Mechanical Behavior of Materials

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Outline

Engineering stress-strain

True stress-strain

Mechanical testing

Effect of temperature, strain rate and hydrostatic pressure

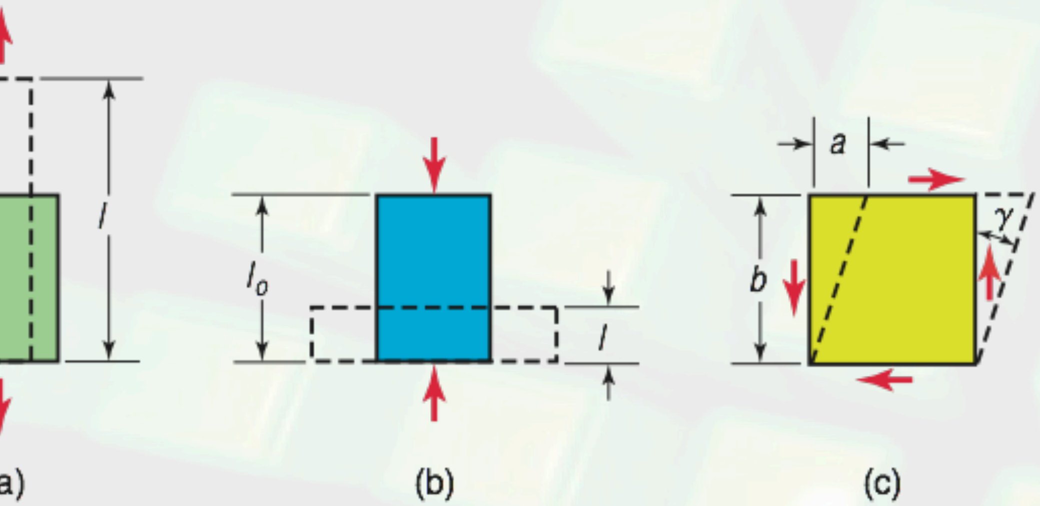
Residual stress

Fatigue, creep

Yield criterion

Flow stress and work of deformation

Definition of Stress and Strain



E 2.1 Types of strain. (a) Tensile. (b) Compressive. (c) All deformation processes in manufacturing involve of these types. Tensile strains are involved in ing sheet metal to make car bodies, compressive in forging metals to make turbine disks, and shear in making holes by punching.

Engineering Normal Strain:

$$e = \frac{l - l_o}{l_o}$$

Shear Strain:

$$\gamma = \frac{a}{b}$$

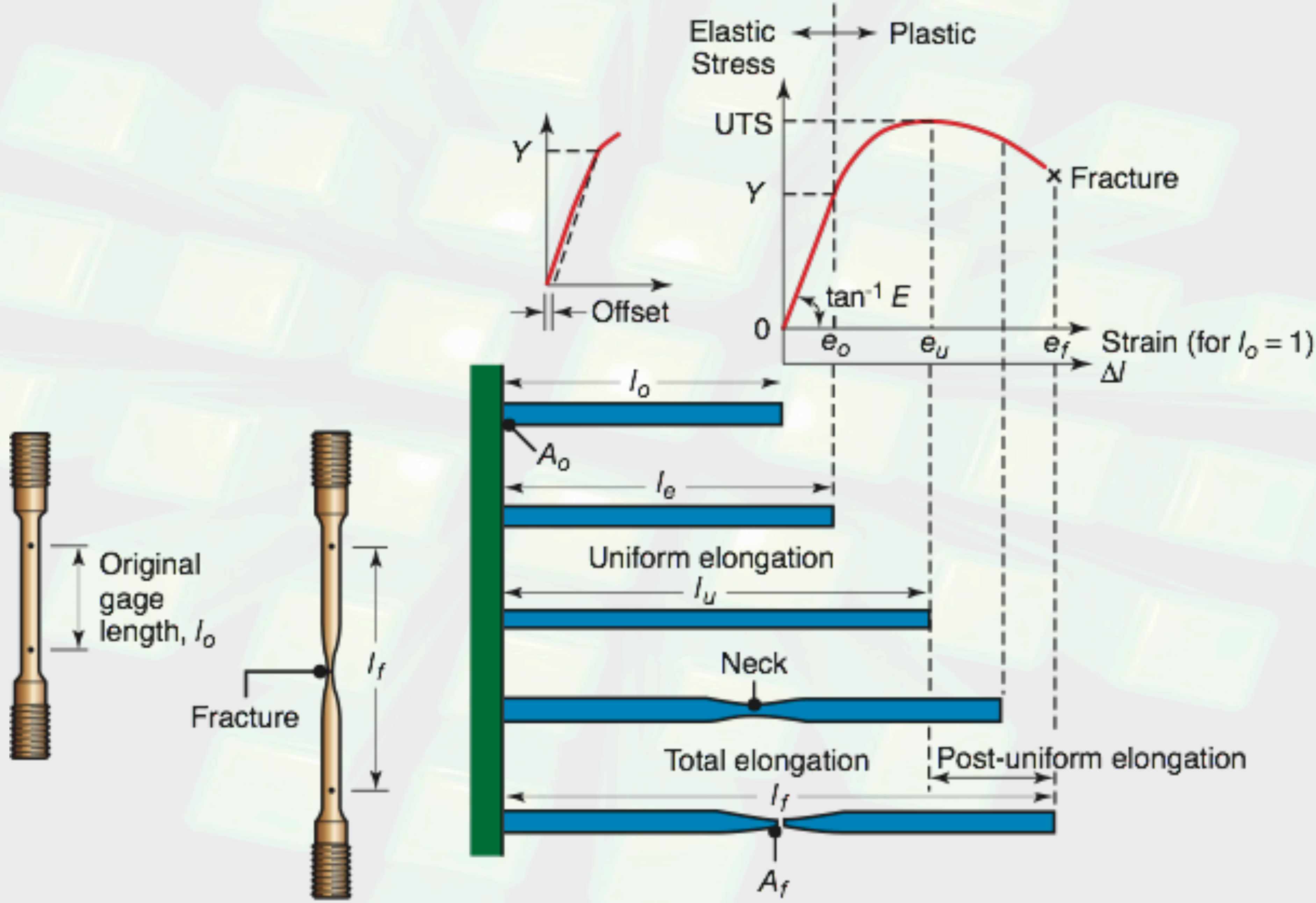
True stress

$$\sigma = \frac{P}{A}$$

True strain

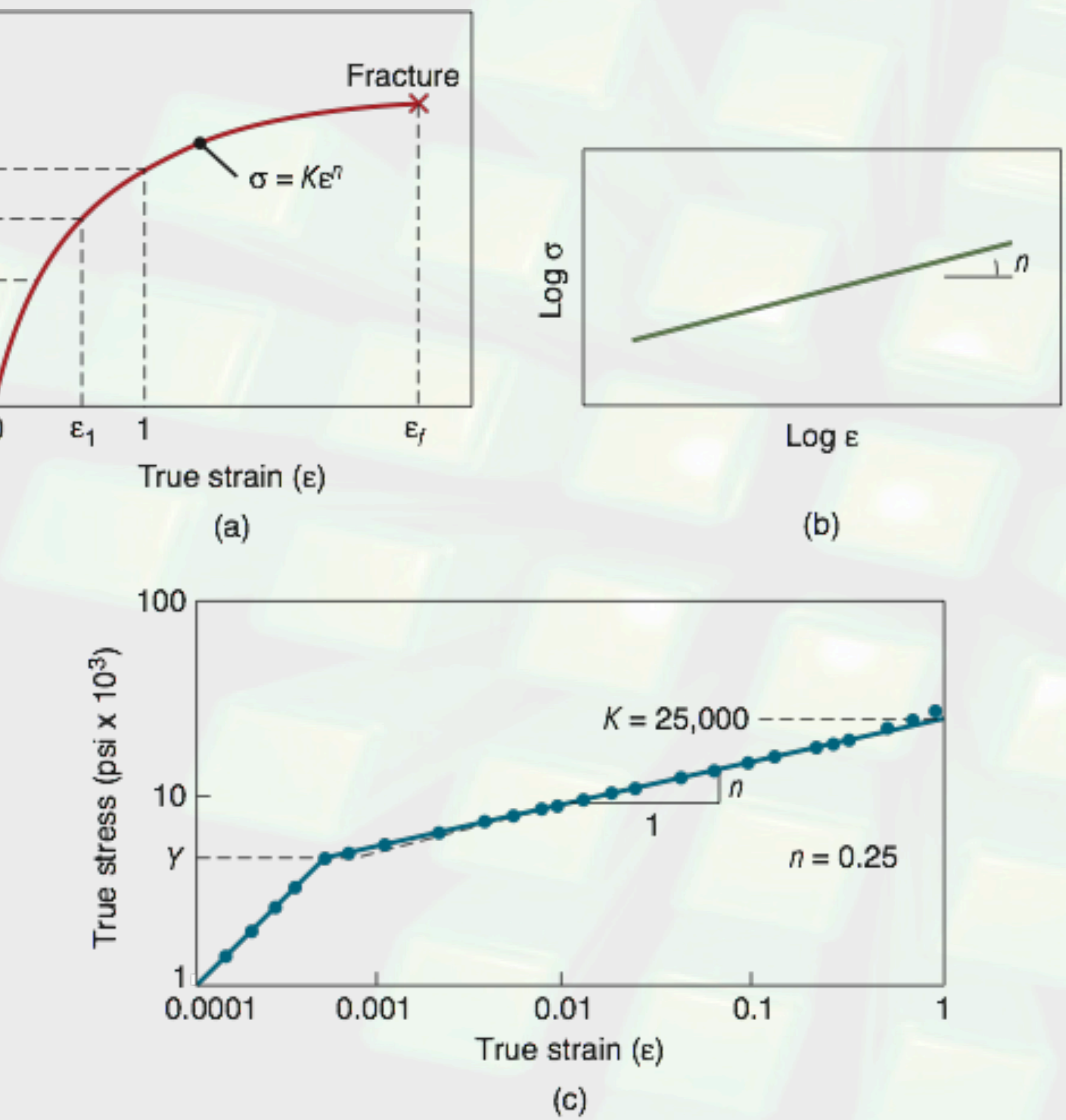
$$\varepsilon = \ln\left(\frac{l}{l_o}\right) = \ln\left(\frac{A_o}{A}\right) = \ln\left(\frac{D_o}{D}\right)^2 = 2\ln$$

Tensile Test



(a) (b)

True Stress – True Strain Curve



Flow rule:

$$\sigma = K\varepsilon^n$$

K = Strength coefficie

n = Strain hardening expo

FIGURE 2.5 (a) True stress--true curve in tension. Note that, unlike engineering stress-strain curve, the always positive and that the slope de with increasing strain. Although in the range stress and strain are proportio total curve can be approximated power expression shown. On this cu the yield stress and Y_f is the flow str True stress-true strain curve plotte log-log scale. (c) True stress-true curve in tension for 1100-O alu plotted on a log-log scale.

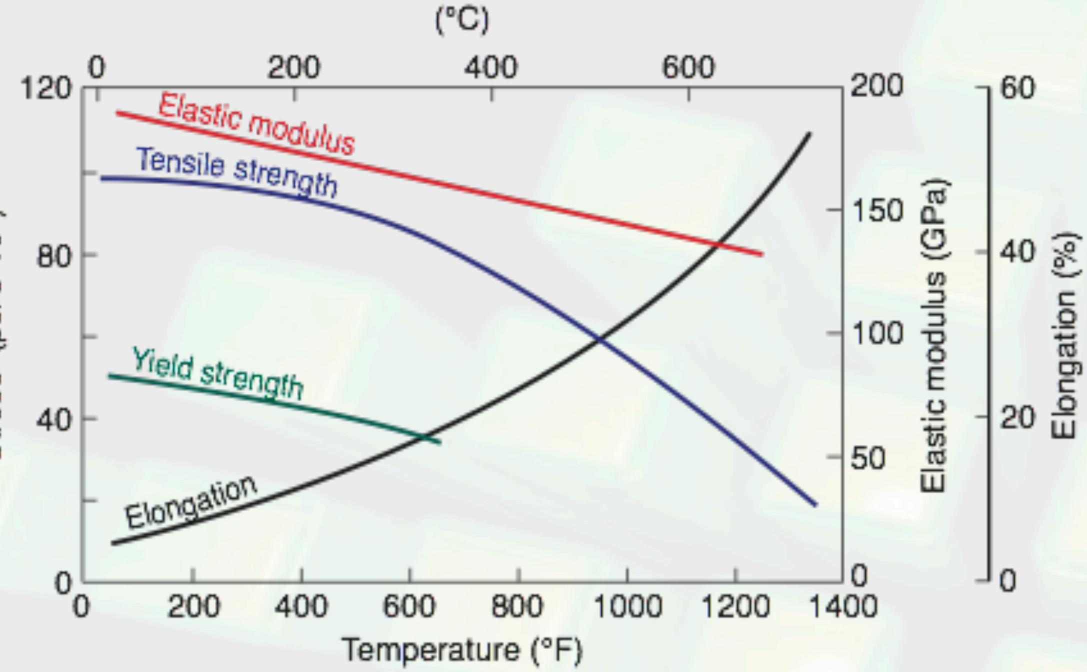
Relation

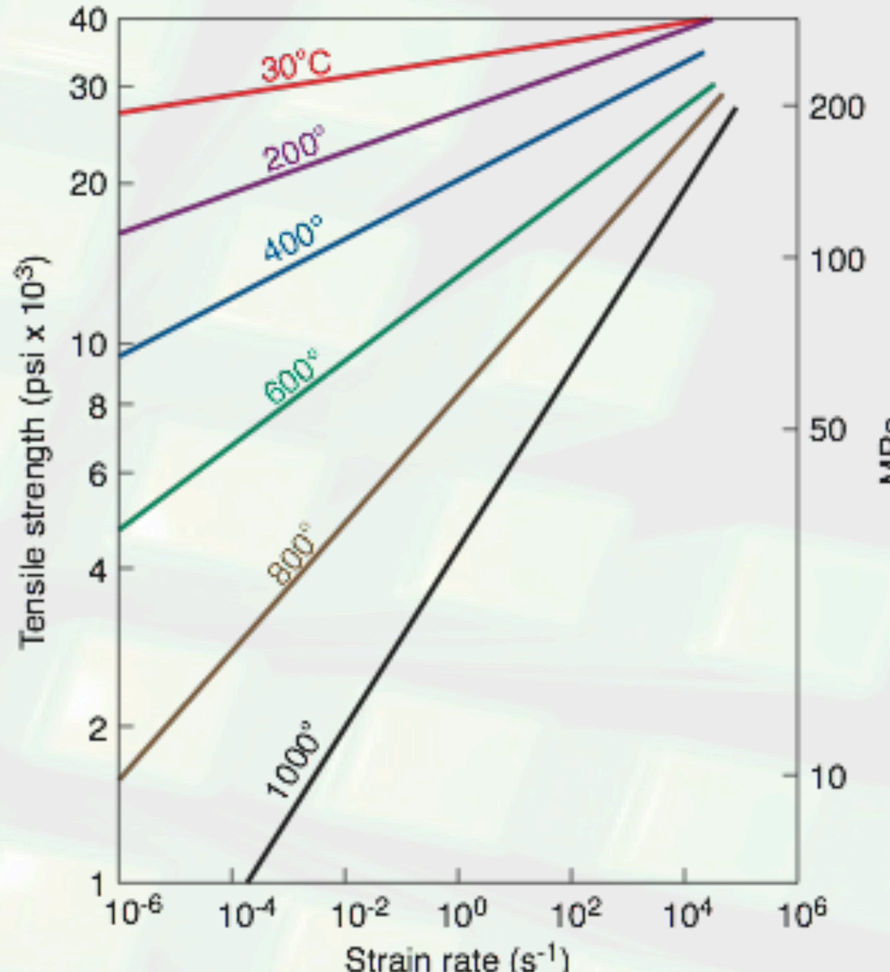
onset of necking: true strain $\varepsilon = n$

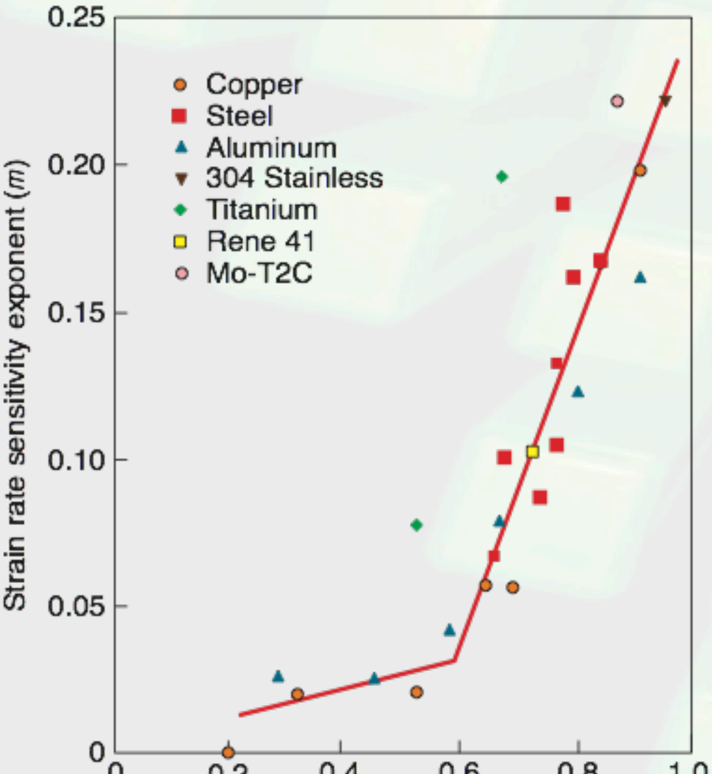
int: At UTS, $\frac{dP}{d\varepsilon} = 0, \varepsilon = \ln\frac{A_0}{A}, P = \sigma A = \sigma A_0 e^{-\varepsilon}$)

ample Calculate of UTS: A material has a true stress-strain rela
$\sigma = 100{,}000e^{0.5}$ psi. Calculate the ture UTS and engineering UT
s material.

Temperature and Strain Rate Effects







Strain rate:

$$\dot{e} = \frac{de}{dt} = \frac{v}{l_0}$$

$$\dot{\varepsilon} = \frac{d\varepsilon}{} = \frac{v}{}$$

$$\sigma = C\dot{\varepsilon}^m$$

C = Strength coeffici

m = Strain-rate sensitivit

Effect of Hydrostatic Pressure

Hydrostatic pressure increases ductility

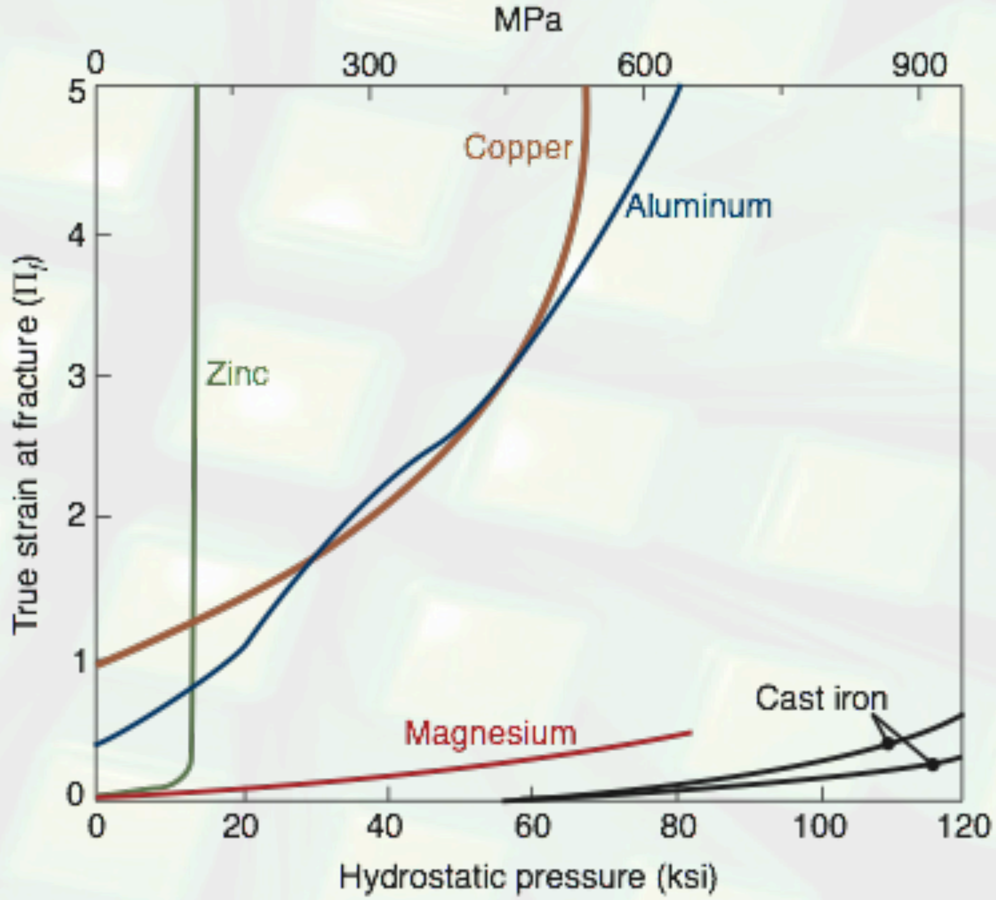
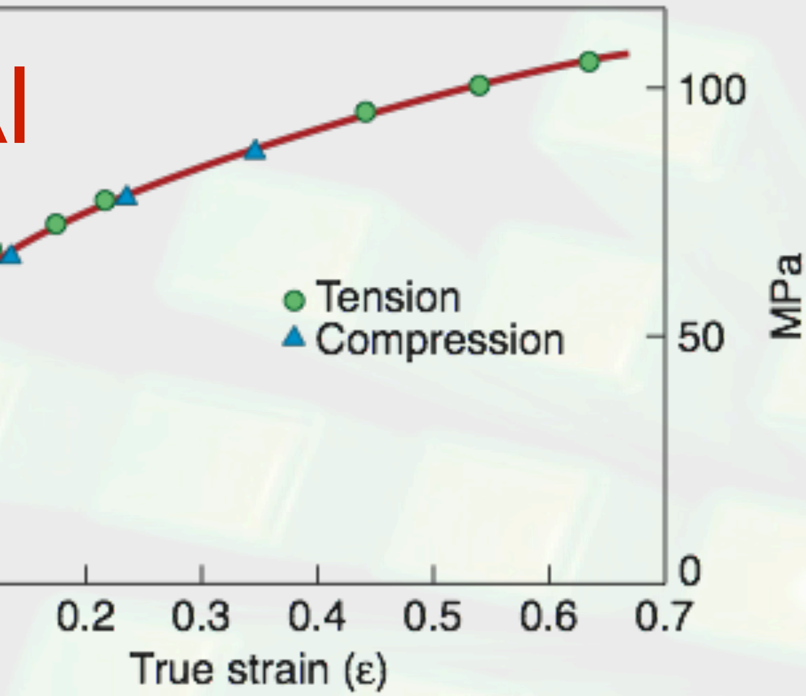
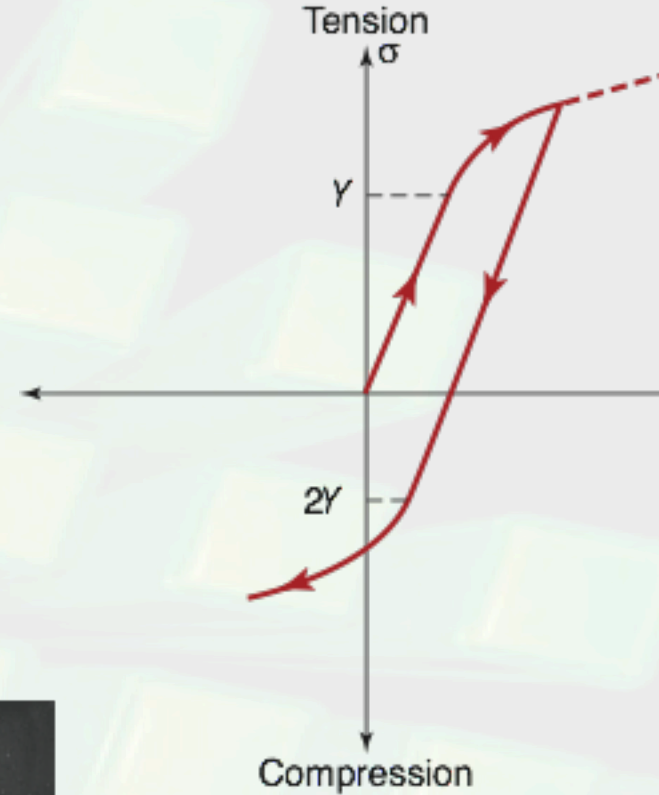


FIGURE 2.13 The effect of hydrostatic pressure on true strain at fracture in tension for various metals. Even cast iron becomes ductile under high pressure.

Compression

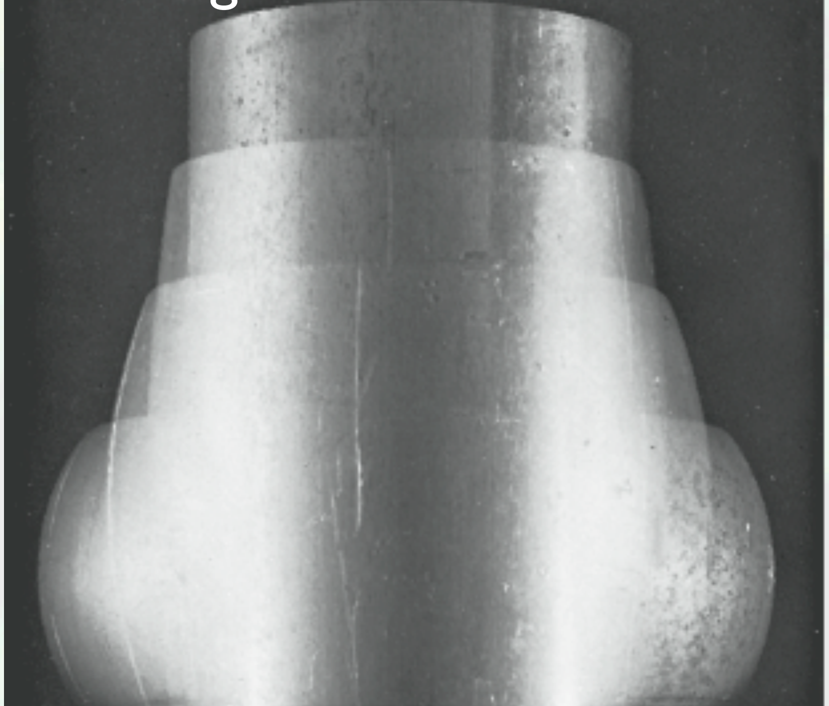
Al





Baushinger effe

Barreling



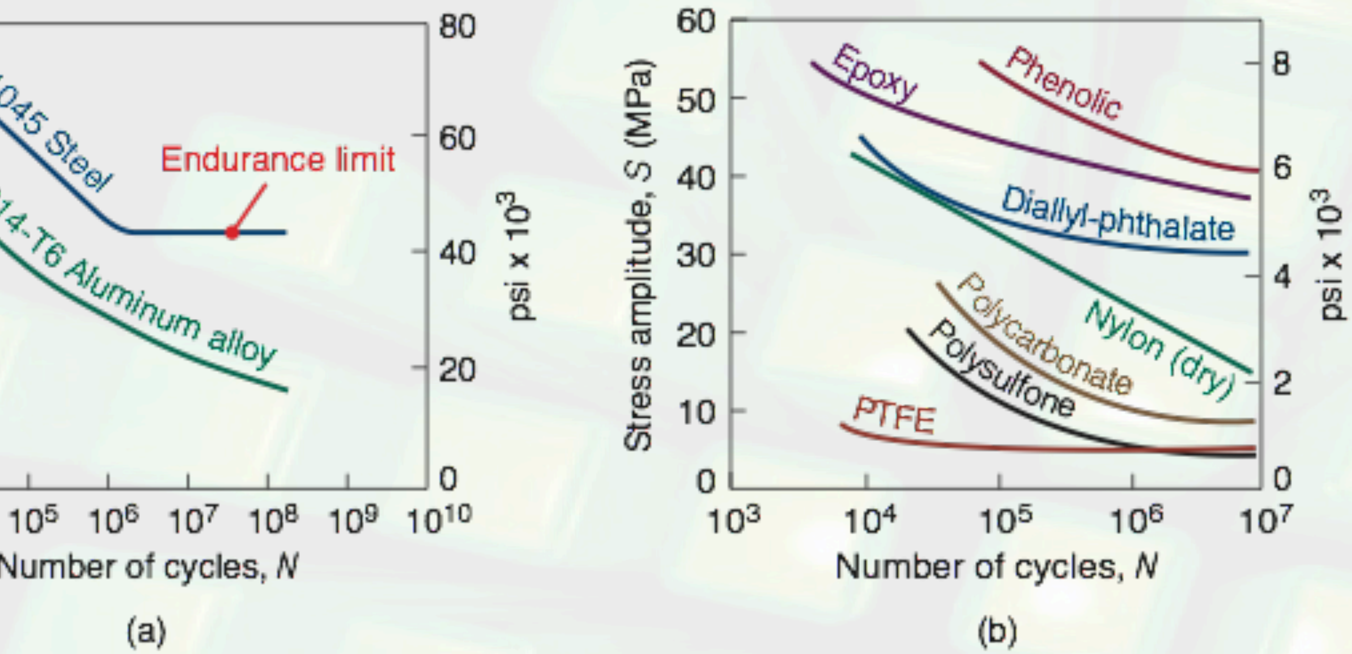
Hardness Tests

Indenter	Shape of indentation: Side view	Shape of indentation: Top view	Load, P	Hardness number
10-mm steel or tungsten carbide ball	D, d	d	500 kg 1500 kg 3000 kg	$HB = \frac{2P}{(\pi D)\left(D - \sqrt{D^2 - d^2}\right)}$
Diamond pyramid	136°	L	1–120 kg	$HV = \frac{1.854P}{L^2}$
Diamond pyramid	$L/b = 7.11$ $b/t = 4.00$ t	b L	25 g–5 kg	$HK = \frac{14.2P}{L^2}$
Diamond cone	120° t = mm		60 kg 150 kg 100 kg	HRA, HRC, HRD $= 100 - 500t$
$\frac{1}{16}$- in. diameter steel ball $\frac{1}{8}$- in. diameter steel ball	t = mm		100 kg 60 kg 150 kg 100 kg	HRB, HRF, HRG, HRE $= 130 - 500t$

Hardness is not i
material prop

Hardness is prop
to yield stren

Fatigue and Creep



GURE 2.26 Typical *S-N* curves for two tals. Note that, unlike steel, aluminum es not have an endurance limit.

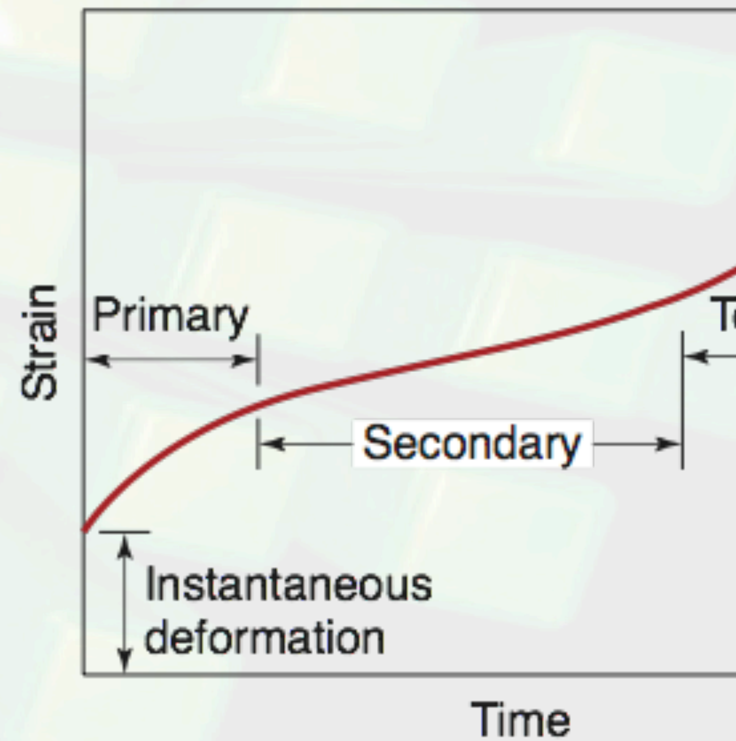
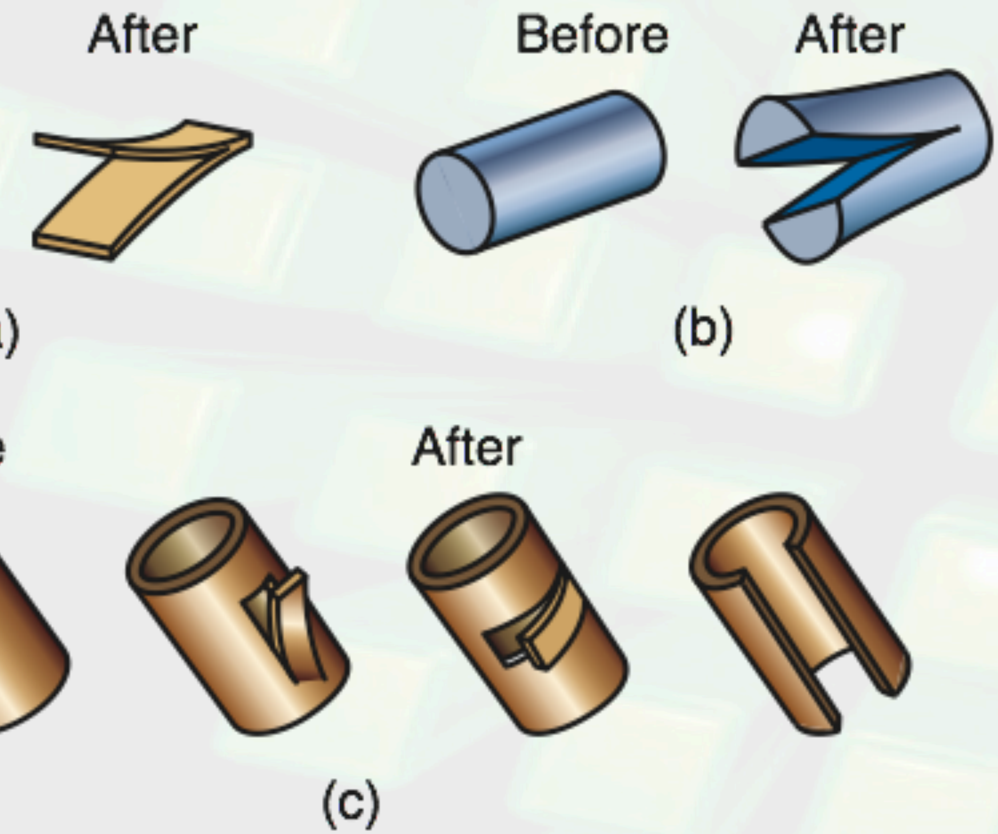


FIGURE 2.28 Schematic illustration creep curve. The linear segment

Residual Stress and its Effect

Residual stress: stress left in the part after unloading.



1 Distortion of parts with residual stresses after cutting
a) rolled sheet or plate; (b) drawn rod; (c) thin-walled

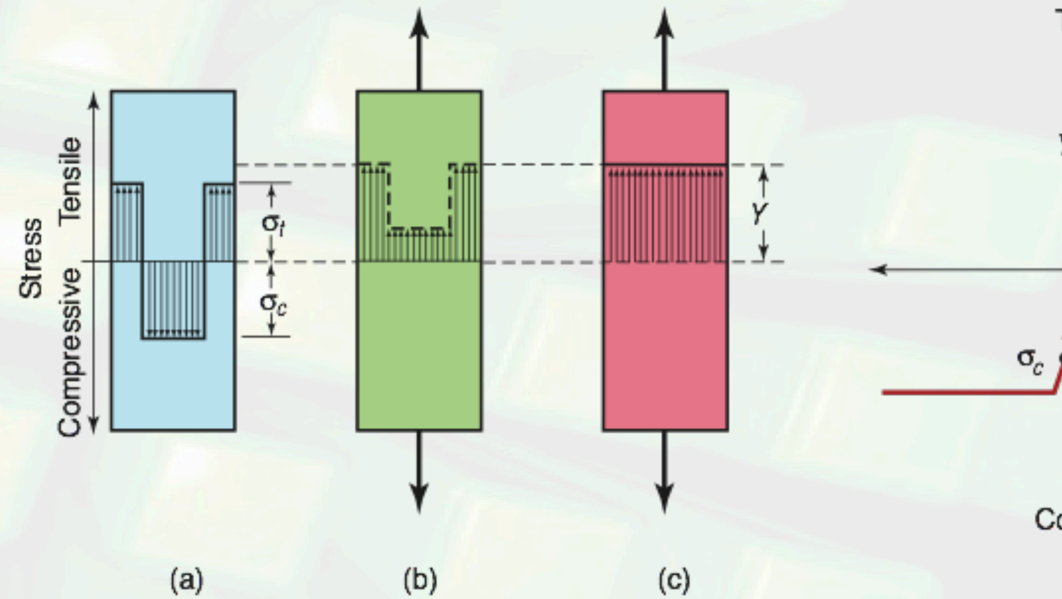
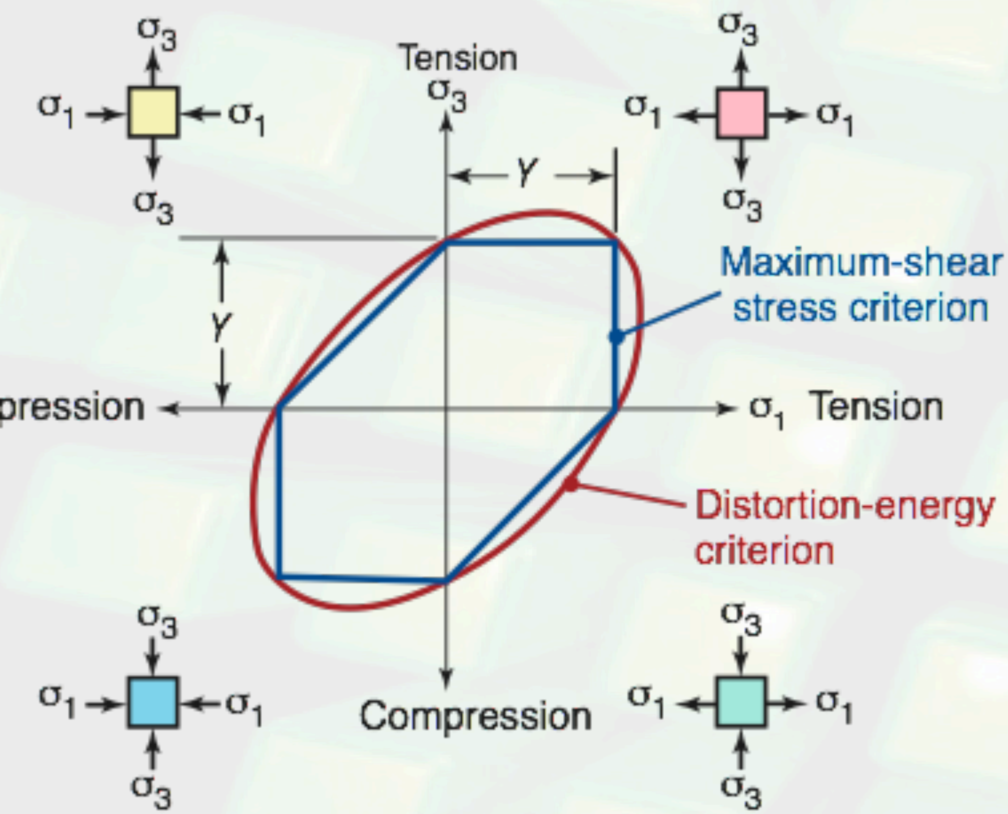


FIGURE 2.32 Elimination of residual
stretching. Residual stresses can be also
eliminated by **thermal treatments**, suc
relieving or annealing.

Yield Criteria



URE 2.36 Plane-stress diagrams for maximum
ar-stress and distortion-energy criteria.
e that $\sigma_2 = 0$.

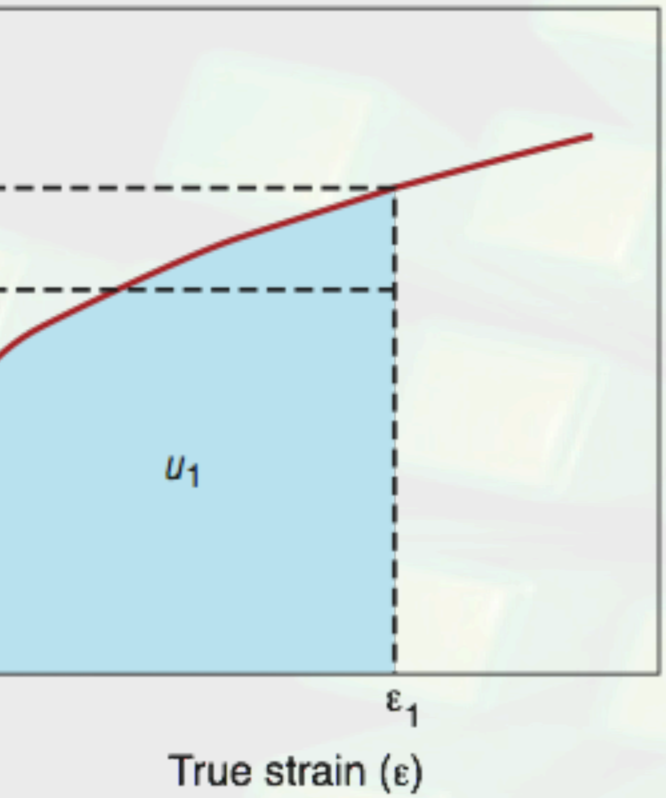
Maximum-shear-stress (Tresca) criterio

$$\sigma_{max} - \sigma_{min} = Y$$

Distortion-energy (Von Mises) criterio

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 =$$

Flow Stress and Work of Deformation



URE 2.37 Schematic illustration of true s-true strain curve showing yield stress erage flow stress, specific energy u_1 and stress Y_f.

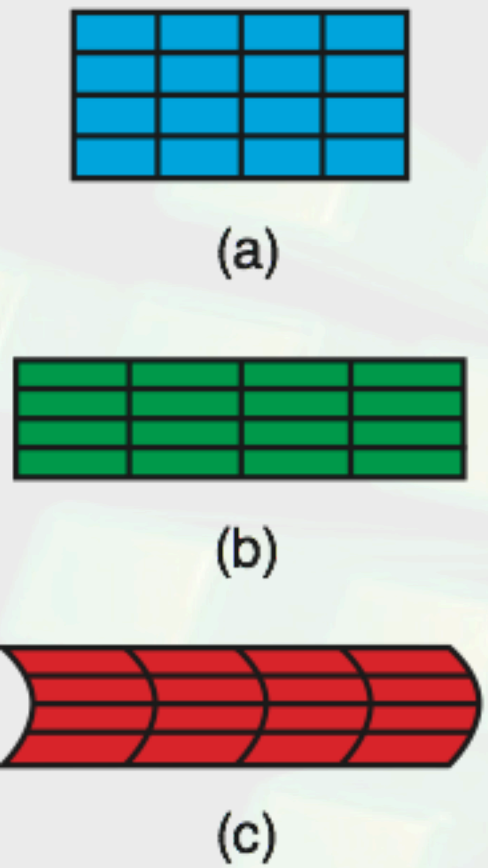
Flow stress:

$$\bar{Y} = \frac{K\varepsilon_1^n}{n+1}$$

Specific energy

$$u = \int_0^{\varepsilon} \bar{\sigma}\, d\bar{\varepsilon}$$

Ideal & Redundant Work



38 Deformation of grid patterns in a
(a) original pattern; (b) after ideal
; (c) after inhomogeneous deformation,
dundant work of deformation. Note that
ly (b) with additional shearing, especially at
ayers. Thus (c) requires greater work of
than (b). See also Figs. 6.3 and 6.49.

Total specific energy:

$$u_{total} = u_{ideal} + u_{friction} + u_{redundant}$$

Efficiency: $\eta = \dfrac{u_{ideal}}{u_{total}}$

Work of deformation:

$$W = u_{total} \times \text{Volume}$$

Heat rise in work piece:

$$\Delta T = \frac{u_{total}}{\rho c}$$

Summary

Engineering stress-strain vs true stress-strain

Mechanical testing methods

- Tension vs compression test
- Important properties: Young's modulus, yield strength, toughness, modulus of resilience

Effect of various parameters

- Temperature
- Strain rate
- Loading direction (Baushinger effect)
- Hydrostatic pressure
- Residual stress

Yield criterion: Tresca vs Von Mises

Work of deformation

- Total work= ideal + frictional + redundant work
- Heat generation in workpiece