CompTest 2023

11th International Conference on Composite Testing and Model Identification

Girona, Spain May 31 – June 2

UNIVERSITY OF
Southampton

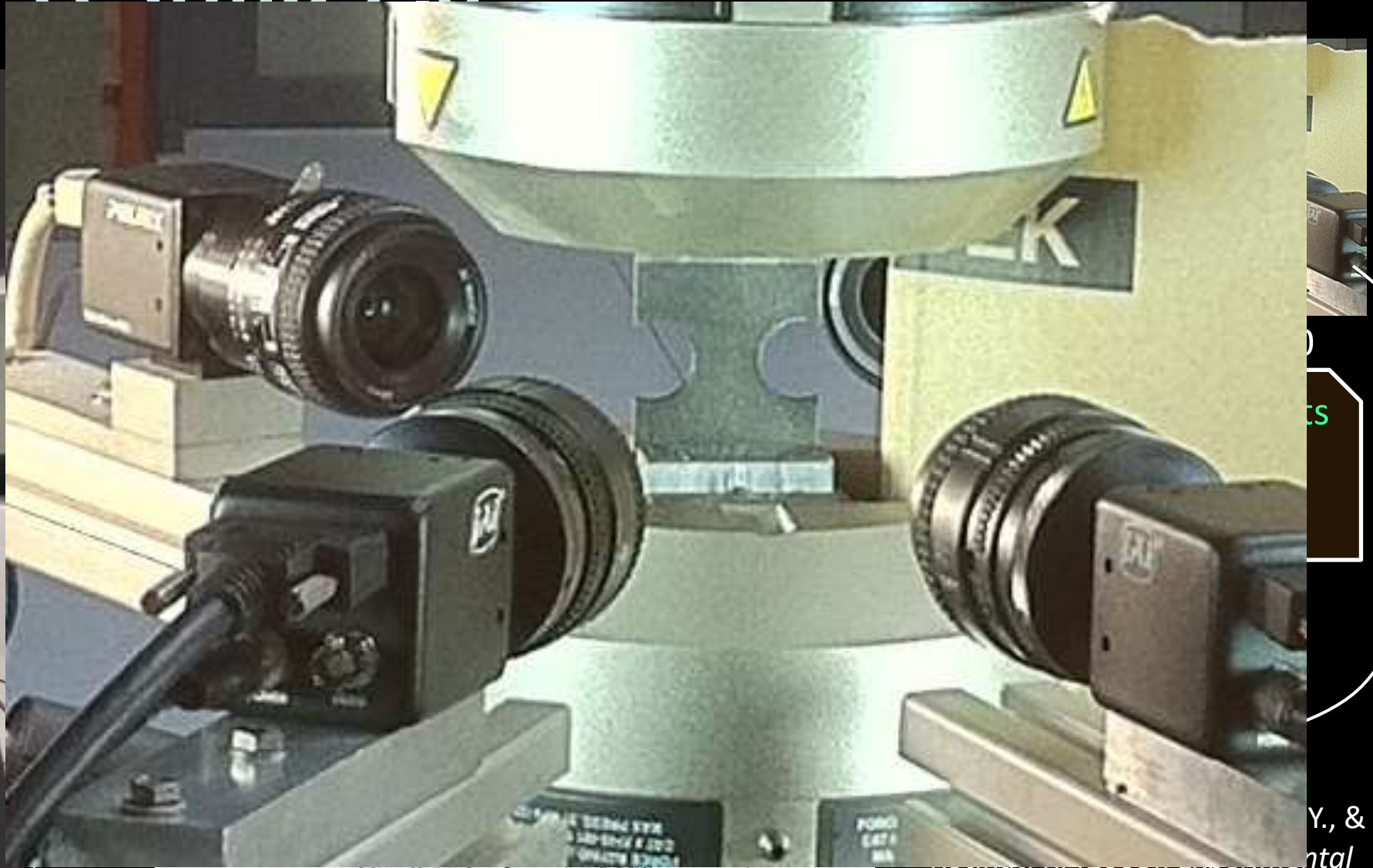# Material Testing 2.0 for composites

Prof. Fabrice PIERRON

Faculty of Engineering and Physical Sciences
University of Southampton, UK

Also R&D Director at

MatchID
Metrology beyond colors
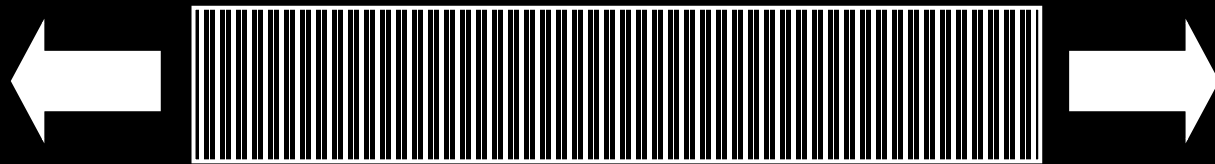
www.matchid.eu

Material Testing 2.0

Motivation

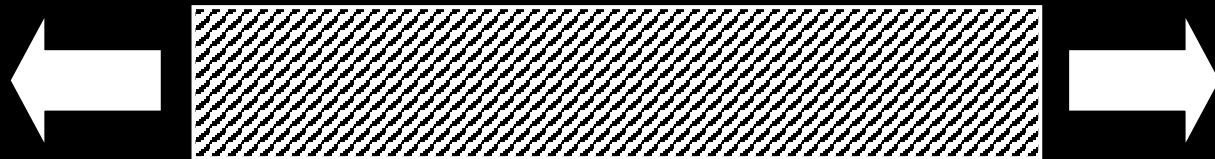## Test efficiency
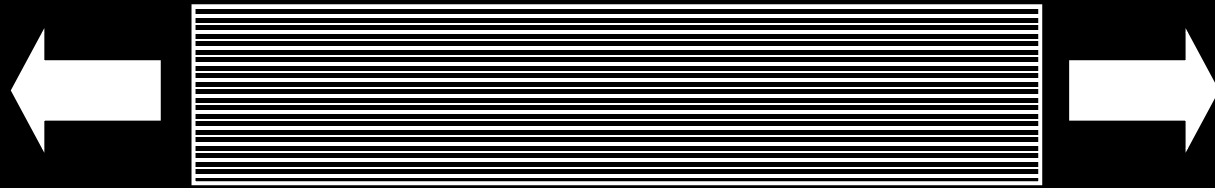
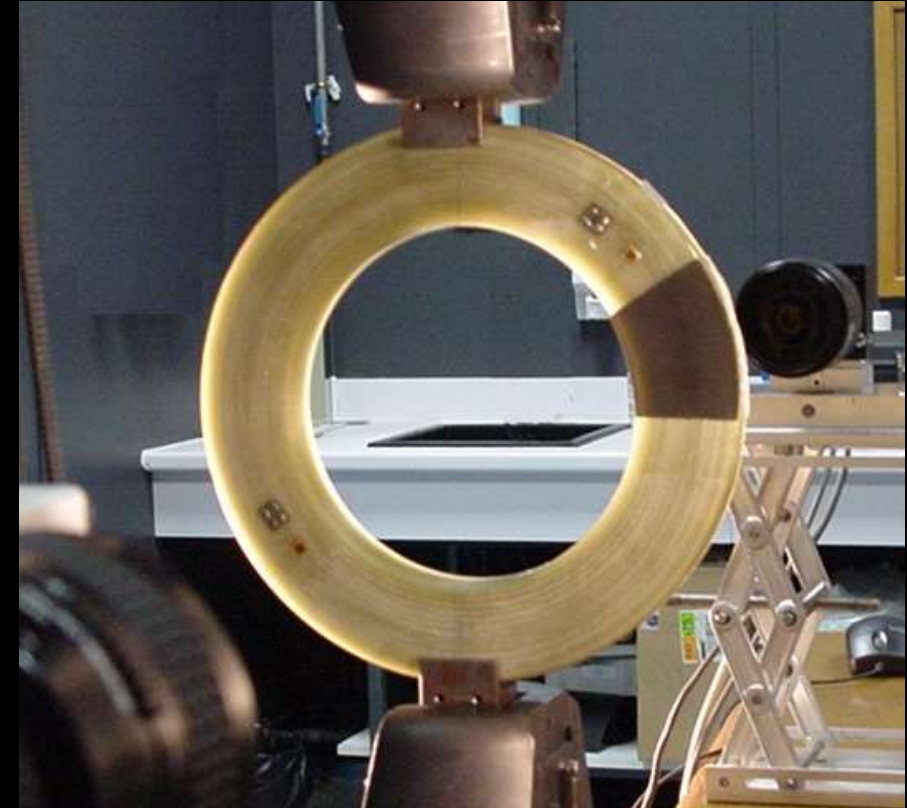
0°   tensile test

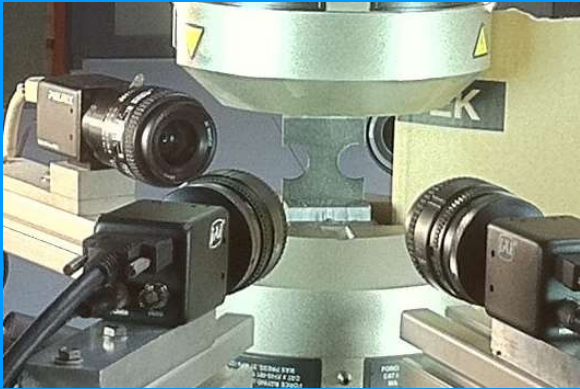90°   tensile test

Shear test (off-axis)

Complex geometry

Key features of MT2.0

Decreasing level of maturity

→

Digital Image Correlation

Guide of good practice
www.idics.org

MatchID DIC courses

Inverse identification

- Finite Element Model Updating (FEMU)
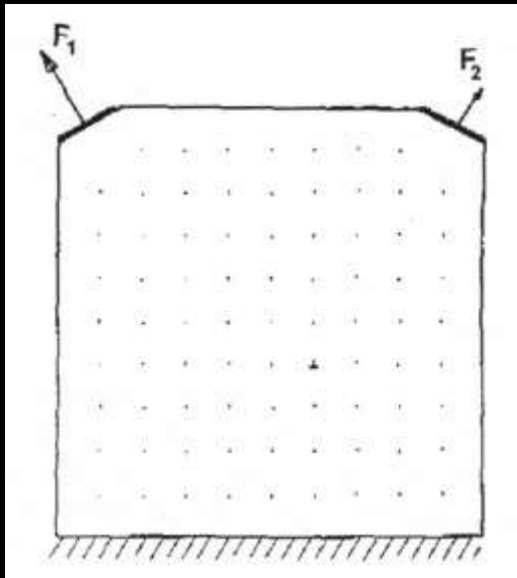
- Virtual Fields Method*

- Model discovery

MT2.0 Test configurations

- Test design

- Uncertainty quantification

Digital twin
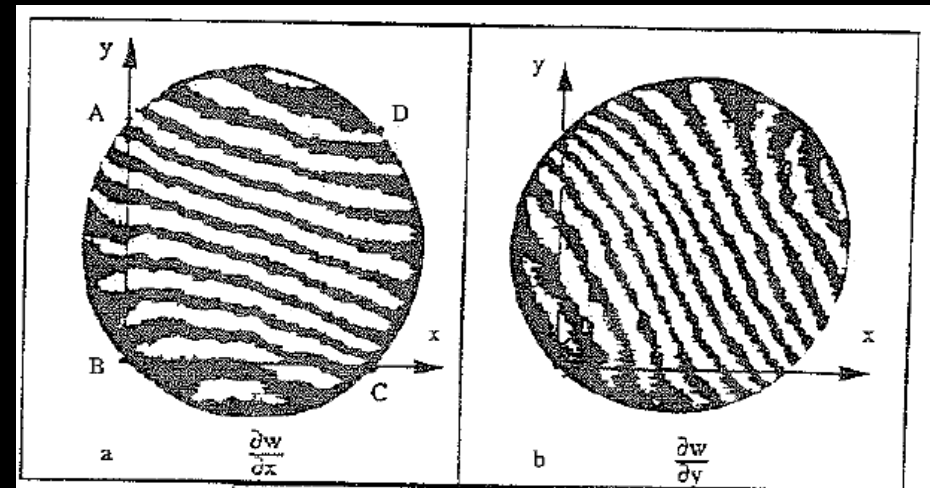
The pioneers

- ## 1991
  - Point tracking

Textile membrane

Camera system

- ## 1993
  - Moiré deflectometry
  - Carbon/epoxy composite

Hendriks, M. A. N. (1991). Identification of the mechanical behaviour of solid materials, TU Eindhoven. **PhD.**

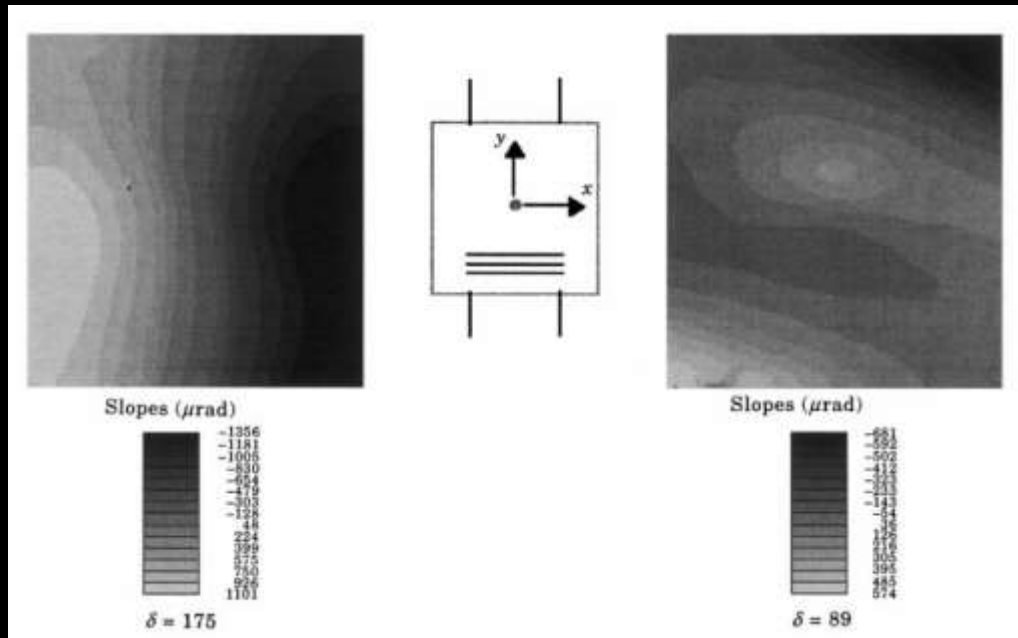Grédiac, M. and A. Vautrin (1993). European Journal of Mechanics a-Solids **12(6): 819-838.**
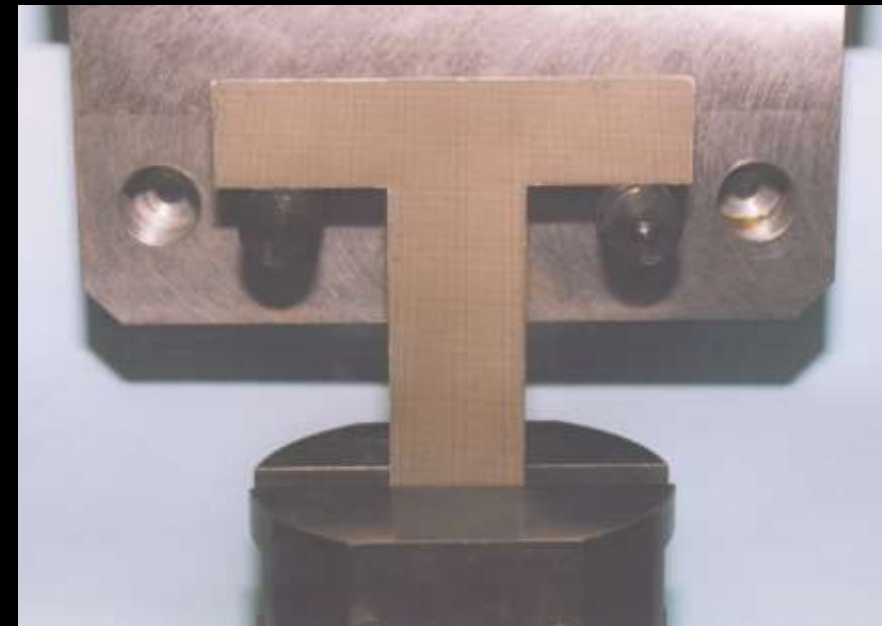
Better cameras

- 1998
  - Glass-epoxy UD
  - 'Optimized' geometry

Grédiac, M., et al. (1998).
Journal of Sound and Vibration **210(5): 643-659.**

- 1999
  - Carbon/epoxy plates
  - Vibration tests, deflectometry

Grédiac, M., Pierron F., Surrel Y. (1999)
Experimental Mechanics **39(2): 142-149.**
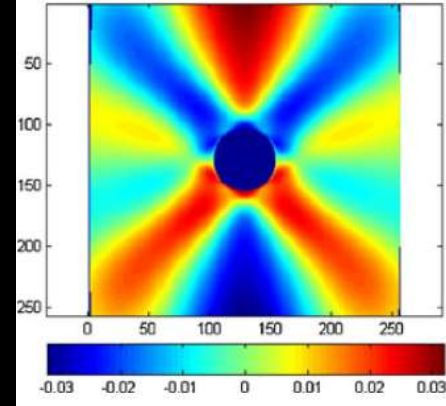
Some test configurations

Unnotched shear

Pierron, F., et al. (2007). Strain **43(3): 250-259.**
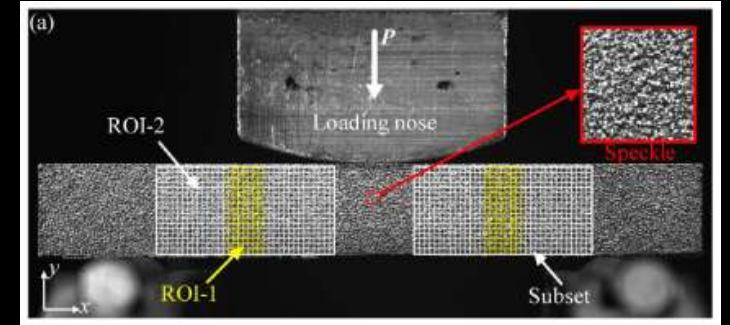Chalal, H., et al. (2006). Comp. A **37(2): 315-325.**

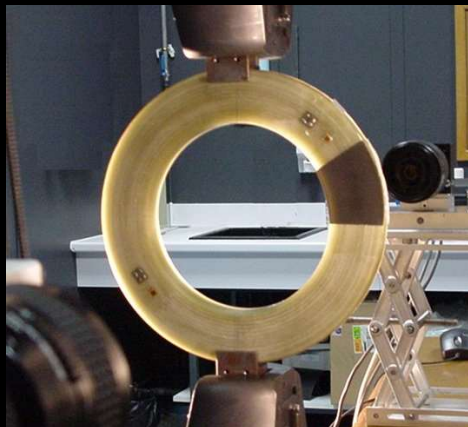## Open hole

Seon, G., et al. (2019).
App. Sci. **9(13): 2647.**

Gogu, C., et al. (2013).
Exp. Mech. **53(4): 635-648.**

Three-point bending

He, T., et al. (2018).
Comp. Struct. **184: 337-351.**

Ring

Moulart, R., et al. (2006). Comp. A **37(2): 326-336.**

Off-axis tension

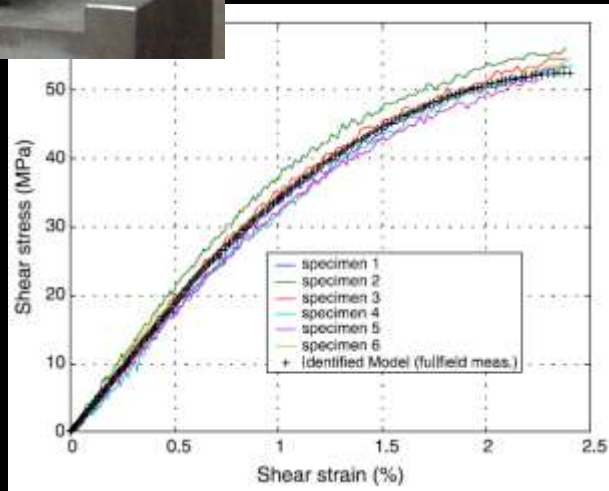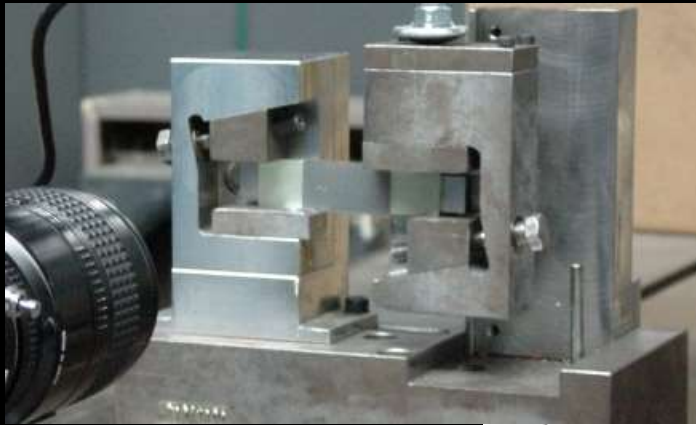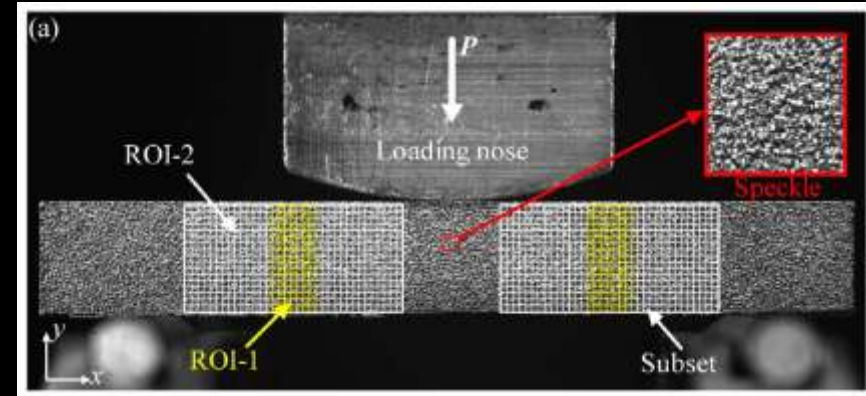Tavianatou, P., et al. (2022). EMMC 18 conference.

MAF

Wang, P., et al. (2016). Strain **52(1): 59-79.**
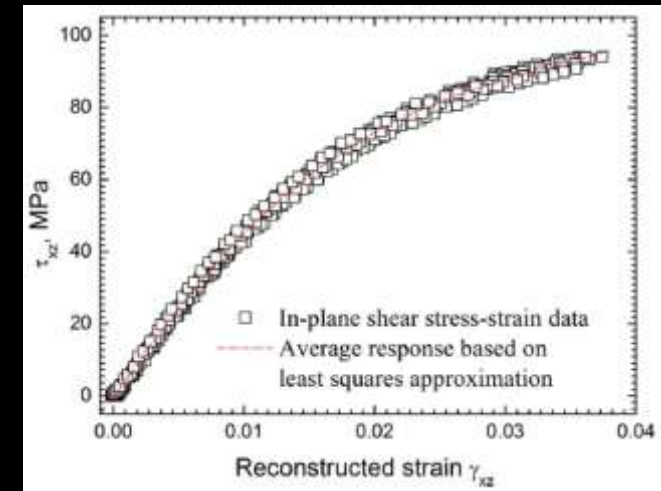
Non-linear behaviour (shear)

- **All stiffness components plus non-linear shear**

- **Interlaminar (all stiffness plus shear non-linearity)**

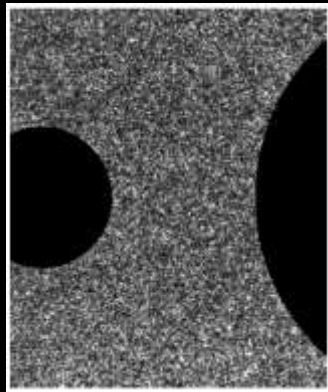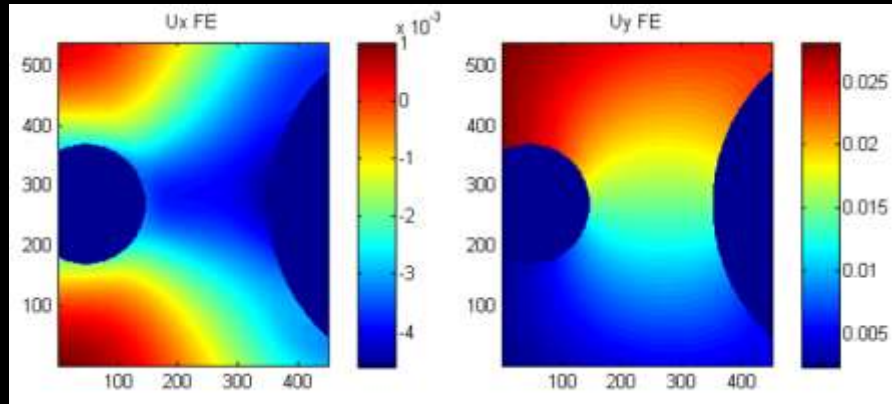Chalal, H., et al. (2006). Comp. A **37(2): 315-325.**

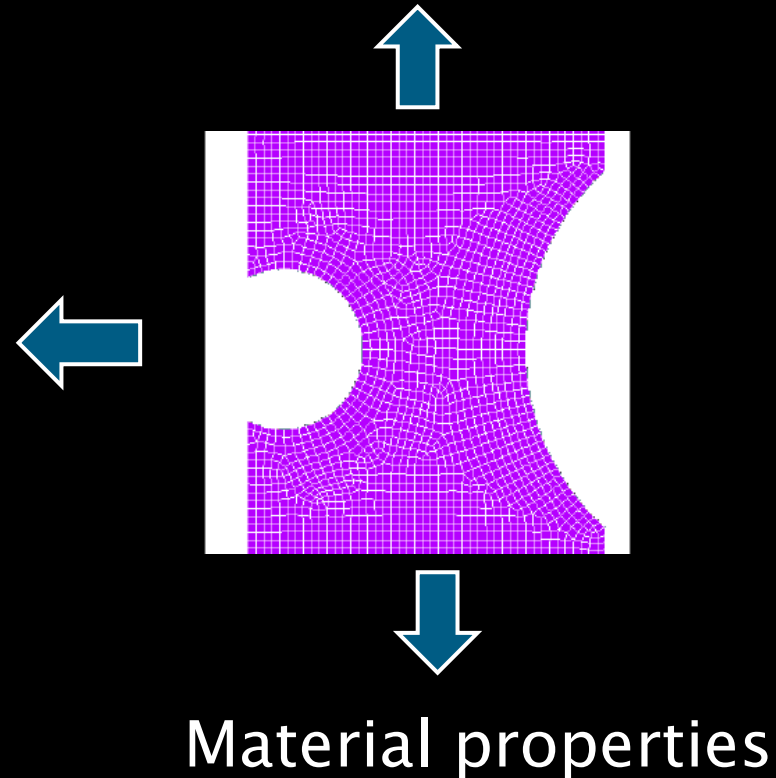He, T., et al. (2018). Comp. Struct. **184: 337-351.**

HOW TO DESIGN A TEST RATIONALLY?

Digital Twin

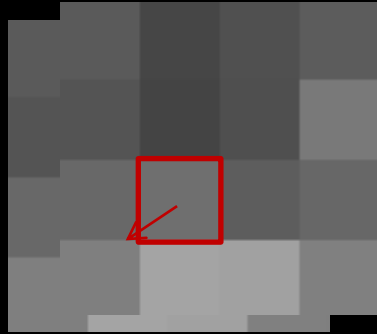- Simulate the complete identification chain

- Starting point:

Real speckle pattern (from experiment)

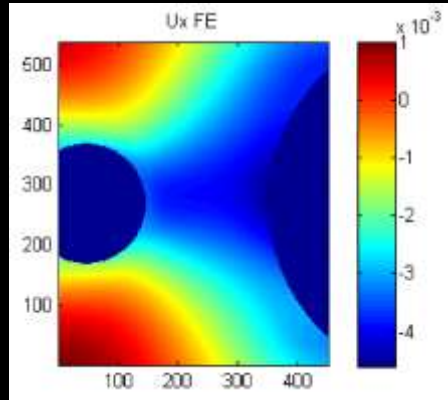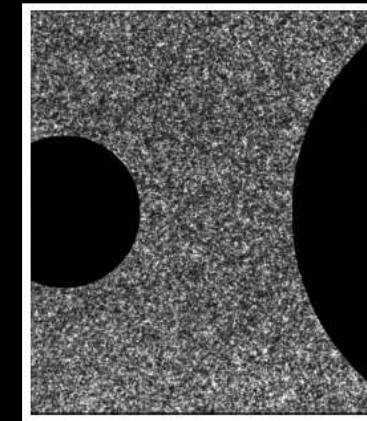Material properties

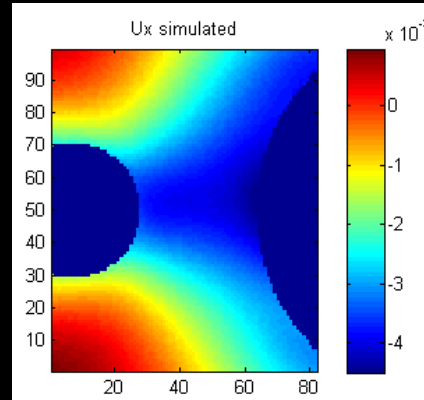# Synthetic image deformation

- ## Principle

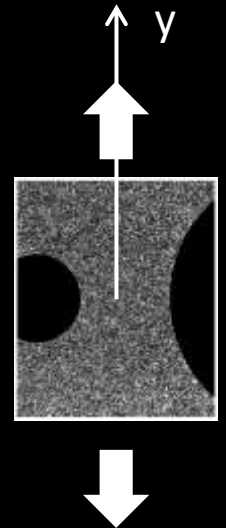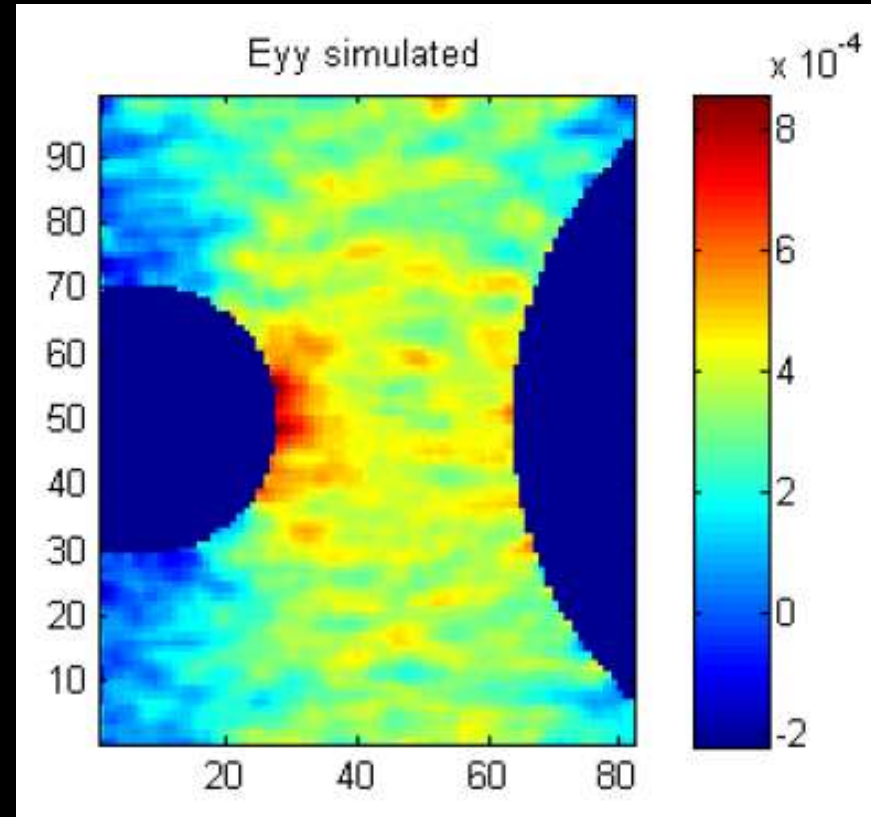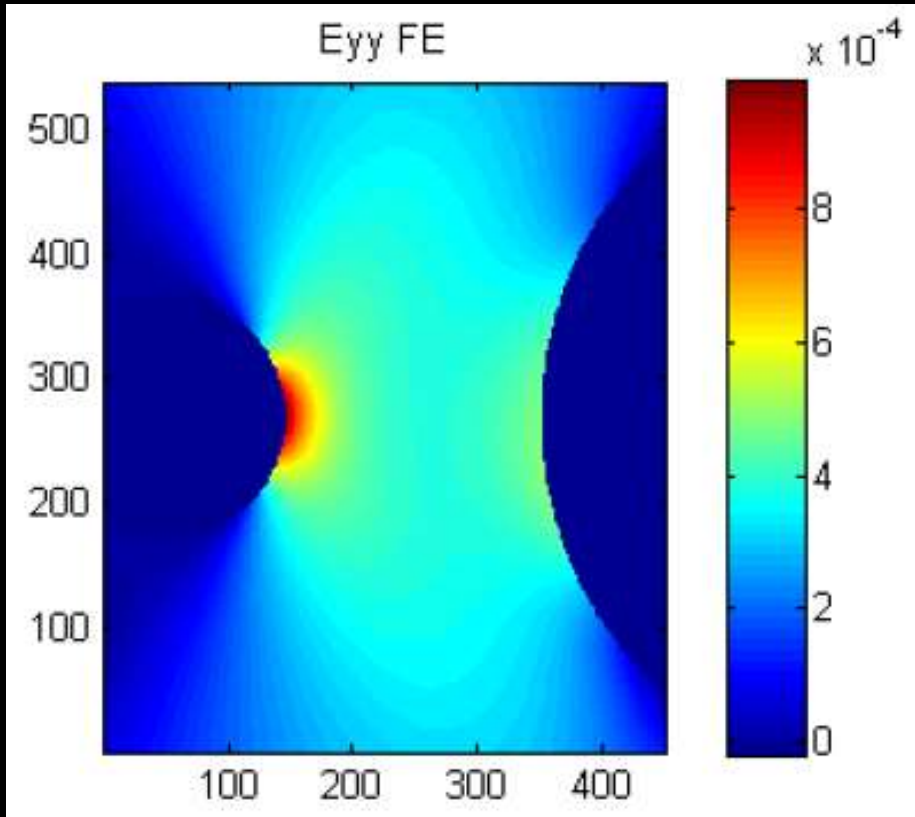New pixel intensity: average of

Doing this for all pixels leads to a deformed image
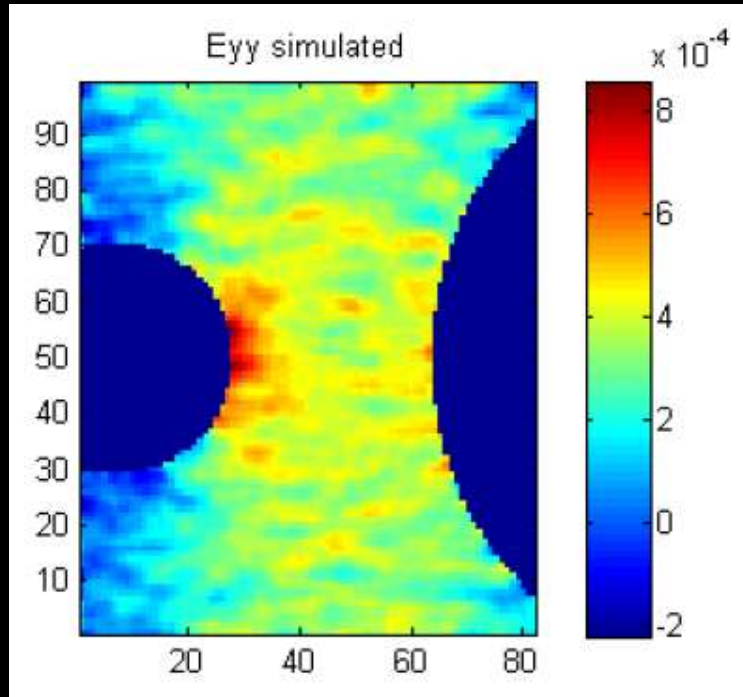
DIC leads to simulated displacements affected by the correlation

≠

More realistic simulations

Identification simulation

- VFM

Eyy simulated   x 10⁻⁴

Orthotropic stiffnesses
(identified)

Error metric

Digital Twin (DT)

Orthotropic stiffnesses
(reference)

Test design

- Orthotropic PVC foam

Orthotropy axes

θ: off-axis angle
α: loading angle
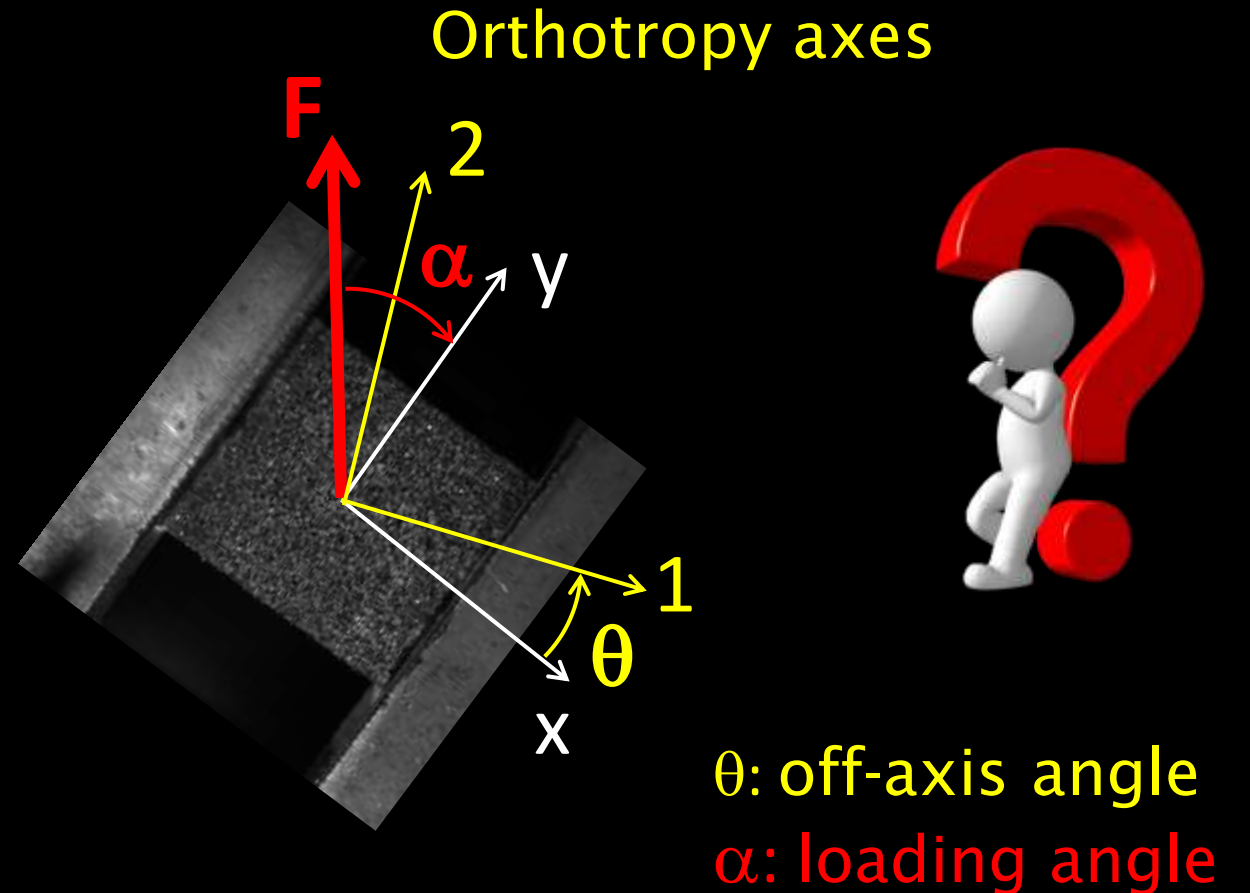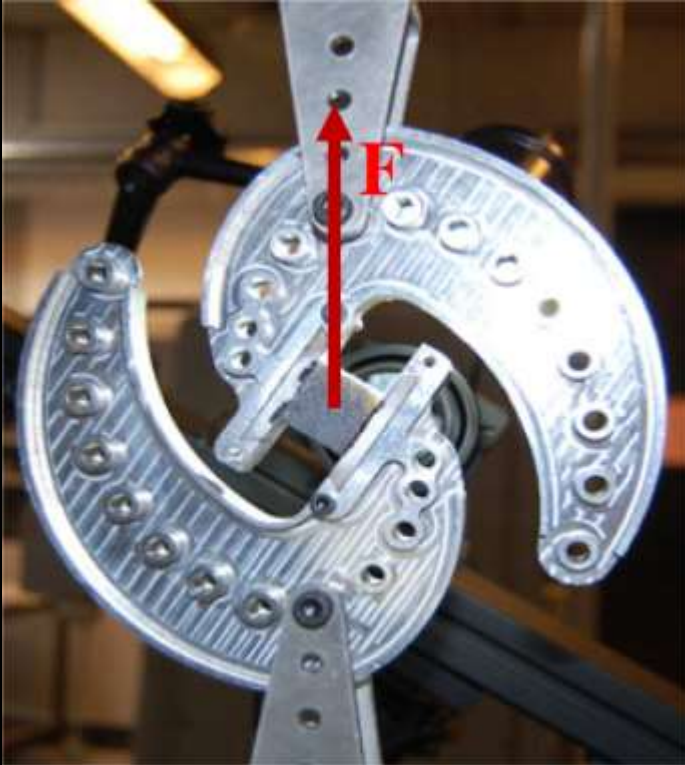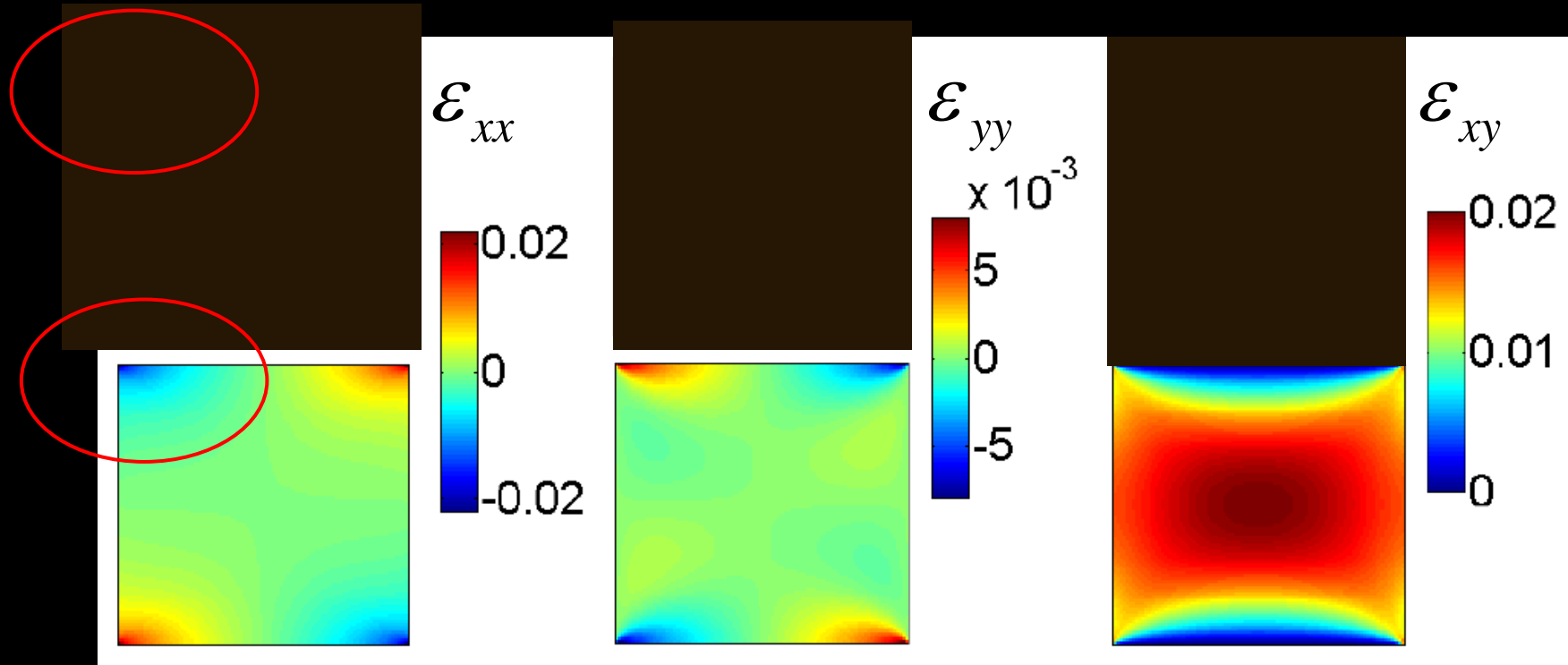
Wang, P., Pierron, F., Rossi, M., Lava, P., & Thomsen, O. T. (2016). Strain, 52(1), 59-79. doi:10.1111/str.12170
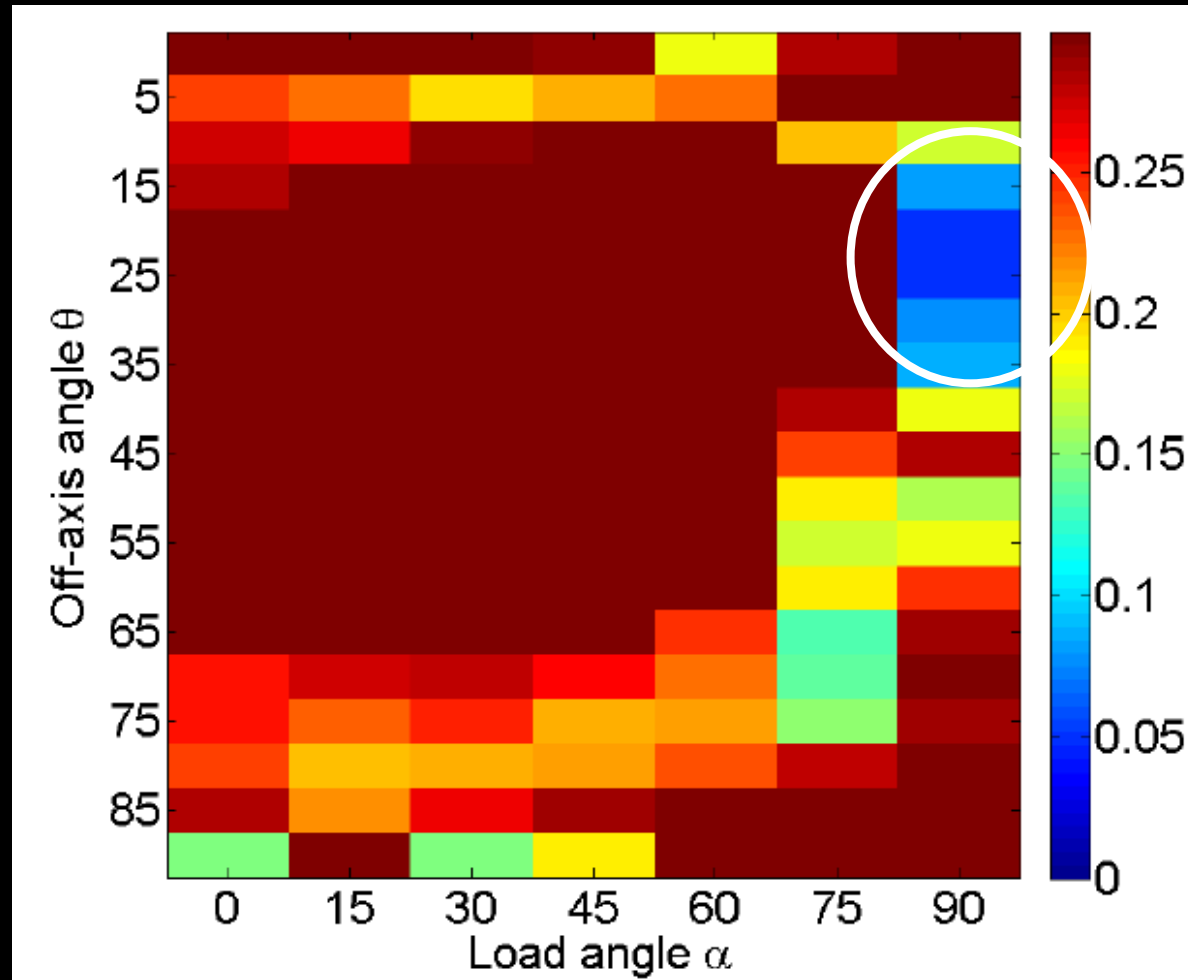
DIC as a low pass filter

FE/DIC reconstructed strains

$\mathcal{E}_{xx}$

$\mathcal{E}_{yy}$

$\mathcal{E}_{xy}$
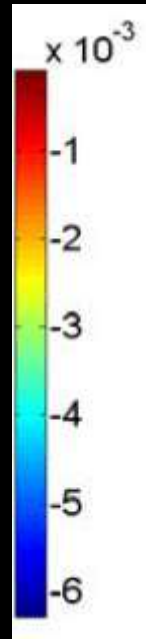
FE strains

Systematic error

- Noise free images

$$\sqrt{\sum_{ij}\left(\frac{Q_{ij}^{id}-Q_{ij}^{ref}}{Q_{ij}^{ref}}\right)^{2}}$$
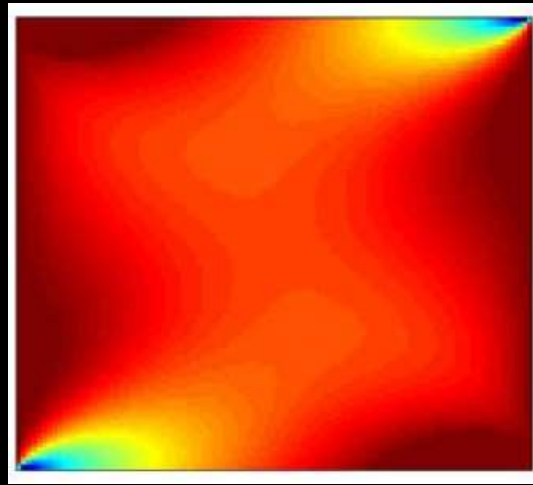
$$(ij)=(11,22,12,66)$$
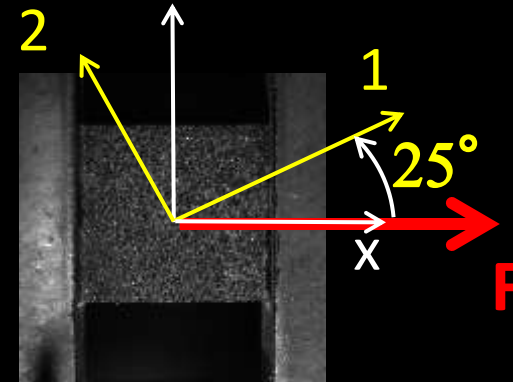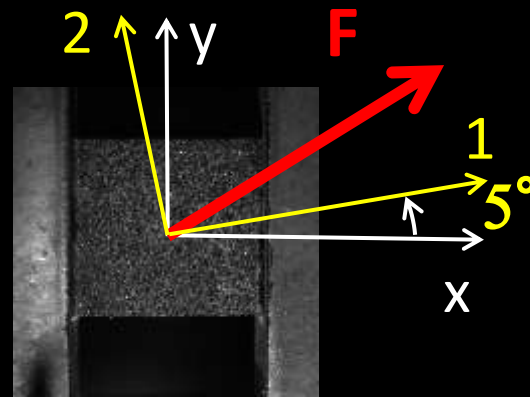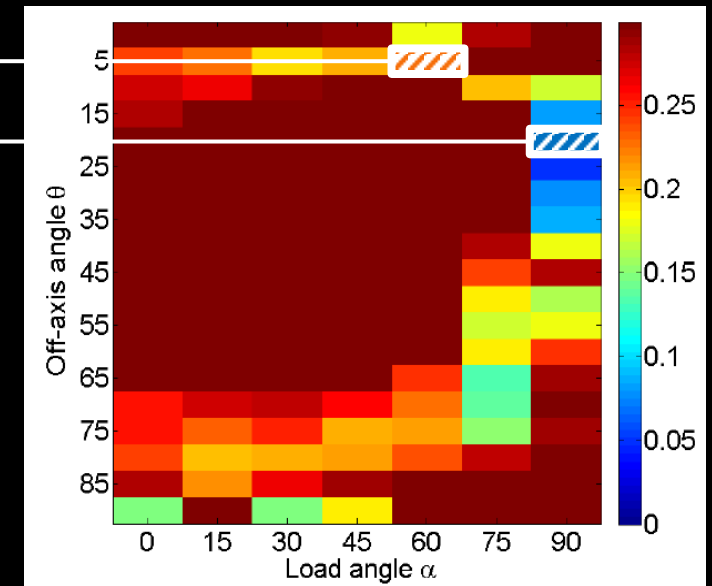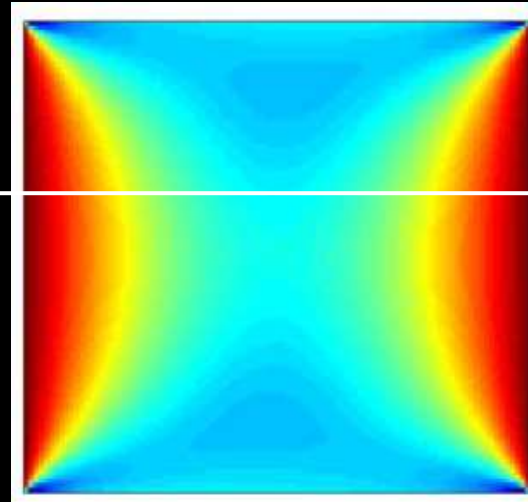
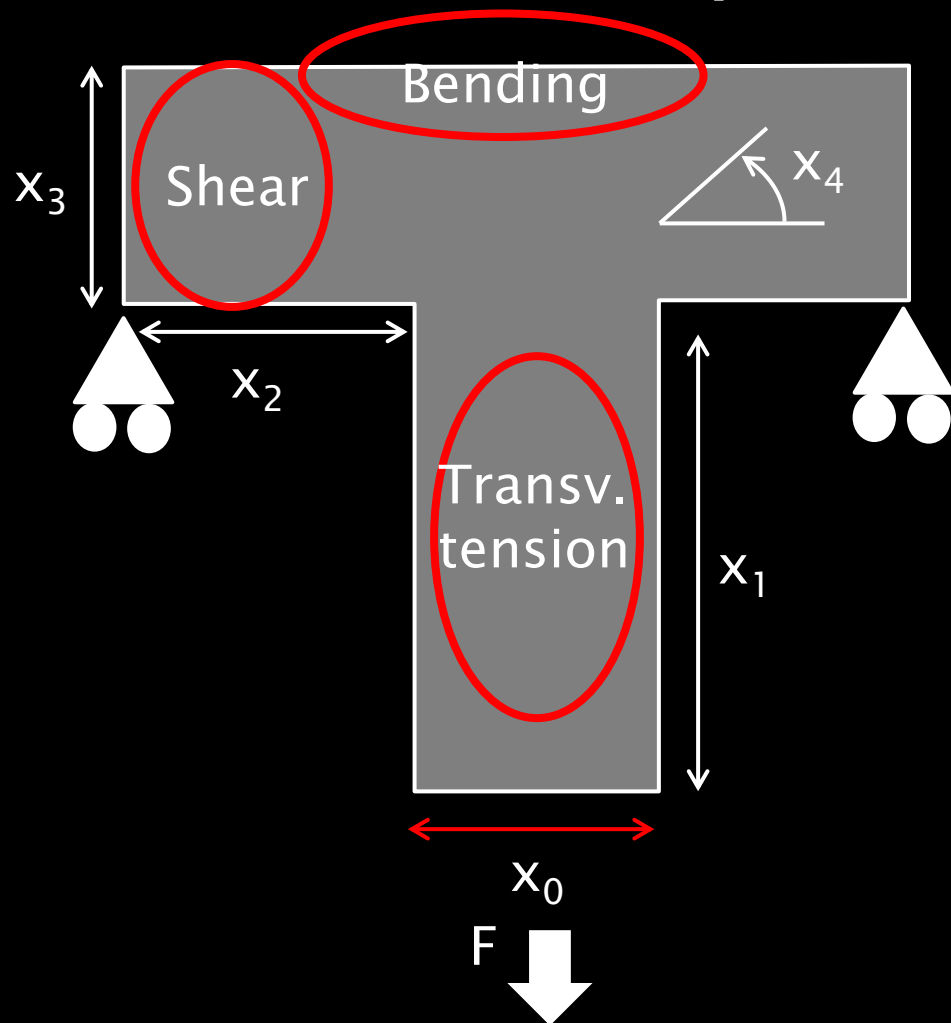Systematic error
of about 6%

Good vs bad configuration

Beware of intuitive choices
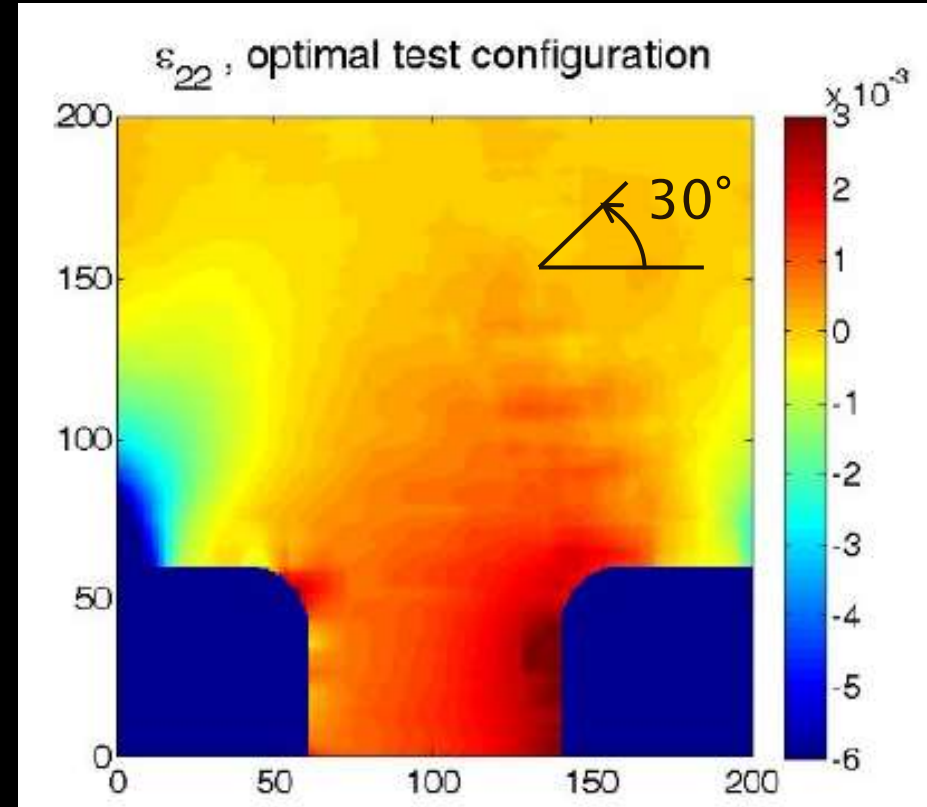
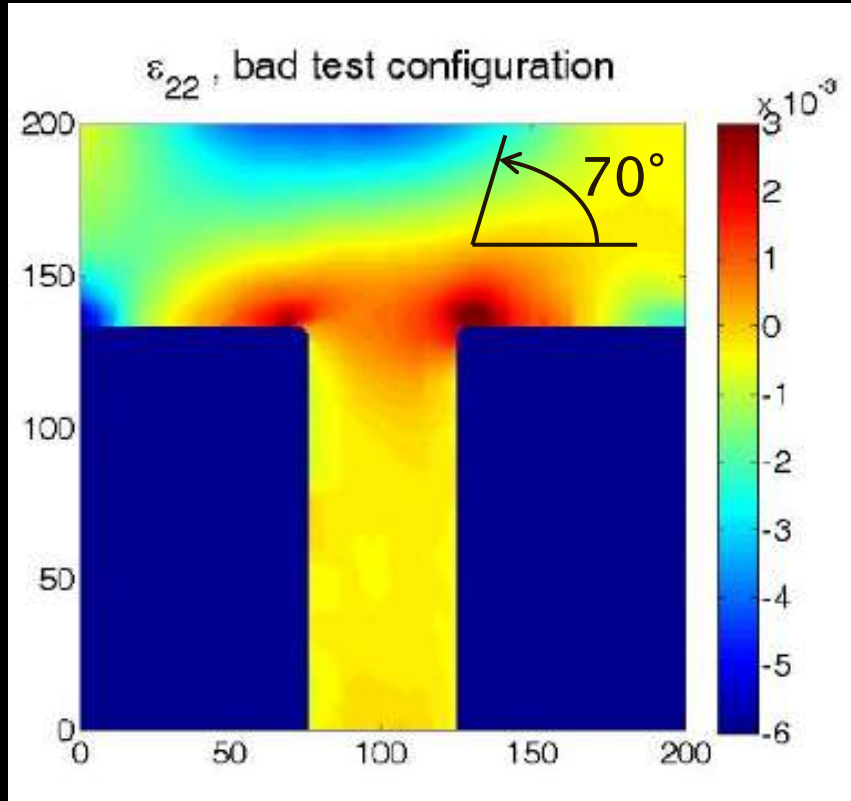- Back to the T-shaped specimen

Genetic algorithm
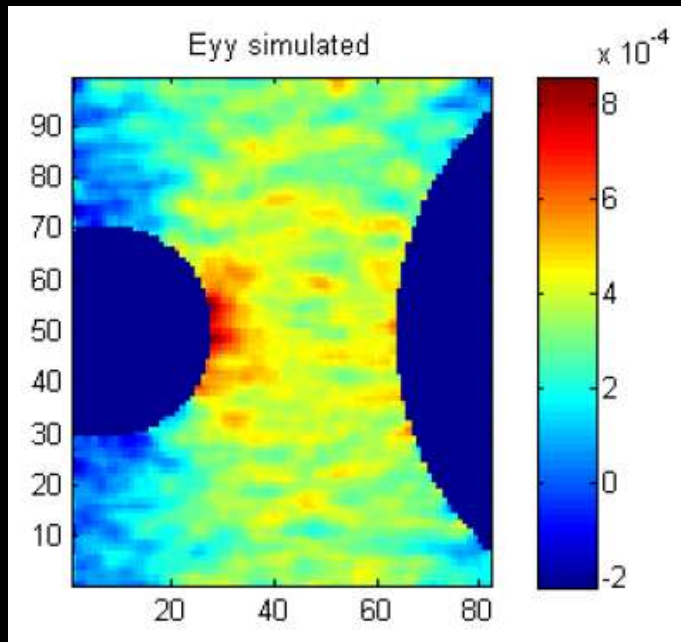- Geometry
- DIC parameters

X. Gu, F. Pierron, unpublished, 2018

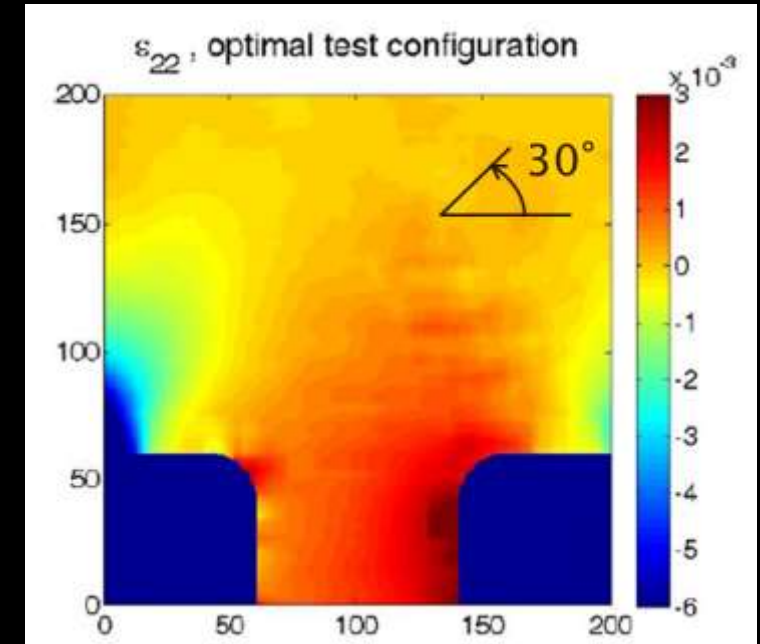# Beware of intuition

Take home message

DIC: game changer

Legacy tests are "suboptimal"

Test design & Standardization
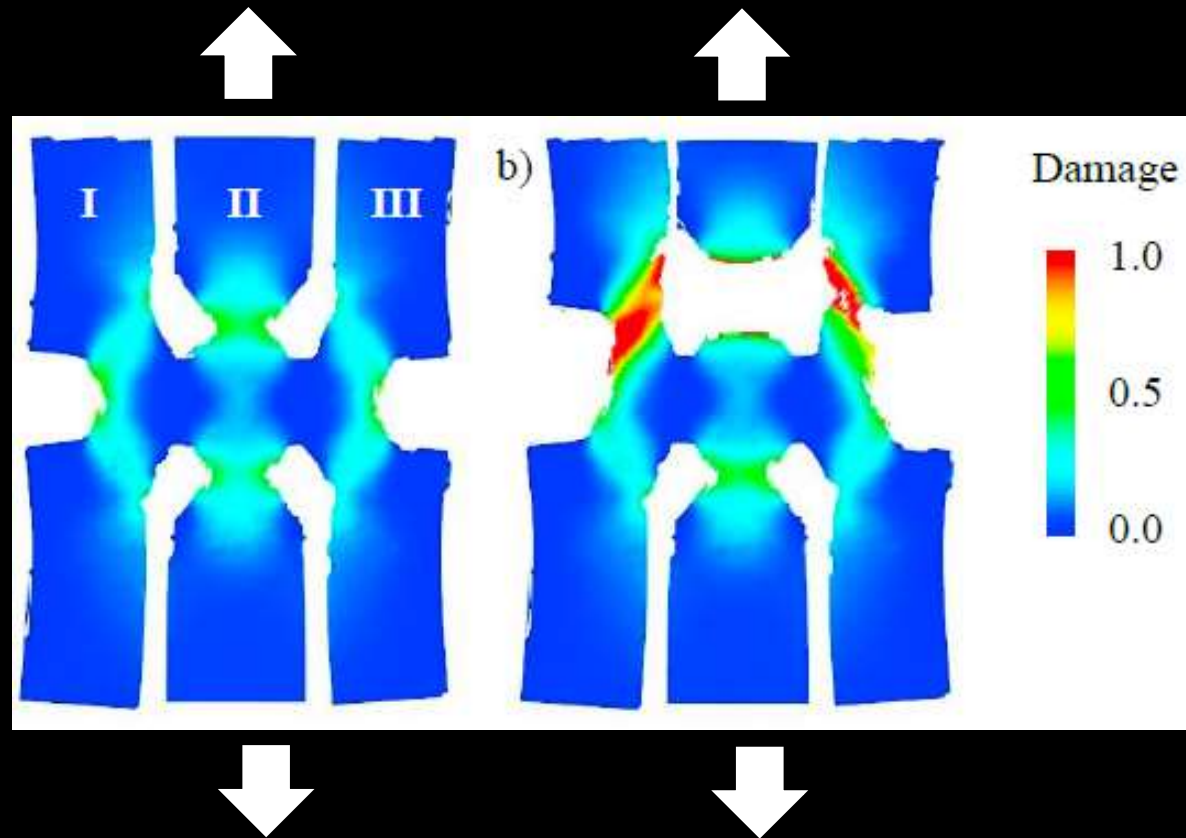
MT.2.0

References (Open Access)

- MT2.0: a brief review
  - Includes a section on composites

    Pierron, Strain, 2023

- Test design
  - Explore the design space rationally

    Pierron and Grédiac, Strain, 2021

Fracture?

- Specimen with multiple fracture site (metal)

Küsters, N. and A. Brosius (2019
Procedia Manufacturing **29: 458-463.**