Measurement Capabilities

In-plane Measurements

- In-plane longitudinal velocities along MD ($v_{L,MD}$) and CD ($v_{L,CD}$)
- In-plane shear velocities along CD ($v_{S,\ MD\text{-}CD}$) and at 45 deg. with respect to MD ($v_{S,\ 45}$)
- In-plane specific stiffnesses:

$Q'_{11} = \left(v_{SO-MD}\right)^2$ (MD longitudinal specific elastic stiffness constant)

$Q'_{22} = \left(v_{SO-CD}\right)^2$ (CD longitudinal specific elastic stiffness constant)

$Q'_{66} = \left(v_{S-MD-CD}\right)^2$ (MD-CD or CD-MD shear specific elastic stiffness constant)

$$Q'_{12} = \left\{ \left[2v_{s-45}{}^2 - \frac{\left(Q'_{11} + Q'_{22}\right)}{2} - Q'_{66} \right]^2 - \left[\left(\frac{Q'_{11} - Q'_{22}}{2} \right) \right]^2 \right\}^{\frac{1}{2}} - Q'_{66}$$

- In-plane elastic stiffness constants (assuming that density can be computed):

$Q_{11} = \rho Q'_{11}$

$Q_{22} = \rho Q'_{22}$

$Q_{66} = \rho Q'_{66}$

$Q_{12} = \rho Q'_{12}$

- In-plane engineering constants:

$\nu_{MD-CD} = \nu_{12} = \dfrac{Q_{12}}{Q_{11}} = \dfrac{Q'_{12}}{Q'_{11}}$ (MD-CD Poisson's ratio)

$\nu_{CD-MD} = \nu_{21} = \dfrac{Q_{12}}{Q_{22}} = \dfrac{Q'_{12}}{Q'_{22}}$ (CD-MD Poisson's ratio)

$$E_{MD} = Q_{11} - \frac{Q_{12}{}^2}{Q_{22}} = Q_{11}(1 - \nu_{12}\nu_{21})$$ (MD Young's modulus)

$$E_{CD} = Q_{22} - \frac{Q_{12}{}^2}{Q_{11}} = Q_{22}(1 - \nu_{12}\nu_{21})$$ (CD Young's modulus)

$$G_{MD-CD} = Q_{66}$$ (MD-CD shear modulus)

- In-plane stiffness anisotropy ratio:

$$R_{MD-CD} = \frac{E_{MD}}{E_{CD}} = \frac{Q_{11}}{Q_{22}} = \frac{Q'_{11}}{Q'_{22}}$$

- Polar diagram with 15-degree angular increment:
    - Stiffness orientation angle (SOA)
    - MD/CD stiffness ratio
    - Max/Min stiffness ratio

Out-of-plane Measurements

- Soft-platen thickness (loading pressure set to 50 kPa)

- Out-of-plane longitudinal velocity: $v_{L\text{-}ZD}$

- Out-of-plane longitudinal specific stiffness:

$$C'_{33} = (v_{L-ZD})^2$$

- Out-of-plane longitudinal elastic stiffness constant (assuming that grammage is available):

$$C_{33} = \rho\, C'_{33}$$