Polypropylene 35°C 24 Feb - 2004

Tensile Creep Compliance

$$D(t) = 1.2\, t^{(0.1)} \ GPa^{-1}$$

t is in seconds.

loading $\sigma = 0$ for $t < 0$

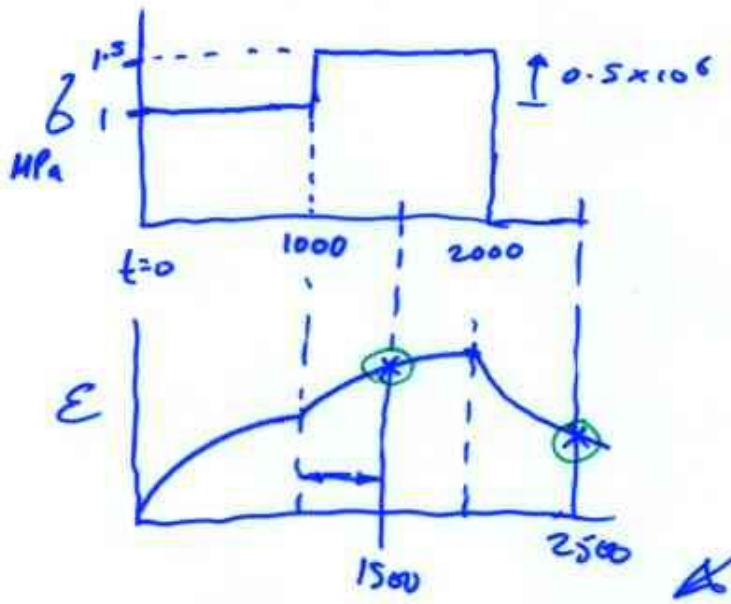
$\sigma = 1 MPa$ $\quad 0 \leq t < 1000s$

$\sigma = 1.5 MPa$ $\quad 1000s \leq t < 2000s$

$\sigma = 0$ $\quad 2000s \leq t$

find $\varepsilon(t)$ $\quad t = 1500$ sec

$t = 2500$ sec.



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

$i = -\infty$

(a) $\varepsilon(1500\,s) = \underbrace{(1\times10^6)}_{1MPa}\underbrace{(1.2\times10^{-9})(1500)^{0.1}}_{D(1500)}$

$+ (0.5\times10^6)(1.2\times10^{-9})(1500-1000)^{0.1}$

$\varepsilon = 3.6\times10^{-3}$ $\quad 0.361\,\%$

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(b) ε (2500 sec)

$$(1\times10^{6})(1.2\times10^{-9})(2500)^{0.1}$$
$$+(0.5\times10^{6})(1.2\times10^{-9})(2500-1000)^{0.1}$$
$$-(1.5\times10^{6})(1.2\times10^{-9})(2500-2000)^{0.1}$$

$$\varepsilon = 0.052\times10^{-2} = \underline{0.052\ \%}$$

(a) 10mm Bolt

$\Rightarrow A = \left(\frac{10\times10^{-3}}{2}\right)^2 \pi = \underline{7.85\times10^{-5}\,m^2}$

$\sigma_0 = \frac{F_0}{A} = \frac{2\times10^3}{7.85\times10^{-5}} = \underline{25.5\,MPa}$

E_0? $\quad E = 5\exp(-t^{\frac{1}{3}})\,GPa$ if $t=0$, $\exp(--)=1$

$E_0 = 5\,GPa$

$\varepsilon_0 = \frac{\sigma_0}{E_0} = \frac{25.5\times10^6}{5\times10^9} = \underline{5.1\times10^{-3} \approx 0.5\%}$

(b) 24 hours

$E(24\text{ hours}) = 5e^{-24^{\frac{1}{3}}}\,GPa = 2.79\times10^8\,Pa$

$\sigma_{24} = E(24) * \varepsilon = (2.79\times10^8)(5.1\times10^{-3})$

$= \underline{1.43\,MPa}$

$e^{\sqrt[3]{24}} \approx e^{-3}$

$F = \sigma A = (1.43\times10^6)(7.85\times10^{-5})$

$F = 111\,N$ Strain is constant.

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(c) Bolt re-tightened to orig force

$\Rightarrow$ re-tightened to orig stress also.

$\Delta\sigma = 25.5 - 1.43 = 24.07\,MPa$

additional Strain

$E(0) = 5\,GPa \Rightarrow$ extra $\varepsilon = \frac{24.07\times10^6}{5\times10^9} = 4.81\times10^{-3}$

So $\varepsilon = \underbrace{4.81\times10^{-3}}_{\text{2nd Tightening}} + \underbrace{5.1\times10^{-3}}_{\text{1st}} \approx 9.9\times10^{-3}$

(d) Further 48 Hrs later...

$\varepsilon_1 = 5.1 \times 10^{-3}$ for 72 Hours

$\varepsilon_2 = 4.8 \times 10^{-3}$ " 48 Hours

$$\underset{72\,Hrs}{\sigma} = (5.1\times10^{-3})(5\times10^{9})\exp(-72^{\frac{1}{3}}) + (4.8\times10^{-3})(5\times10^{9})\exp(-48^{\frac{1}{3}})$$

$$= 4\times10^{5} + 6.4\times10^{5} \text{ Pa}$$

$$\sigma = 10.4\times10^{5}\ P_a \simeq 1.04\ MPa$$

$$F = \sigma A = (1.04\times10^{6})(7.85\times10^{-5})$$

$$F = 81.64\ N$$

note we can work with $\Delta\sigma$ or $\Delta\varepsilon$.