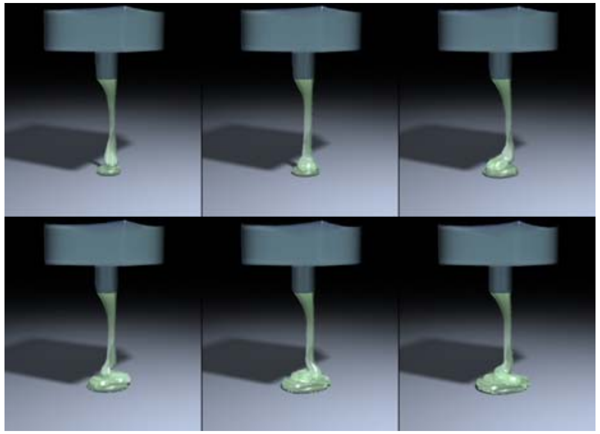
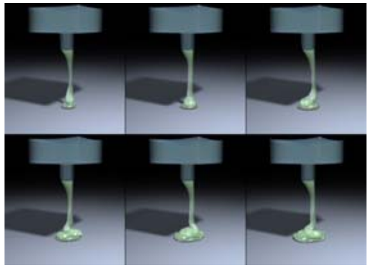


Physical basis of dental material science 9.

Mechanical properties 3.

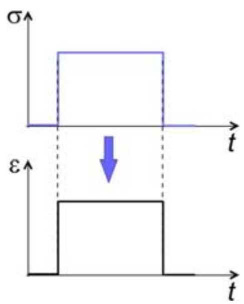
Viscoelasticity:

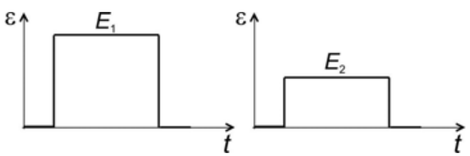
materials that exhibit both viscous and elastic characteristics when undergoing deformation.



Ideal elastic body

Constant force (stress)

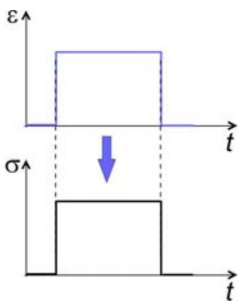




$E_1 < E_2$

no stress relaxation!

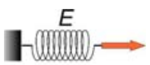
Constant deformation



Hooke's law: $\sigma = E\varepsilon$

$\sigma_{shear} = G\gamma$

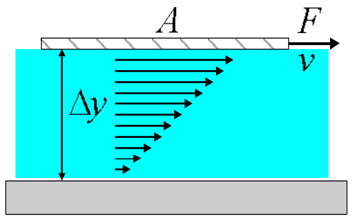
Model:



Hookean elastic spring

Viscosity (η):

measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress.



A: surface
F: force
Δy: layer thickness
ν : speed

Newton's friction law:

$$F_s = \eta \cdot A \cdot \frac{\Delta v}{\Delta y} \dashrightarrow \frac{F_s}{A} = \eta \cdot \frac{\Delta v}{\Delta y}$$

velocity gradient

viscosity (internal friction coefficient)

$[\eta]$ = Pa·s

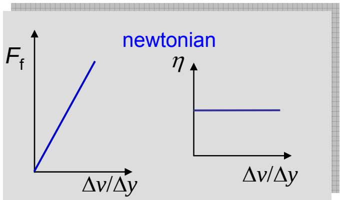
$$\sigma_{shear} = \eta\, g_{speed}$$

e.g. at 20 ºC:

material	air	water	blood (37°)	glycerine
η (mPa·s)	0.019	1	2–8	1490

Normal (or newtonian) fluid:

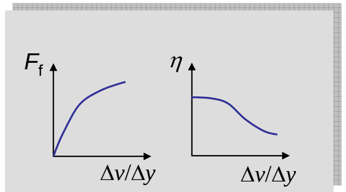
The viscosity depends only on the temperature (independent from e.g. velocity gradient or speed of flow).



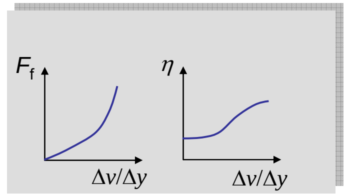
Anomalous (or non-newtonian) fluids:

The viscosity depends on the **velocity gradient**.

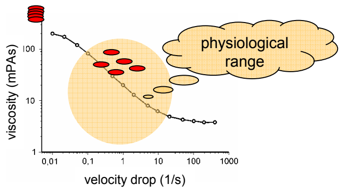
Pseudoplastic:
Viscosity decreases with the rate of shear.



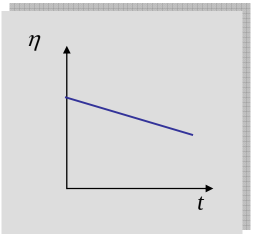
Dilatant:
Viscosity increases with the rate of shear.

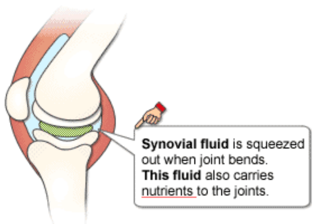


blood

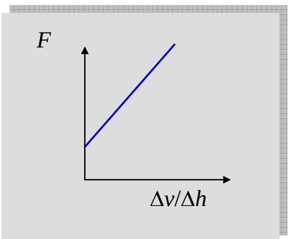


Tixotropy: normally viscous, but becomes flow if stressed.





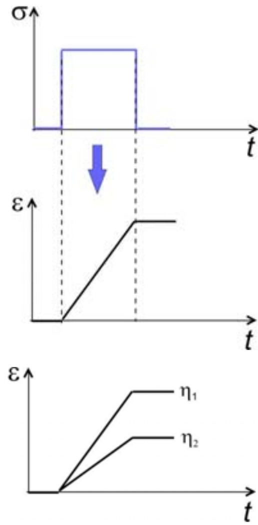
Bingham-fluid: behaves as a rigid body at low stresses but flows as a viscous fluid at high stress.



Tooth-paste

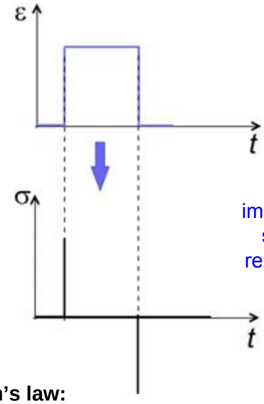
Ideal viscous body

Deformation in the case of constant force (stress).



$\eta_1 < \eta_2$

Constant deformation

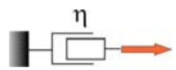


immediate stress relaxation

Newton's law:

$$\sigma_{shear} = \eta\, g_{speed}$$

Model:

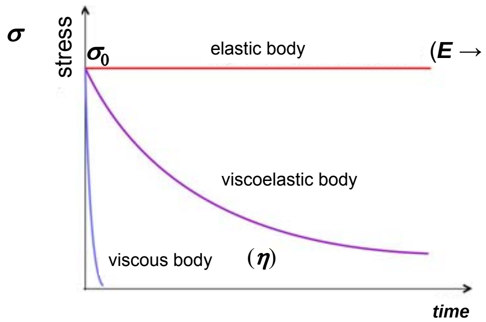


Newtonian dumper

dashpot

Viscoelasticity:

After instant deformation:



Hooke's law

$$\sigma = E\varepsilon$$

$$\sigma_{\text{shear}} = G\gamma$$

Stress relaxation:

$$\sigma = \sigma_0 e^{-\frac{t}{t_{\text{rel}}}}$$

$$t_{\text{rel}} = \frac{\eta}{G}$$

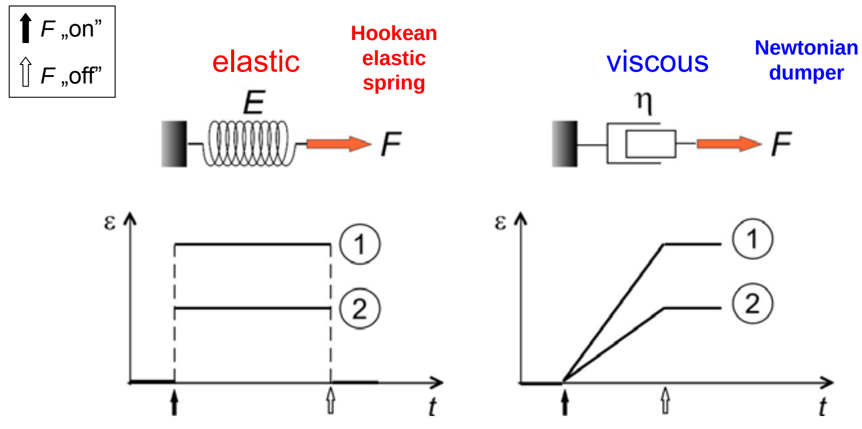
relaxation time

Newton's law

$$\sigma_{shear} = \eta\, g_{\text{speed}}$$

Changing deformation in the case of contant force

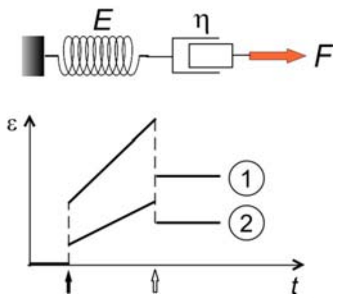
Models:



$E_1 < E_2$

$\eta_1 < \eta_2$

viscoelastic - Maxwell

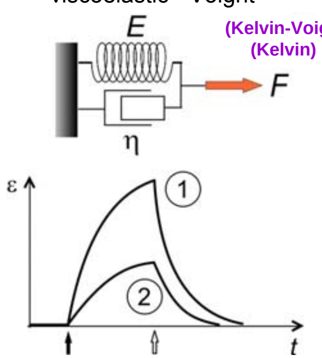


$E_1 < E_2$

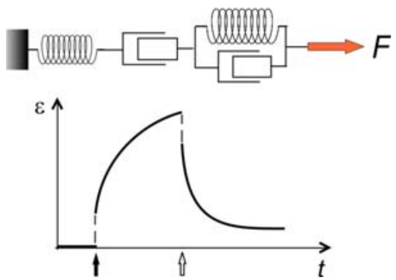
$\eta_1 < \eta_2$

viscoelastic - Voight

(Kelvin-Voigt)
(Kelvin)

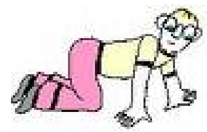


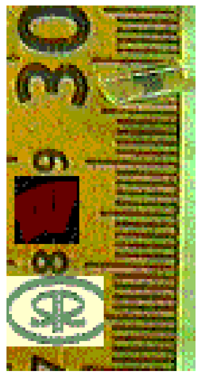
viscoelastic
- Burgers



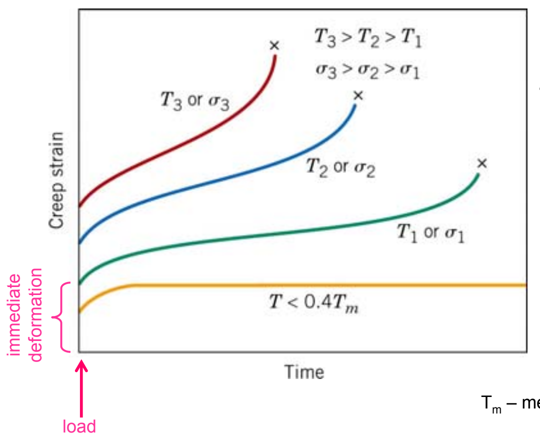
Creep:

is the slow change in the dimensions of a material due to prolonged stress.





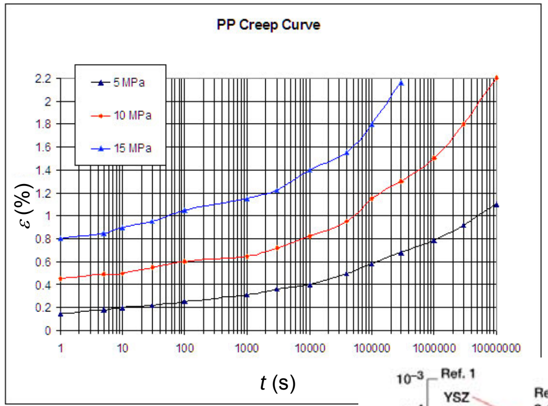
$1\text{–}10^7$ s **!!**



temperature!
e.g. metals
$0.4T_o < T$

T_m – melting point

Modell: ? — Maxwell

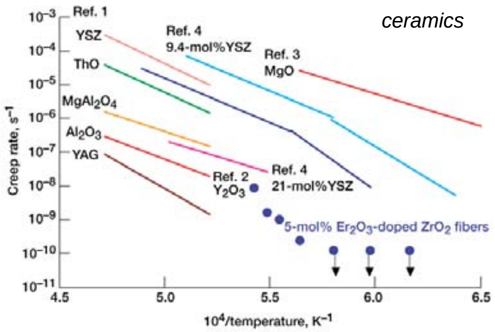


Polipropilene (PP)

ε – creep strain

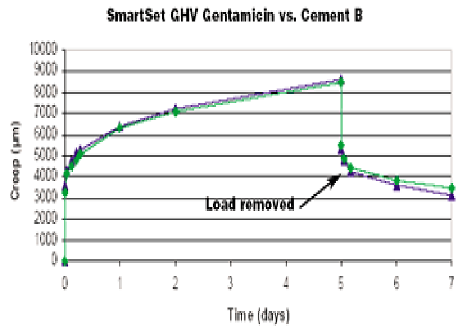
$\frac{\Delta \varepsilon}{\Delta t}$ creep rate

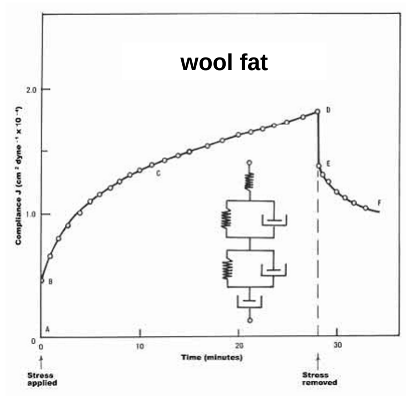
ceramics



Relaxation (recovery)

Rearrengment after stress removed.

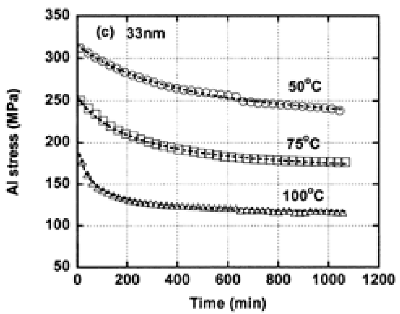




Relaxation

Decreasing of the inner stress in the case of constant deformation.

aluminium



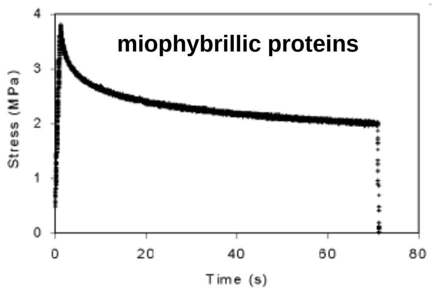
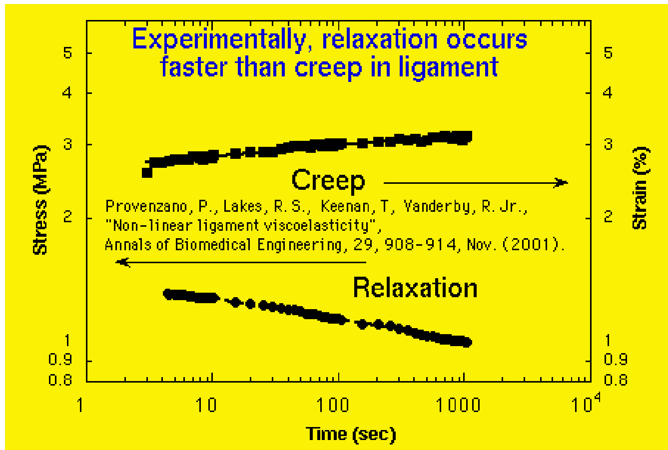


FIGURE 4. Original data of stress vs. time obtained by relaxation tests with films of MPNT.



Fatigue:

structural damage that occurs when a material is subjected to cyclic loading.

(The nominal maximum stress values are less than the ultimate tensile stress limit)

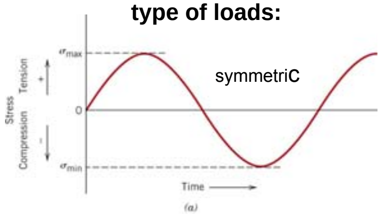
Long, repeated load

→ structural changes

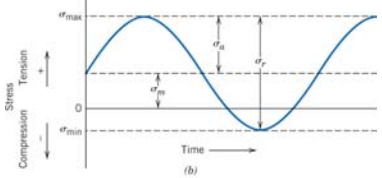
→ stength decreases

cracks!

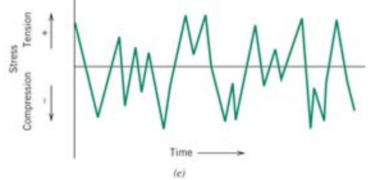
type of loads:



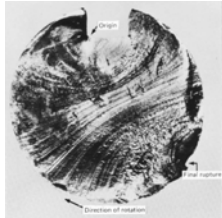
symmetriC



asymmetriC



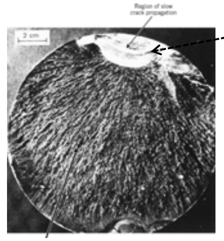
random



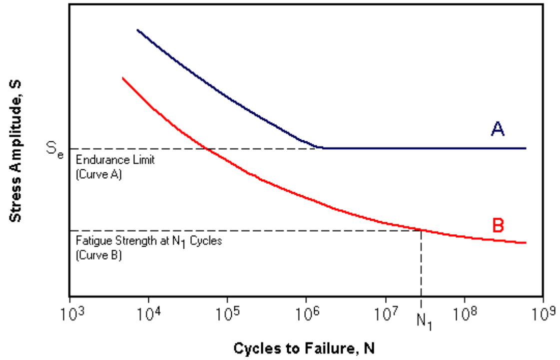
(fracture structure in rotating steel)

(fatigue striation in Al)

crack



rapid failure



Fatigue S-N curve:

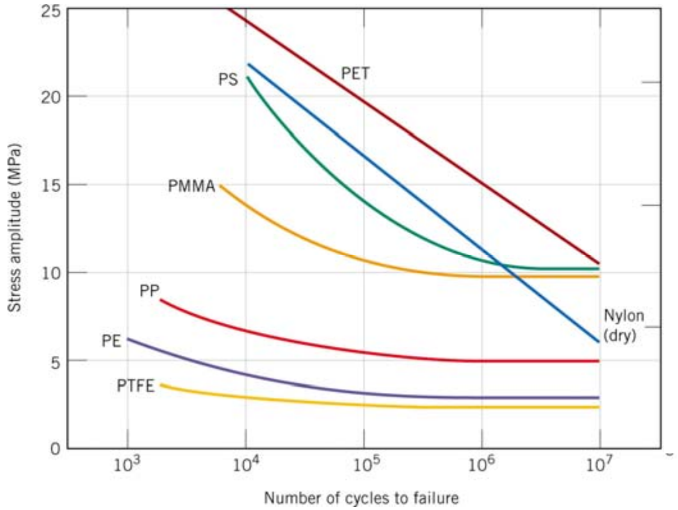
e.g. steel, titanium, …

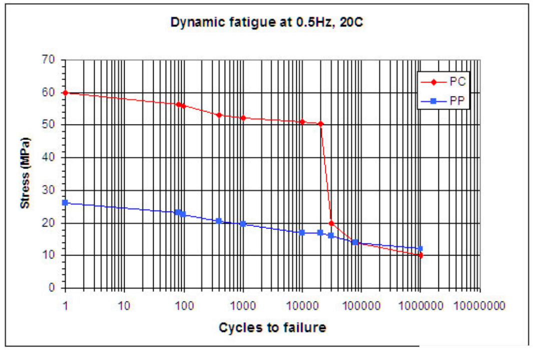
e.g. aluminium, copper, …

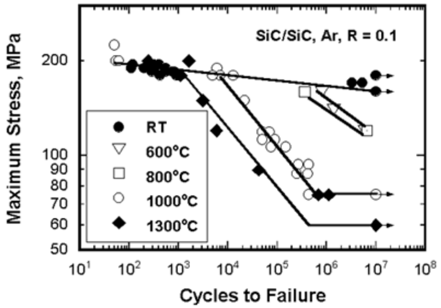
polymers

PET: Polyethylene terephthalate
PS: Polystyrene
PMMA: Poli(methil metacrylate)

PP: Polyethylene terephthalate
PE: Polyethylene
PTFE: Polytetrafluoroethylene







Abrasion (loss of tooth structure by mechanical forces)

Hardness!

(e.g. hardness of enamel)