swerea | SICOMP

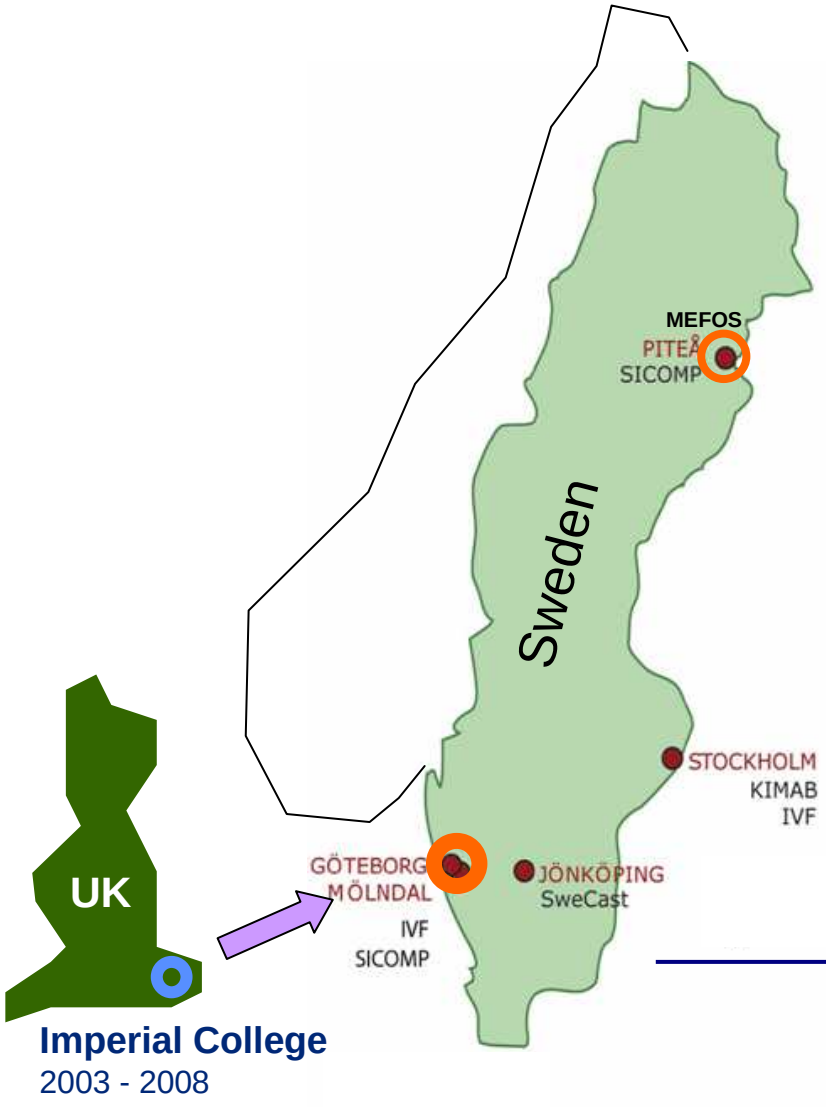
Stiffness of impact damage zones in composites measured by full field methods

Robin Olsson

Seminar organised by BSSM

NPL, Teddington, UK, 11th March 2010

SICOMP – where we are and what we do



Imperial College
2003 - 2008

Swerea SICOMP

Swedish non-profit institute for research on polymer composites.

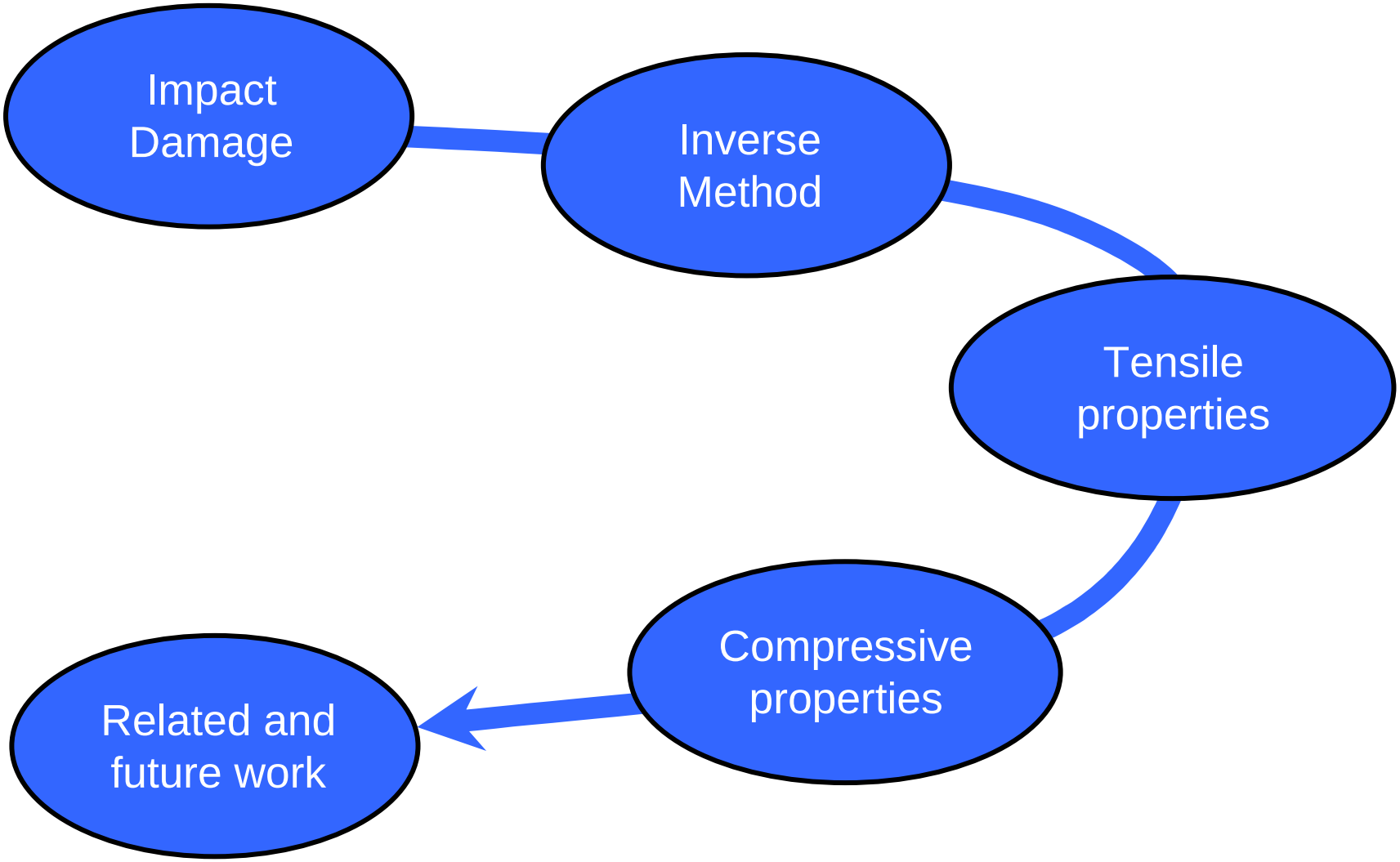
Owners: Industry 51%, Government 49%

Staff: 30

Member of *Swerea* – a group of Swedish materials research institutes.

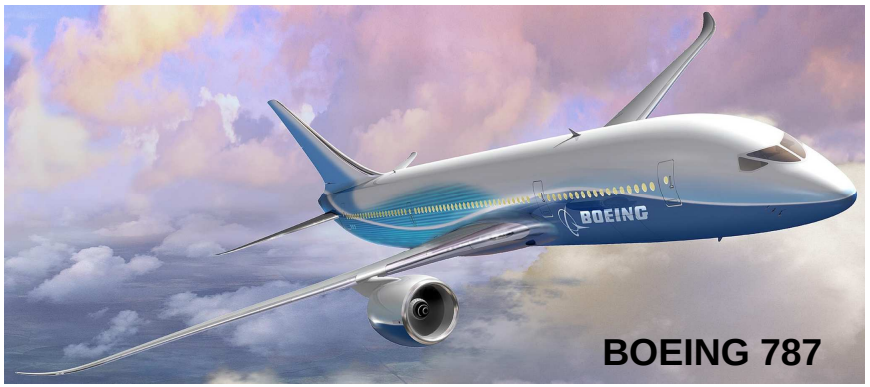
Most of the present work was done at
Imperial College London

Outline of presentation

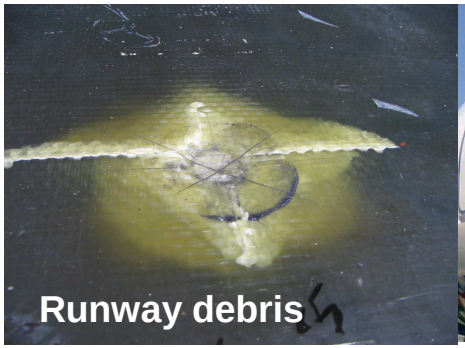


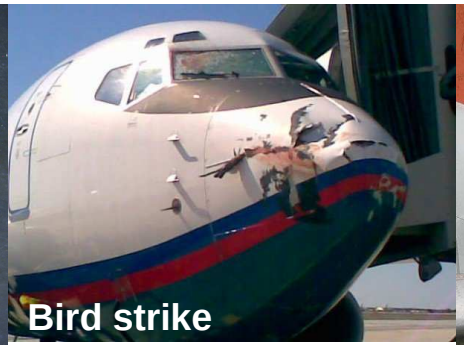
Impact threats on composite structures

AIRBUS A350



BOEING 787

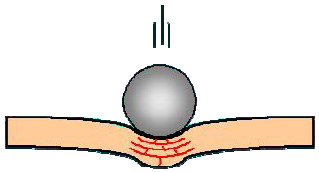

Runway debris


Bird strike

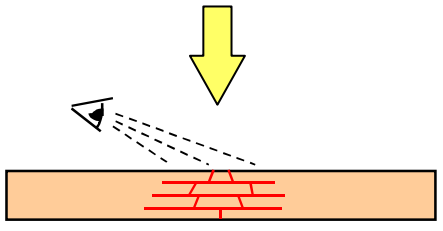

Hail stones


Dropped tools

Problem of impact damage on composites

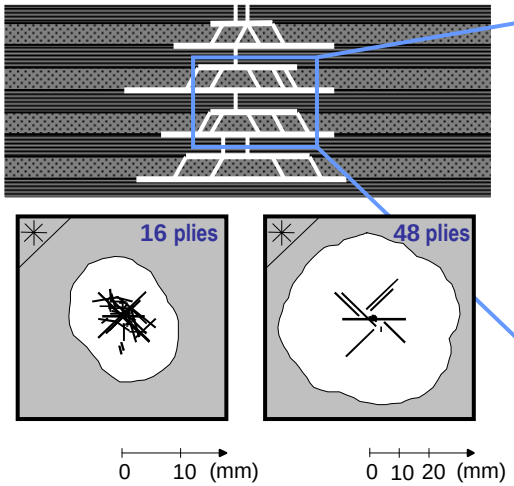


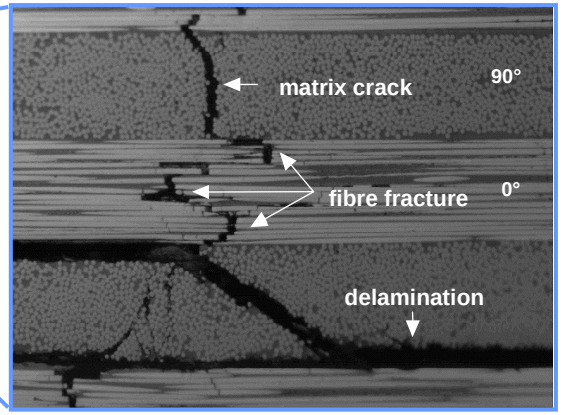
Impact damage happens easily

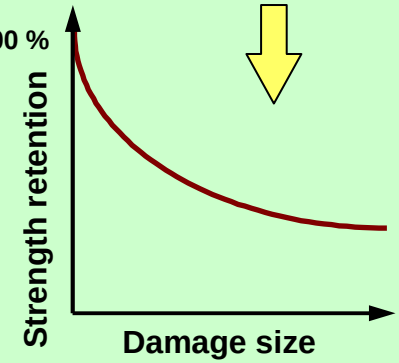


Often invisible by naked eye inspection

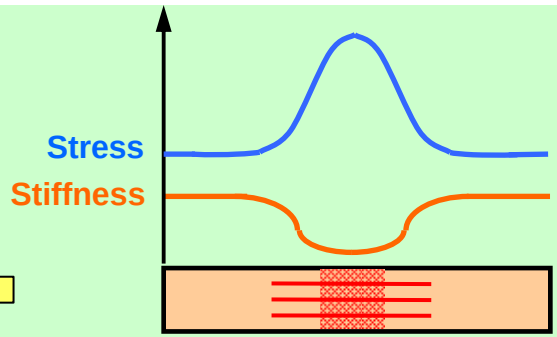
Complex damage affecting all plies







Significantly reduced strength



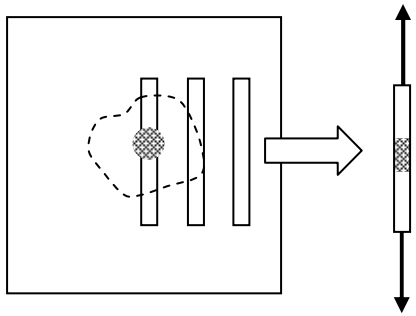
Stiffness distribution in damage zone is crucial

Davies & Olsson (2004) The Aeronautical J.

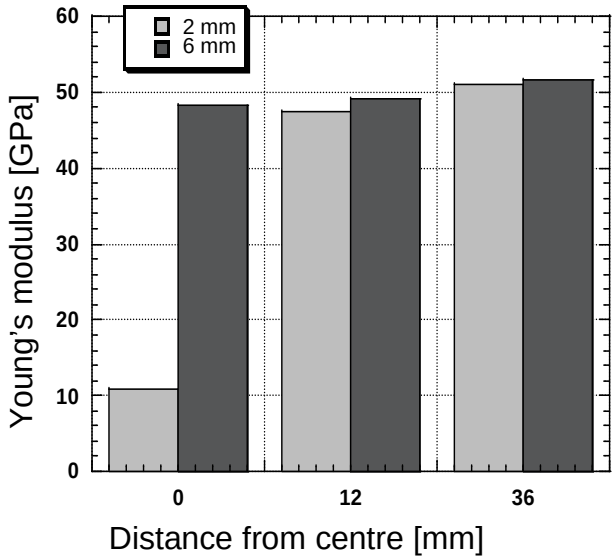
Initial studies of stiffness of impact damage

Coupons cut from damage zone

Sjögren, Krasnikovs, Varna *(2001). Composites A*



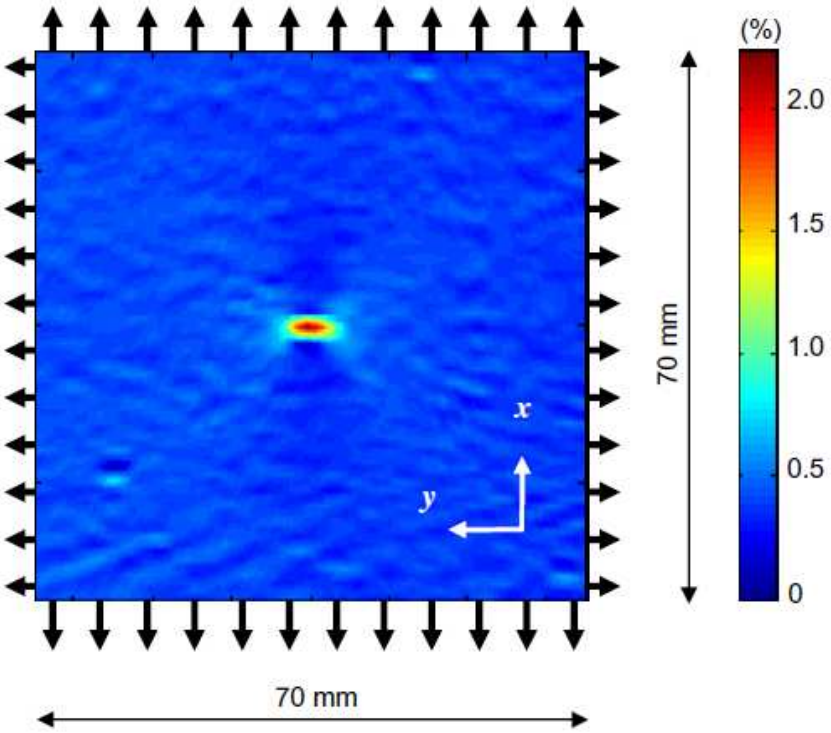
Tensile stiffness distribution



Drawbacks

- **Destructive method**
- **Properties only obtained in discrete points**
- **Free edges cause premature tensile cracking**
- **Strip specimens buckle very prematurely**

In-situ full field measurement of damage



Advantages

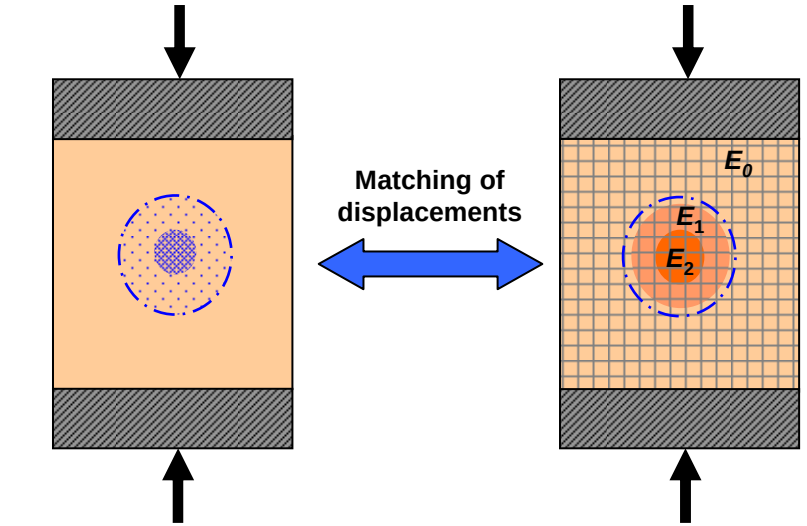
- **Potentially non-destructive method**
- **Full field description of damage zone**
- **Entire range of in-situ behaviour measured**

Disadvantage

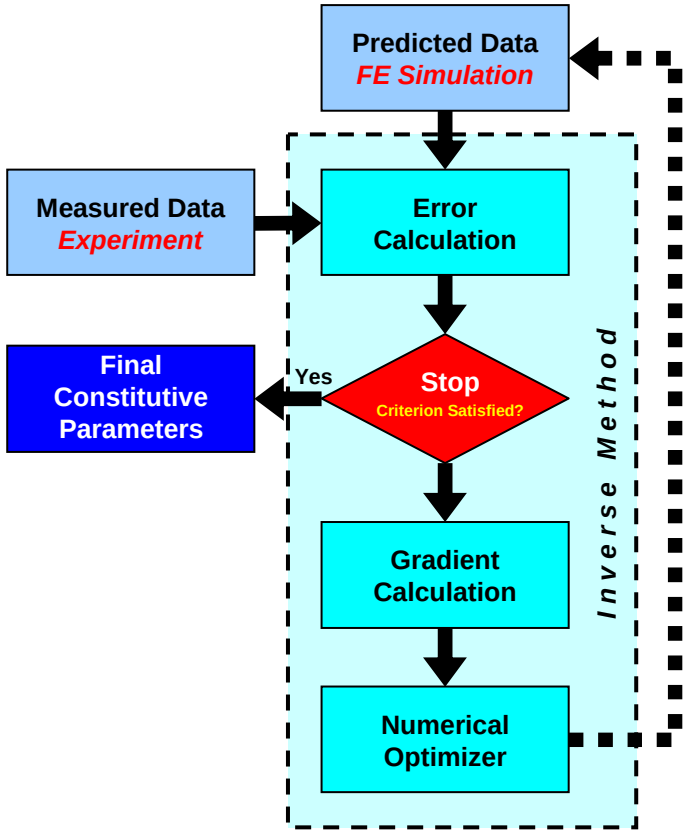
- **Numerical inverse methods required for evaluation**

Inverse method – our approach

Iterative updating of material parameters in Finite Element model



Displacement fields in loaded specimen measured by Digital Image Correlation (DIC)



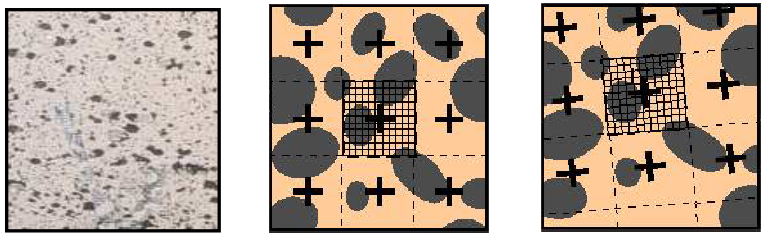
Flowchart of the approach

Sztefek & Olsson (2008), Composites Part A.

Digital image correlation system at IC

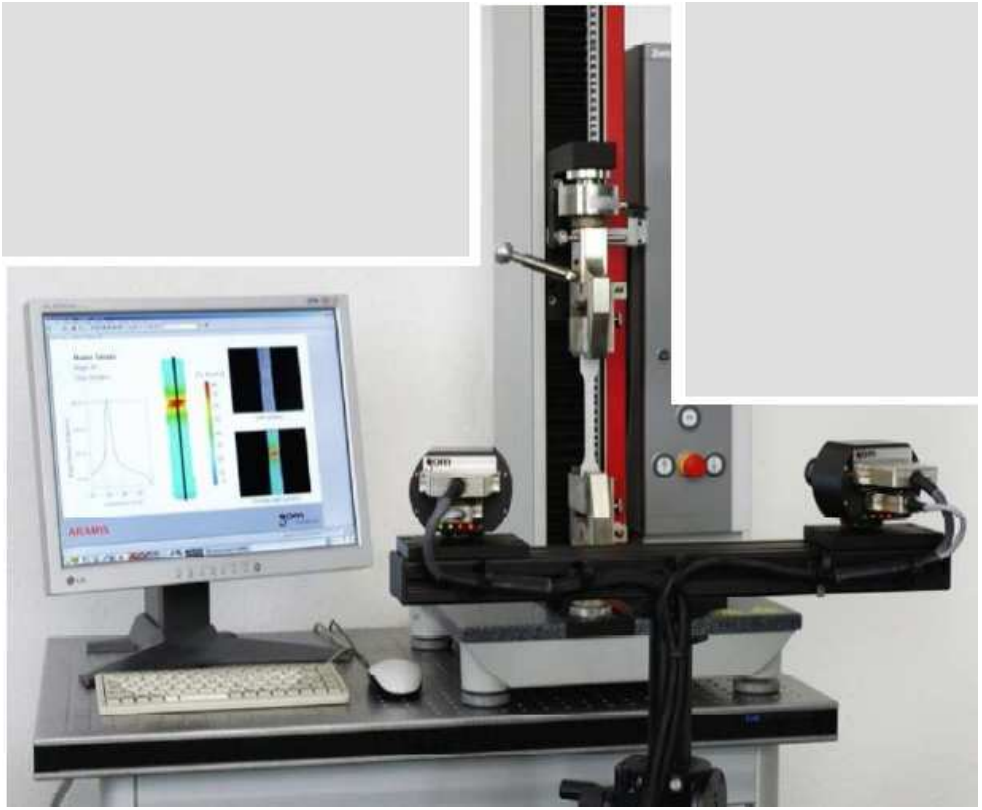
Non-contact optical 3D deformation measuring system

System type	GOM ARAMIS 1.3 M
4 cameras in master and slave mode	
Camera resolution	1280 × 1024 pixels
Measuring volume	10 × 8 × 8 mm³ to 1.7 × 1.4 × 1.4 m³
Max. frame rate	12 Hz
Strain range	0.05% up to <100%
Strain accuracy	up to 0.02%

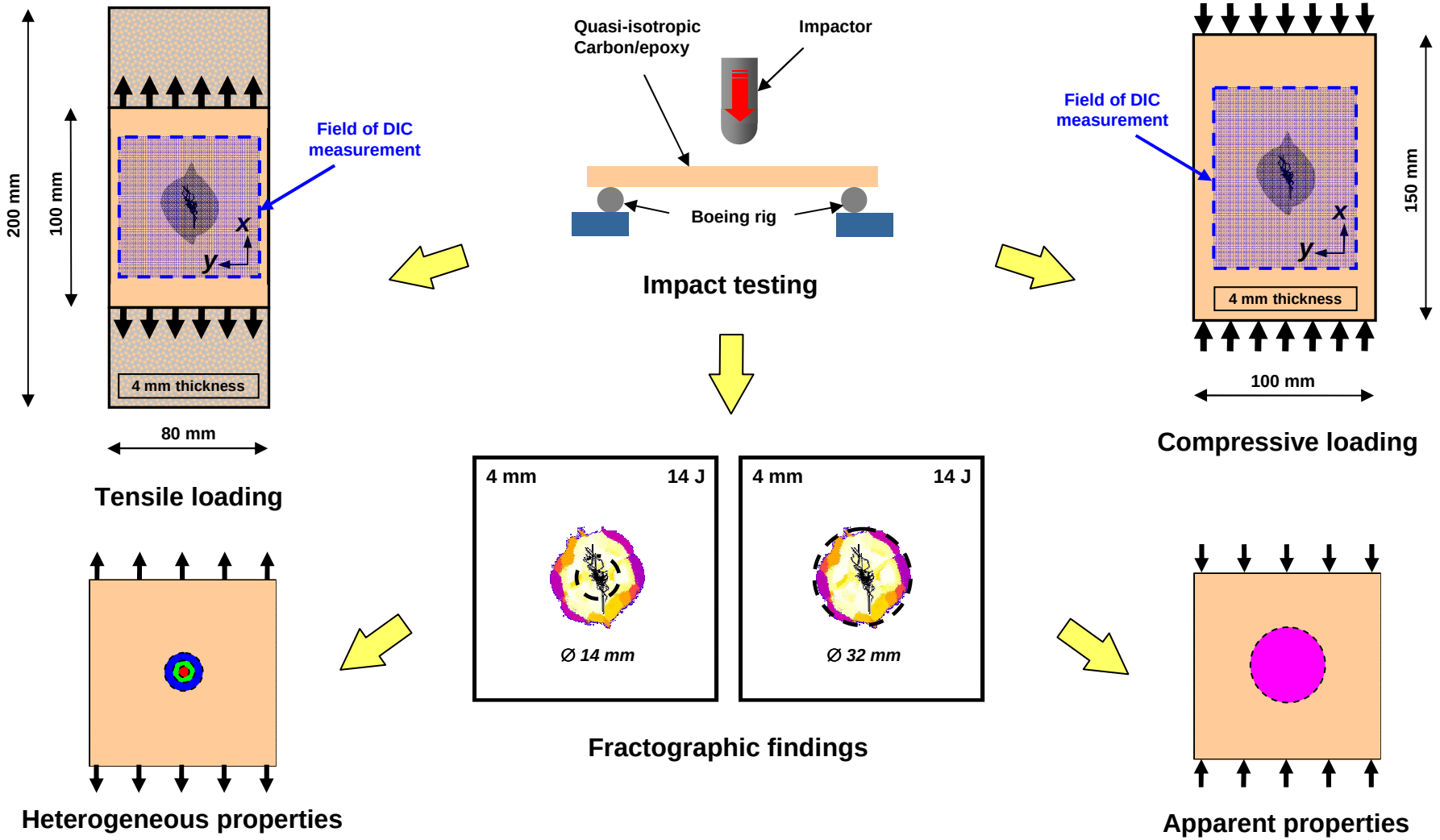


Speckle pattern | Before deformation | During deformation

DIC Principle



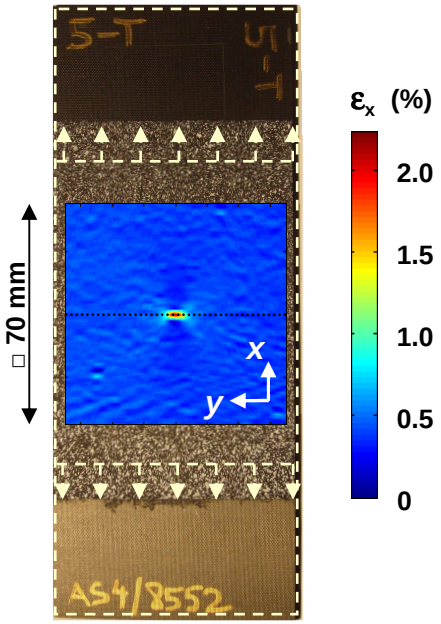
Overview of experiments

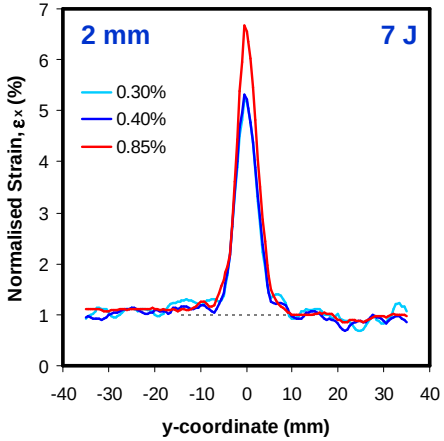


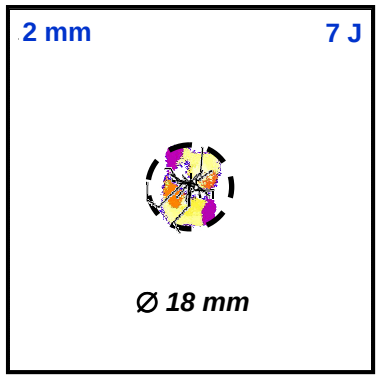
Tension – inverse analysis

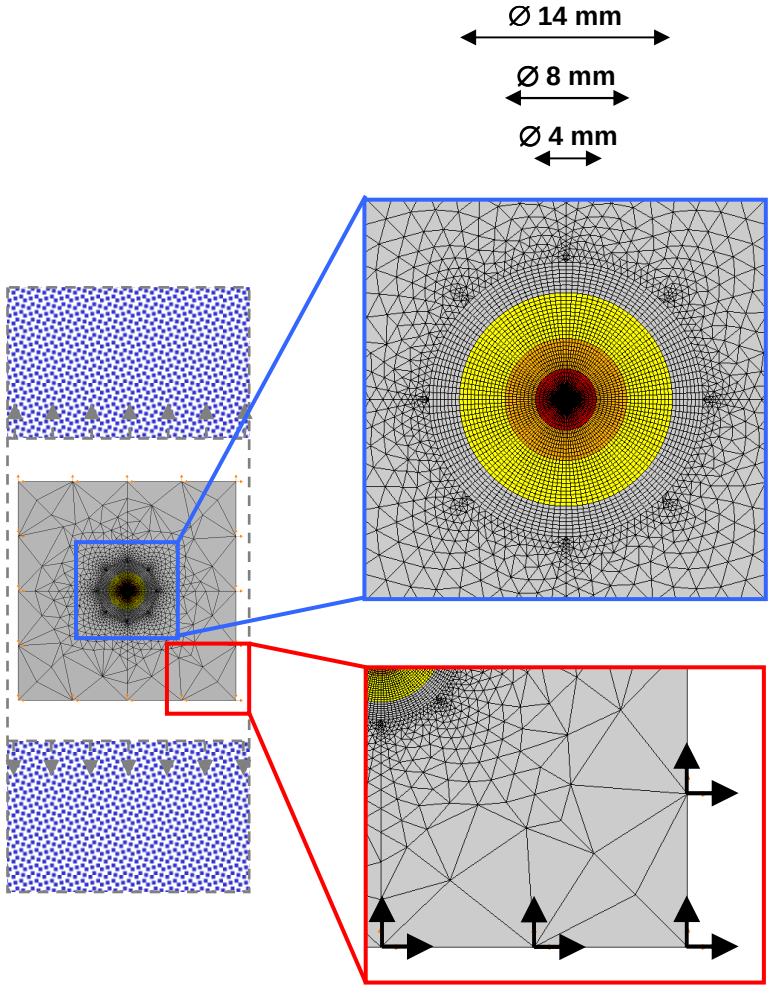
FE analysis

- **Homogeneous isotropic thin shell**
- **Full-field boundary conditions**

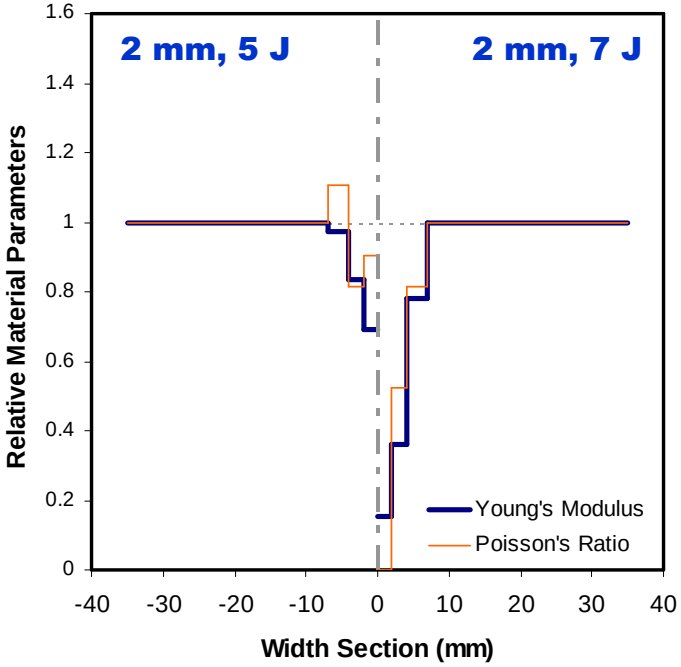


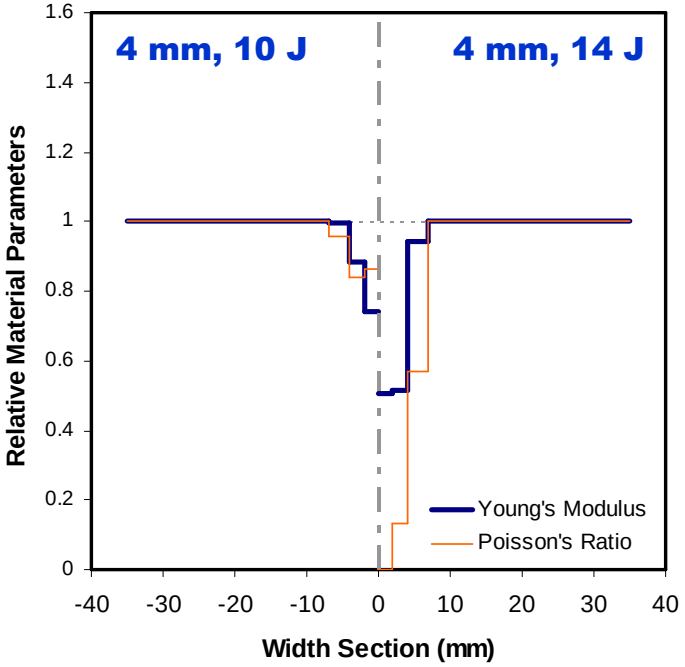


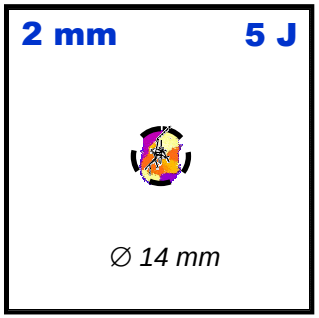


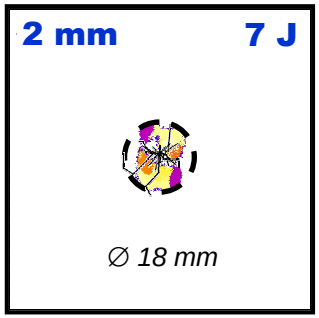


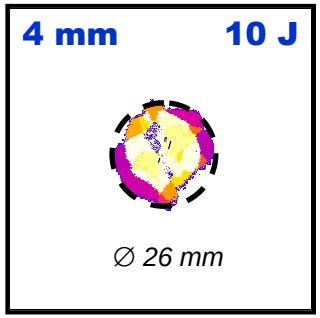
Tension – results

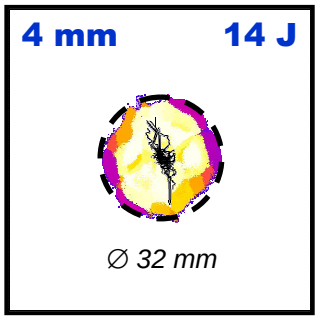






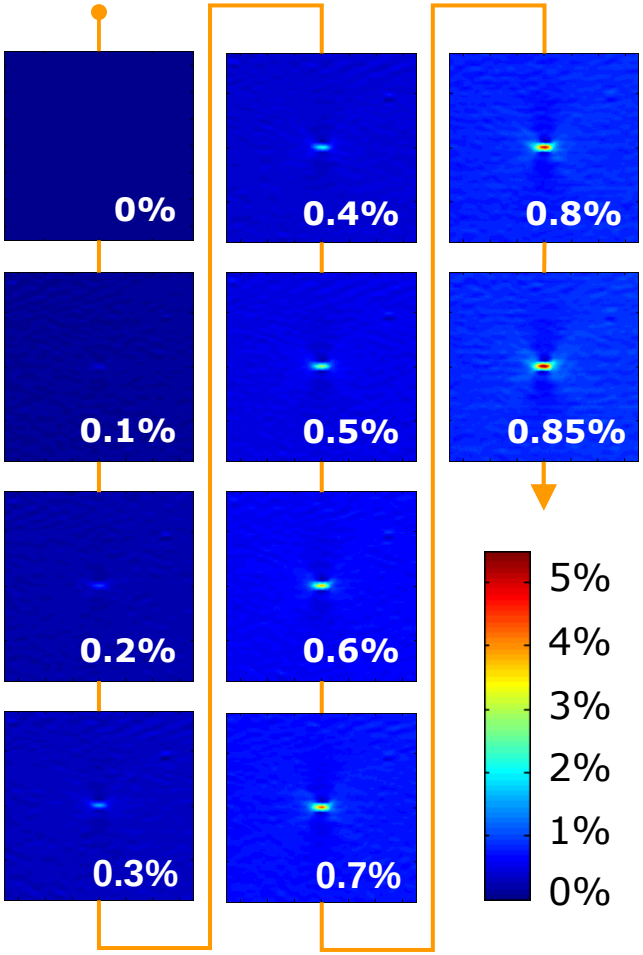




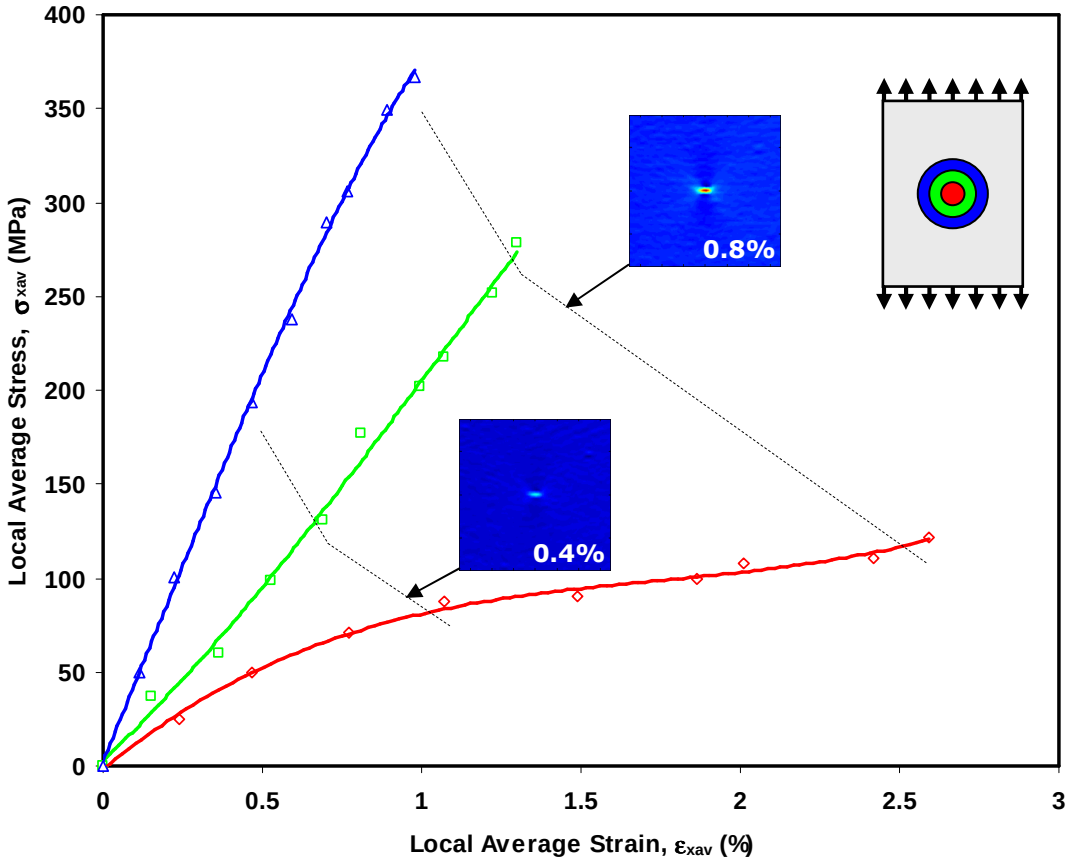


Sztefek & Olsson (2008). Composites Part A

Tension – nonlinear material behaviour

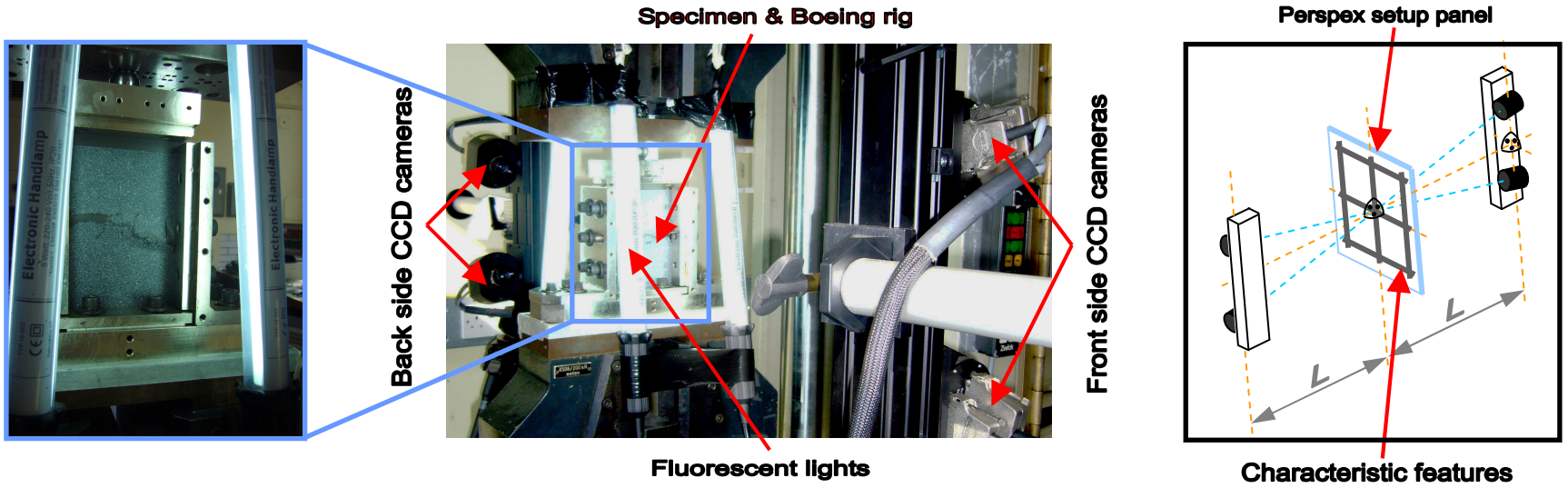


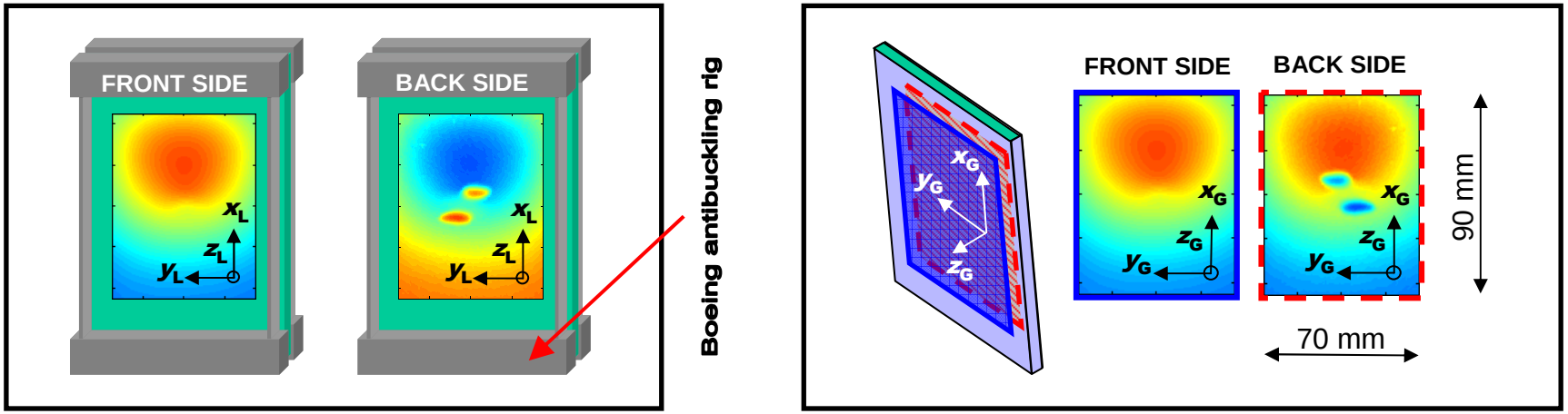
Strain concentrations at different applied (far-field) strains



Heterogeneous nonlinearity

Experimental setup in compression

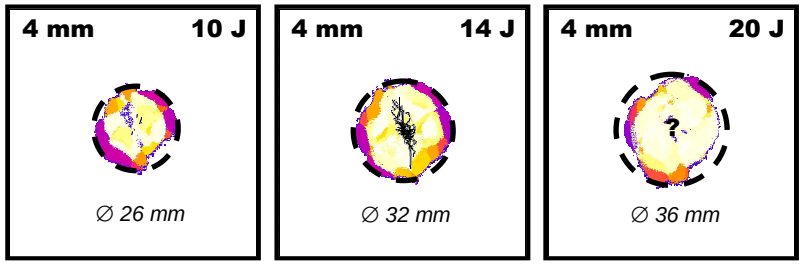


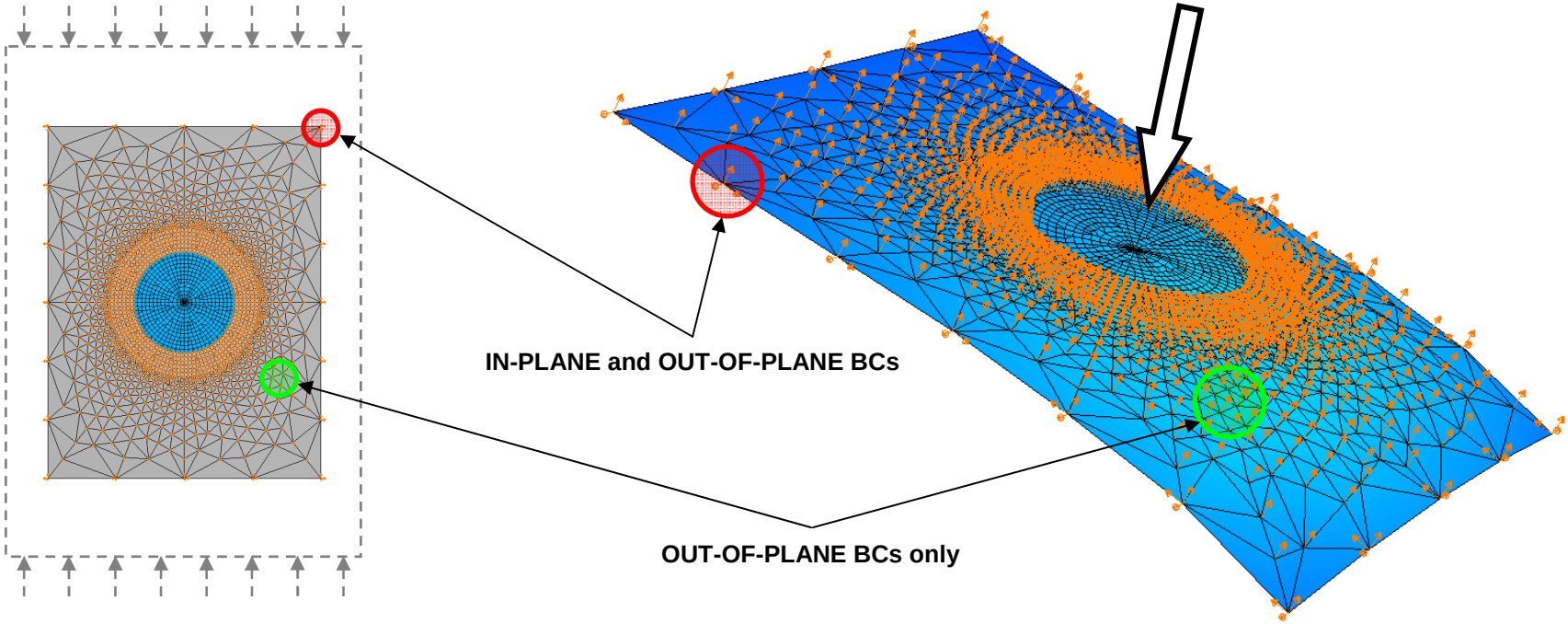


Finite element model in compression

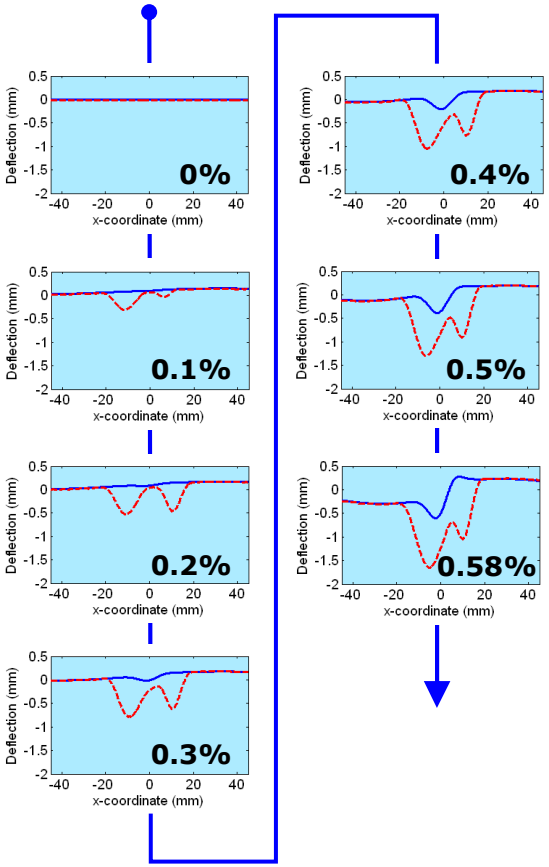
FE analysis

- **Homogeneous isotropic thin shell**
- **Geometrically nonlinear analysis**
- **Full-field boundary conditions**

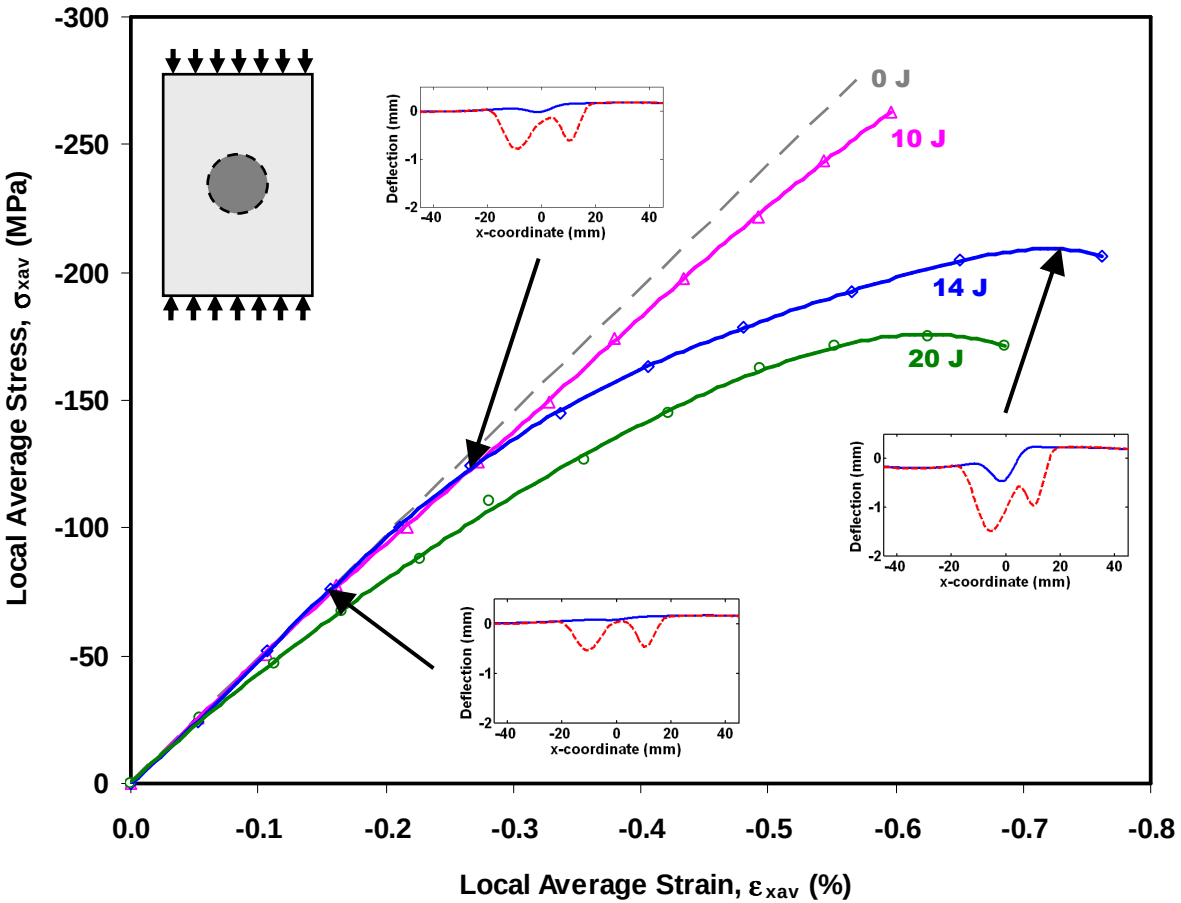




Apparent material nonlinearity in compression



14 J: Buckling patterns at different applied strains

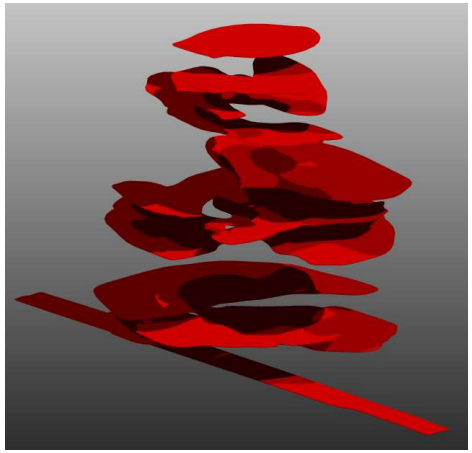


Comparison of apparent material behaviour

Sztefek & Olsson (2009). Composites Part A

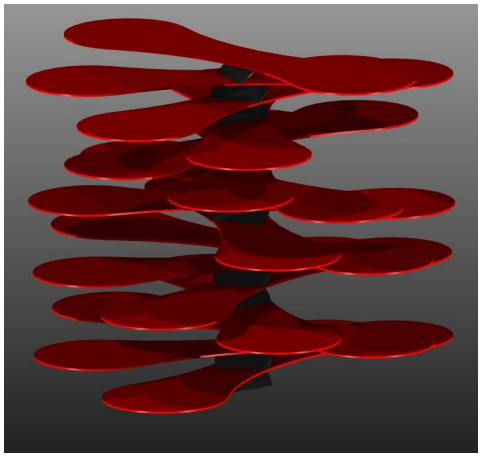
Structural FE model of impact damage

Realistic damage

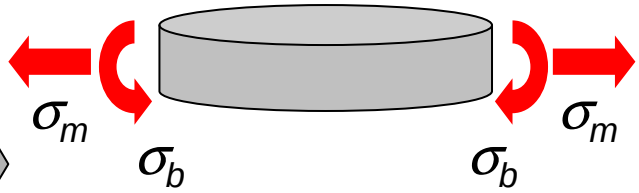


- **Determine structural behaviour by detailed analysis**
- **Then represent damage by nonlinear element**

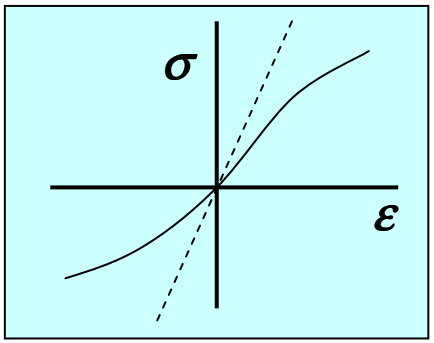
Simplified model

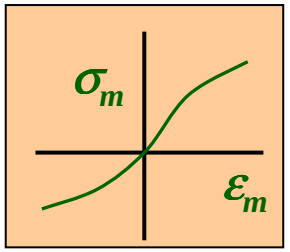


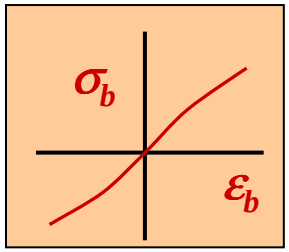
Equivalent model



Behaviour of damaged ply



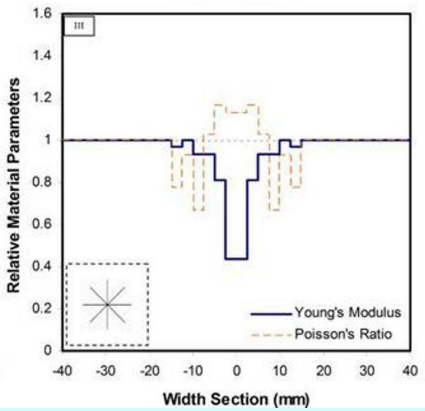


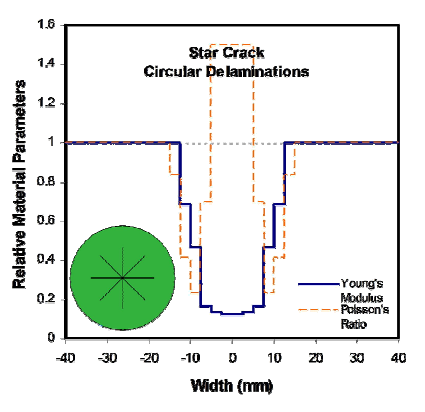


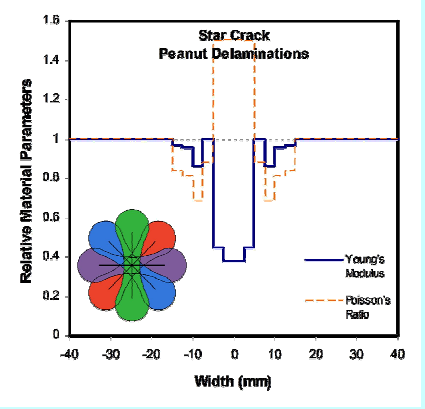
FE-model of impact damage in tension

Generic damage

2 mm, 8 ply laminate



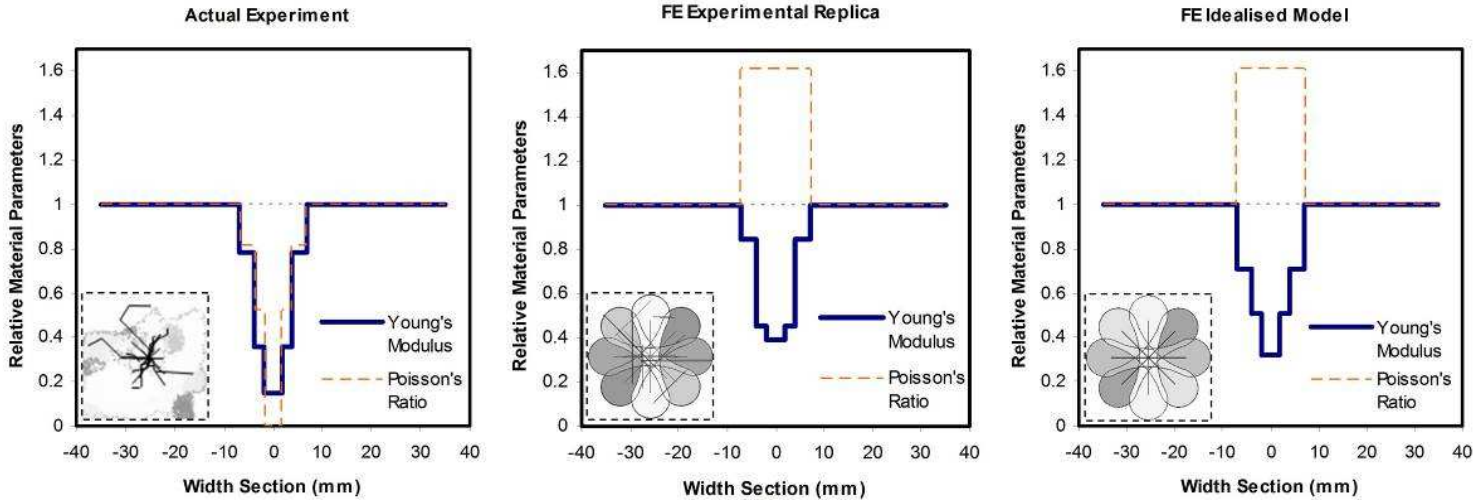




Too local influence **Too extensive influence** **Realistic influence**

Impact damage

2 mm, 16 ply laminate

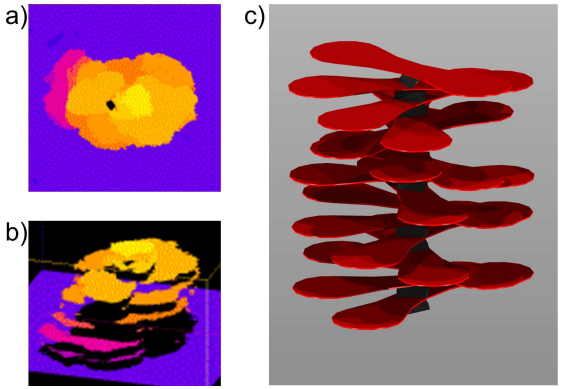


Sufficient to model cracks and delaminations by regular pattern

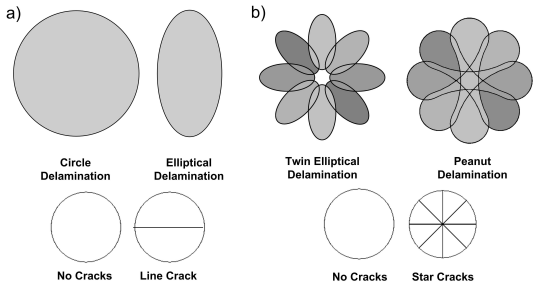
Craven, Sztefek, Olsson (2008). Compos Sci Technol.

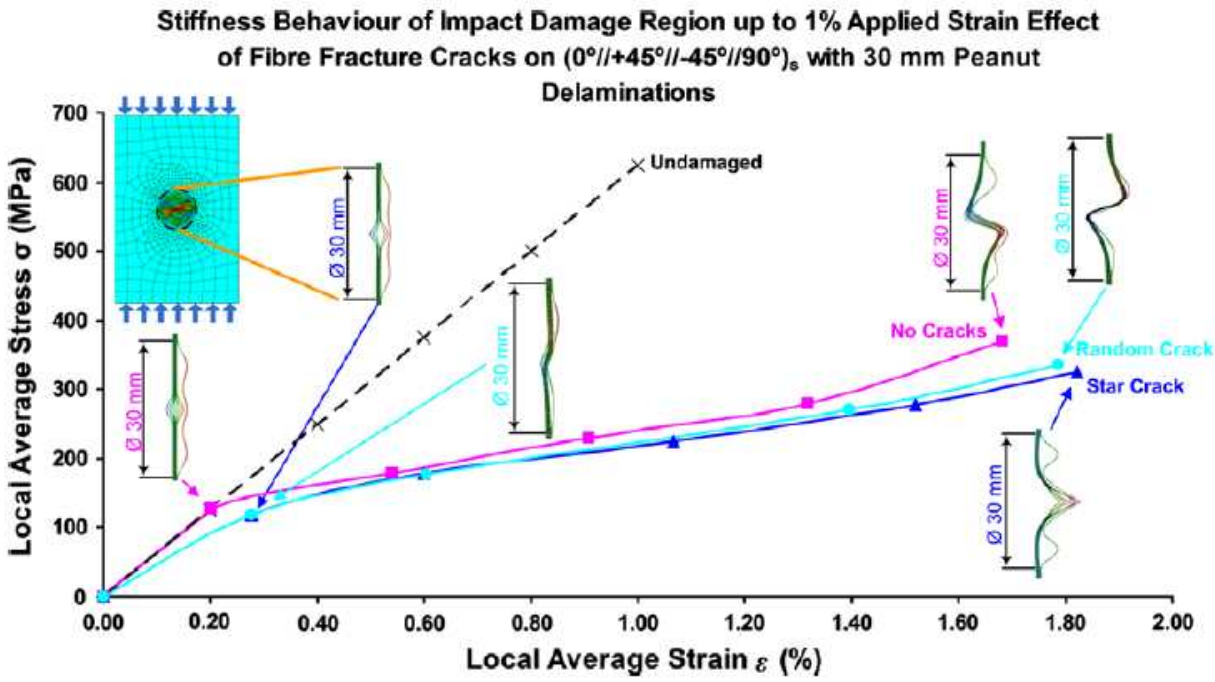
FE-model of impact damage in compression

Damage 3D geometry



Assumed damage patterns





Craven, Iannucci, Olsson (2010). Composites A

Possible future development

- **Determination of flexural stiffness by out-of-plane loading**
- **Measurement on ground to support decisions on need for repair**
- **Measurements in flight to support decisions on maintenance**
- **In-vivo measurement of nonlinear biological tissue**

Related work by Kim, Pierron, Wisnom and Syed-Muhamad (2007)

- **Local flexural stiffness determined by out-of-plane loading and measurement of slopes**
- **Direct inverse method (Virtual fields method) used**
- **Polynomial smoothing limited stiffness gradients**