In-plane shear testing with tubular specimens

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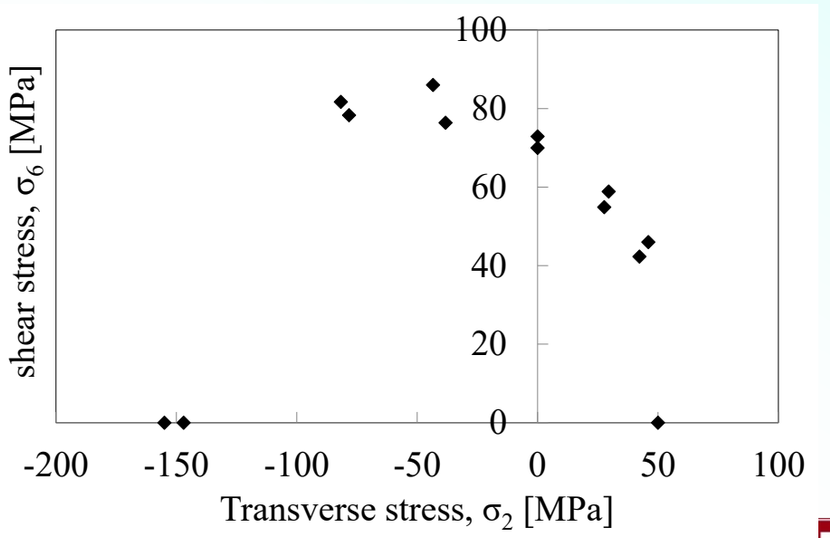
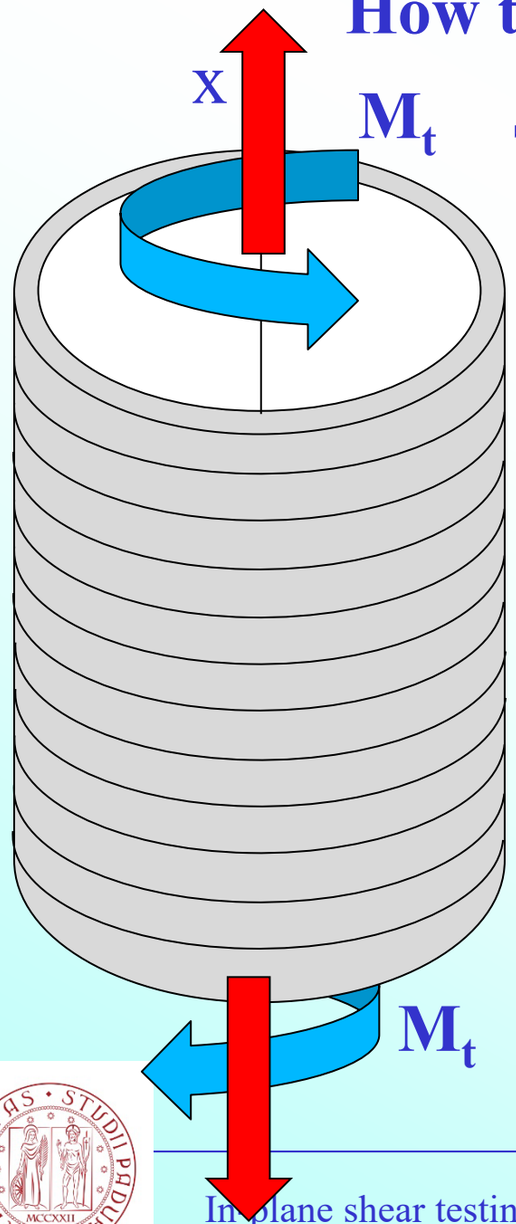


Tube configuration

How to obtain a pure shear stress (σ_6) on a tubular specimen?



Tube under torsion with the UD fibres oriented either at 0° or at 90° with respect to the tube's axis (x-axis)

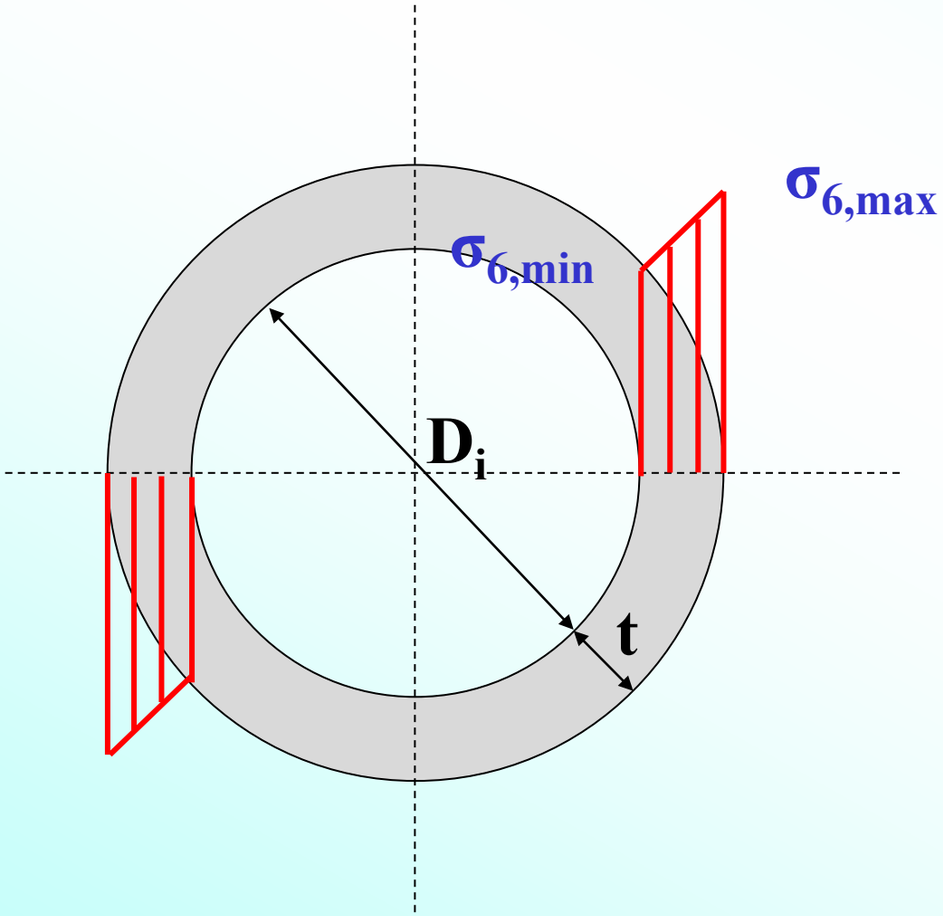
0° → serious issues in manufacturing (large split formation during the demoulding phase)

90°

Combining torsion and tension loadings, possibility to obtain bi-axial stress states (σ_6 and σ_2) or (σ_6 and σ_1)

$$\lambda_1 = \frac{\sigma_2}{\sigma_1},\ \lambda_2 = \frac{\sigma_6}{\sigma_1},\ \lambda_{12} = \frac{\sigma_6}{\sigma_2}$$

Stress state



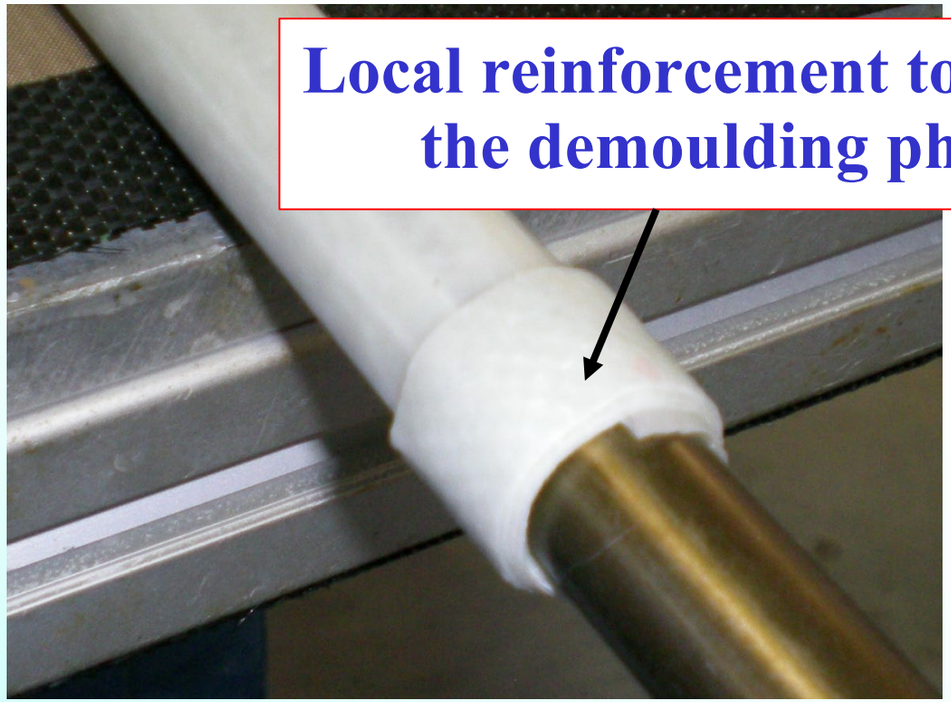
$$\frac{\sigma_{6,\max}}{\sigma_{6,\min}} = \frac{D_e}{D_i} = 1 + 2\frac{t}{D_i}$$

The larger the tube and the thinner the thickness, the lower the stress gradient and the effect of the curvature!

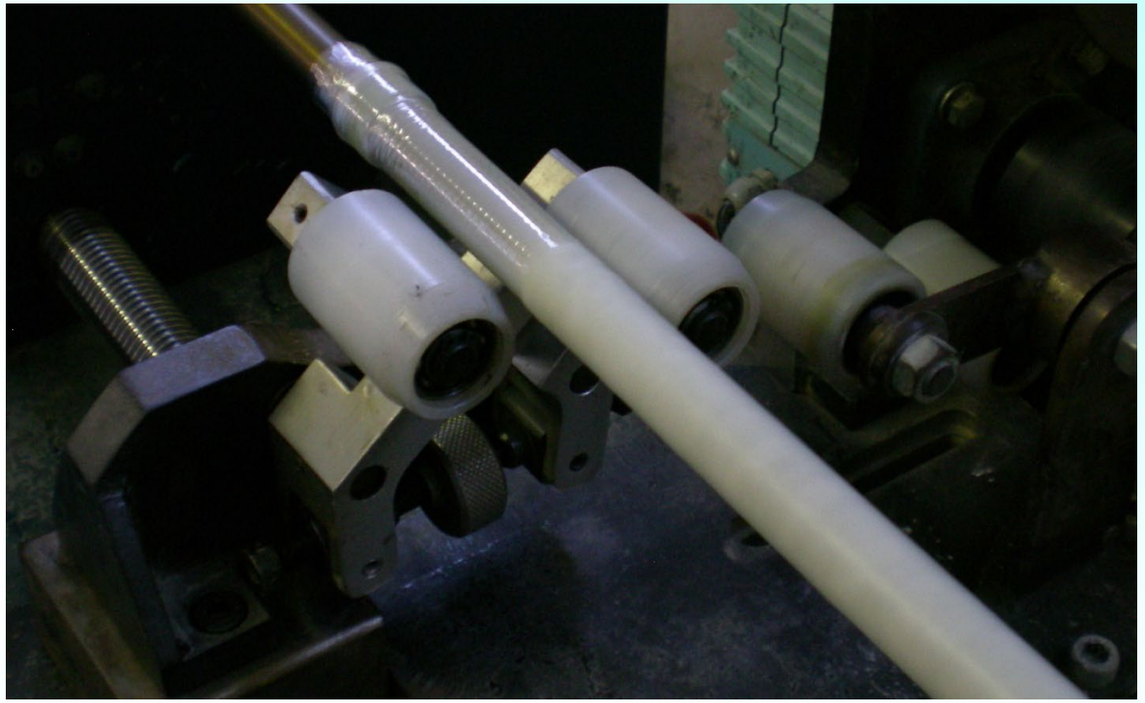
Quaresimin M., Carraro P.A., On the investigation of the biaxial fatigue behaviour of unidirectional composites, Composites Part B, 54 (2013) pp. 200–208.

Tube manufacturing

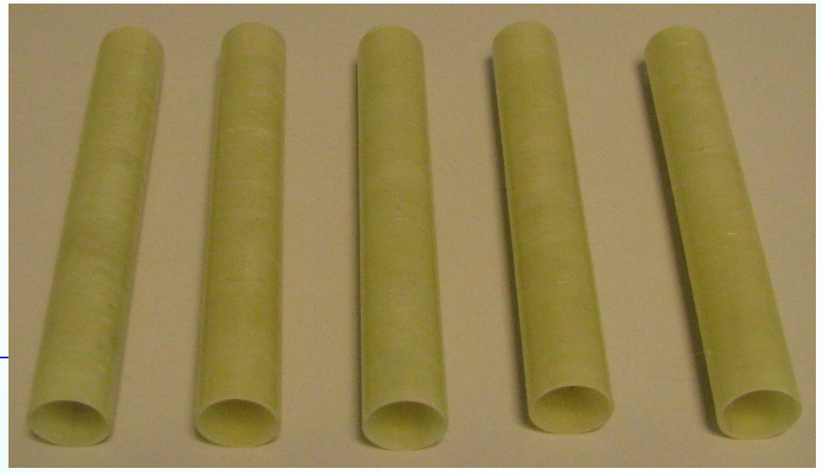
Mandrel wrapping + heat shrinking tape + autoclave moulding



Local reinforcement to help the demoulding phase

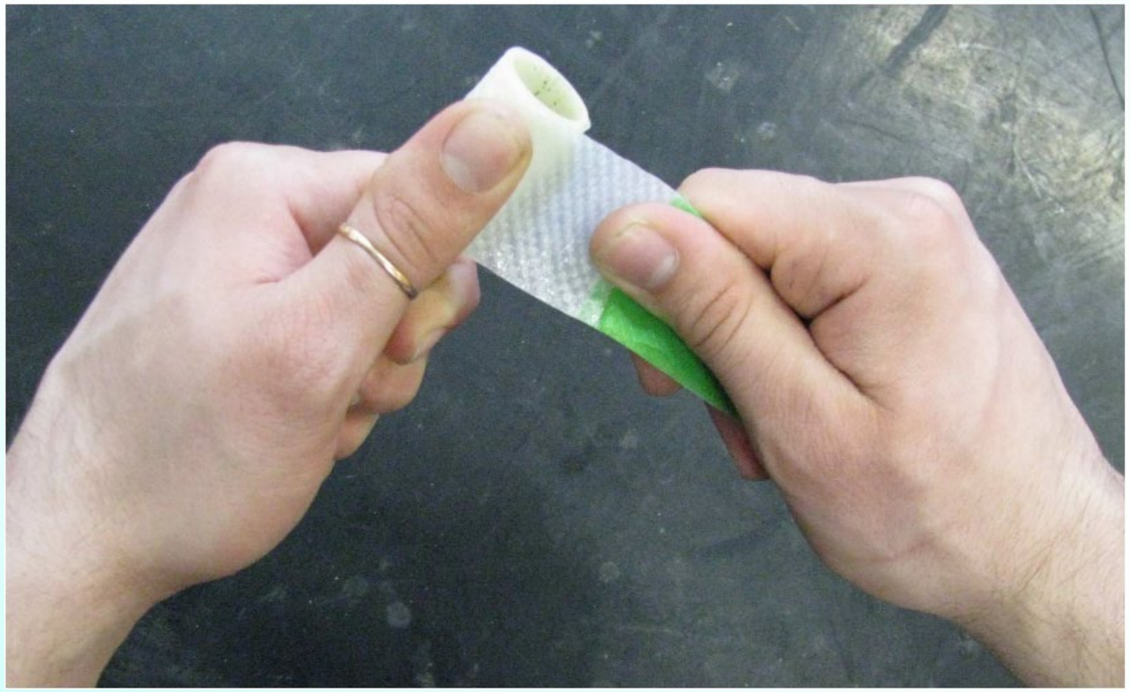


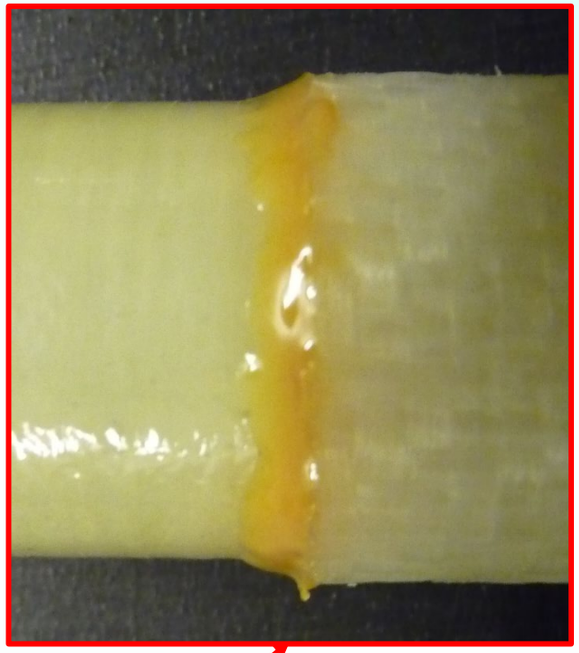
Typically, 1 meter long tubes can be manufactured and then cut into specimens of suitable length

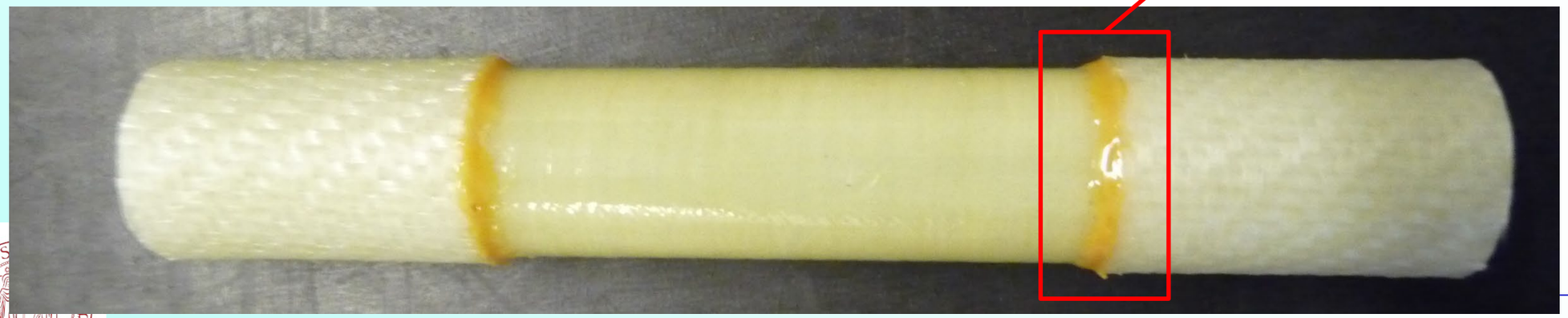


Tabbing

Pre-preg glass epoxy woven tabs rolled around the tube ends and cured in an oven

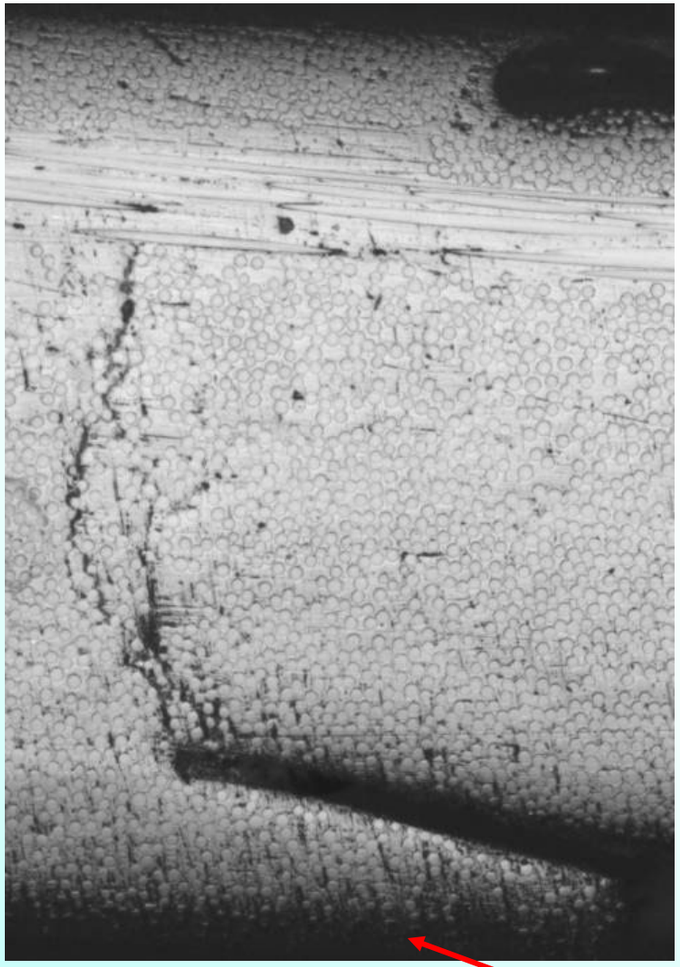


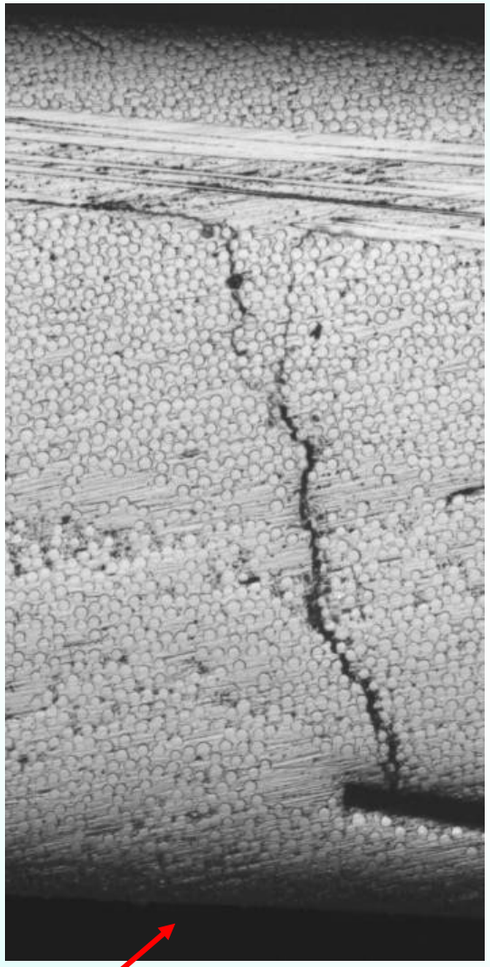




A resin fillet helps avoiding tab failures, particularly under compressive loads

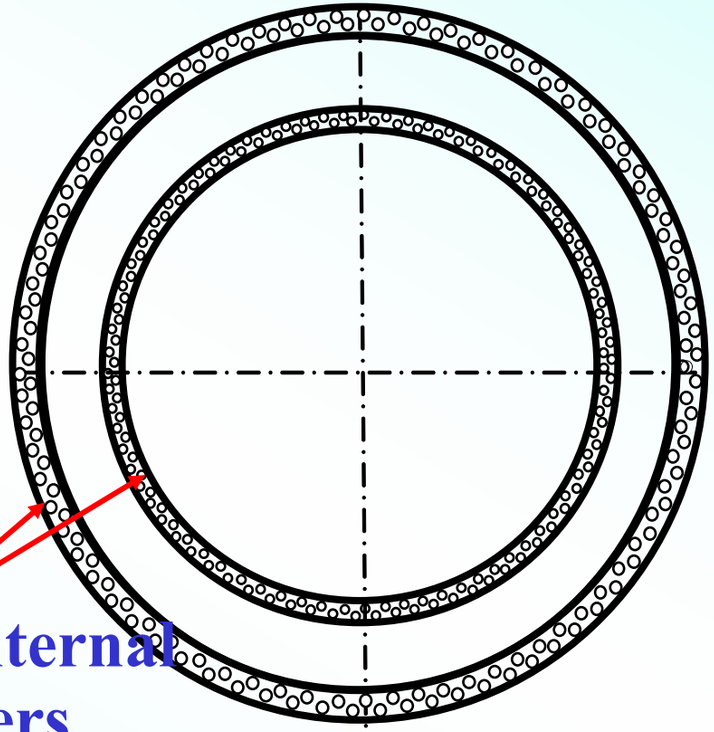
Possible surface defects due to the heat shrinking tape





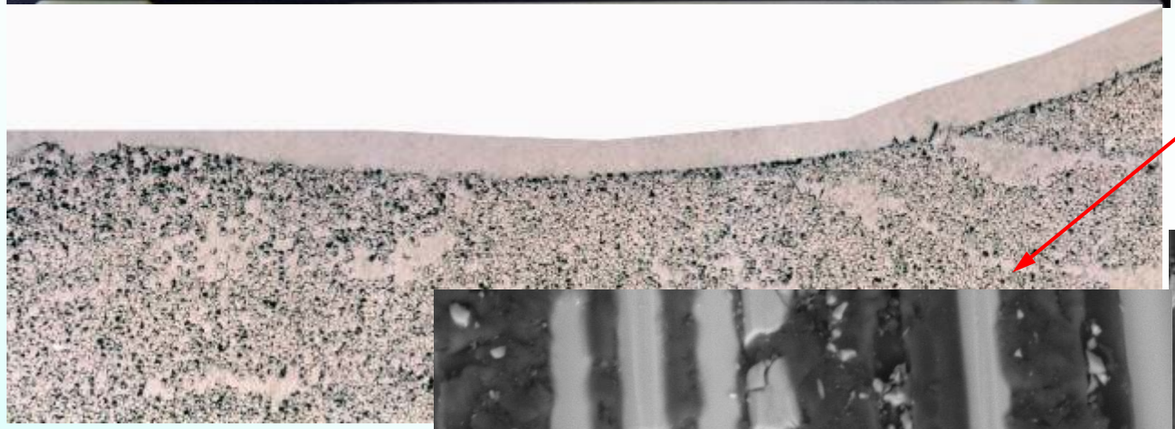
External surface

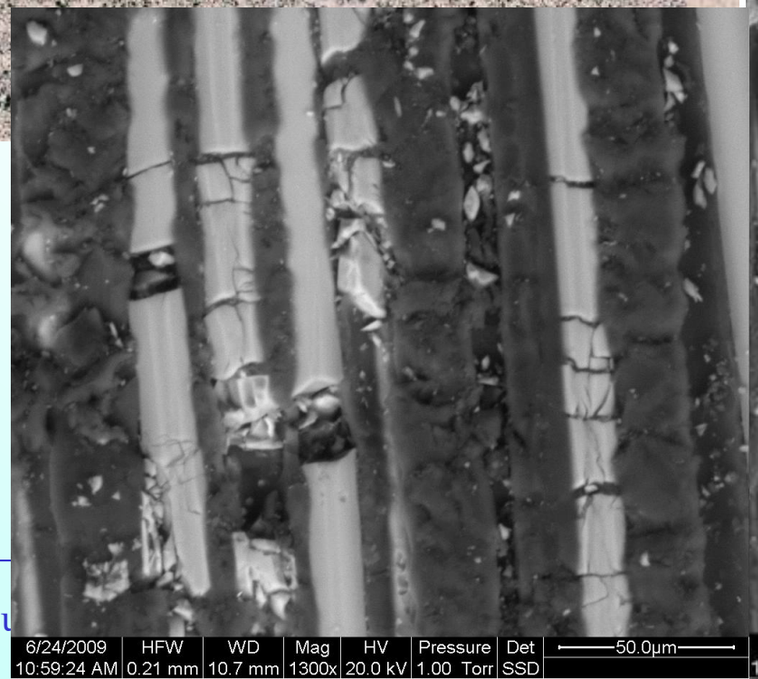
They can be avoided by optimizing the pull and the feed of the heat shrinking tape, or using a cross-ply lay-up (focusing the attention on the crack initiation in the 90° plies only)

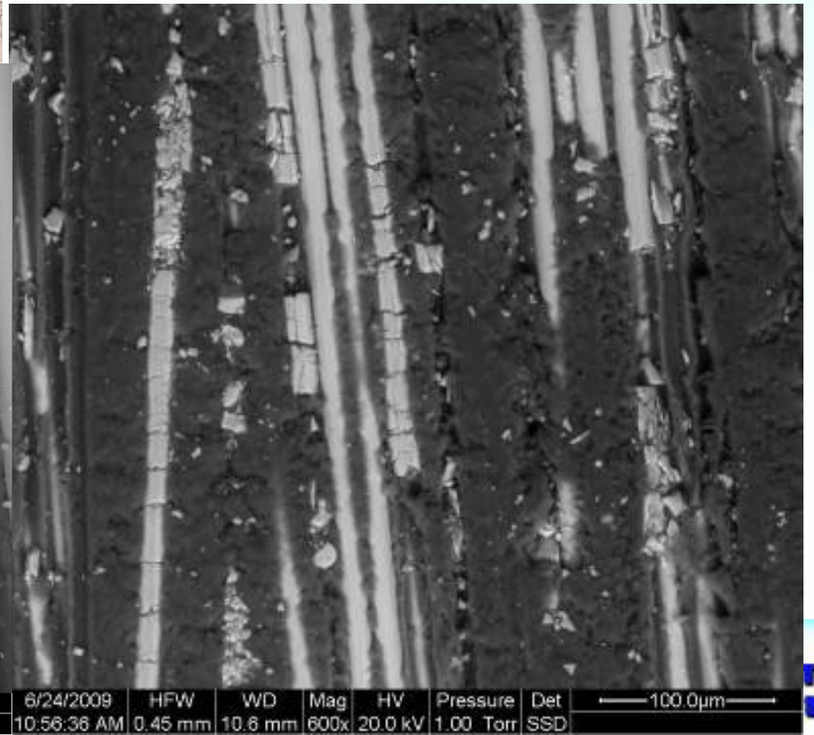


Thin external/internal fabric layers

Tube machining: NOT OF HELP!

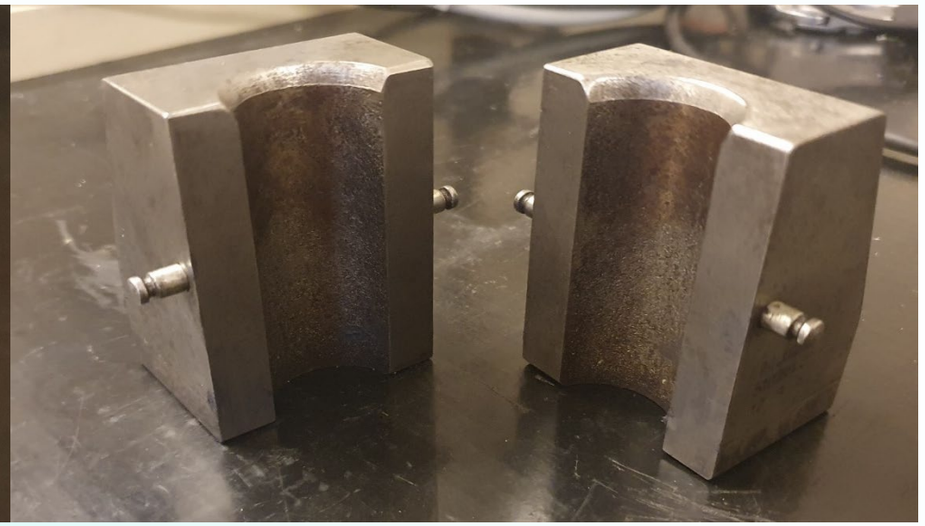


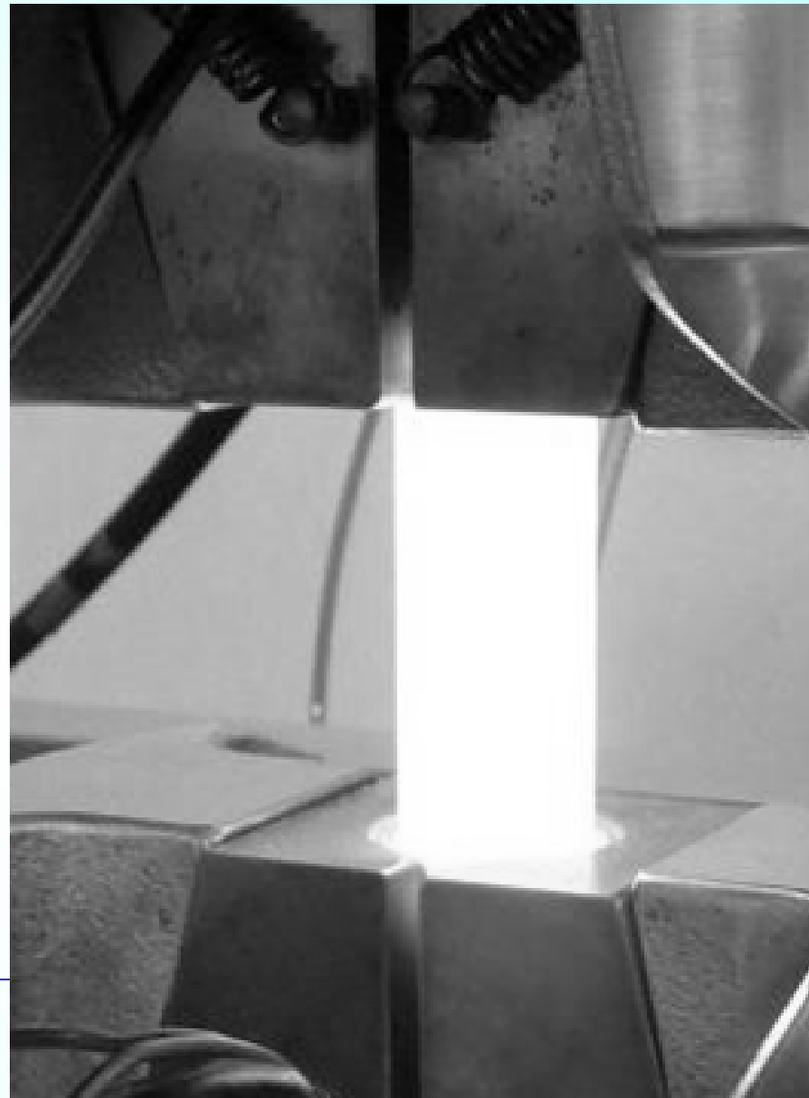




Clamping

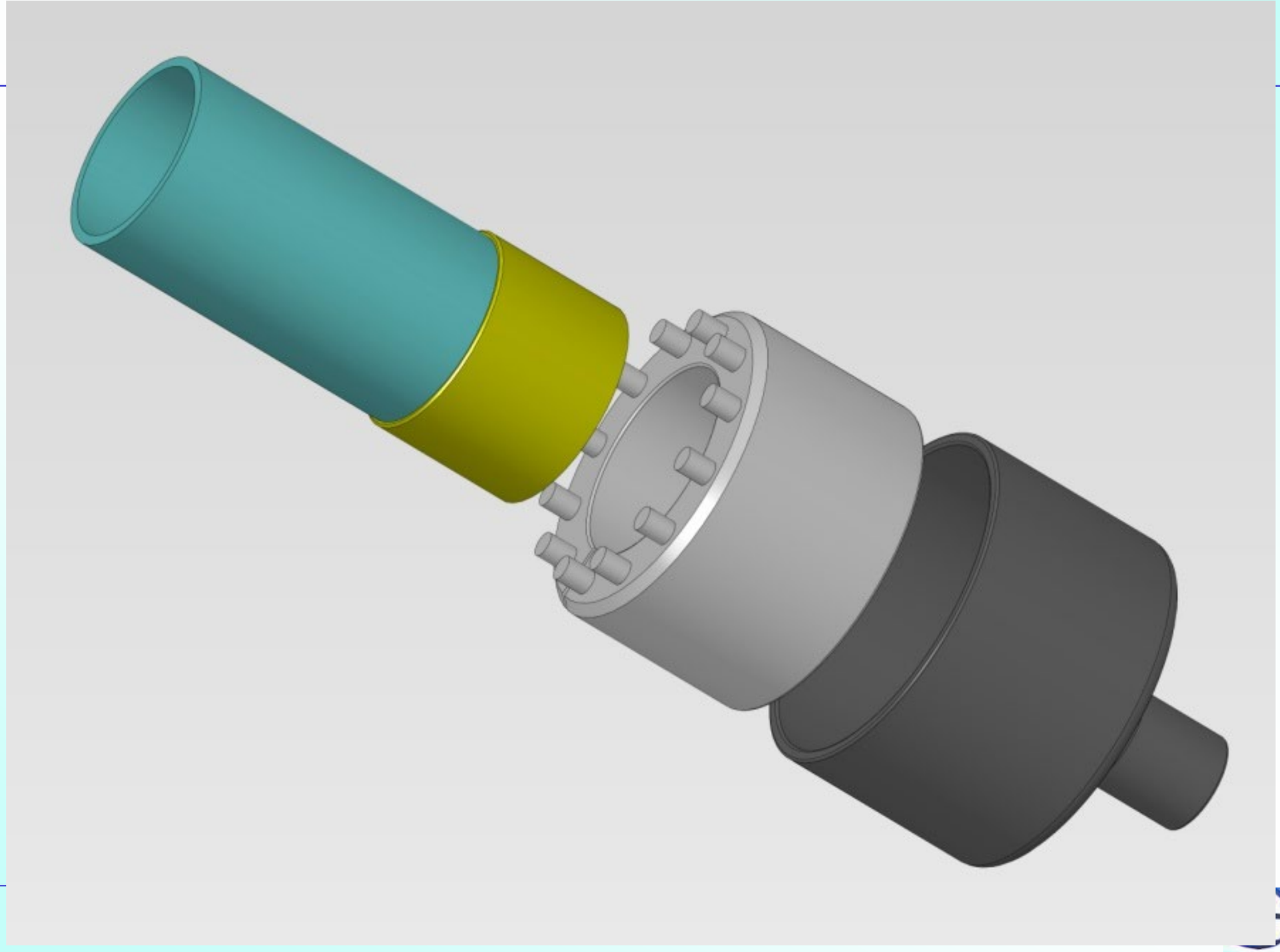
The correct clamping of tubular specimen requires cylindrical grips, which at the end control the tube diameter in the tab zone and the accuracy of the manufacturing required



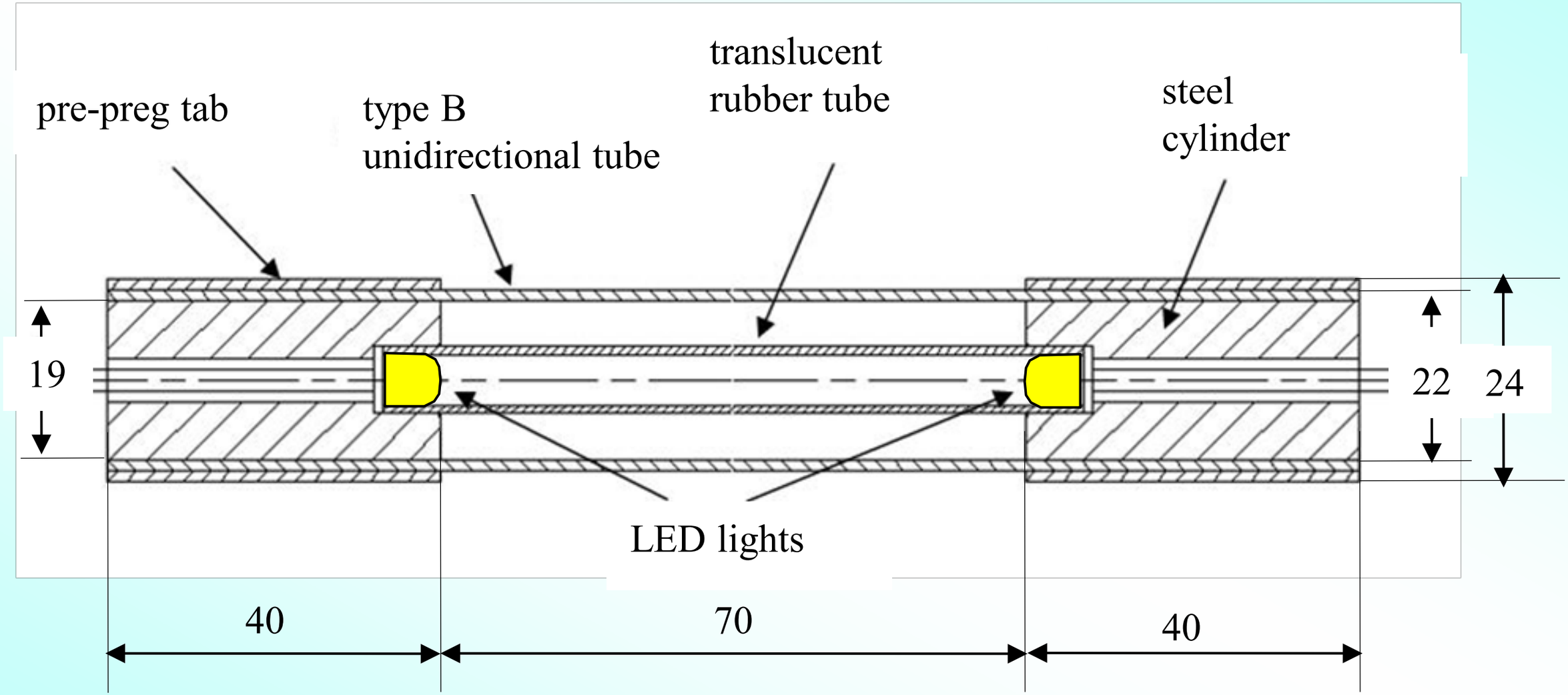


Clamping

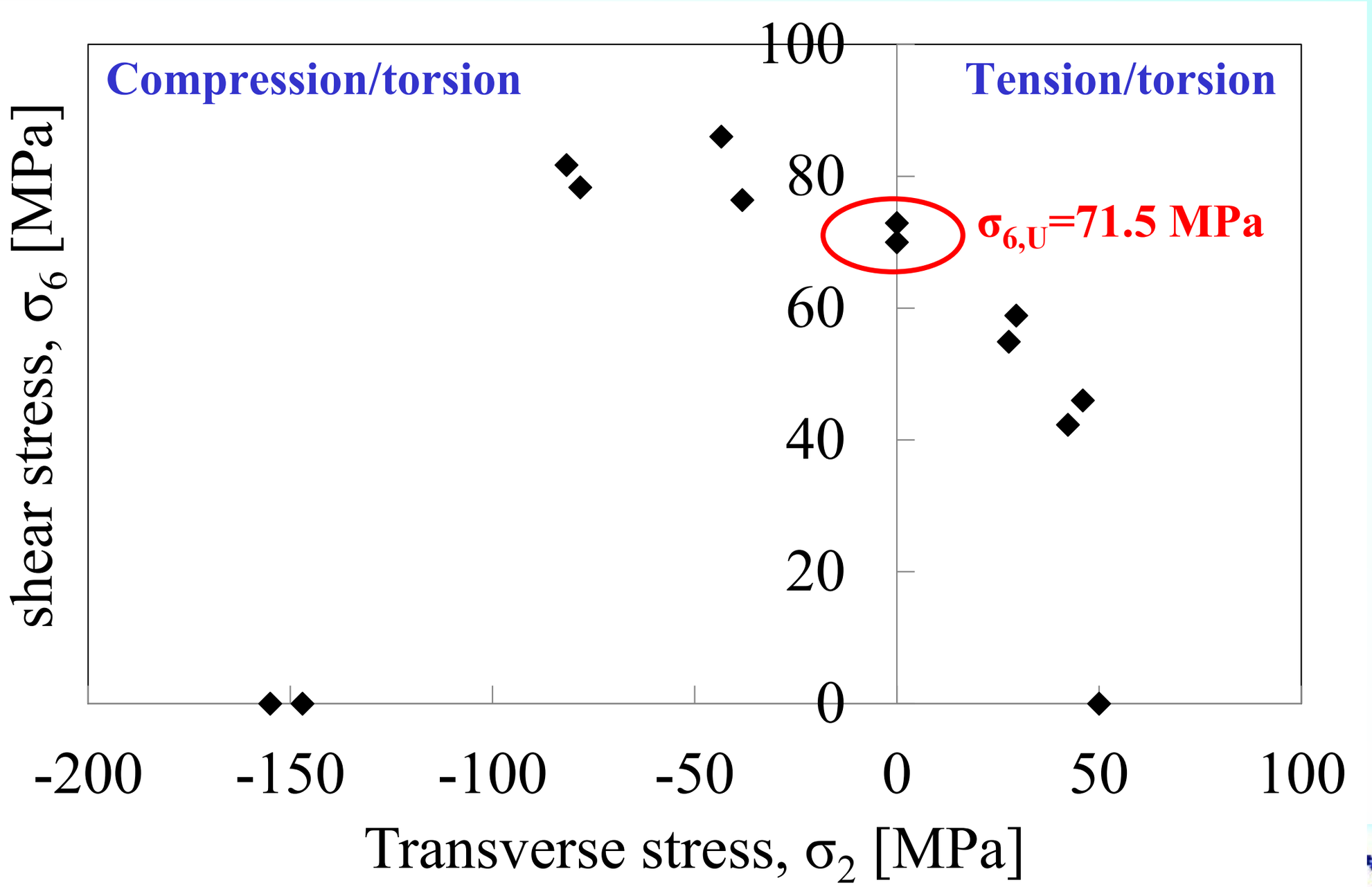
For large tubes, a dedicated clamping system is required, keyless friction locking devices can be used successfully



Internal light for damage analysis (G/E only)



Multiaxial proportional tests on 90° UD G/E tubes



Conclusions

Advantages of tubular specimens:

- **No free edges**
- **Pure shear stress state under torsion (direct assessment of the shear strength, modulus and constitutive law)**
- **No stress concentrations and very limited stress gradients**
- **Possibility of combining shear and transverse stress using the same specimen configuration**

Drawbacks:

- **Not easy to manufacture**
- **Require a (tension)/torsion machine**

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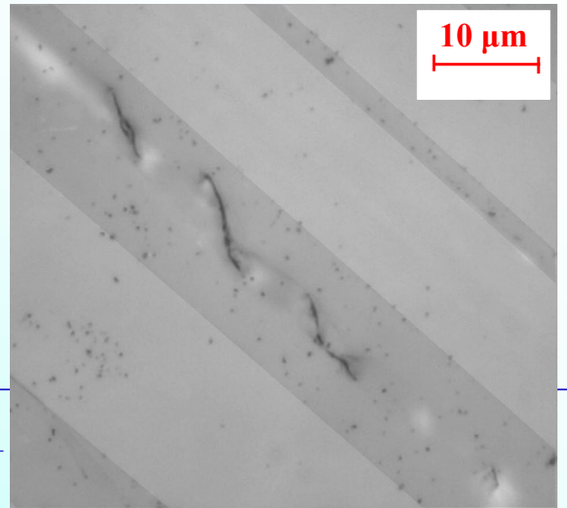

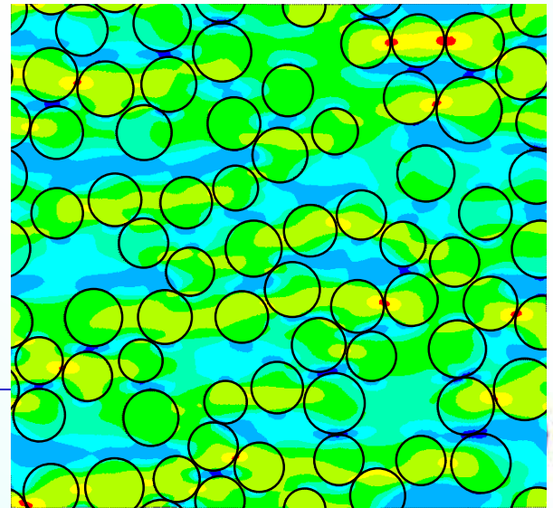

In-pl mens –

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