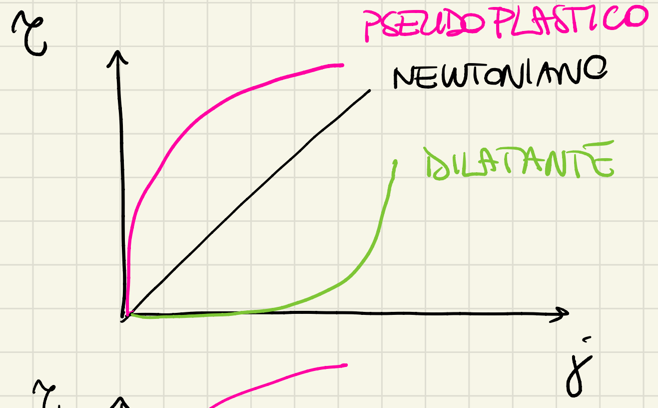
LEZIONE 14 7.12.2022

Viscosità dei fluidi polimerici

I fluidi polimerici allo stato gommoso presentano un comportamento reologico NON-NEWTONIANO

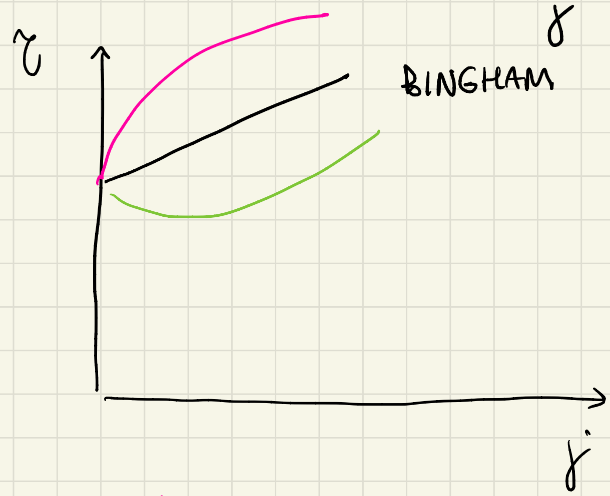
$\boxed{\tau_y = 0}$



$\tau = k\dot{\gamma}^n$

Legge di Potenza

$\boxed{\tau_y > 0}$



FLUIDI di HARSCHEL e BULKLEY

$$\boxed{\tau = \tau_y + k\dot{\gamma}^n}$$

k = INDICE di CONSISTENZA $[Pa \cdot s^n]$

n = ESPONENTE

REOLOGIA FONDAMENTALE X

(1) I PROCESSI di TRASFORMAZIONE

$T \gg T_g$, $10^1 s^{-1} < \dot{\gamma} < 10^5 s^{-1}$

(2) PROPRIETÀ MECCANICHE $T \geq T_g$

COMPORTAMENTO VISCOELASTICO

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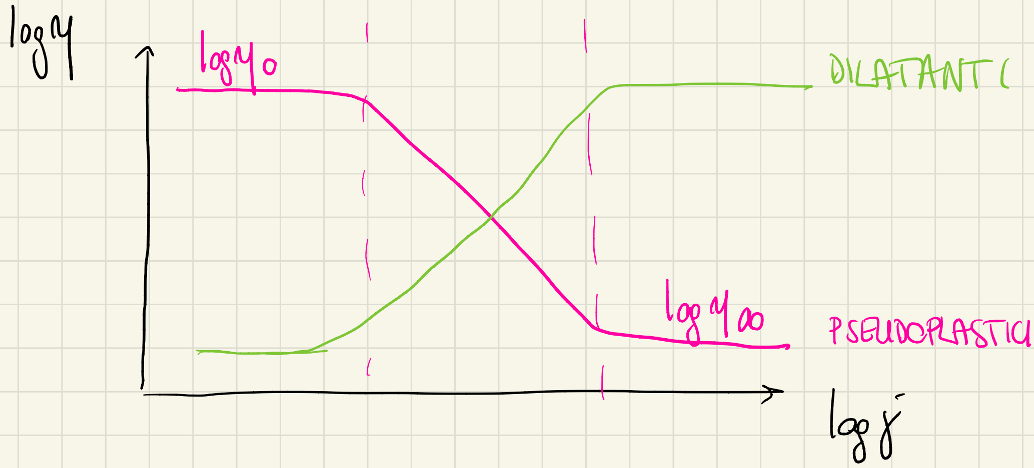
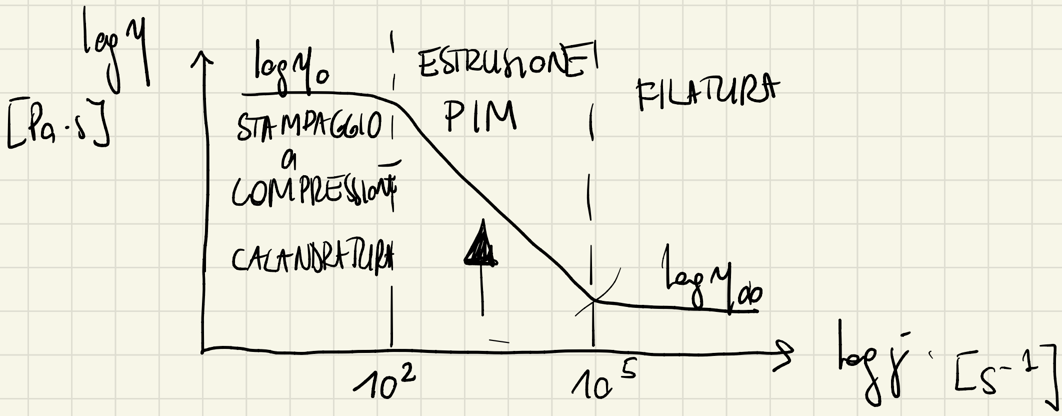
(1)





$\log \eta \rightarrow \eta$ VISCOSITÀ DINAMICA
VISCOSITÀ APPARENTE
VISCOSITÀ COMPLESSA

$\log \eta_0 \rightarrow \eta_0$ VISCOSITÀ INTRINSECA
ZERO SHEAR RATE VISCOSITY

$\log \eta_\infty \rightarrow \eta_\infty$ VISCOSITÀ ad ELEVATE $\dot{\gamma}$
INFINITE SHEAR RATE VISCOSITY

$\boxed{\text{CROSS}}$ $$\eta(\dot{\gamma}) = \eta_\infty + \frac{\eta_0 - \eta_\infty}{1+(k\dot{\gamma})^m}$$

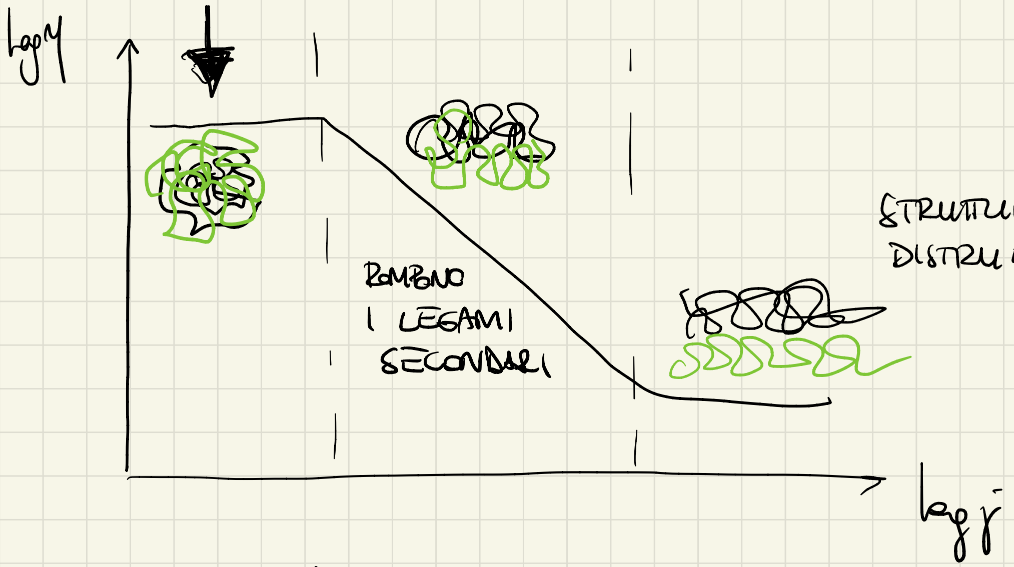
$\boxed{\text{CARREAU YASUDA}}$ $$\eta(\dot{\gamma}) = \left[1 + (\lambda\dot{\gamma})^a\right]^{\frac{n-1}{a}} (\eta_0 - \eta_\infty) + \eta_\infty$$

$\lambda \rightarrow$ TEMPO di RILASSAMENTO del POLIMERO

a esponente
n
k

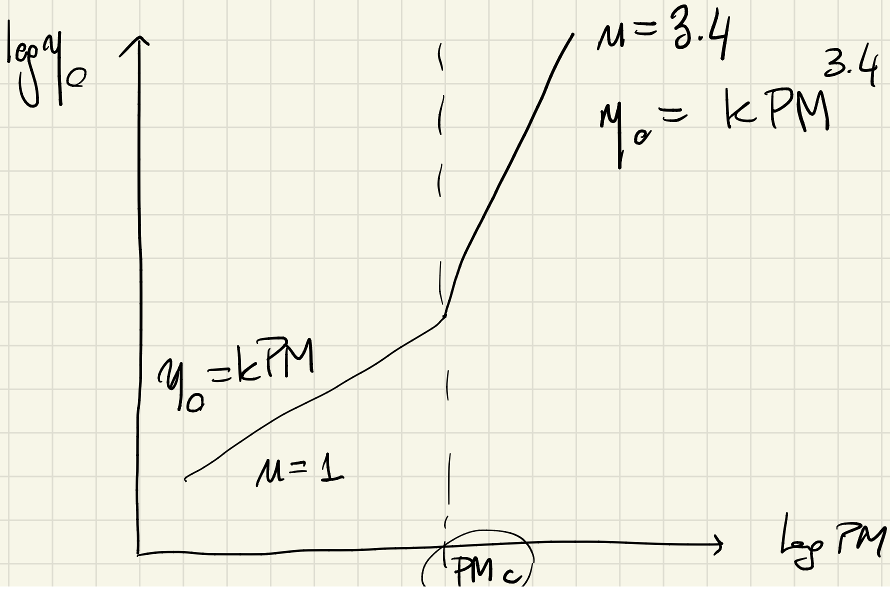
Legge di Potenza

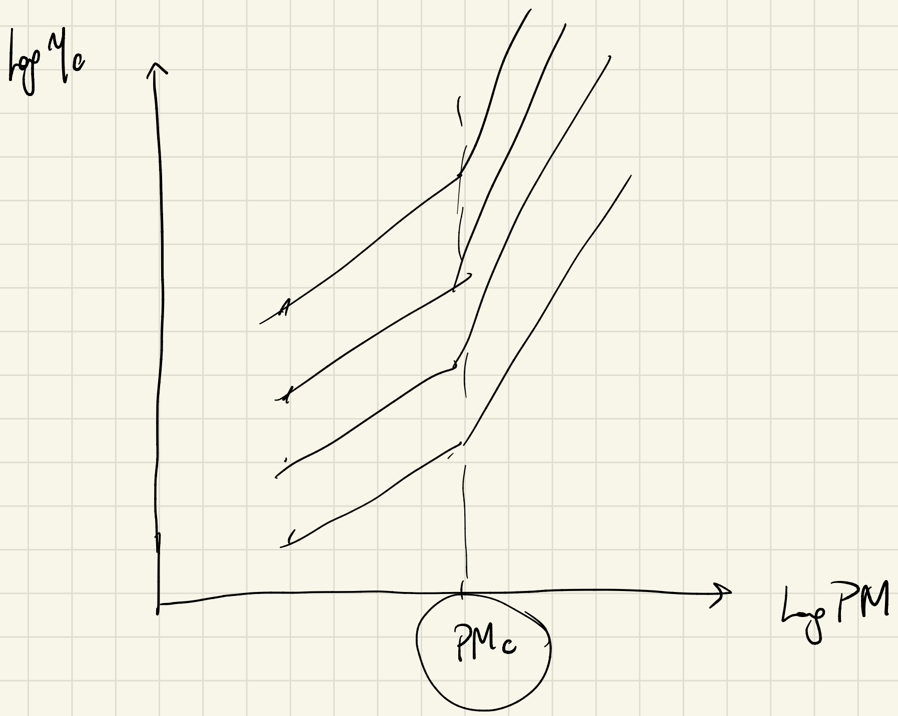
$$\eta(\dot{\gamma}) = k\,\dot{\gamma}^{\,n-1}$$



EFFETTO del PESO MOLECOLARE

$$\eta_0 = k\,PM^{n}$$





PROCESSI di RICICLO MECCANICO $PM > PM_C$

PRINCIPIO di EQUIVALENZA t - T

Metodo sperimentale utilizzato per parametrizzare una grandezza fisica es. VISCOSITÀ

FATTORE di SPOSTAMENTO a_T

$$\log a_T = \frac{-C_1 (T - T_r)}{C_2 + (T - T_r)}$$

Eq.ne di William-Landel Ferry WLF

$C_1 = 17.4 \; [-]$

$C_2 = 51.6 \; [K] \text{ o } [°C]$

Ricavata Sperimentale

$T_r = T_G$

$T_G < T < T_G + 200°C$

$$\log a_T = \log \frac{\eta(T)}{\eta(T_G)} = \frac{-C_1 \Delta T}{C_2 + \Delta T}$$

$$\log a_T = \log \frac{E(T)}{E(T_G)}$$

$E(t,T)$ = MODULO di RILASSAMENTO

$D(t,T)$ = MODULO di CREEP

↳ Proprietà meccaniche

ESERCIZIO

$T_G = 95°C$ $\eta_G = 10^{12}$ Pa·s

$T_1 = 110°C$ $\eta_1 = 4\eta_P$

- CALCOLARE T_P
- QUANTO VARIA η SE HO UN'OSCILLAZIONE INTORNO a T_P di $\pm$ 1°C

APPLICO WLF

$$\underbrace{\log a_T = \log \frac{\eta_1}{\eta_G} = \frac{-c_1 (T_1 - T_G)}{c_2 + (T_1 - T_G)}}_{\text{FATTORE di SPOSTAMENTO}}$$

$$\log a_T = \frac{-17.4\,(110-95)}{51.6 + (110-95)} = \frac{-17.4 \times 15}{51.6 + 15} = -3.9$$

$$\log a_T = \log \eta_1 - \log \eta_G$$

$$\log \eta_1 = \log a_T + \log \eta_G$$

$\log \eta_1 = -3.9 + 12 = 8.1$

$\eta_1 = 10^{8.1}$ [Pa·s]

$$\boxed{\begin{array}{l}\text{Per } T \gg T_g \qquad T > T_g + 200\,°C \Rightarrow \text{Arrhenius} \\ \qquad \eta = A e^{\frac{E_{att}}{T}}\end{array}}$$

$$\eta_P = \frac{\eta_1}{4} = 10^{7.5} \ [\text{Pa·s}]$$

Riapplico WLF $\qquad \Delta T = T_P - T_G$

$$\log a_T = \log \frac{\eta_P}{\eta_G} = \frac{-C_1 \Delta T}{C_2 + \Delta T}$$

$$\log a_T = \log \eta_P - \log \eta_G$$
$$\overset{!}{=} 7.5 - 12 = -4.5$$

$$-4.5 = \frac{-17.4 \cdot \Delta T}{51.6 + \Delta T}$$

$$+4.5(51.6+\Delta T) = +17.4\,\Delta T$$

$$\Delta T = 18^{\circ}C$$

$$T_P - T_G = 18^{\circ}C$$

$$T_P = 95^{\circ}C + 18^{\circ}C = 113^{\circ}C \mp 1^{\circ}C$$

se $T_P = 114^{\circ}C$ quanto vale η_P?

se $T_P = 112^{\circ}C$ " " η_P?

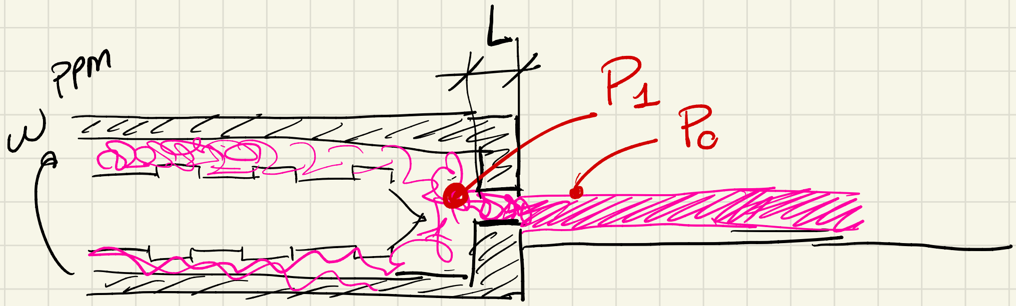
$$\log a_T = \frac{-C_1 \Delta T}{C_2 + \Delta T} = \frac{-17.4 \cdot 19}{51.6 + 19} = -4.6$$

$$-4.6 = \log \eta_P - 12$$

$$\log \eta_P = 12 - 4.6 = 7.3 \qquad \eta_P = 10^{7.3}\,[Pa \cdot s]$$

se $\Delta T = 17^{\circ}C \rightarrow \eta_P = 10^{7.6}\,[Pa \cdot s]$

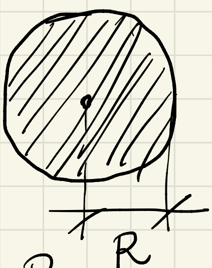
EFFETTO della VISCOSITÀ sul FLUSSO



Q FLUSSO VOLUMETRICO $\left[\frac{cm^3}{s}\right]$

$$\boxed{Q = K \frac{\Delta P}{\eta}}$$

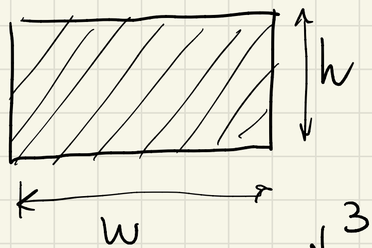
Fattore di Resistenza — geometria dello stampo



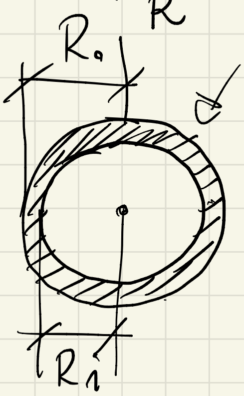
$$K = \frac{\pi R^4}{8L}$$

$$\dot{\gamma} = \frac{6Q}{\pi R^2}$$

$$\dot{\gamma} = \frac{6Q}{wh^2}$$



$$K = \frac{wh^3}{12L}$$

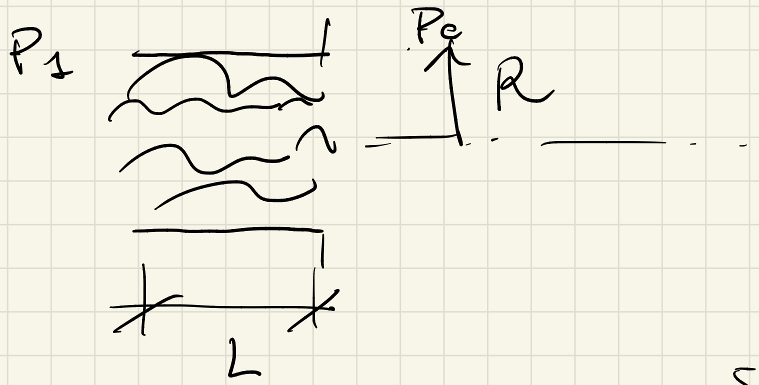


$$K = \frac{2\pi (R_i + R_o) h^3}{12L}$$

$$\dot{\gamma} = \frac{6Q}{\pi (R_i + R_o) h^2}$$

$R = 5cm$

$L = 5cm$



$1bar = 10^5 Pa$

$P_1 = 10\,bar = 10^6\,Pa$

$P_0 = 1\,bar = 10^5\,Pa$

$\eta = 10^{7.5}\,Pa\cdot s$

$$K = \frac{\pi R^4}{8L} = \frac{\pi \times 5^{3\cancel{4}}}{8\cdot \cancel{5}}$$

$$= \frac{3.14 \times 5^3}{8} = 49\,[cm^3]$$

$$\Delta P = P_1 - P_0 = 10^6 - 10^5 = 9\times 10^5\,Pa$$

$$Q = 49\,[cm^3]\;\frac{9\times \cancel{10^{5}}\,[Pa]}{10^{\cancel{7.5}\,2.5}\,[Pa\cdot s]}$$

$$Q = \frac{49 \times 9}{10^{2.5}} \left[\frac{cm^3}{s}\right]$$

$$= 1.4 \ \frac{cm^3}{s}$$

$1h = 3600\ s$

$$Q = 1.4 \times 3600 \ \frac{cm^3}{h}$$

$$= 5029 \left[\frac{cm^3}{h}\right]$$

$$V = L \cdot R^2 \cdot \pi$$

$$L = \frac{V}{\pi R^2} = \frac{5029}{\pi \cdot 5^2} = 64 cm$$

In 1h estrude 64 cm