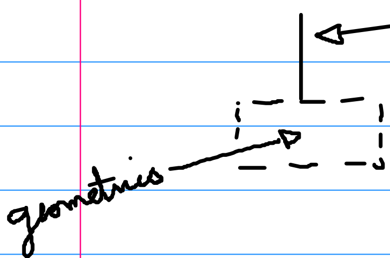
Chapitre 4 : comment mesurer les ≠ paramètres

I Quels appareils de mesure ?

1) Rhéomètres commerciaux

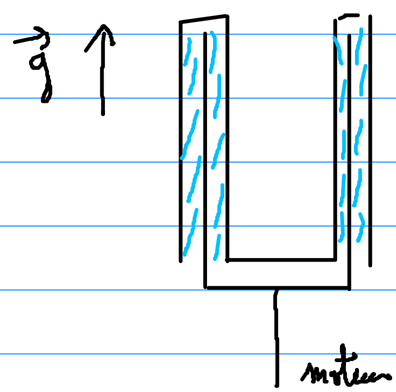


moteur ⇒ mesurer / contrôler la déformation

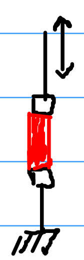
capteur de force ⇒ mesurer / contrôler la contrainte

≠ géométries

ex double couette



2) Machine de traction (solides viscoélastiques)

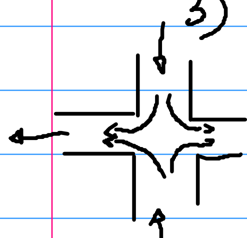


capteur de position / moteur ⇒ ε mesuré ou contrôlé

capteur de force ⇒ σ mesurée ou contrôlée

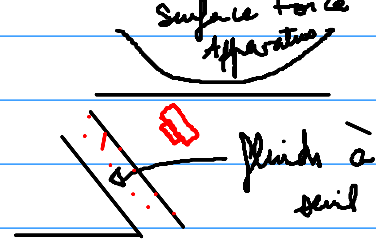
3) Expériences ad-hoc

écoulement extensionnel



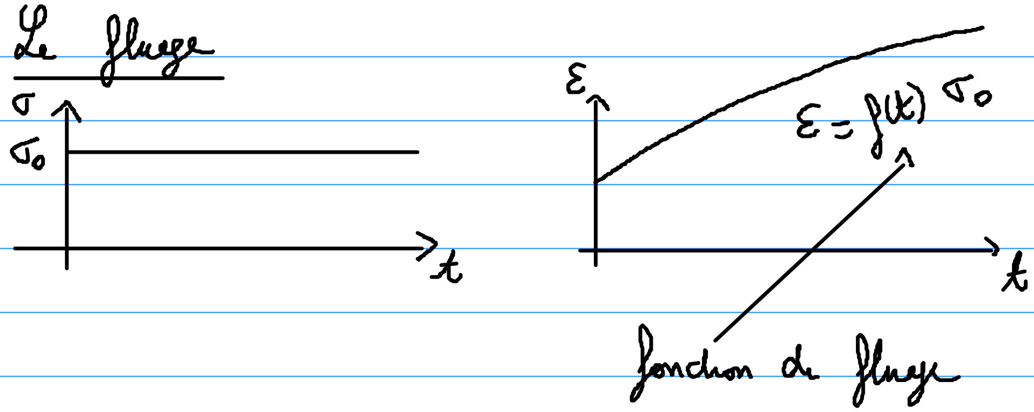
→ microfluidique

SFA Surface Force Apparatus

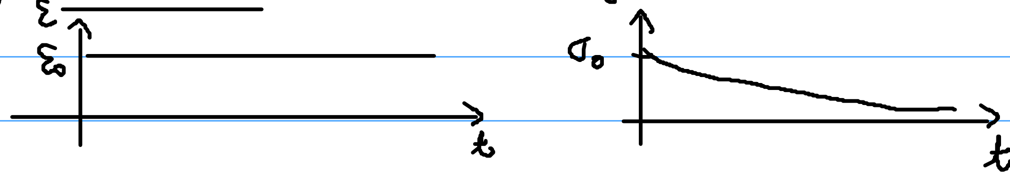


II – Quelle sollicitation ? Quelle mesure ?

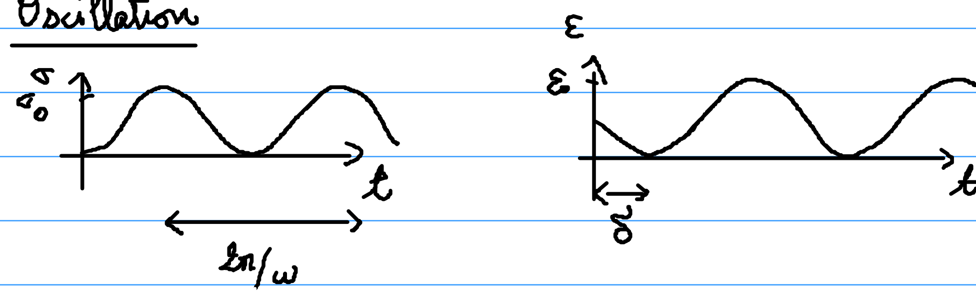
a) Le fluage



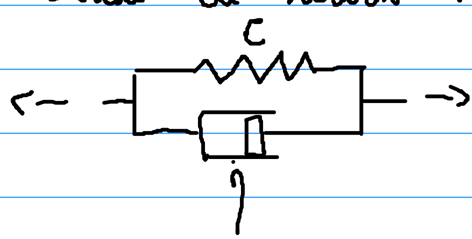
b) La relaxation



c) Oscillation



exemple Solide de Kelvin-Voigt



$$\sigma = E\varepsilon + \eta\dot{\varepsilon}$$

$$\dot{\varepsilon} + \frac{E}{\eta}\varepsilon = \frac{\sigma}{\eta}$$

Fluage $t < 0 \quad \sigma = 0$

$t \geq 0 \quad \sigma = \sigma_0$

$$\varepsilon = \frac{\sigma_0}{E}\left(1 - e^{-t/\tau}\right)$$

$$f(t) = \frac{1 - e^{-t/\tau}}{E}$$

Relaxation $\varepsilon = \varepsilon_0$ $\sigma = E\varepsilon_0$

$g(t) = E$

Oscillation $\sigma^* = \sigma_0 e^{i\omega t}$ $\varepsilon^* = \varepsilon_0 e^{i\omega t}$

$$\sigma_0 = E\varepsilon_0 + \eta i\omega\varepsilon_0$$

$$\sigma^* = \varepsilon_0(E + i\omega\eta)\, e^{i\omega t}$$

$$\sigma = Re(\sigma^*) = \varepsilon_0 \underbrace{E}_{G' = E} \cos\omega t - \underbrace{\omega\eta}_{G''}\varepsilon_0 \sin\omega t$$

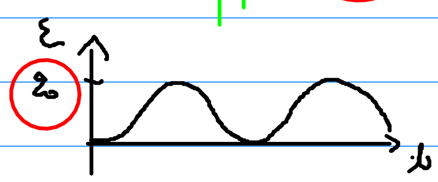
$$= \sigma_0 \cos(\omega t + \delta)$$

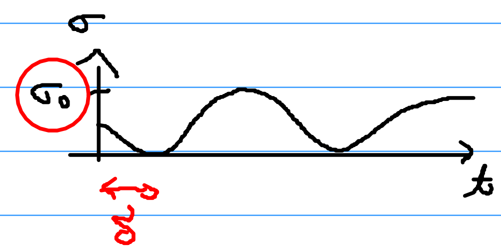
$$= \sigma_0(\cos\omega t \cos\delta - \sin\omega t \sin\delta)$$

$$\sigma_0 \cos\delta = \varepsilon_0 G' \qquad \sigma_0 \sin\delta = G''\varepsilon_0$$

$$G' = \frac{\sigma_0}{\varepsilon_0}\cos\delta \qquad G'' = \frac{\sigma_0}{\varepsilon_0}\sin\delta$$

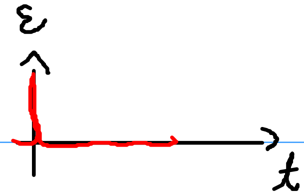
$$\tan\delta = \frac{G''}{G'}$$

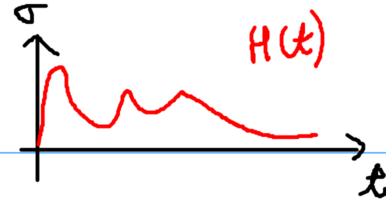


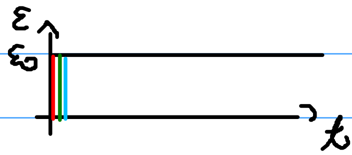


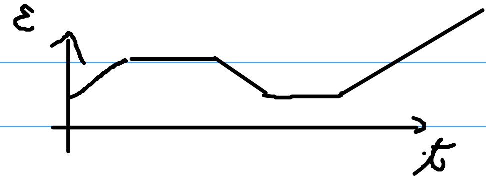
III – La fonction réponse

- Fluides complexes
- Fonction complexe $\Leftrightarrow$ ressorts et pistons
- $G'(\omega)$ $G''(\omega)$
- réponse à un dirac $H(\omega)$









$$\sigma = \int_0^{+\infty} g(t - t^*)\ \varepsilon(t^*)\ dt^*$$

La réponse à n'importe quelle sollicitation