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## Monitoring System for impact and delamination detection - qualification of Structural Health Monitoring (SHM) systems



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Cooperation of three Fraunhofer Institutes



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Betriebsfestigkeit  
Systemzuverlässigkeit



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Fraunhofer Institute for Structural Durability and System Reliability LBF, Darmstadt, Germany

Fraunhofer Institute for Non-Destructive Testing IZFP, Dresden branch, Germany

Fraunhofer Institute for Silicate Research ISC, Würzburg, Germany

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### Monitoring System for Impact and Delamination Detection

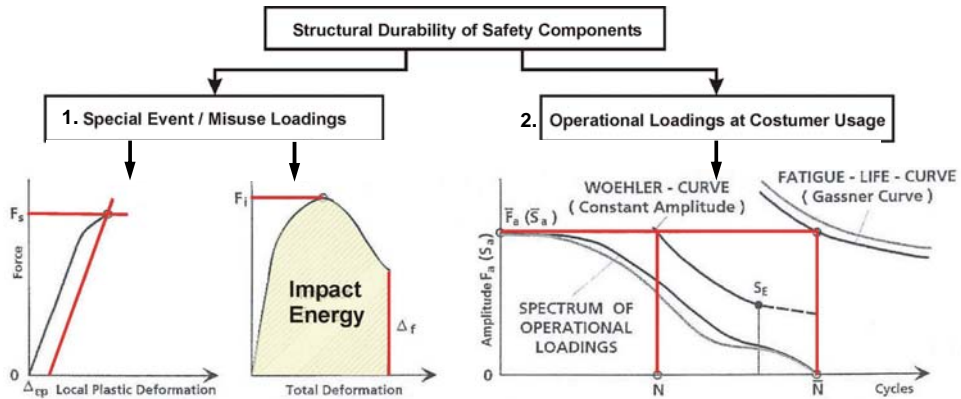
**impact induced delamination is a danger for fiber reinforced composites**



source: (<http://mitglied.lycos.de/nature2000/04032005.htm>)



**Monitoring System for Impact and Delamination Detection**



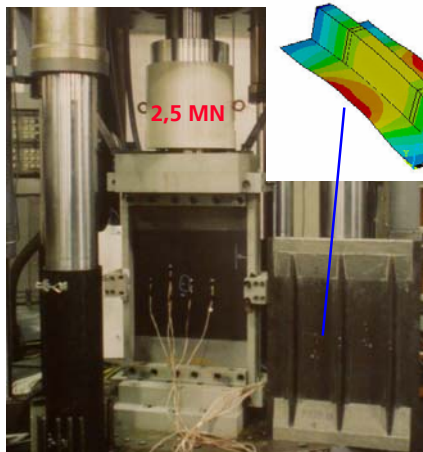
⇒ **Monitoring System for:**

- 1. Acoustic Emission Events (e.g. Impact)**
- 2. Fatigue (Delamination)**

**Monitoring System for Impact and Delamination Detection**

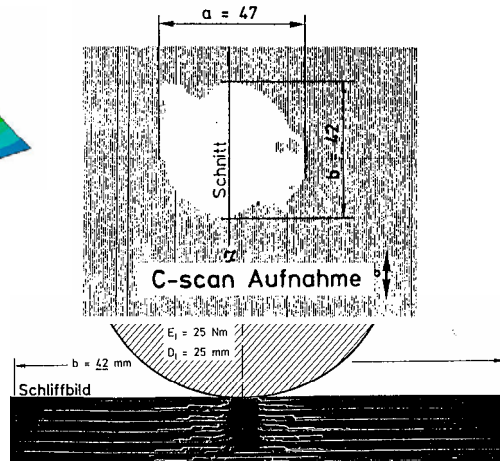
**1. Misuse Loadings / Impact (Acoustic Emission Events)**

Misuse e.g. Buckling



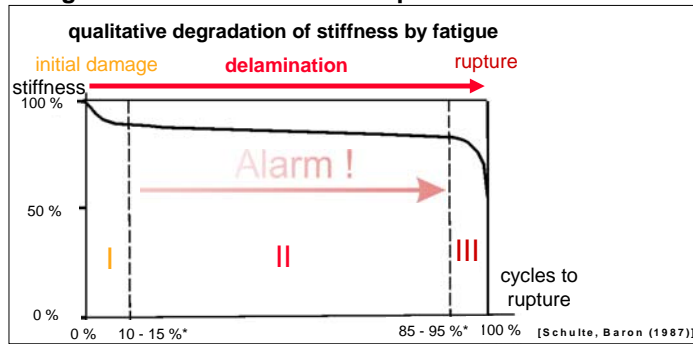
compression test at Fraunhofer LBF

Impact



impact induced delamination

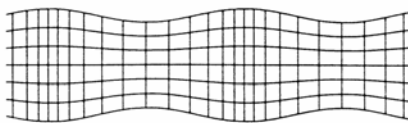
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**2. Fatigue of high loaded endless fibre composite structures**



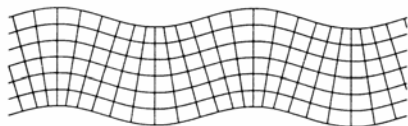
- I      **Formation and propagation of transversal cracks**
  - II     **Formation and propagation of delamination with further mechanical loading of the structure.**
  - III    **Fibre cracks mostly in the delaminated area lead to rupture in a chain reaction.**
- 

\* depending on the type of material  
 (e.g. woven fabric, or multiaxial fabric)

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**functional principle of the system is based on the interaction of defects with guided waves**



S0: symmetric mode  
 ("Quasi-longitudinal wave")

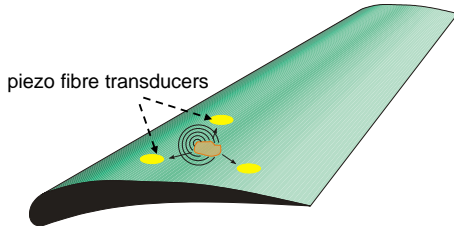


A0: antisymmetric mode  
 ("Bending wave")

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**two modes of operation are possible:**

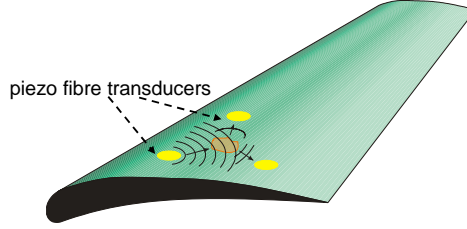
**passive mode**



the transducers operate in the sensor mode

➔ **Impact** and **fibre rupture** generate lamb-waves. By differences in the transit times to three sensors the origin of the waves can be calculated.

**active mode**



some transducers generate lamb-waves in the actuator mode.

➔ **Delamination** can be actively monitored by position and size. Tomographic or holographic modes of operation are possible.

**Monitoring System for Impact and Delamination Detection**

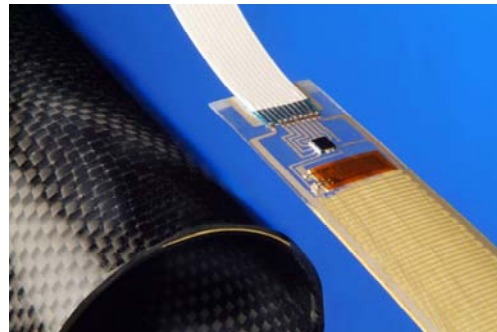
**piezo fibre transducers**

advantages:

- + low thickness
- + high flexibility



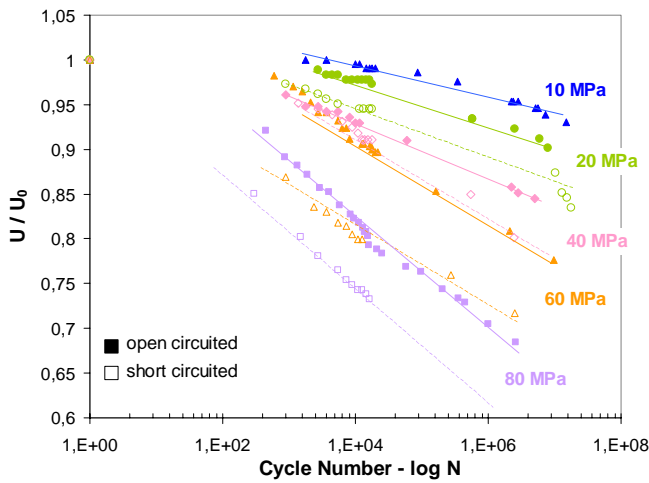
minimal fibre diameter: 15-20  $\mu\text{m}$   
thickness of transducer: 0.5 mm



piezo fibre transducer embedded in CFRP-tube of 40 mm diameter.

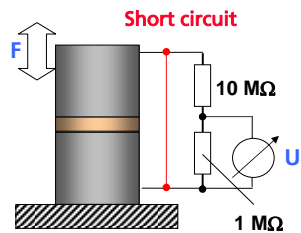
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durability of piezoelectric material in sensors



Loss of voltage from  
5% at 10 MPa and  $3 \times 10^6$  cycles  
40% at 80 MPa

The fatigue of a short circuit system is ten times faster than an open system



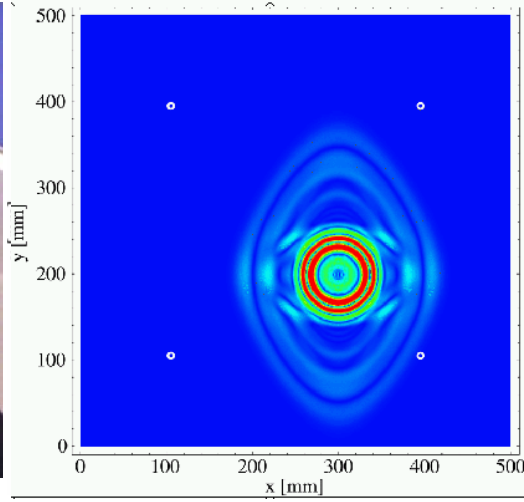
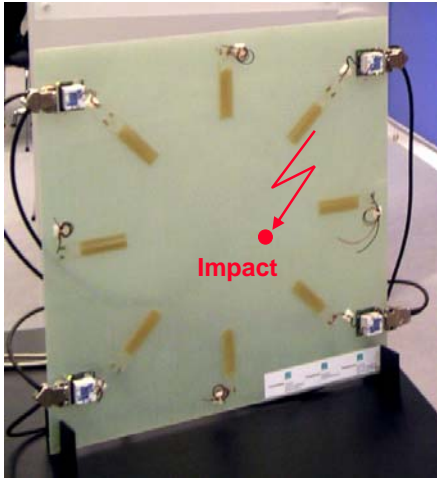
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advantages of integrated piezo fibre transducers compared to applied monitoring devices

applied monitoring device	integrated monitoring device
<ul style="list-style-type: none"> <li>+ easy to apply in accessible areas</li> <li>+ no influence on the structural durability of the fibre composite material</li> </ul>	<ul style="list-style-type: none"> <li>+ better bonding of the integrated element to the structure (top and bottom side are used)</li> <li>+ lower costs in mass production possible</li> <li>+ monitoring device can be integrated everywhere in the structure</li> <li>+ better protection from environmental effects</li> <li>+ better protection from forces of acceleration</li> <li>+ no influence on aerodynamic shapes</li> <li>- possible influence of the embedded device on the structural durability of the fibre composite material must be taken into consideration.</li> </ul>

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Demonstrator 1: GFRP-plate with embedded Piezo fibre transducers.  
Simulation of guided wave propagation after generation by impact.



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Demonstrator 2: Sandwich-Structure of a small aircraft with embedded piezo fibre transducers



manufactured in the mould of a lightweight aircraft



www.hk-aircraft.de

cross-sections of wind energy rotorblades:



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Demonstrator for passive Impact detection



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Monitoring System for Impact and Delamination Detection

manufacturing of the demonstrator in vacuum infusion technology



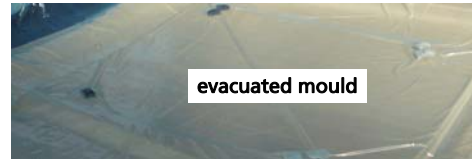
sewing of the piezotransducer



protection of the contacting solution



lay-up of multi-axial fabric



evacuated mould



lay-up of sandwich foam and inner woven fabric



resin infusion



with kind support:

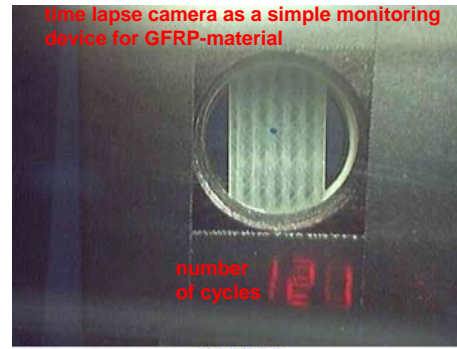
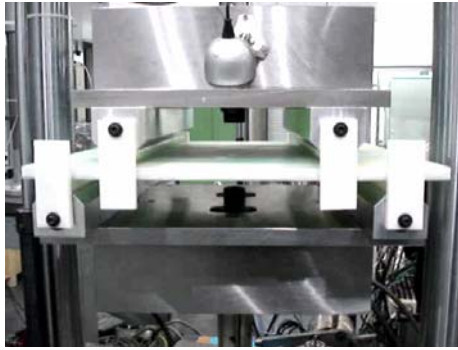


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## Monitoring System for Impact and Delamination Detection

### Conclusion: Qualification of SHM-Systems:

- a degraded signal by fatigue of the monitoring device must not mix up with a signal of a failure in the structure.  
→ durability/ reliability SHM-System > durability of the monitored structure
- the integrated piezo fibre transducers must not have a negative effect on the structure.
- the sensitivity (correct response in an early stage of a failure) must be checked in a preliminary test and should match with a different SHM-system i.e. show the correct position and size of a delamination.



  
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## Monitoring System for Delamination Detection

# thank you for your attention !

  
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→ Open Technology Forum, April 6th 2006, Dr. Dieter Hentschel:  
Monitoring System for impact and delamination detection - microsystem for Structural Health Monitoring (SHM) of lightweight structures (part 2)

  
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