CompTest 2004

Measurement of meso-scale deformations for modelling textile composites

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Advantages of Textile Composites

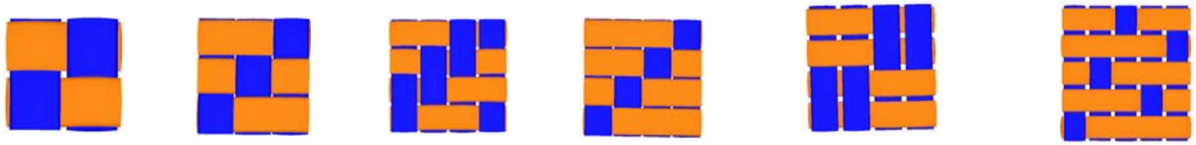
Textile Preforms:

- Easy to handle in the dry form
- Ability to conform to double curvature surfaces
- Suitable for RTM, thermoforming
- Through thickness reinforcement in case of 3D textiles

Textile Composites:

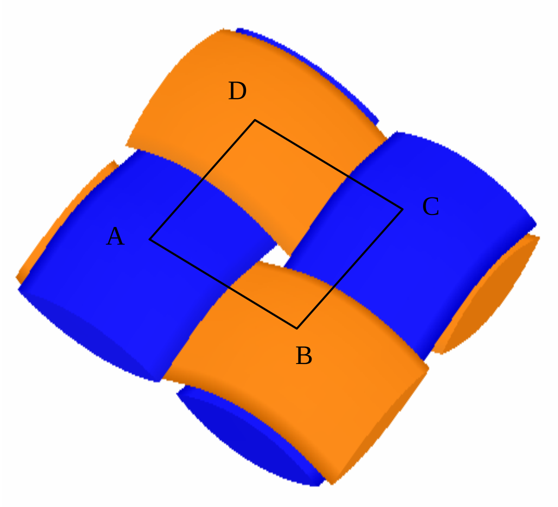
- Damage tolerance
- Superior fracture toughness
- Lower in-plane moduli
- Prediction of thermo-mechanical properties an order of magnitude more complex than unidirectional laminates.
- Mechanical properties sensitive to processing

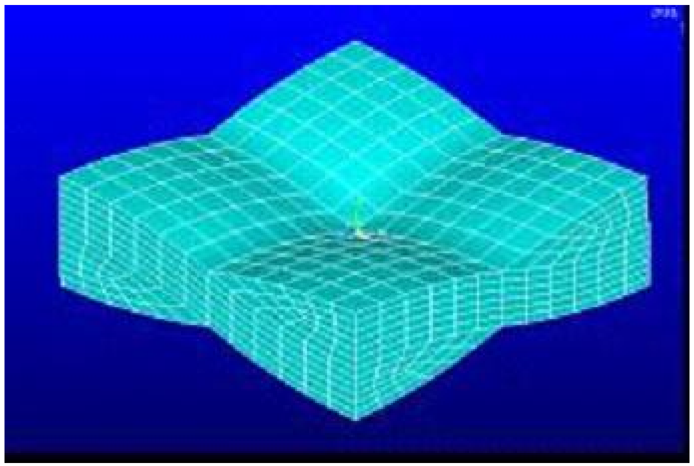
Textile Composites



Unidirectional laminates: micro- and macro- scales

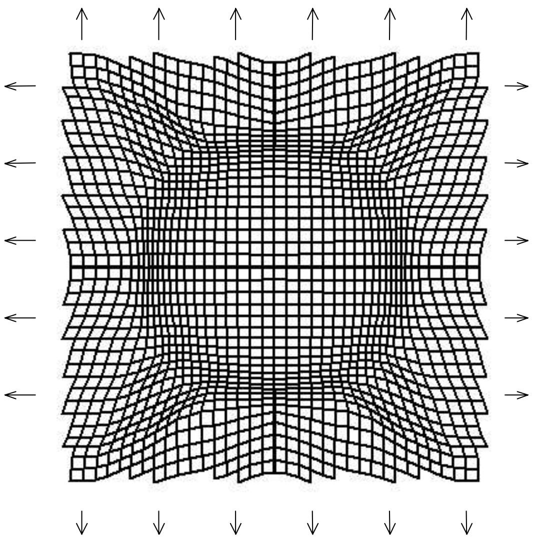
Textile Composites: additional level: meso-scale

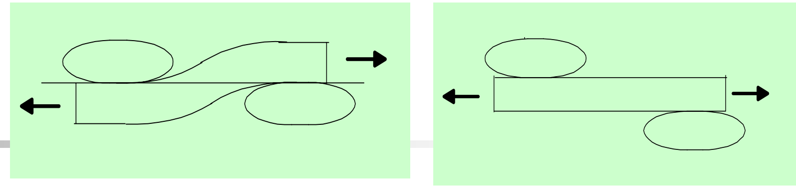




Meso-scale representation: weave repeat & RUC

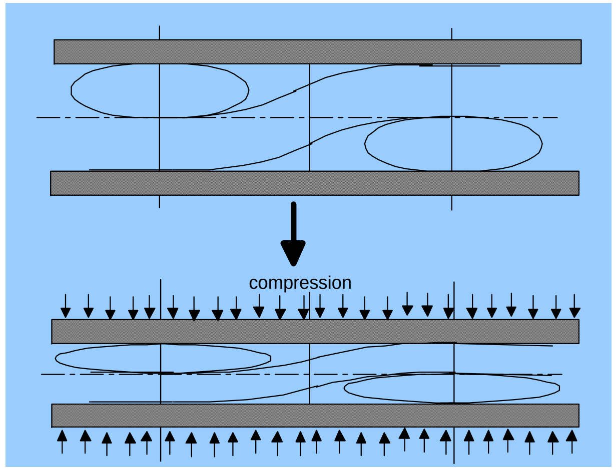
Meso-scale deformations during processing

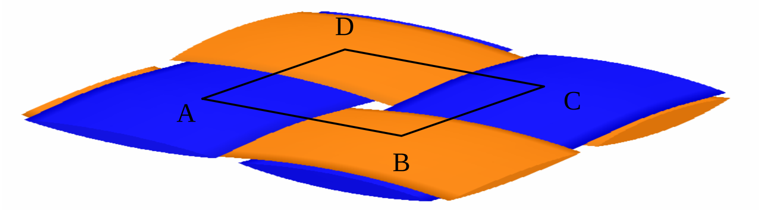




Uniaxial tension: crimp interchange

Biaxial tension: tow-compaction, slight reduction in crimp amplitude

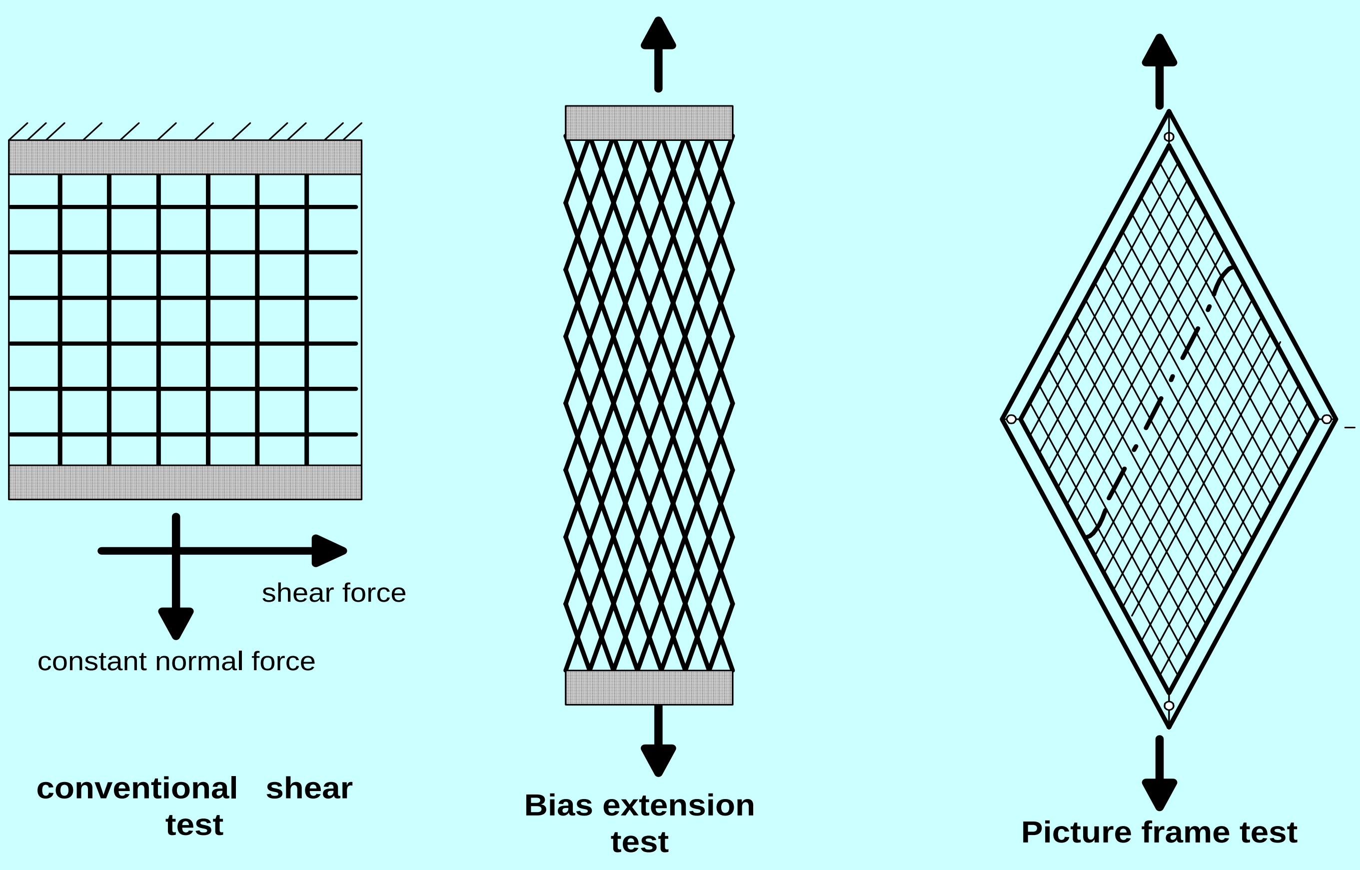




In-plane shear: change in inter-tow angles, tow cross-section, tow amplitude, fabric thickness

Transverse compression: tow compaction, tow flattening, reduction in crimp amplitude

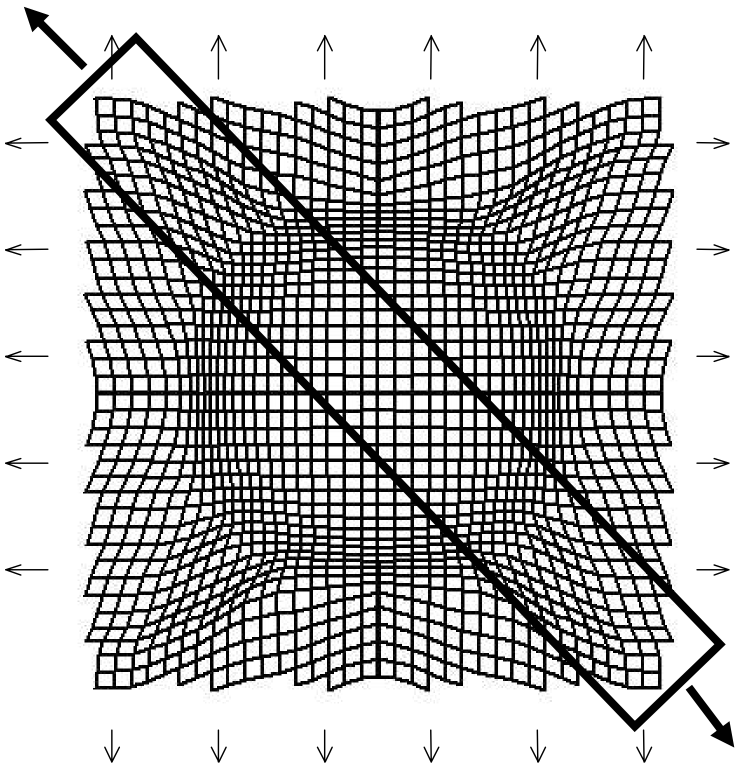
Shear test methods



Biaxial shear: KES tester ±8º , onset of wrinkles before shear-lock

Picture frame: fabric tension not controlled, thread distortion due to normal boundaries at the clamping area, onset of wrinkles

Bias extension: convenient, non-uniform shear zones, dominated by tension near the lock-limit, closely represents draping forces



Importance of in-plane shear on composite properties

•Significant changes to fibre orientations, fibre-volume-fractions, laminate thickness

•Non-orthogonal Repeating unit cell (RUC)

•RUC geometry varies at each position in a component.

Why bias-extension test?

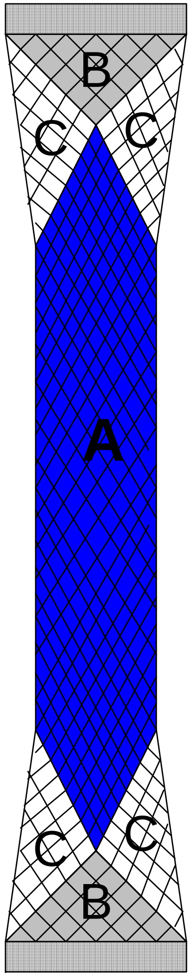
•Closely represents the draping process

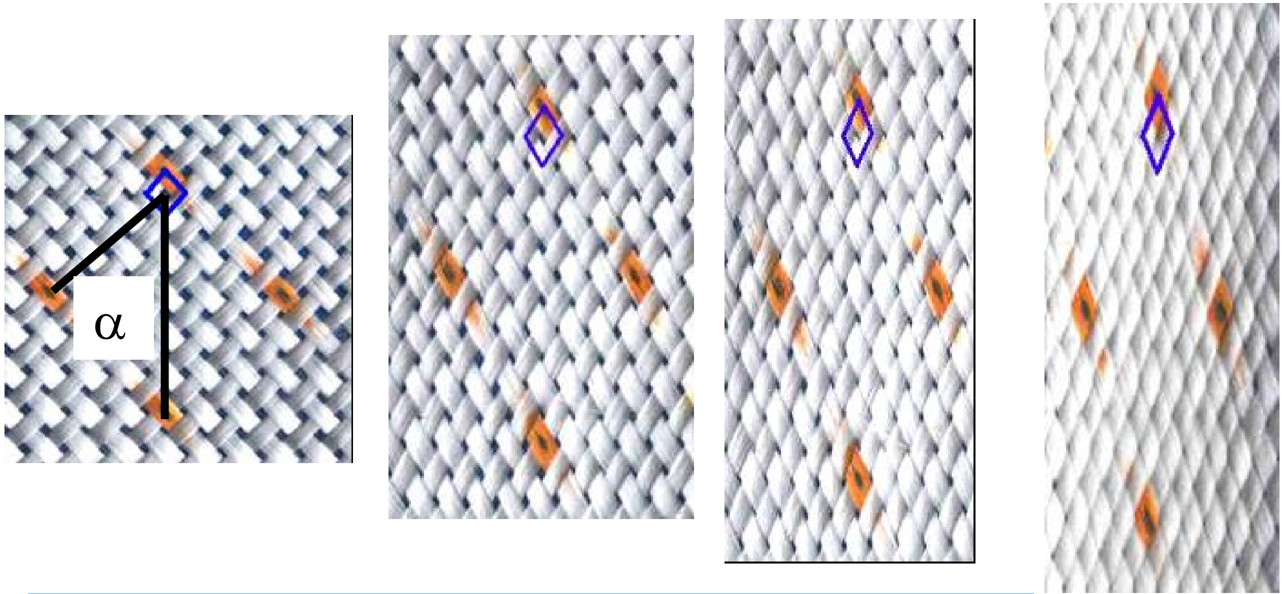
•Non-uniform shear near the clamps (in a bias extension test) is similar to the effect of blank holders in a forming process

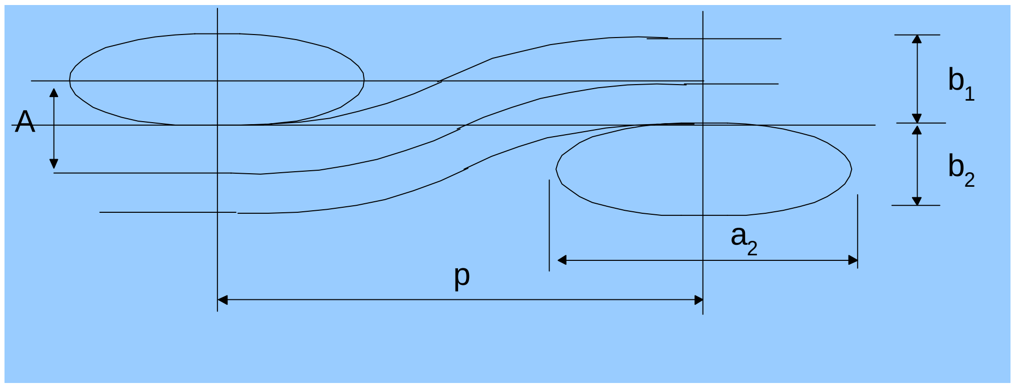
•Wide-strip bias-extension is closer to the reality

Main objectives:

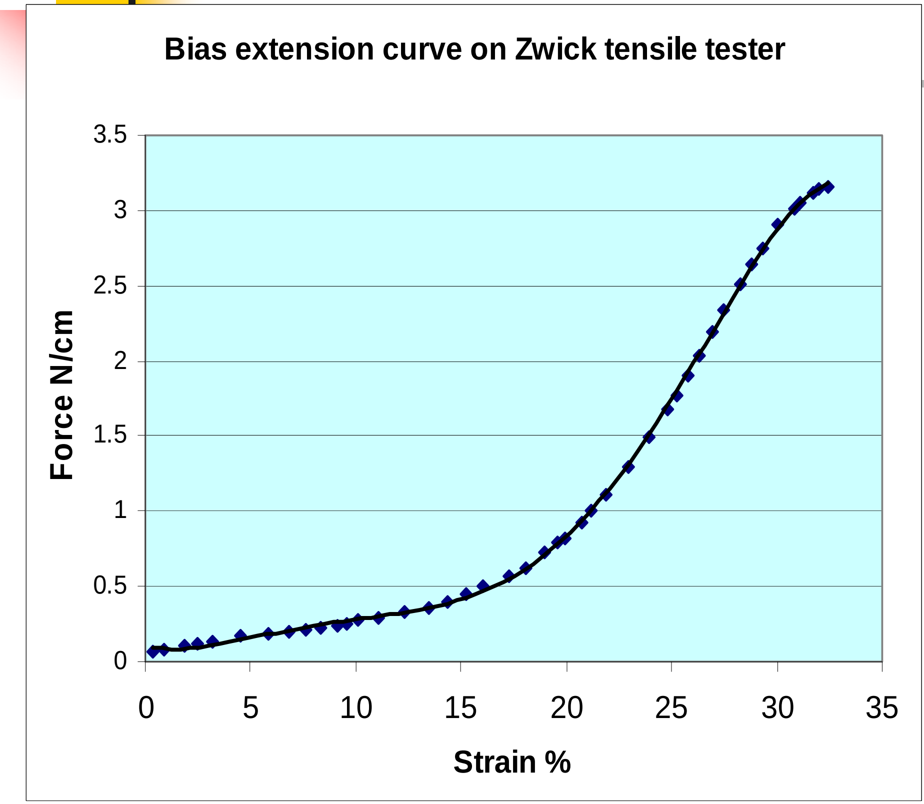
- To measure constitutive shear properties of textiles to assist mechanics-based drape modelling
- To measure the tow geometry changes due to shear in order to construct a more realistic RUC

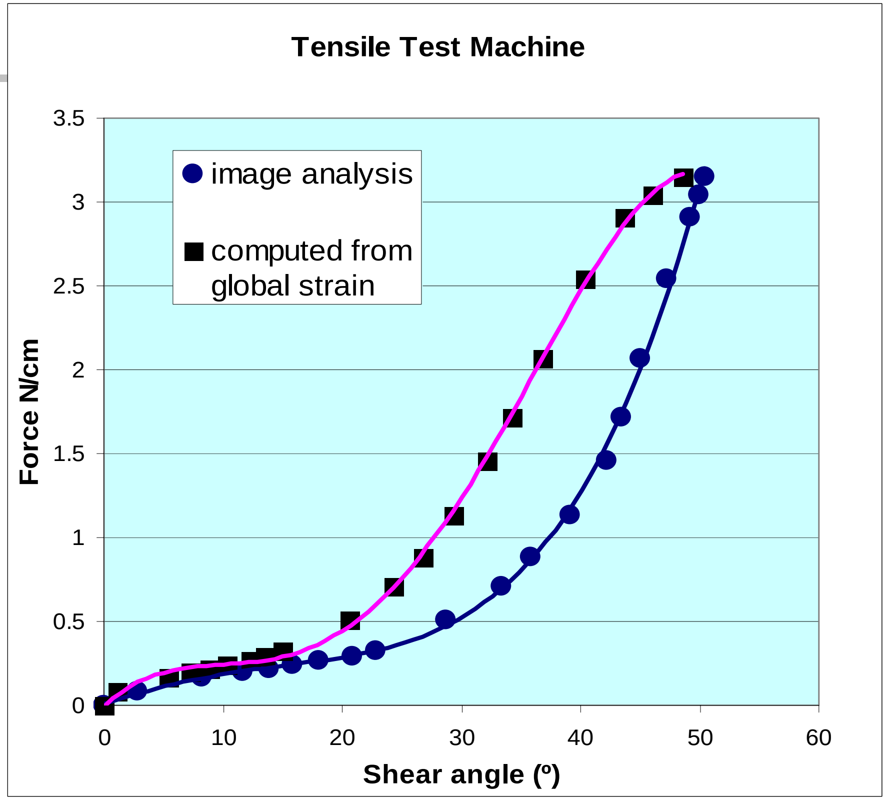






Shear load-deformation





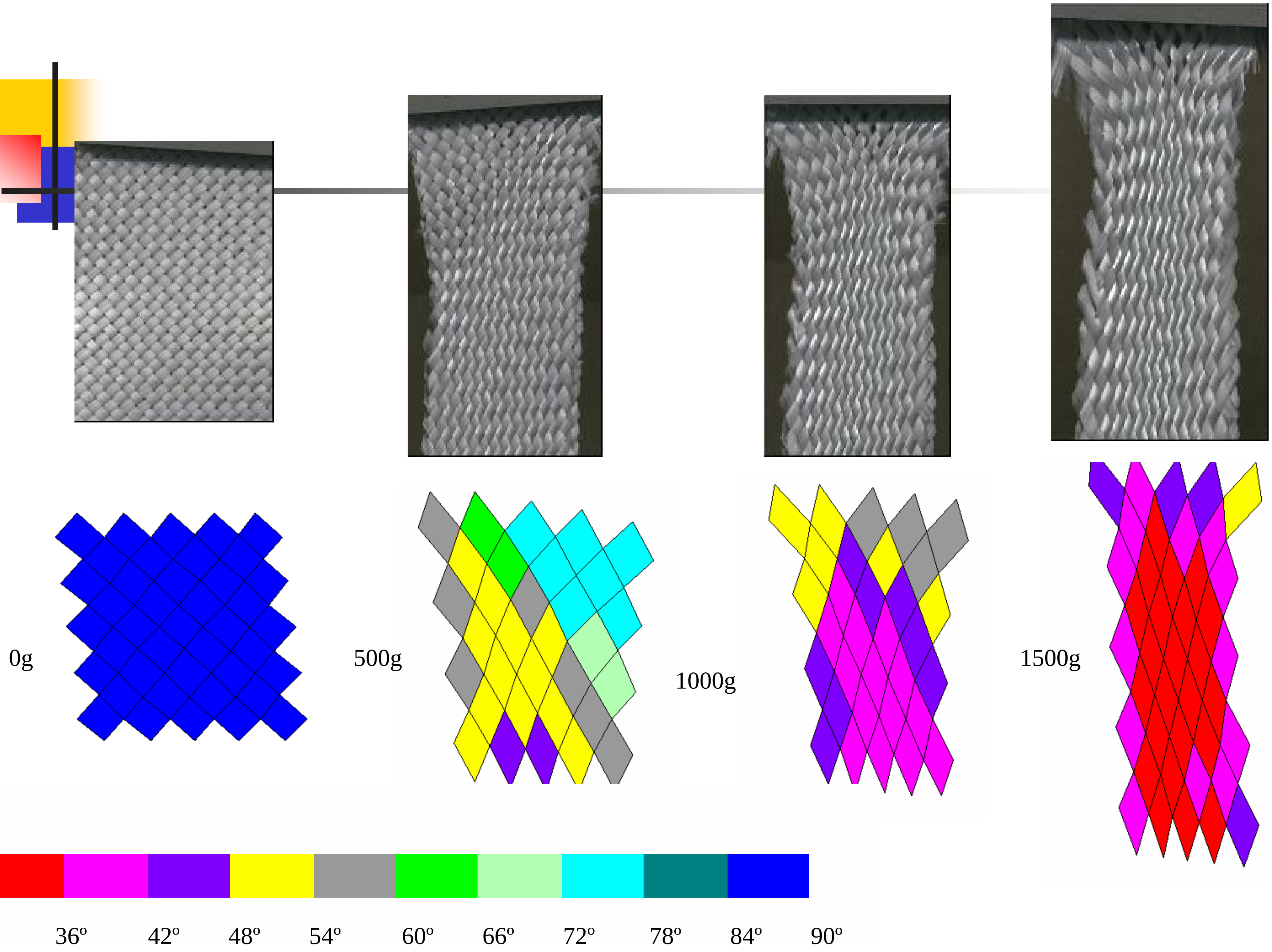
Half included angle, $\alpha = \cos^{-1}\left(\left(1+\varepsilon_{ax}\right)\cos\alpha_0\right)$

Shear angle: $\theta = 90 - 2\alpha$

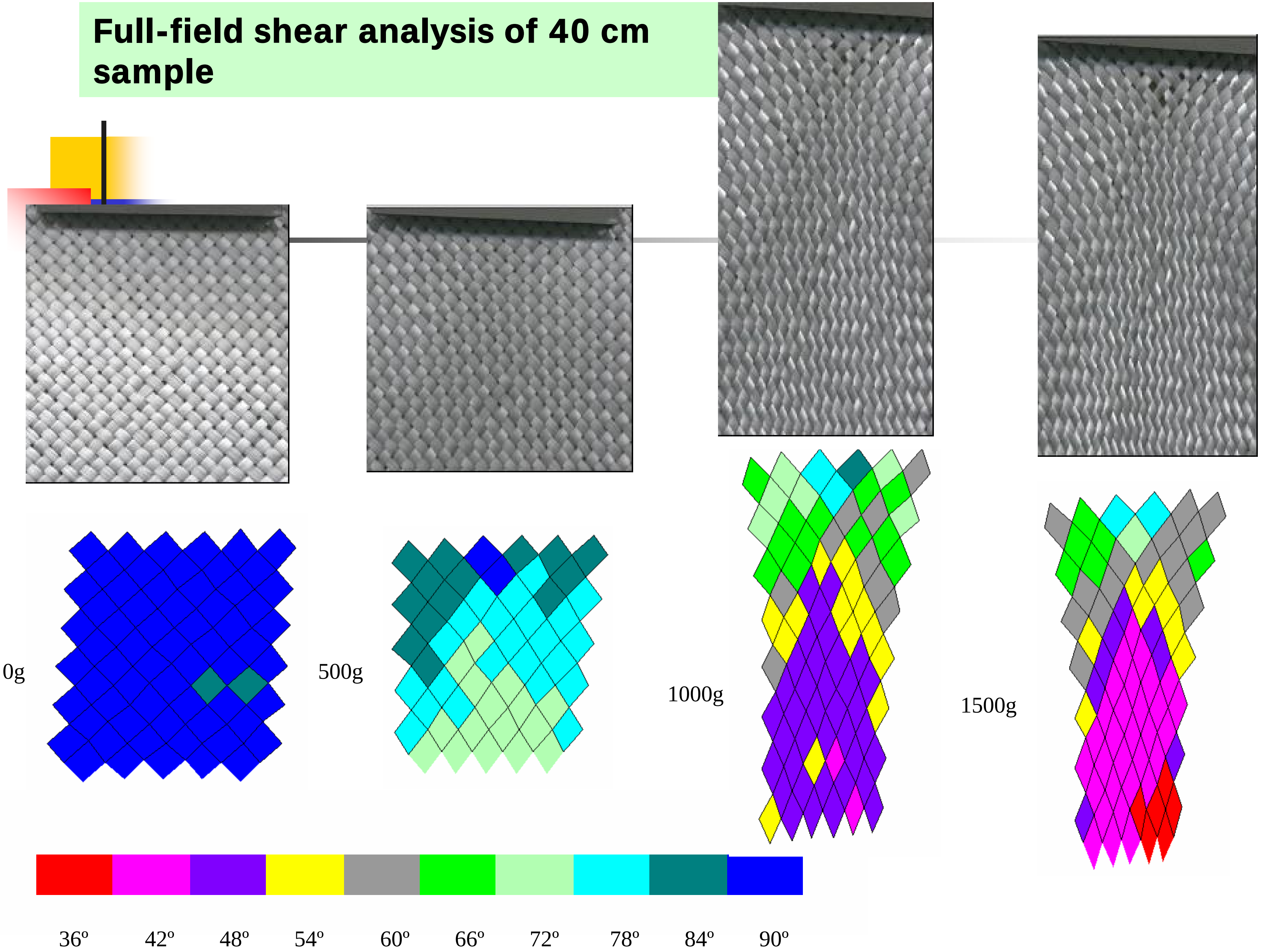
Test Set-up

Inexpensive full-field imaging at high magnification

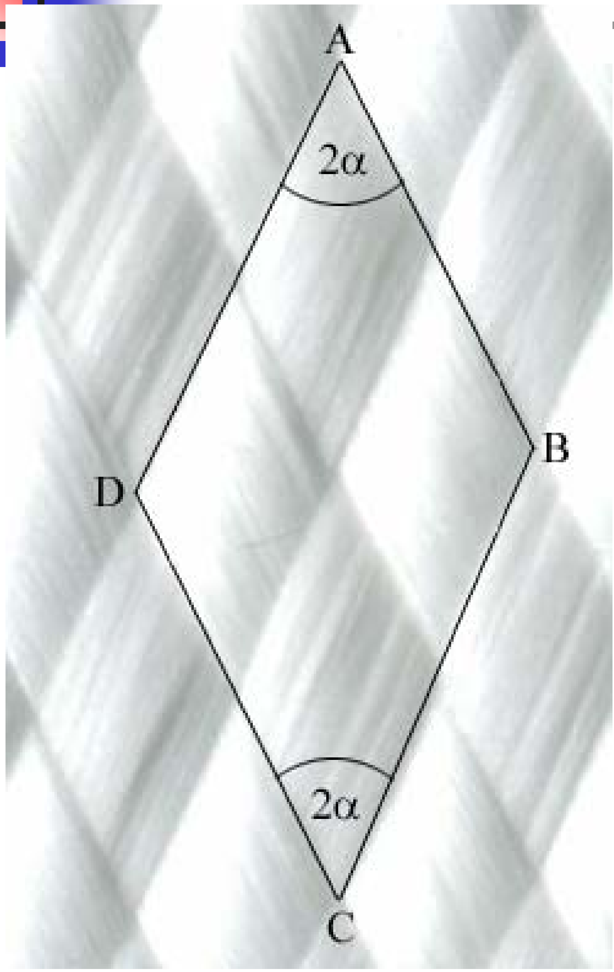
Full-field shear analysis of 7.5 cm sample

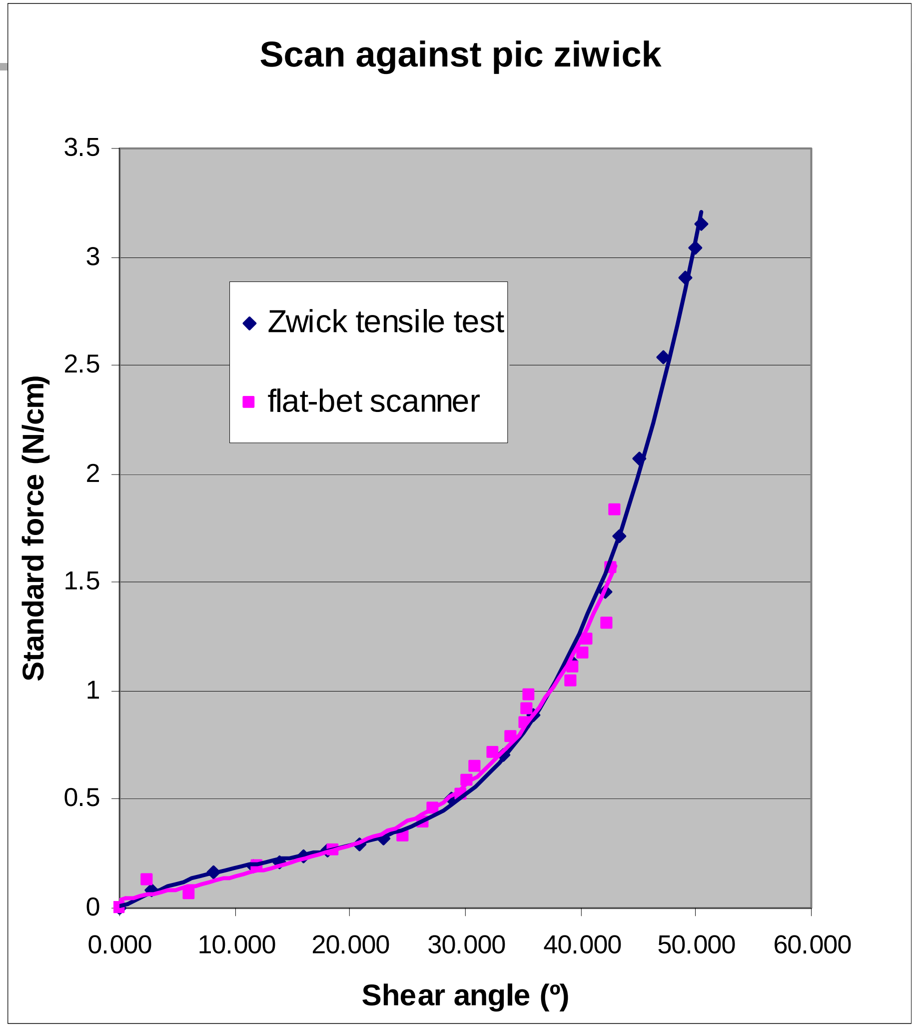


Full-field shear analysis of 40 cm sample

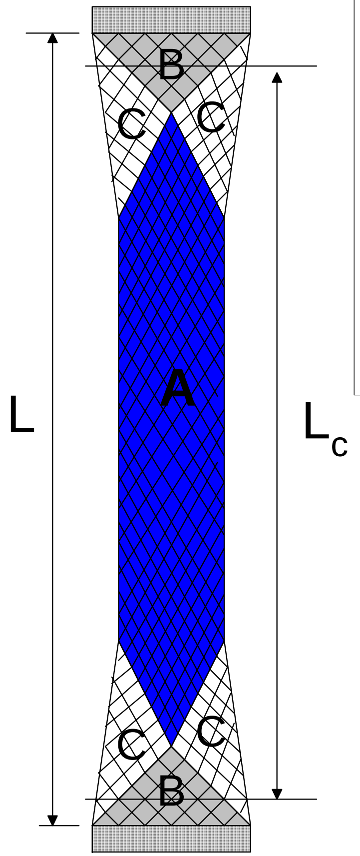


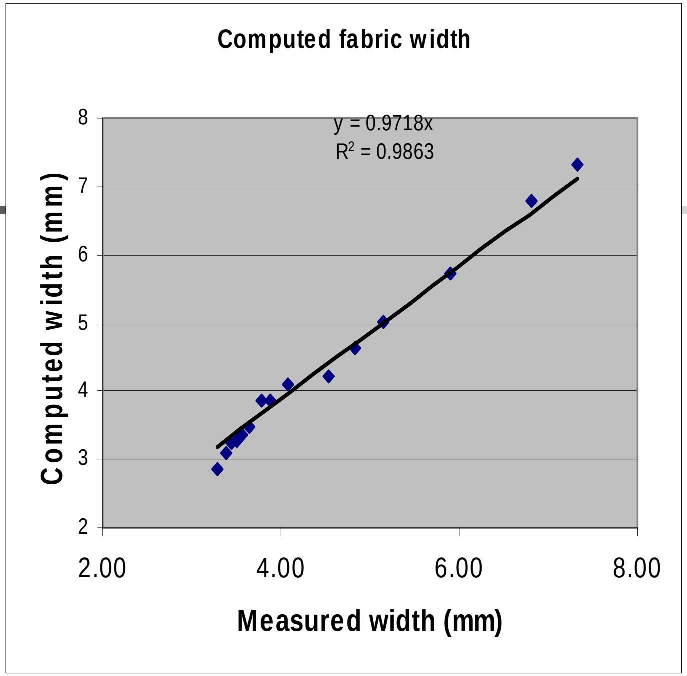
Comparison of flat-bed scanner set-up and Zwick tensile tester

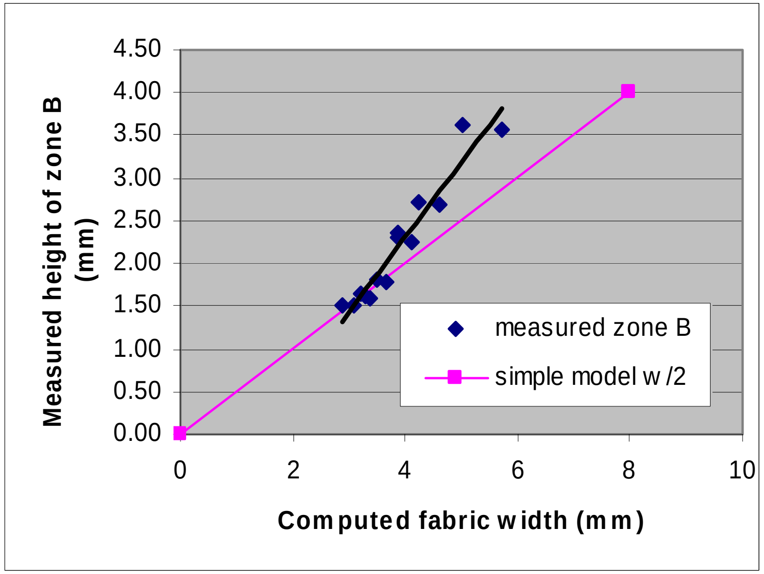




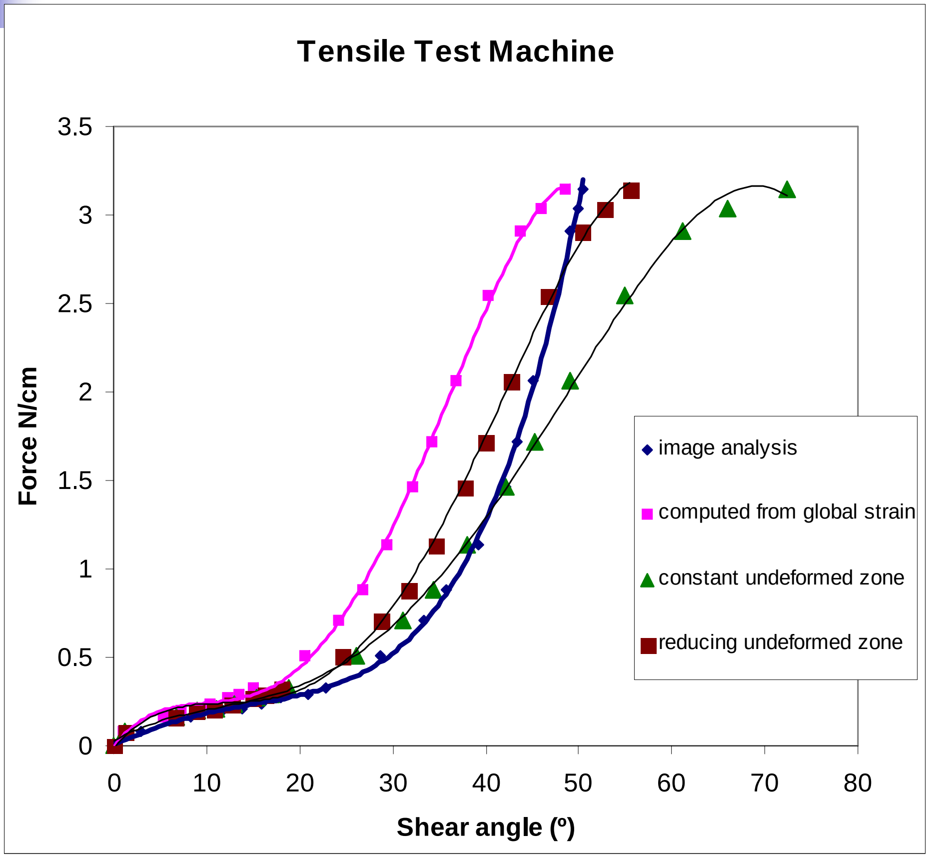
Computation of shear angle based on fixed & variable zone B







Computation of corrected shear angle from corrected global strain

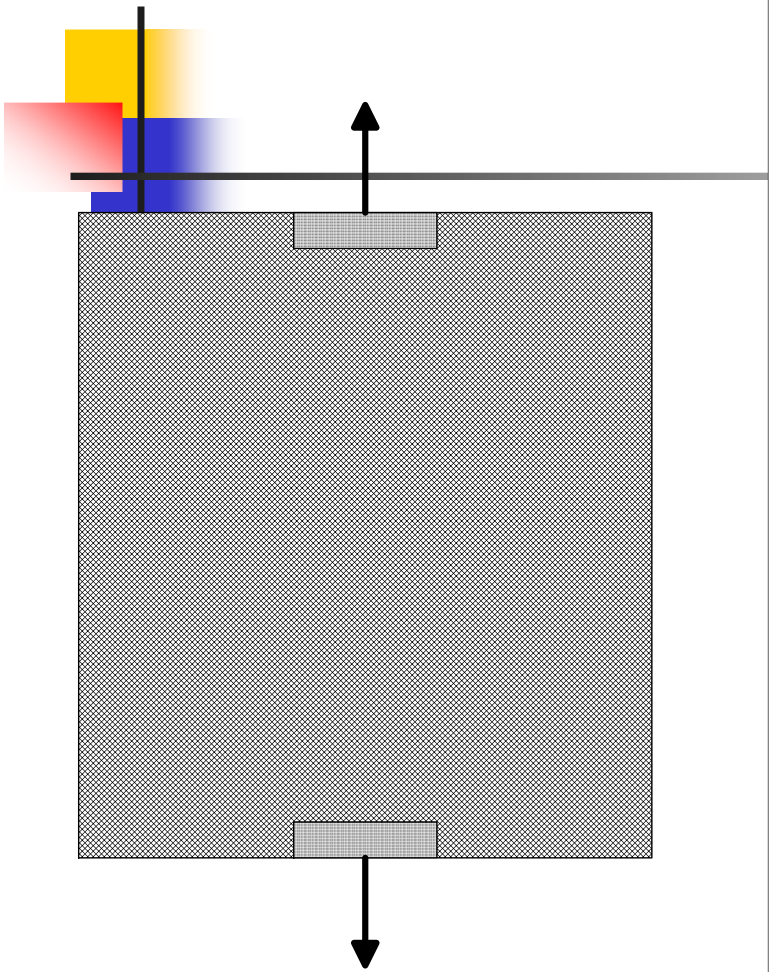


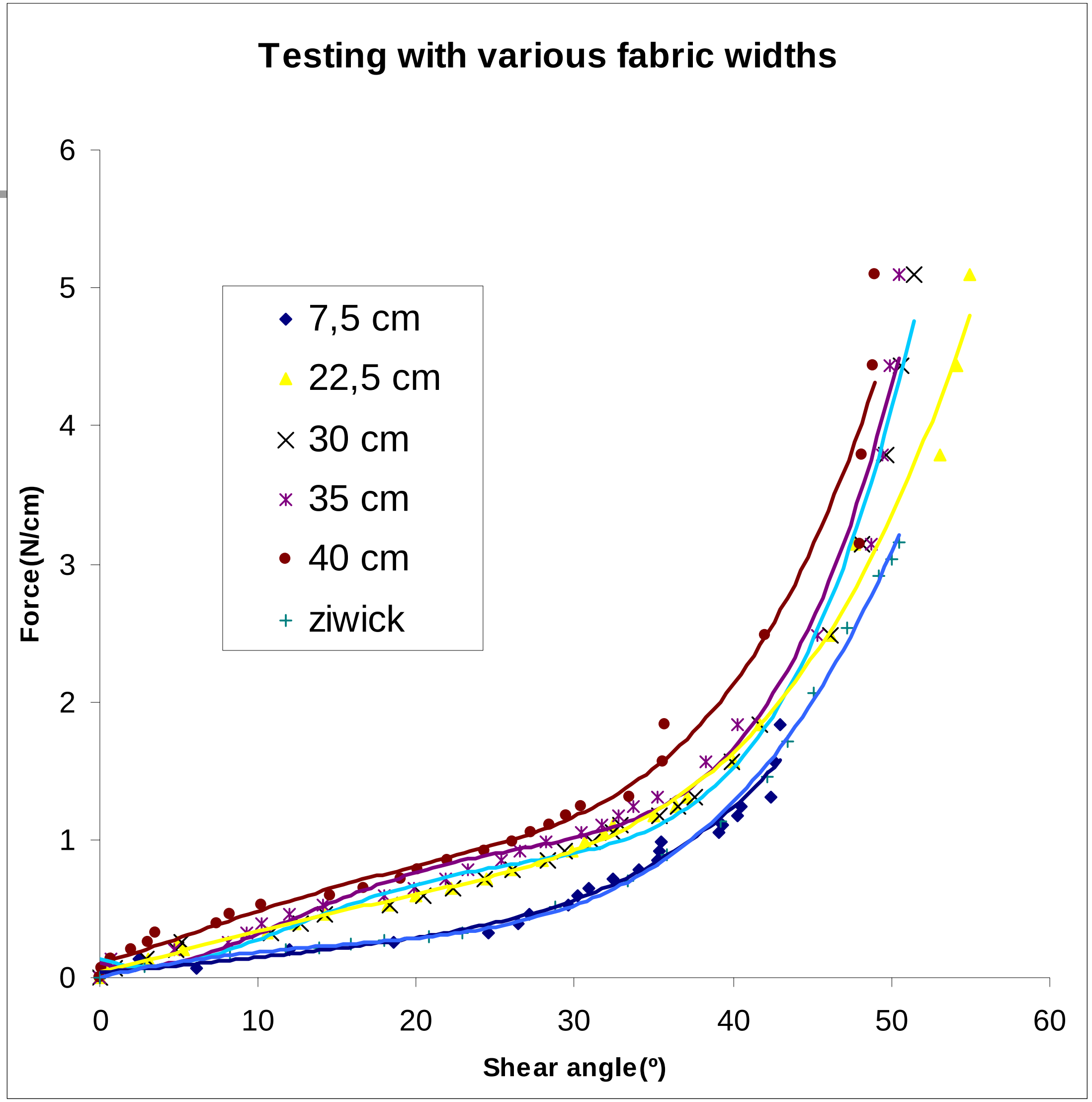
$$l_c = l - \frac{w_0}{2}$$

$$l_c = l - \frac{w}{2}; where, w = w_0 \frac{\sin\alpha}{\sin\alpha_0}$$

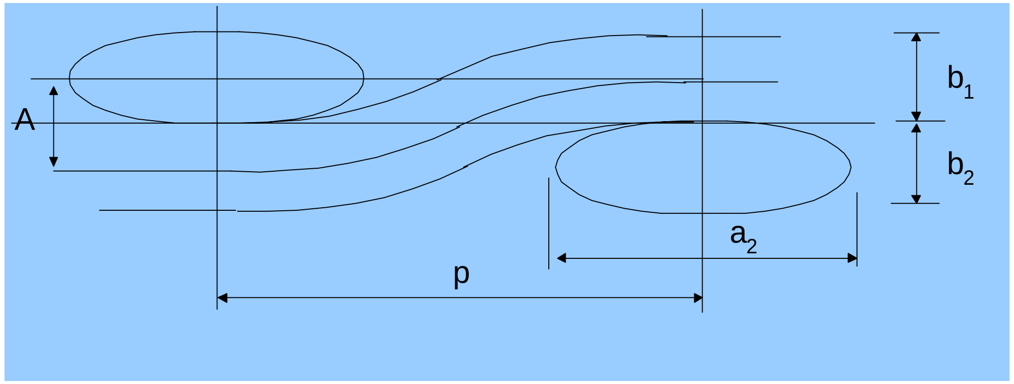
Tow slippage close to lock angle

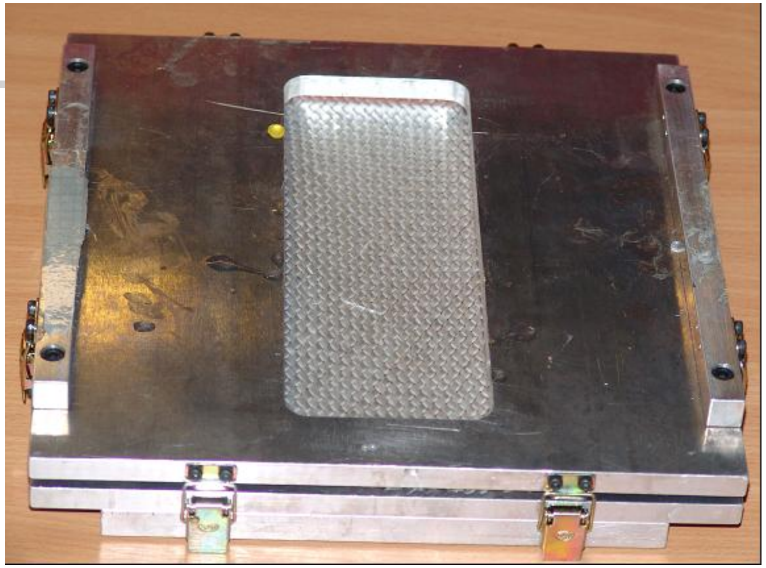
Bias extension tests on wide samples: grab tensile test

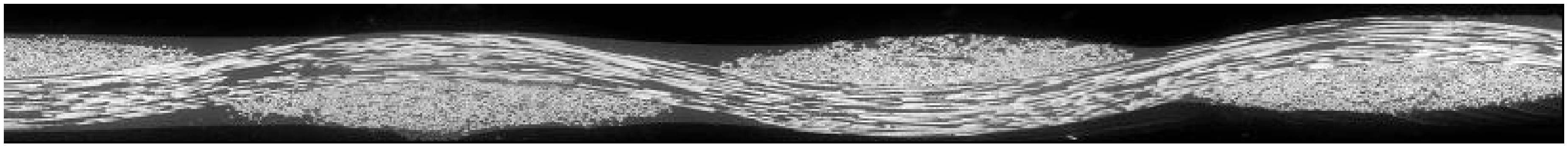


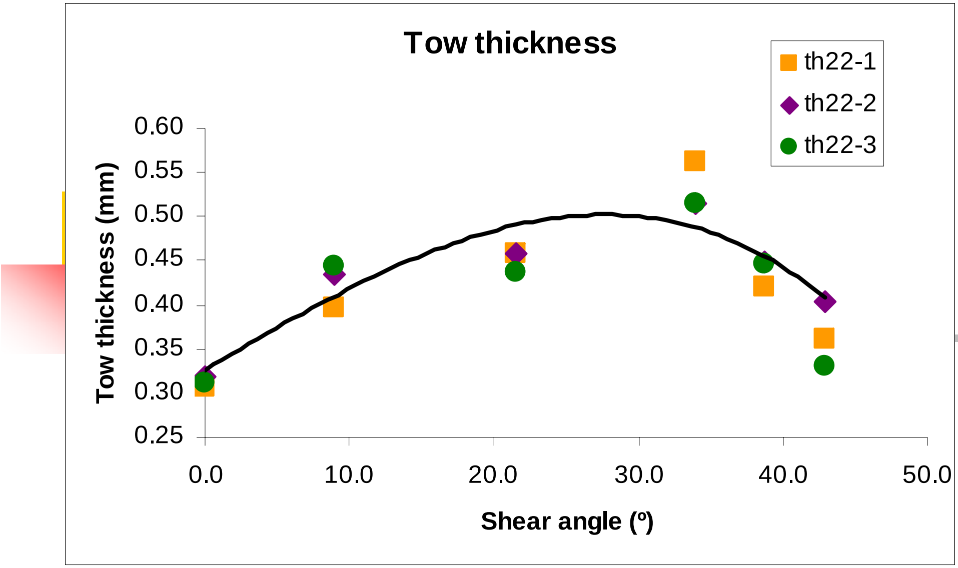


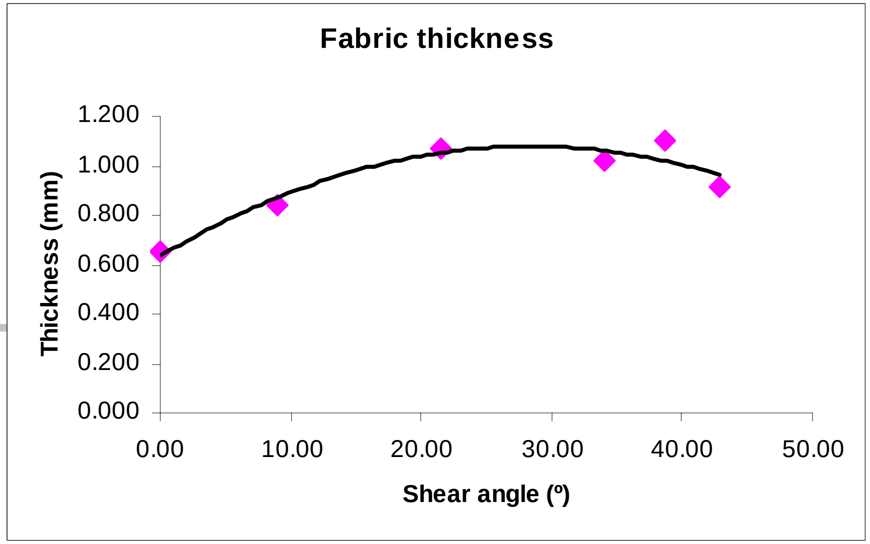
Tow deformation analysis

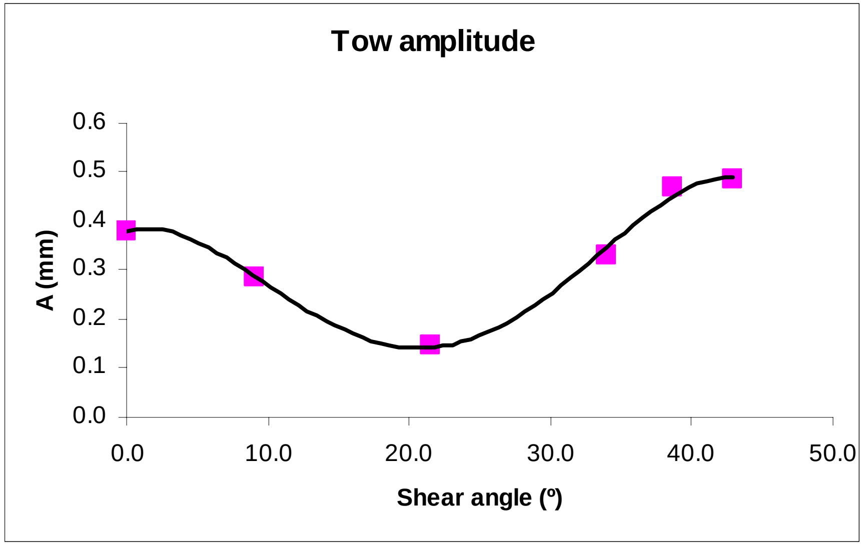


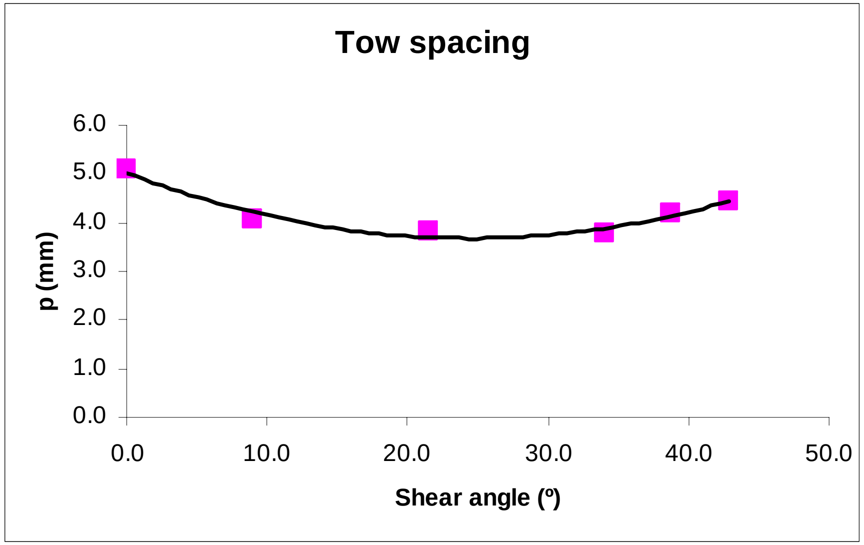





Tow thickness
th22-1
th22-2
th22-3
Tow thickness (mm)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.0
10.0
20.0
30.0
40.0
50.0
Shear angle (º)


Fabric thickness
Thickness (mm)
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0.00
10.00
20.00
30.00
40.00
50.00
Shear angle (º)

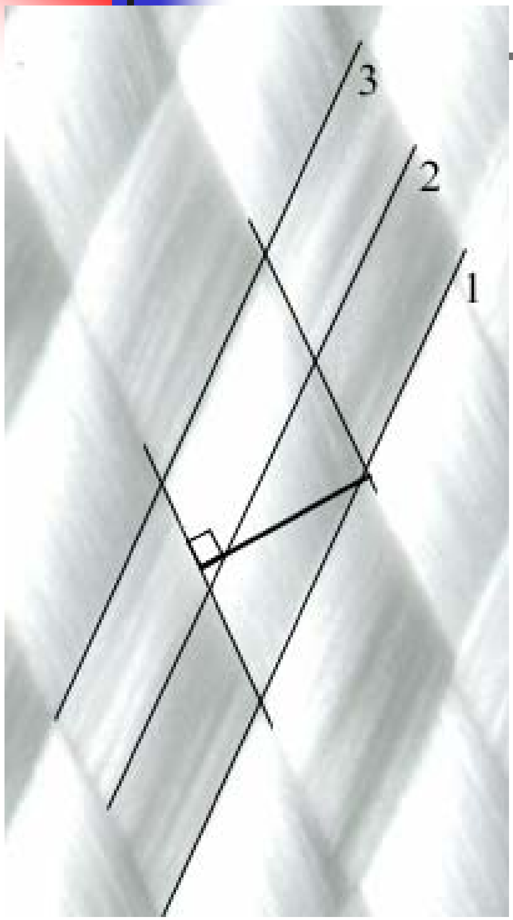

Tow amplitude
A (mm)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
10.0
20.0
30.0
40.0
50.0
Shear angle (º)

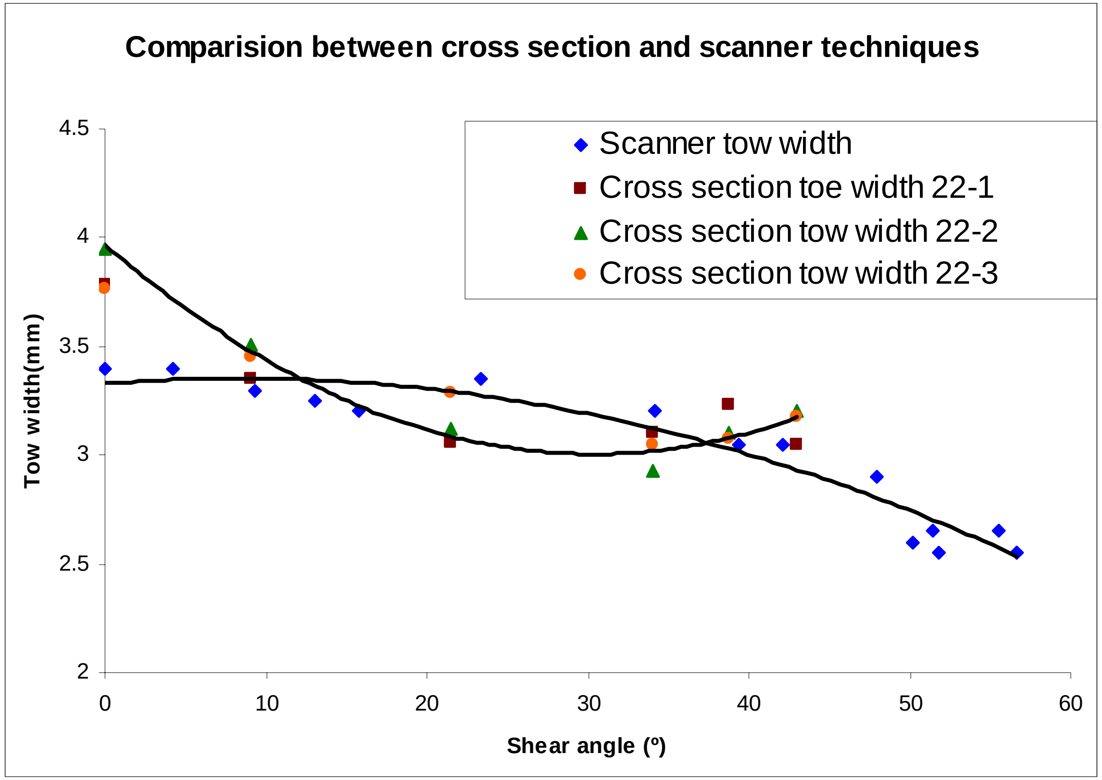

Tow spacing
p (mm)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
Shear angle (º)

Measurement of tow width:

•Scanned image gives a better measurement

•Tow width in each unit cell can be measured





Discussion

- Wide strip bias extension test represents boundary conditions closer to draping.
- By accounting for undeformed zone, shear angles can be computed from global strain values
- Tow slippage occurs in case of a standard width sample. This can be minimised in case of a wide-strip test.
- An inexpensive full-field shear strain measurement technique has been developed. This can potentially be extended to shear strain mapping on a draped surface.
- Geometric parameters of a deformed unit cell have been measured using microscopic techniques. While tow width can be measured from the scanned image, tow thickness can be obtained from a section. Further work is being carried-out using a stereo-imaging technique.
- RUC for each unit cell can be constructed based on the shear angle.