

Physical basis of dental material science

9.

Mechanical properties 3.

Bodies

elastic material



force results reversible change.

elastic or viscous?



nor elastic and nor viscous.

viscoelastic material

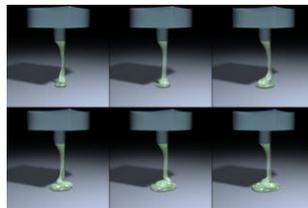
viscous material



force results flow, irreversible change.

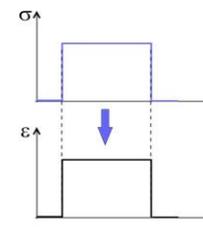
Viscoelasticity:

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

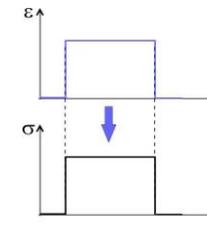


Ideal elastic body!

Constant force (stress)

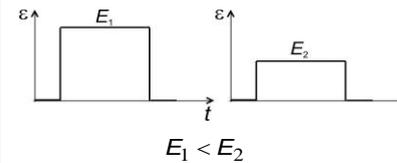


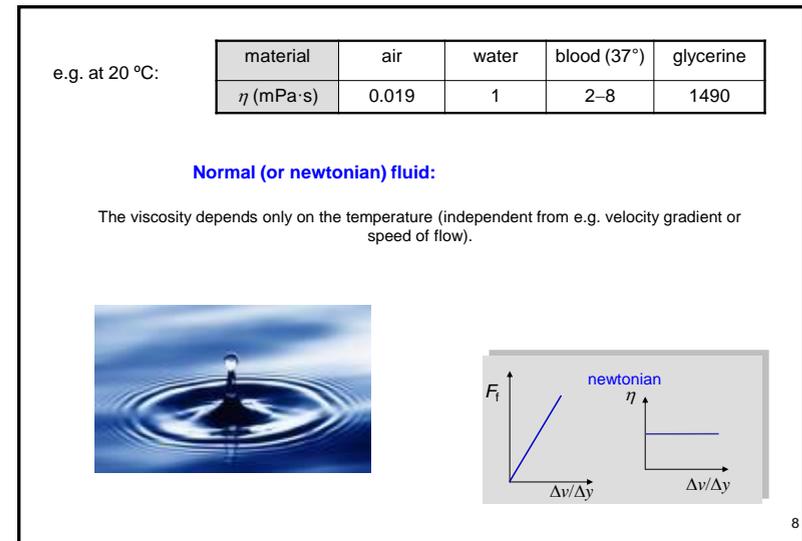
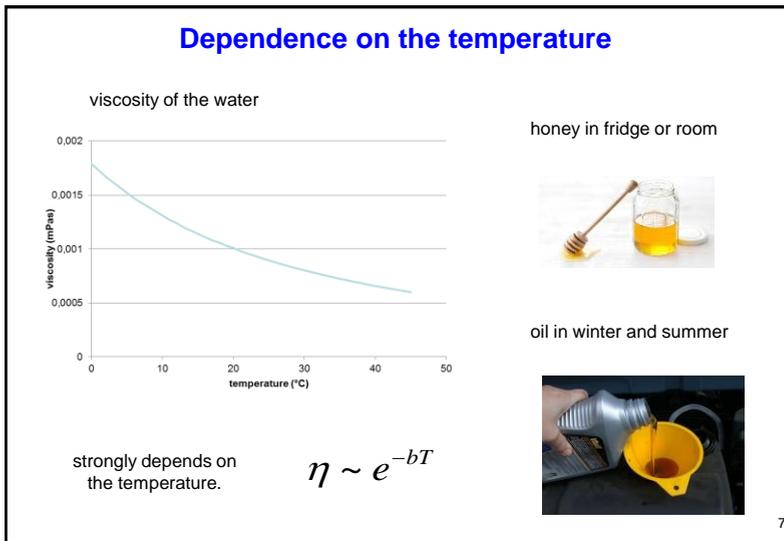
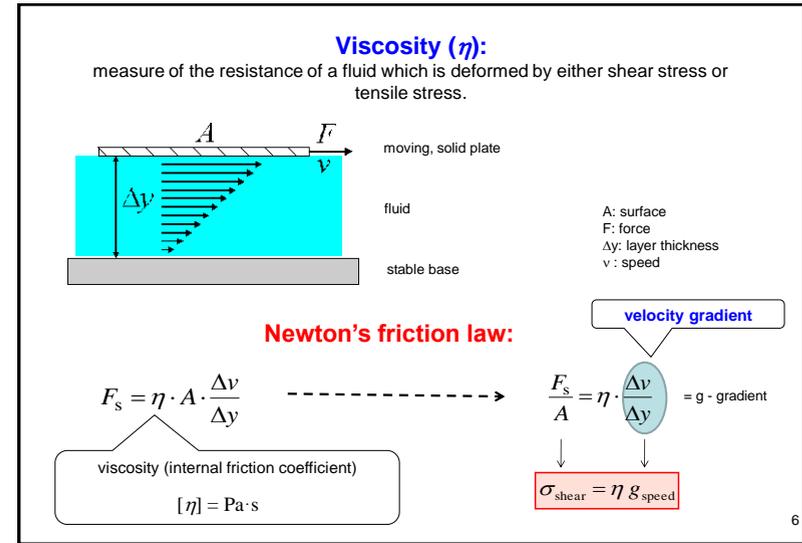
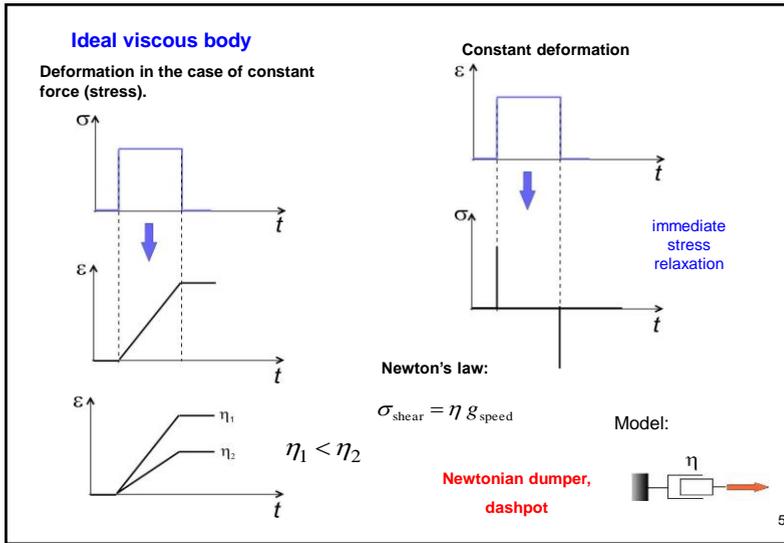
Constant deformation



Hooke's law: $\sigma = E\varepsilon$
 $\sigma_{\text{shear}} = G\gamma$

Model:



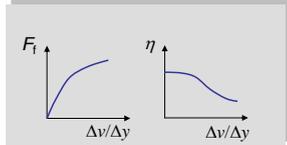


Anomalous (or non-newtonian) fluids:

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

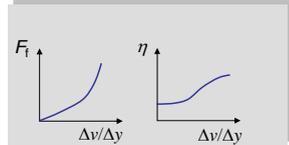
Pseudoplastic:

Viscosity decreases with the rate of shear.

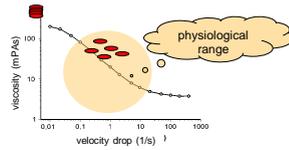


Dilatant:

Viscosity increases with the rate of shear.



blood

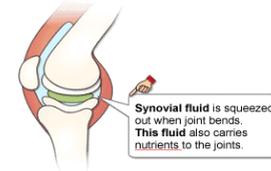
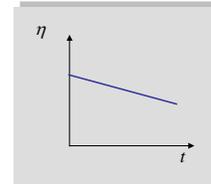


Silly Putty



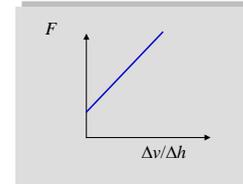
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Tixotropy: normally viscous, but becomes flow if stressed.



Bingham-fluid (plastics):

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



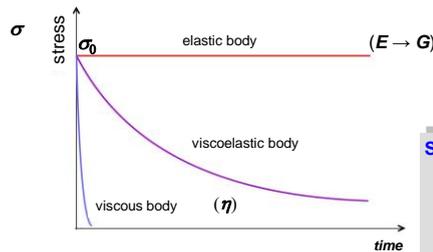
Tooth-paste



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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

$$\sigma_{\text{shear}} = \eta s_{\text{speed}}$$

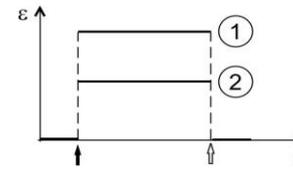
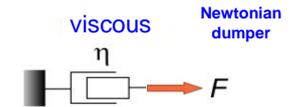
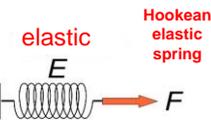


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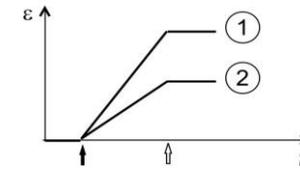
Changing deformation in the case of constant force

Models:

↑ $F_{\text{„on“}}$
↑ $F_{\text{„off“}}$

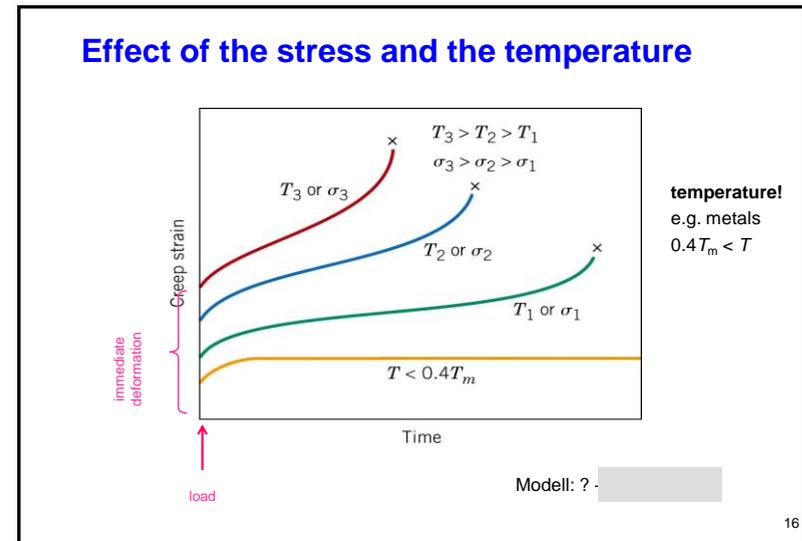
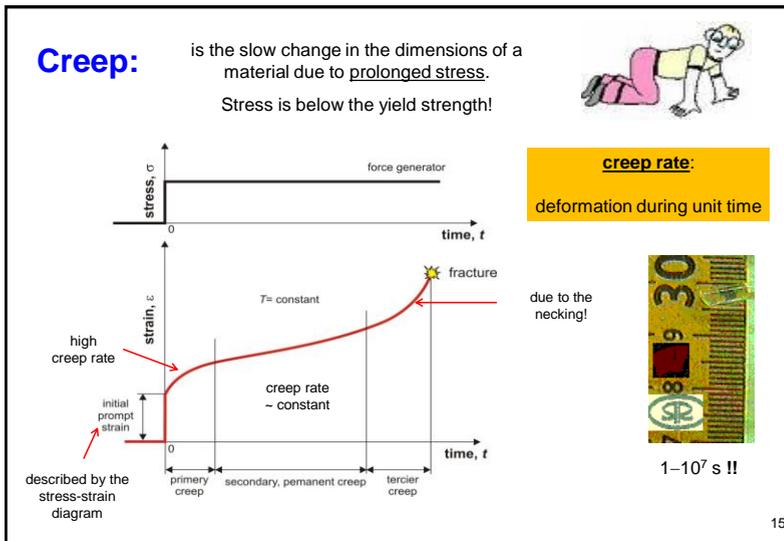
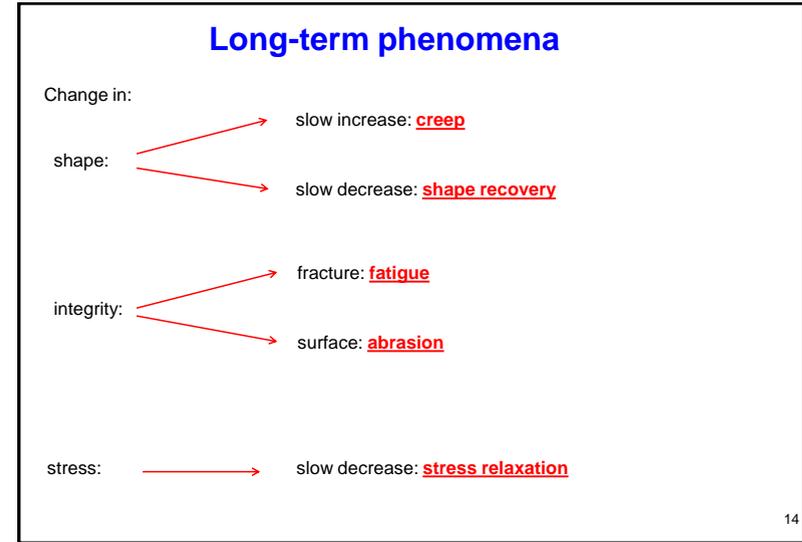
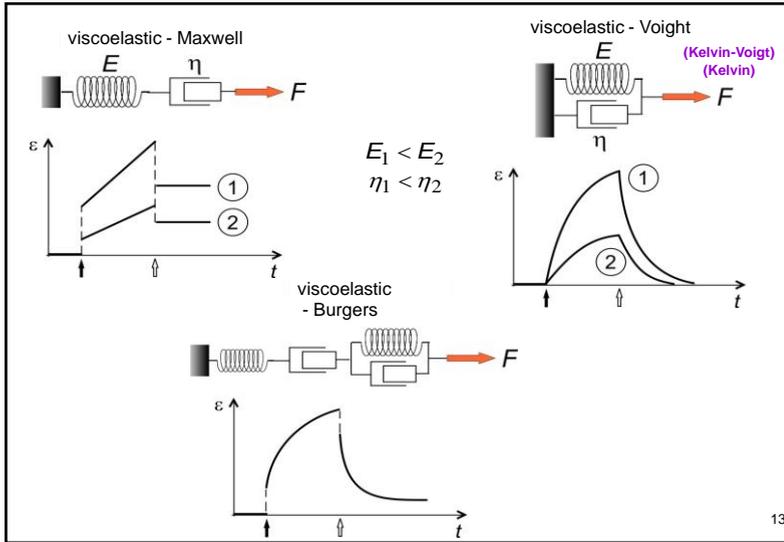


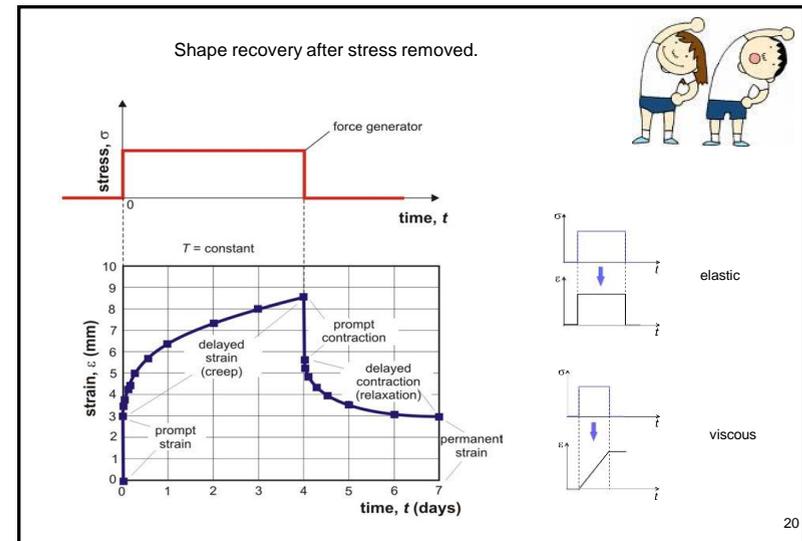
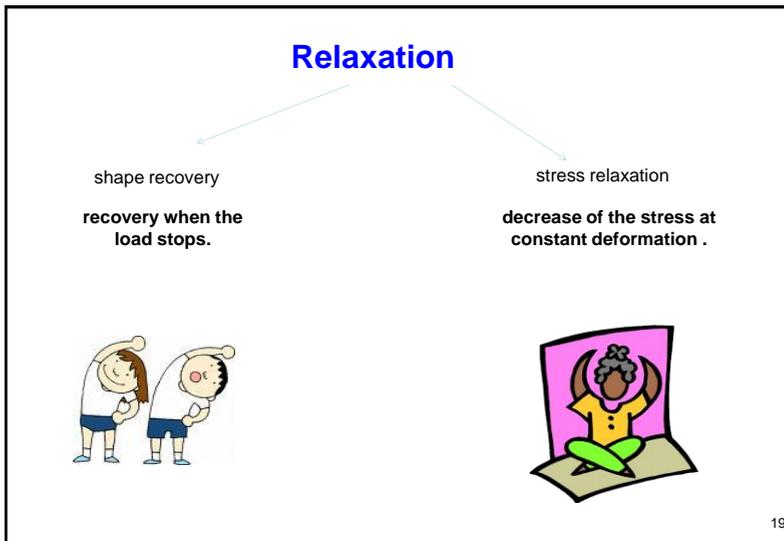
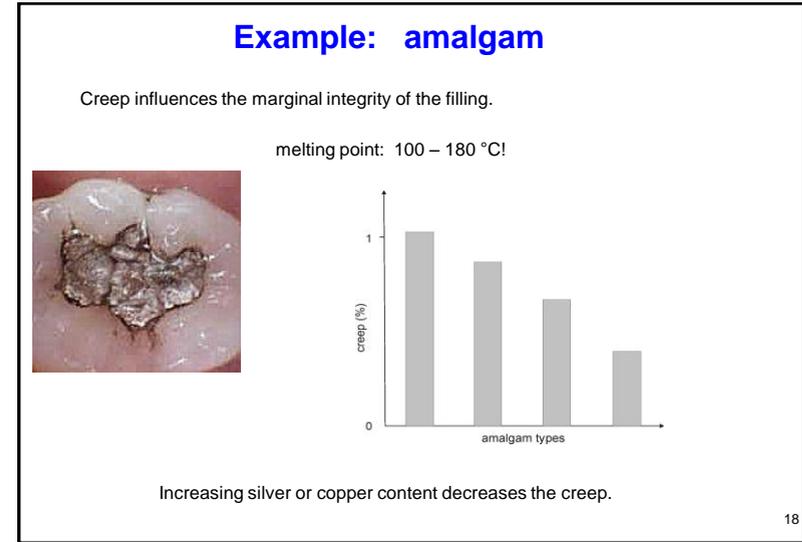
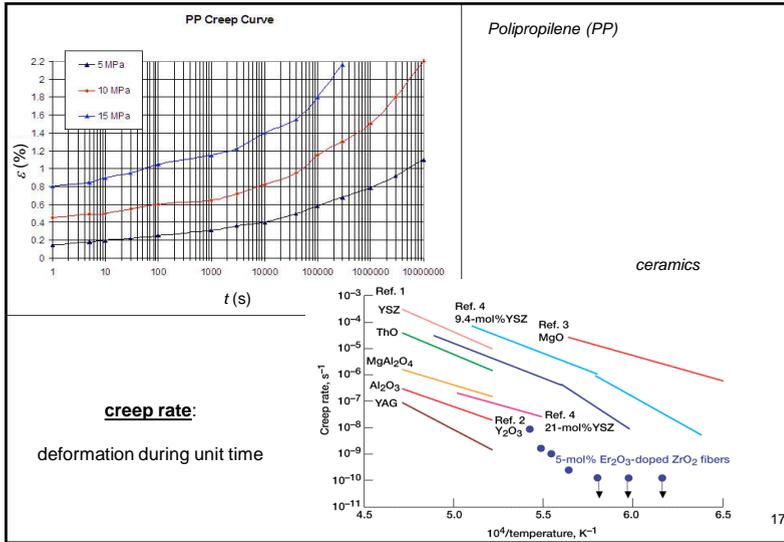
$$E_1 < E_2$$



$$\eta_1 < \eta_2$$

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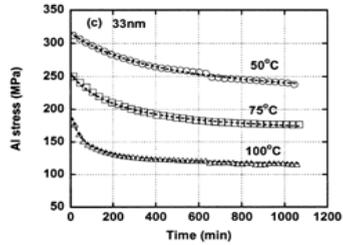




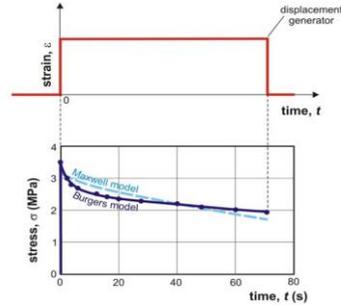
Stress relaxation

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

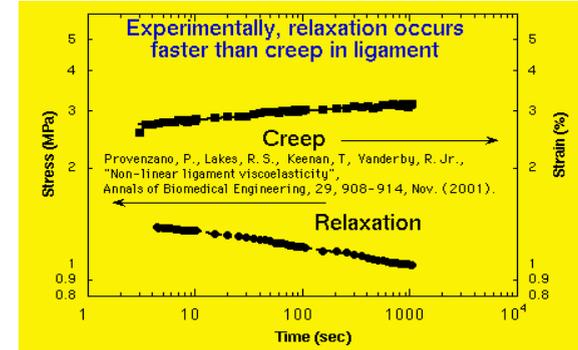
aluminium



film made of myofibrillar proteins



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Fatigue

is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading.



Stress is below the strength!

Fatigue is a **stochastic process**.

Long, repeated load

→ structural changes

→ strength decreases

cracks!

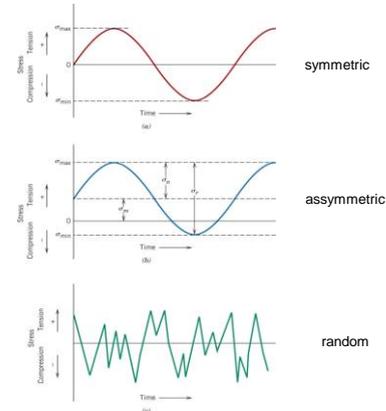
Damage is cumulative.

Fatigue is usually associated with tensile stresses.

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Type of loads

Dynamic fatigue



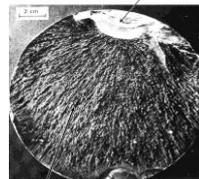
Static fatigue:

Long-term stress results decrease in strength.

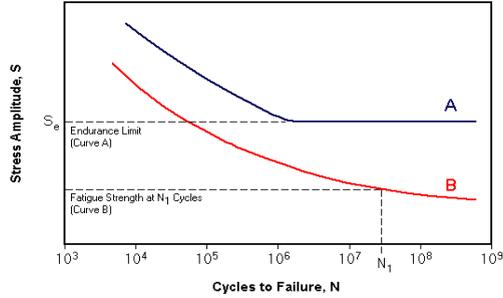
a test equipment



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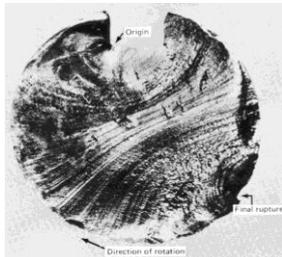
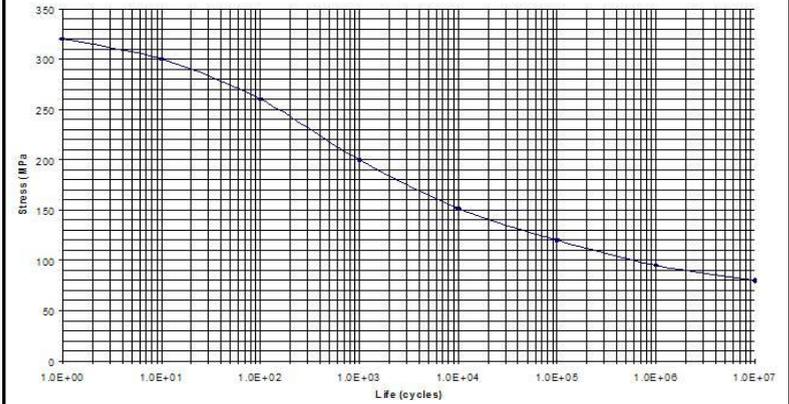
Fatigue S-N curve:



e.g. steel, titanium, ...

e.g. aluminium, copper, ...

S-N CURVE FOR BRITTLE ALUMINIUM WITH A UTS OF 320 MPa



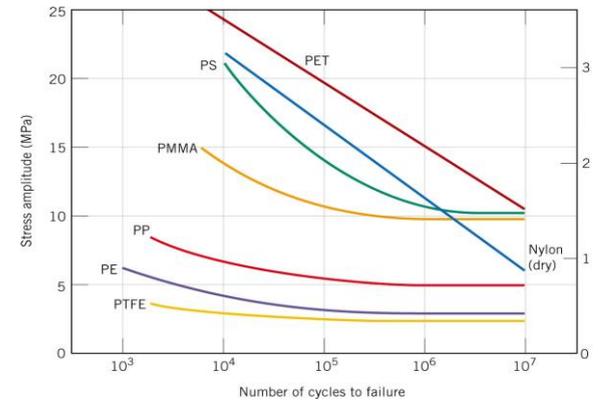
a test equipment

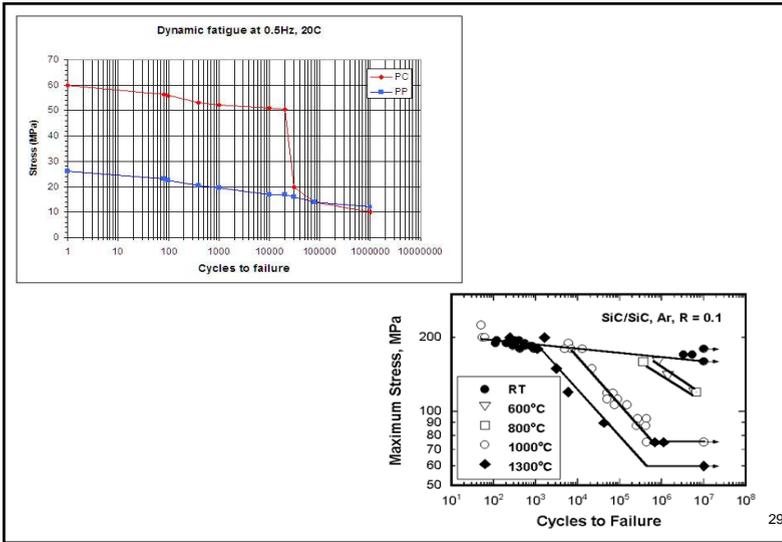


S-N curves of different polymers

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

PP: Polyethylene terephthalate
 PE: Polyethylene
 PTFE: Polytetrafluoroethylene





Some factors

Geometry: Notches and variation in cross section.

Surface quality: Surface roughness.

Material type: E.g. composites and polymers differ markedly from metals.

Grain size: For most metals, smaller grains yield longer fatigue lives.

Temperature: Extreme high or low temperatures can decrease fatigue strength.

Prevention: E.g. stress should be below threshold of fatigue limit.

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Abrasion



Loss of the structure by mechanical forces.

E.g.: toothbrush abrasion causes V-shaped notches

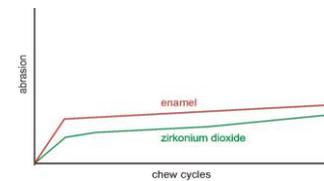
(Erosion a chemical event!)

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Role of hardness

Most commonly affected: premolars and canines.
(position)

Cementoenamel junction
(very thin enamel)
is sensitive.



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

(cementum a little bit less hard than the dentine.)

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