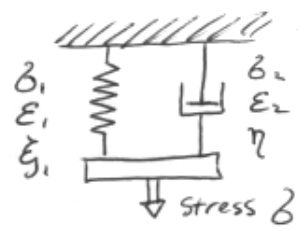


KELVIN MODEL

Spring in parallel with a dashpot



$$\sigma_1 = \xi E_1 \epsilon_1 \quad \sigma_2 = \eta \frac{d\epsilon_2}{dt}$$

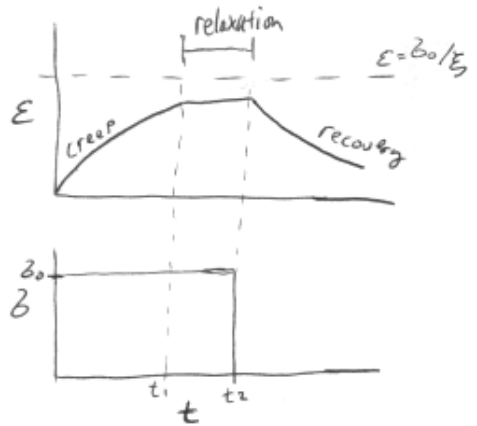
$$\left. \begin{aligned} \sigma &= \sigma_1 + \sigma_2 \\ \epsilon &= \epsilon_1 = \epsilon_2 \end{aligned} \right\} \rightarrow \text{Governing Equation: } \sigma = \xi E + \eta \dot{\epsilon}$$

CREEP: const stress $\sigma_0 \Rightarrow \sigma_0 = \xi E + \eta \dot{\epsilon}$ differential Eqn
 $\Rightarrow \epsilon = \frac{\sigma_0}{\xi} (1 - e^{-\xi t / \eta})$

RELAXATION: const strain $= \dot{\epsilon} = 0$ so $\sigma = \xi E$

RECOVERY: remove stress $0 = \xi E + \eta \dot{\epsilon} \Rightarrow \epsilon = \epsilon' e^{-\xi t / \eta}$ $\epsilon' = \text{initial strain}$

Behaviour:



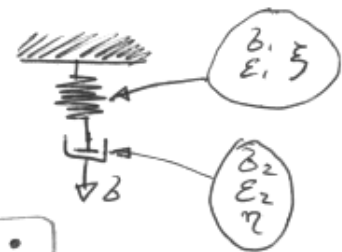
reasonable approximation for creep & recovery.

does not account for relaxation

(b) Maxwell Model

Spring in SERIES with DASHPOT

$$\sigma_1 = \xi E_1 \epsilon_1 \quad \sigma_2 = \eta \frac{d\epsilon_2}{dt} = \eta \dot{\epsilon}_2 \text{ again}$$



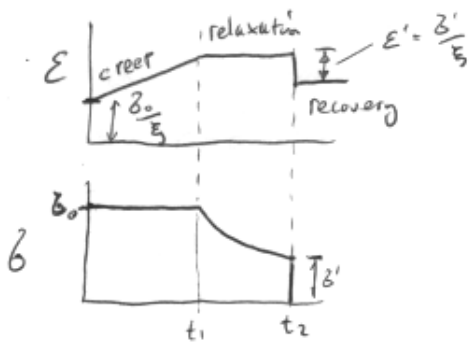
but now $\left. \begin{aligned} \sigma &= \sigma_1 = \sigma_2 \\ \epsilon &= \epsilon_1 + \epsilon_2 \end{aligned} \right\} \rightarrow \text{GOVERNING EQUATION: } \dot{\epsilon} = \frac{\dot{\sigma}}{\eta} + \frac{\dot{\sigma}}{\xi}$

CREEP $\dot{\sigma} = 0$ (const stress)
 $\Rightarrow \dot{\epsilon} = \sigma_0 / \eta$

RELAXATION $\dot{\epsilon} = 0$ (const strain)
 $\Rightarrow \sigma = \sigma_0 e^{-\xi t / \eta}$ ($\sigma = \sigma_0$ @ $t = t_0$)

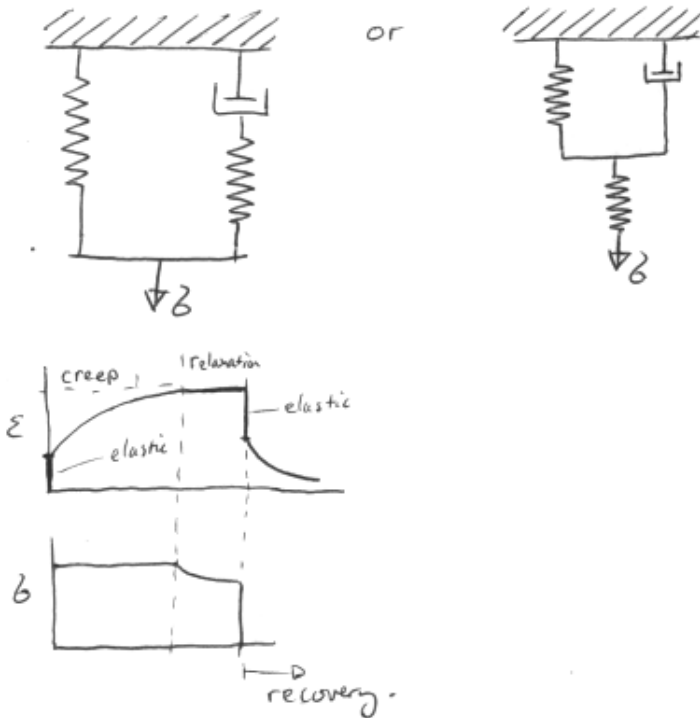
RECOVERY remove stress
 \Rightarrow elastic strain recovers instantly
 but no further recovery $\sigma, \dot{\sigma} = 0 \Rightarrow \dot{\epsilon} = 0$

Behaviour of Maxwell Model



poor approximation of creep
(deformation grows without bound)
poor approx of recovery
(only elastic part recovers)
acceptable approx of relaxation

(C) Standard Linear Solid (Zener) combination of first 2



Behaviour

- instantaneous strain when stress applied plus creep towards a limit
- instantaneous partial recovery when stress removed, plus gradual recovery after leading to ultimately complete recovery.
- for constant strain, stress will relax

$$\text{Force} = (10)(9.81) = 98.1 \text{ N}$$

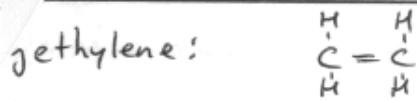
$$\text{Area} = \pi r^2 = (\pi)(5 \times 10^{-3})^2 = 25\pi \times 10^{-6} \text{ m}^2$$

$$\Rightarrow \sigma = \frac{F}{A} = \frac{98.1}{25\pi \times 10^{-6}} = 1249 \text{ MPa} = 1.249 \times 10^3 \text{ GPa}$$

tensile creep compliance $D = 2 - \exp(-0.1t) \text{ GPa}^{-1}$
@ 10 hours $D = 2 - \exp(-1) \text{ GPa}^{-1}$

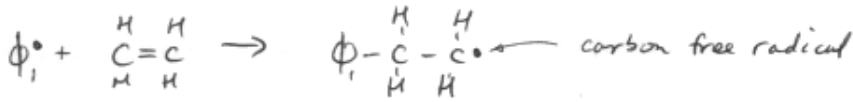
$$\epsilon = D\sigma = (2 - e^{-1})(1.249 \times 10^3) = 2.039 \times 10^{-3}$$

∴ change in length = (orig length)(strain)
 $(1\text{m})(2.039 \times 10^{-3}) = \underline{\underline{2.039 \text{ mm}}}$



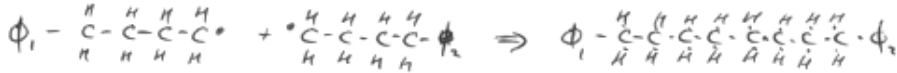
monomer

initiation initiator (Free radical) opens C=C Bond

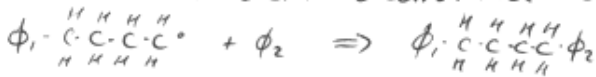


termination

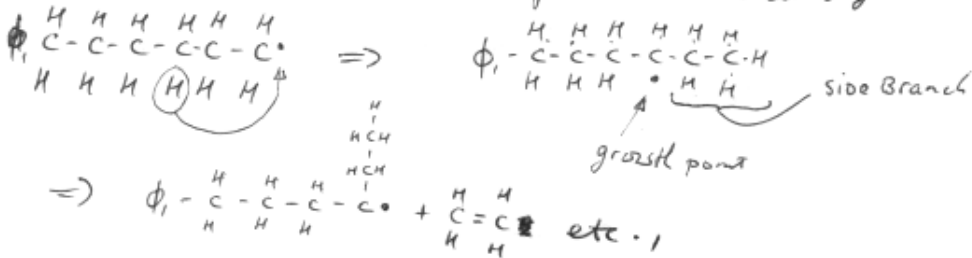
2 carbon free radicals meet



or can meet some other electron rich molecule



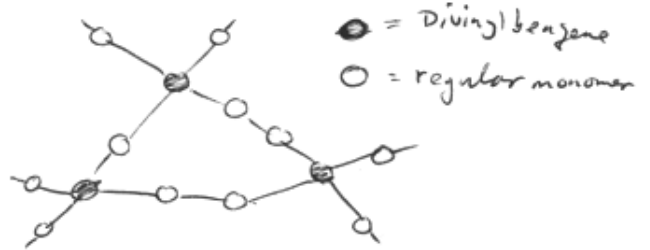
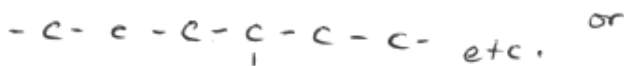
Back Biting is when free radical @ end of chain takes a Hydrogen from further back in chain. That point then becomes graft site



Side branches appear at irregular intervals on the chains

Copolymerizing with Divinylbenzene crosslinks polymer

end up with



Cross Linking

Improves strength & stiffness, especially @ high temperatures.

cross-linked structure won't "melt" @ elevated temperature,

RMM = mass of a molecule divided by $\frac{1}{12}$ mass of an atom of Carbon 12

RMM of PE monomer $2 \times \text{Carbon} \Rightarrow 24$
 $4 \times \text{Hydrogen} \Rightarrow \frac{4}{28} \times 10^5 = \underline{2800000}$

① Higher RMM gives higher impact strength.

② MWD: narrow distribution \rightarrow sharp melting point \rightarrow good for injection moulding (rapid cooling)
 \rightarrow poor for extrusion
 wide distribution \rightarrow wide melts range \rightarrow not so good for inj. mould
 \rightarrow good for extrusion due to good melt strength.

(C) Crystalline structure is encouraged by symmetric molecules without side branches or bulky sidegroups

\hookrightarrow allows for regular packing

Slow cooling helps too as it allows more time for crystalline structure to form

Amorphous structure is encouraged by opposite

Bulky sidegroups, random sidebranches, asymmetric molecules.

② Crystallinity improves stiffness & strength

Amorphous is less stiff, less strong, but often better impact resistance as amorphous region can dissipate energy.