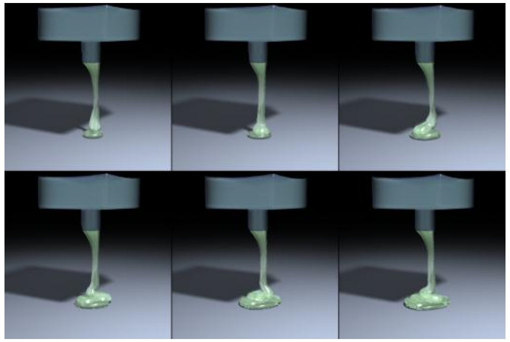
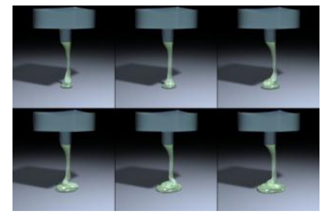


Physical basis of dental material science 9.

Mechanical properties 3.

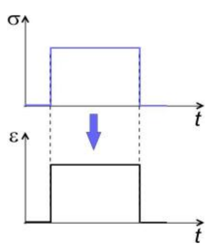
Viscoelasticity:

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

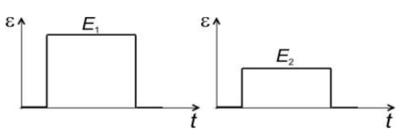


Ideal elastic body

Constant force (stress)

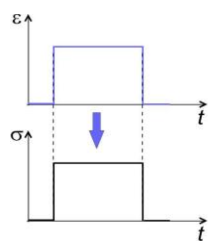


no stress relaxation!



$E_1 < E_2$

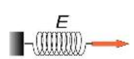
Constant deformation



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

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

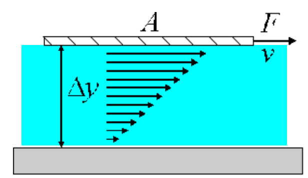
Model:



Hookean elastic spring

Viscosity (η):

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



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

Newton's friction law:

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

velocity gradient

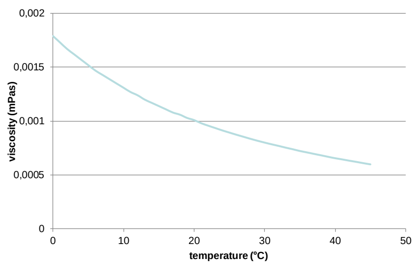
viscosity (internal friction coefficient)

$[\eta] = \text{Pa}\cdot\text{s}$

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

Dependence on the temperature

viscosity of the water



honey in fridge or room

oil in winter and summer

strongly depends on the temperature.

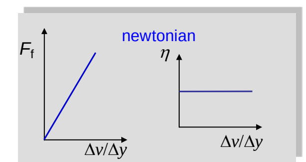
$$\eta \sim e^{-bT}$$

e.g. at 20 °C:

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

Normal (or newtonian) fluid:

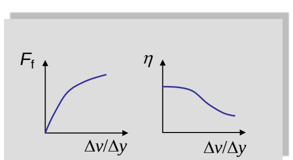
The viscosity depends only on the temperature (independent from e.g. velocity gradient or speed of flow).



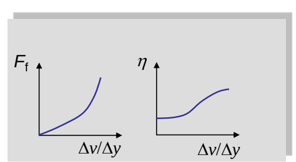
Anomalous (or non-newtonian) fluids:

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

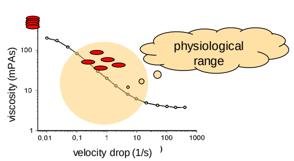
Pseudoplastic:
Viscosity decreases with the rate of shear.



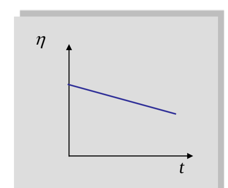
Dilatant:
Viscosity increases with the rate of shear.

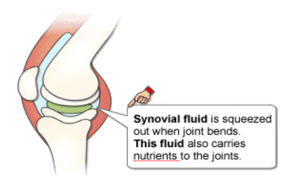


blood

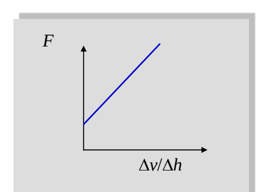


Tixotropy: normally viscous, but becomes flow if stressed.

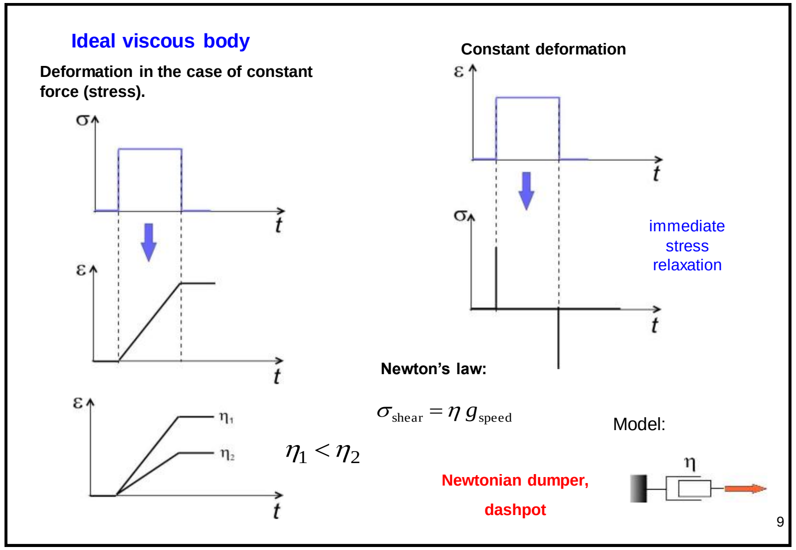


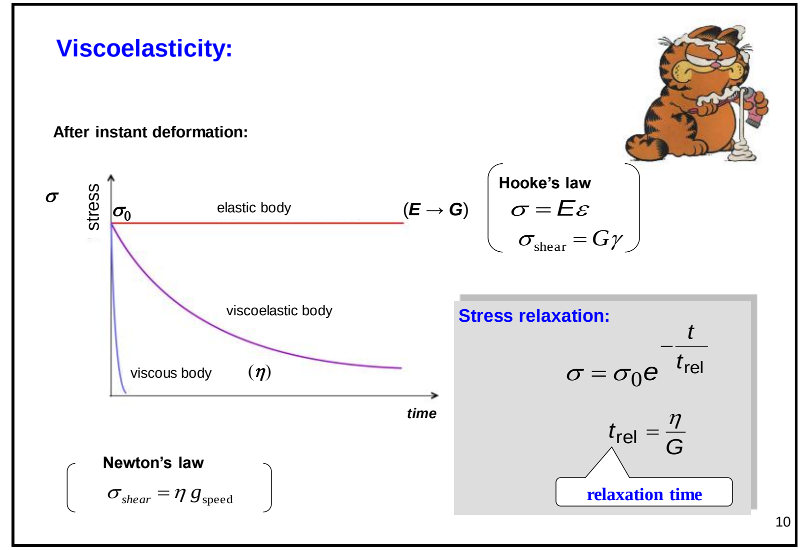


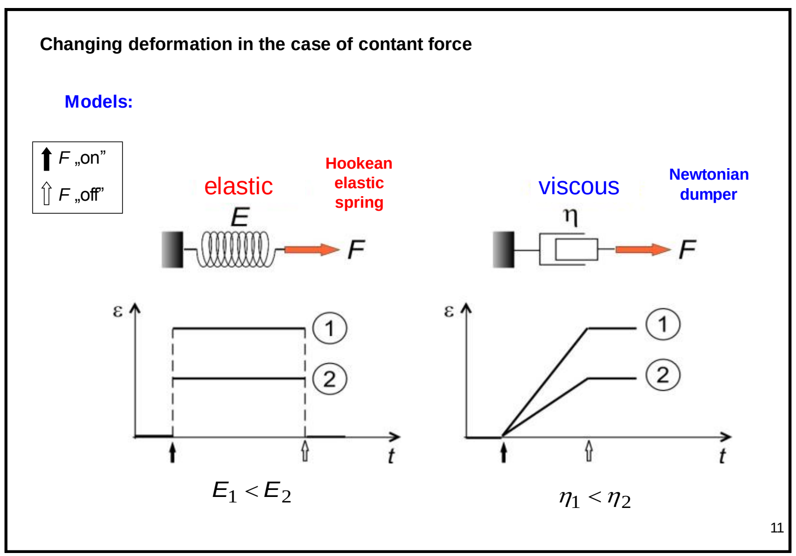
Bingham-fluid: behaves as a rigid body at low stresses but flows as a viscous fluid at high stress.

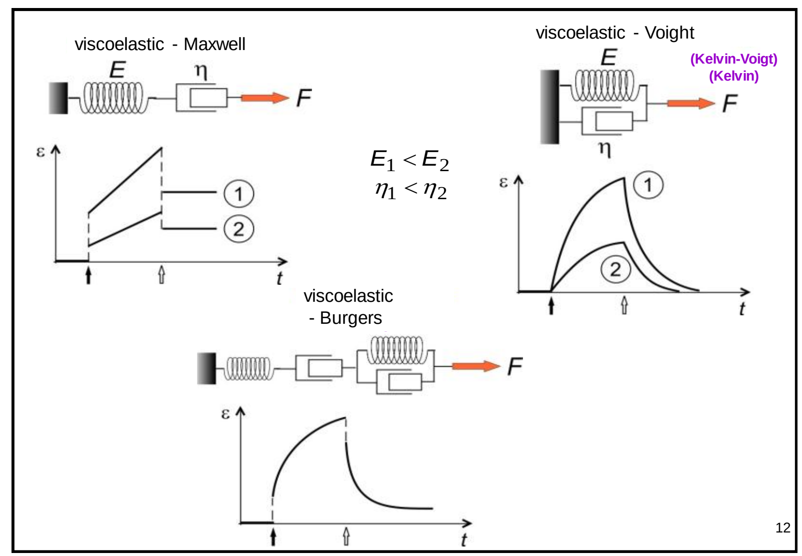


Tooth-paste


Ideal viscous body
Deformation in the case of constant force (stress).
Constant deformation
immediate stress relaxation
Newton's law:
$\sigma_{shear} = \eta\, g_{speed}$
$\eta_1 < \eta_2$
Model:
Newtonian dumper, dashpot
9

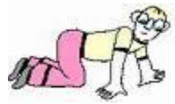

Viscoelasticity:
After instant deformation:
stress
σ_0
elastic body
viscoelastic body
viscous body (η)
time
($E \to G$)
Hooke's law
$\sigma = E\varepsilon$
$\sigma_{shear} = G\gamma$
Stress relaxation:
$\sigma = \sigma_0 e^{-\frac{t}{t_{rel}}}$
$t_{rel} = \frac{\eta}{G}$
relaxation time
Newton's law
$\sigma_{shear} = \eta\, g_{speed}$
10

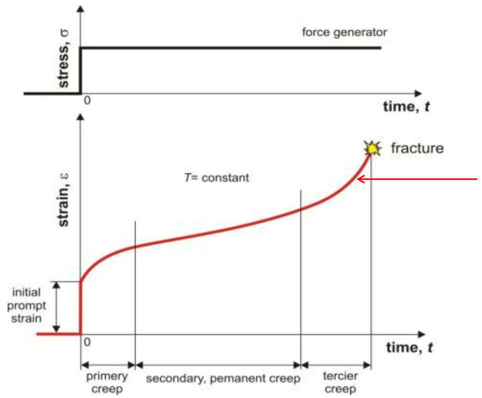

Changing deformation in the case of contant force
Models:
F „on"
F „off"
elastic
Hookean elastic spring
viscous
Newtonian dumper
$E_1 < E_2$
$\eta_1 < \eta_2$
11


viscoelastic - Maxwell
viscoelastic - Voight
(Kelvin-Voigt)
(Kelvin)
$E_1 < E_2$
$\eta_1 < \eta_2$
viscoelastic - Burgers
12

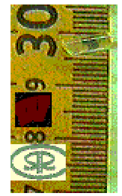
Creep:

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



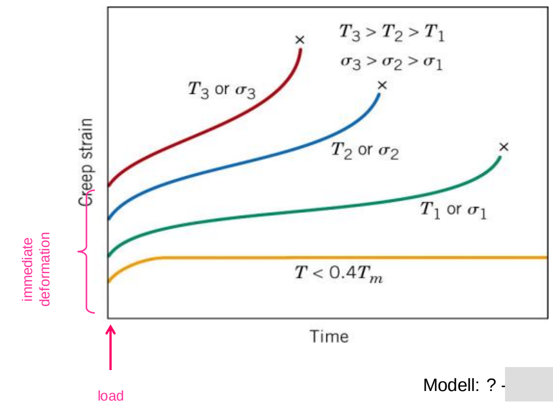


due to the necking!



$1–10^7$ s !!

Effect of the stress and the temperature

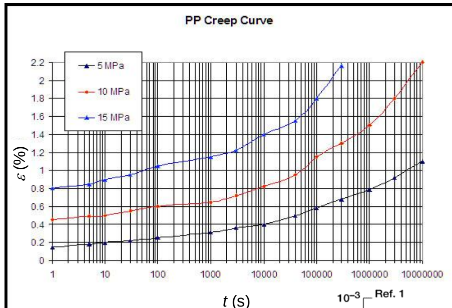


temperature!

e.g. metals

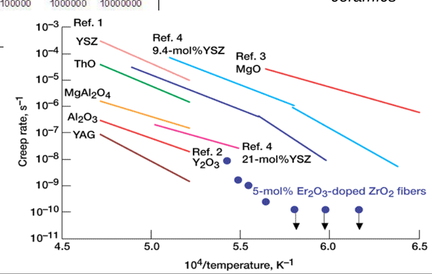
$0.4T_m < T$

Modell: ? -



Polipropilene (PP)

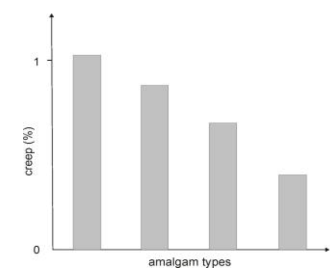
ceramics



Example: amalgam

Creep influences the marginal integrity of the filling.

melting point: 100 – 180 °C!



Increasing silver or copper content decreases the creep.

Relaxation

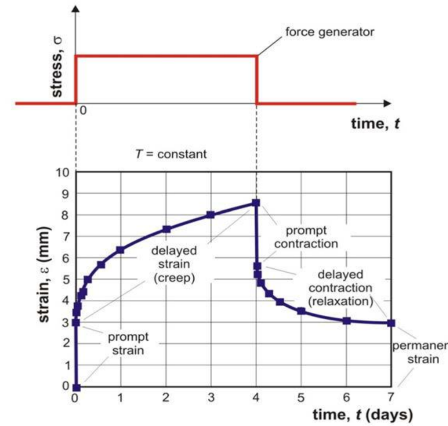
shape recovery

recovery when the load stops.

stress relaxation

decrease of the stress in constant deformation .

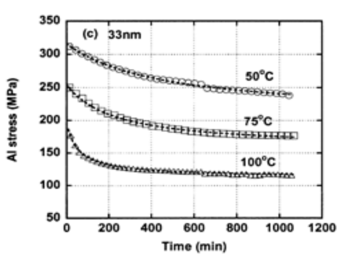
Shape recovery after stress removed.



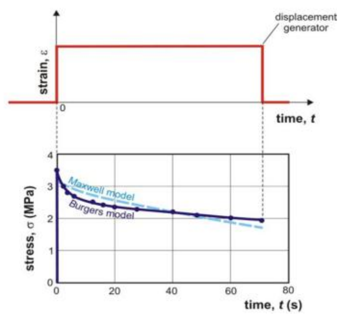
Stress relaxation

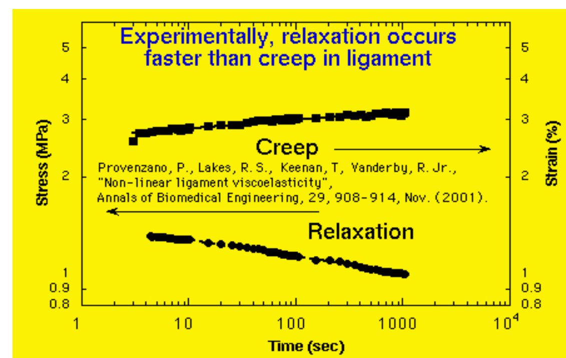
Decreasing of the inner stress in the case of constant deformation.

aluminium



film made of myofibrillar proteins





Fatigue

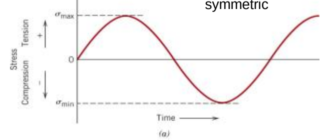
Long, repeated load

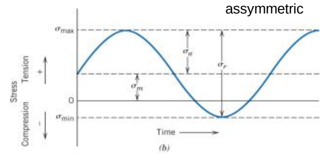
→ structural changes

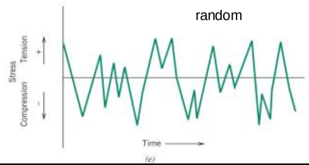
→ strength decreases

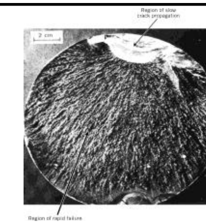
cracks!

type of loads:

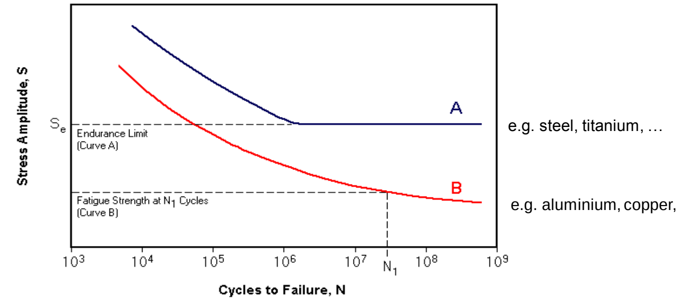


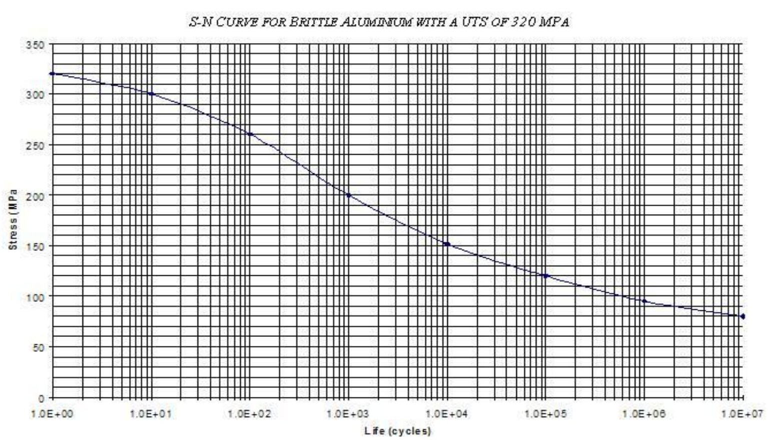


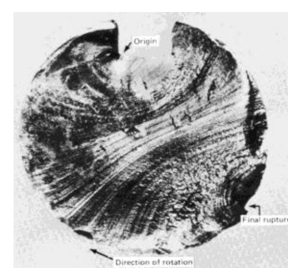




Fatigue S-N curve:





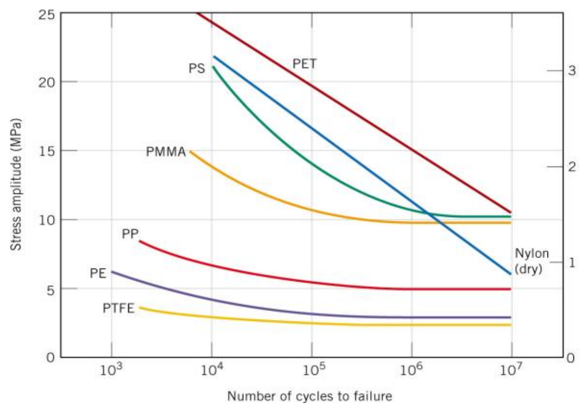


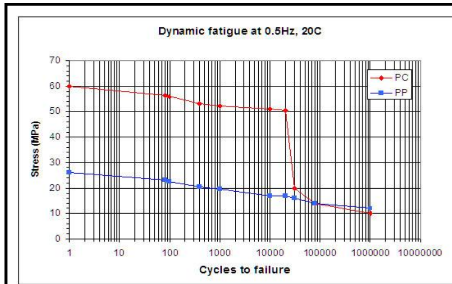
a test equipment

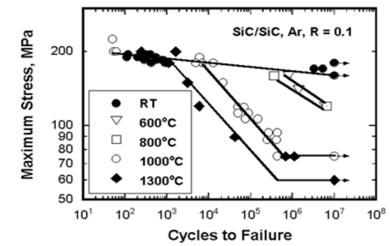
S-N curves of different polymers

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

PP: Polyethylene terephthalate
PE: Polyethylene
PTFE: Polytetrafluoroethylene







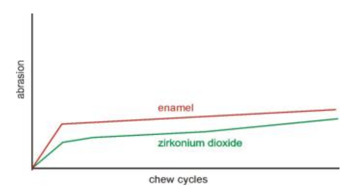
Abrasion

Loss of the structure by mechanical forces.

Role of hardness

Most commonly affected: premolars and canines.

Cementoenamel junction
(very thin enamel)



material	*HV* (MPa)	*HK* (MPa)
Enamel	≈ 3400	3400-4000
Dentin	≈ 600	≈ 700
Amalgam	≈ 1000	

(cementum a little bit less than the dentine.)