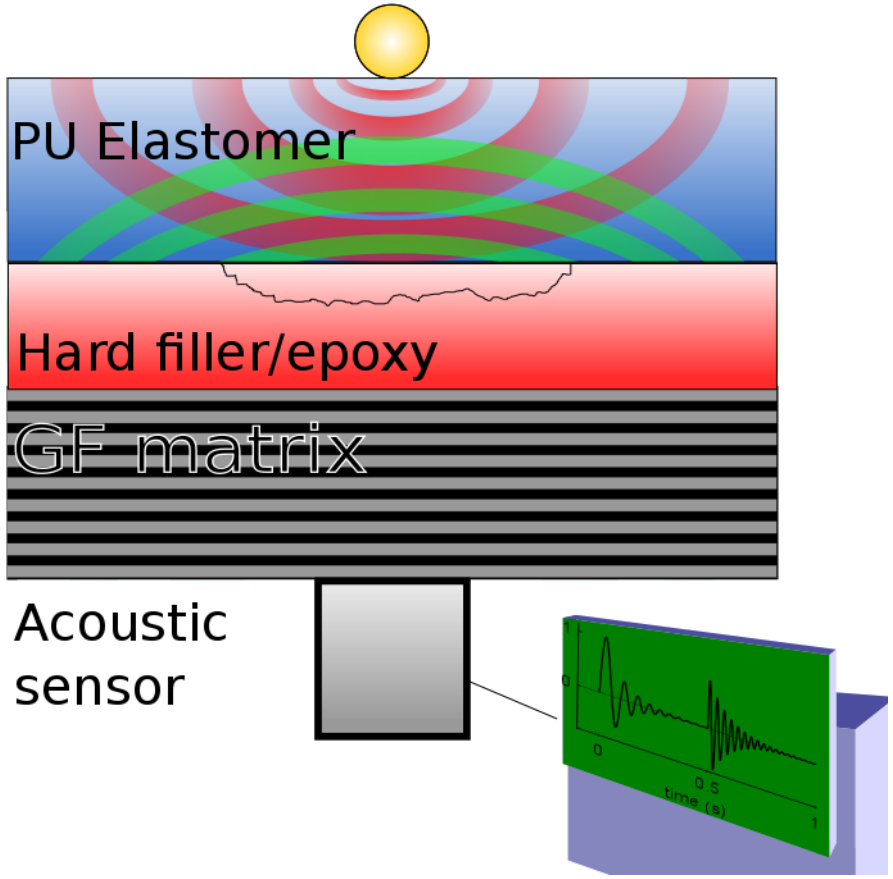
Single Point Impact Fatigue Testing

- Substituting water drops
  - Polymer pellets
- Known impact location
- Impact speeds similar to droplet impacts
- Controllable impact rate



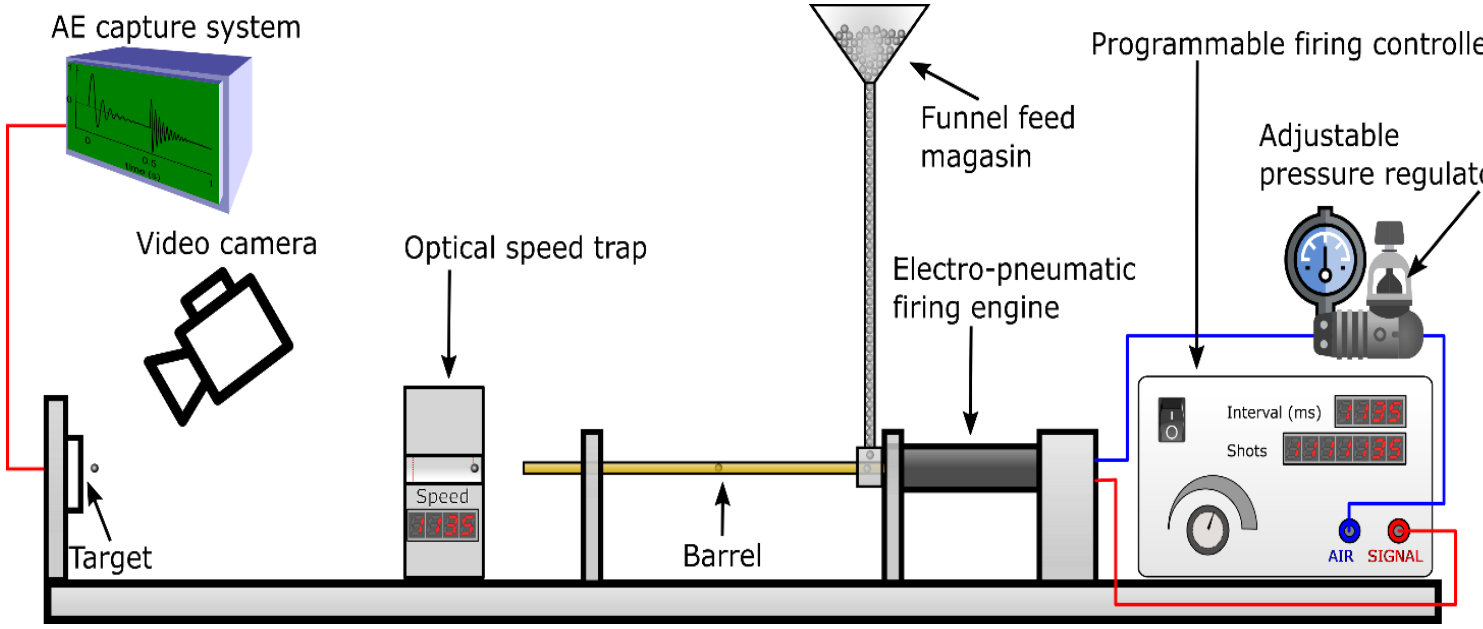
Single point impact fatigue testing(SPIFT)

- Inspired by the work of G. Prayogo
  - Simulating droplet impact with polymer projectile
- Can mimic speed and energy of droplet
  - 100 m/s to 160 m/s
- Accelerated damage testing
  - 5 impacts per second
  - 1-30 min to damage
- Allows for in-situ damage monitoring
  - Visual with camera
  - Acoustic emission
- Small specimen size
  - cheaper
  - faster
  - more evaluation options



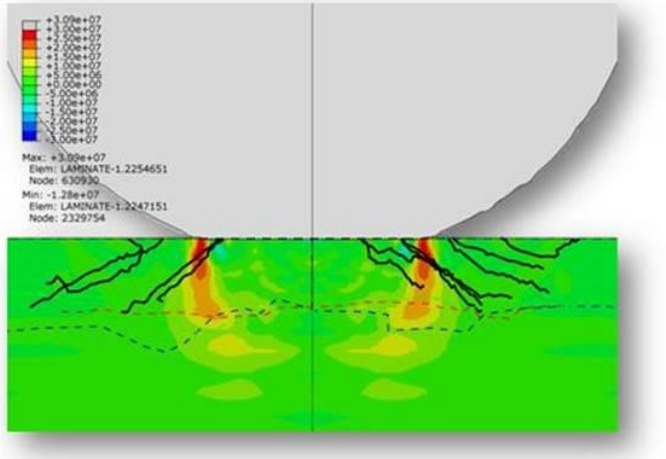
Single point impact fatigue testing

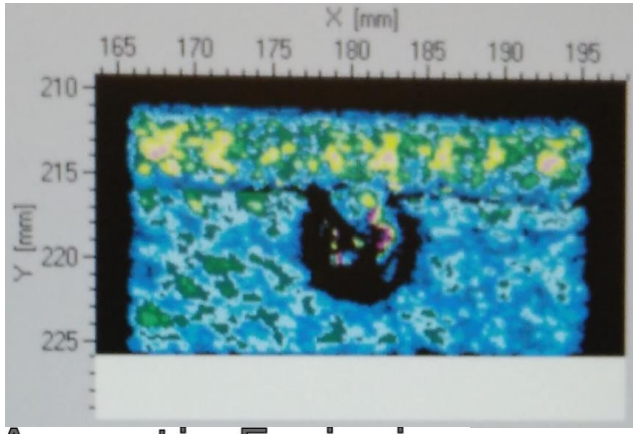
- Inspired by the work of G. Prayogo
  - Simulating droplet impact with polymer projectile
- Can mimic speed and energy of droplet
  - 100 m/s to 160 m/s
- Accelerated damage testing
  - 1-2 impacts per second
  - 1-30 min to damage
- Allows for in-situ damage monitoring
  - Visual with camera
  - Acoustic emission
- Small specimen size
  - cheaper
  - faster
  - more evaluation options

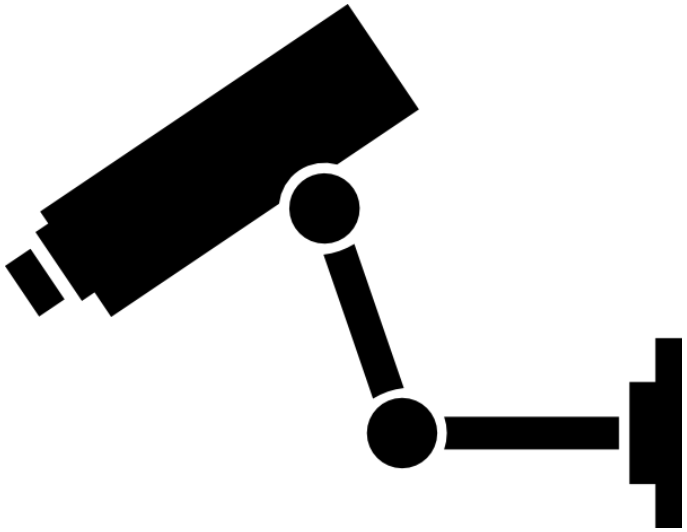


Damage assessment methods

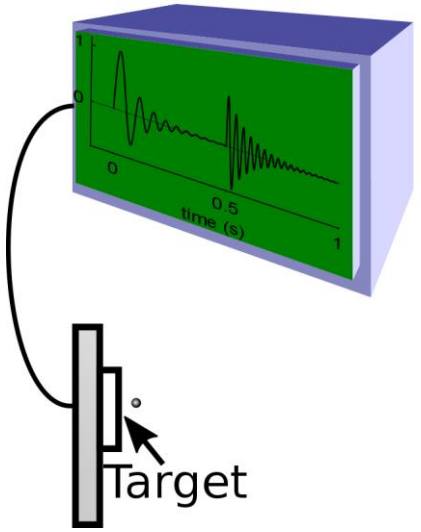
- Insitu methods
  - Camara
  - Acoustic emission
- ex situ methods
  - X-ray tomography
  - Ultrasound scanning
  - Informing FEM Models

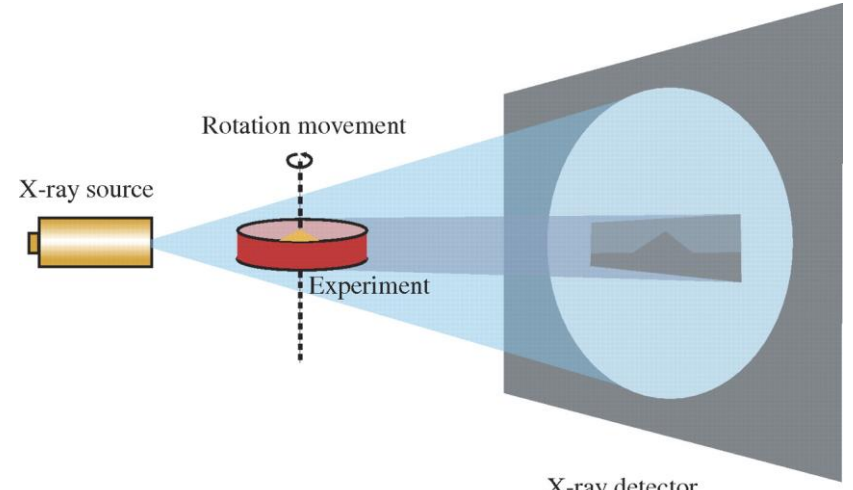




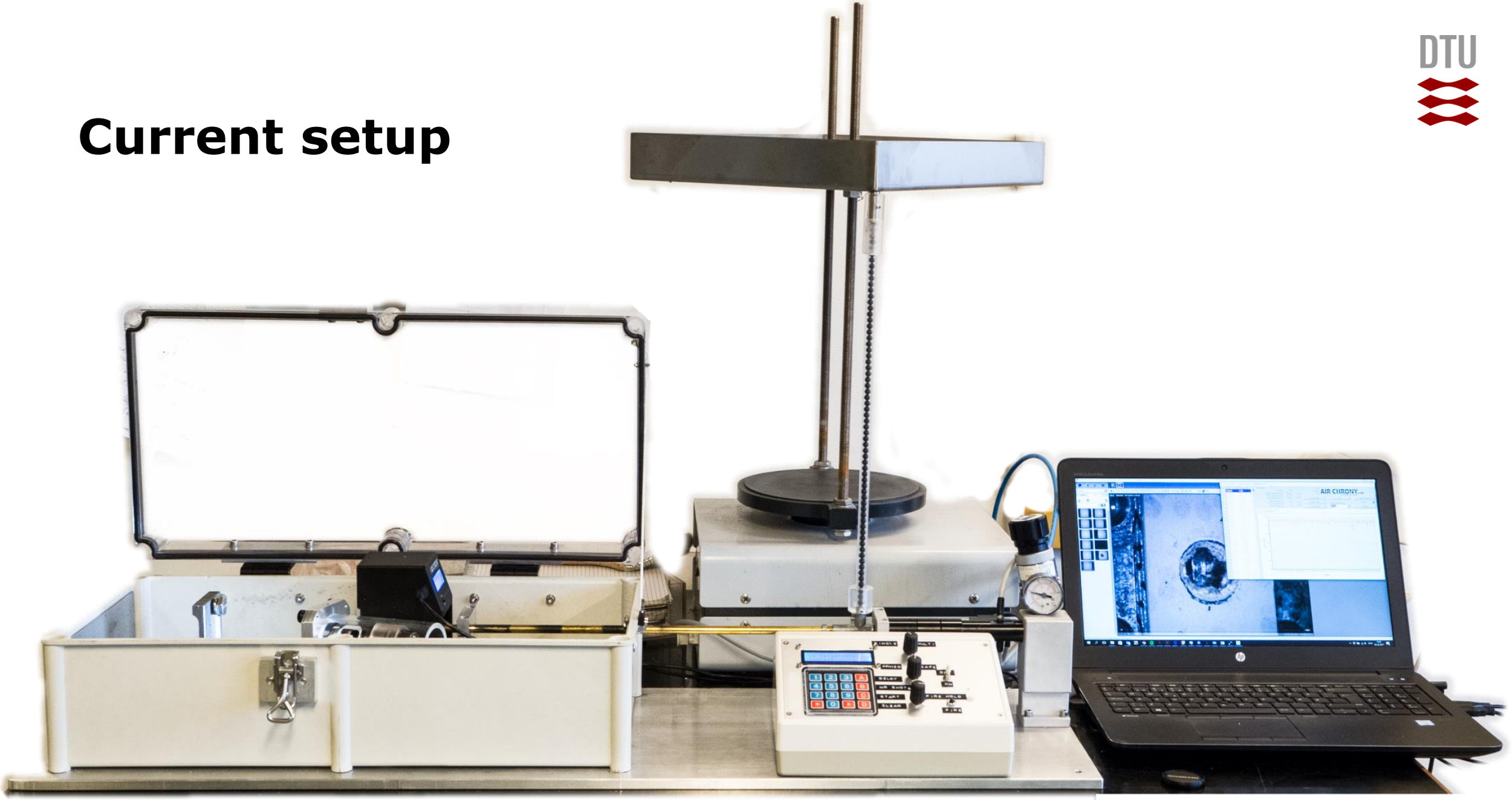


Acoustic Emission

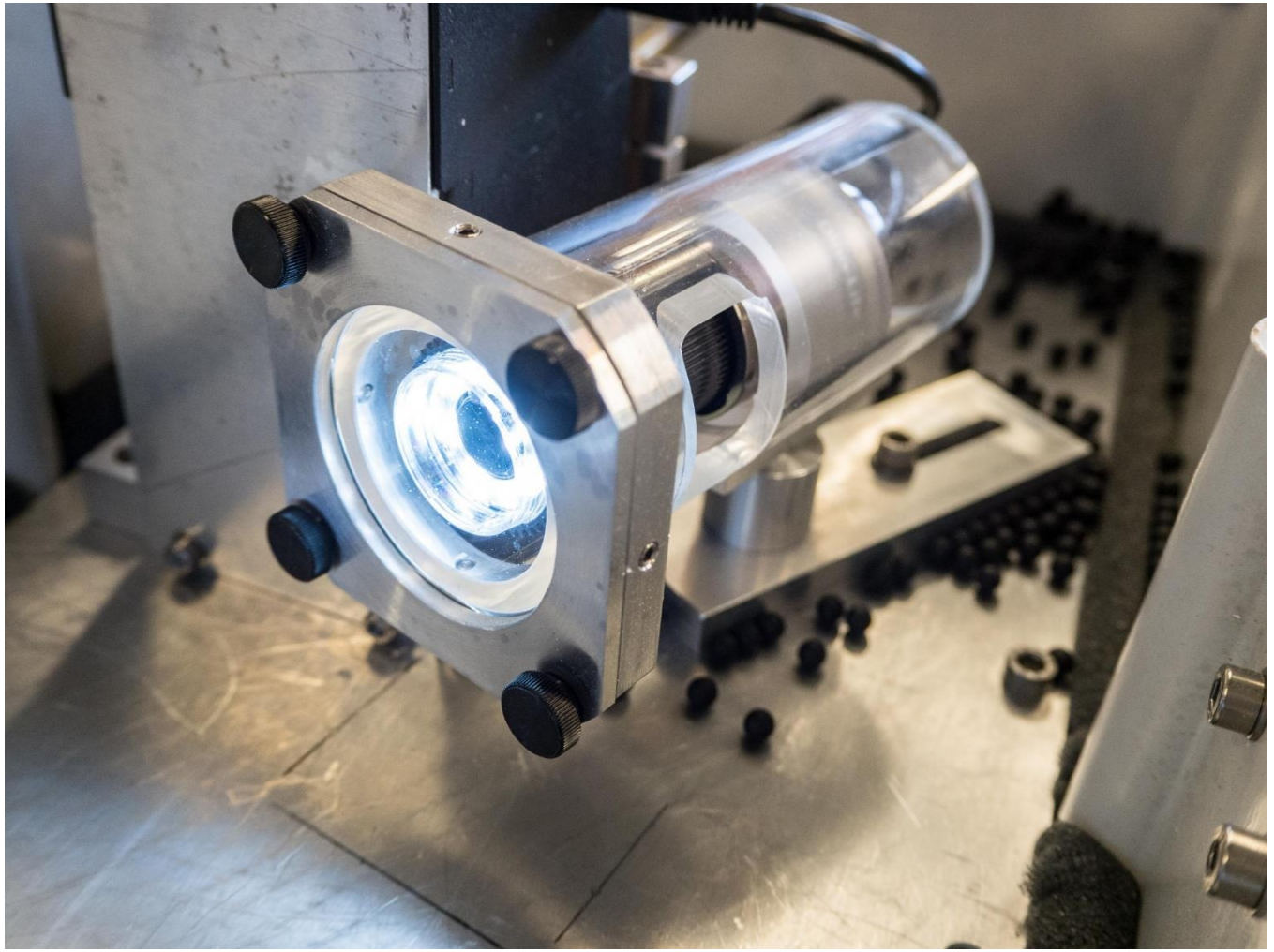




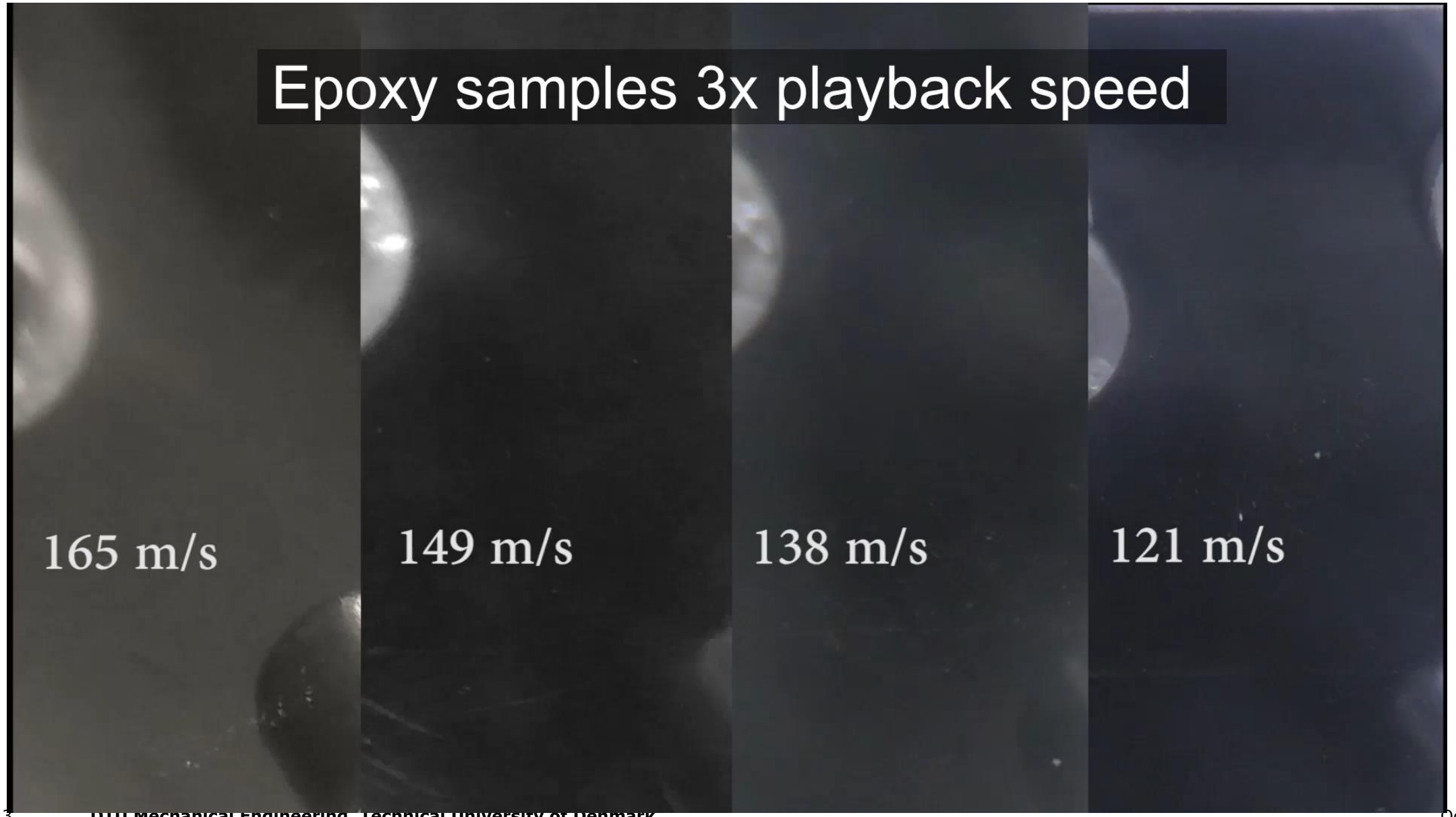
Current setup



Current setup

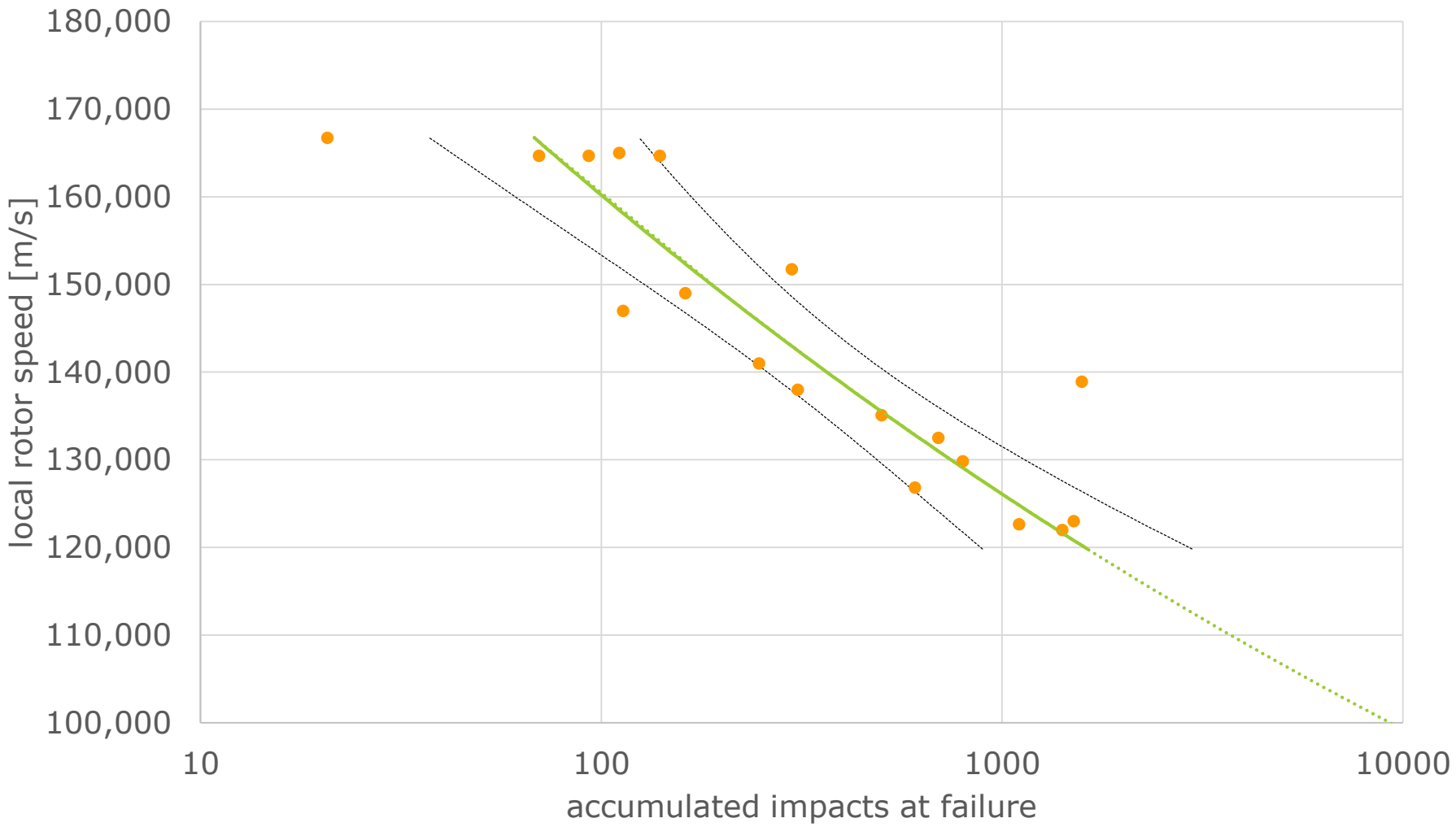


Comparing impact speeds on epoxy coating

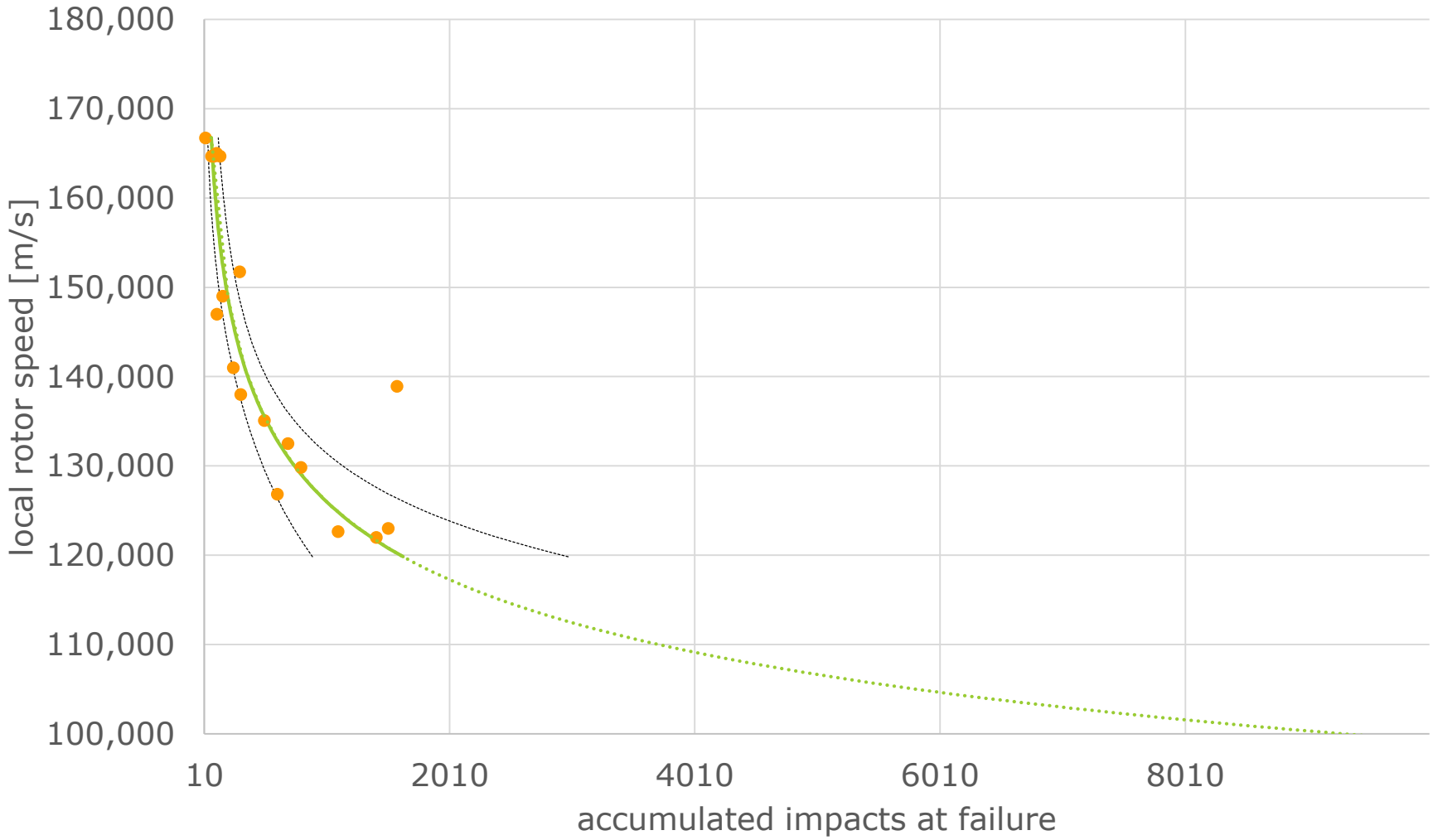


SN curves

- Fitted according to ASTM e739



SN curves

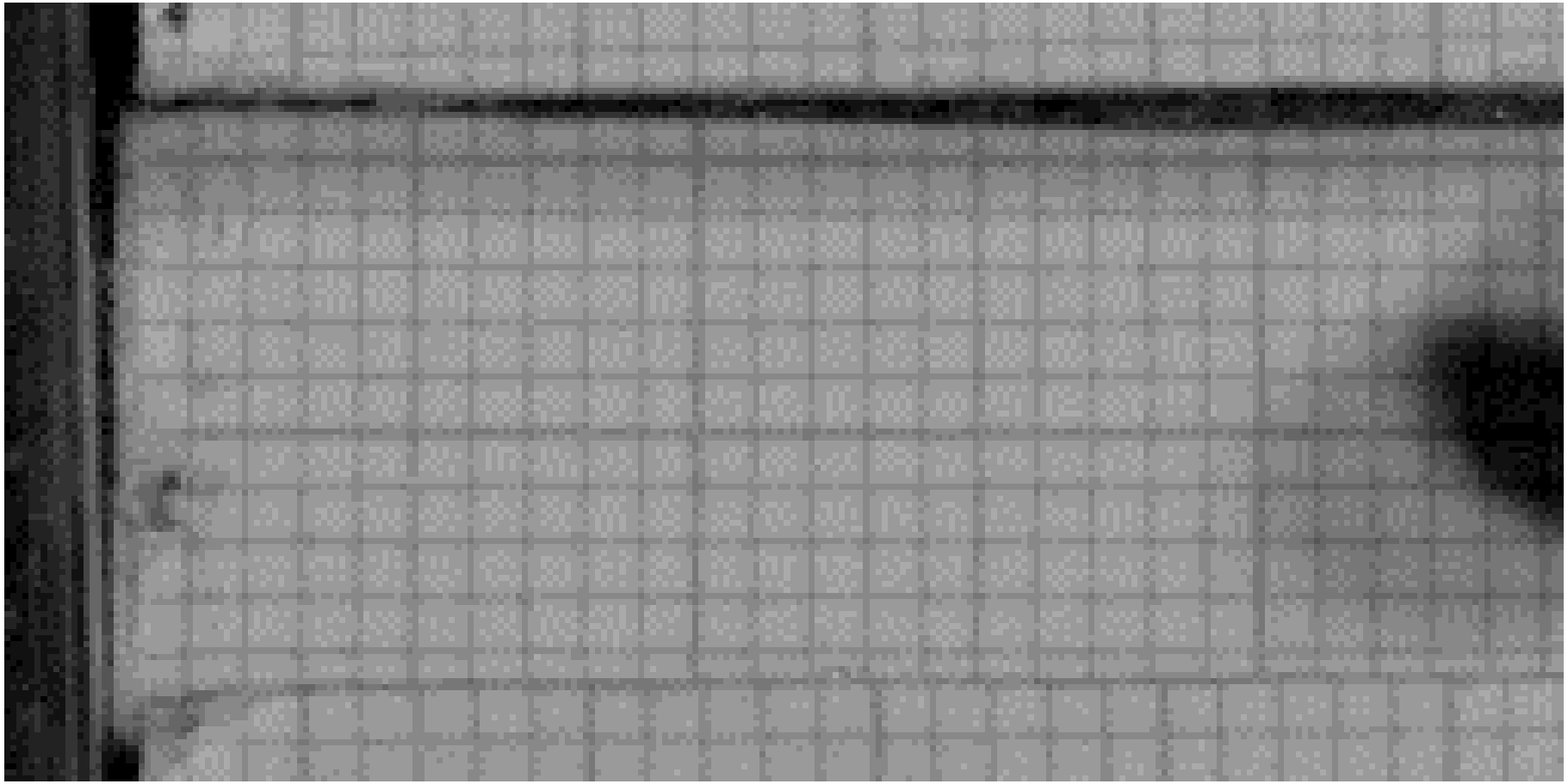

180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
local rotor speed [m/s]
10
2010
4010
6010
8010
accumulated impacts at failure

Accelerated implementation of materials and surface solutions

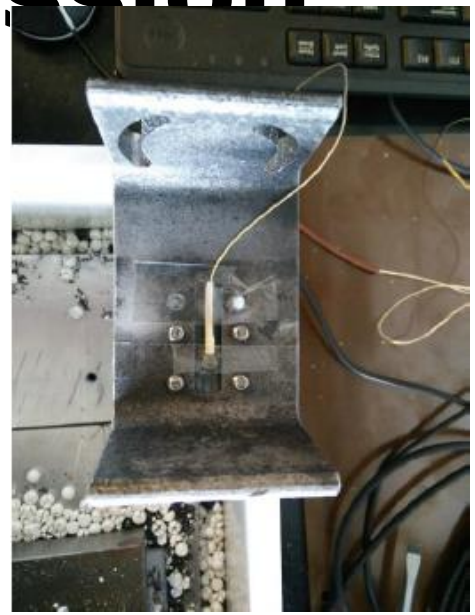
- Do you have material problems and need assistance finding the right experts to help you?
- The Fast Track industrial portal can help you rapidly find the right experts and equipment that can help solve your problem
- An expert panel with representatives from DTU, AAU, DTI, FORCE will evaluate your problem and help you how to proceed.
- You can contact us on www.fast-track.nu or contact project manager Kasper T. Therkildsen: +45 40 12 23 76

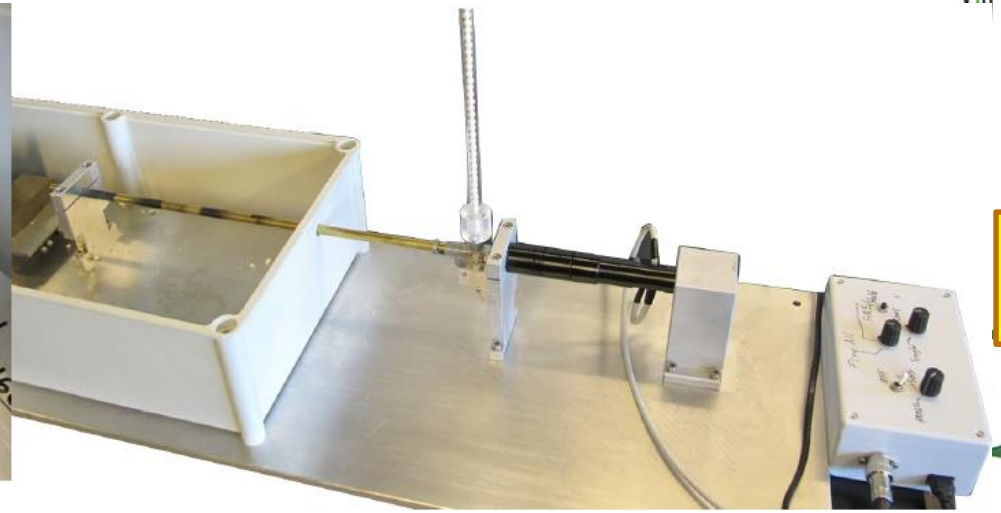
Highspeed imaging

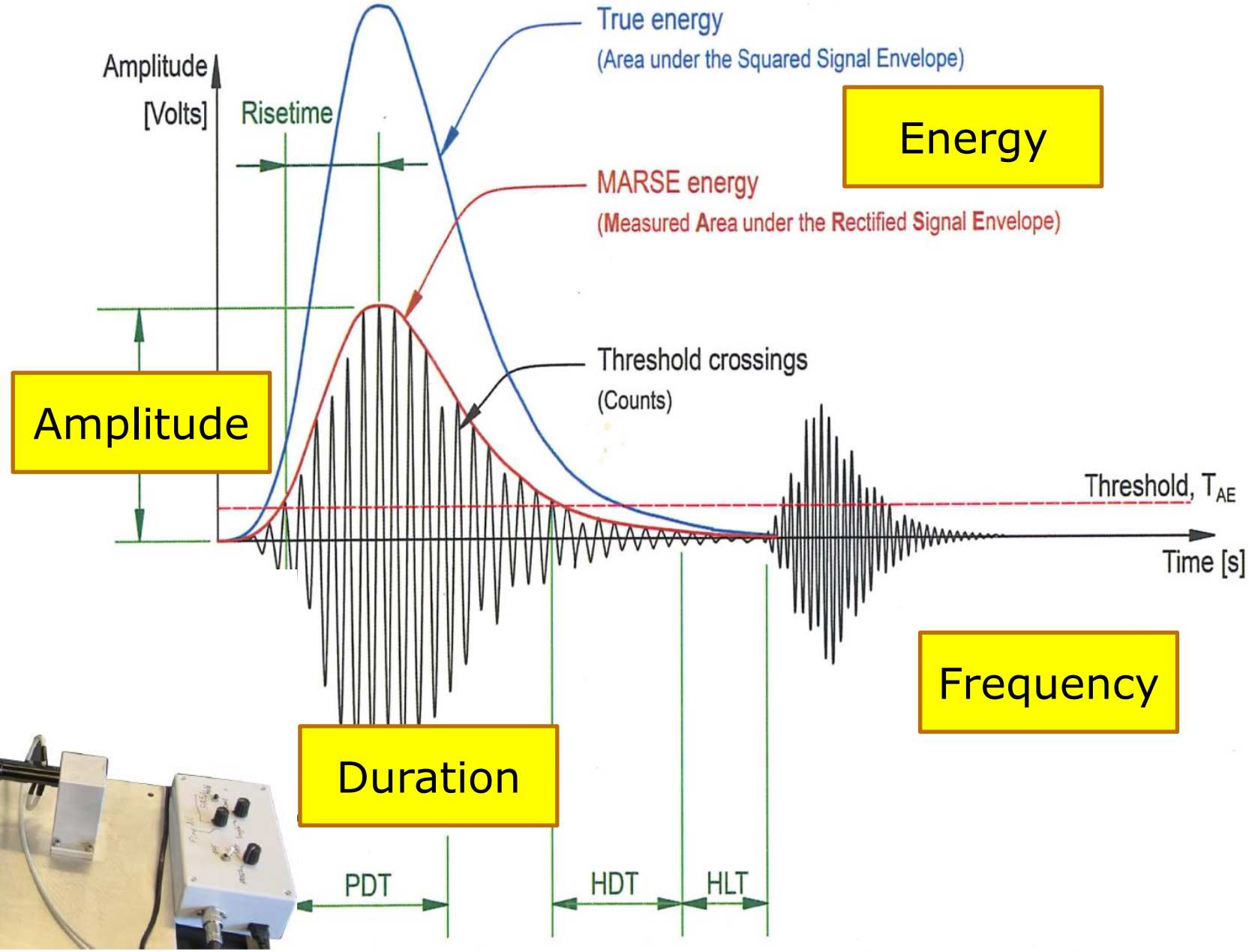
- Highspeed camera
  - Phantom v2512 fast
- Filmed at
  - 355.000 FPS



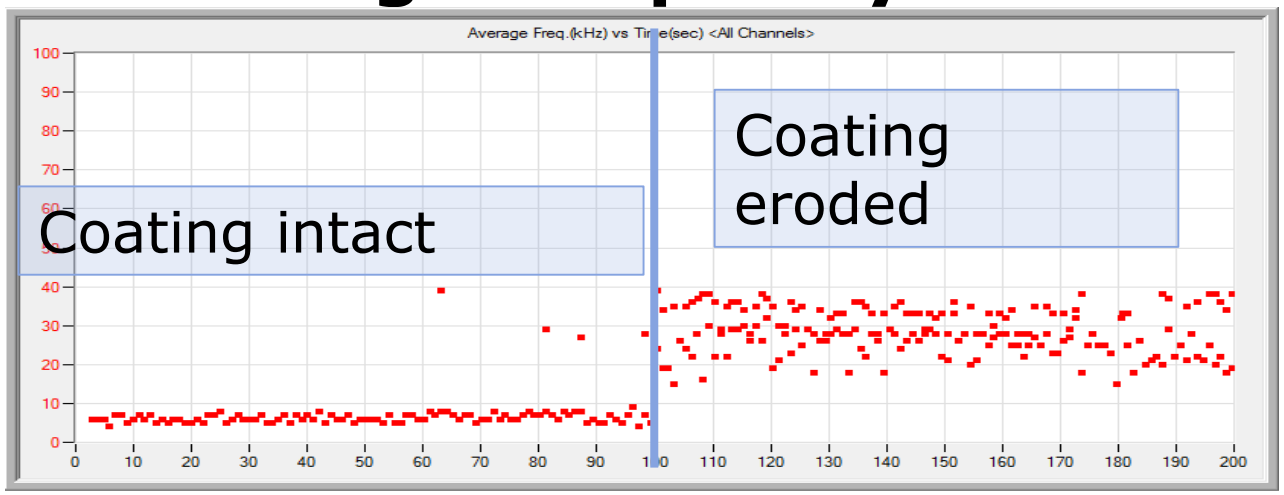
Acoustic emission



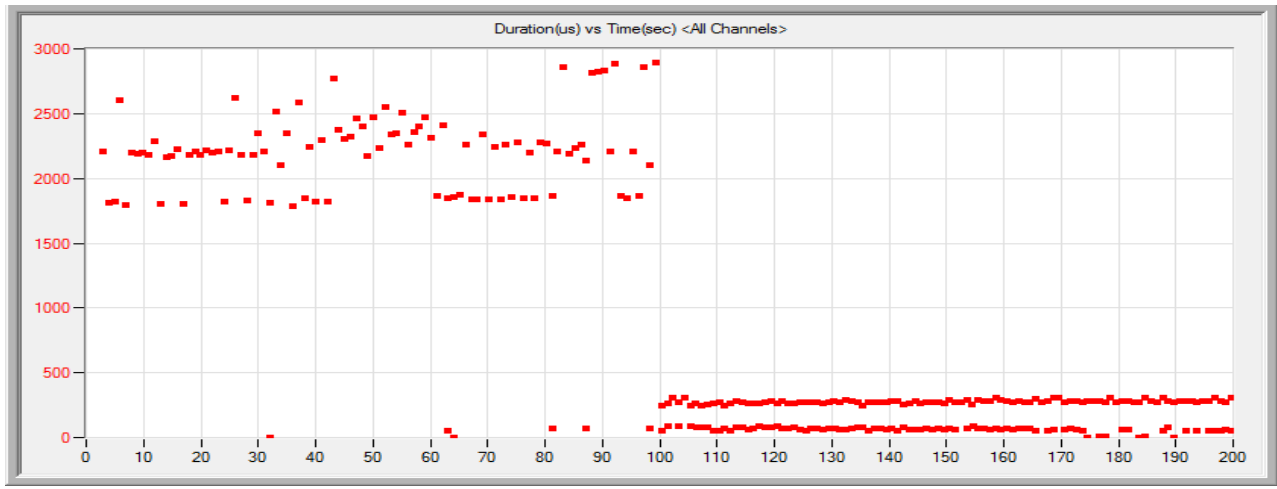




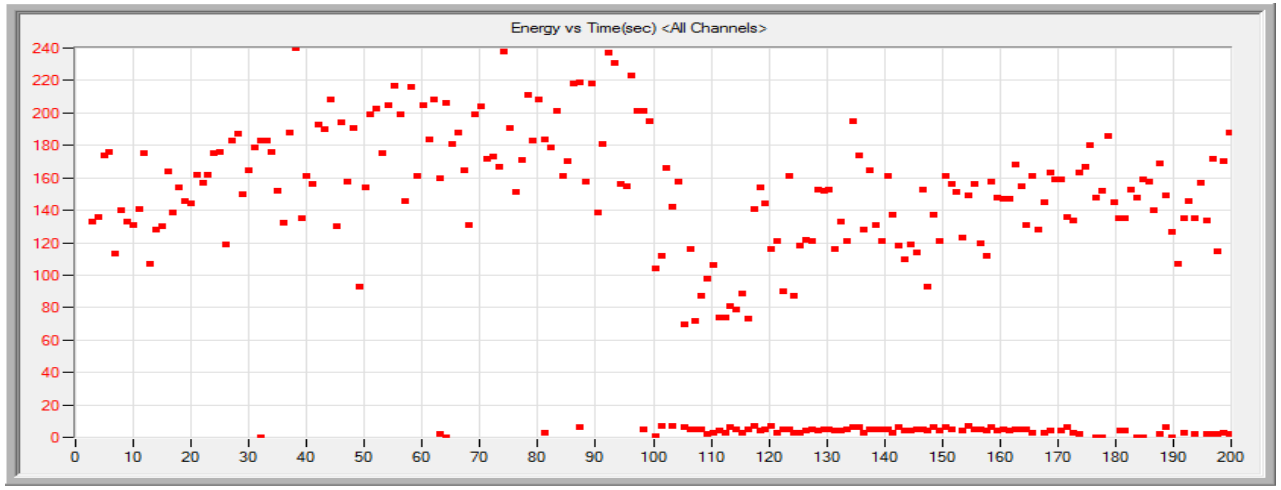
Average Frequency



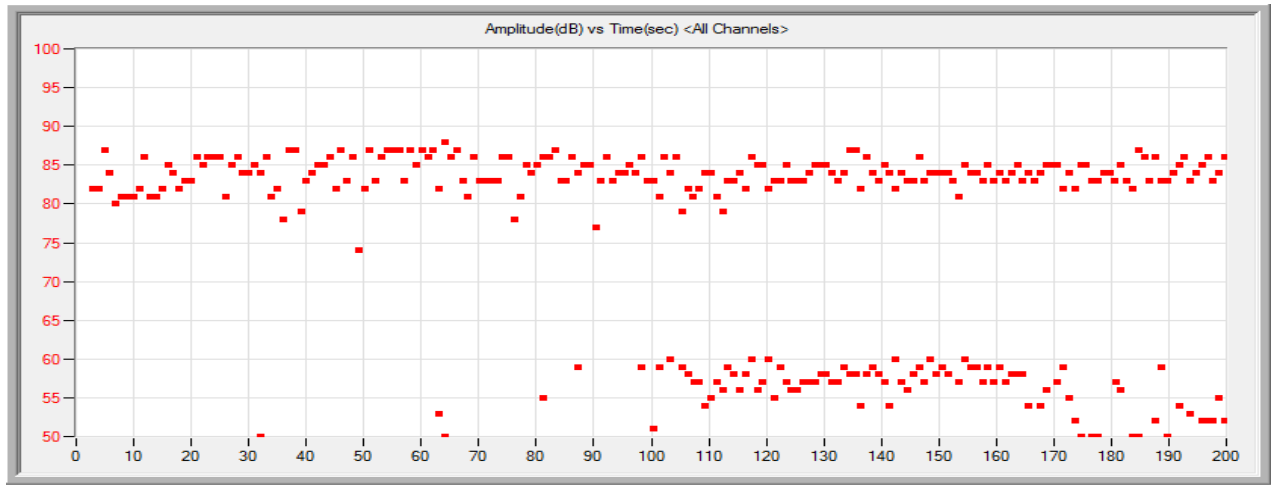
Duration



Energy



Amplitude



AE Hit Matrix

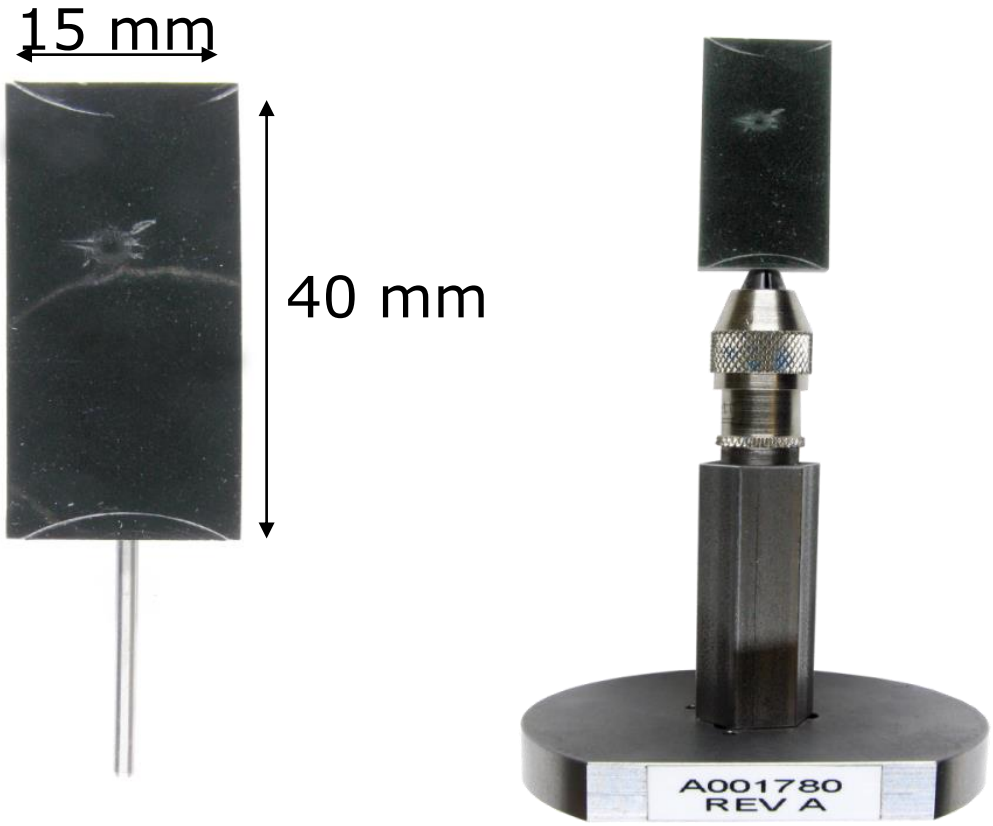
When coating is eroded…

- Frequency goes up
- Duration goes down a lot!
- Energy goes down a little
- Amplitude is unchanged
- Get two AE hits per impact

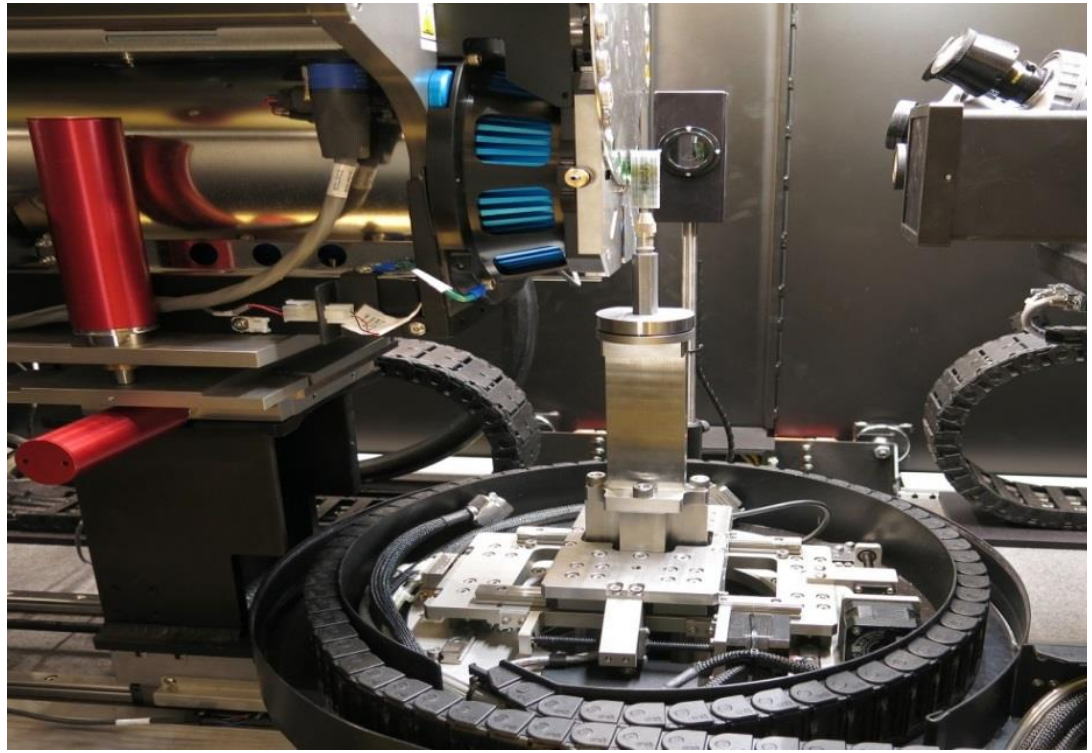
	Counts	Av. Freq (kHz)	Duration (μs)	Energy	Amplitude (dB)
Type 1 fully protective	13	7	2065	177	84
Type 2: coating damaged?	8	28	285	161	85
Type 2: coating eroded	8	26	284	135	84

2 ex situ methods

2.1 X-ray tomography

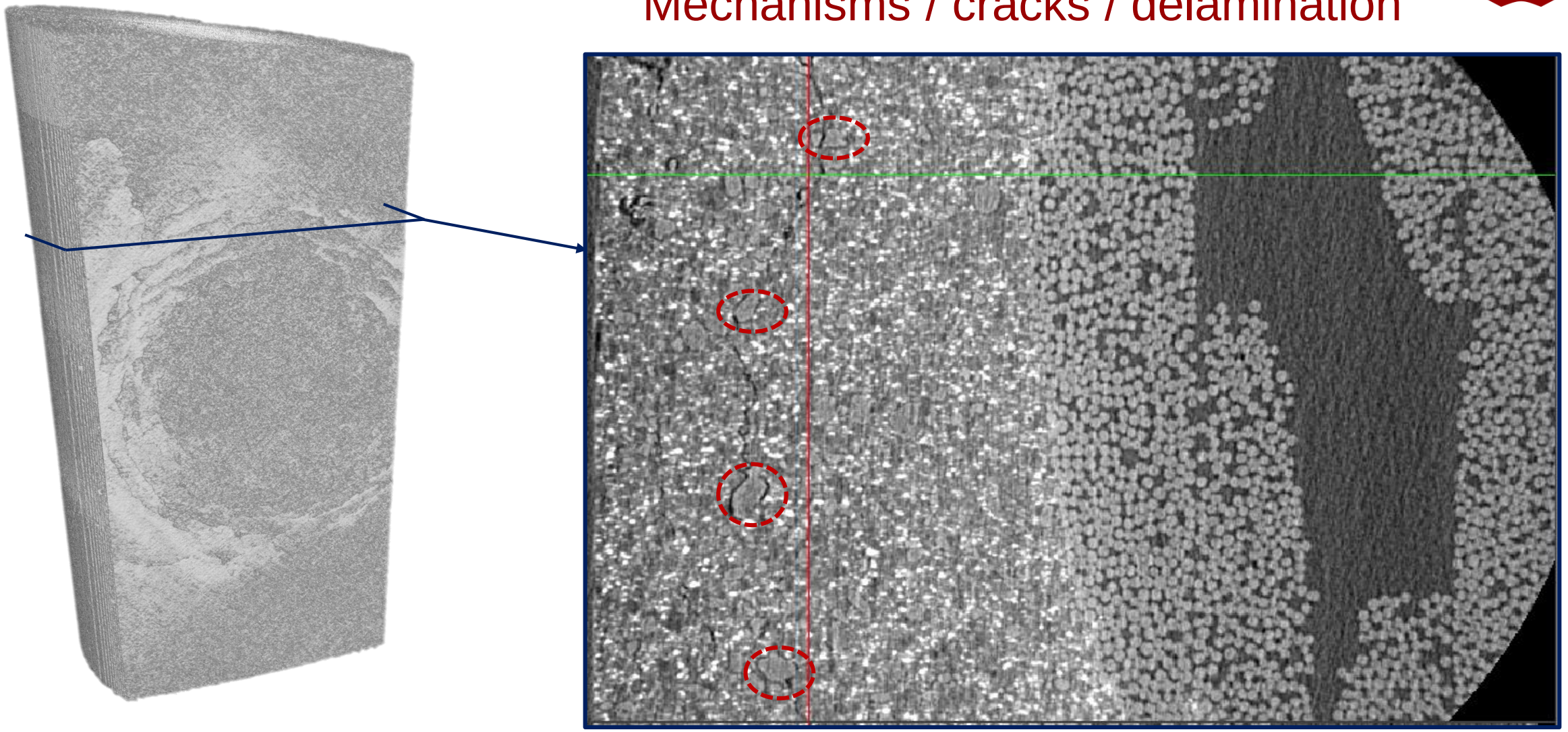


Place the metal pin in the hole and place in the holder parallel to the flat surface to ensure same position

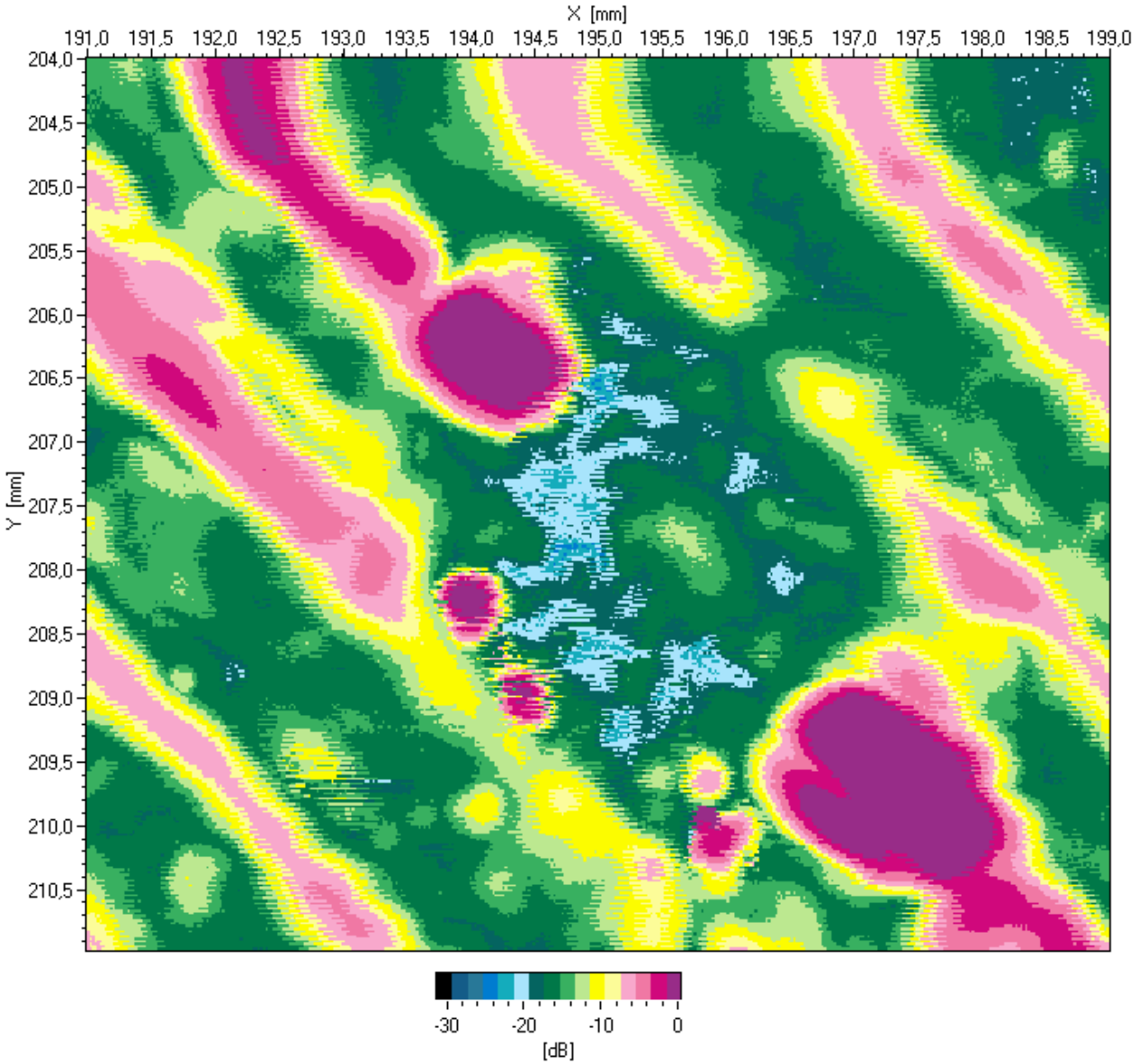


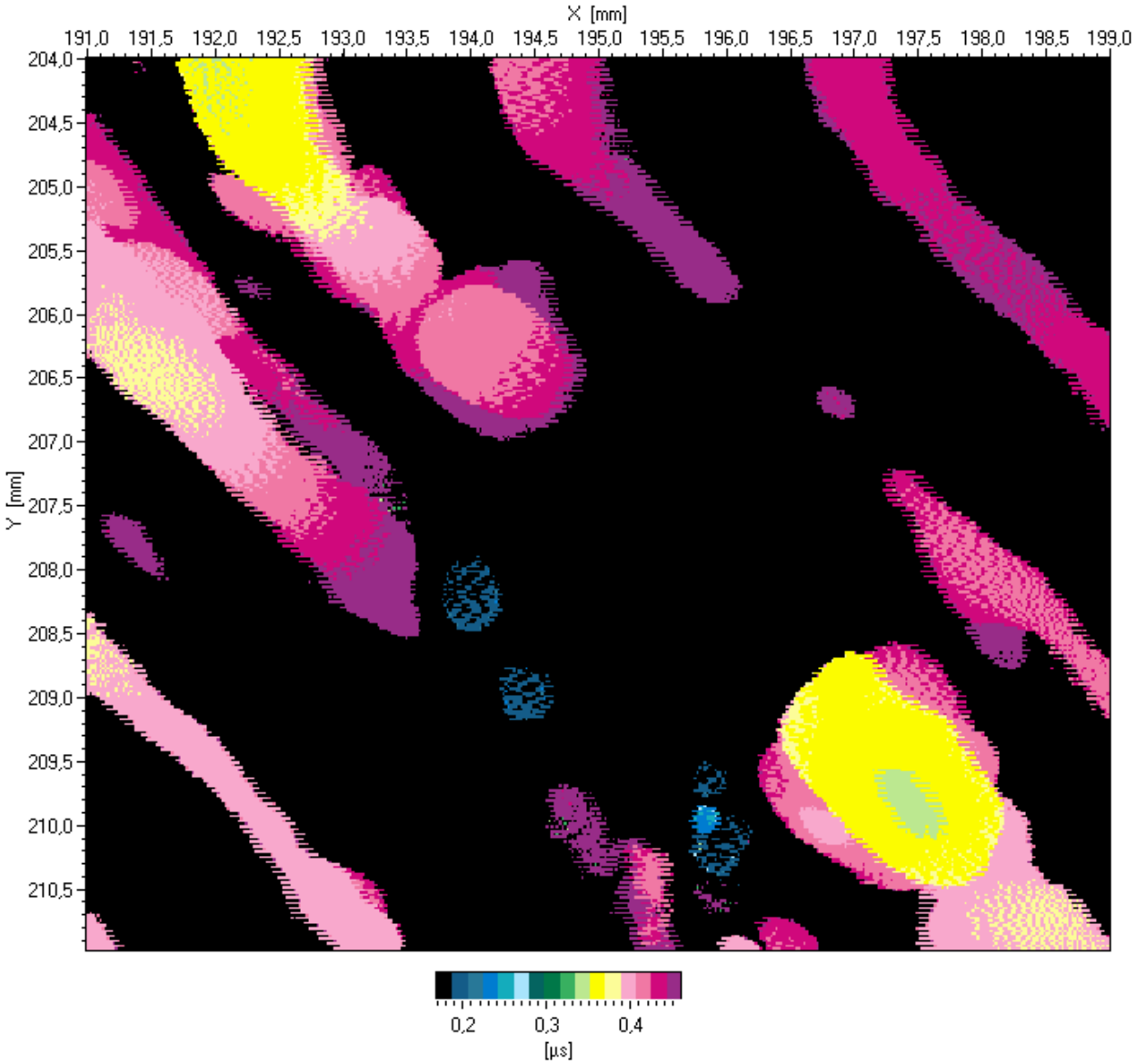
Specimen placed in the 3D X-Ray Tomography

Mechanisms / cracks / delamination



Ultrasnound scanning



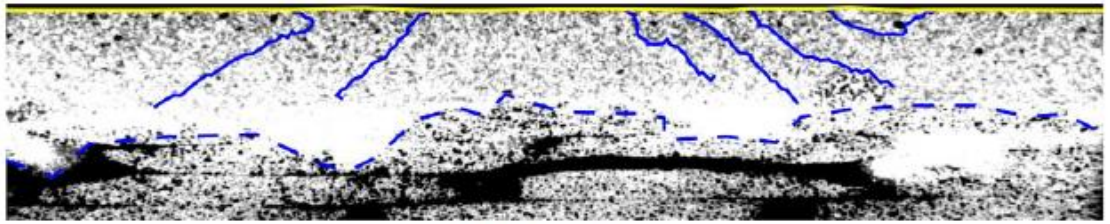


Modelling (FEM)

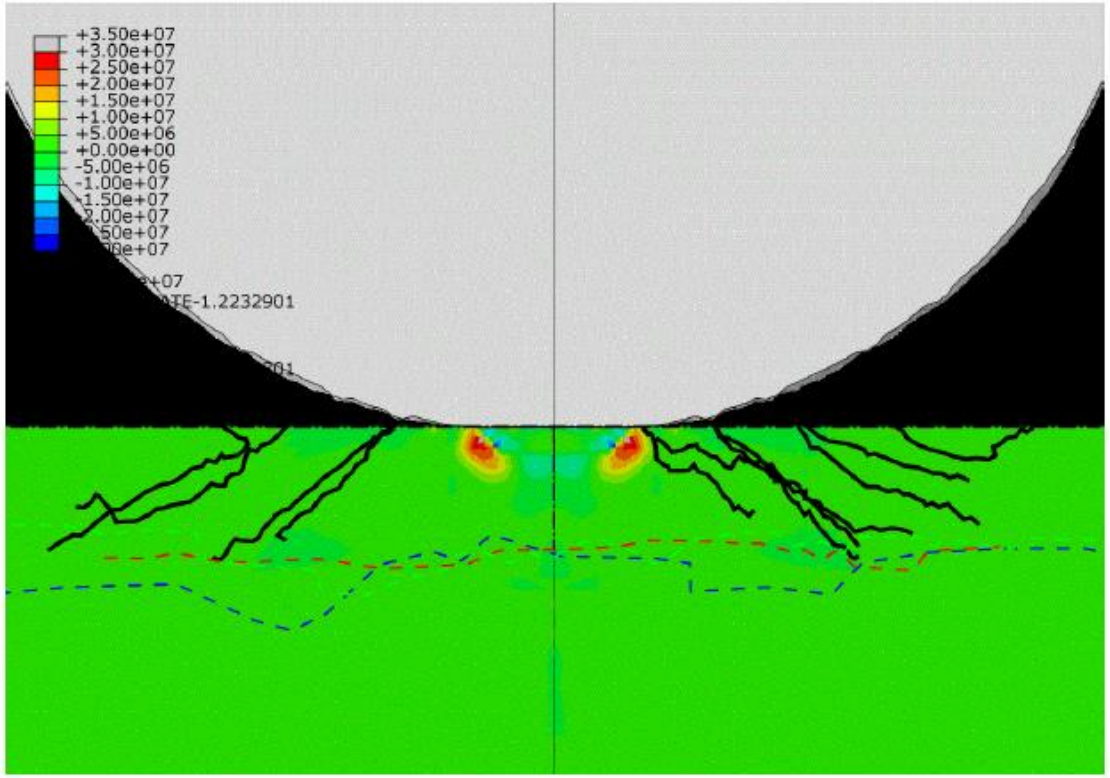
CT scans:

Erik Vogeley, COM

Anthony Fraisse, COM



CT scan



- CT scans of the specimens reveal cracks in gelcoat with ca 45 deg. to the surface
- High shear stresses along the crack paths due to travelling shear wave front, 30 Mpa
- Angles less than 45 are also seen, probably due to traveling of the contact edge