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Fatigue damage analysis of pultruded glass fiber reinforced materials with acoustic emission methods

1st EASN WORKSHOP ON
AEROSTRUCTURES
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Pultruded Materials

- Good mechanical properties
- Favorable industrial process
- Structural members: bridges, civil structures, anti-noise panels, lightweight vehicles

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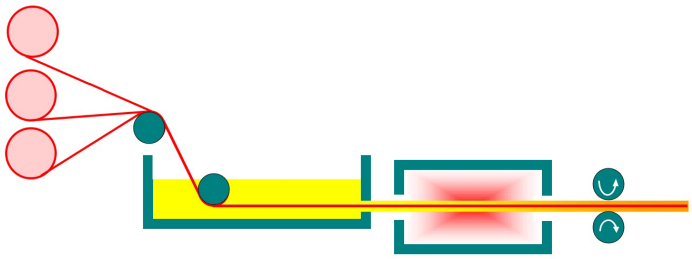
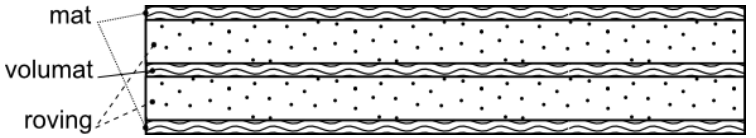
Pultruded Materials





Material layers arrangement

- Fiber pulling + matrix extrusion
- Good fiber alignment and polymerization

- Unpredictable fatigue behavior
- Little knowledge on damage modes

damage mode assessment;
NDT monitoring

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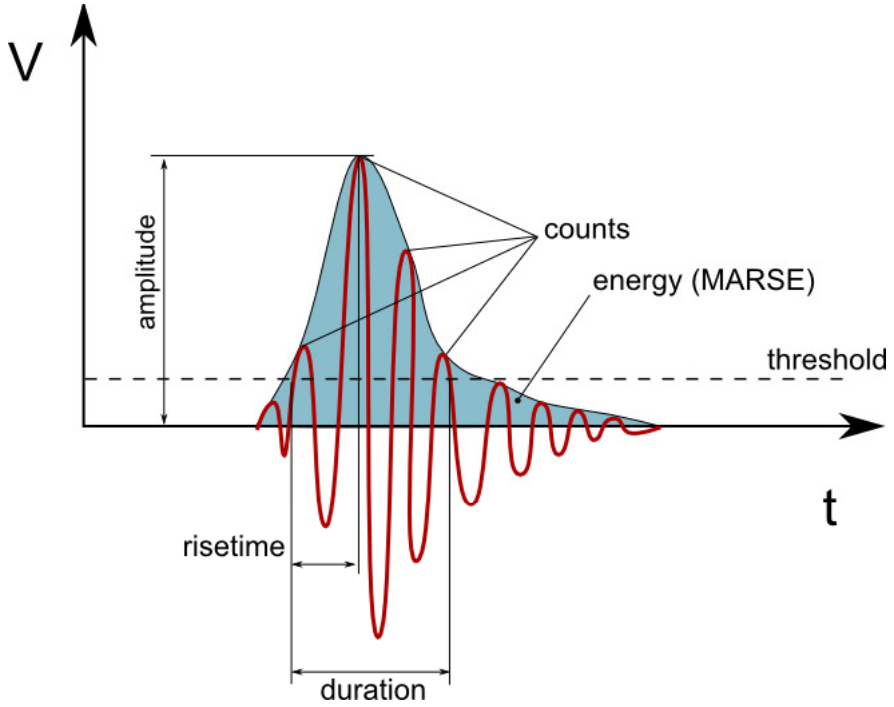
Acoustic Emission



Most promising technique for our purpose

- Assess damage type
- Localize microstructural damage
- Continuous monitoring during testing or operations

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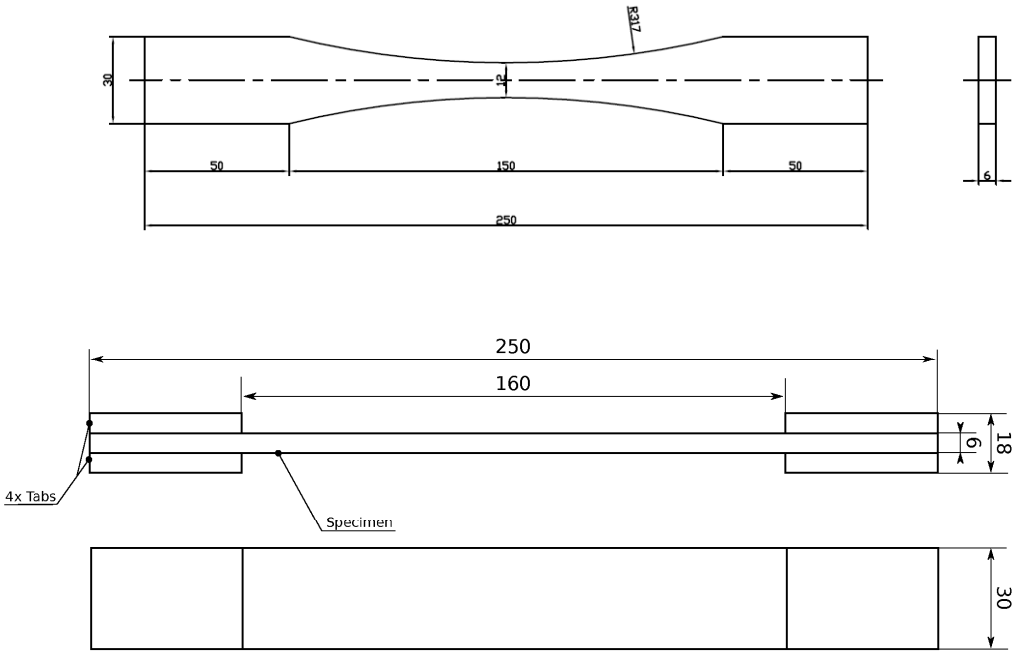
Testing plan and methodology



"Dogbone" and tabbed specimens

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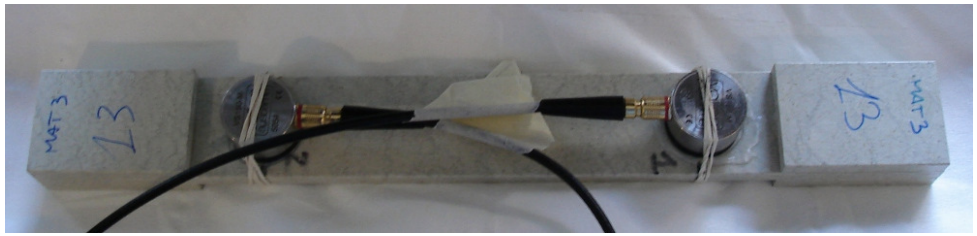
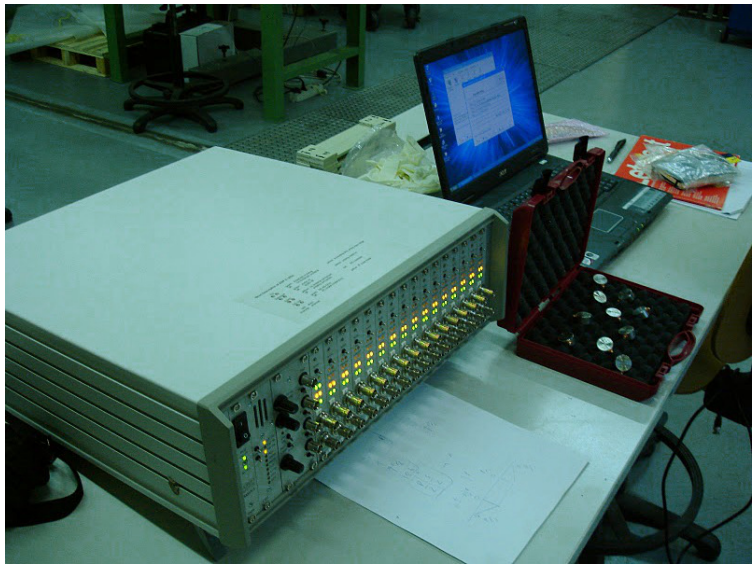
Testing plan and methodology



AE monitoring

- Continuous signal recording
- Localization of events
- AE parameters recording



AE instrument (Vallen Systeme GmbH)

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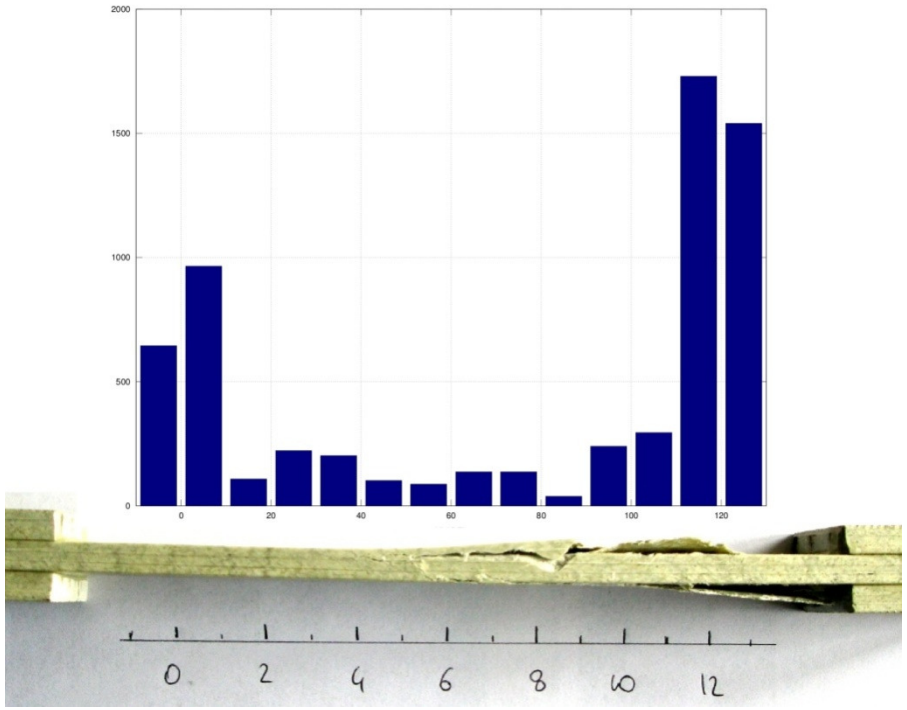
Testing plan and methodology

Static tests

- Used to assess instrument capabilities and material issues
- Location processor indicates in real-time the failure position



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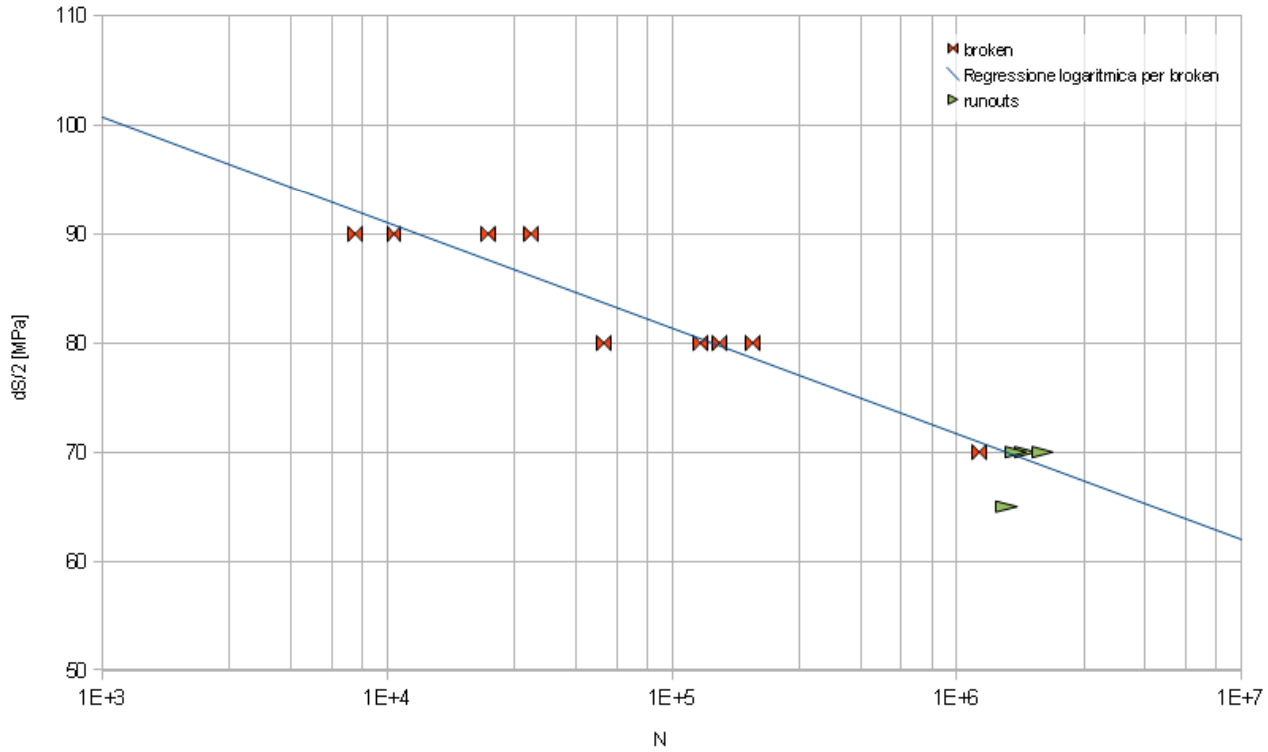
Testing plan and methodology

Axial fatigue testing plan (R=0.1) with analysis of

- broken specimens
- Run outs



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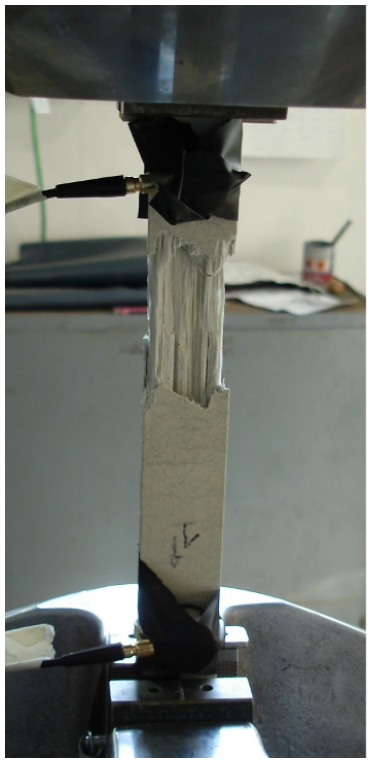
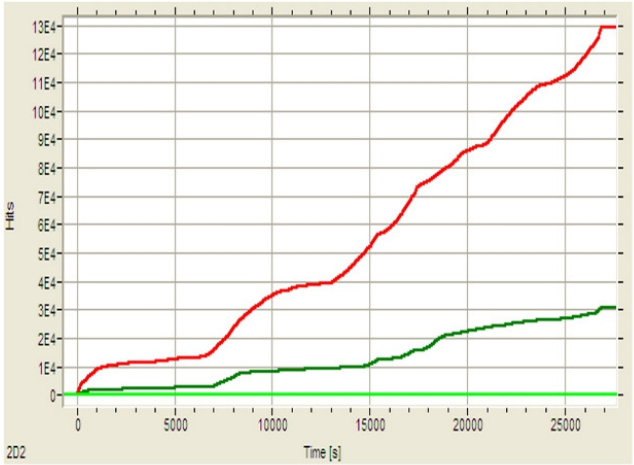
Testing plan and methodology

Real-time data suggests:

- damage accumulation
- possible non-critical development of flaws
- final breakage





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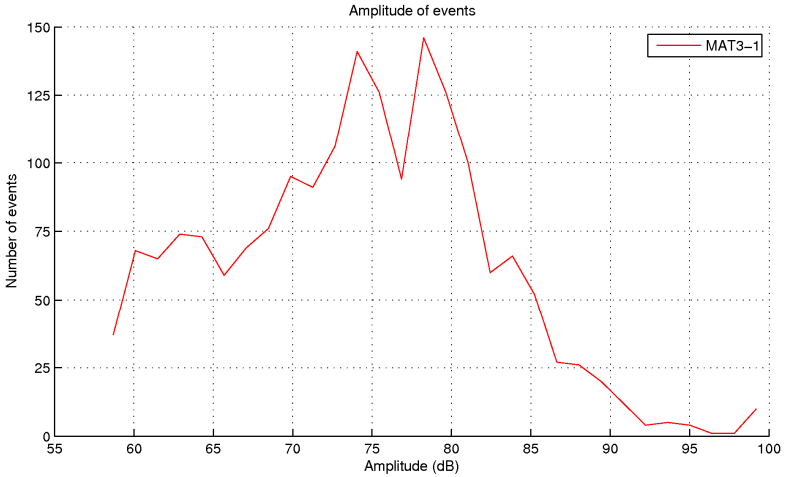
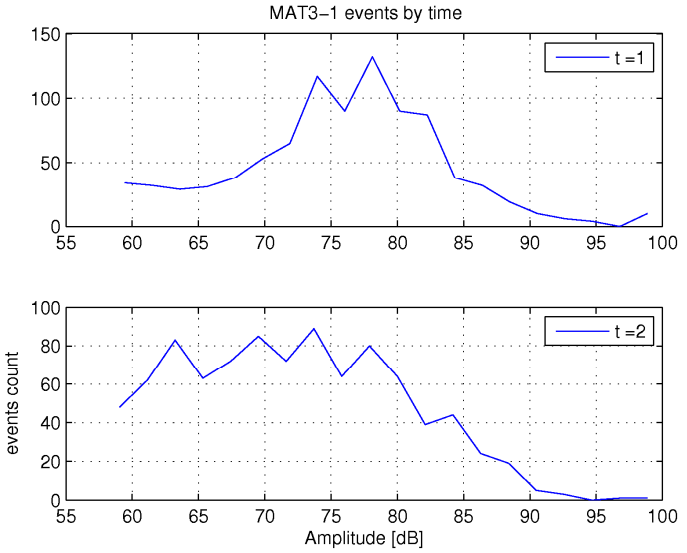
AE static data postprocessing

Amplitude seems to be a candidate parameter to differentiate between failure modes (static tests)





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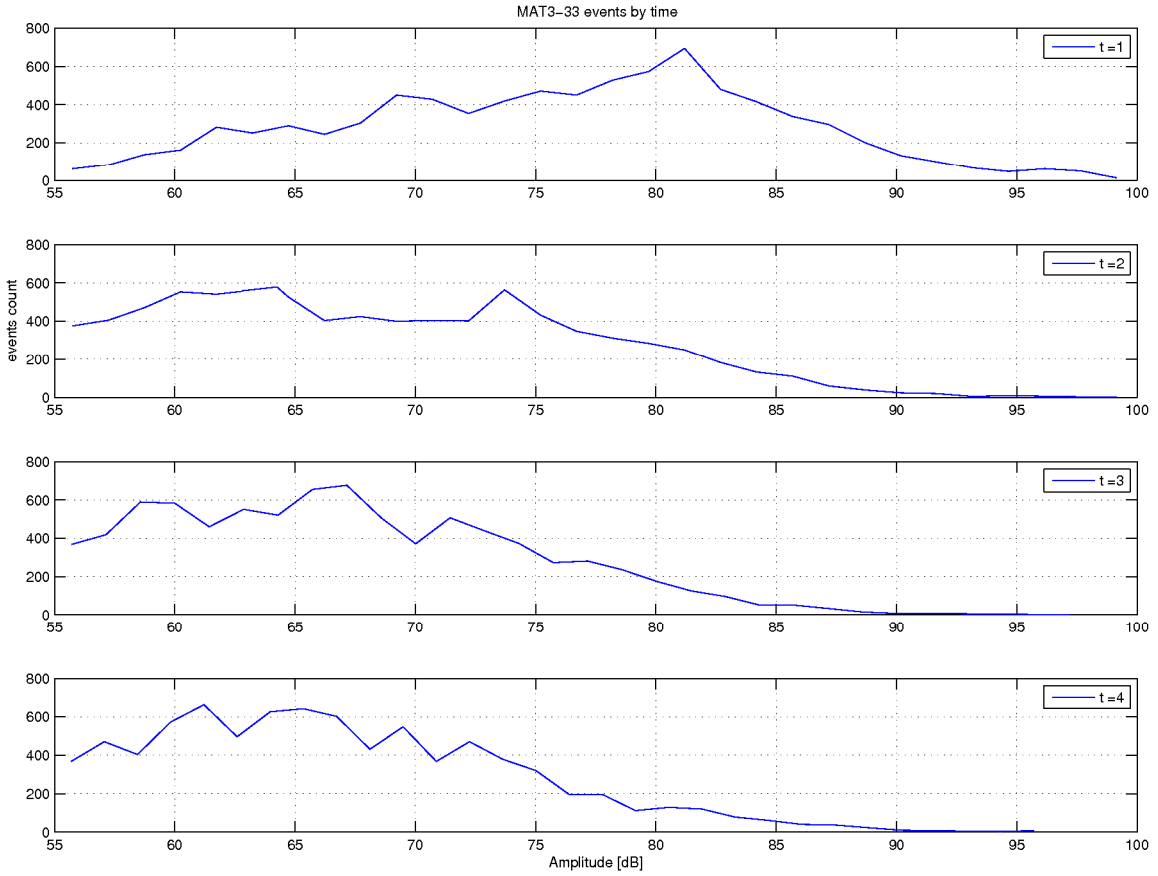
AE fatigue data postprocessing

Different characteristic amplitudes in different phases of the test



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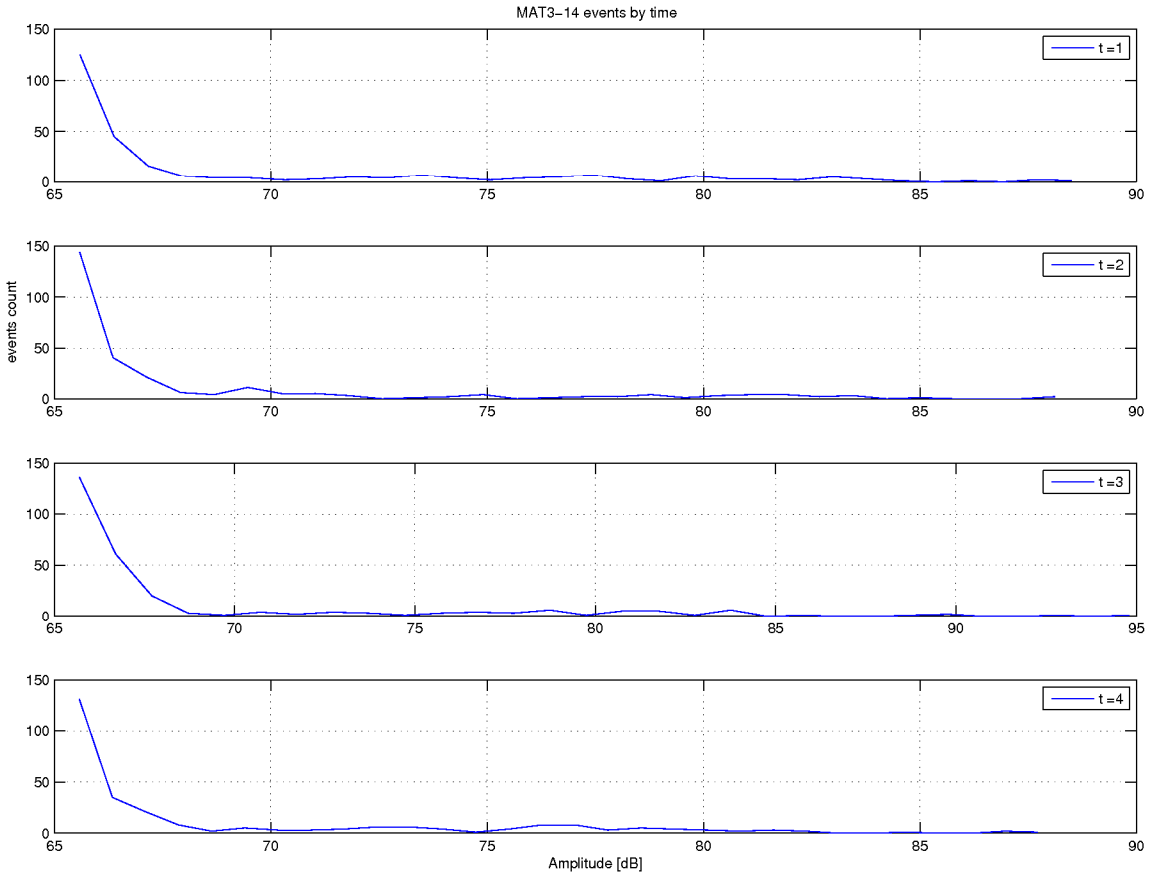
AE fatigue data postprocessing

Runout specimens present only low-amplitude activity



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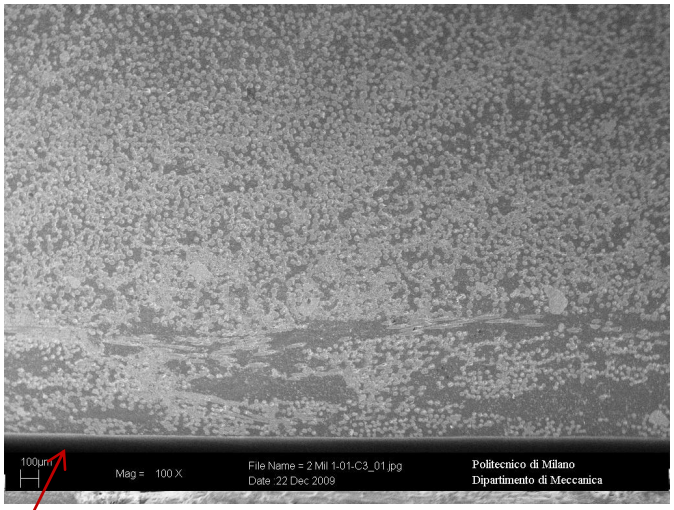
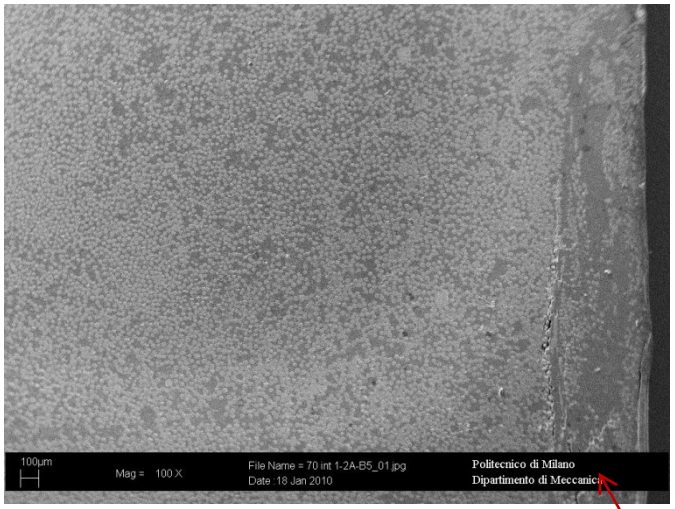
Microstructural damage assessment

SEM images; tests interrupted at 2/3 N



70 MPa



80 MPa

90 MPa

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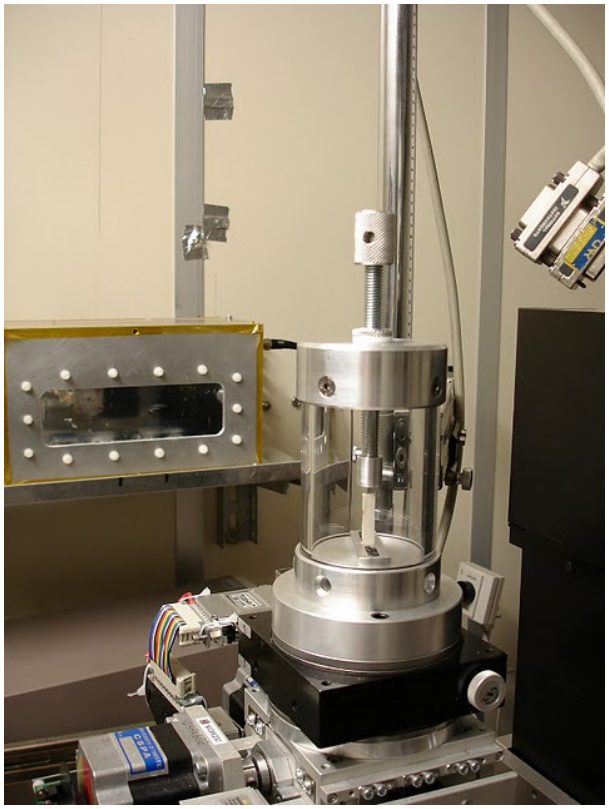
Microstructural damage assessment

Computerized Tomography (CT) images (Sincrotrone Trieste)

- tests interrupted at 2/3 N and non stressed specimens
- specimens cut in high AE activity zones



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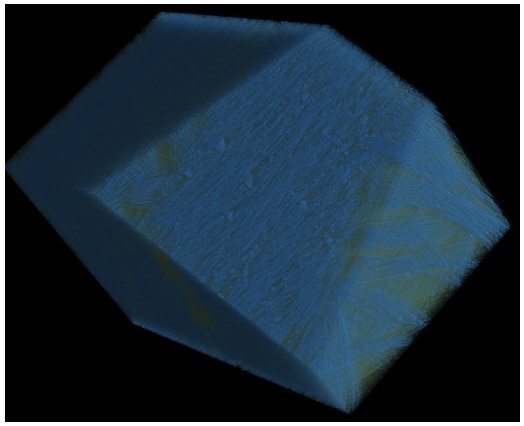
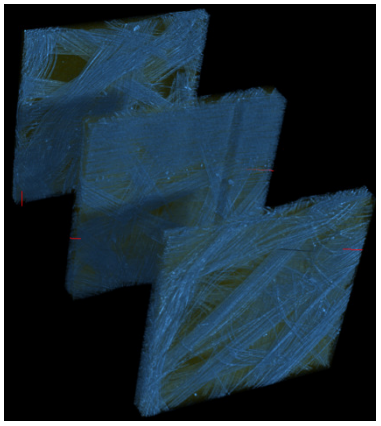
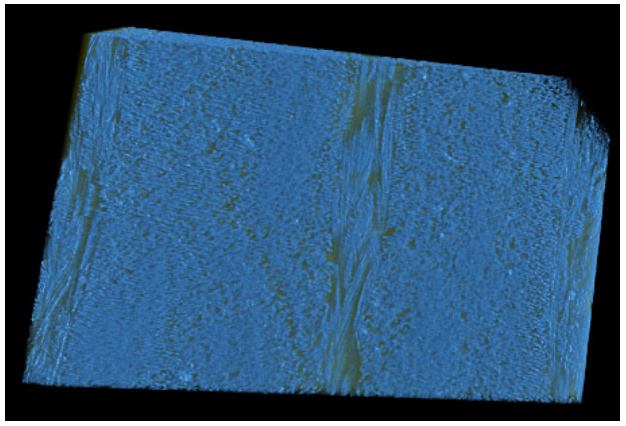
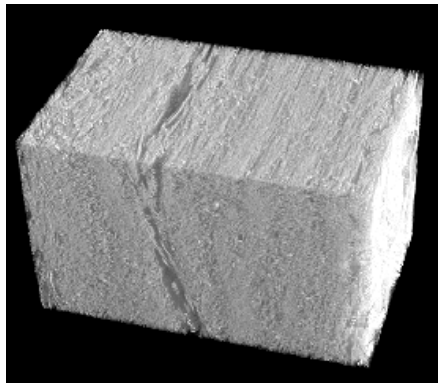
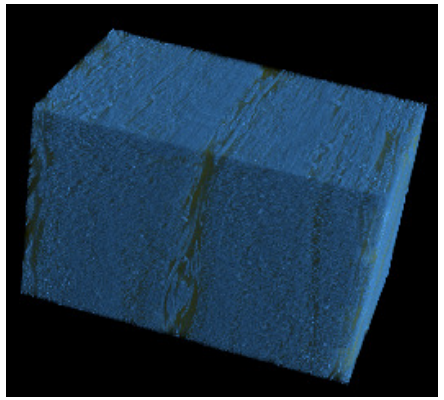
Microstructural damage assessment

Reconstructions:

- Non-stressed samples appear undamaged
- High stressed specimens present debonding between fiber and MAT layer
- Presence of additive lumps (which can be source of AE)
- CT acquisition time doesn't allow to obtain large amounts of data

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Summing up

- AE amplitude can be correlated with micro/ macrostructural damage
- A specimen loaded under fatigue limit doesn't show neither AE activity at high amplitude nor damage
- Emission modes with different amplitudes are found in all fatigue specimens

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Summing up

- In damaged specimens 75dB events are found particularly in the first half of the fatigue test
- Mid amplitude events (55 to 70dB) are found before failure
- CT images suggest that 75 and 80dB events can be correlated to a fiber-packets debonding failure mode
- If further tests confirm the association between a certain amplitude and a precise failure mode, it will be able to develop monitoring criteria based on acoustic emission features, which can assess the damage in terms of residual strength.

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Future developments

- Introduction of signal frequency analysis
- Failure mode assessment by other AE signal features
- Real-time monitoring of full-scale components
- Extension of the technique to other composites materials and structures

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Thanks for your attention