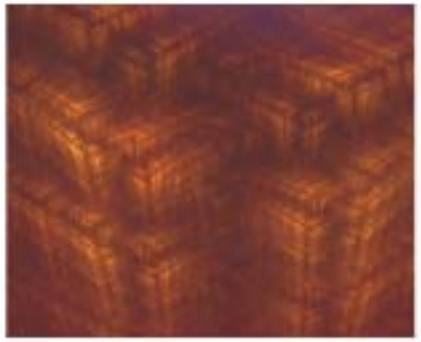


An Experimental and Numerical Analysis of the V-notched Rail Shear Test to Measure the Shear Properties of Fiber-Reinforced Polymers

Essam Totry, Carlos González & Javier LLorca
Universidad Politécnica de Madrid & IMDEA-Materials
E. T. S. de Ingenieros de Caminos. 28040 - Madrid, Spain

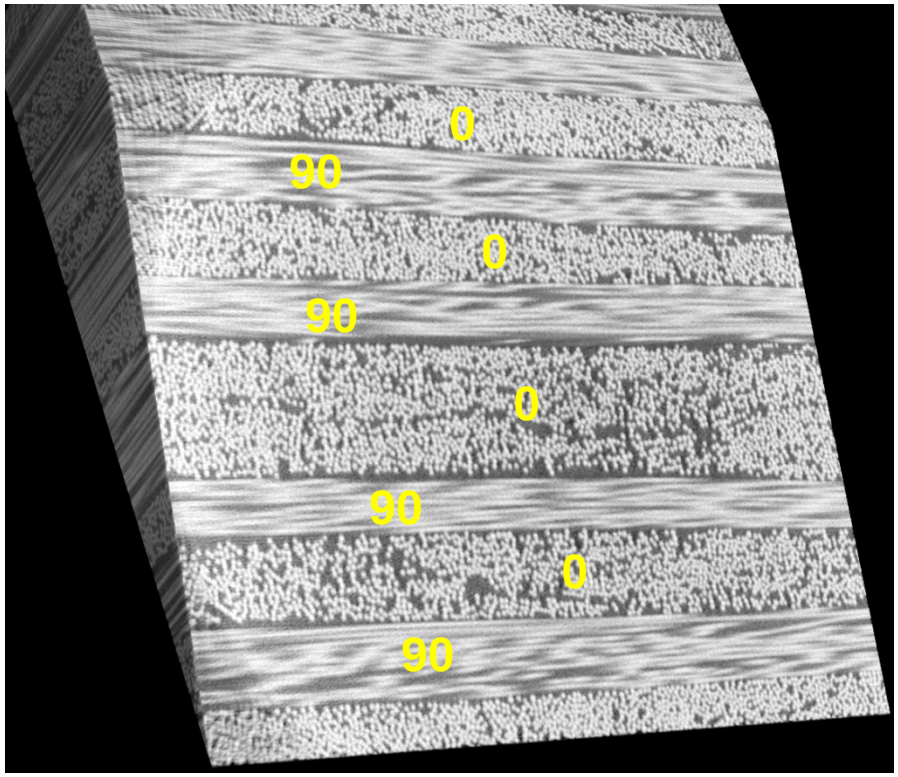
CompTest2008, 20-22 October 2008, University of Dayton, Dayton, USA

Outlines

- Composite materials tested
- Experimental techniques
  Experimental setup
- Results
- Computational micromechanics
- Conclusions

Composite Materials

Fibers	Matrix	Composite
High Strength carbon fibers (T700S); V_f=59% High Modulus carbon fibers (M40J); V_f=59% Glass fibers (E-glass) V_f=54%	+ Epoxy MTM57	MTM57/T700S $[0/90]_{3s}$ MTM57/M40J $[0/90]_{3s}$ MTM57/E-glass $[0/90]_{4s}$



The 350 300 [mm^2] plates were cured in an autoclave at 120^{o}C

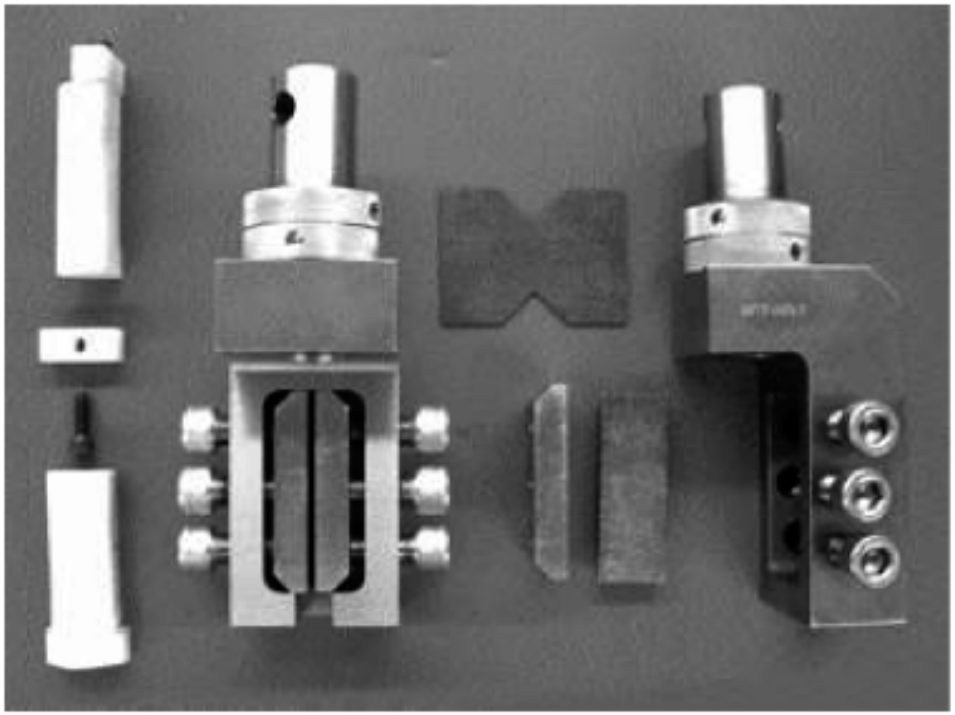
X-Ray Tomography

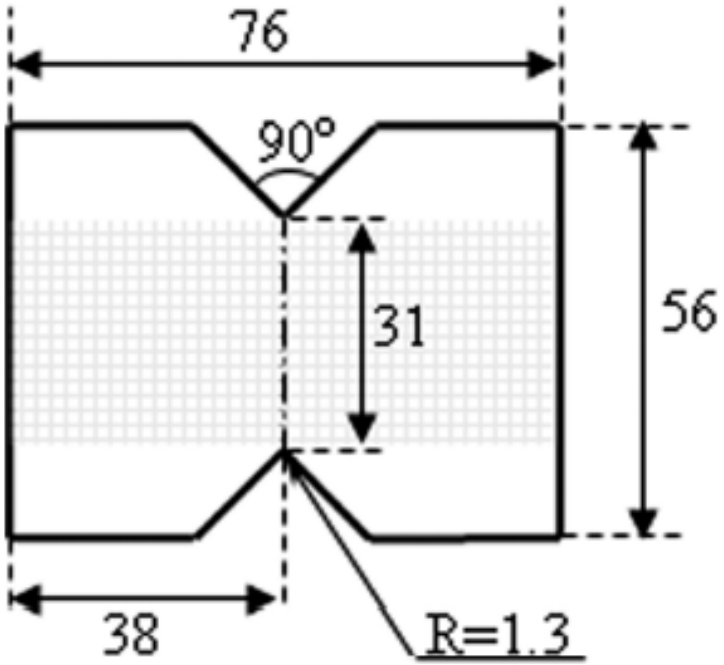
Stacking sequence of $[0/90]_{4s}$ glass/ MTM57 epoxy laminate

Phoenix X-Ray Nanotom (80 kV, pixel resolution 2.5 μm)

Sample preparation and Test fixture

V-Notched shear fixture and sample dimensions [mm]

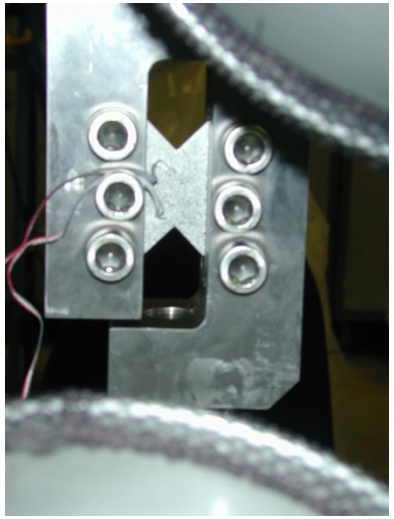




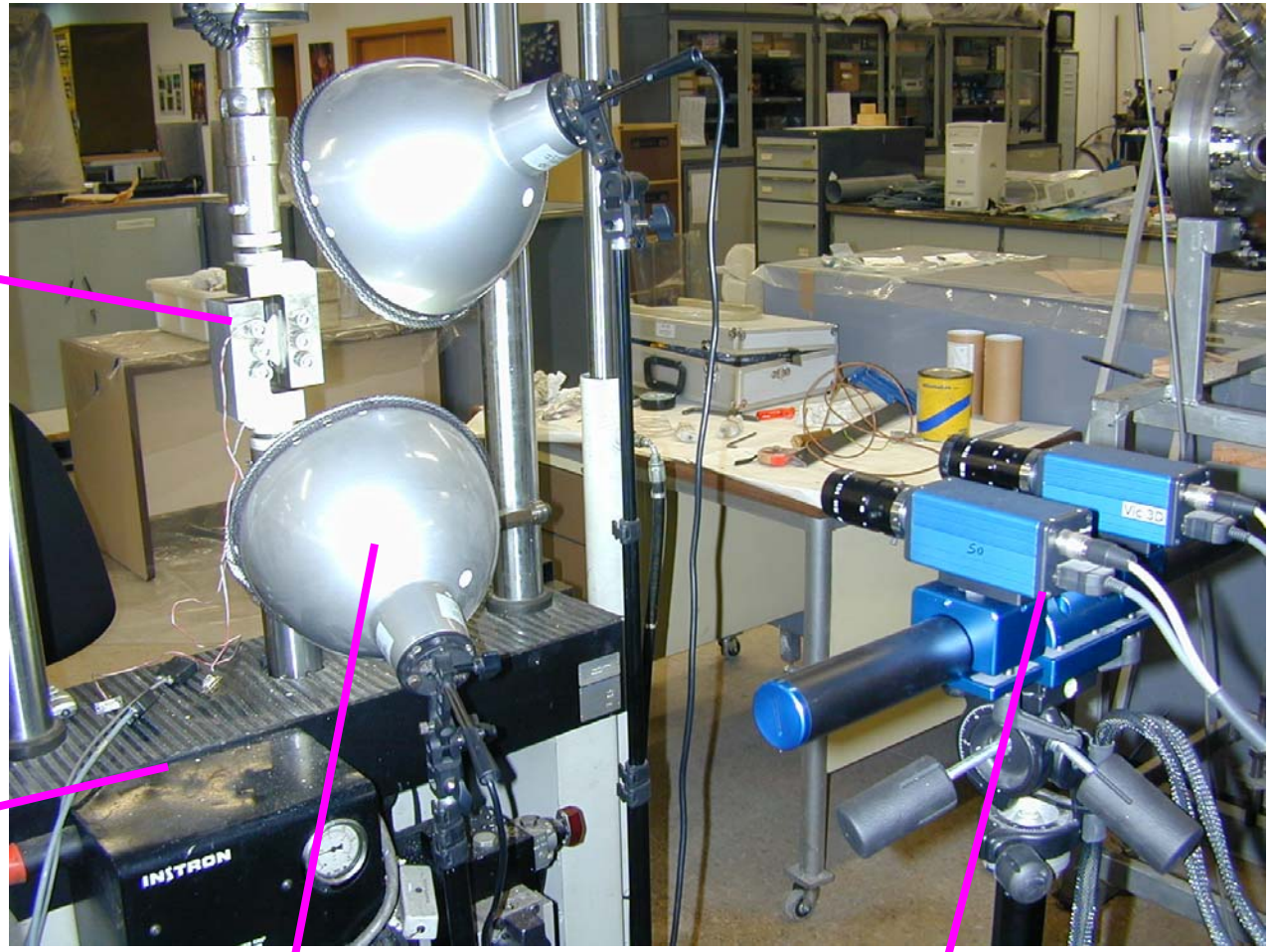
According to the Standard ASTM D 7078

Experimental setup

Strain rate of 1[mm/min]



Sample



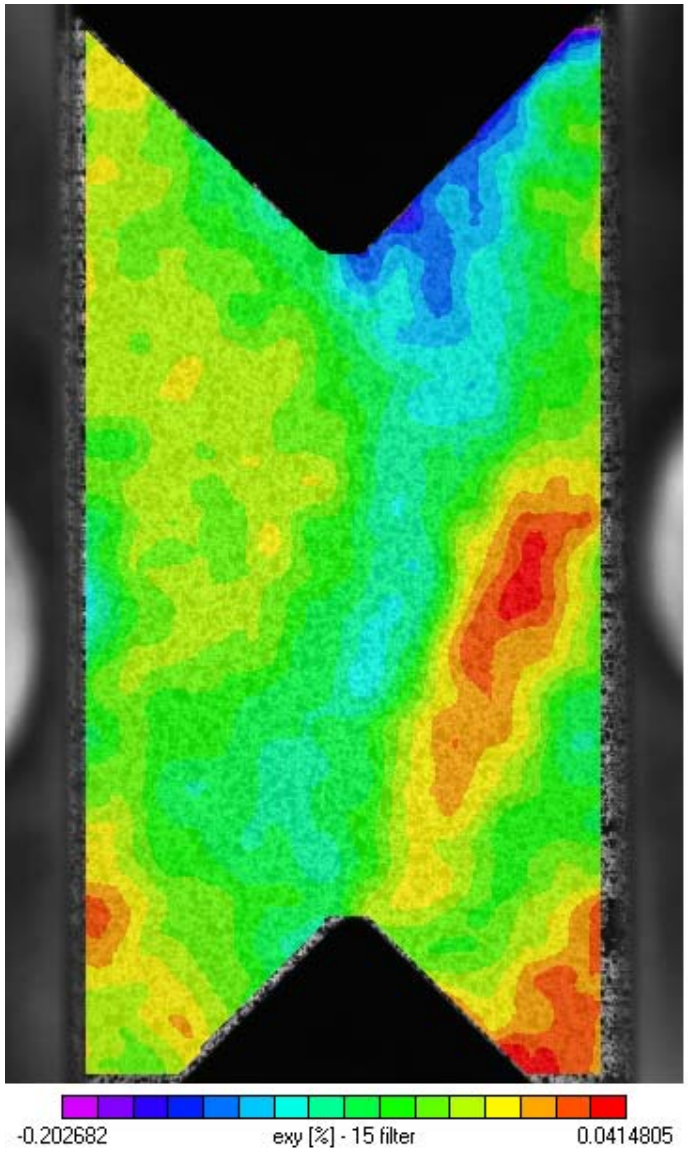
Instron 8501
Hydraulic sys.

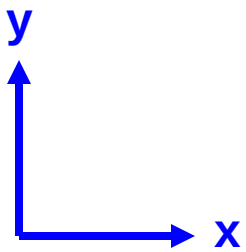
Illumination lights

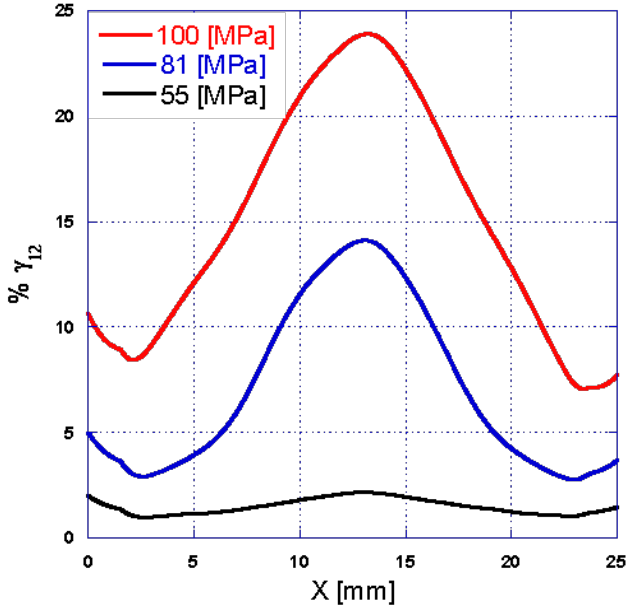
Digital Image Correlation cameras

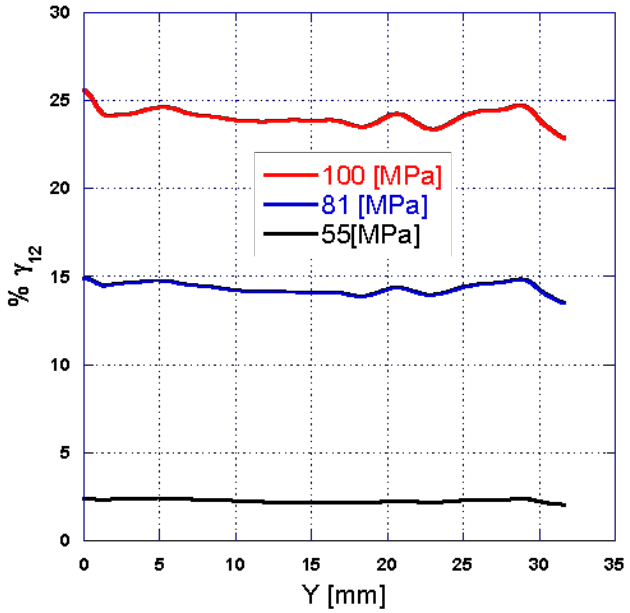
Shear Stain field γ_{12}

Glass fibers composite (MTM57/E-glass)



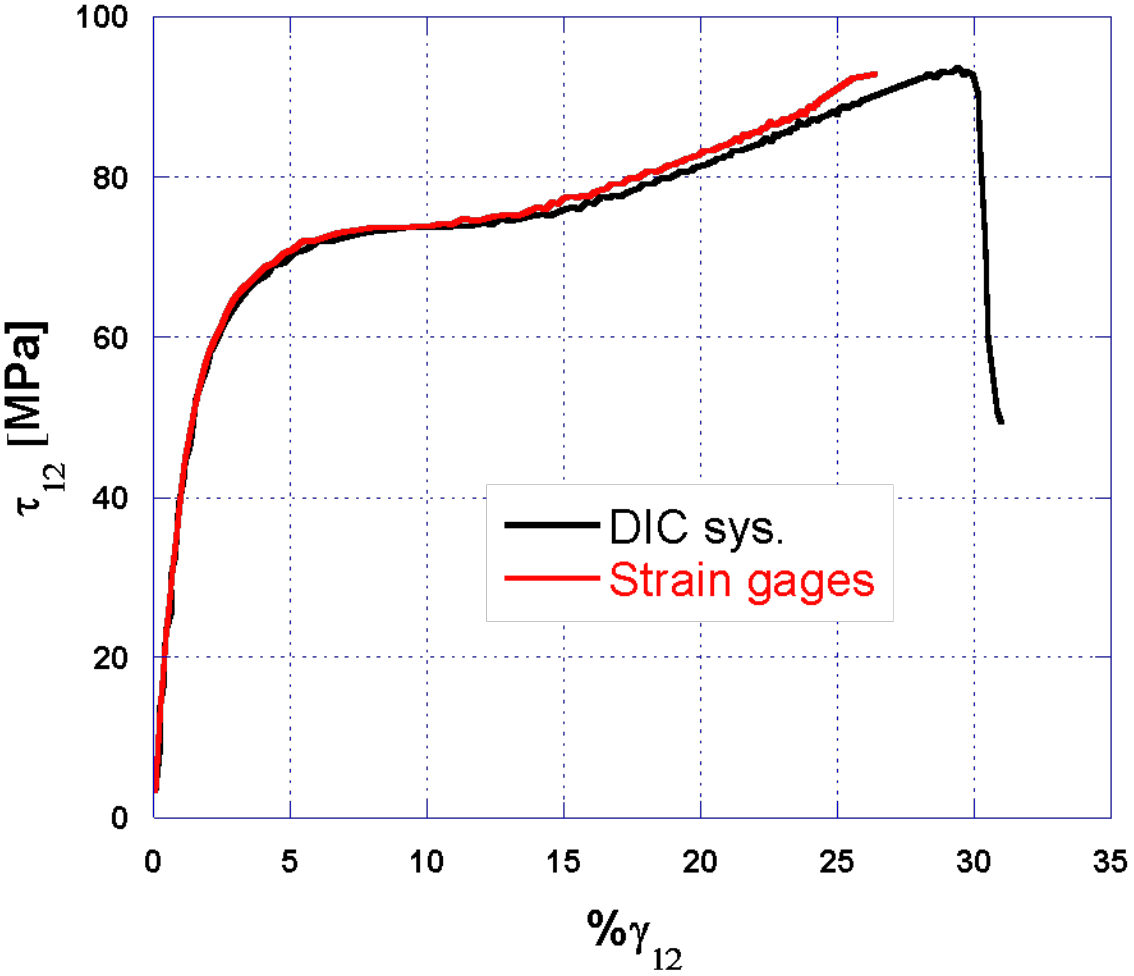


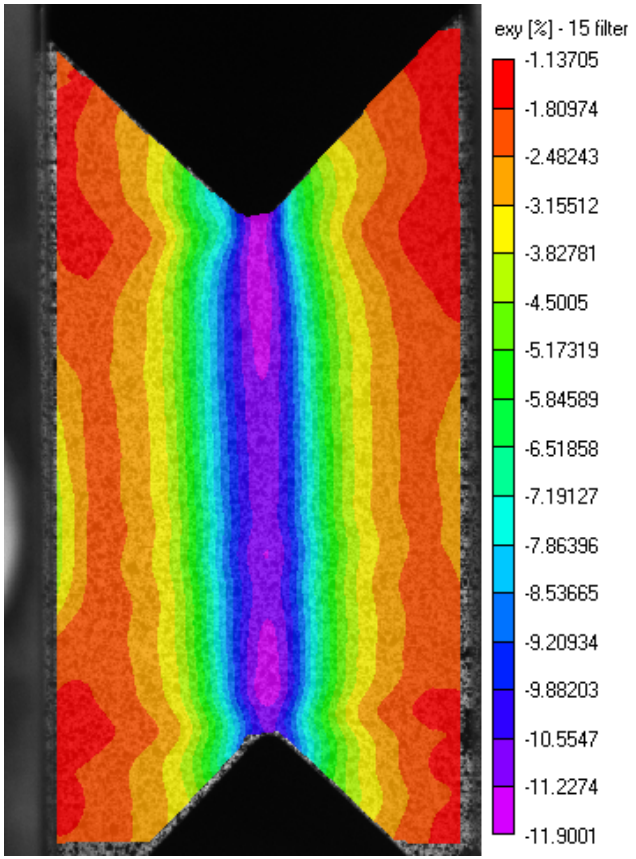




Results

Comparison between DIC and strain gages

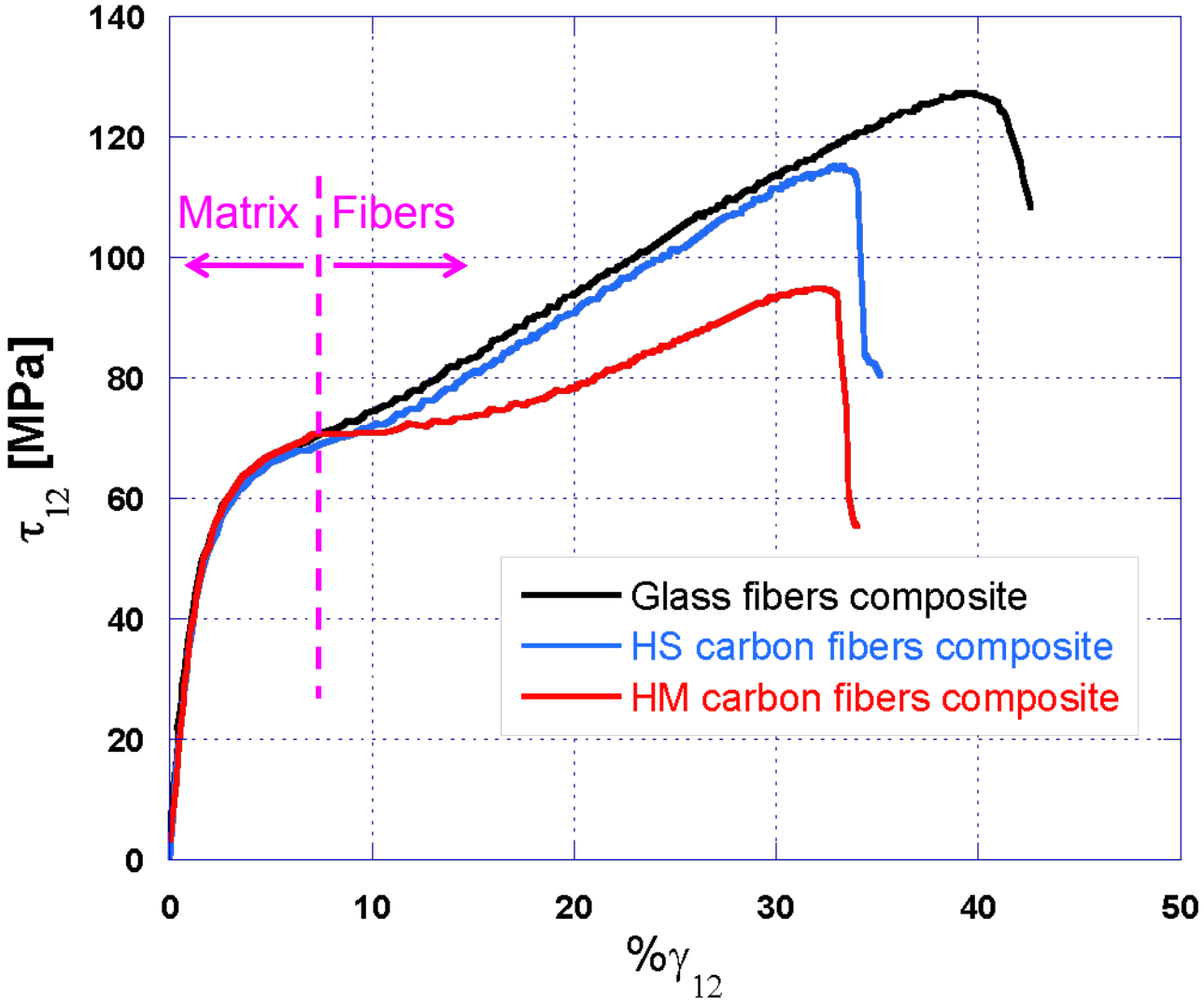




HM carbon composite (MTM57/M40J)

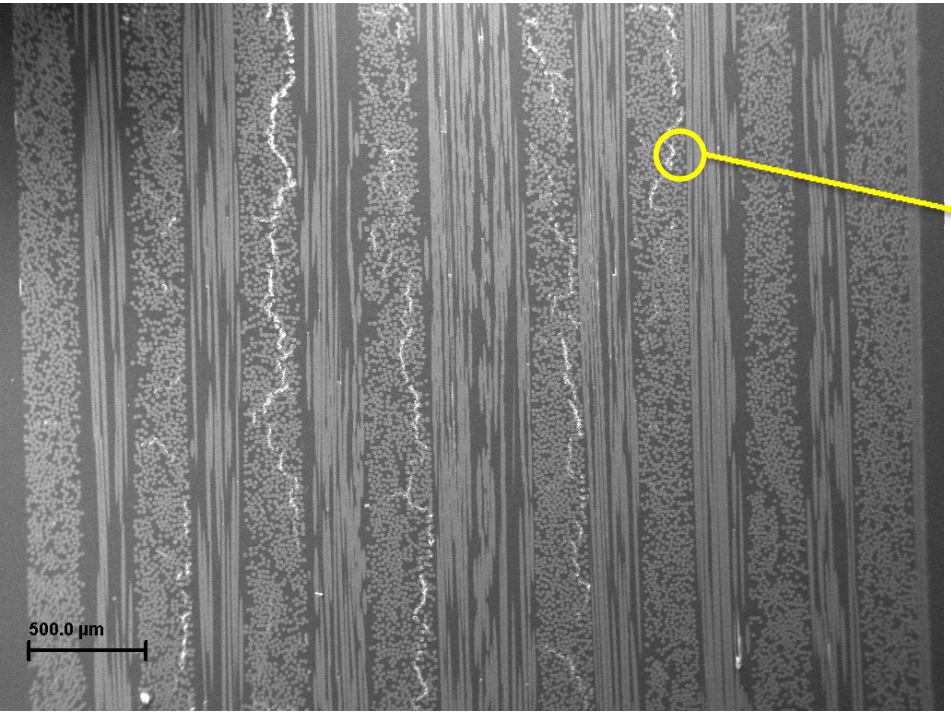
Results

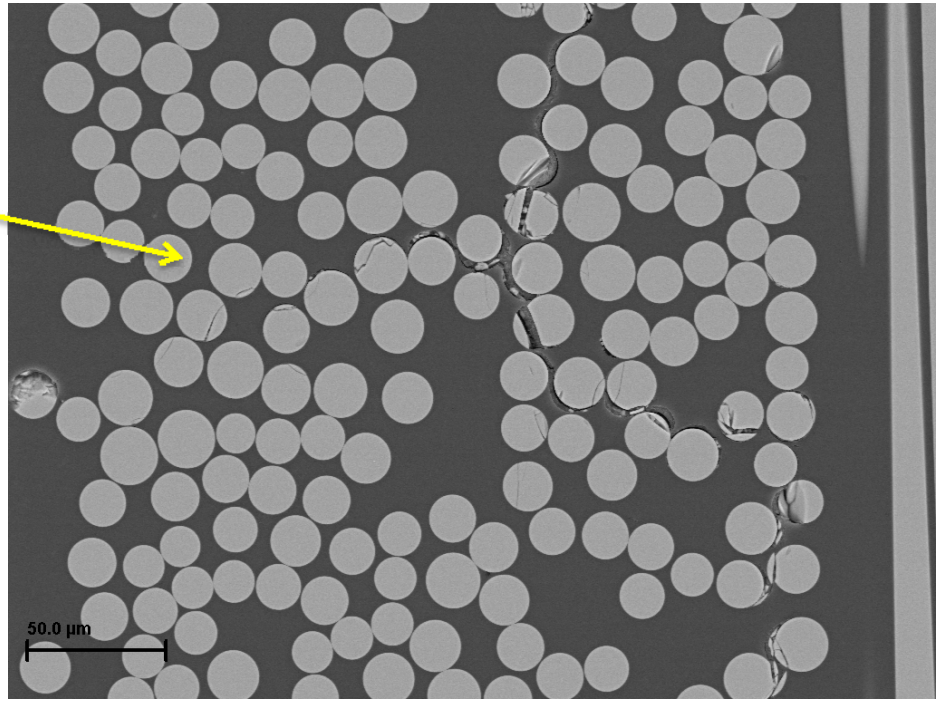
Matrix and fibers dominated regions

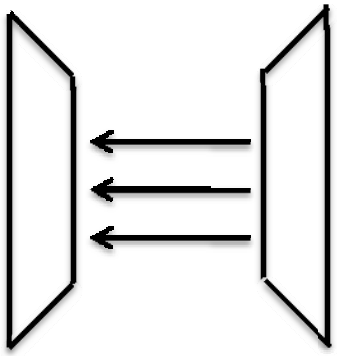


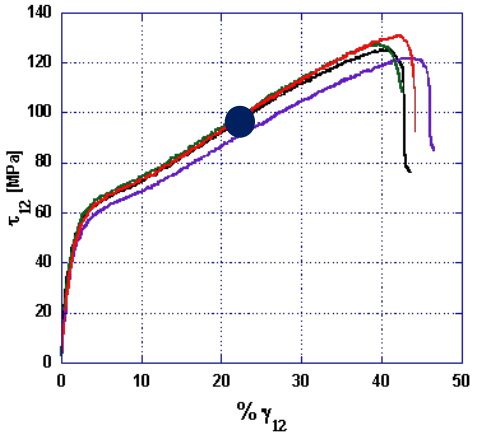
Results

SEM images of glass fiber composite loaded up to 96 [Mpa]



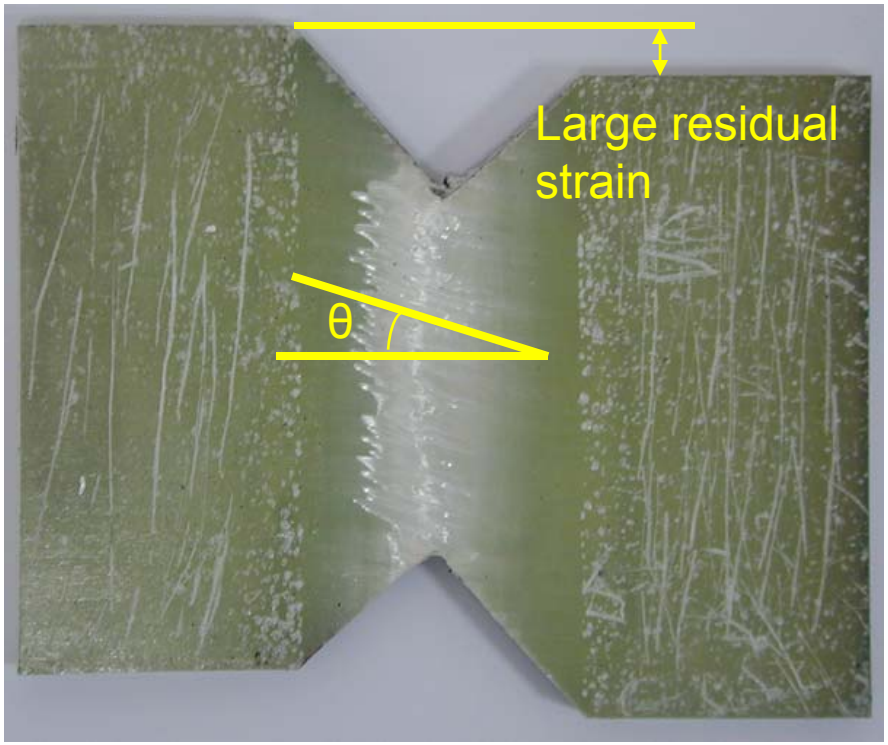


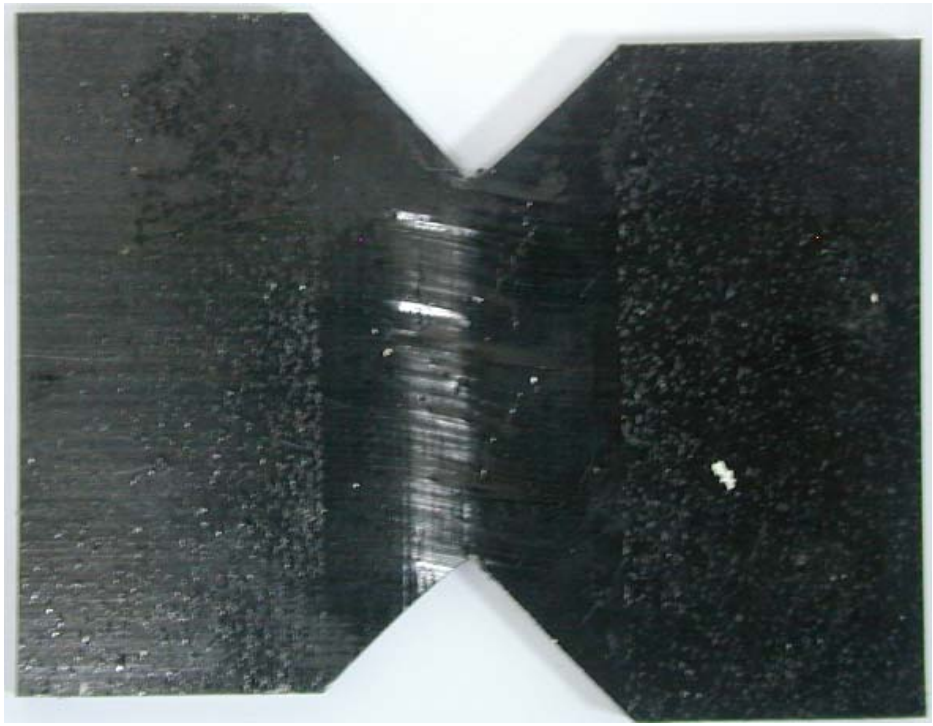




Deformation and failure modes

Failure modes for composites $[0/90]_{ns}$



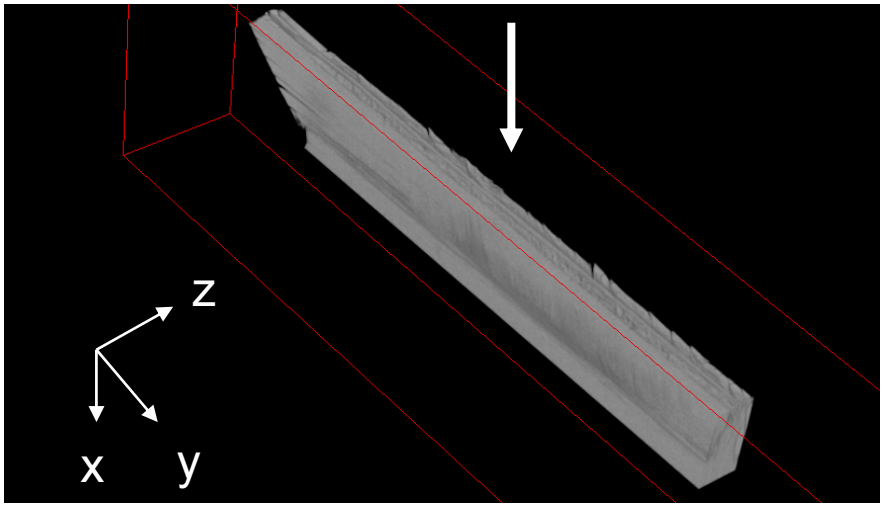


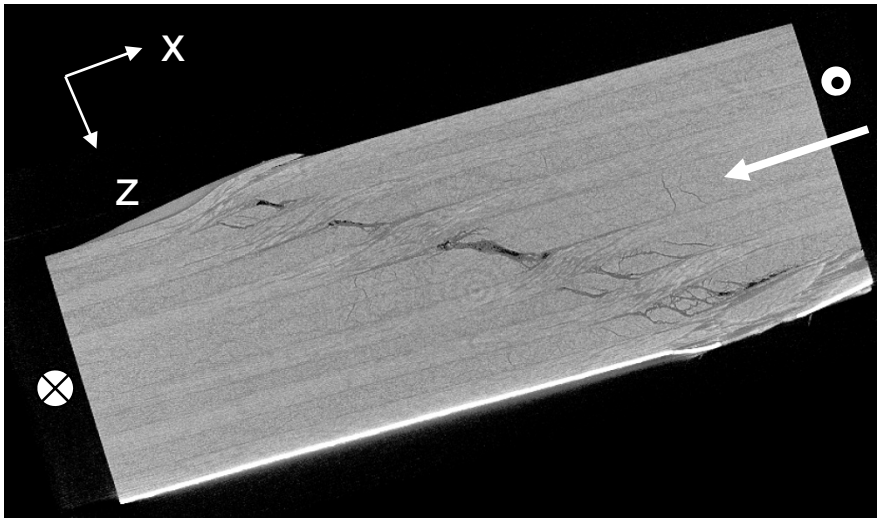
MTM57/E-glass

MTM57/M40J

Deformation and failure modes

X-Ray Tomography -Damage



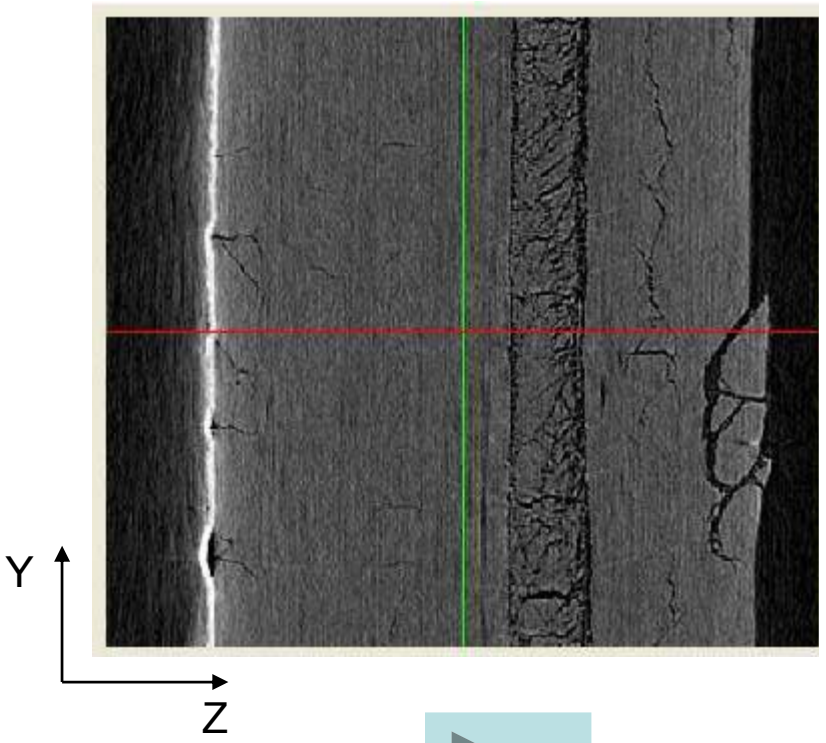


$[0/90]_{3s}$ carbon/ MTM57 epoxy laminate

Phoenix X-Ray Nanotom (80 kV, pixel resolution 2.5 μm)

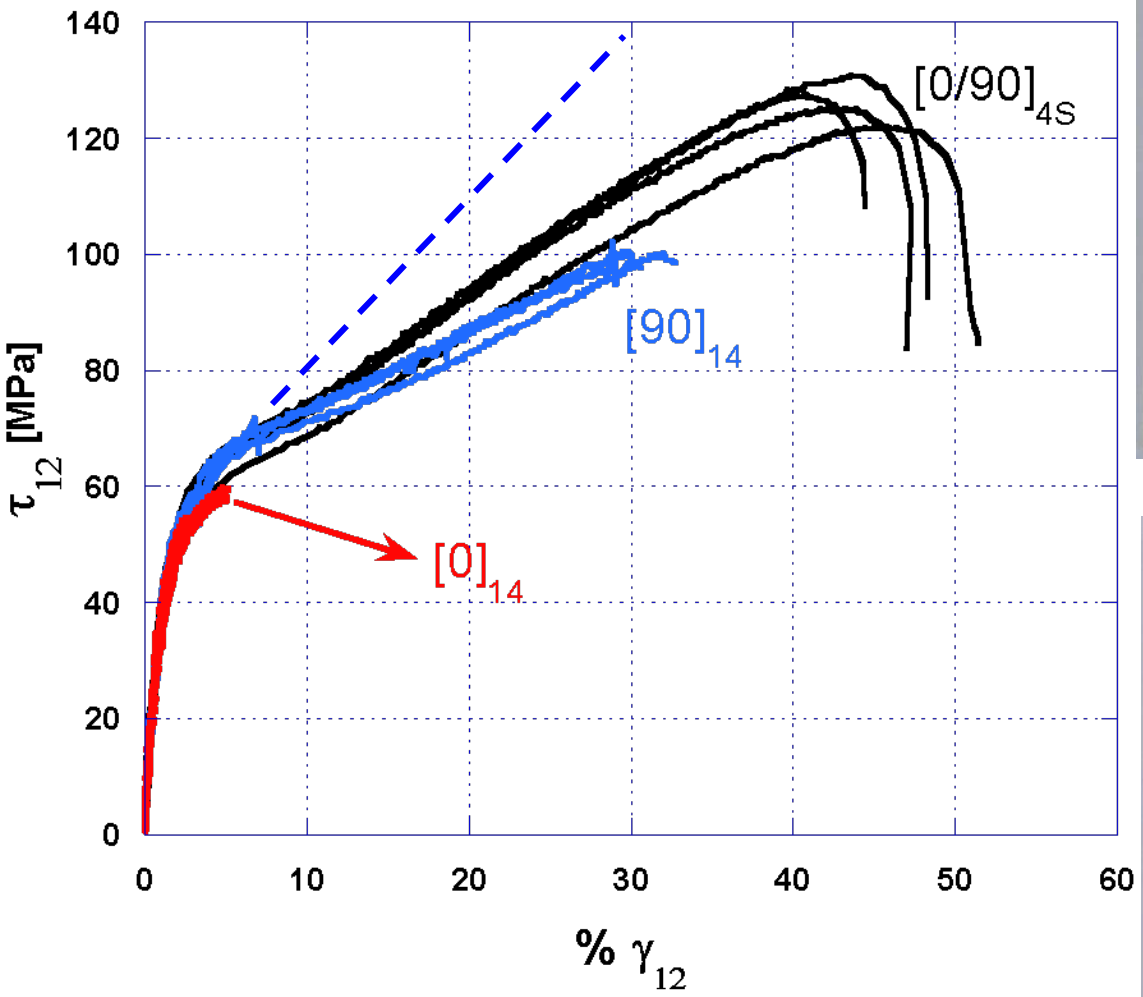
(Advanced Composites Group)

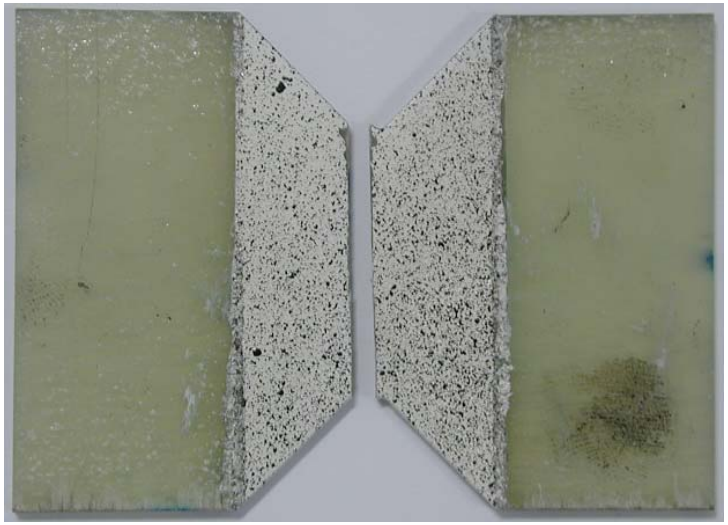
Slice movie yz

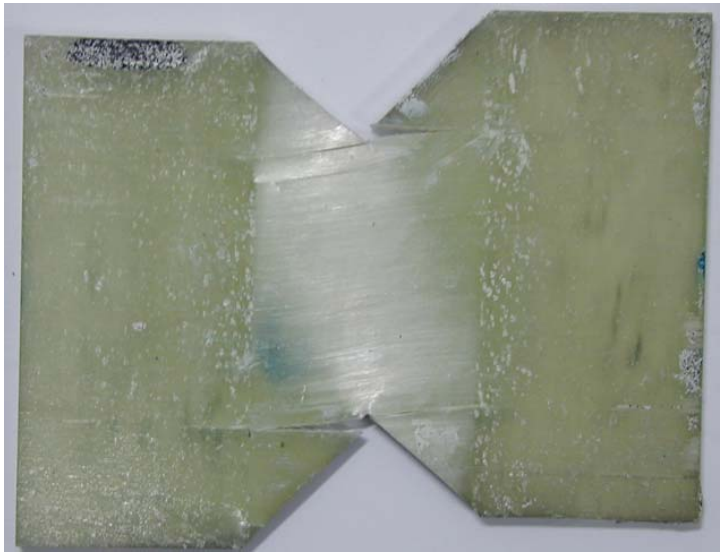


Effect of fibers orientation

MTM57/E-glass

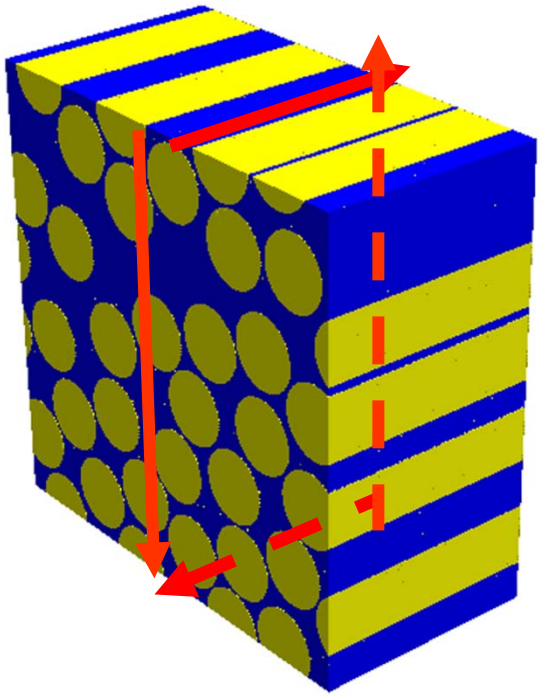






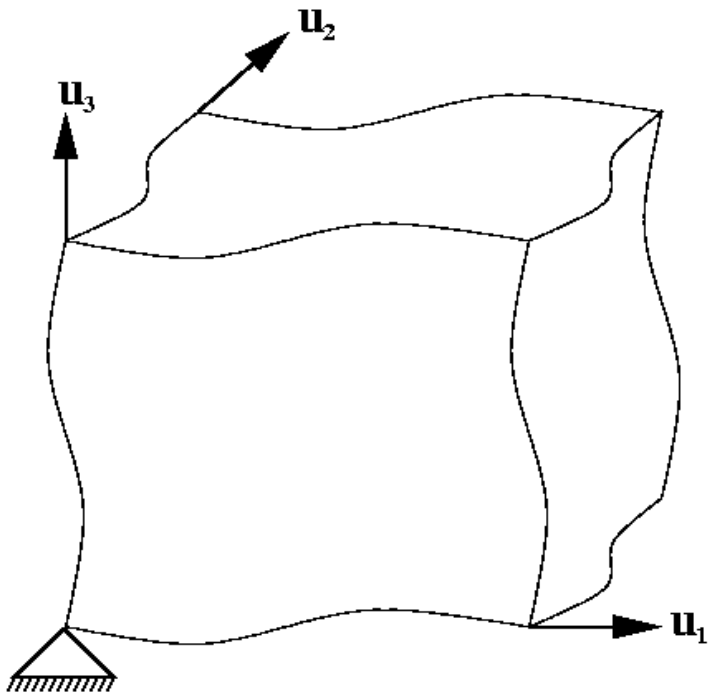
Computational micromechanics

- Matrix and fibers were meshed with 10-node modified tetrahedra (C3D10M in Abaqus).
- Periodic boundary conditions are applied along the 3 axes to eliminate surface effects.



$$\vec{u}(0, x_2, x_3) - \vec{u}(L_1, x_2, x_3) = \vec{U}_1$$
$$\vec{u}(0, x_2, x_3) - \vec{u}(L_1, x_2, x_3) = \vec{U}_1$$
$$\vec{u}(0, x_2, x_3) - \vec{u}(L_1, x_2, x_3) = \vec{U}_1$$

$$\vec{U}_2 \equiv (0, \delta_s, \delta_s) \quad ; \quad \gamma_{12} = \arctan\left(\frac{\delta_s}{L_0}\right)$$



Matrix

- Isotropic elasto-plastic solid with no hardening and following Mohr-Coulumb criterion

  - $E_m = 3.35 \text{ GPa} \qquad \upsilon_m = 0.35$
  - $\left|\tau_T\right| + \sigma_n \tan \Phi = c = S_T$
  - $\Phi = 15^o \quad ; \quad c = 60 \text{ MPa}$

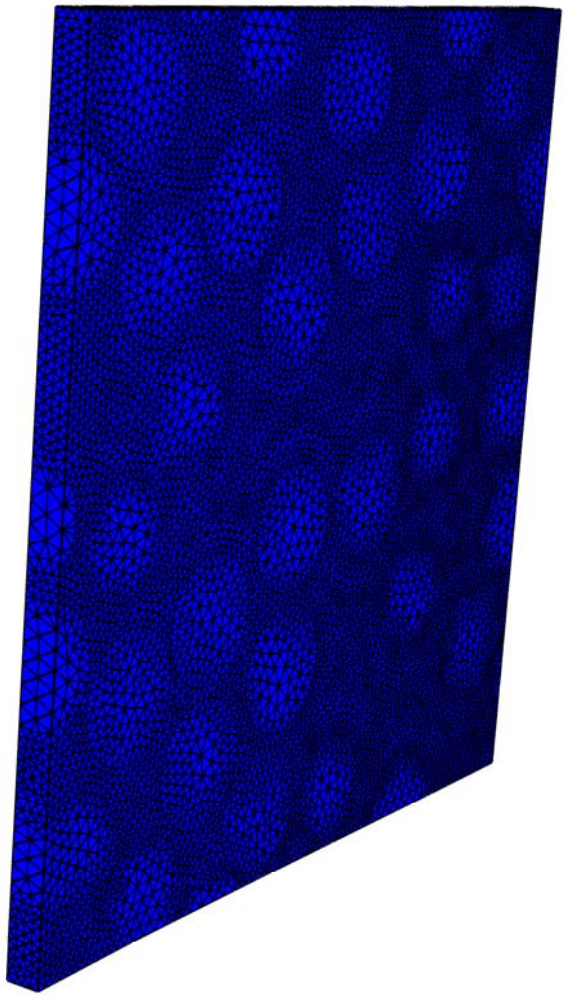
Fibers

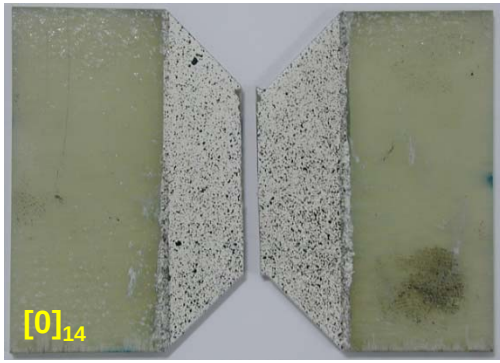
- Isotropic, linear elastic solids

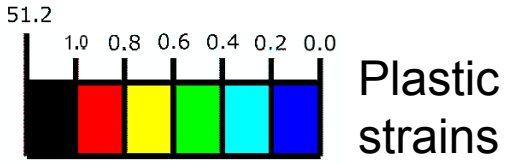
  - $E_f = 74 \text{ GPa} \qquad \upsilon_f = 0.2$

Computational micromechanics

Shear parallel to fibers

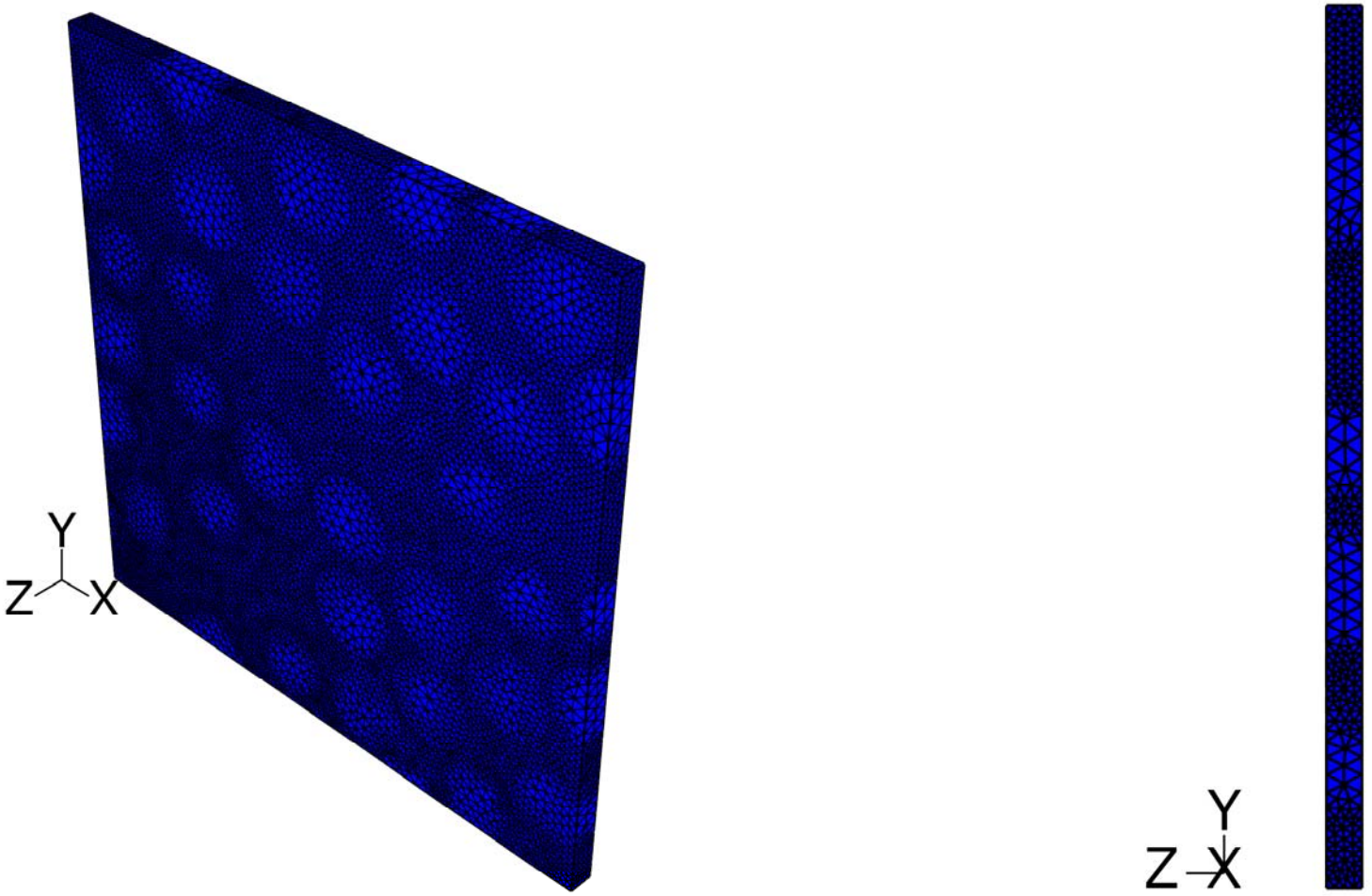


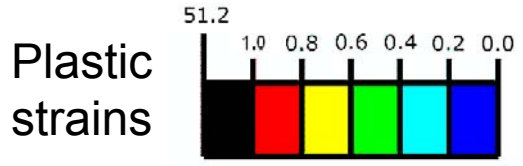




Computational micromechanics

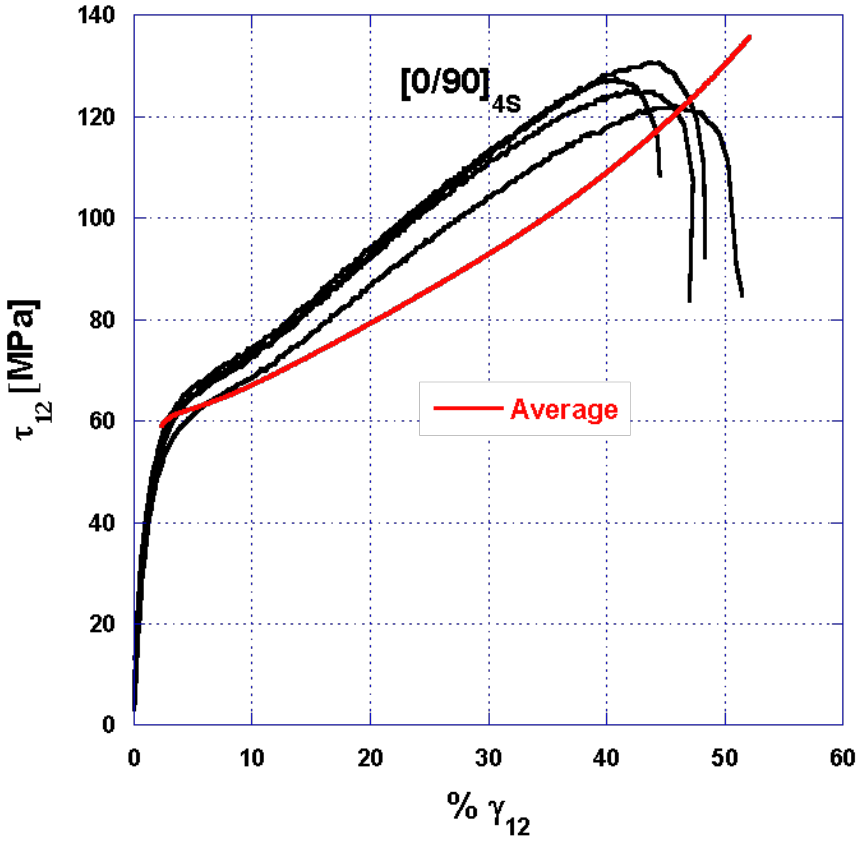
Shear perpendicular to fibers

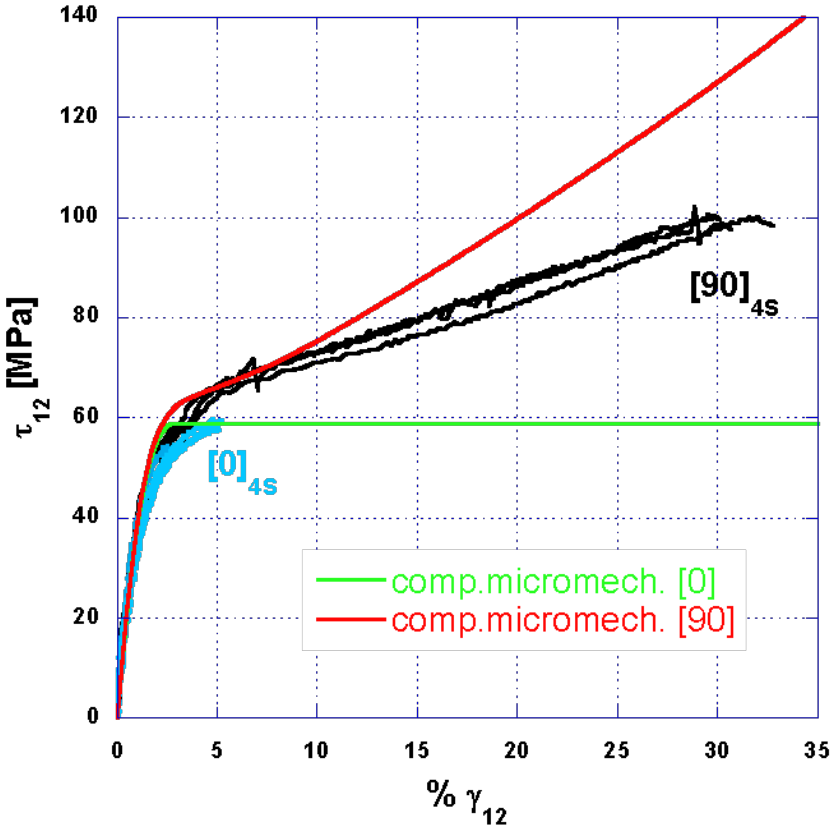




Computational micromechanics

Experimental and numerical Stress-Strain curves





Conclusions

- Using the Digital Image Correlation system it was possible to obtain the full displacement and shear strain fields all the way during the shear test.
- The composites exhibit very large deformation and increase in the Stress up to failure.
- The composites exhibited different failure modes depend on the fiber orientation.
- The computational micromechanics models are able to predict the shear mechanical response of the composites.

Thank you for your attention