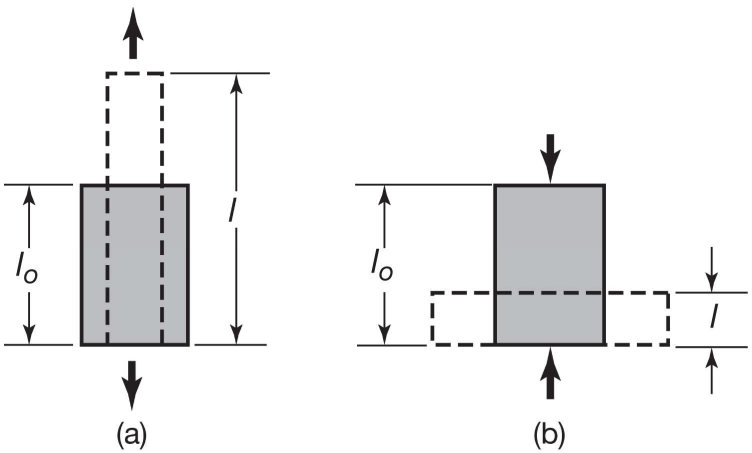
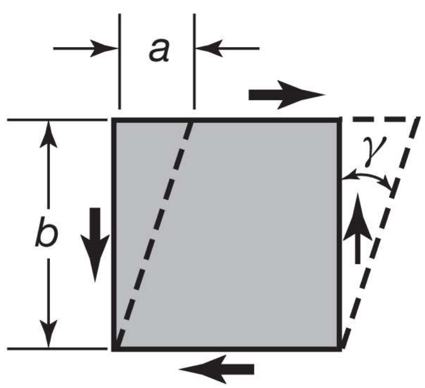
MechanicsIn Design and Manufacturing

+ Mechanical Behavior of Materials

Strain

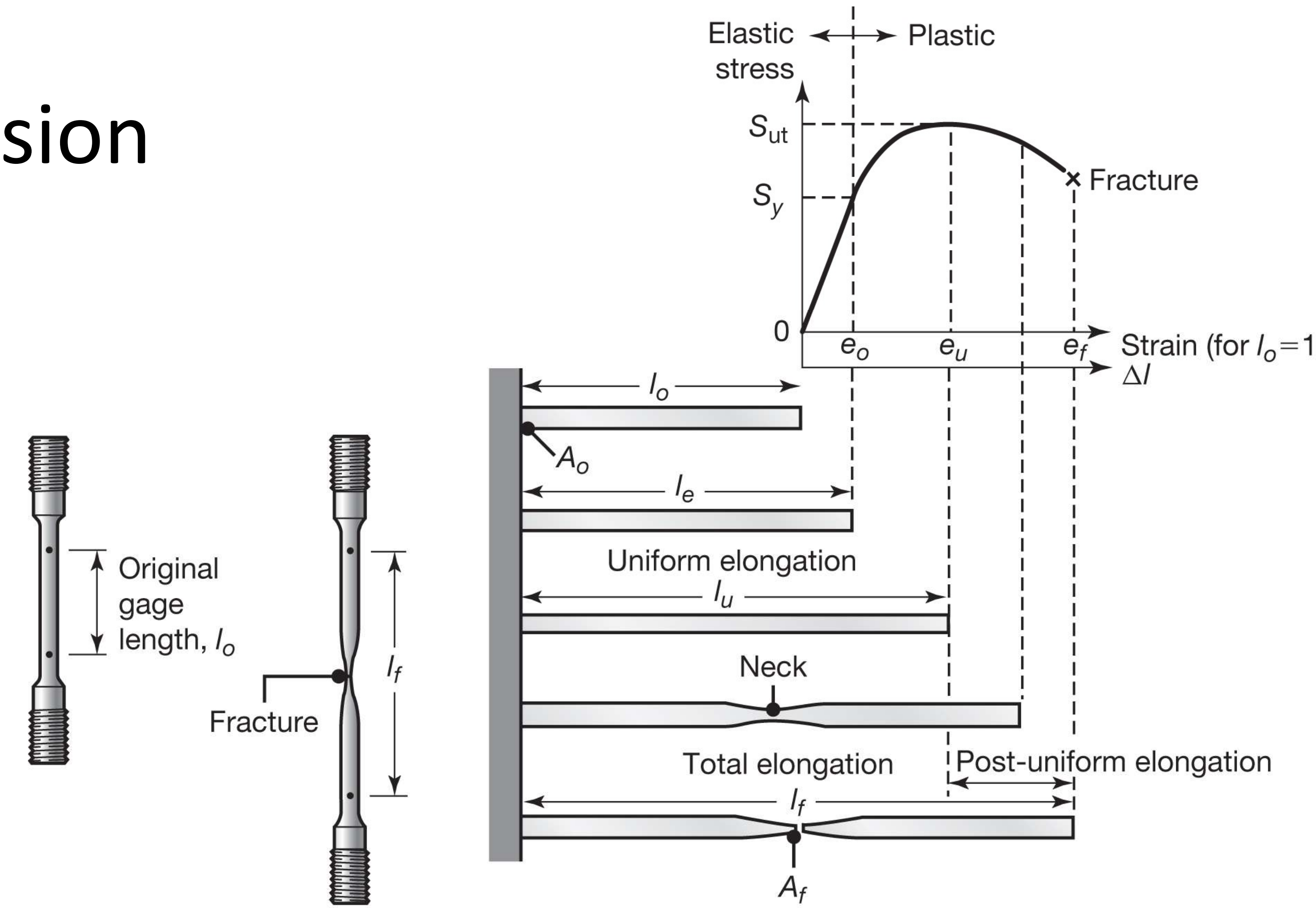


- Average linear strain



- Shear strain

Tension



Elastic
stress
Plastic
S_{ut}
S_y
Fracture
0
e_o
e_u
e_f
Strain (for $l_o = 1$)
Δl
l_o
A_o
l_e
Uniform elongation
l_u
Neck
Total elongation
Post-uniform elongation
l_f
A_f
Original
gage
length, l_o
l_f
Fracture

Ductility

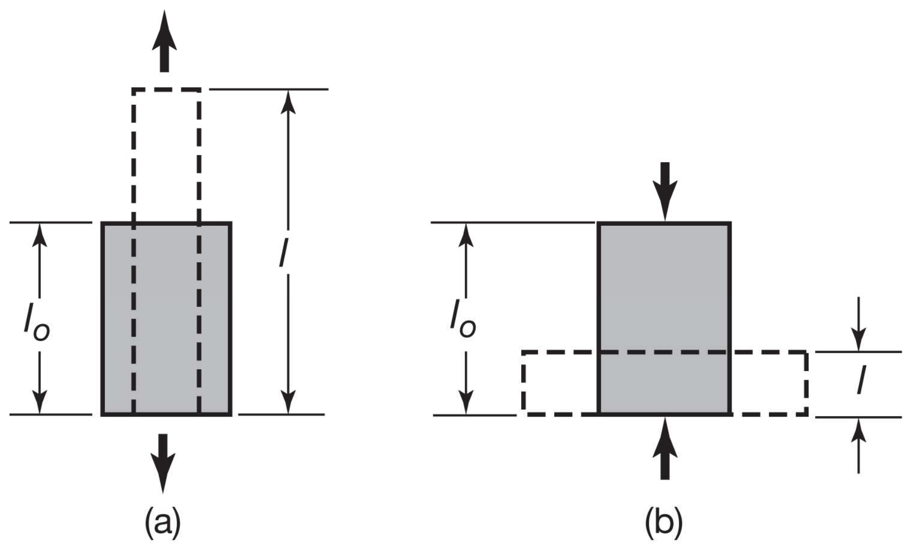
- A measure of strain material can endure before fracturing

True Stress/Strain

- True Stress

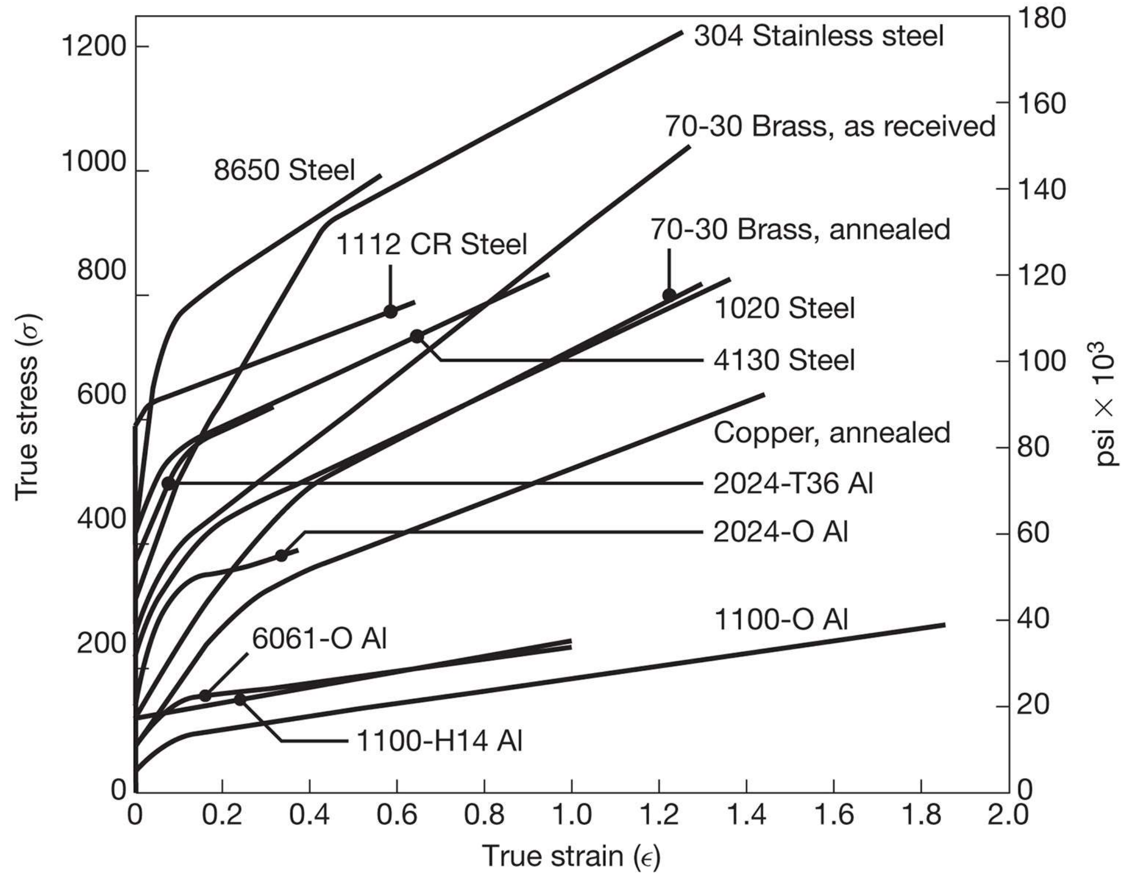
- True Strain

Comparing engineering/true strains



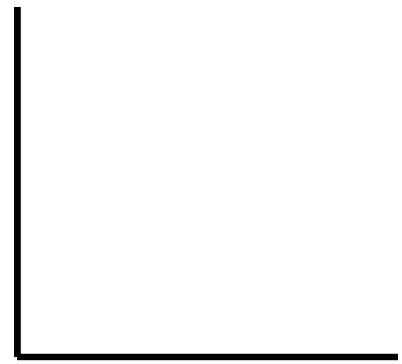
True Stress-True Strain Curves

Flow Stress



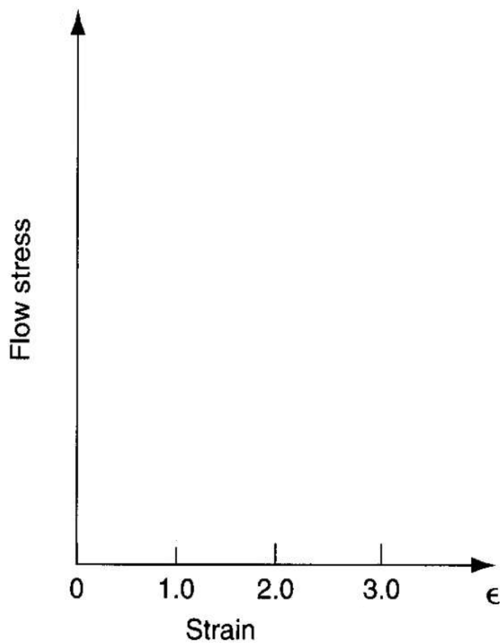
304 Stainless steel
70-30 Brass, as received
8650 Steel
1112 CR Steel
70-30 Brass, annealed
1020 Steel
4130 Steel
Copper, annealed
2024-T36 Al
2024-O Al
1100-O Al
6061-O Al
1100-H14 Al
True stress (σ)
psi × 10^3
True strain (ϵ)
0
200
400
600
800
1000
1200
20
40
60
80
100
120
140
160
180
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

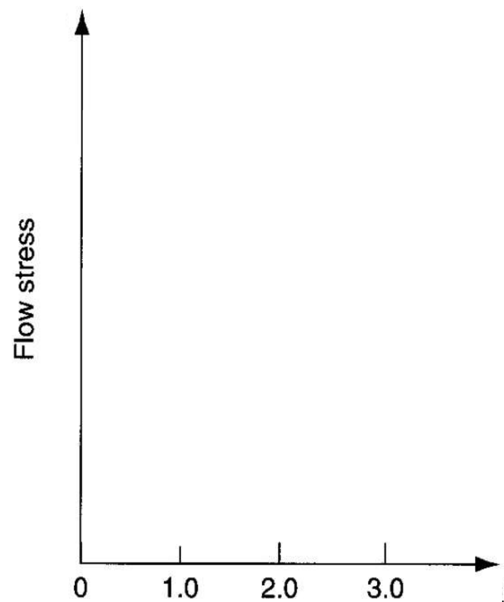
Flow Theories



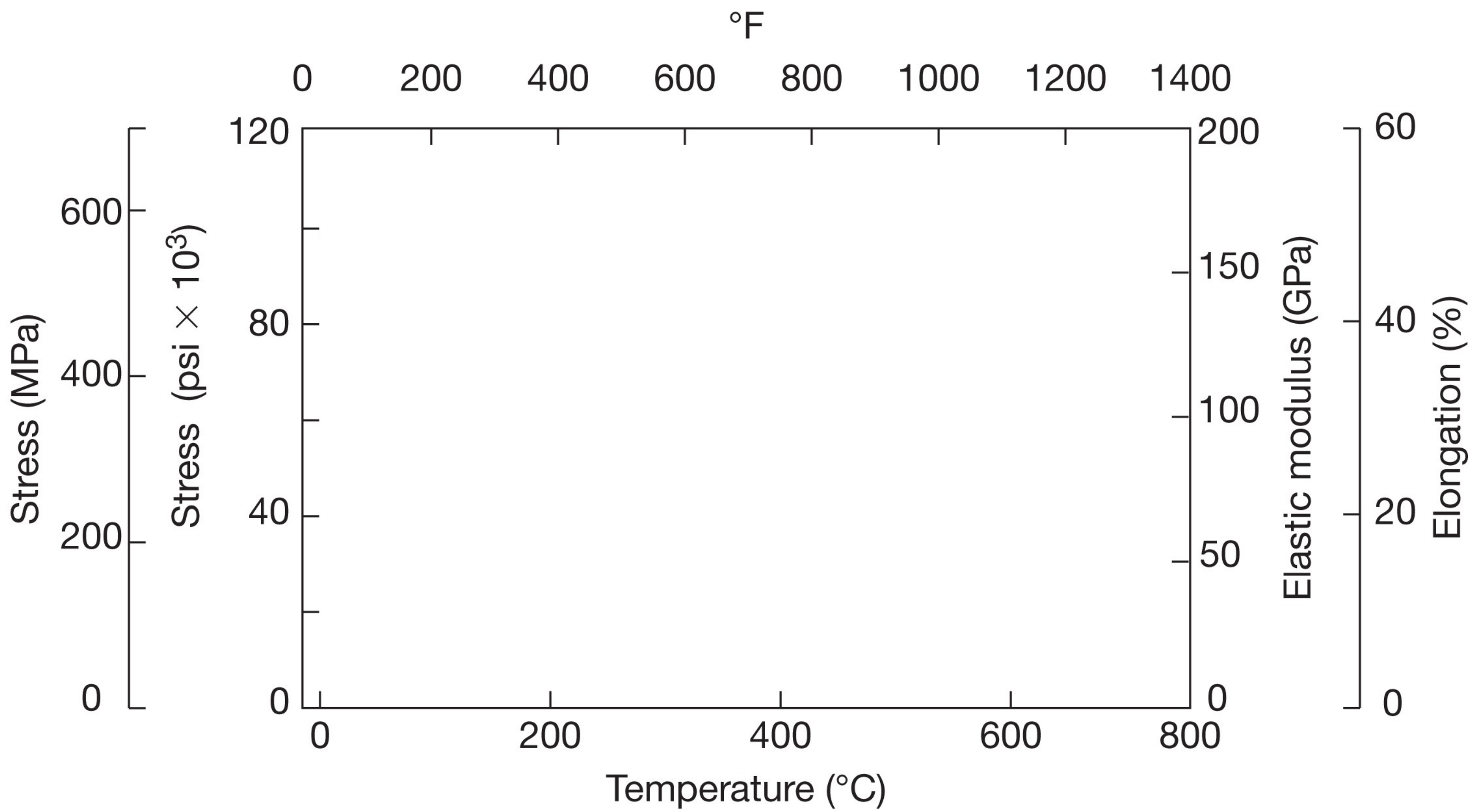
Strain Rate

Process	True Strain ε	Deformation speed (m/s)	Strain Rate
Cold Working			
Forging, rolling	0.1-0.5	0.1-100	$1\text{-}10^3$
Wire and tube drawing	0.05-0.5		$10\text{-}10^4$
Explosive forming	0.05-0.2	10-100	$10\text{-}10^5$
Hot/warm working			
Forging, rolling	0.1-0.5	0.1-30	$1\text{-}10^3$
Extrusion	2-5	0.1-1	$10^{-1}\text{-}10^2$
Machining	1-10	0.1-100	$10^3\text{-}10^6$
Sheet metal forming	0.1-0.5	0.05-2	$1\text{-}10^2$
Superplastic forming	0.2-3	$10^{-4}\text{-}10^{-2}$	$10^{-4}\text{-}10^{-2}$

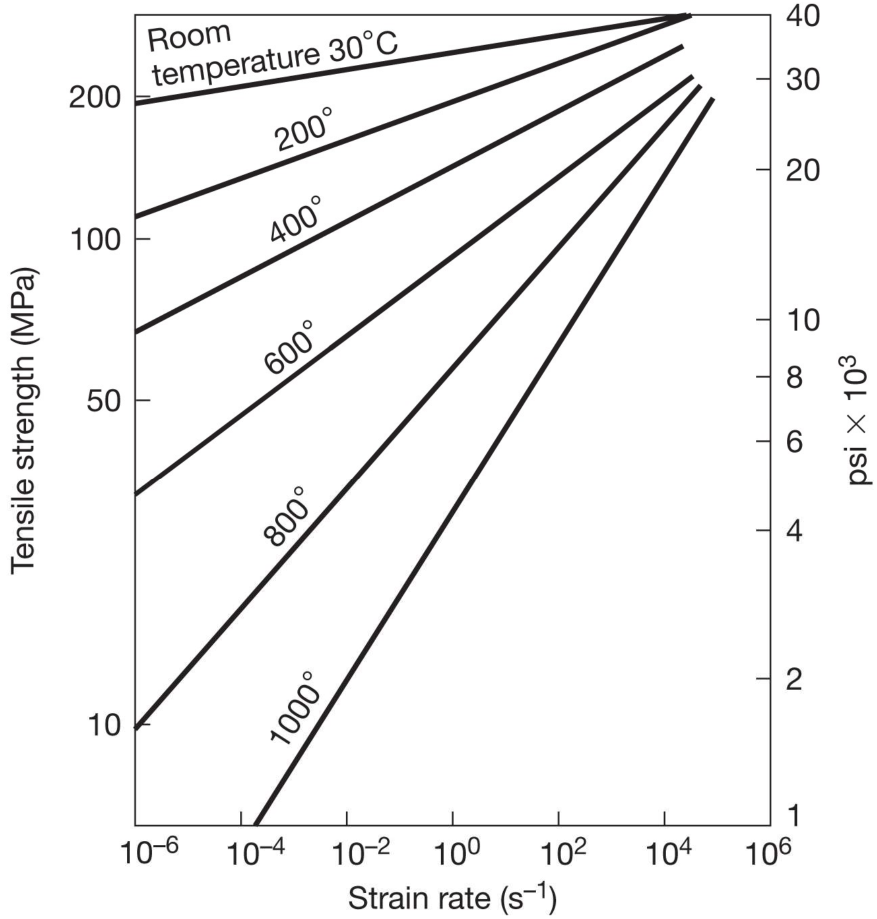




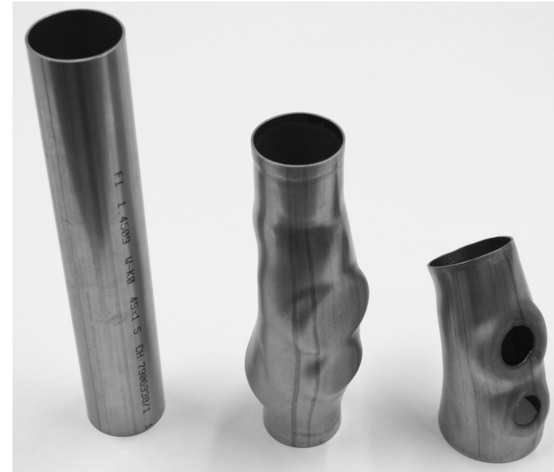
Temperature

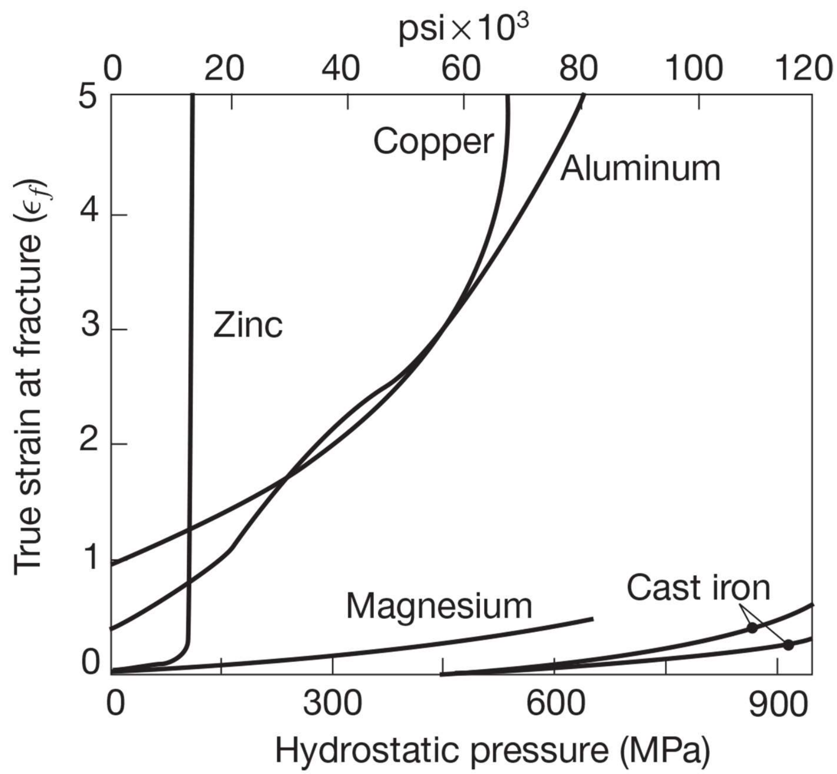


Effect of Temperature

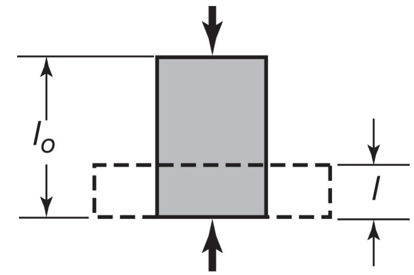


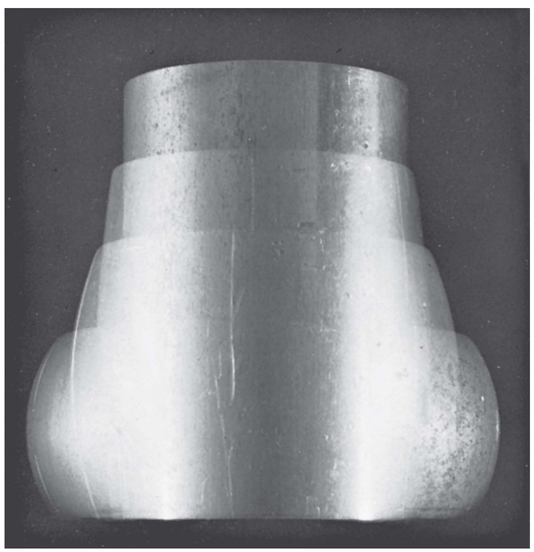
Effect of Hydrostatic Pressure

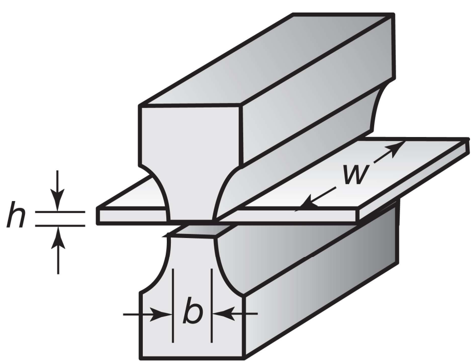




Compression

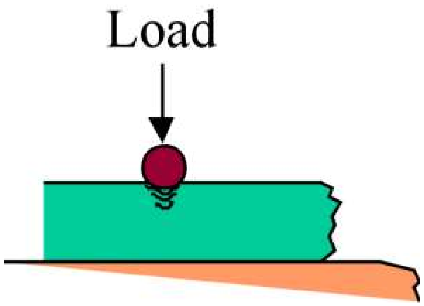


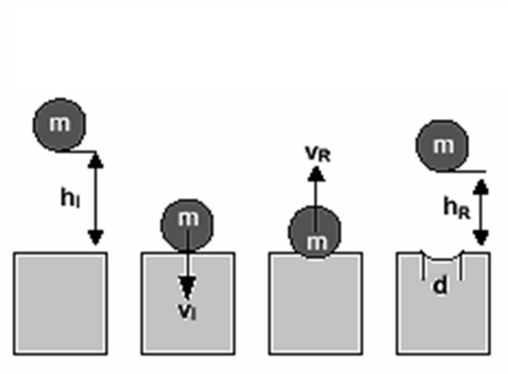




Hardness


INCREASING HARDNESS
Talc
1
Gypsum
2
Calcite
3
Fluorite
4
Apatite
5
Feldspar
6
Quartz
7
Topaz
8
Corundum
9
*
(not included)
Diamond
10
Fingernail
Copper Coin
Knife/Glass
Steel Tool


Load

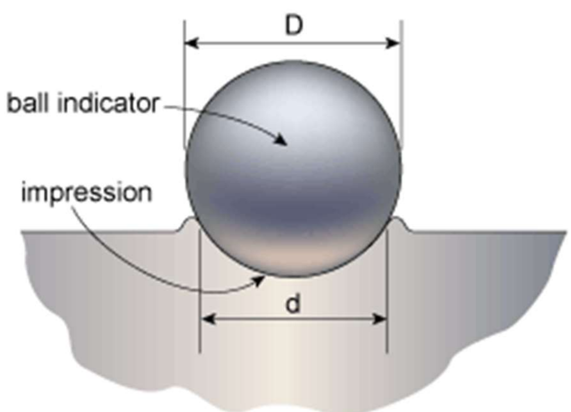

m
h_I
m
v_I
v_R
m
m
h_R
d

The beginning…Brinell hardness

- Probe: 10 mm diameter steel ball
- Load: 3,000 kg
- Modifications

- Time: 30s

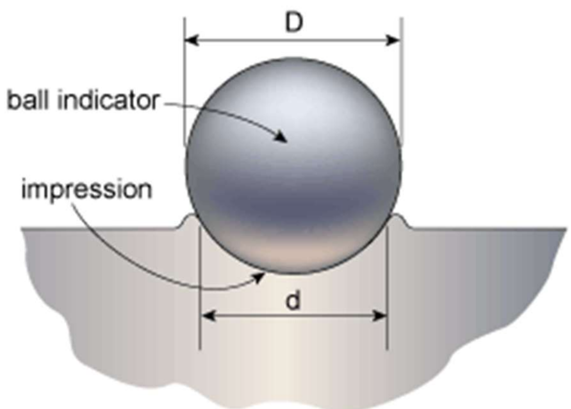
- BHN=



Meyer Hardness

- More realistic definition of hardness
- Forms the basis of more modern indentation experiments

- H_{Meyer} =



- Problems with spherical indentation

Rockwell Hardness….adding depth sensing

- First easy test
- Small impression so finished parts can be tested without damage

- 2-stage test
  - 10kg “minor load”

- A scale:

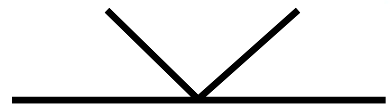
-

- B scale:

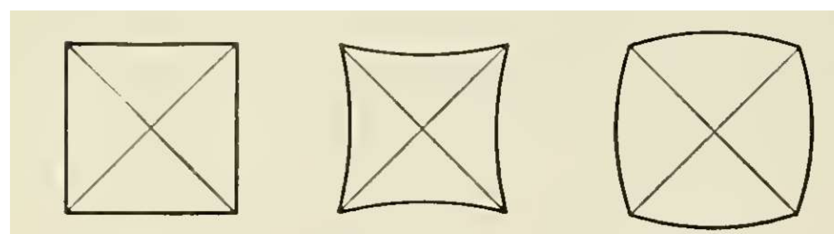
- C scale:

Vickers Indentation

- Problem of similitude solved by using a pyramidal indenter



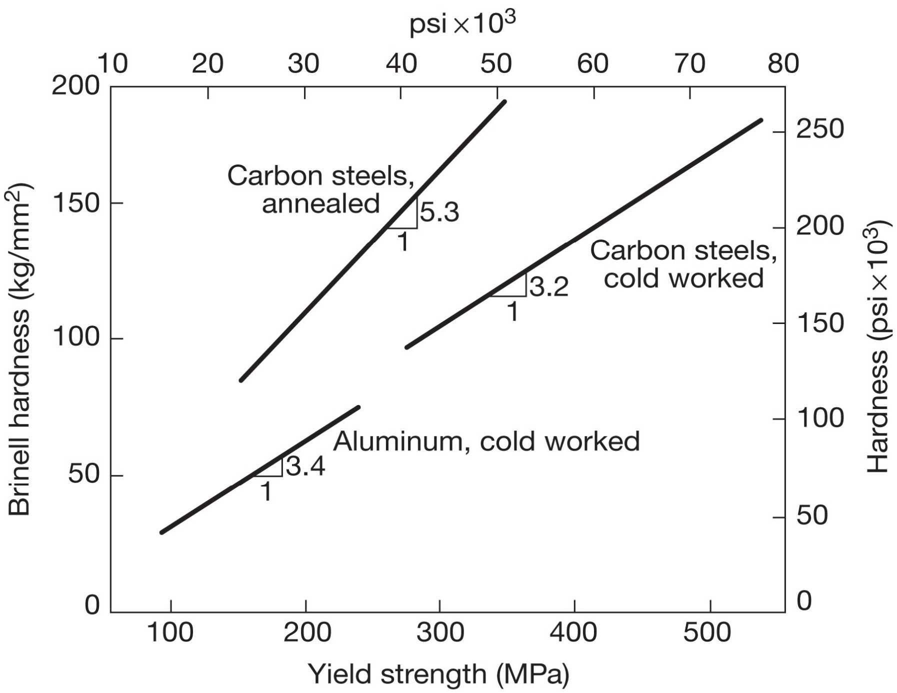
Wikipedia



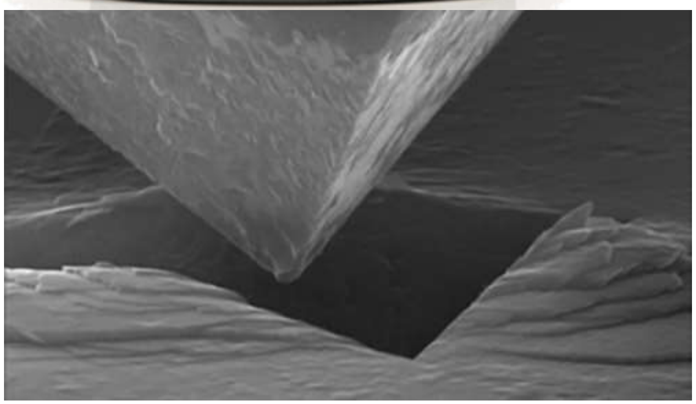
Rockwell - Rockwell Superficial - Brinell - Vickers - Shore Hardness Conversion

Rockwell						Rockwell Superficial				Brinell		Vickers	Shore Hardnell
A	B	C	D	E	F	15-N	30-N	45-N	30-T	3000 kg	500 kg	136	
60kg Brale	100kg 1/16" Ball	150kg Brale	100kg Brale	100kg 1/8" Ball	60kg 1/16" Ball	15kg Brale	30kg Brale	45kg Brale	30 kg 1/16" Ball	10mm Ball Steel	10mm Ball Steel	Diamond Pyramid	Sciero-scope
86.5	---	70	78.5	---	---	94.0	86.0	77.6	---	---	---	1076	101
86.0	---	69	77.7	---	---	93.5	85.0	76.5	---	---	---	1044	99
85.6	---	68	76.9	---	---	93.2	84.4	75.4	---	---	---	940	97
85.0	---	67	76.1	---	---	92.9	83.6	74.2	---	---	---	900	95
84.5	---	66	75.4	---	---	92.5	82.8	73.2	---	---	---	865	92
83.9	---	65	74.5	---	---	92.2	81.9	72.0	---	739	---	832	91
83.4	---	64	73.8	---	---	91.8	81.1	71.0	---	722	---	800	88
82.8	---	63	73.0	---	---	91.4	80.1	69.9	---	705	---	772	87
82.3	---	62	72.2	---	---	91.1	79.3	68.8	---	688	---	746	85
81.8	---	61	71.5	---	---	90.7	78.4	67.7	---	670	---	720	83
81.2	---	60	70.7	---	---	90.2	77.5	66.6	---	654	---	697	81

Hardness vs. Strength



Modern Instrumented Indentation

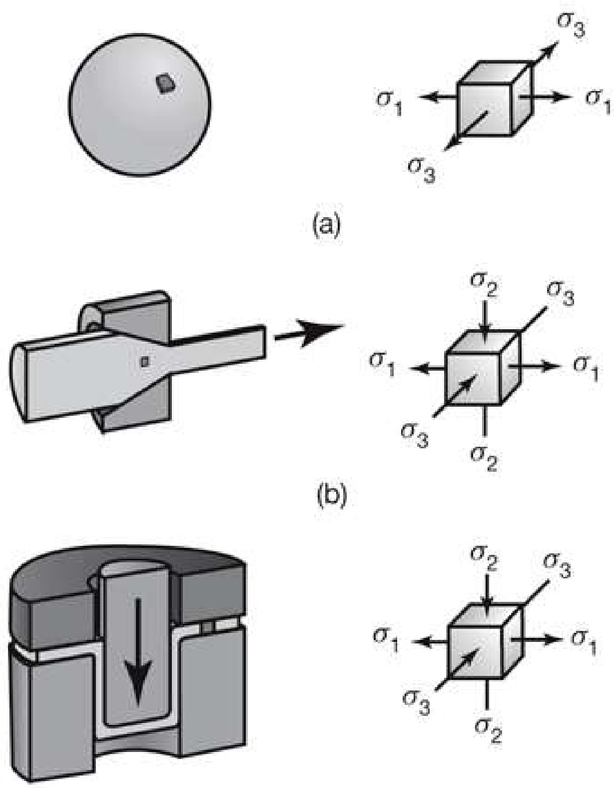


- P-h curve

- Possible to determine E, via the Oliver-Pharr Method

Yielding Criteria

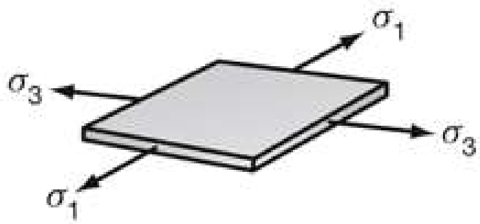
- A tensile test cannot inform failure in a 3D state of stress

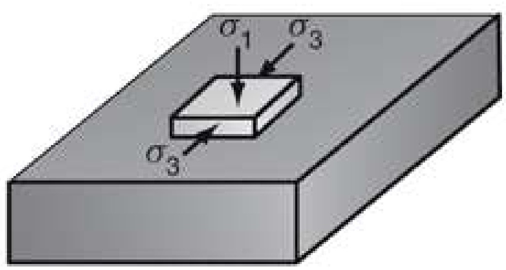


- Maximum shear stress theory

- Von Mises

Plane Stress/Strain



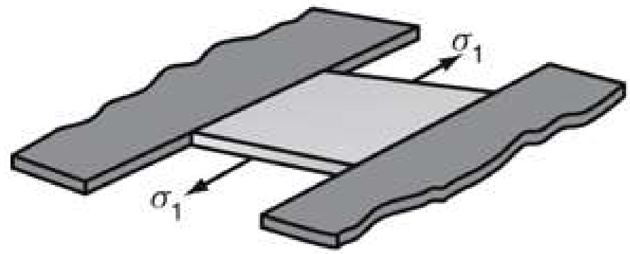


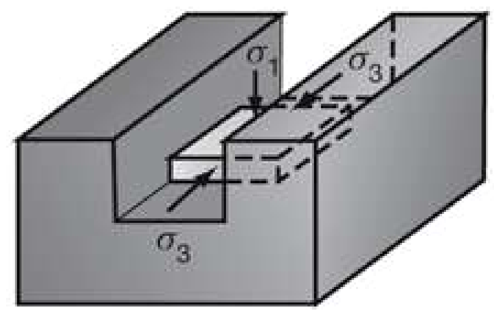
Maximum shear stress theory

First/third quadrants

Second/fourth quadrants

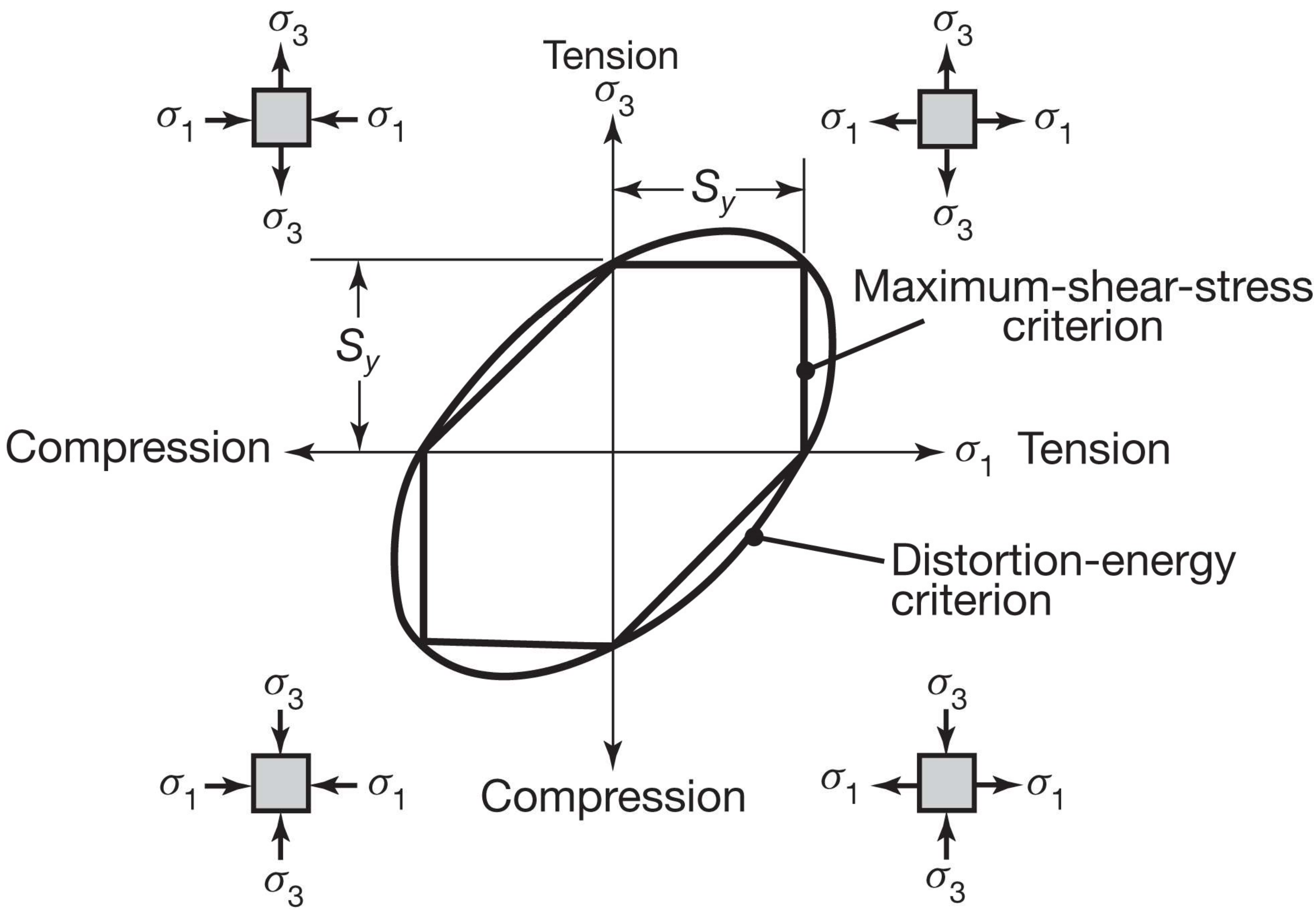
Von Mises





Von Mises

FIGURE 2.32 Plane-stress diagrams for maximum-shear-stress and distortion-energy criteria. Note that $\sigma_2 = 0$.



Effective Stress/Strain

Maximum shear stress theory

Von Mises