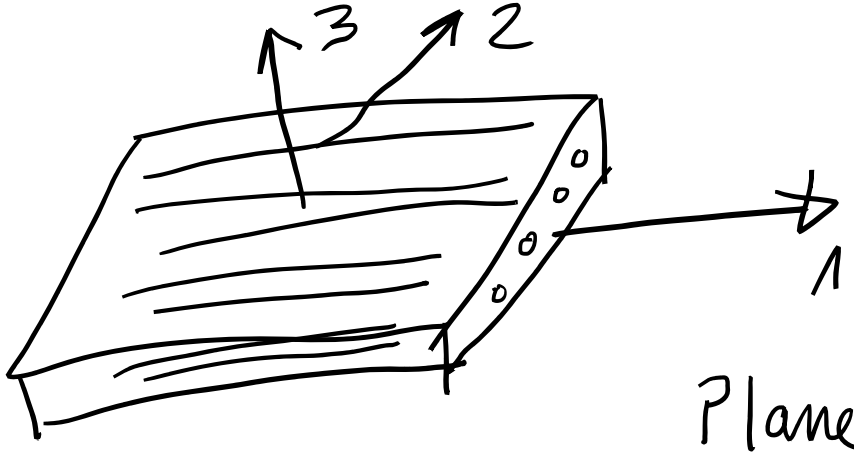
UD-Lamina



~~orthotropic~~

9 independent Const

E_{11}, E_{22}, E_{33}

G_{12}, G_{13}, G_{23}

$\nu_{12}, \nu_{13}, \nu_{23}$

transversal isotropic

5 ind. Const.

$E_{11}, E_{22} = E_{33}$,

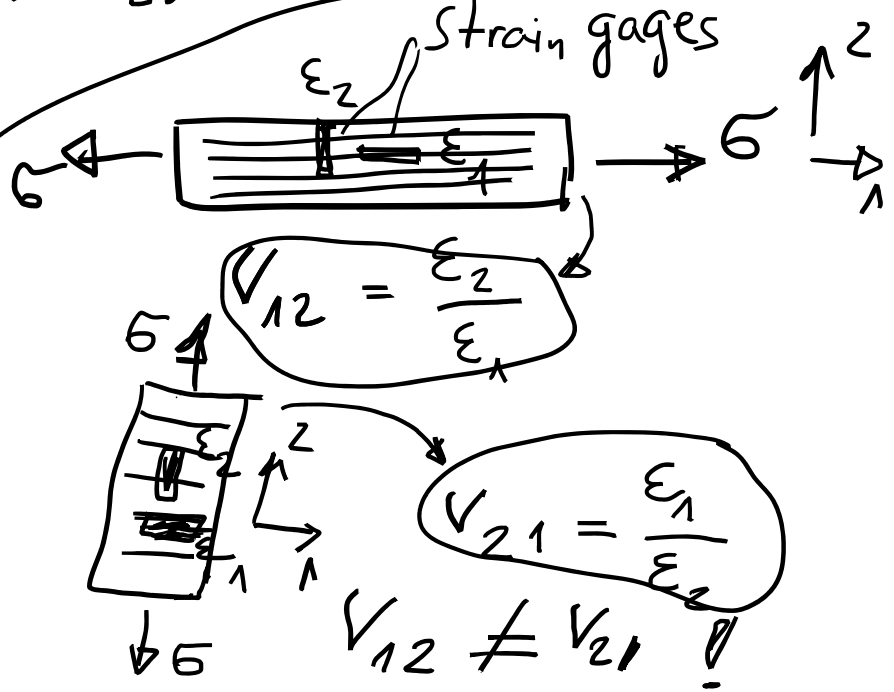
G_{12}, ν_{12}, G_{23}

Plane stress

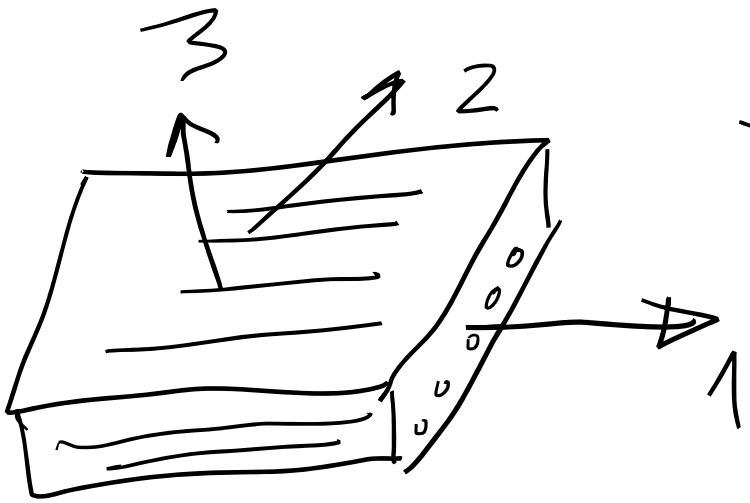
4 ind. Const

E_{11}, E_{22}

G_{12}, ν_{12}



ν_{12}: major Poisson ration / ν_{21}: minor



UD-Lamina stiffness matrix

$$\begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \tau_{12} \end{pmatrix} = \begin{pmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \gamma_{12} \end{pmatrix}$$

$$Q_{12} = Q_{21} \; !$$

E_f, ν_f
E_m, ν_m
Q_f

$\longrightarrow$ E_{11}, E_{22}
G_{12}, ν_{12} $\longrightarrow$ $\begin{pmatrix} Q_{11} & Q_{12} & 0 \\ Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{pmatrix}$

Theoretical:

$$E_{11} = E_f \varphi_f + E_m (1 - \varphi_f)$$
$$\nu_{12} = \nu_f \varphi_f + \nu_m (1 - \varphi_f)$$

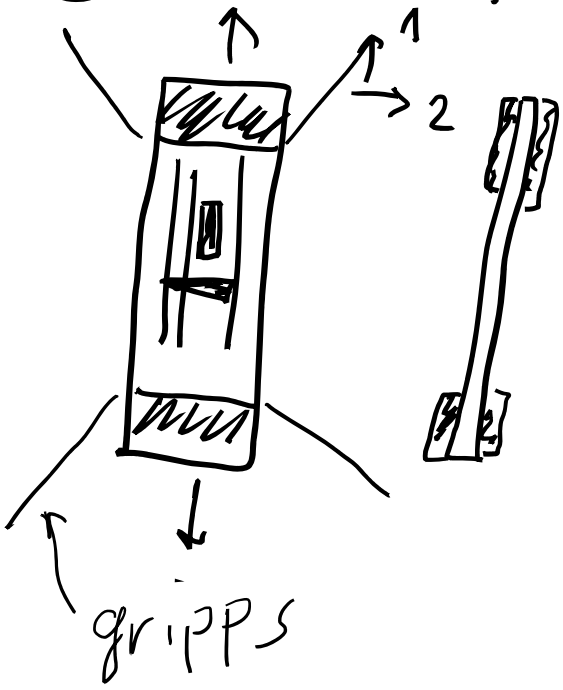
E_{22}
G_{12} $\longrightarrow$ See Semi empirical equations

Experimental determination of UD-Lamina Properties

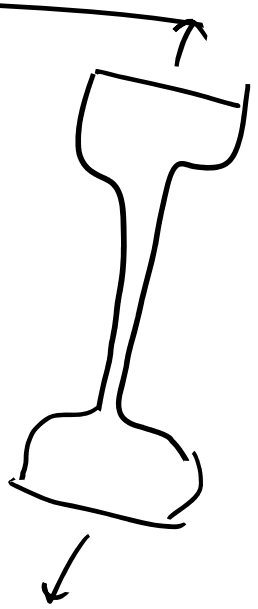
E_{11}, E_{22}, ν_{12}, G_{12}

---

(1) uniaxial tensile test: E_{11}, ν_{12}, σ_{11} failure

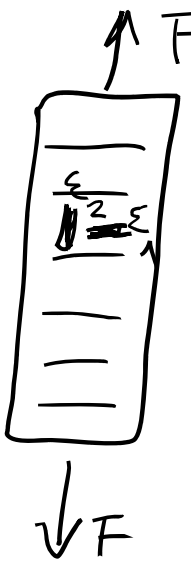


$$\begin{pmatrix} \sigma_{11} \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} Q_{11} & Q_{12} & 0 \\ Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ 0 \end{pmatrix}$$ or



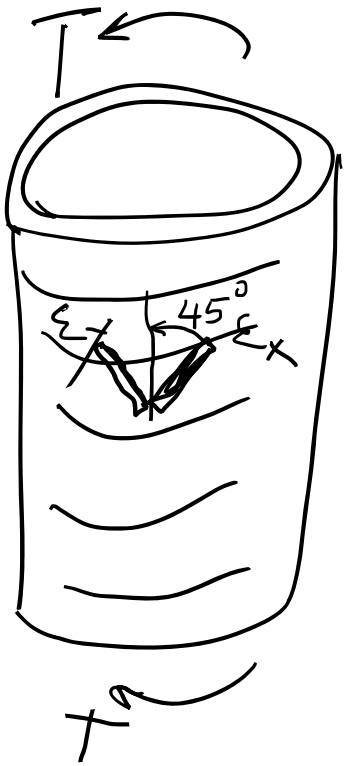
measurment uncertainties:

(2) uniaxial tensile test : E_{22}, ν_{21}, ε_{22} failure

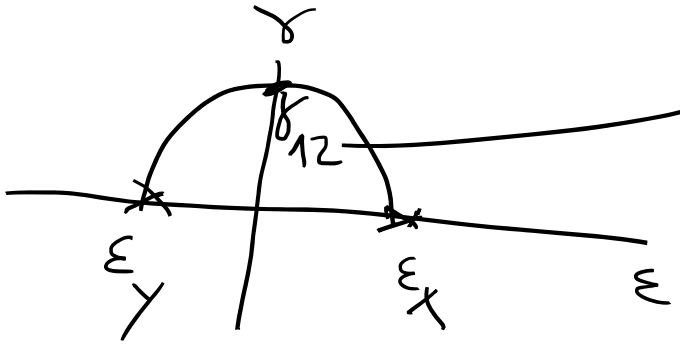


better

③ Torsion test : G_{12}, τ_{12} failure

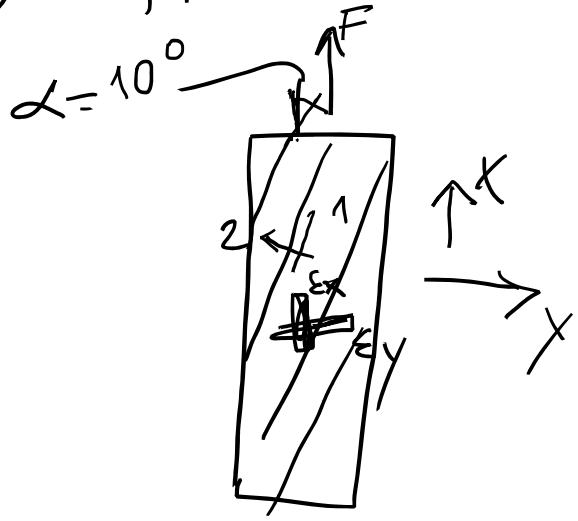


$$\tau_{12} = G_{12} \cdot \gamma_{12}$$



$$\tau_{12} = f(T, R, t)$$

④ off-axis tensile test : G_{12}



$$\begin{pmatrix} \sigma_x \\ 0 \\ 0 \end{pmatrix} \xrightarrow{\text{rotate}} \begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \tau_{12} \end{pmatrix}$$

$$\begin{pmatrix} \varepsilon_x \\ \varepsilon_y \\ 0 \end{pmatrix} \xrightarrow{\text{rotate}} \begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \gamma_{12} \end{pmatrix}$$

$$\begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \gamma_{12} \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} & 0 \\ S_{12} & S_{22} & 0 \\ 0 & 0 & S_{66} \end{pmatrix} \begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \tau_{12} \end{pmatrix} \Rightarrow \gamma_{12} = S_{66}\,\tau_{12} \longrightarrow G_{12}$$

(5) Biaxial tension/torsion test