ESERCIZIO TUBO IN PRESSIONE

Un tubo di PVC plasticizzato di raggio interno Ri=50 mm, raggio esterno Re=60 mm e lunghezza L=3 m è soggetto a temperatura ambiente ad una pressione P=8 bar.
La temperatura di transizione vetrosa del PVC in oggetto è pari a Tg=-20°C.
La curva maestra del PVC (alla Tg) ha un andamento del tipo:

D(t)=1.2t^0.1 [GPa-1]

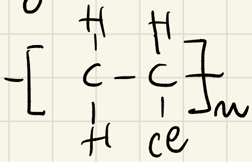
1) Calcolare lo stato di tensione e deformazione del tubo al tempo t=0 sapendo che il modulo di Poisson n=0.38 ed il modulo elastico istantaneo a temperatura ambiente del tubo è pari a E=3 MPa

2) Calcolare lo stato di deformazione dopo un tempo t=4h

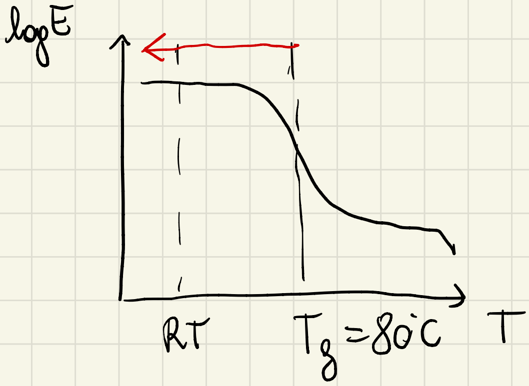
3) Calcolare lo stato di deformazione ad un tempo t=6.5h, sapendo che al tempo t=5h la pressione del tubo diventa pari a 9 bar e al tempo t=6h la pressione del tubo diventa pari a 3 bar.

PVC → @ RT è Rigido

$T_g \simeq 80°C$



un TP AMORFO

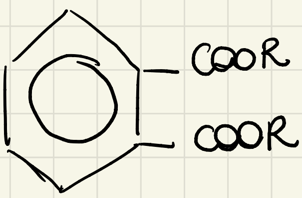


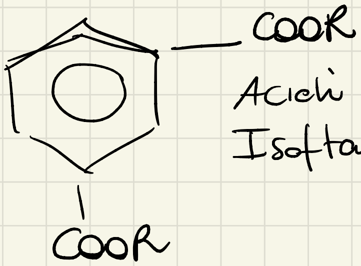
$\boxed{\text{PVC – P}}$ PVC plasticizzato

Sono state addizionate sostanze chimiche durante il processo di produzione con lo scopo di ridurne la rigidezza

ESEMPI di PLASTICIZZANTI per il PVC

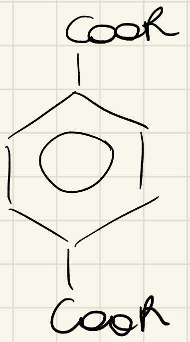
FTALATI





Acidi Isoftalici

R. – COOH CARBOSSILICO

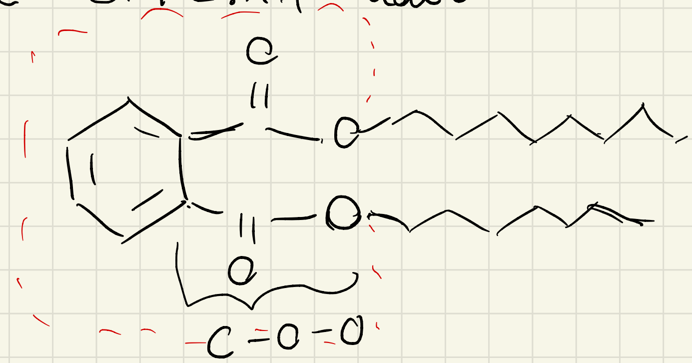


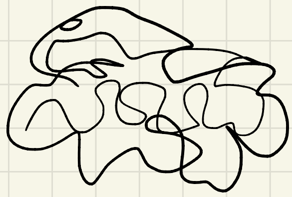
TERFTALATI

- Liquidi
- Incolore
- Poco volatili
- Poco solubili in H_2O

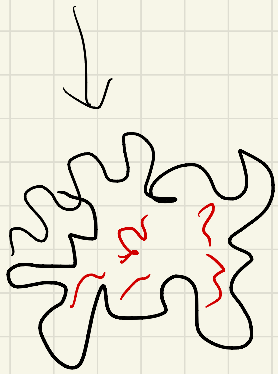
Esempio per il PVC

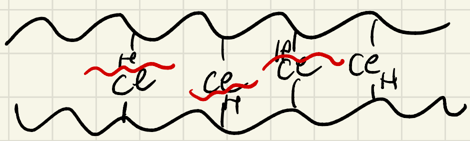
2 - etilesilftalato



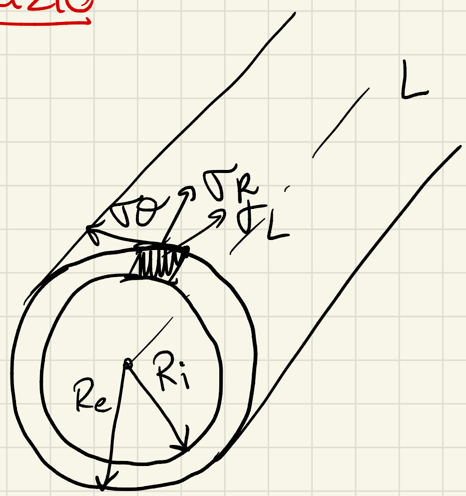


V_F





ESERCIZIO



$P = 8\,bar = 0,8\,MPa$
$(1\,bar = 10^5\,Pa)$

$Ri = 50\,mm$

$Re = 60\,mm$

$L = 3\,m$

$\nu = 0,38$

$E = 3,4\,MPa$

Calcolare lo stato di tensione e deformazione del tubo al $t=0$, RT

$$\sigma_\theta = P \frac{Ri^2}{Re^2 - Ri^2}\left[1 + \left(\frac{Re}{r}\right)^2\right]$$

$$\sigma_R = P \frac{Ri^2}{Re^2 - Ri^2}\left[1 - \left(\frac{Re}{r}\right)^2\right]$$

$$\sigma_L = \nu\left(\sigma_\theta + \sigma_R\right)$$

Se $r = R_i$ HO LE CONDIZIONI più GRAVOSE

$$\sigma_\theta = P \frac{R_i^2 + R_e^2}{R_i^2 - R_e^2}$$

$$\boxed{\sigma_R = -P}$$

$t = 0$

STATO di TENSIONE

$\sigma_\theta = 4.4\ MPa$

$\sigma_R = -0.8\ MPa$

$\sigma_L = 1.4\ MPa$

STATO di DEFORMAZIONE piana

$\varepsilon_L = 0$

$$\varepsilon_r = \frac{1}{E}\left[\sigma_r - \nu\,(\sigma_\theta + \sigma_L)\right]$$

$$\varepsilon_\theta = \frac{1}{E}\left[\sigma_\theta - \nu\,(\sigma_r + \sigma_L)\right]$$

$$\varepsilon_r = \frac{1}{3.4}\left[-0.8 - 0.38\,(4.4 + 1.4)\right]$$

$$\varepsilon_\theta = \frac{1}{3.4}\left[4.4 - 0.38(-0.8+1.4)\right]$$

$$\varepsilon_r = \frac{1}{3}(-3) = -0.01\%$$

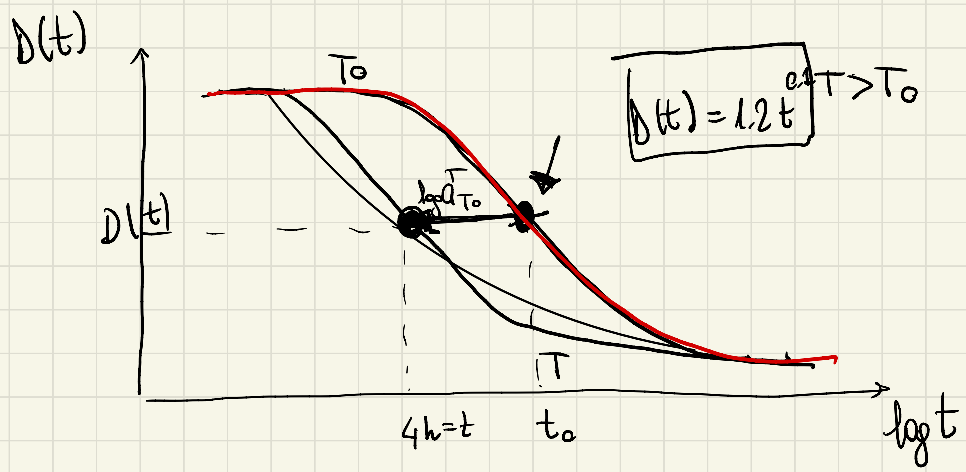
$$\varepsilon_\theta = \frac{1}{3}(4.628) = 1.5 = 0.015\%$$

[h]	0	4	5	6.5
σ_r	-0.8	-0.8		
[MPa] σ_θ	4.4	4.4		
σ_L	1.4	1.4		
ε_r	-0.01%	-1.1%		-0.6%
ε_θ	0.015%	6.2%		3%
ε_L	—	—		

(2) $\varepsilon\,(t = 4h)$, $RT = 20^\circ C$

$$\varepsilon(t) = \sigma_0\, D(t) \qquad \underline{\text{CREEP}}$$

$D_{T_0}(t)$ $\qquad$ $D_T(t)$



$$\log a_{T_0}^{T} = \log \frac{t}{t_0}$$

$$a_{T_0}^{T} = \frac{t}{t_0} \Rightarrow t_0 = \frac{t}{a_{T_0}^{T}}$$

<u>WLF</u> $\qquad \log a_{T_0}^{T} = -\dfrac{c_1\, \Delta T}{c_2 + \Delta T} = \dfrac{-17.4 \times 40}{51.6 + 40}$

$$= -7.6$$

$$a_{T_0}^{T} = 3 \times 10^{-7}$$

$$t = 4h = 4 \times 3600 = 14.4 \times 10^{3}\ [s]$$

$$t_0 = \frac{t}{a_{T_0}^{T}} = \frac{14.4 \times 10^{3}}{3 \times 10^{-7}} = 4.8 \times 10^{10}\ [s]$$

$$\varepsilon(t_0) = \sigma_0 \, D(t/a^T_{T_0})$$

$$\frac{t}{t_0} = a^T_{T_0}$$

$$t_0 = \frac{t}{a^T_{T_0}}$$

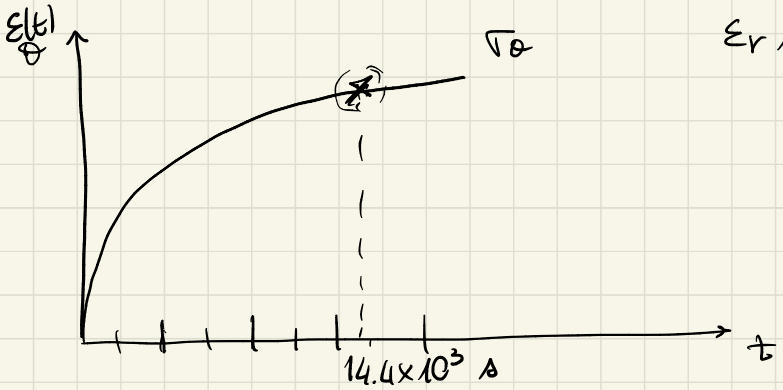
$$\varepsilon_r(t_0) = \sigma_r \times 1.2 \left(4.8 \times 10^{10}\right)^{0.1}$$

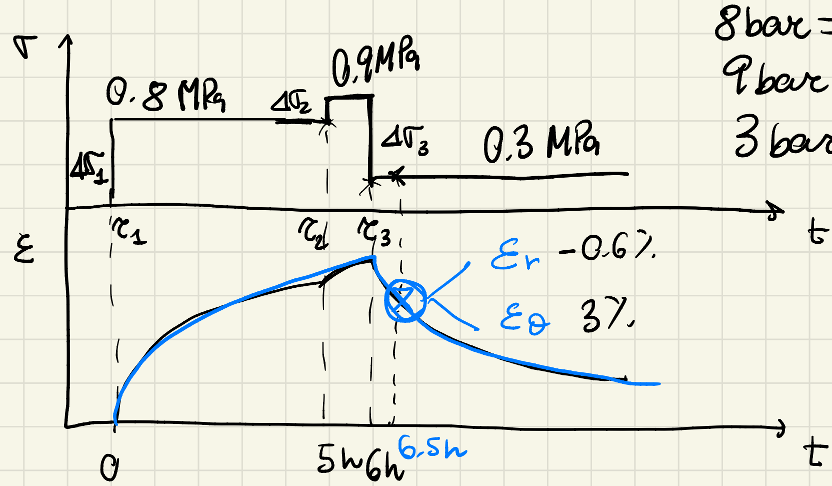
$$\varepsilon_\theta(t_0) = \sigma_\theta \times 1.2 \left(4.8 \times 10^{10}\right)^{0.1}$$

$$\varepsilon_r(4h) = -0.8 \times 10^{6} \times \left(4.8 \times 10^{10}\right)^{0.1} \times 1.2 \, 10^{-9} = -11.23 \times 10^{-3}$$

$$= -1.1\,\%$$

$$\varepsilon_\theta(4h) = 4.4 \times 1.2 \left(4.8 \times 10^{10}\right)^{0.1} \times 10^{-3} = 6.2\,\%$$





8bar = 0.8MPa
9bar = 0.9MPa
3 bar = 0.3MPa

$$\varepsilon(t) = \sum_{i=1}^{n} \Delta\sigma_i \, D(t - \tau_i)$$

$$D_{T_0}(t) = 1.2\, t^{0.1}$$

$\tau_1 = 0$

$\tau_2 = 5h \rightarrow \tau_{2eq}$

$\tau_3 = 6h \rightarrow \tau_{3eq}$

$t_{6.5h} = t_{eq}$

$$t_0 = \frac{t}{a^T_{T_0}}$$

$$\tau_{i_0} = \frac{\tau}{a^T_{T_0}}$$

CALCOLO LA DEFORMAZIONE RADIALE $\varepsilon_r(6.5h)$

$\boxed{\sigma_r = -P}$

$\Delta\sigma_{1_r} = \sigma_1 - 0 = -0.8$ MPa

$\Delta\sigma_{2r} = \sigma_{r_2} - \sigma_{r_1} = -0.9 + 0.8 = -0.1$MPa

$\Delta\sigma_{3r} = \sigma_{r_3} - \sigma_{r_2} = -0.3 + 0.9 = 0.6$MPa

$$D(t_0 - \tau_1) =$$

$$\tau_1 = 0$$

$$\tau_2 = 3600 \times 5 = 18'000\,s$$

$$\tau_3 = 3600 \times 6 = 21600\,s$$

$$t_4 = 6.5 \times 3600 = 23400\,s$$

$$D\left(\frac{t-\tau}{a_{T_0}^T}\right)$$

I $\dfrac{23400 - 0}{a_{T_0}^T}$ II $\dfrac{23400 - 18'000}{a_{T_0}^T}$

III $\dfrac{23400 - 21600}{a_{T_0}^T}$ $a_{T_0}^T = 3 \times 10^{-7}$

$\times 10^{6}$

$$\varepsilon_r(6.5h) = \Delta\sigma_1 D(t - \tau_1) + \Delta\sigma_2 D(t - \tau_2) + \Delta\sigma_3 D(t - \tau_3)$$

$$= \left[-0.8 \times 1.2 \left(\frac{23400}{3\times10^{-7}}\right)^{0.1} - 0.1 \times 1.2 \left(\frac{5400}{3\times10^{-7}}\right)^{0.1} + 0.6 \times 1.2 \left(\frac{1800}{3\times10^{-7}}\right)^{0.1}\right] \times 10^{-3}$$

$$= -0.6\%$$

CALCOLO $\varepsilon_\theta(6,5h)$

$\Delta\sigma_{1\theta} = 4.4\ MPa$

$\Delta\sigma_{2\theta} = 0.55\ MPa$

$\Delta\sigma_{3\theta} = -3.3\ MPa$

$$\varepsilon_\theta(6.5h) = \left[4.4 \times 1.2 \left(\frac{23400}{3\times10^{-7}}\right)^{0.1} + 0.55 \times 1.2 \left(\frac{5400}{3\times10^{-7}}\right)^{0.1} - 3.3 \times 1.2 \left(\frac{1800}{3\times10^{-7}}\right)^{0.1}\right] \times 10^{-3}$$

$$\simeq 3\%$$