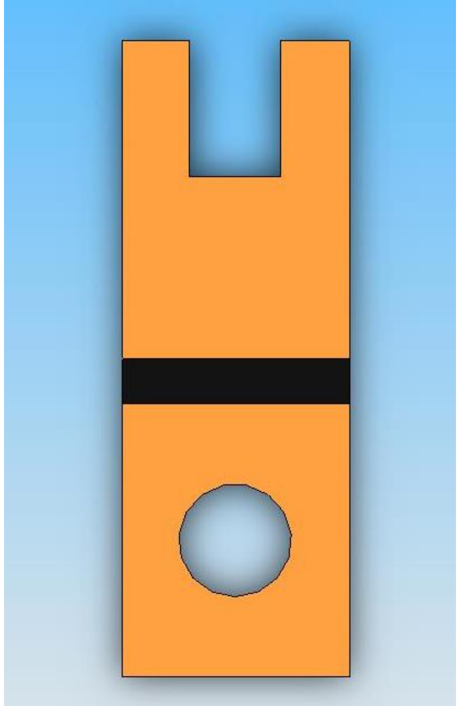
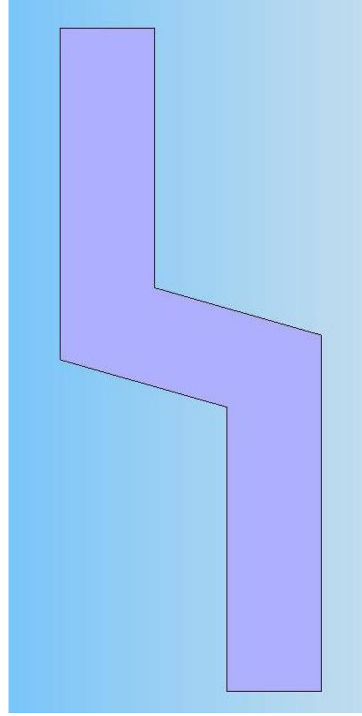
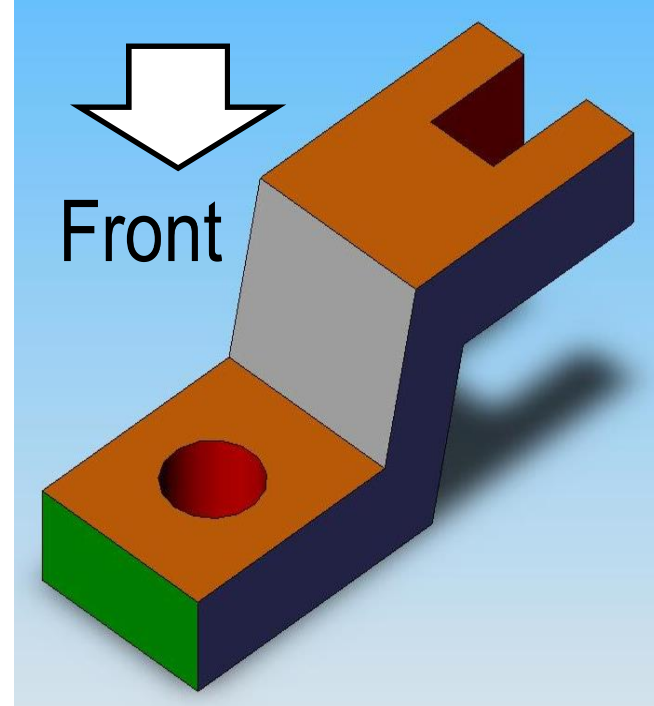
Lec 2: Technical Drawing

Review of technical drawing

1. Orthographic projection
2. Isometric projection
3. Sectioning
4. Dimensioning



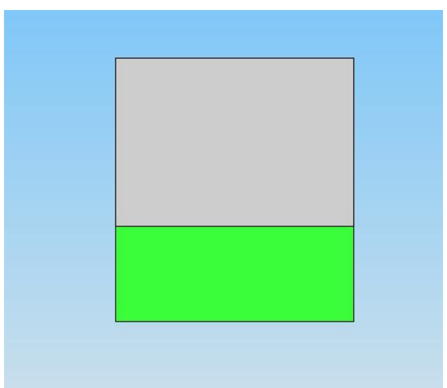




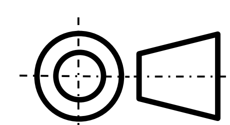
Front

Right

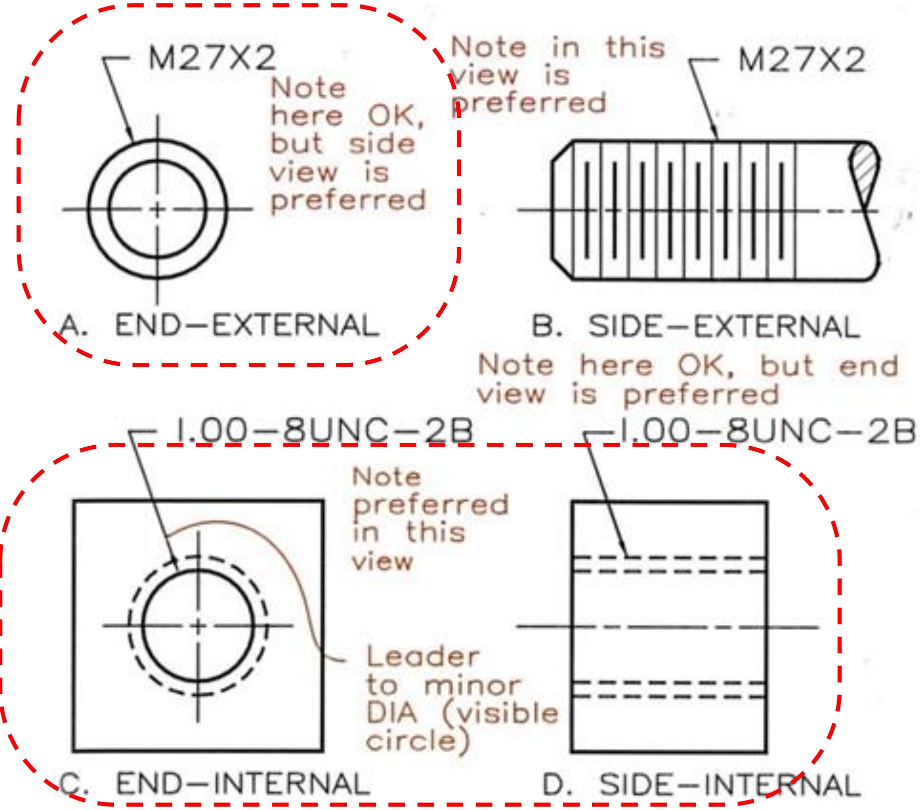
	Top View	
Left View	Front View	Right View
	Bottom View	

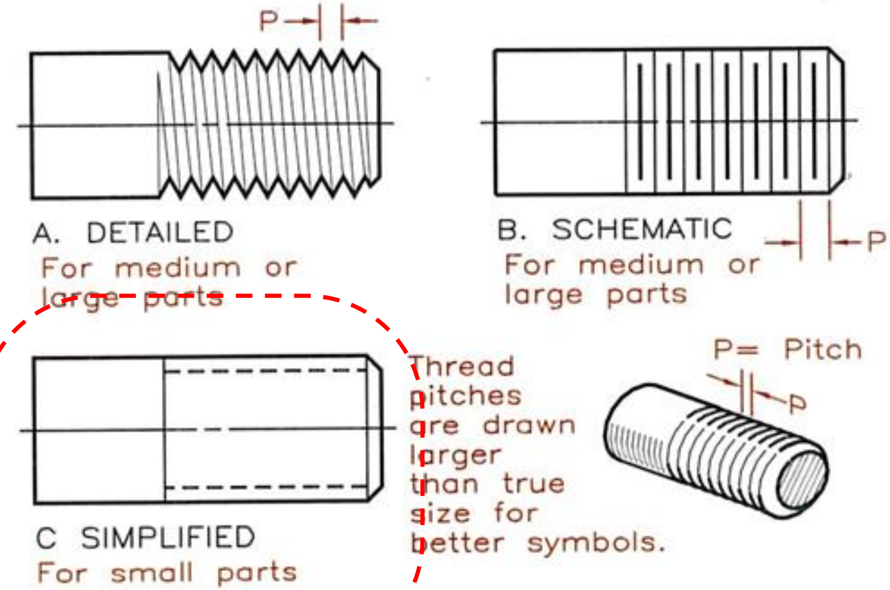


Bottom



Orthographic drawing: threads



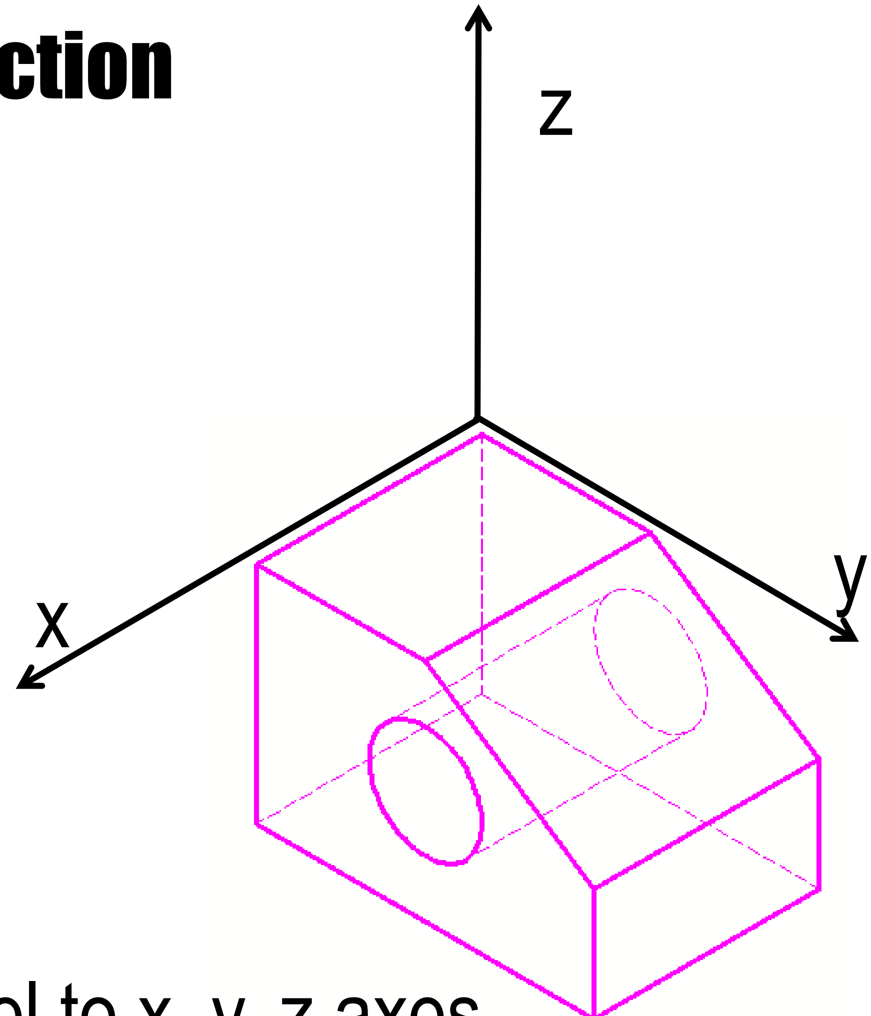


[Earle, 1992]

Recommended styles

3. Isometric (3D) Projection

- Coordinate system



- Drawing conventions

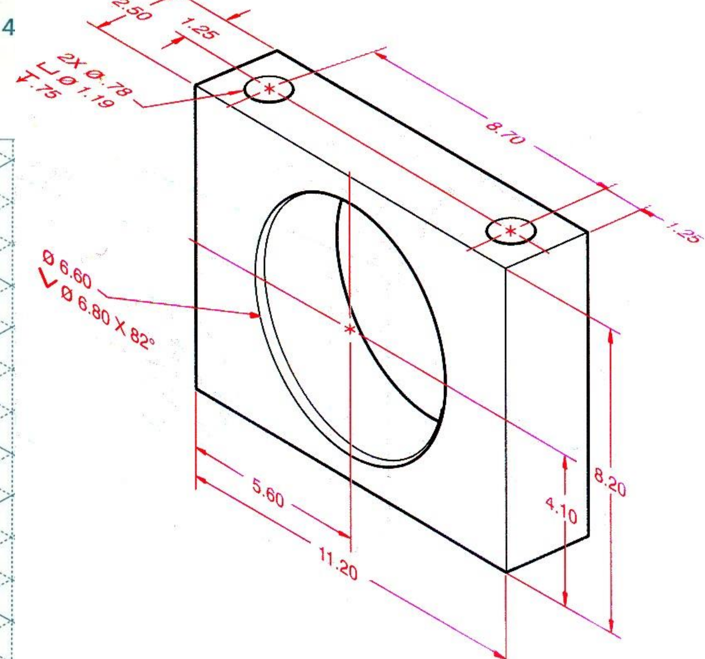
Line: All lines parallel to x, y, z axes

Circle: - Draw a circumscribing square

- Blend in with an ellipse

Practice

K•E ISOMETRIC • 4 X 4 TO THE INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 4

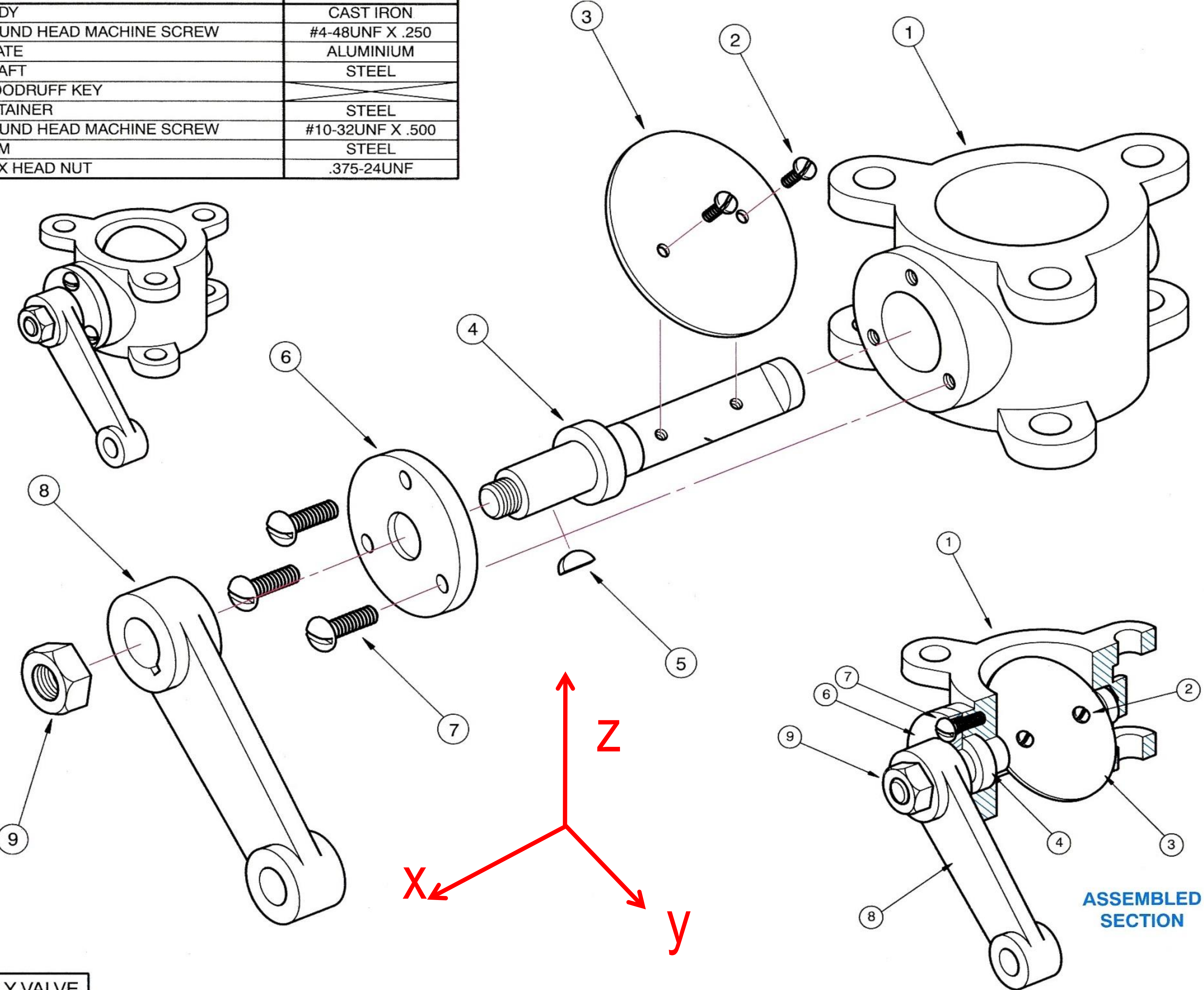


Line: All lines parallel to x, y, z axes

Circle: - Draw a circumscribing square

- Blend in with an ellipse

1	1	BODY	CAST IRON
2	2	ROUND HEAD MACHINE SCREW	#4-48UNF X .250
3	1	PLATE	ALUMINIUM
4	1	SHAFT	STEEL
5	1	WOODRUFF KEY	
6	1	RETAINER	STEEL
7	3	ROUND HEAD MACHINE SCREW	#10-32UNF X .500
8	1	ARM	STEEL
9	1	HEX HEAD NUT	.375-24UNF

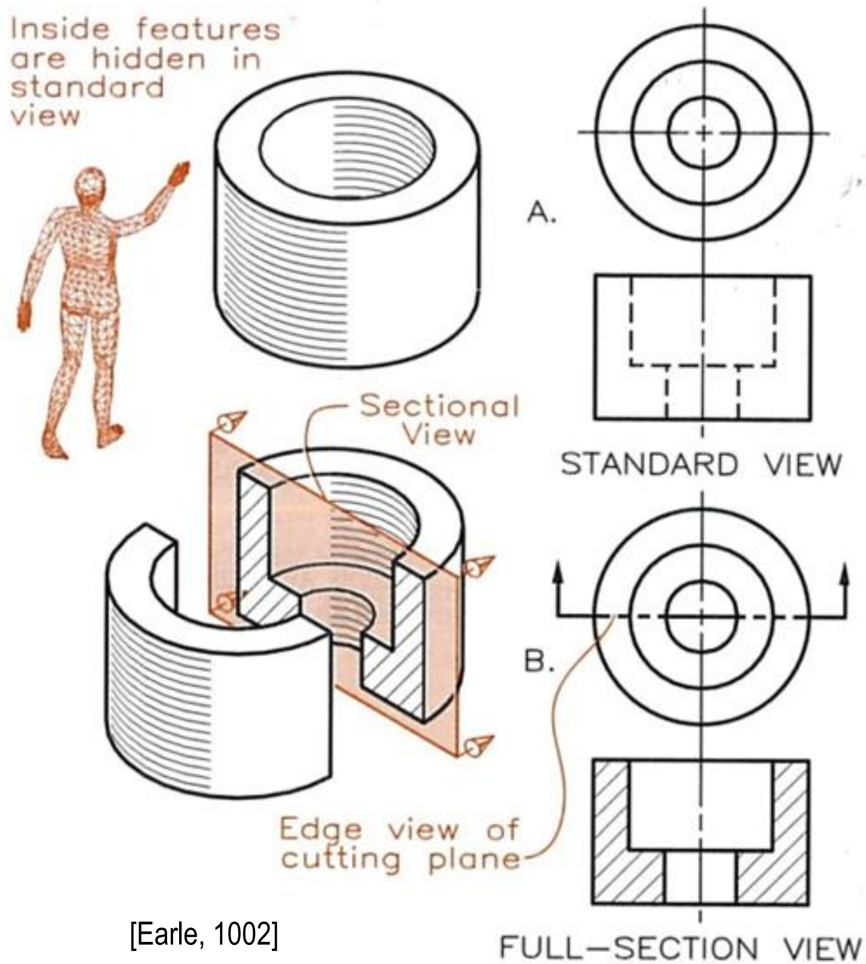


BUTTERFLY VALVE

4. Sectioning

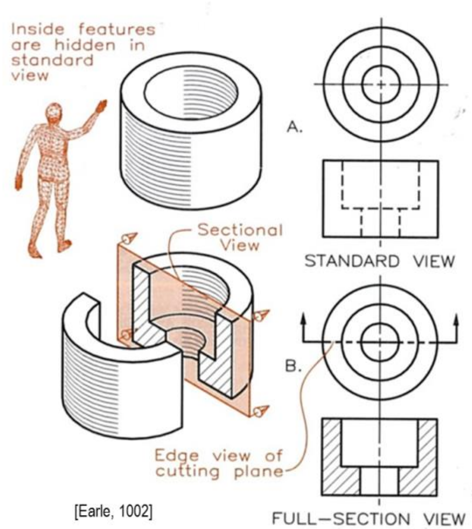
- Why: view internal features or profile

- Techniques
  - Complete
  - Partial
  - Zig-zag
  - Rotate



[Earle, 1002]

4. Sectioning

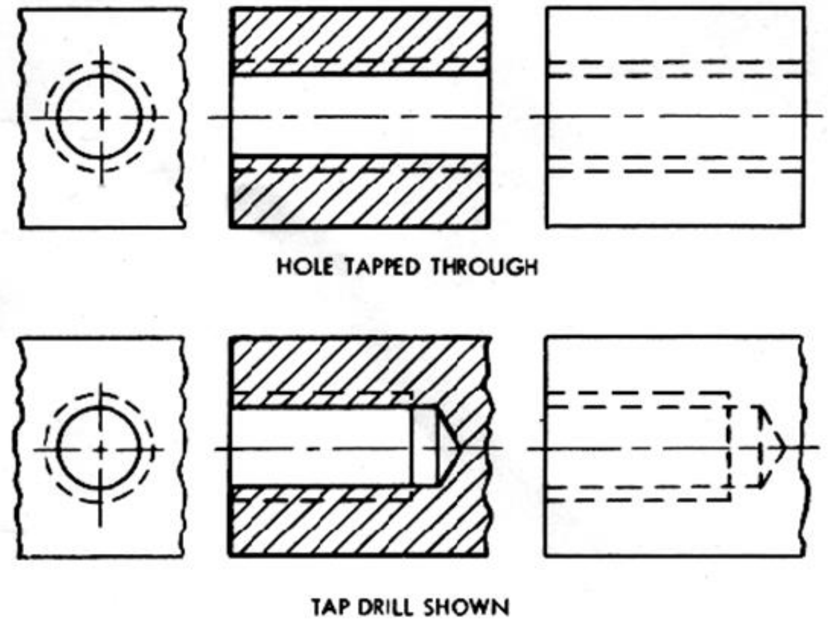


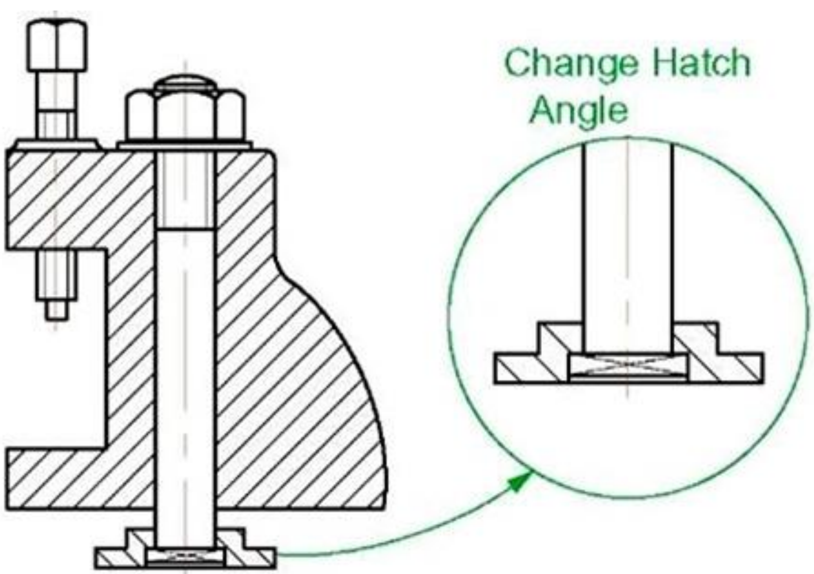
[Earle, 1002]

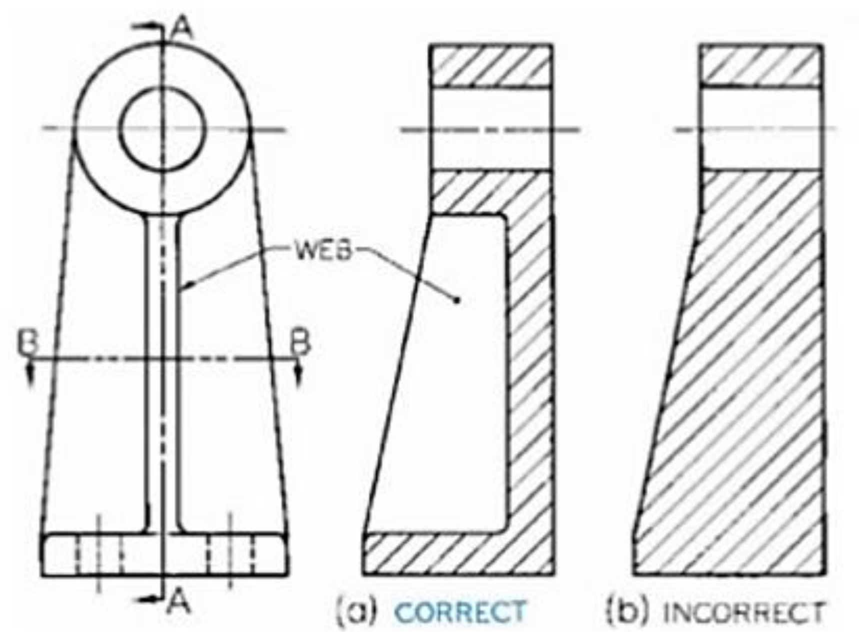
1. Choose a view for sectioning
2. Mark the cutting plane with bold lines
3. Draw arrows to indicate viewing direction
4. Draw the sectioned view, and name it (optional)
5. Add cross-hatching pattern to cut areas

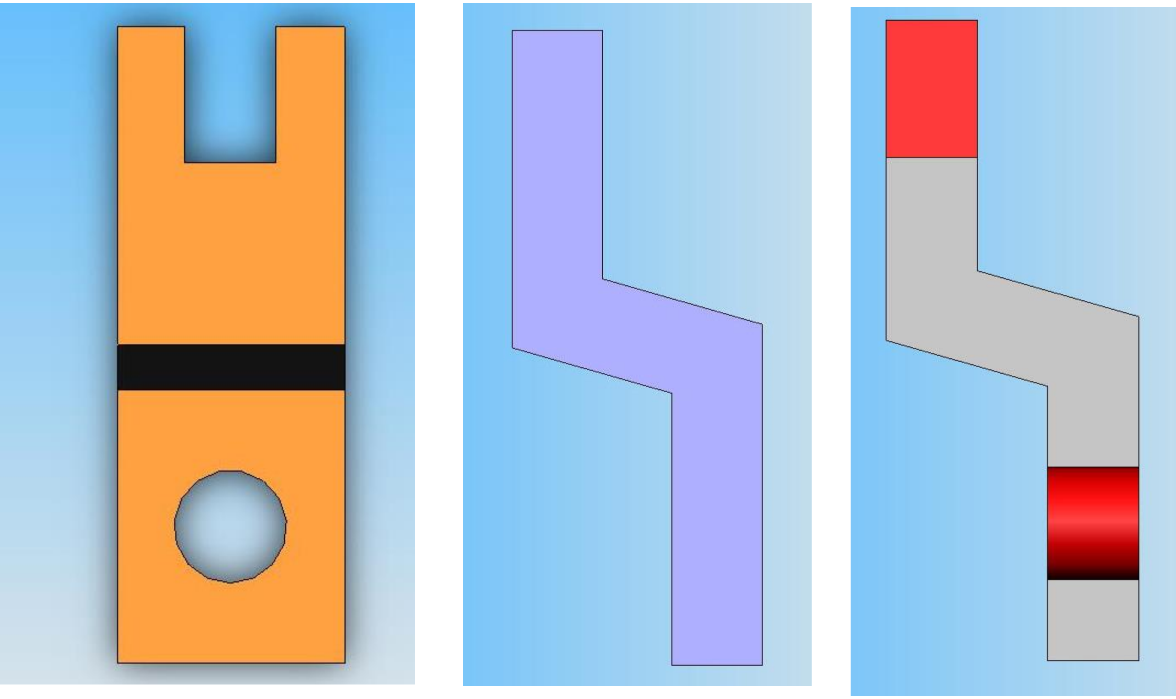
Sectioning rules:

- Hatching lines stop at solid lines
- Use different hatch angles for different parts
- Avoid sectioning a solid part





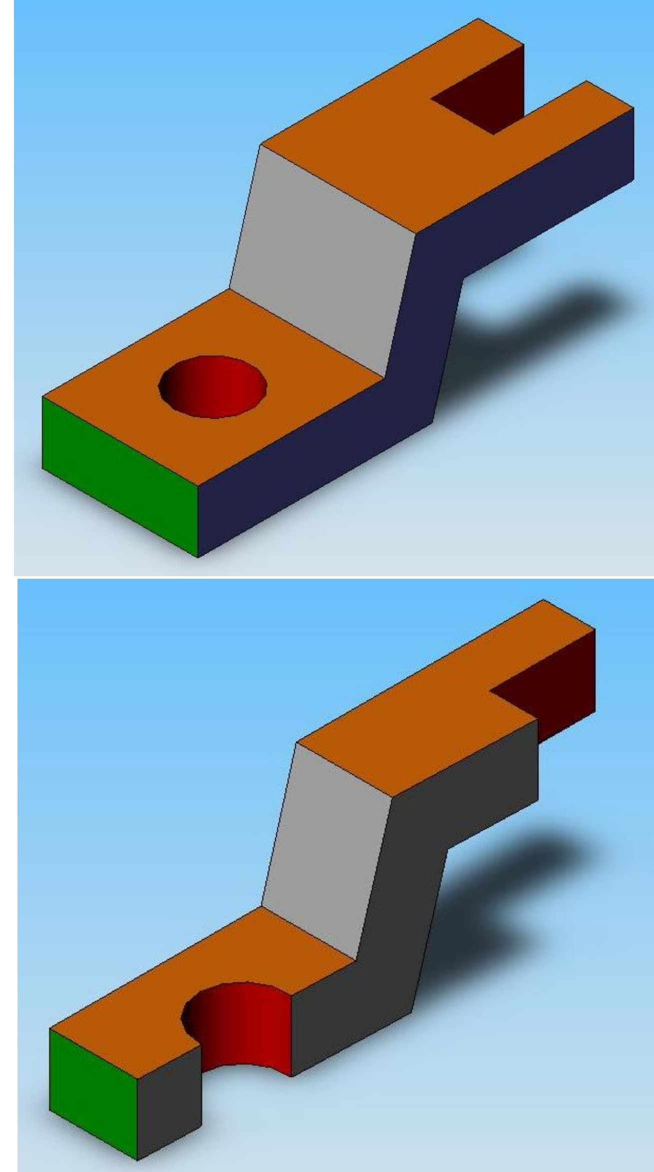




Front

Right

Section



1. Choose a view for sectioning
2. Mark the cutting plane with bold lines
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4. Draw the sectioned view, and name it (optional)
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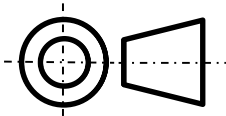
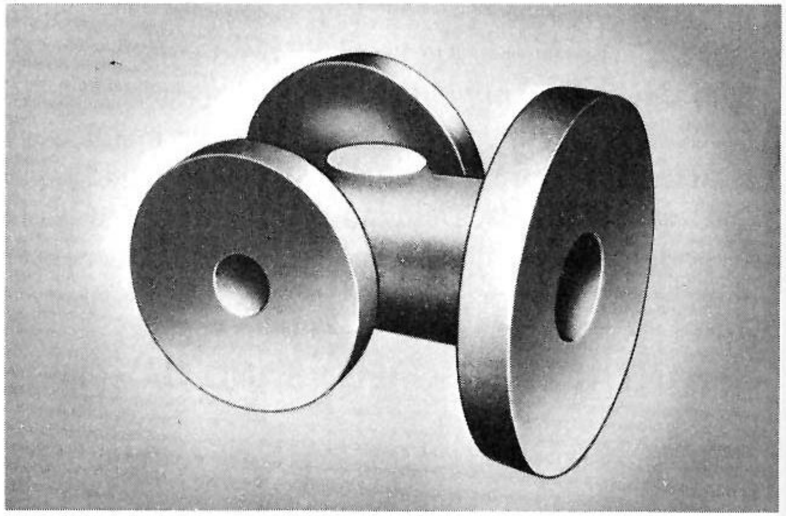
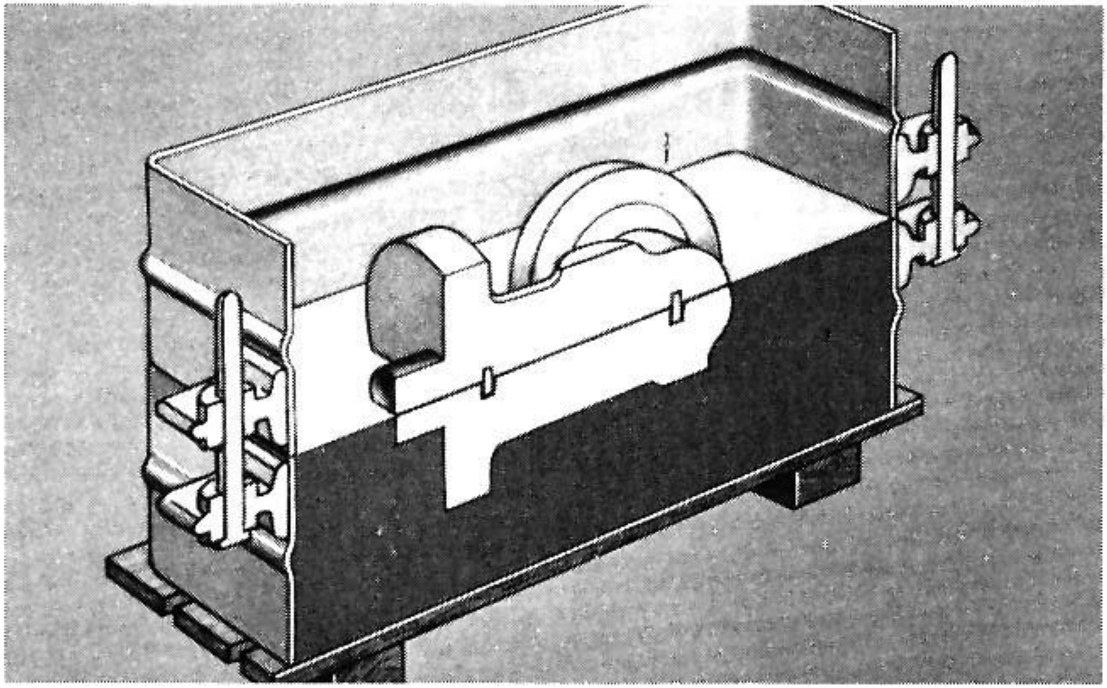
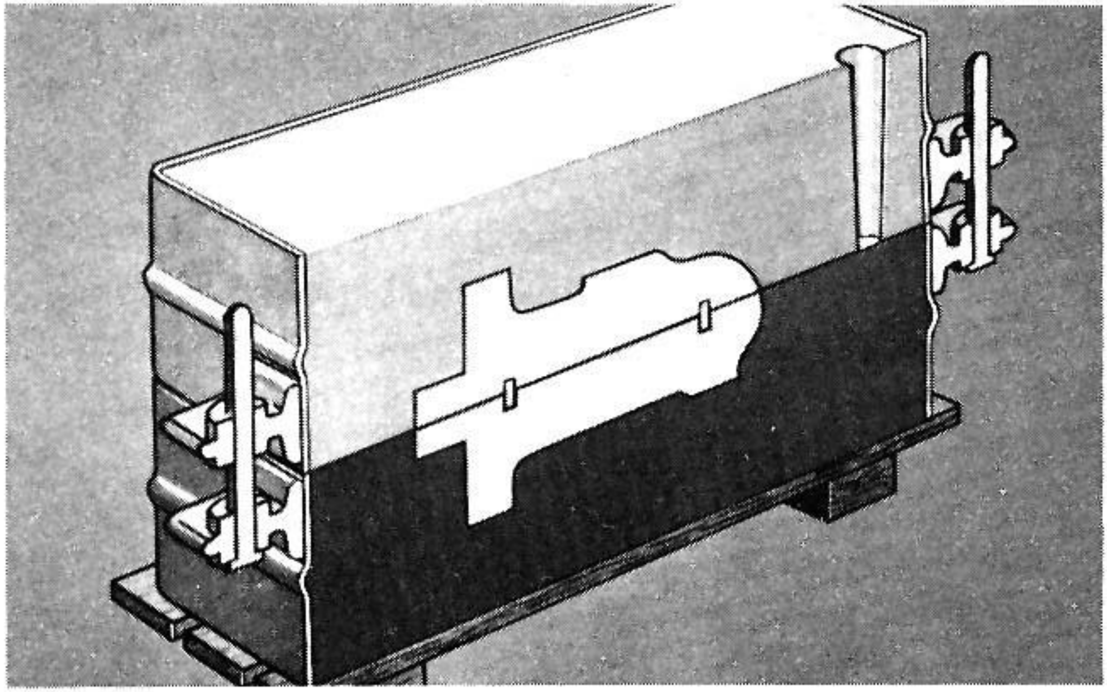


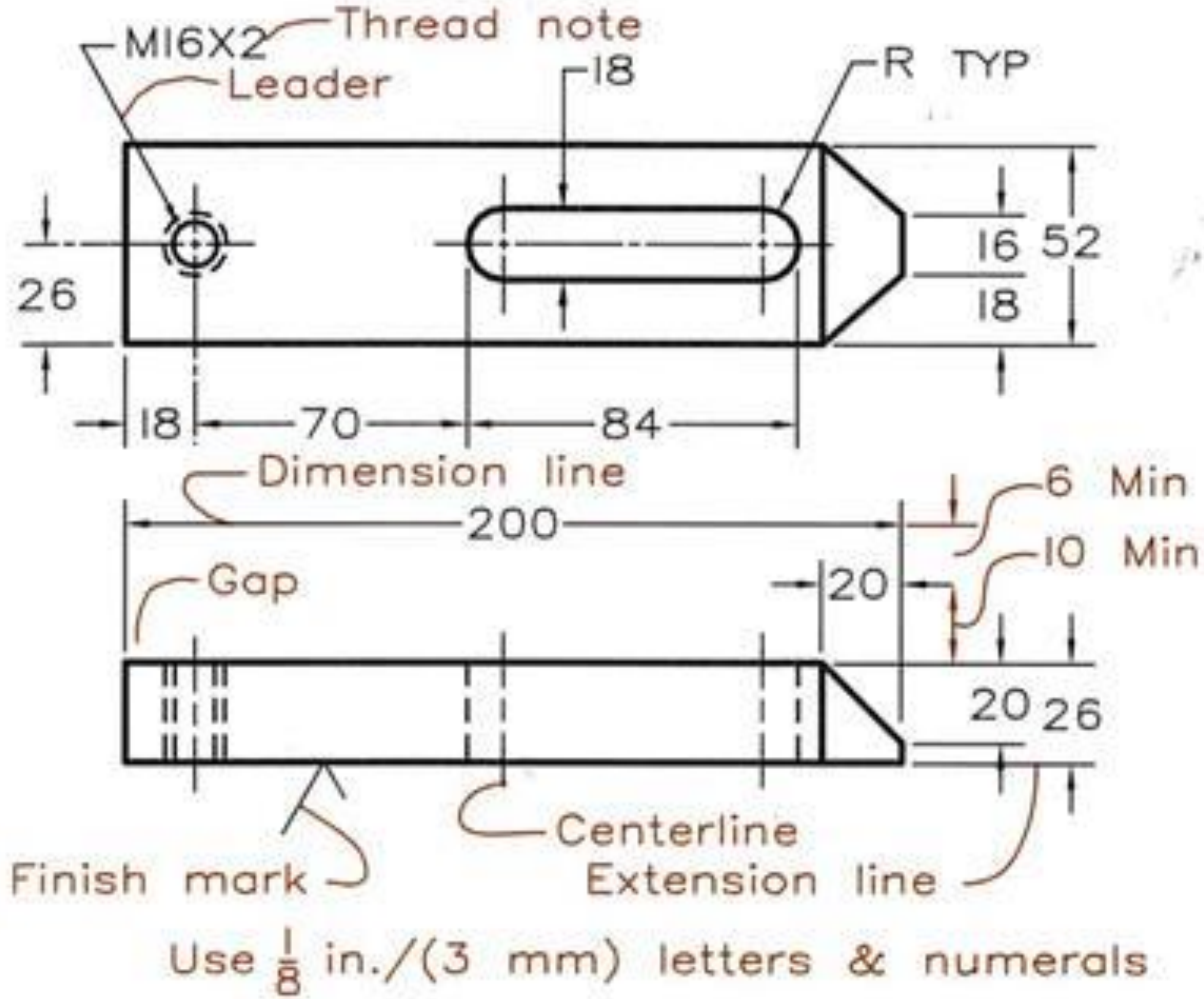




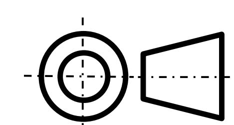


3-4

5. Dimensioning: rules

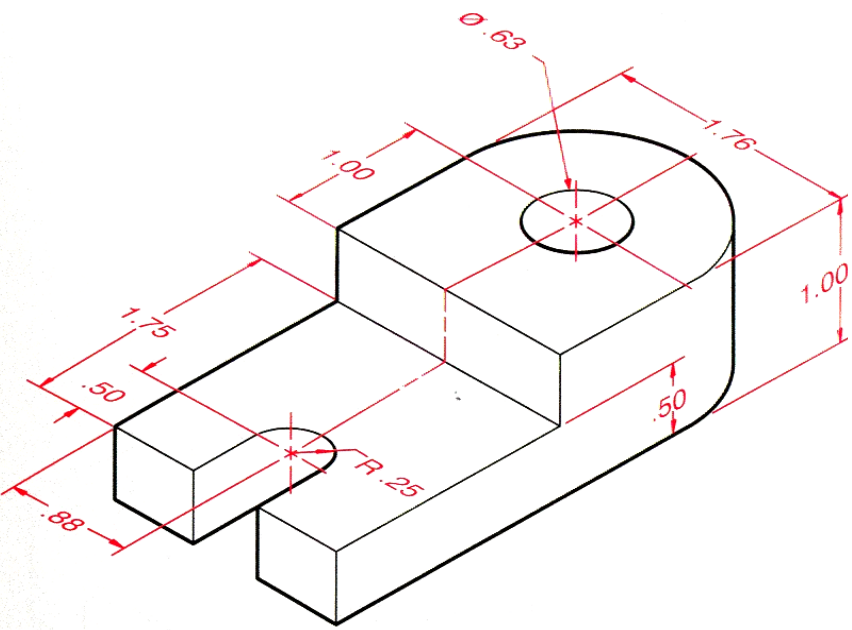


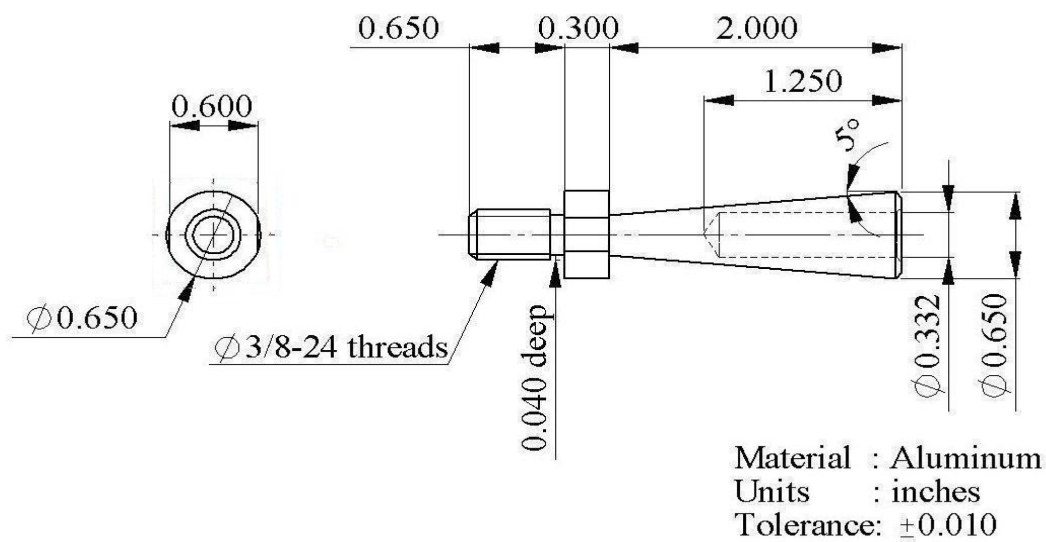
Material: 1020 steel
Unit: mm



5. Dimensioning: rules

- Specify unit.
- Use guideline to extend feature, leave a gap to the main drawing.
- Write dimension between arrows or tic marks.
- All lines must be parallel to x, y, z axes or part feature.
- Label diameter with "Ø" and radius with “R"

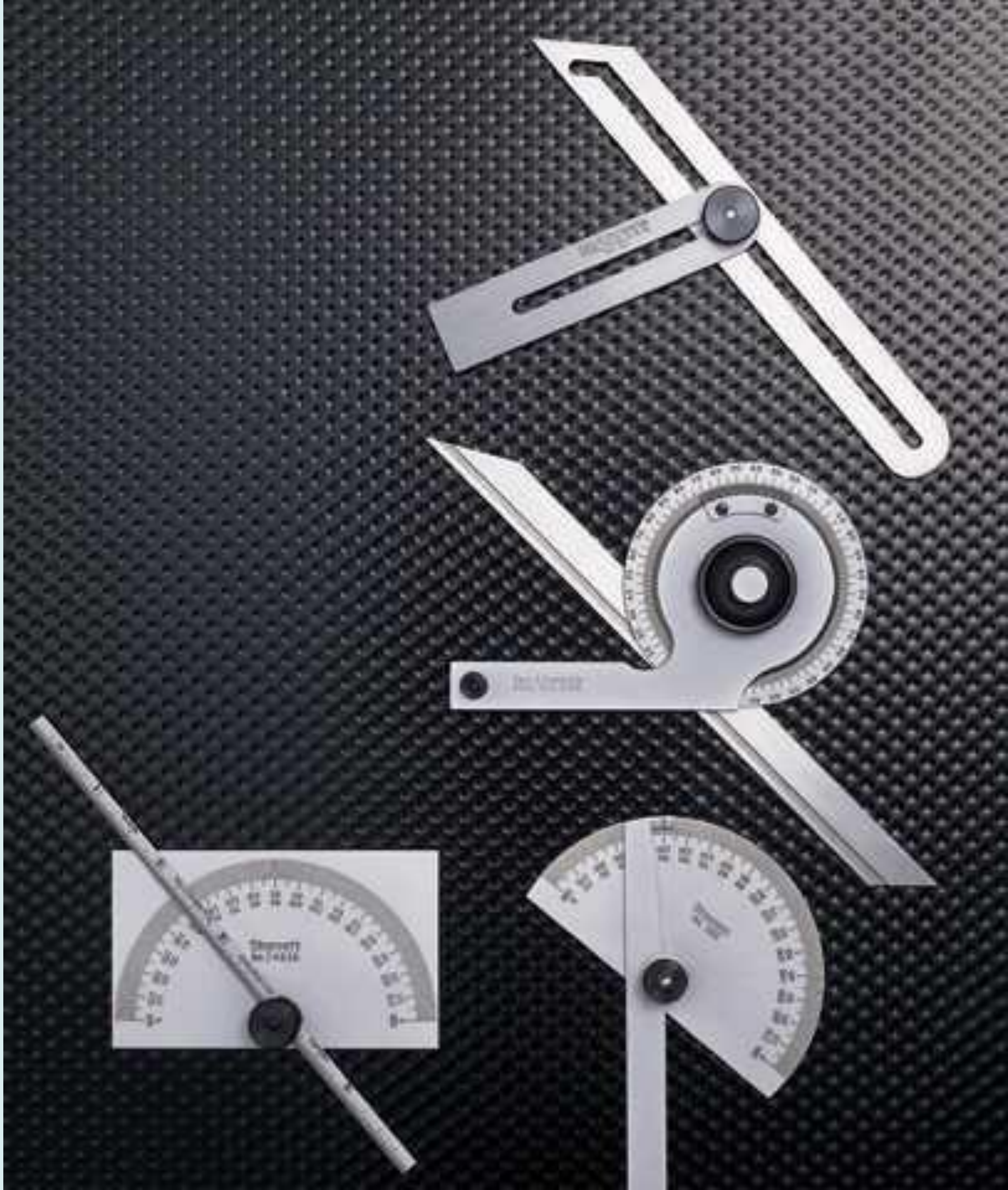




3. Effect of manufacturing processes

Process	Tolerance (in)	Finish Ra (μin)
Sand casting	± 0.0500	500-1000
…		
Turning	± 0.0020	15-250
…		
Grinding	± 0.0003	5-75

Contact type: protractor



Source:
http://www.starrett.com/

Contact type: caliper

Dial caliper

Vernier caliper

Source: http://www.starrett.com/

Contact type: height gage

Source: http://www.starrett.com/

Contact type: indicator

Source: http://www.starrett.com/

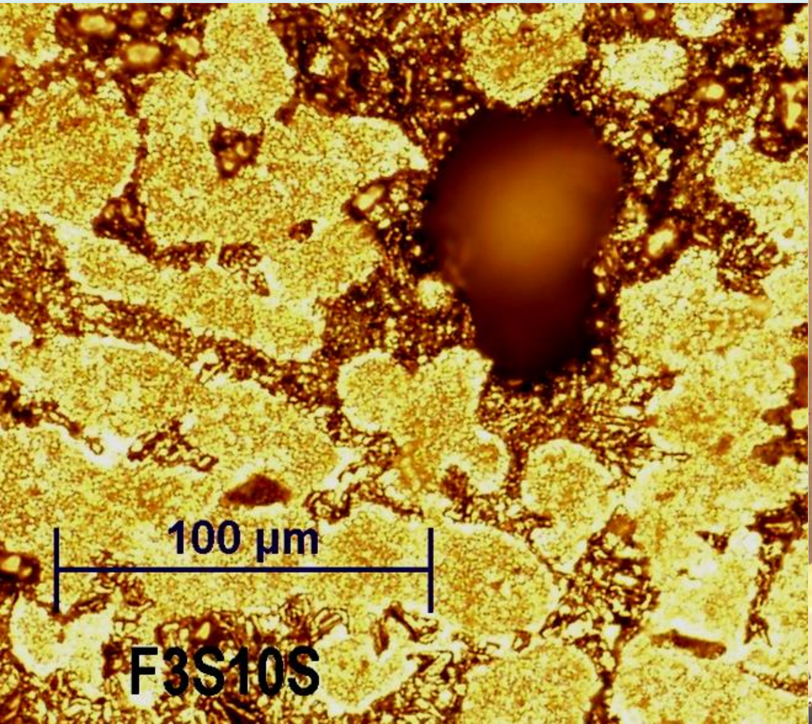
Contact type: micrometer

Source: http://www.starrett.com/

Non-contact type: optical comparator (profile projector)

Source: http://mitutoyo.com

Non-contact type: measuring microscope



Non-contact type: profile laser scanner

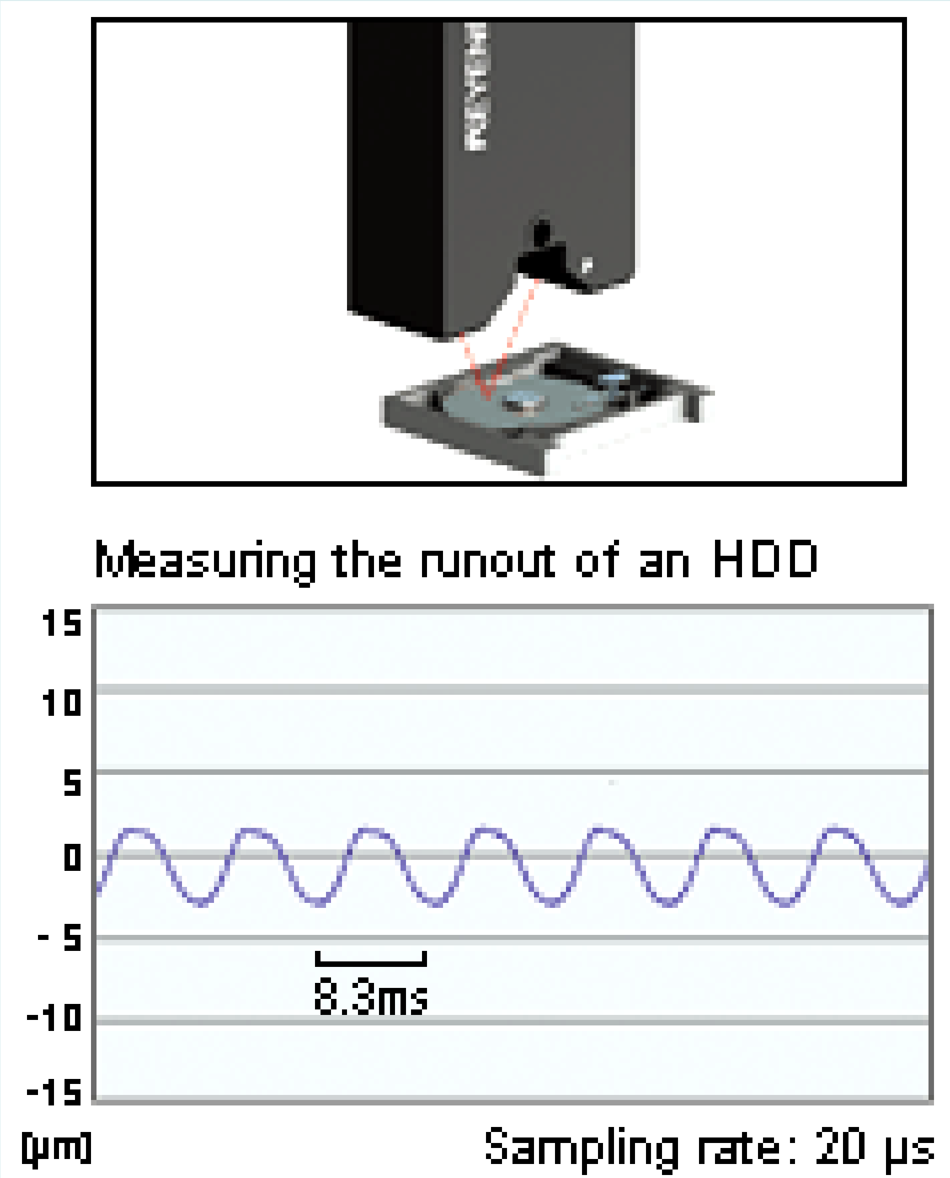
Contact type: coordinate measuring machine (CMM)

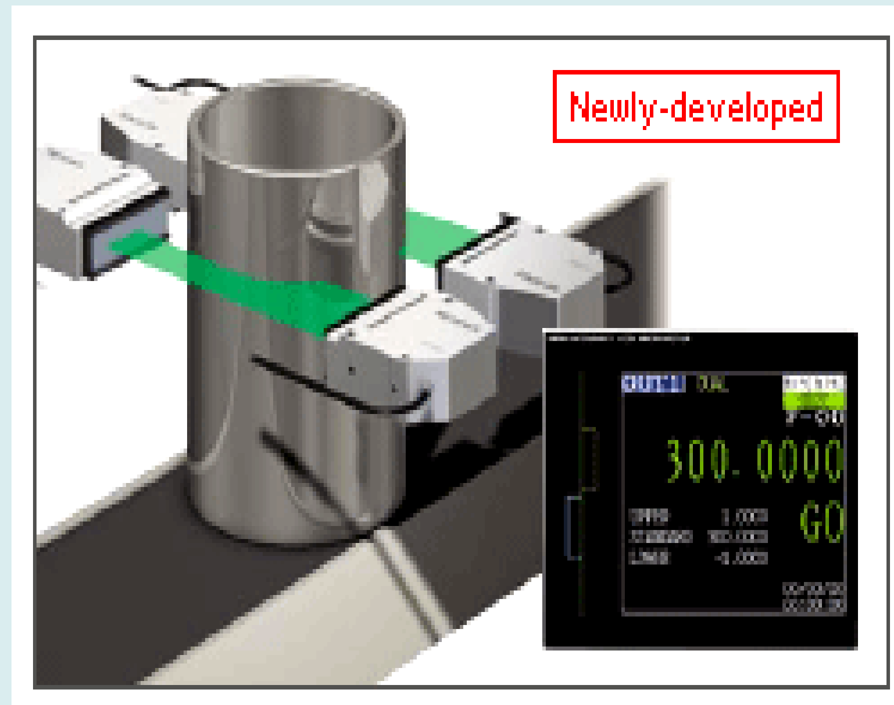
http://www.mitutoyo.com

Contact type: form measurement

Source: http://www.taylor-hobson.com/

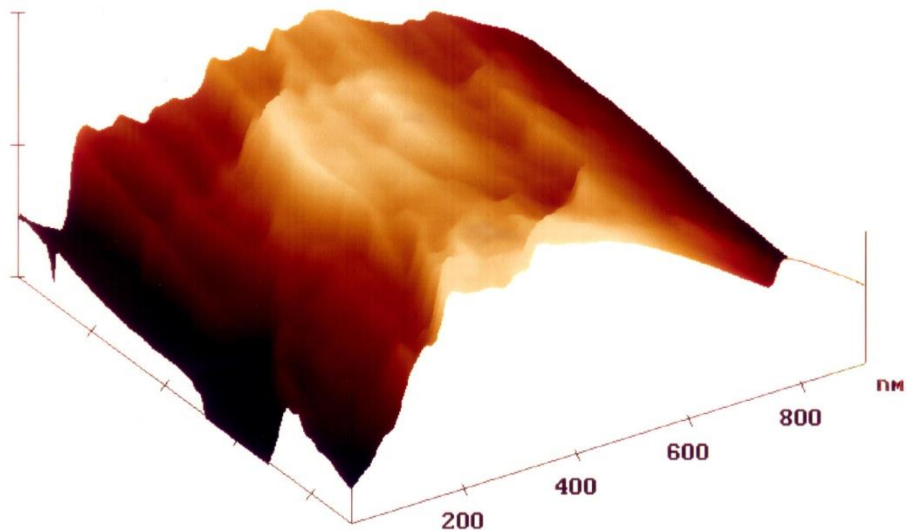
Non-contact type: laser sensor

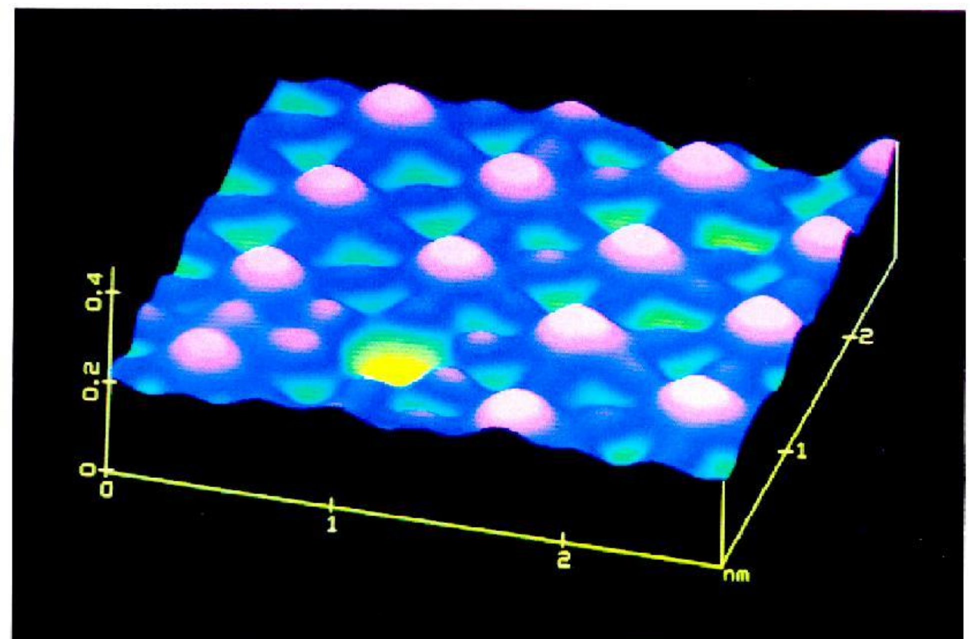




Source: www.keyence.com

Semi-contact type: Scanning probe microscopy





Iodine atoms in a 3x3 array adsorbed on platinum. Data from Dr. Bruce Schardt, Purdue University.

Contact type: surface profile measurement (profilometer)

Source: http://www.mitutoyo.com/

Equipment

Contact type: Profilometer

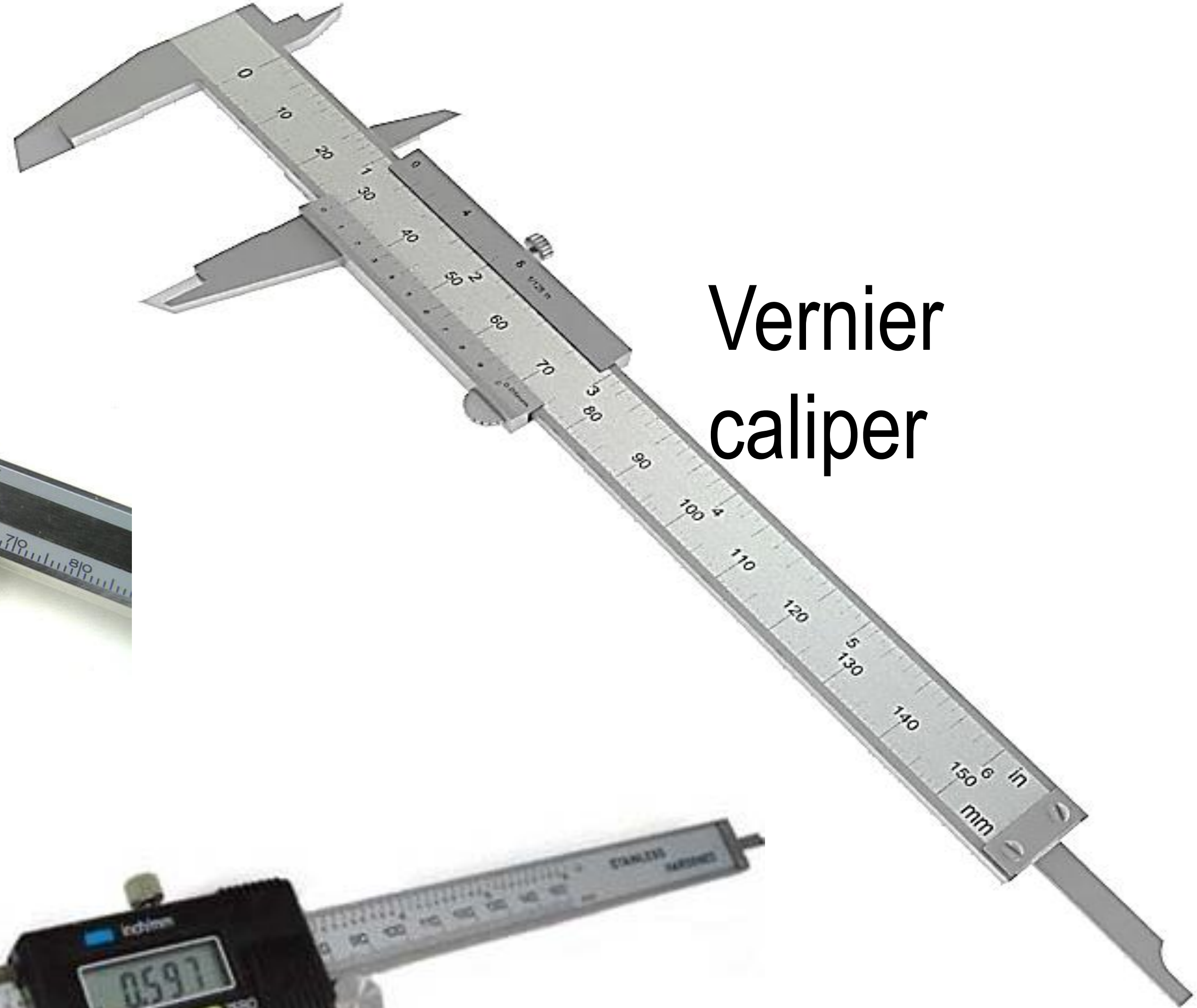
[www.processinstruments.ca]

Equipment

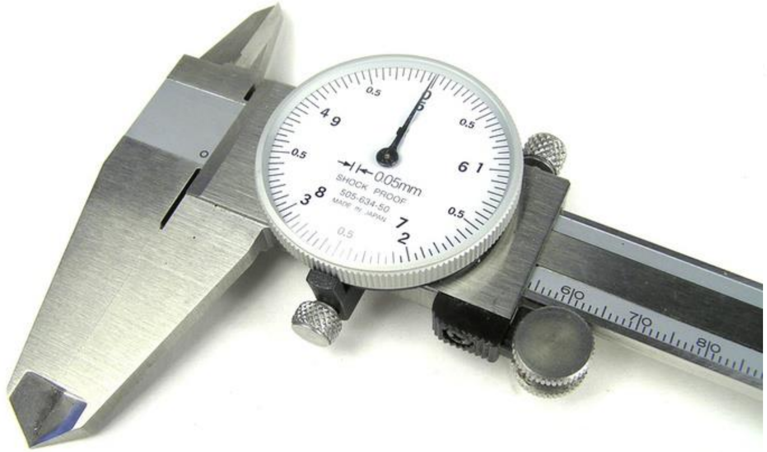
Noncontact type: interferometer

Source:
http://www.zygo.com/?/met/profilers/newview7000/

6. Caliper

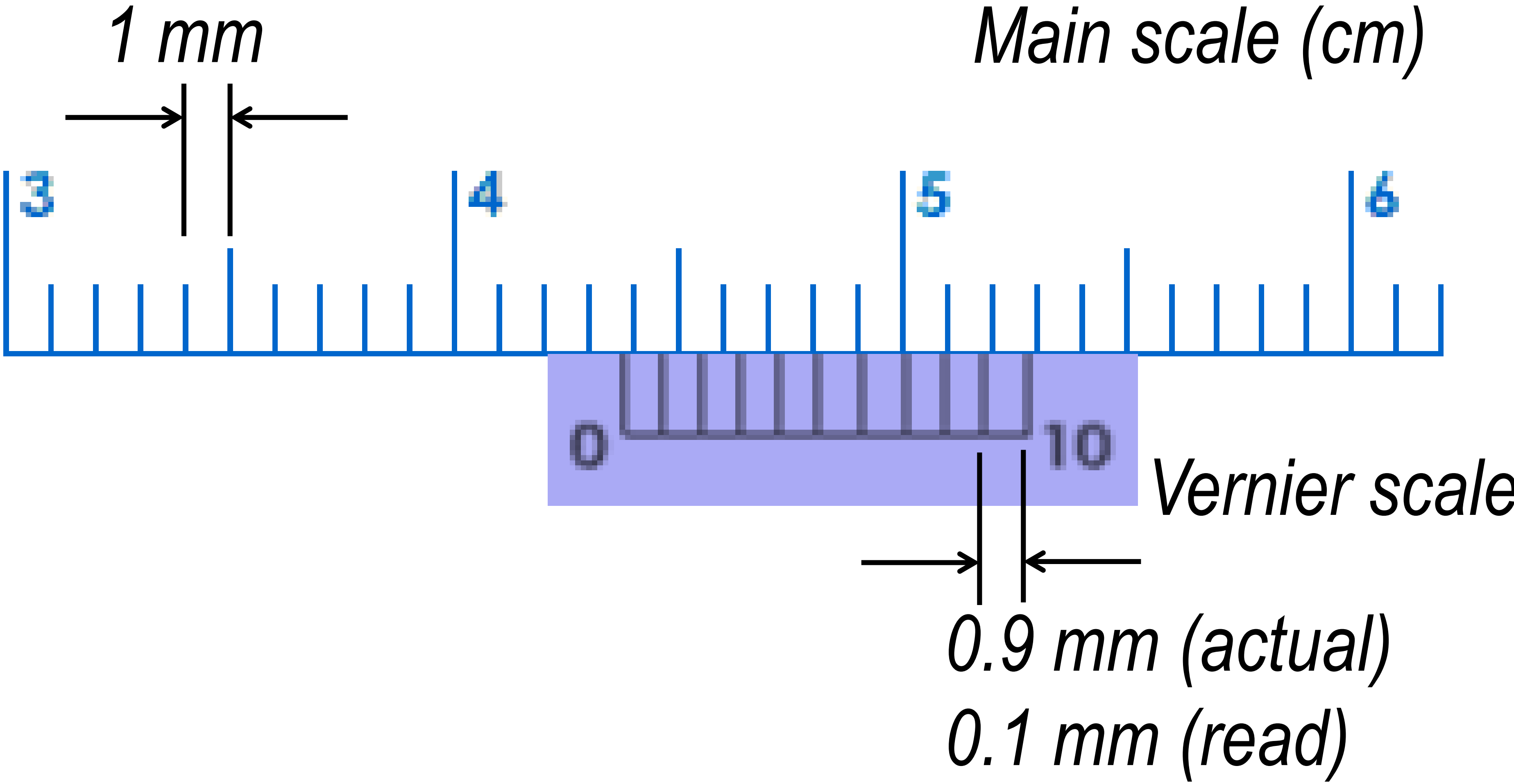


Vernier caliper

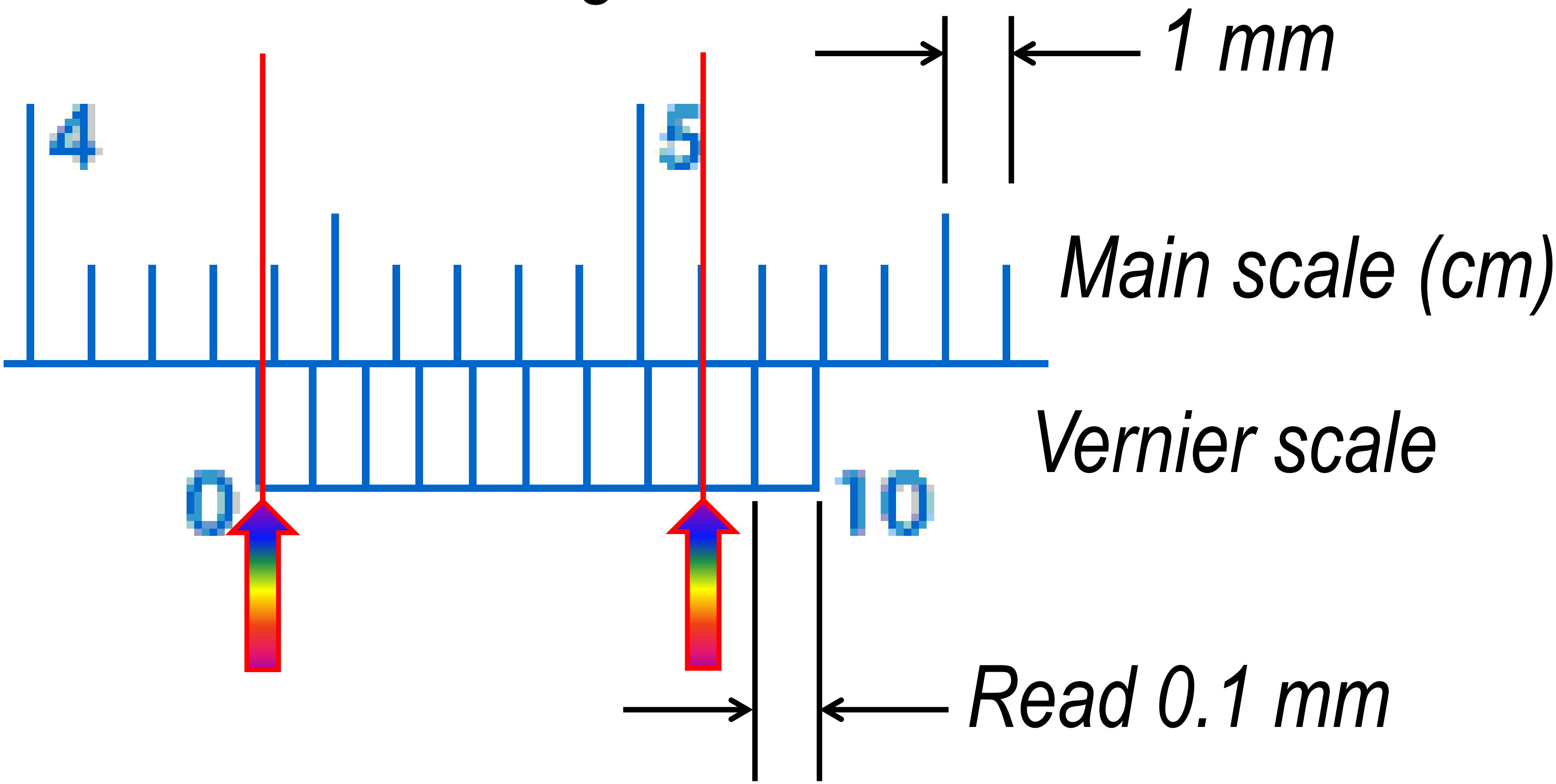


Dial caliper

Digital caliper


1 mm
Main scale (cm)
3
4
5
6
0
10
Vernier scale
0.9 mm (actual)
0.1 mm (read)

Vernier scale reading

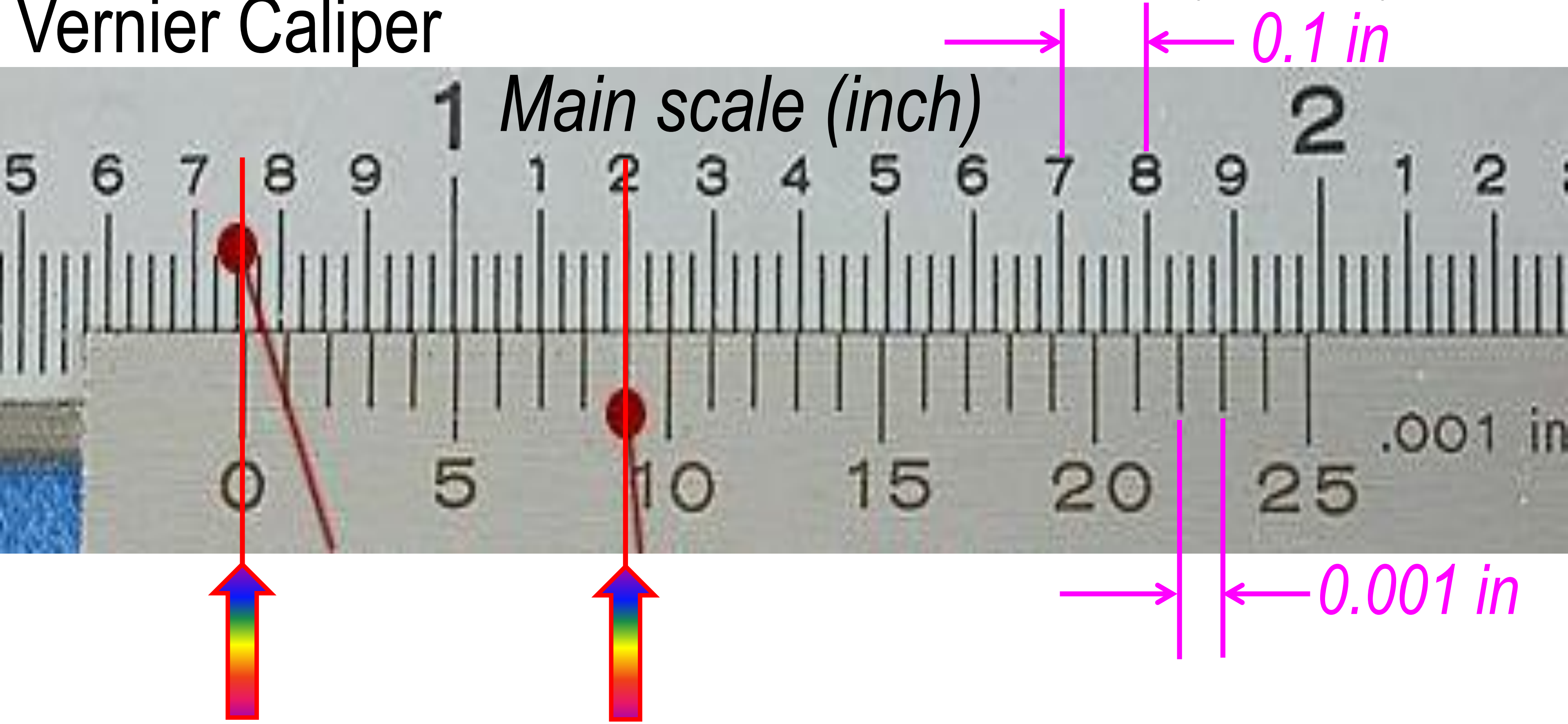


43.0 + 8(0.1) = 43.8 mm

Reading: ____________ mm (1 decimal digit)

Vernier Caliper

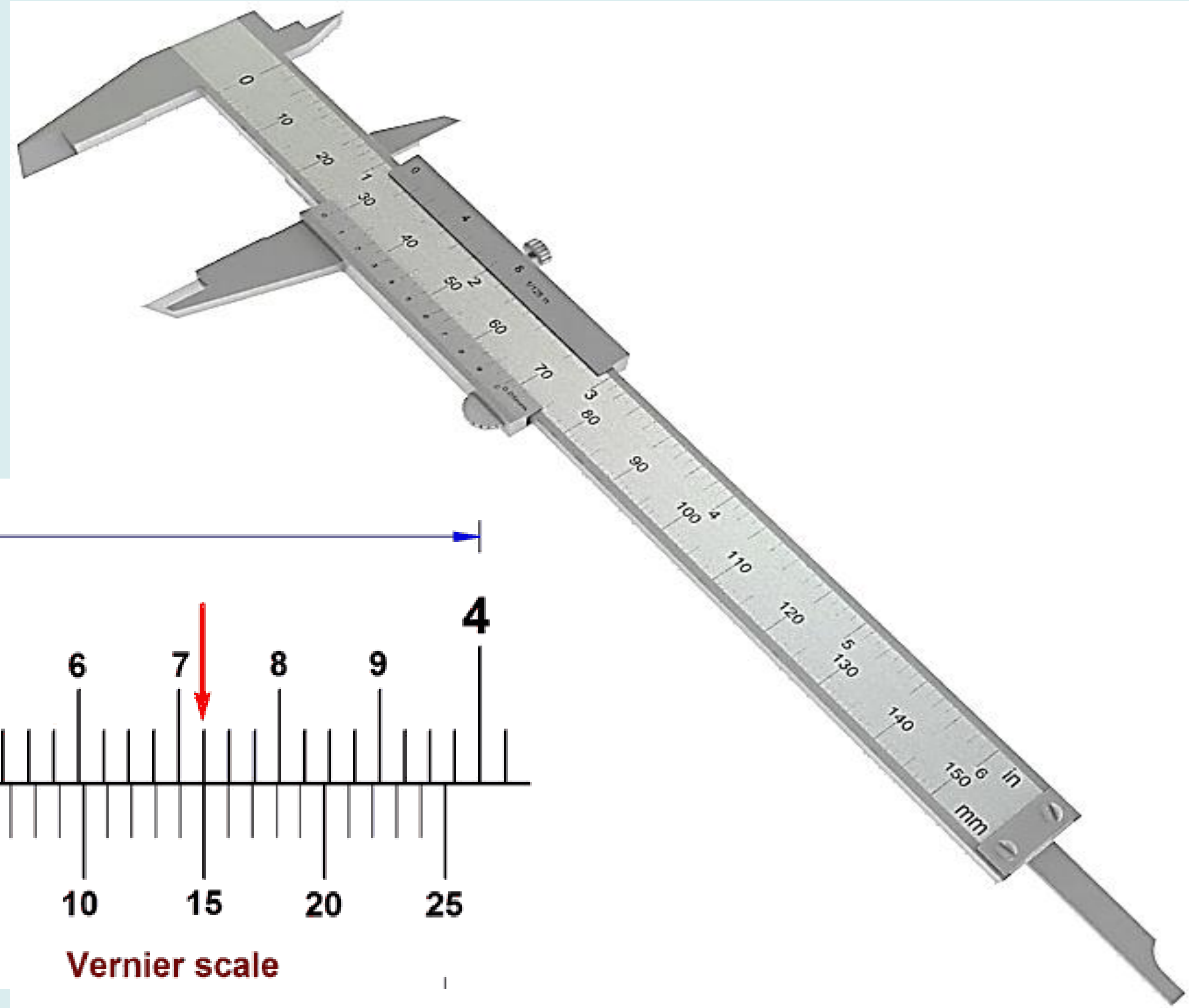
http://paulbudzik.com/tools-techniques/Measuring%20Tools/measuring-tools.html

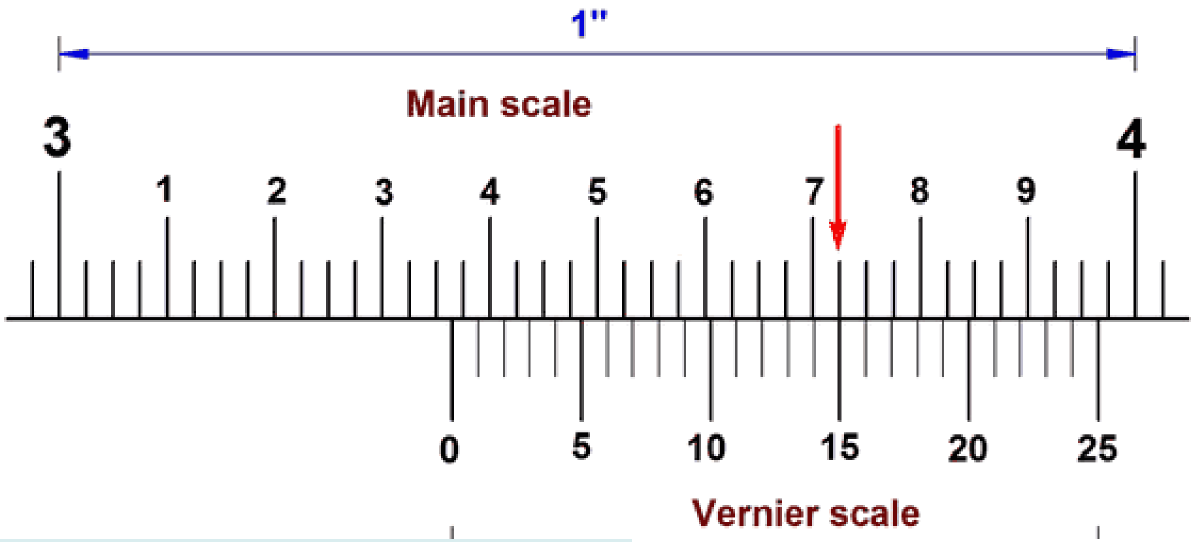


0.700 + 2(0.025) + 9(0.001) = 0.759 in

Reading: ___________ in (3 decimal digits)

Vernier Caliper



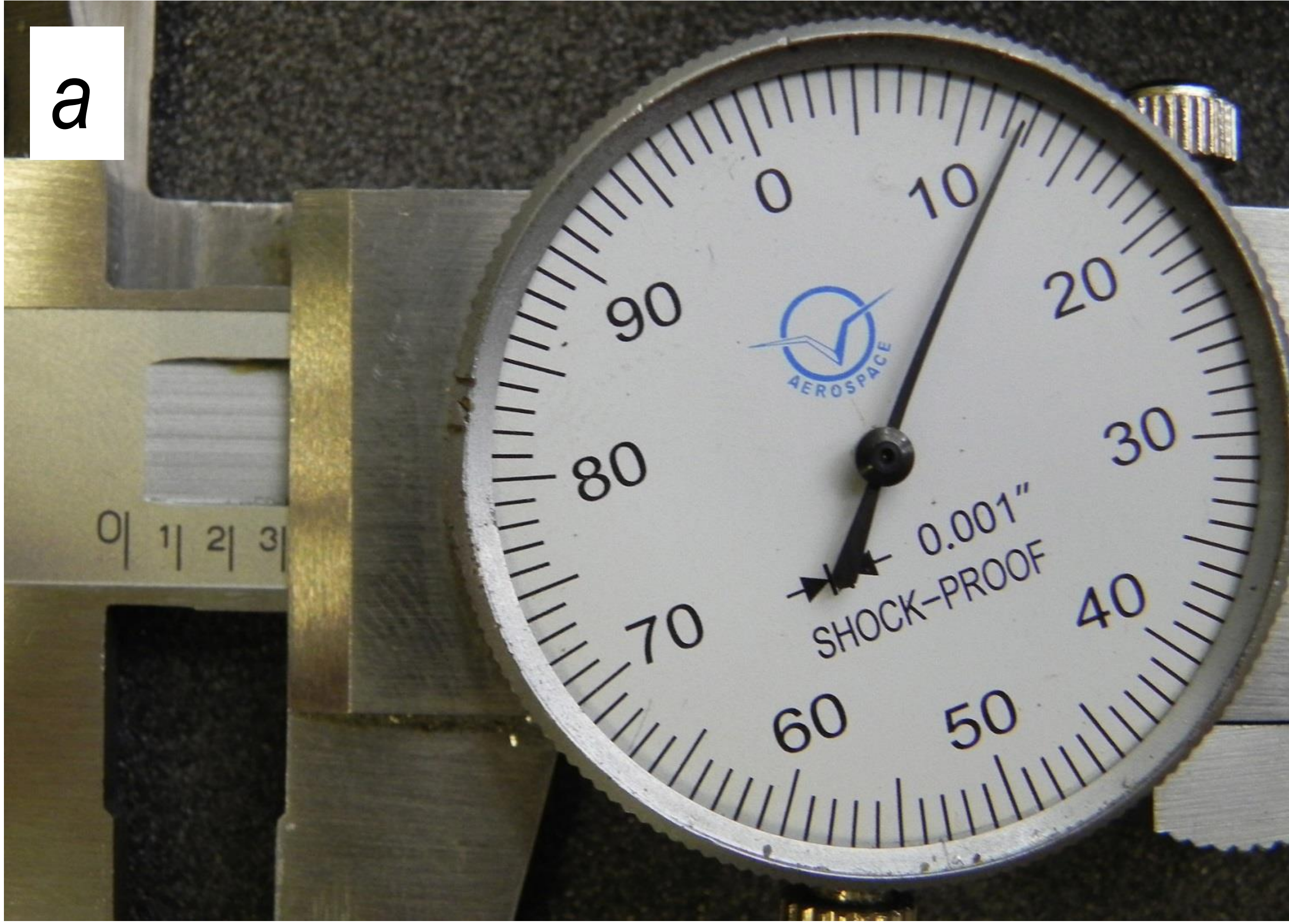


Reading: ____________ in (3 decimal digits)


ONLY THE BRAVE
TIME 2
TWELVE
ONE
TIME 4
3 BAR
TIME 1
TIME 3
DZ7333

Rakuten.com

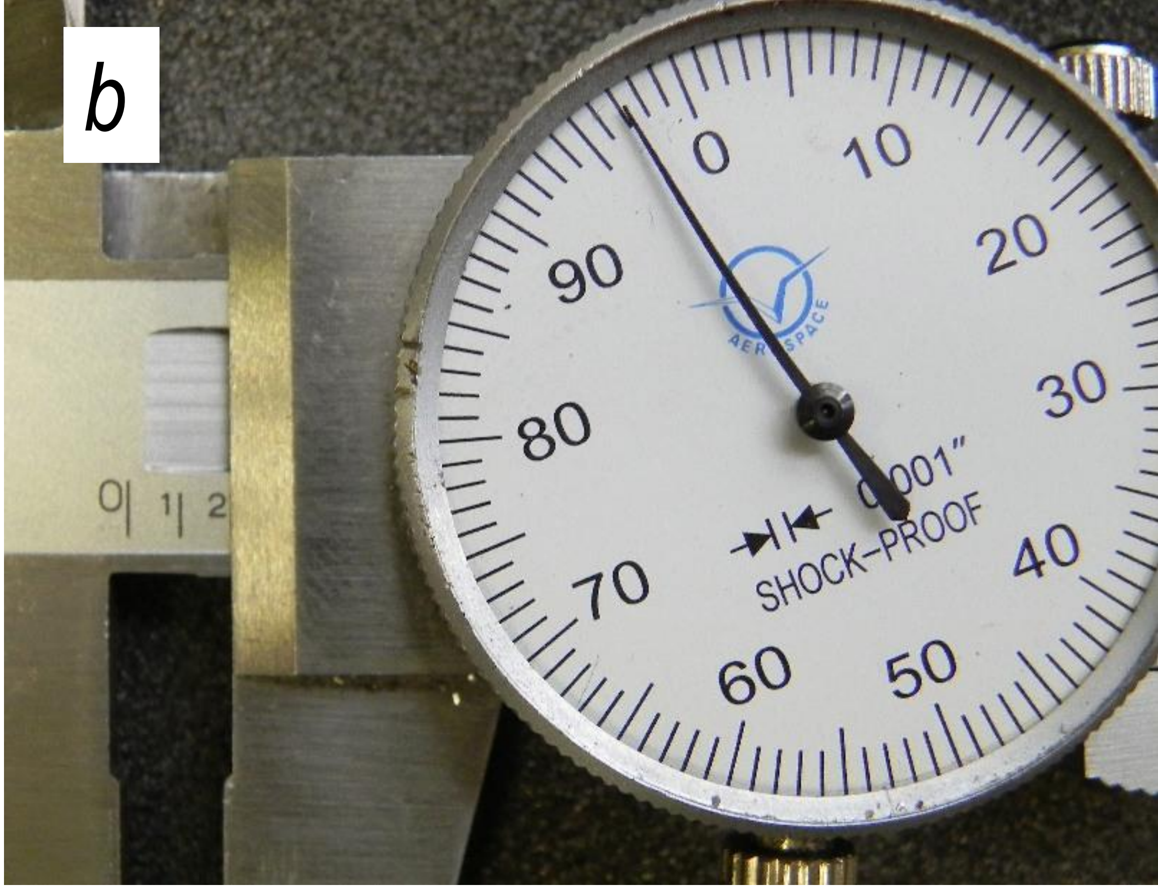
Dial Caliper



3(0.1) + 12(0.001) + 0.0005 = 0.3125 inch

Reading: ____________ inch (4 decimal digits)

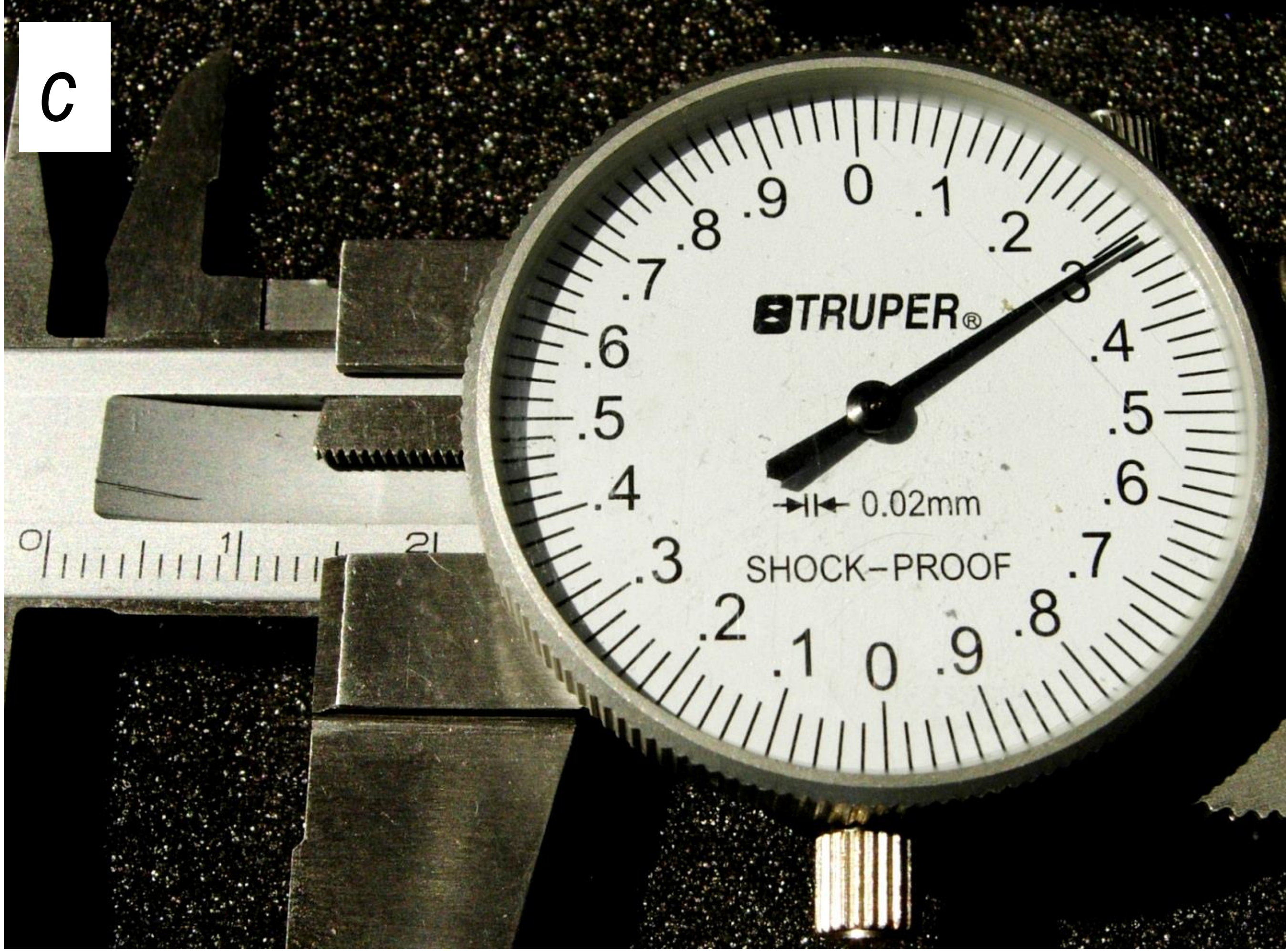
Dial caliper



$1(0.1) + 97(0.001) = 0.1970$ inch

Reading: ____________ inch (4 decimal digits)

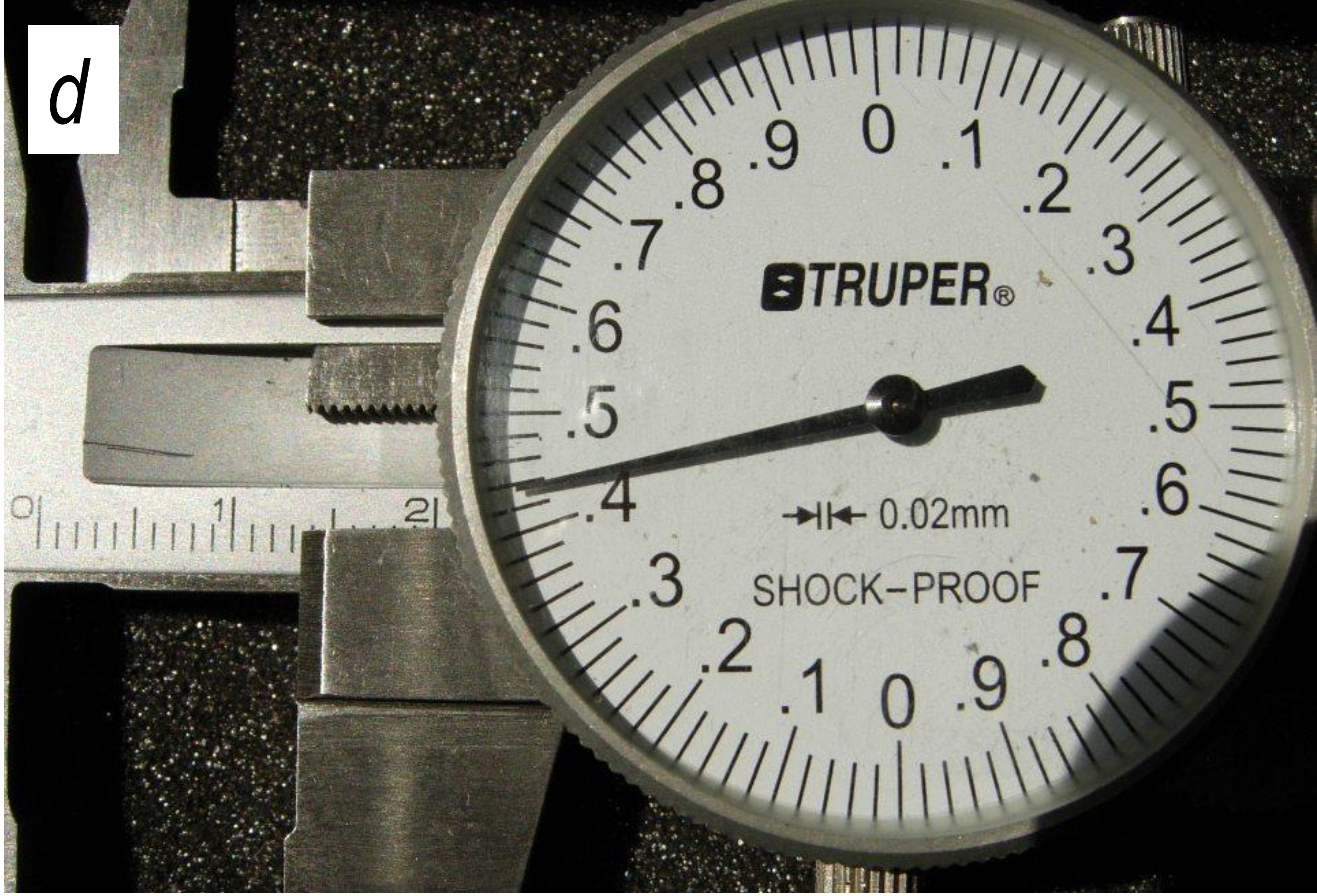
Dial caliper



14 + 0.3 + 0.01 = 14.31 mm

Reading: ____________ mm (2 decimal digits)

Dial caliper



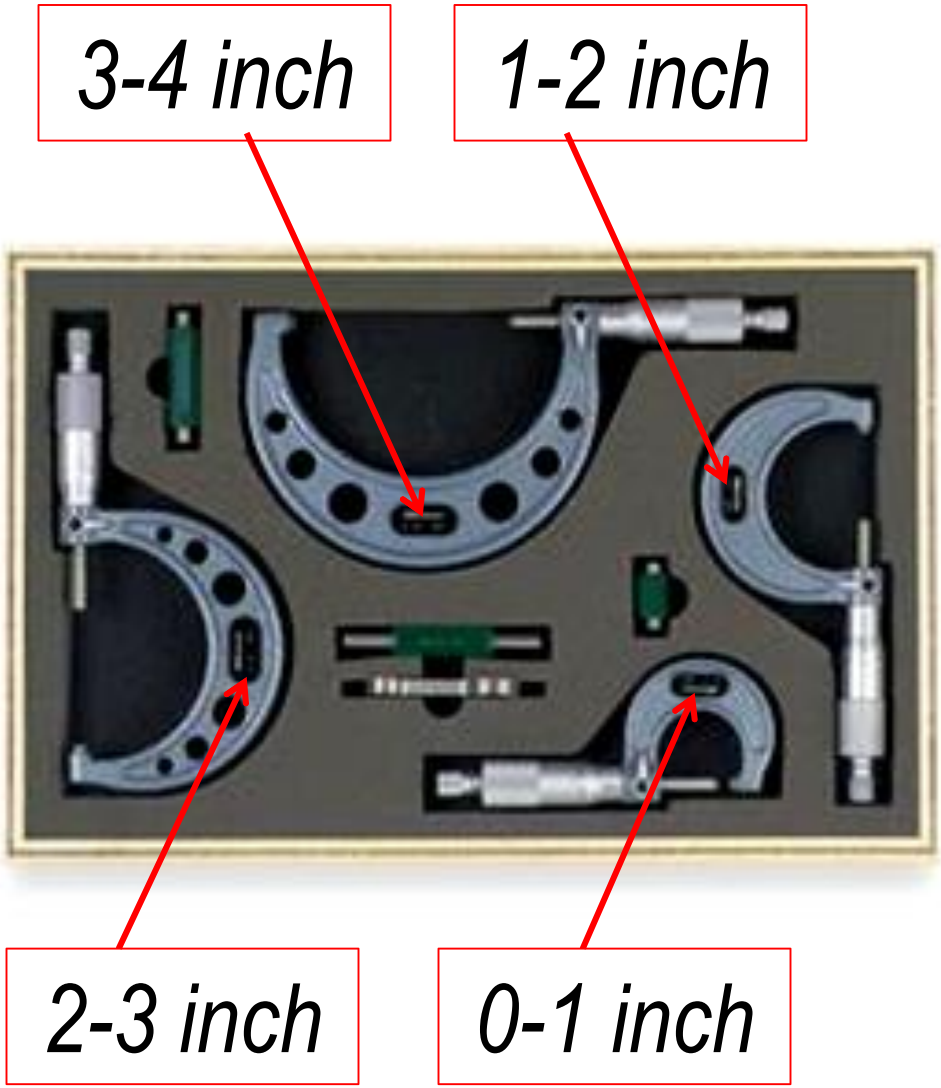
13 + 0.40 + 1(0.02) + 0.01 = 13.43 mm

Reading: ____________ mm (2 decimal digits)

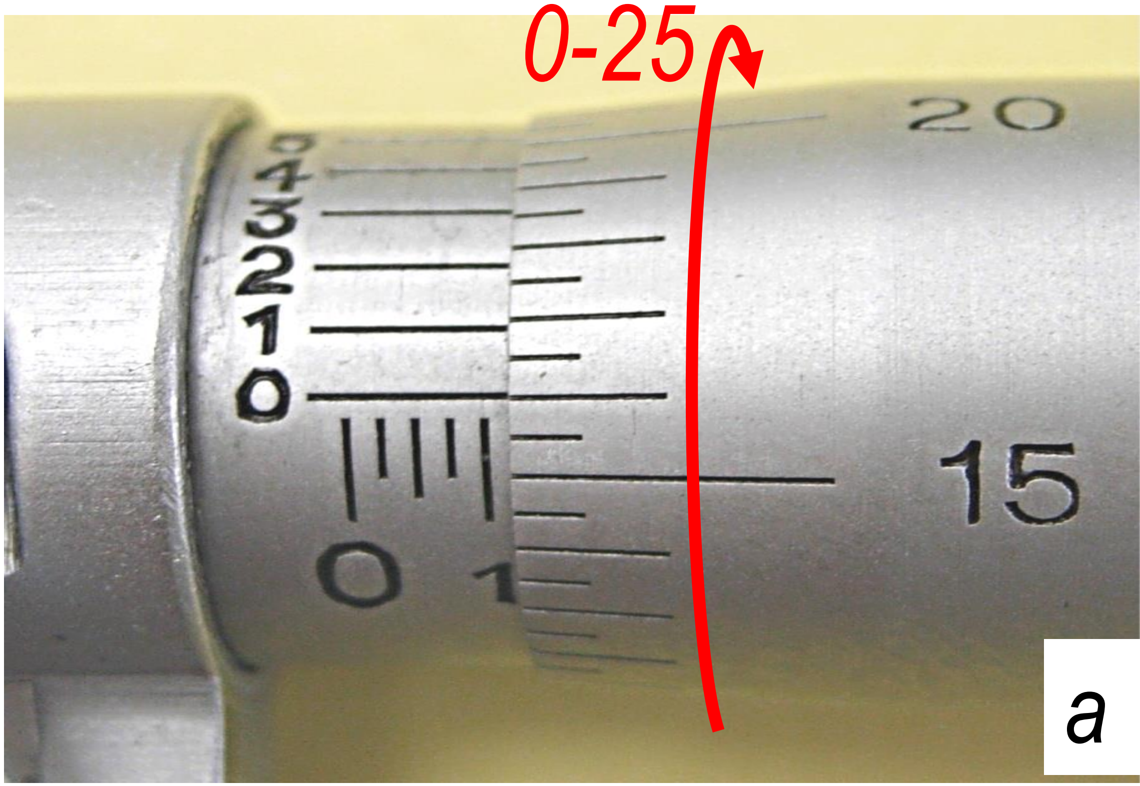
7. Micrometer

www.mitutoyo.com

Micrometer set for different ranges



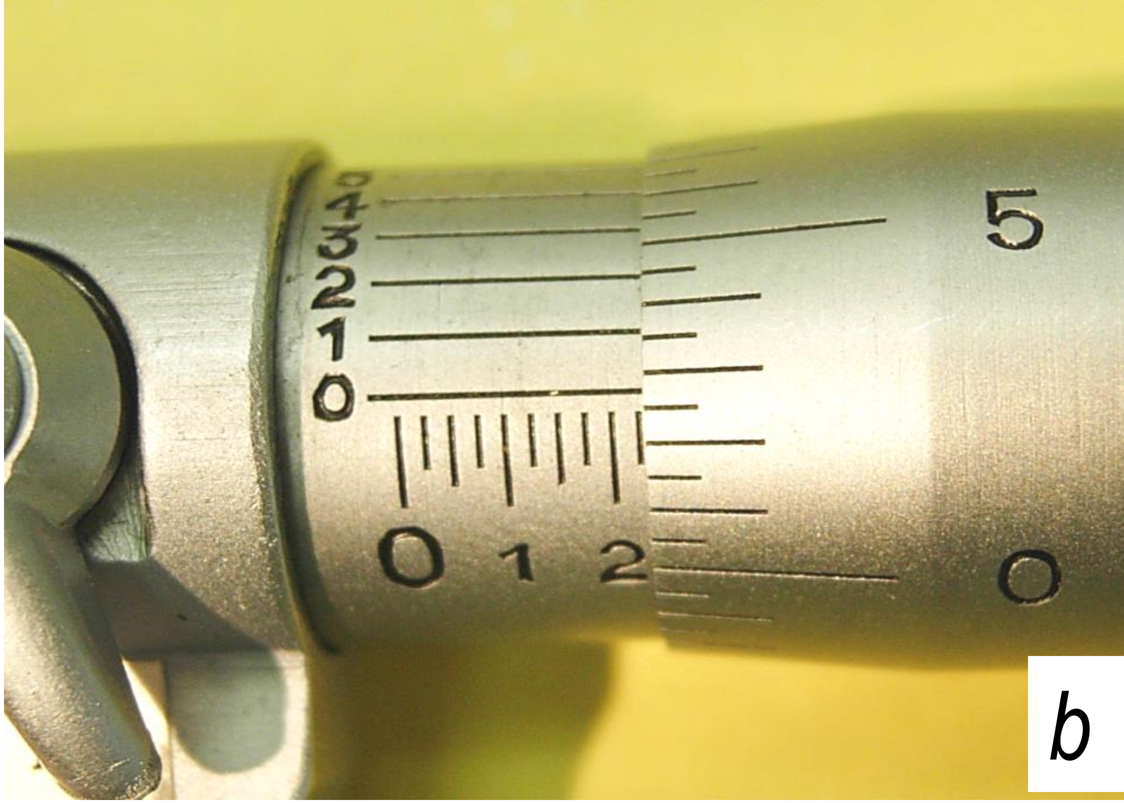
Micrometer



Range:

Reading: ____________ inch (4 decimal digits)

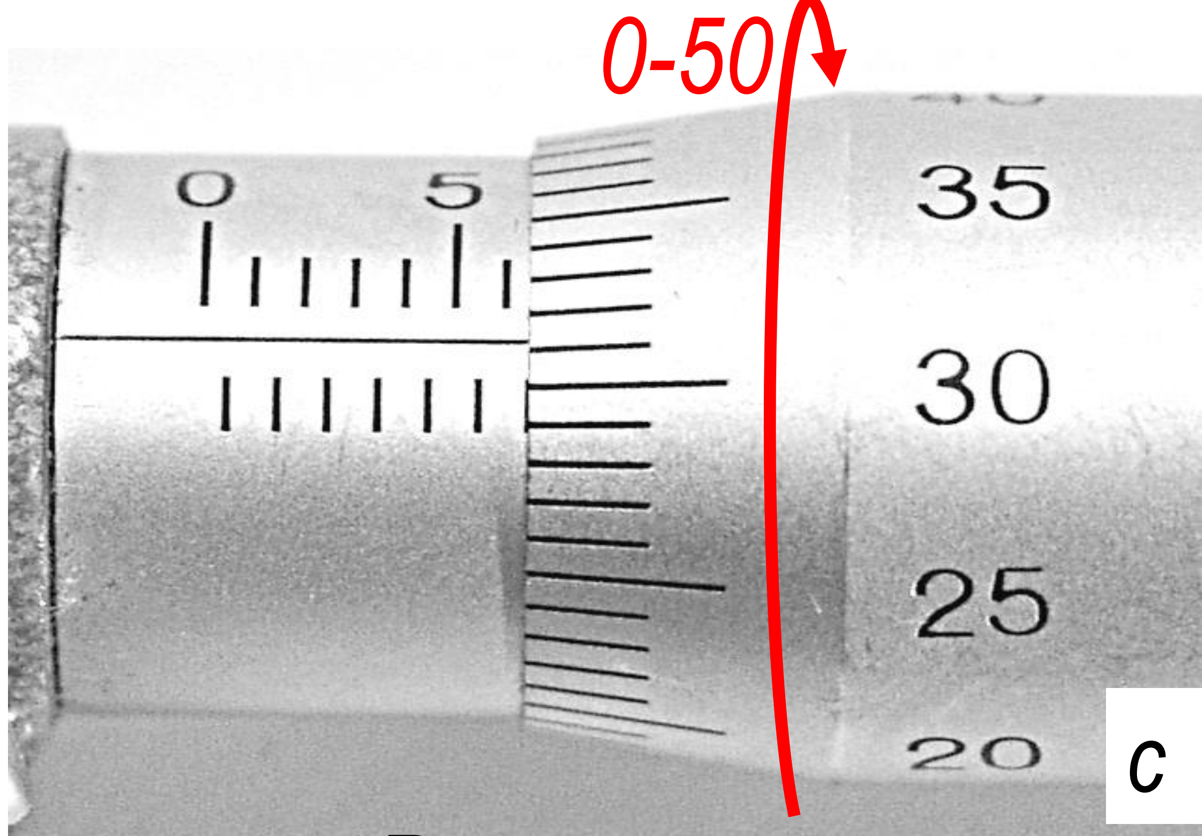
Micrometer



Range:

Reading: ____________ inch (4 decimal digits)

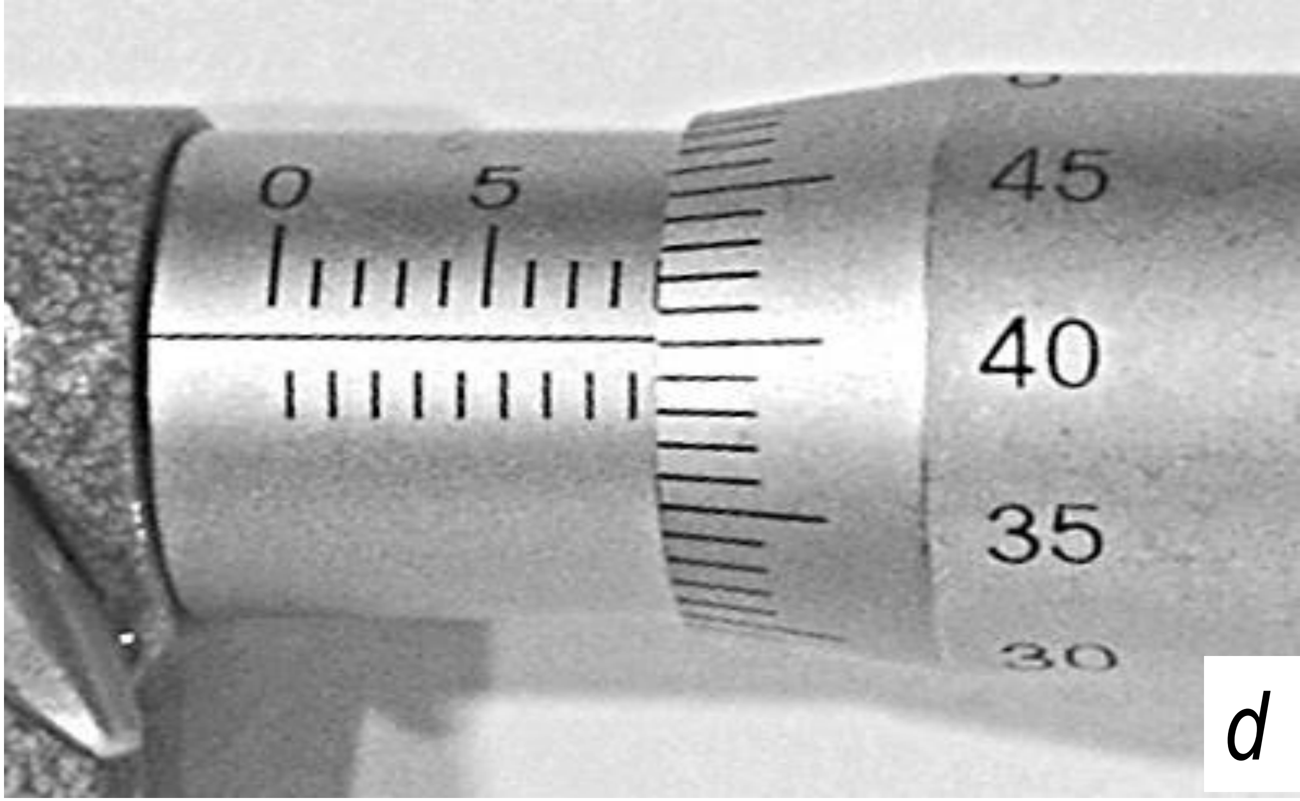
Metric micrometer



Range:

Reading: ____________ mm (3 decimal digits)

Metric
micrometer



Range:

Reading: ____________ mm (3 decimal digits)

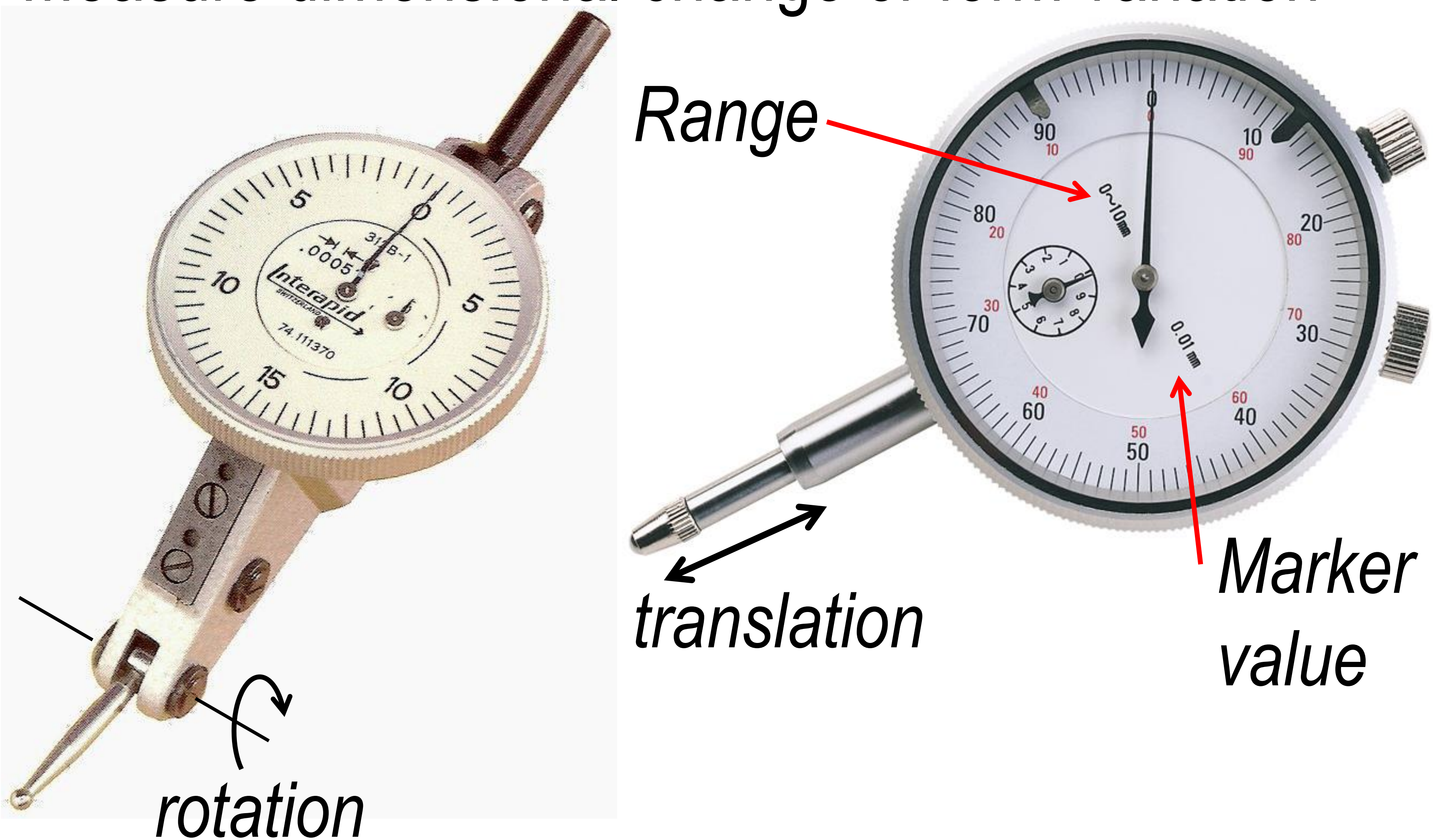
Micrometer Reading

1) DVD (comes with the reference textbook)
2) Lab practice
3) Homework
4) Online practice

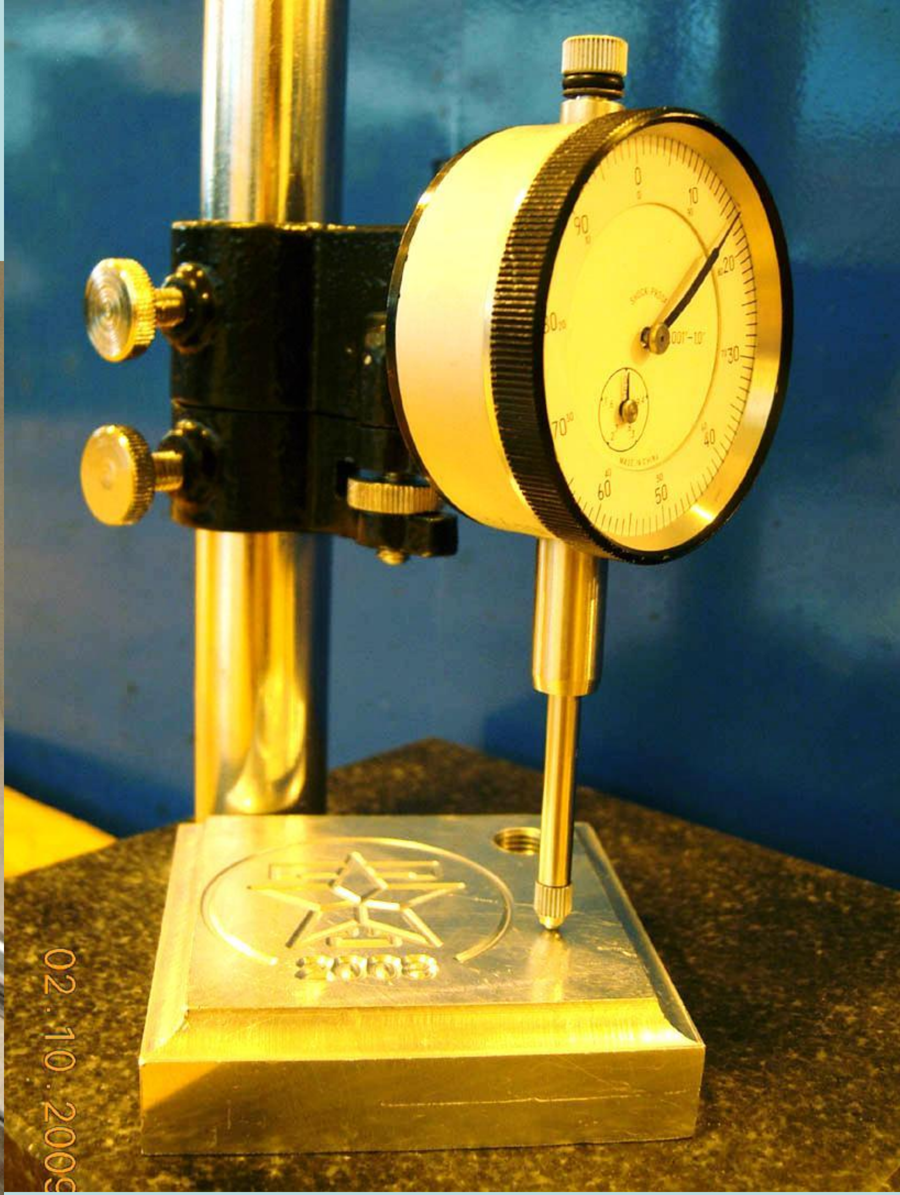
- http://www.linnbenton.edu/auto/day/mike/vernier3.html
- http://www.pastaffing.com/trainmic.asp
- http://cf.linnbenton.edu/eit/auto/krolicp/web.cfm?pgID=2262
- http://www.wisc-online.com /Objects/ViewObject.aspx?ID=MTL1902

8. Indicators

- Amplify small displacement (linear or rotation)
- Measure dimensional change or form variation

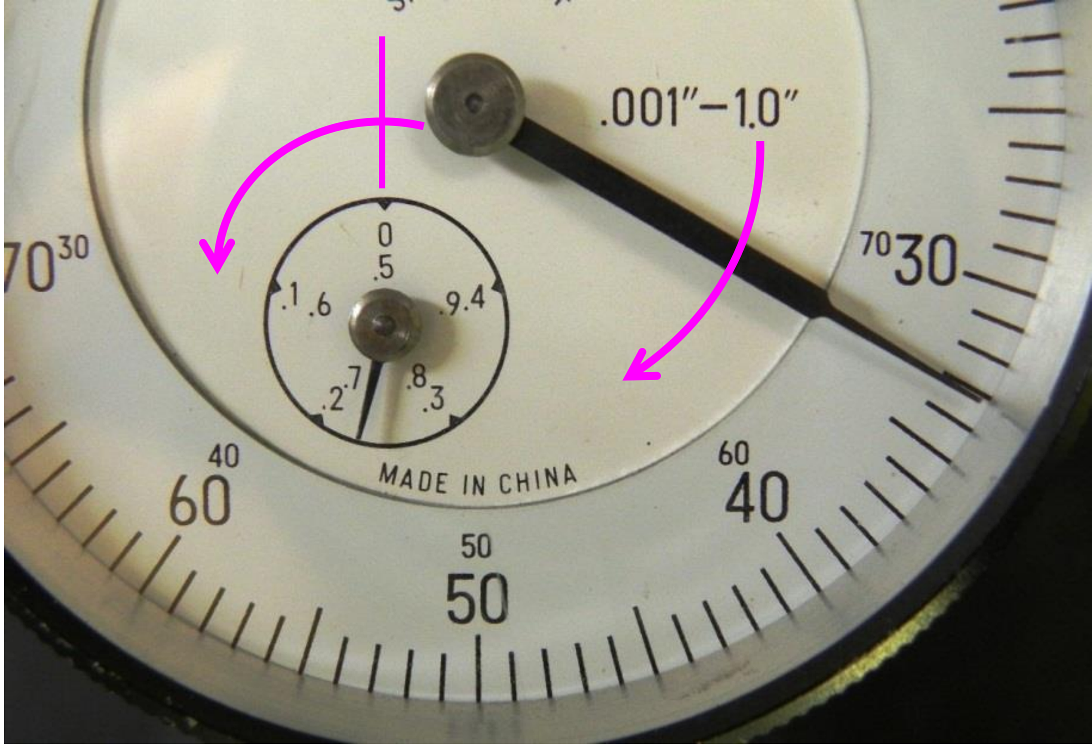


Indicator applications



Indicator

- Assume rotation directions
- Range: 0-1 inch
- Marker: 0.001 inch
- Read small dial then large dial

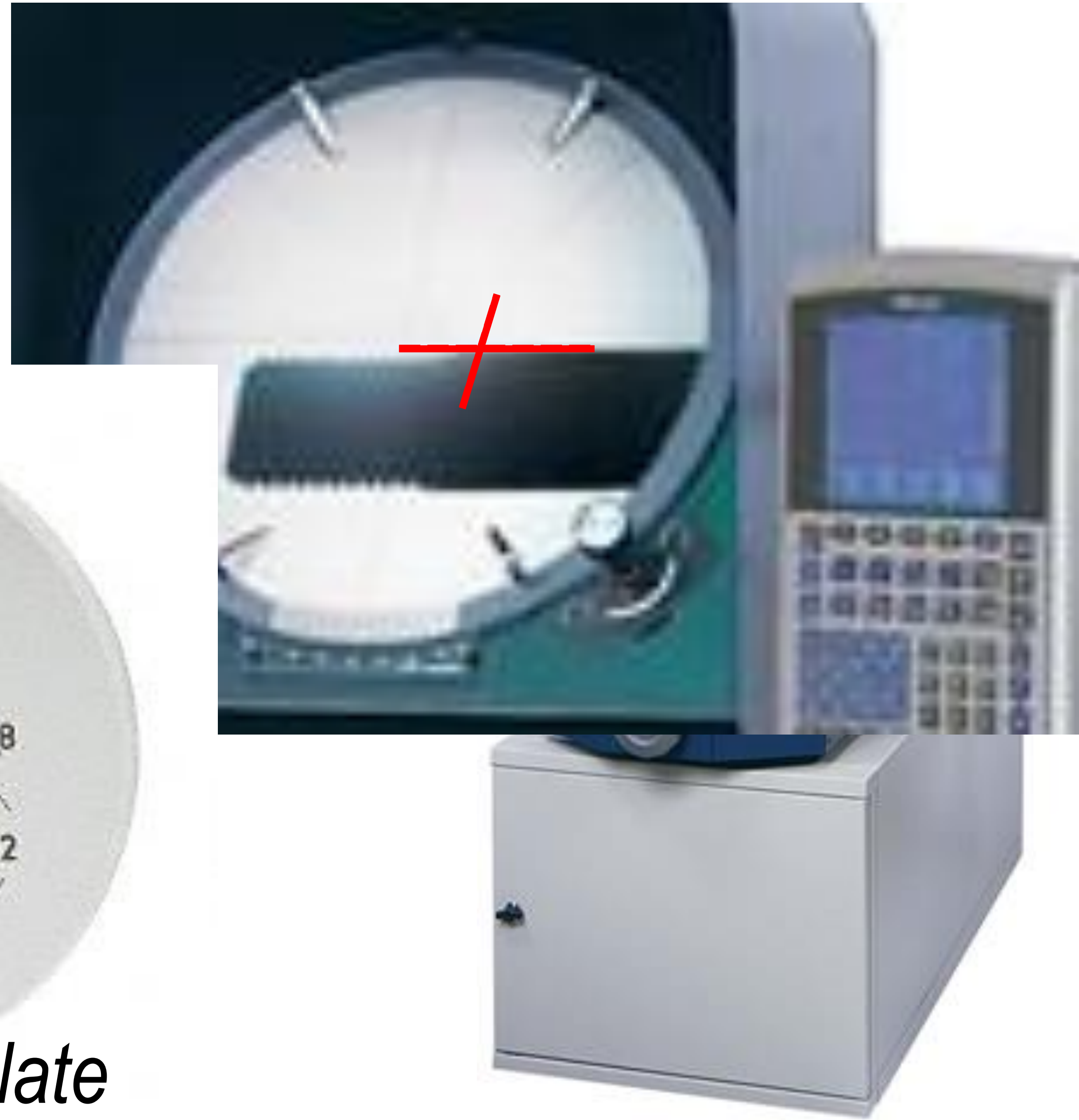


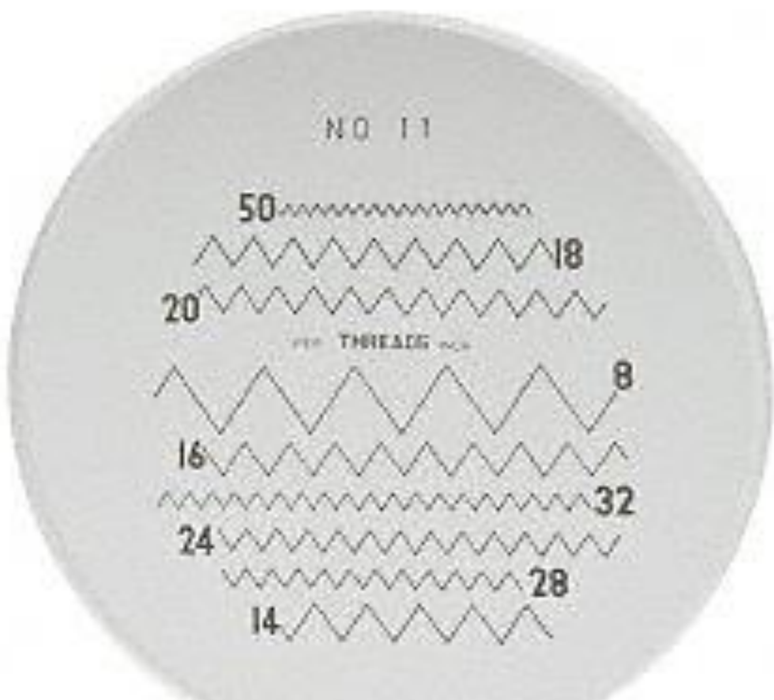
Reading:______________ (4 decimal digits)

$$2(0.1)+33.2(0.001)=0.2332 \text{ inch}$$

9. Profile projector (optical comparator)

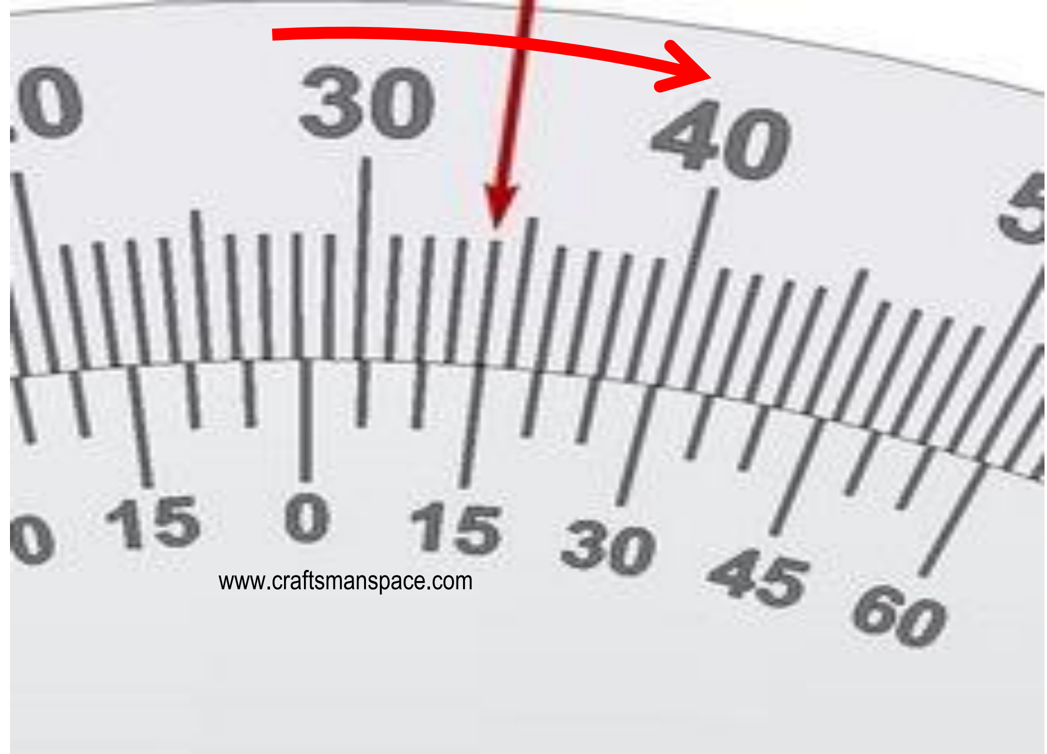
- Magnify image
- Analyze shadow
- Calculate true





Customized template

Angle measurement



Angle measurement and conversion

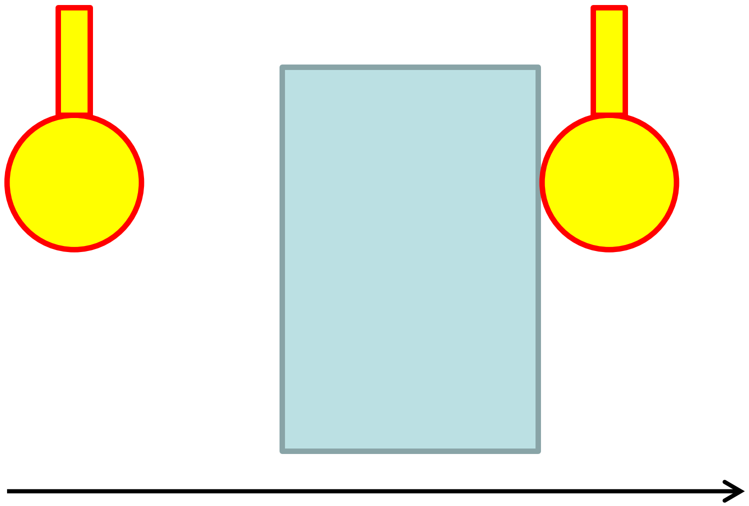
1° = 60 minutes = 3600 seconds

28°15 min

$28 + 15/60 = 28.25°$

10. Coordinate measuring machine (CMM)

- Use precise probes with known dimensions
- Provide coordinate of each point
- Calculate dimension and form



10. Coordinate measuring machine (CMM)

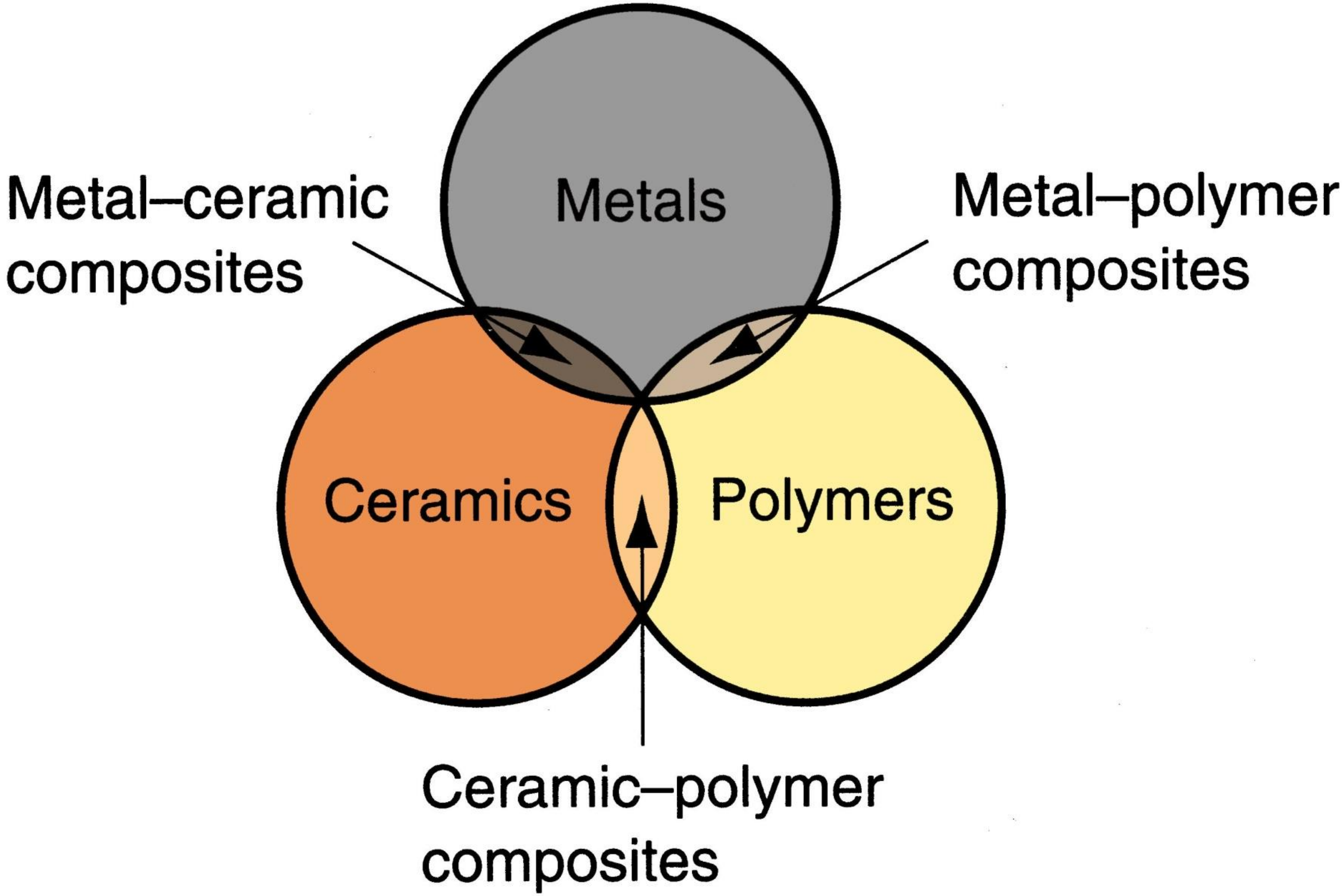
3-DOF probe

http://www.greatgages.com/CMM%20Styli.html

5-DOF probe

RET Lec 3: Engineering Materials

1) Nature of material
2) Mechanical properties
3) Effect of temperature
4) Metals
5) Polymers
6) Material comparison
7) Effect on manufacturing



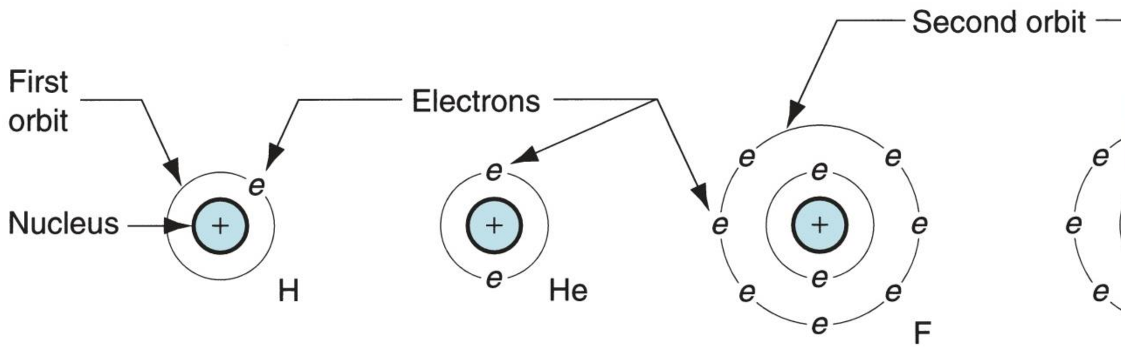
Engineering materials: metal, ceramic, polymer

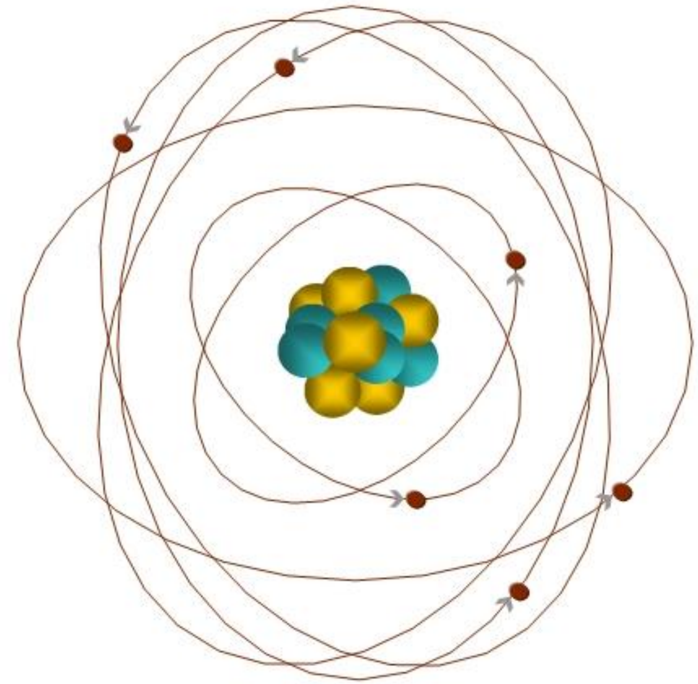
Natural materials: wood, clay, rock, bone…

1. Nature of material

❑Atom

Atom= nucleus + electrons



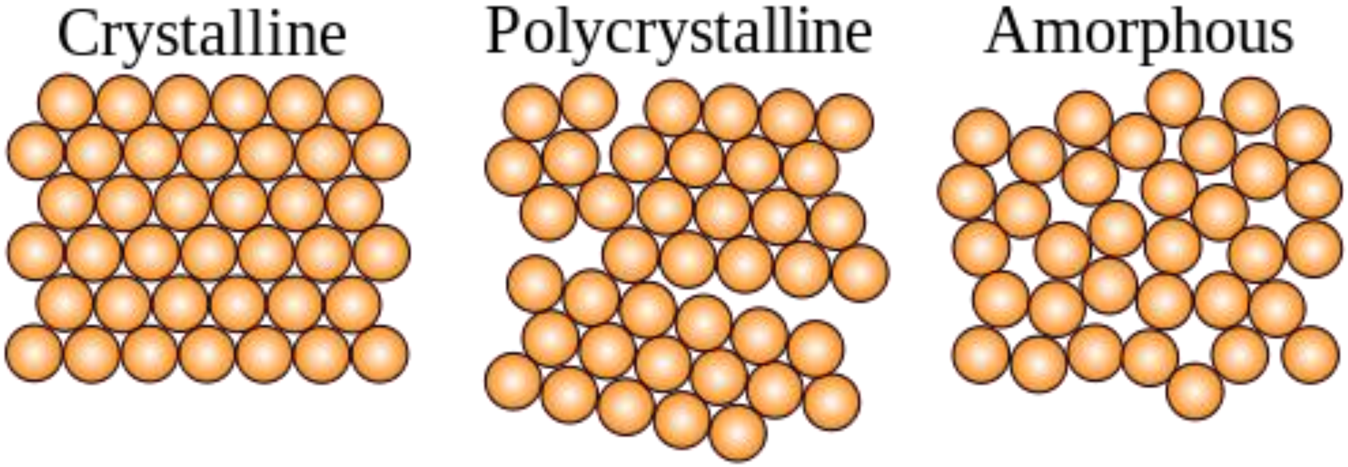


http://www.vtaide.com/png/atom.htm

Bonds: strong primary:

weak secondary:

Break bonds⟶ release atoms (machining)

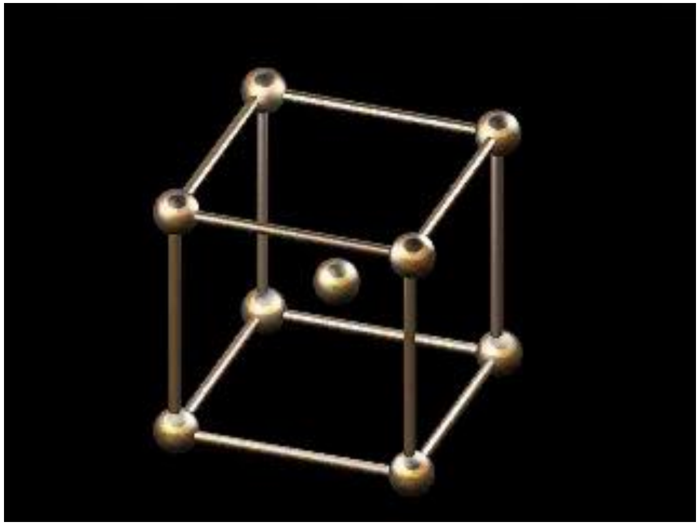


en.wikipedia.org

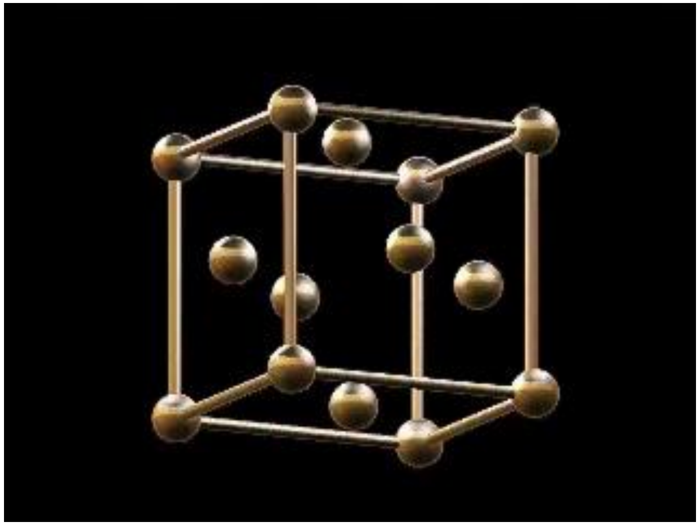
- Crystalline structure
  - ordered
  - 3D
  - metals, ceramics

- Amorphous structure
  - random
  - 3D
  - polymers, ceramics

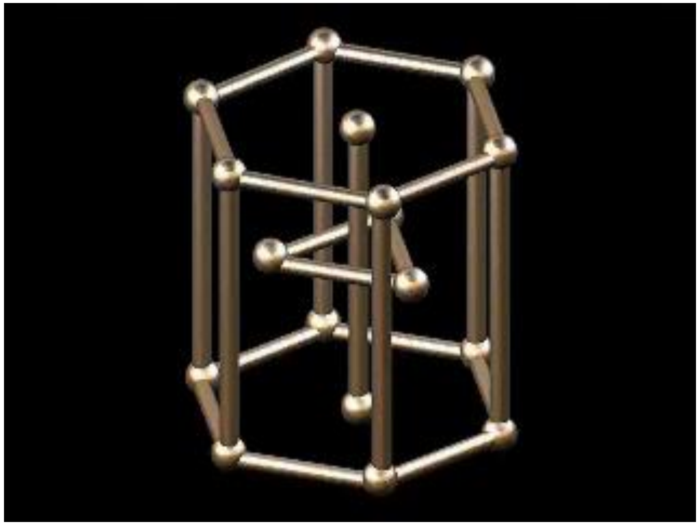
Common crystalline structures



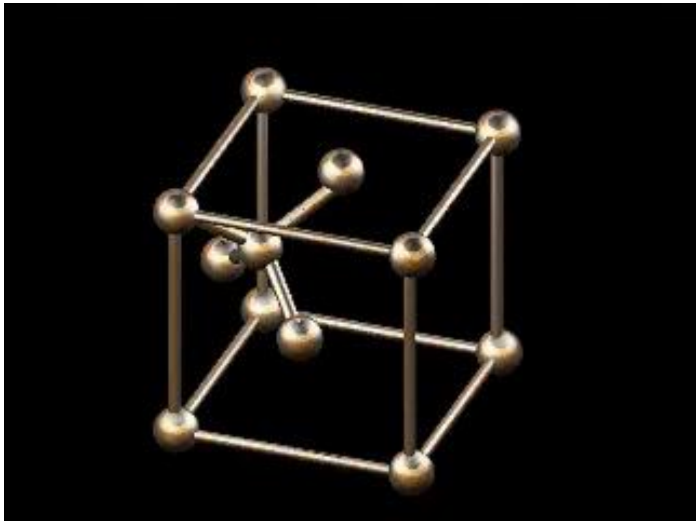
BCC



FCC



HCP



Diamond

2. Mechanical property of material

2.1. Stress and strain

Normal stress $$\sigma = \frac{F}{A}$$

Shear stress $$\tau = \frac{F_s}{A_s}$$

Small strain $$\varepsilon = \frac{\Delta \mathrm{L}}{\mathrm{L}} = \frac{L_f - L_i}{L_i}$$

Large strain $$\varepsilon = ln\frac{L_f}{L_i}$$

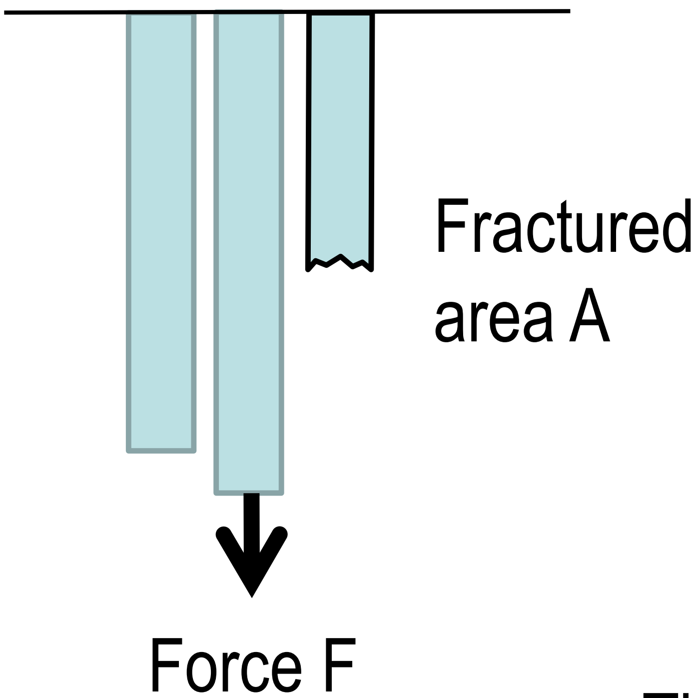
Shear strain $$\gamma$$

Units

	US customary	SI (Metric)
Mass	pound: lb	g, kg
Force	pound: lb	Newton (N)
Length	in, ft	m, cm, mm
Area	in^2, ft^2	m^2, cm^2, mm^2
Strain & shear strain		
Stress & strength		

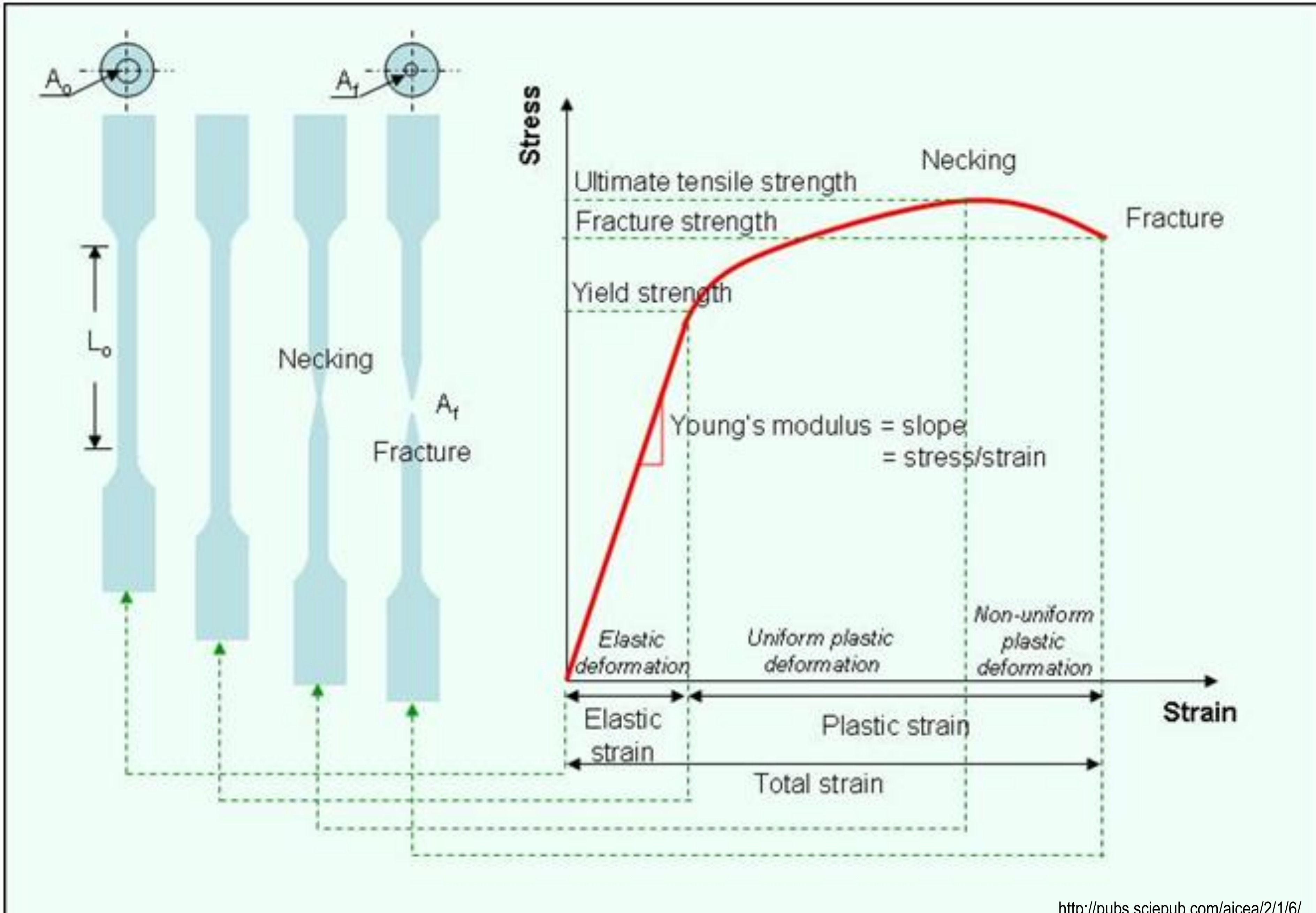
2.2. Tensile test

- Increase force till breaking
- Force is 90° to fractured surface



The ultimate tensile stress (material strength, maximum normal stress) is

$$\sigma_{\max} = \frac{F_{\max}}{A} = S_u$$



http://pubs.sciepub.com/ajcea/2/1/6/

TABLE 3.2 Yield strength and tensile strength for selected metals.

Metal	Yield Strength		Tensile Strength	
	MPa	(lb/in.^{2})	MPa	(lb/in.^{2})
Aluminum, annealed	28	(4,000)	69	(10,000)
Aluminum, CW[a]	105	(15,000)	125	(18,000)
Aluminum alloys[a]	175	(25,000)	350	(50,000)
Cast iron[a]	275	(40,000)	275	(40,000)
Copper, annealed	70	(10,000)	205	(30,000)
Copper alloys[a]	205	(30,000)	410	(60,000)
Magnesium alloys[a]	175	(25,000)	275	(40,000)

Metal	Yield Strength		Tensile Strength	
	MPa	(lb/in.^{2})	MPa	(lb/in.^{2})
Nickel, annealed	150	(22,000)	450	(65,000)
Steel, low C[a]	175	(25,000)	300	(45,000)
Steel, high C[a]	400	(60,000)	600	(90,000)
Steel, alloy[a]	500	(75,000)	700	(100,000)
Steel, stainless[a]	275	(40,000)	650	(95,000)
Titanium, pure	350	(50,000)	515	(75,000)
Titanium alloy	800	(120,000)	900	(130,000)

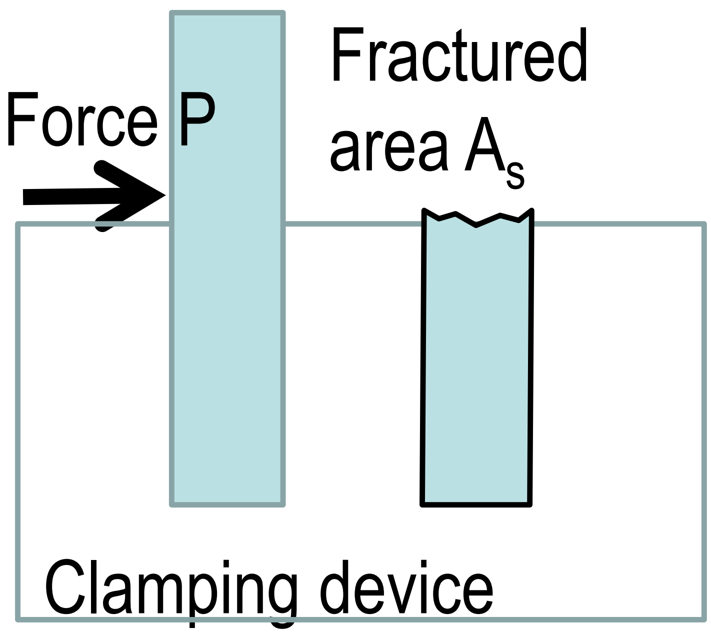
TABLE 3.3 Ductility as percent elongation (typical values) for various selected materials

Material	% elongation
Metals	
Aluminum, annealed	40
Aluminum, cold worked	8
Aluminum alloys, annealed[a]	20
Aluminum alloys, heat treated[a]	8
Aluminum alloys, cast[a]	4
Cast iron, gray[a]	0.6
Copper, annealed	45
Copper, cold worked	10
Copper alloy: brass, annealed	60
Magnesium alloys[a]	10
Nickel, annealed	45

Material	% elongation
***Metals**, continued*	
Steel, low C[a]	30
Steel, high C[a]	10
Steel, alloy[a]	20
Steel, stainless, austenitic[a]	55
Titanium, nearly pure	20
Zinc alloy	10
Ceramics	0
Polymers	
Thermoplastic polymers	100
Thermosetting polymers	1
Elastomers (e.g., rubber)	1

2.3. Shear test

- Increase force till breaking
- Force is parallel to fractured surface

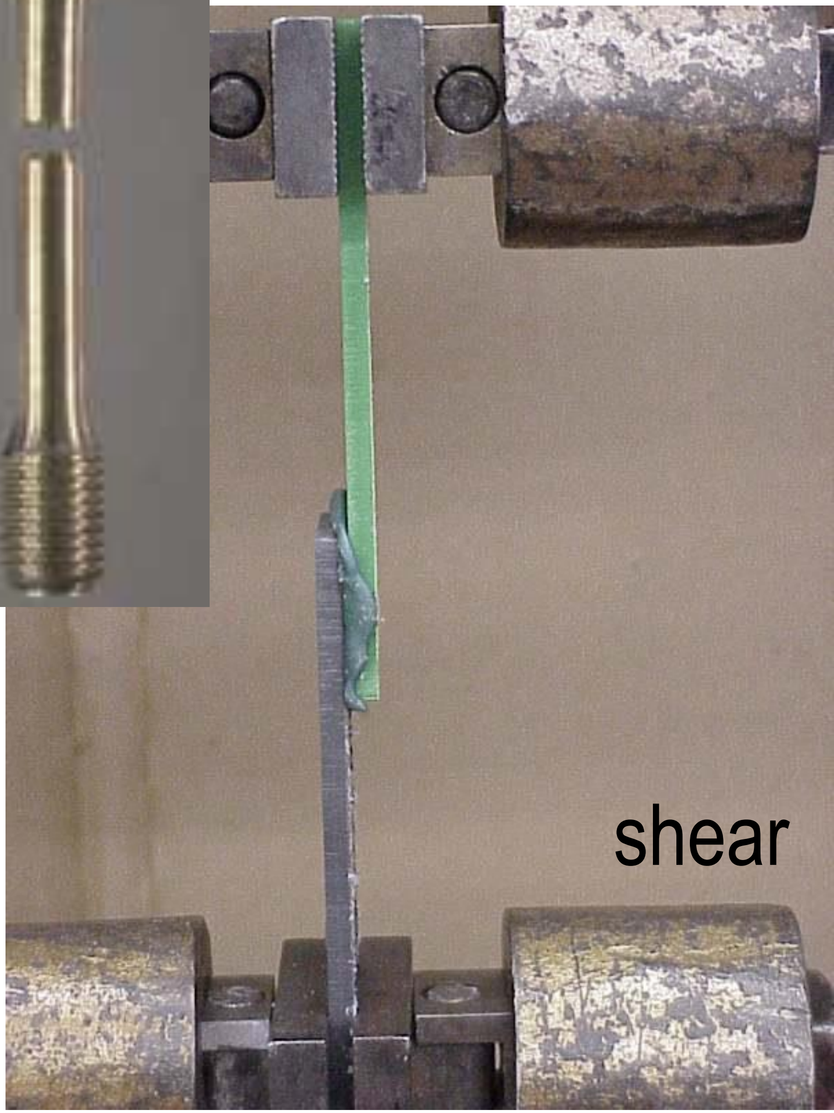


The ultimate shear stress (or material shear strength, or maximum shear stress) is:

$$\tau_{\max} = \frac{P_{\max}}{A_s} = S_s$$

Tensile/shear tester

http://mee-inc.com/services-laboratory.html



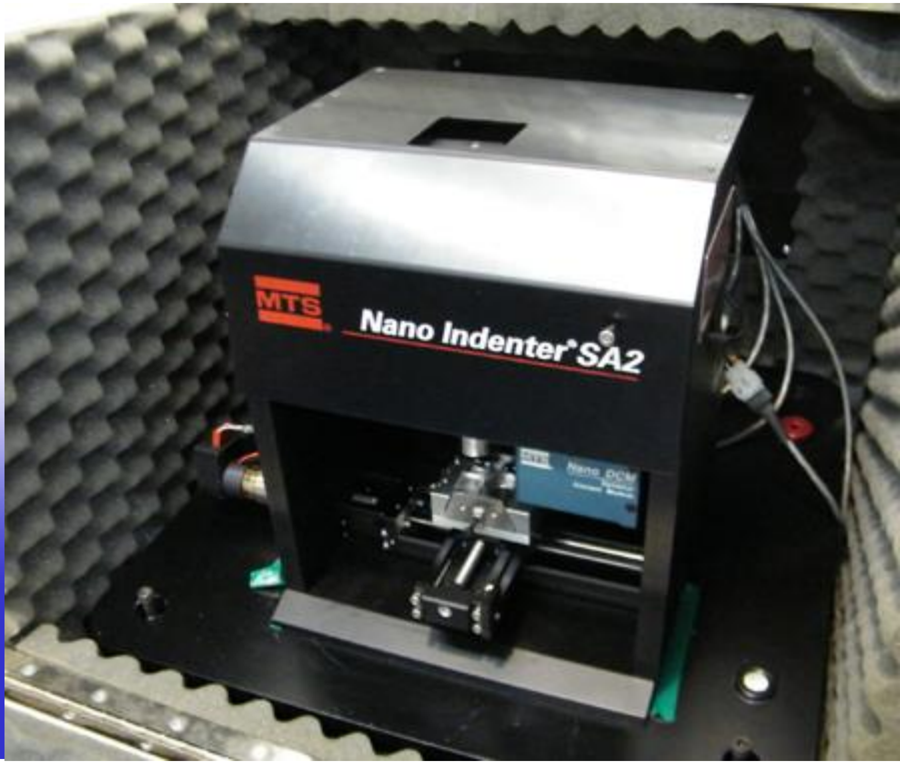
https://alliance.seas.upenn.edu/~medesign/wiki/index.php/Courses/MEAM247-10C-P2

http://forum.woodenboat.com/showthread.php?92446-Waterproof-Glue-Testing-Plan

2.4. Hardness testers

http://www.all-testers.com/hardness-testers.php

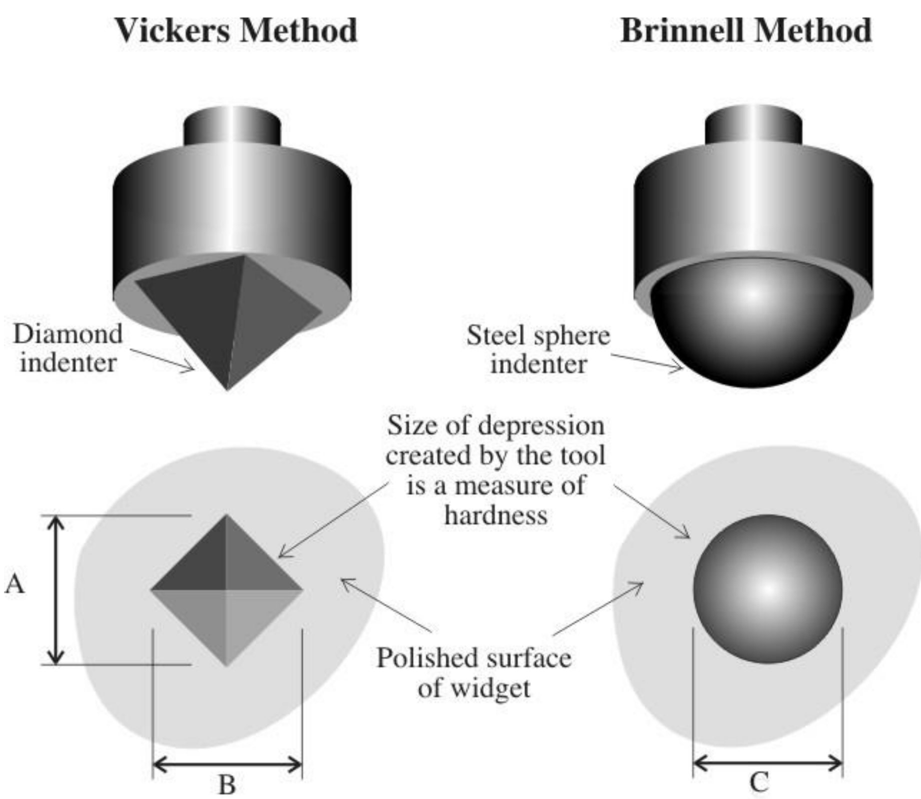
http://www.brystartools.com



http://www.classoneequipment.com

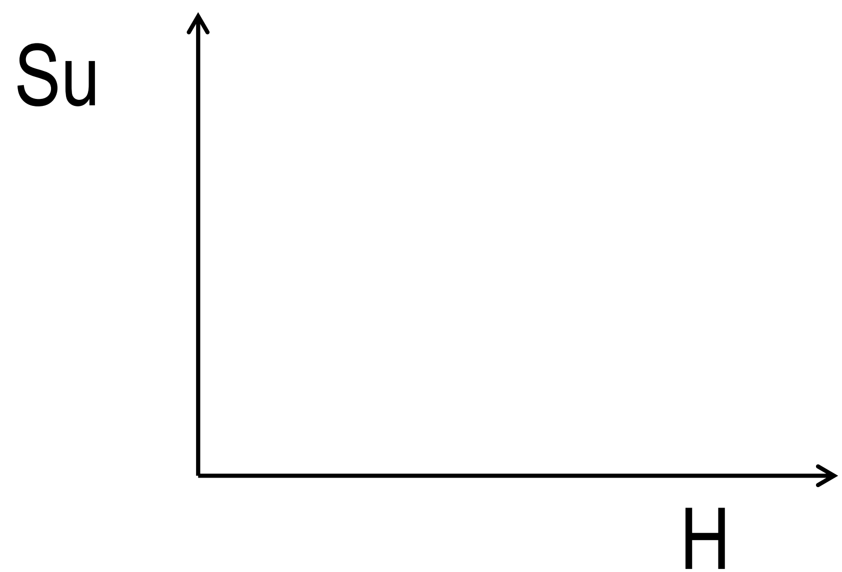
2.4. Hardness test

- Force an indenter @ preset force, time
- Measure indentation
- Calculate hardness (Brinell, Vicker, Knoop, Rockwell…)
- Link to material strength



http://www.thesteelsheet.com/qi.php

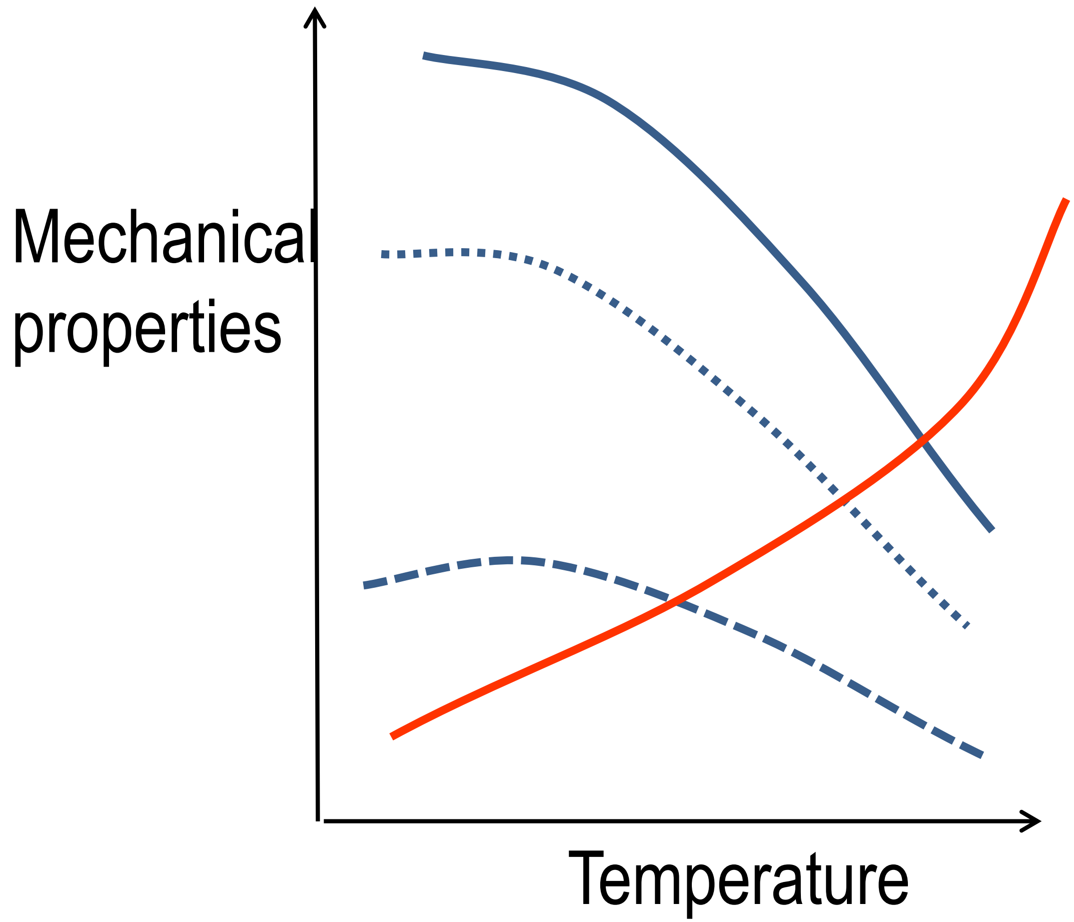
$$H_{\text{Vicker}} = \frac{1.854\,F}{D^2}$$



3. Effects of temperature

Hot
soft
ductile

Cold
hard
brittle

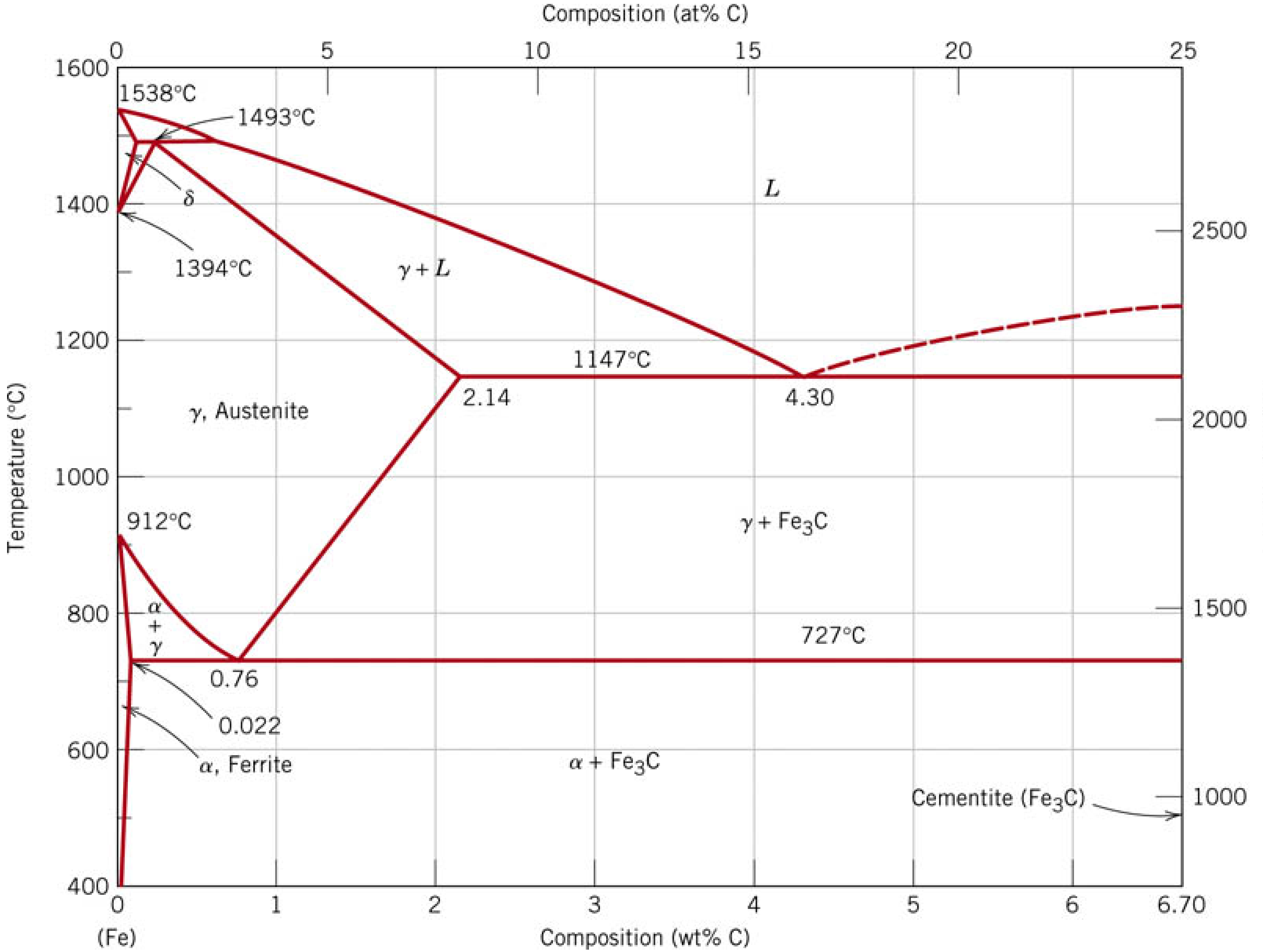


4. Metals

Alloy = mixture of different atoms

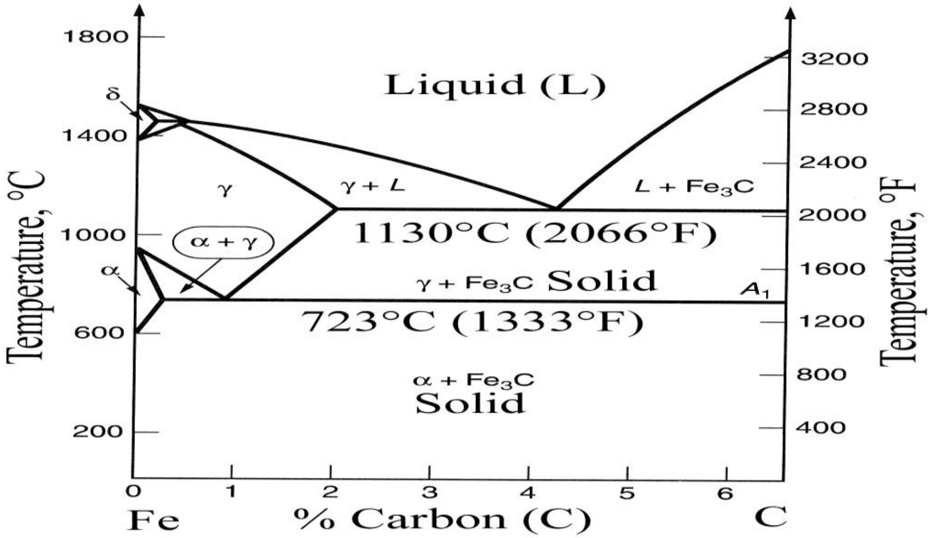
Composite = mixture of different materials (visibly different)

4.2. Ferrous metals



www.e-education.psu.edu

4.2.1. Steels



❑Nomenclature

1015 steel: 0.15% C, Fe (balance)

4140 steel: 0.40% C, 1% Cr, 0.8% Mn, 0.2% Mo, Fe (balance)

Pro’s: Good tension & compression …

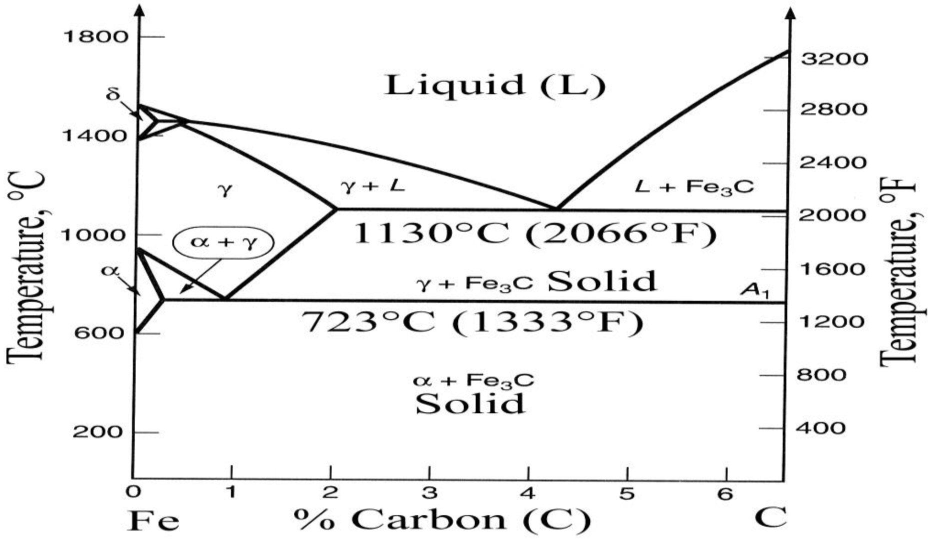
Con’s: High density, corrosive …

Stainless Steels

- Types
  - Austenitic
  - Ferritic
  - Martensitic
  - PH
  - Duplex

- Pro’s and Con’s
  - Corrosion resistant…
  - High density, more expensive …

4.2.2 Cast iron



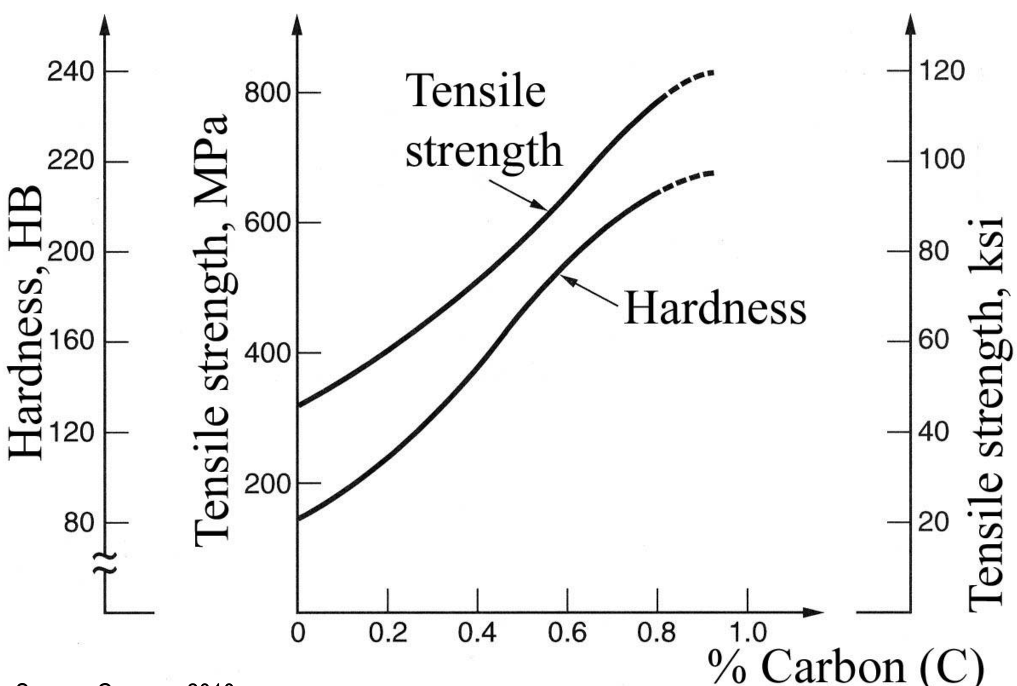
- Types
  - Gray
  - White
  - Ductile

Easy to machine, cast, damping…

Rust, heavy, good compression but poor tension…

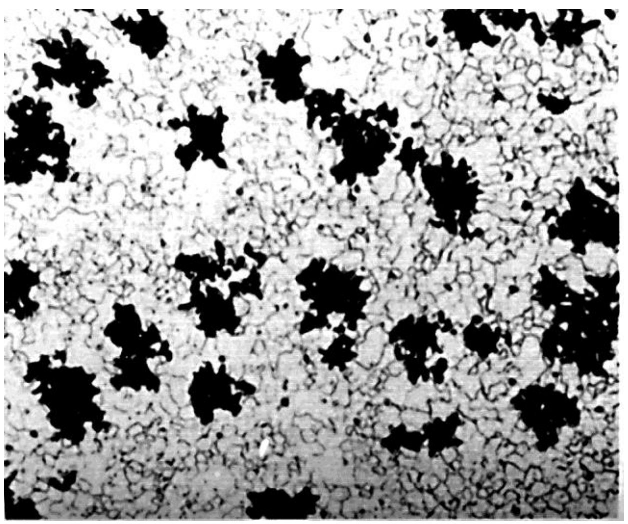
Effects of carbon content

- Optimal carbon → strengthen alloy
- Too much carbon → weaken alloy

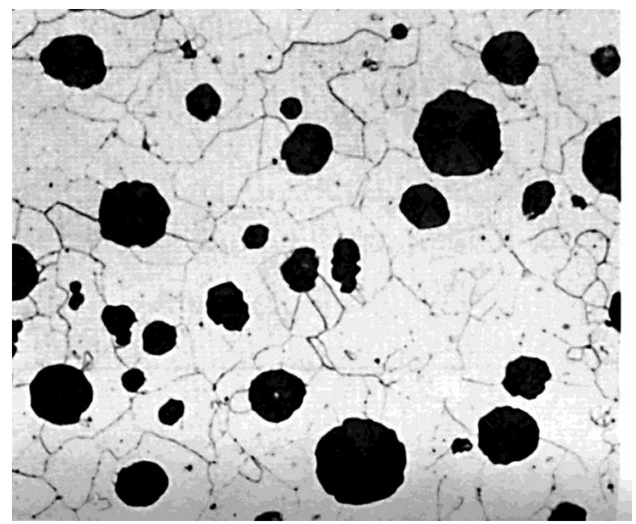


Source: Groover, 2010

Gray cast iron with graphite flake



Malleable cast iron



Nodular cast iron

4.3. Nonferrous metals

4.3.1 Aluminum

Aluminum fuselage of a Boeing 747
Source: http://en.wikipedia.org/wiki/Fuselage

- Wrought: ductile, can be deformed significantly

XXXX-Tx

- Cast: brittle, can be cast easily

AXXX-Tx

- Pro's and Con's

Light, min corrosion, easy to machine

$ more, softer, lower strength (against steel)

4.3. Nonferrous metals

4.3.2 Copper

- CA XXX

 High conductive, soft (easy to fabricate)…

 Lower strength (against steel), corrosive…

4.4 Super alloys

- Types: Fe, Ni, Co based alloys: Rene, Incoloy, Inconel, Stellite, Hastelloy, Monel …

Pro's & Con's

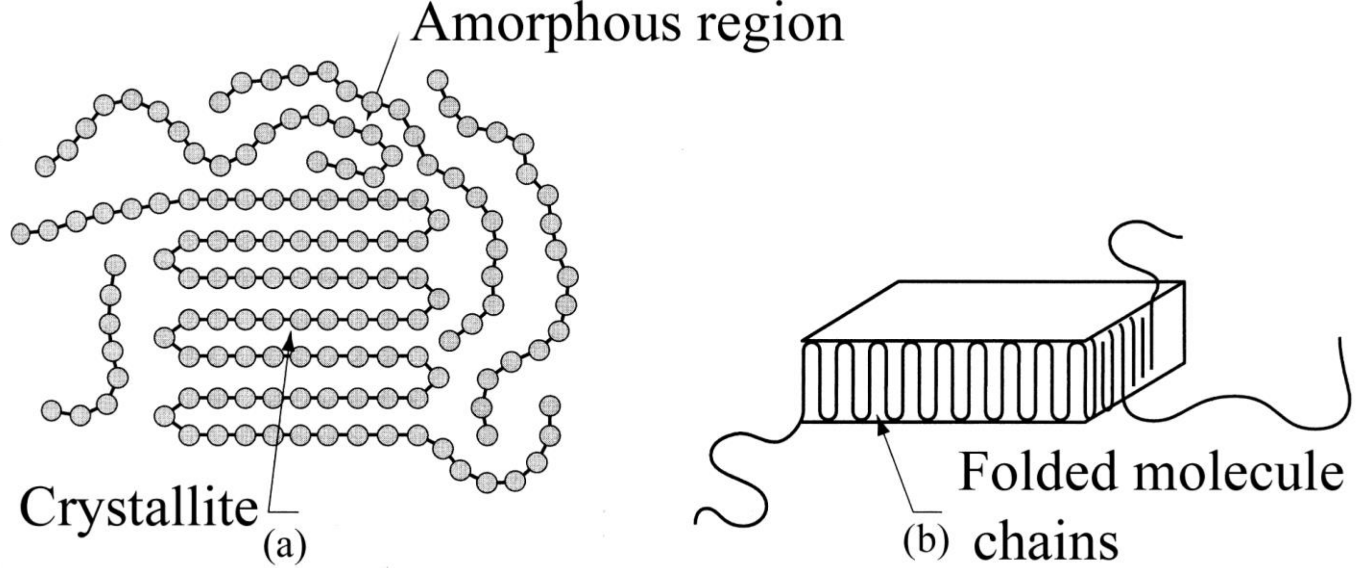
Maintain high strength, hardness at high temperature

$$, heavy, difficult to manufacture

Source: http://www.afterburner.nl/lossie/

5. Polymers

- Basic elements: C, H, O, N
- Polymerization: combine carbons and others to chain molecules.



More crystallinity → metal like

Linear chain branching cross-linking

- Types
  - Thermoplastics — Repeat heating/cooling, linear chains
  - Thermoset — Heat/cool once, cross-linked chains
  - Elastomers — Stretch >10x, coiled chains

- Pro's & Con's

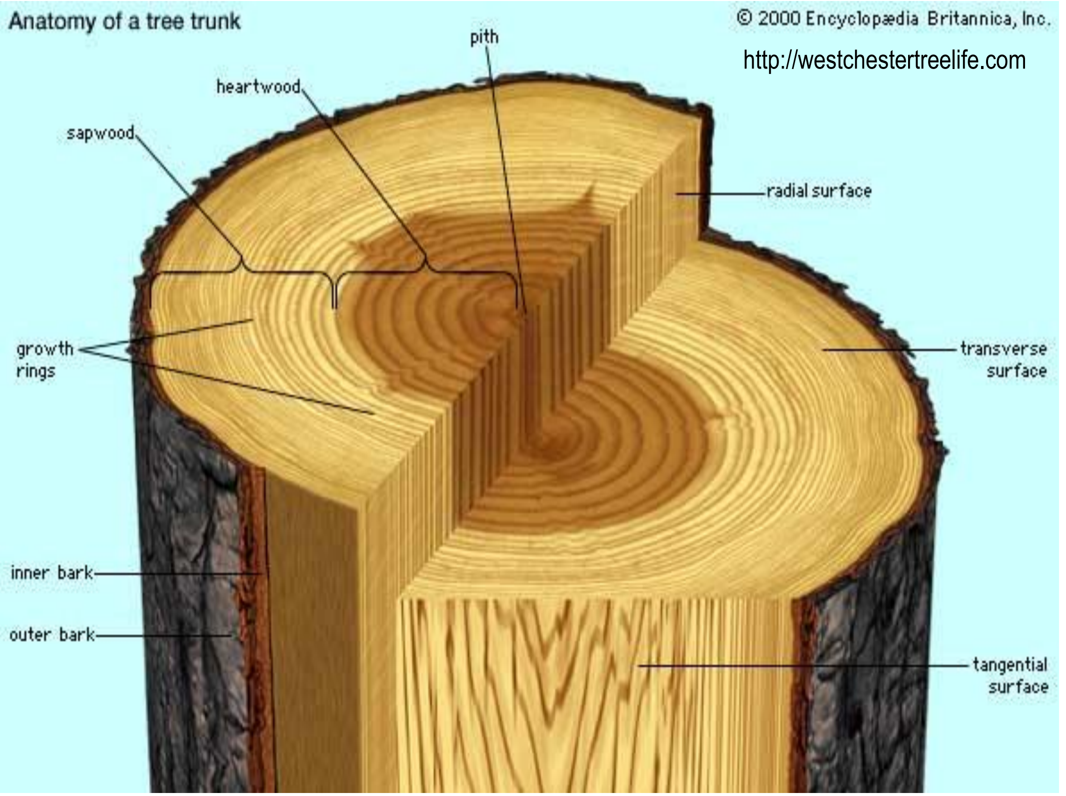
+ Low Tm for processing
+ High ductility
+ Light
+ No rust

– Temp limited
– Low strength, hardness
– Degraded by UV light
– Nonconductive

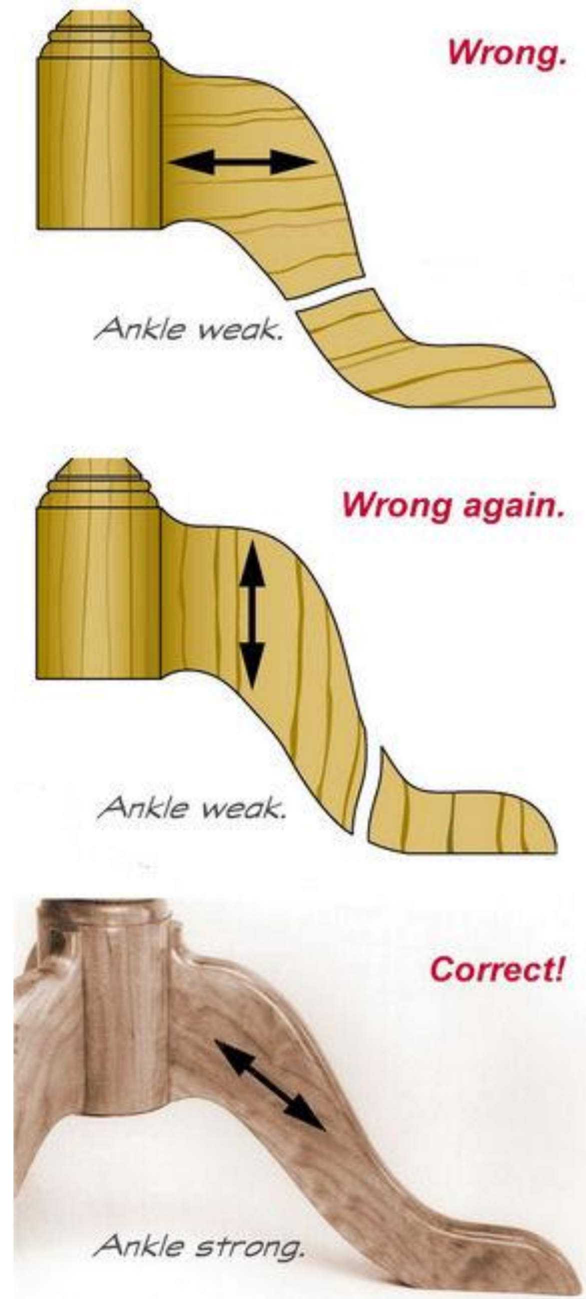
Natural materials: wood, rock, sand, clay, bone…

Wood as engineering material

- Hardwoods from deciduous trees (e.g. ash, beech, birch, mahogany, maple, oak, teak, and walnut).
- Softwoods from evergeen (coniferous) trees (e.g. cedar, cypress, fir, pine, spruce, and redwood).



- Wood is anisotropic. Its strength depends on loading directions (along or across the grains), or content of moisture /chemical treatment.



http://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/3_Wood_Strength/3_Wood_Strength.htm

Wood cutting

NORTH AMERICAN HARDWOODS

Wood Species	Specific Gravity*	Compressive Strength (psi)	Bending Strength (psi)	Stiffness (Mpsi)	Hardness (lb)
Alder, Red	0.41	5,820	9,800	1.38	590
Ash	0.60	7,410	15,000	1.74	1,320
Aspen	0.38	4,250	8,400	1.18	350
Basswood	0.37	4,730	8,700	1.46	410
Beech	0.64	7,300	14,900	1.72	1,300
Birch, Yellow	0.62	8,170	16,600	2.01	1,260
Butternut	0.38	5,110	8,100	1.18	490
Cherry	0.50	7,110	12,300	1.49	950
Chestnut	0.43	5,320	8,600	1.23	540
Elm	0.50	5,520	11,800	1.34	830
Hickory	0.72	9,210	20,200	2.16	†
Maple, Hard	0.63	7,830	15,800	1.83	1,450
Maple, Soft	0.54	6,540	13,400	1.64	950
Oak, Red	0.63	6,760	14,300	1.82	1,290
Oak, White	0.68	7,440	15,200	1.78	1,360
Poplar	0.42	5,540	10,100	1.58	540
Sassafras	0.46	4,760	9,000	1.12	†
Sweetgum	0.52	6,320	12,500	1.64	850
Sycamore	0.49	5,380	10,000	1.42	770
Walnut	0.55	7,580	14,600	1.68	1,010

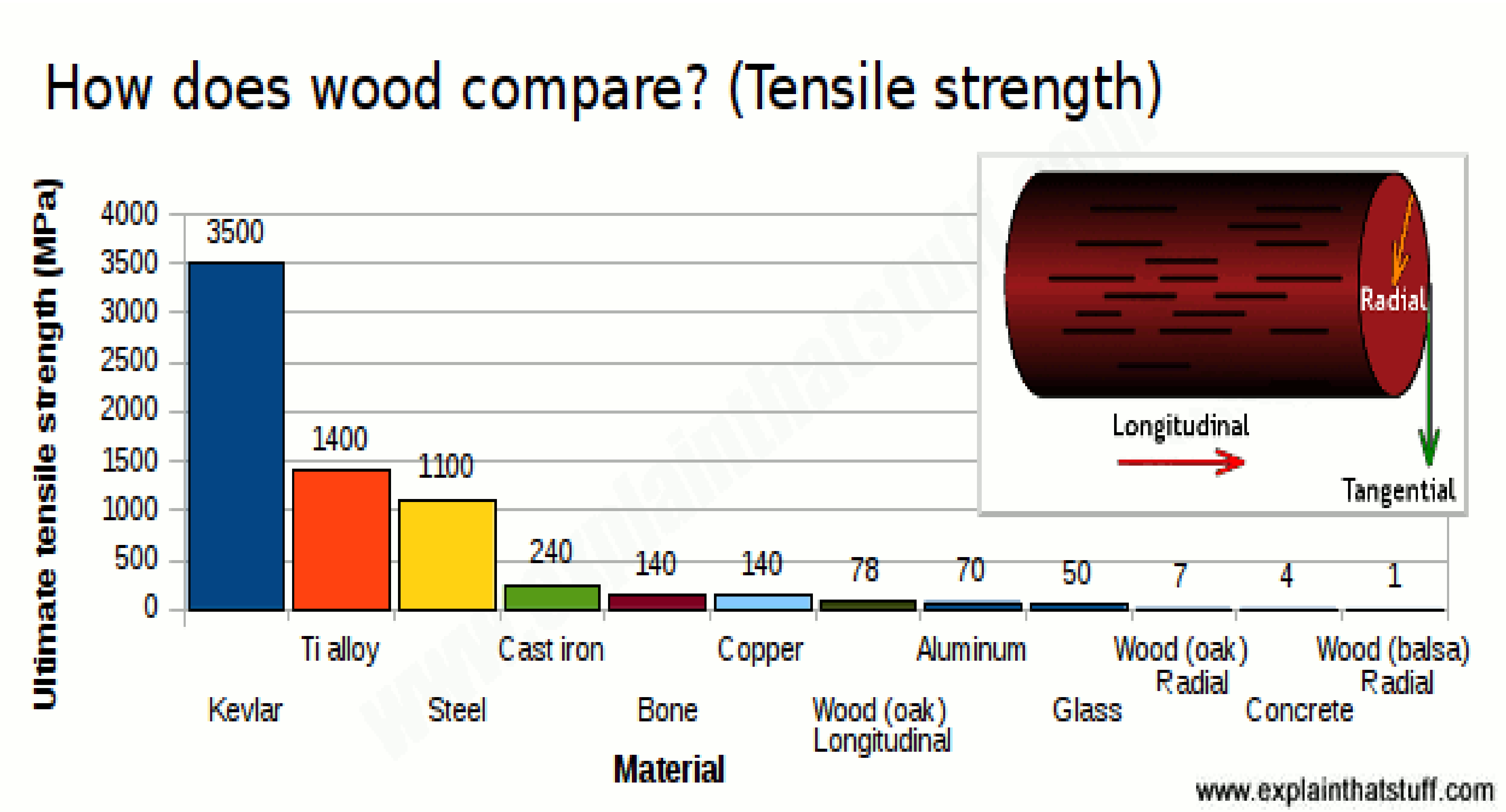
http://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/3_Wood_Strength/3_Wood_Strength.htm

NORTH AMERICAN SOFTWOODS

Wood Species	Specific Gravity*	Compressive Strength (psi)	Bending Strength (psi)	Stiffness (Mpsi)	Hardness (lb)
Cedar, Aromatic Red	0.47	6,020	8,800	0.88	900
Cedar, Western Red	0.32	4,560	7,500	1.11	350
Cedar, White	0.32	3,960	6,500	0.80	320
Cypress	0.46	6,360	10,600	1.44	510
Fir, Douglas	0.49	7,230	12,400	1.95	710
Hemlock	0.45	7,200	11,300	1.63	540
Pine, Ponderosa	0.40	5,320	9,400	1.29	460
Pine, Sugar	0.36	4,460	8,200	1.19	380
Pine, White	0.35	4,800	8,600	1.24	380
Pine, Yellow	0.59	8,470	14,500	1.98	870
Redwood	0.35	5,220	7,900	1.10	420
Spruce, Sitka	0.40	5,610	10,200	1.57	510

http://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/3_Wood_Strength/3_Wood_Strength.htm

- Wood is anisotropic. Its strength depends on loading directions (along or across the grains), or content of moisture /chemical treatment.



6. Comparison

Mechanical properties of selected materials

Materials	S_u (ksi)	ε_f (%)
Gray cast iron	**22 (tensile)**	**~0**
	83 (compressive)	**~0**
2024-O aluminum	**27**	**22**
2024-T3	**70**	**16**
1050 steel –anneal	**92**	**24**
1050 steel – heat treat	**163**	**9**
Polypropylene	**4**	**10-1000**

Material ↔ Manufacturing

Mat'l property	*Affected process*
▪ Thermal: melting temp	*casting, welding, molding*
▪ Mechanical: strength hardness, ductility	*machining, forming*
▪ Chemical: oxidation	*etching, welding*
▪ Metallurgical: alloying	*heat-treating, machining*

Lecture 04

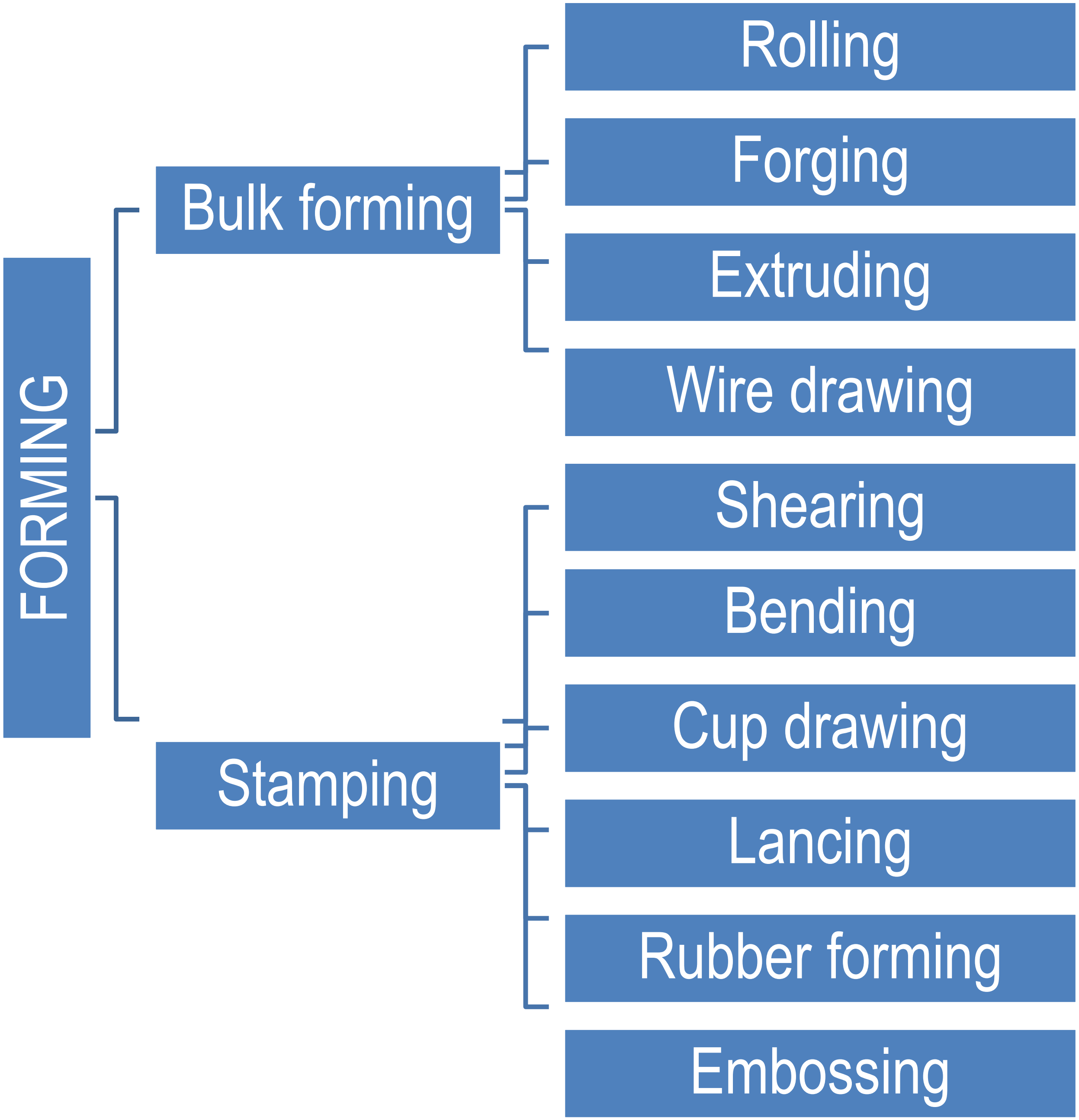
Metal forming & stamping

1. Material behavior
2. Effect of temperature
3. Review
4. Bulk forming processes
    - Rolling
    - Forging
    - Explosive forming
    - Extrusion
    - Wire drawing
5. Stamping processes
    - Shearing & cutting
    - Bending
    - Drawing
    - Lancing
    - Rubber forming
    - Embossing

Art: Vulcan forging the armour of Achilles

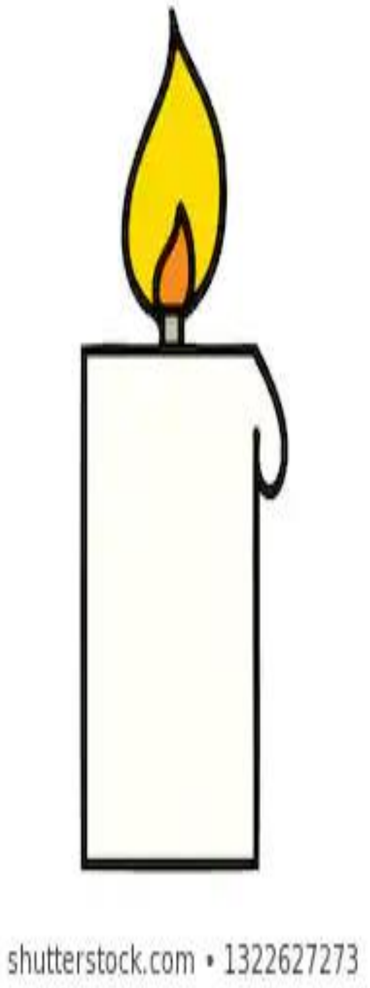
By: Giulio Romano
(1499 - 1546)

http://www.myartprints.com/a/romano-giulio/vulcan-forging-the-armour.html


FORMING
Bulk forming
Stamping
Rolling
Forging
Extruding
Wire drawing
Shearing
Bending
Cup drawing
Lancing
Rubber forming
Embossing

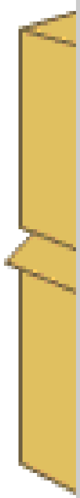
1. Material behavior

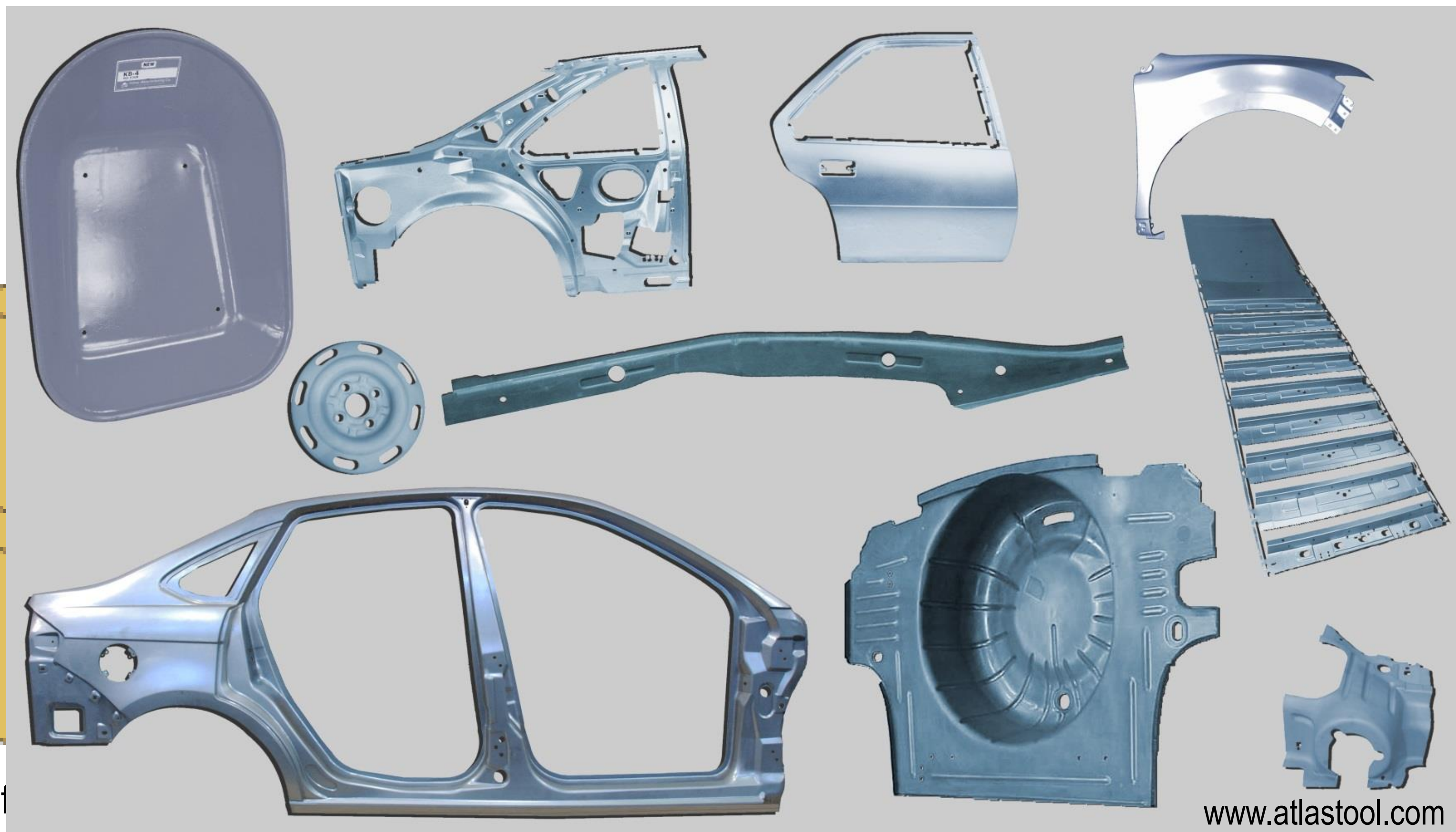
2. Effect of temperature



5. Stamping

	Thickness (mm)	(in)
Plate	t > 6.0	t > 0.250
Sheet	5.9 > t > 0.4	0.249 > t > 0.015
Foil	0.3 > t > 0.02	0.014 > t > 0.000,8





http://www.f

-Boxes

Metal sheet thickness

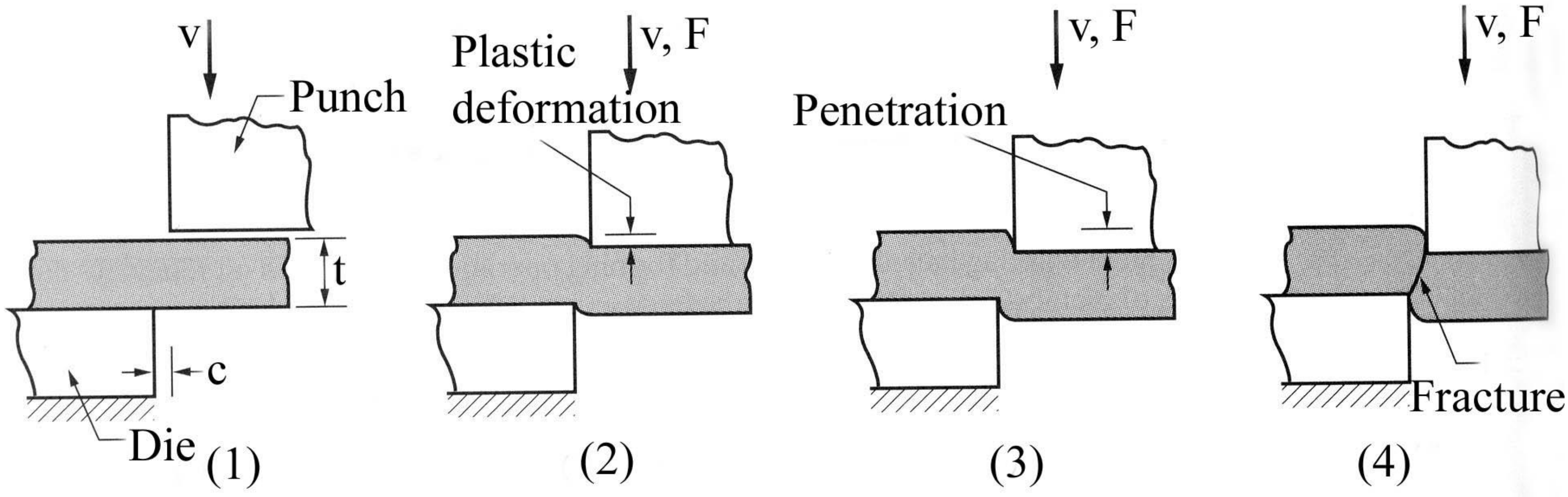
Sheet Metal Gauge Guide

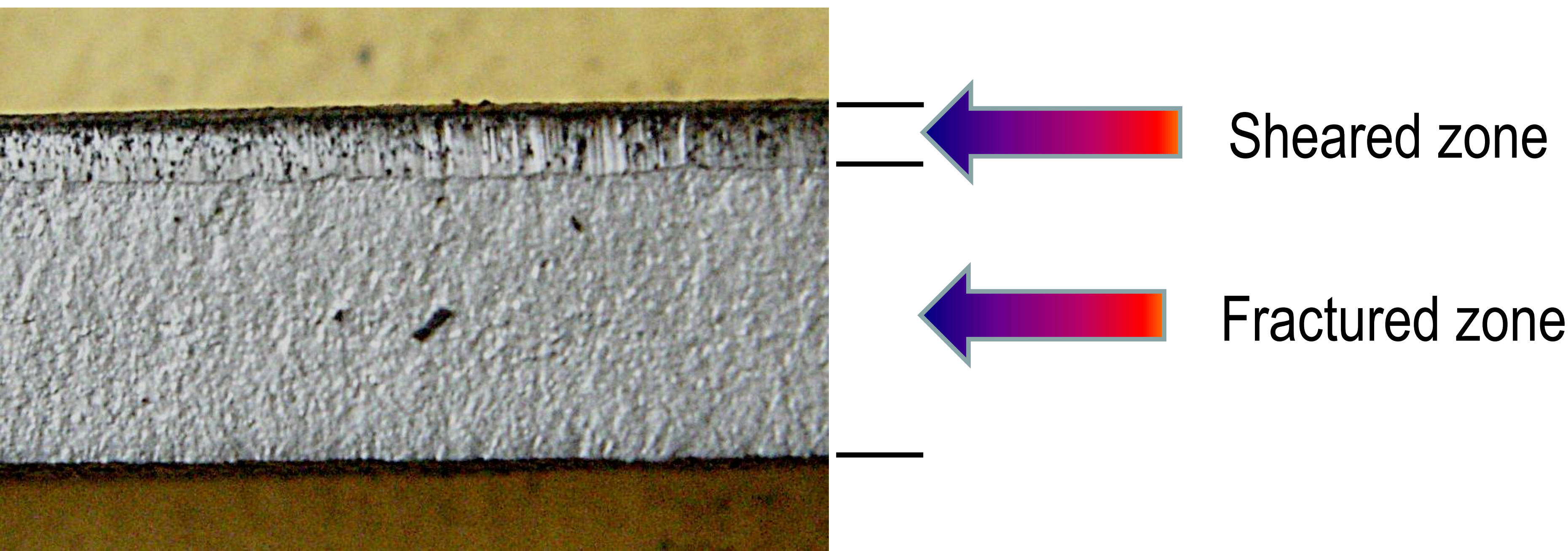
Gauge	Steel (mm)	Galvanized (mm)	Stainless (mm)	Aluminum (mm)
3	0.2391 (6.07)	--	--	--
4	0.2242 (5.69)	--	--	--
5	0.2092 (5.31)	--	--	--
6	0.1943 (4.94)	--	--	0.162 (4.1)
7	0.1793 (4.55)	--	0.1875 (4.76)	0.1443 (3.67)
8	0.1644 (4.18)	0.1681 (4.27)	0.1719 (4.37)	0.1285 (3.26)
9	0.1495 (3.80)	0.1532 (3.89)	0.1563 (3.97)	0.1144 (2.91)
10	0.1345 (3.42)	0.1382 (3.51)	0.1406 (3.57)	0.1019 (2.59)
11	0.1196 (3.04)	0.1233 (3.13)	0.1250 (3.18)	0.0907 (2.30)
12	0.1046 (2.66)	0.1084 (2.75)	0.1094 (2.78)	0.0808 (2.05)
13	0.0897 (2.28)	0.0934 (2.37)	0.0940 (2.40)	0.0720 (1.80)
14	0.0747 (1.90)	0.0785 (1.99)	0.0781 (1.98)	0.0641 (1.63)
15	0.0673 (1.71)	0.0710 (1.80)	0.0700 (1.80)	0.0570 (1.40)
16	0.0598 (1.52)	0.0635 (1.61)	0.0625 (1.59)	0.0508 (1.29)
17	0.0538 (1.37)	0.0575 (1.46)	0.0560 (1.40)	0.0450 (1.10)
18	0.0478 (1.21)	0.0516 (1.31)	0.0500 (1.27)	0.0403 (1.02)
19	0.0418 (1.06)	0.0456 (1.16)	0.0440 (1.10)	0.0360 (0.91)
20	0.0359 (0.91)	0.0396 (1.01)	0.0375 (0.95)	0.0320 (0.81)
21	0.0329 (0.84)	0.0366 (0.93)	0.0340 (0.86)	0.0280 (0.71)
22	0.0299 (0.76)	0.0336 (0.85)	0.0310 (0.79)	0.0250 (0.64)
23	0.0269 (0.68)	0.0306 (0.78)	0.0280 (0.71)	0.0230 (0.58)
24	0.0239 (0.61)	0.0276 (0.70)	0.0250 (0.64)	0.0200 (0.51)
25	0.0209 (0.53)	0.0247 (0.63)	0.0220 (0.56)	0.0180 (0.46)
26	0.0179 (0.45)	0.0217 (0.55)	0.0190 (0.48)	0.0170 (0.43)
28	0.0149 (0.38)	0.0187 (0.47)	0.0160 (0.41)	0.0126 (0.32)

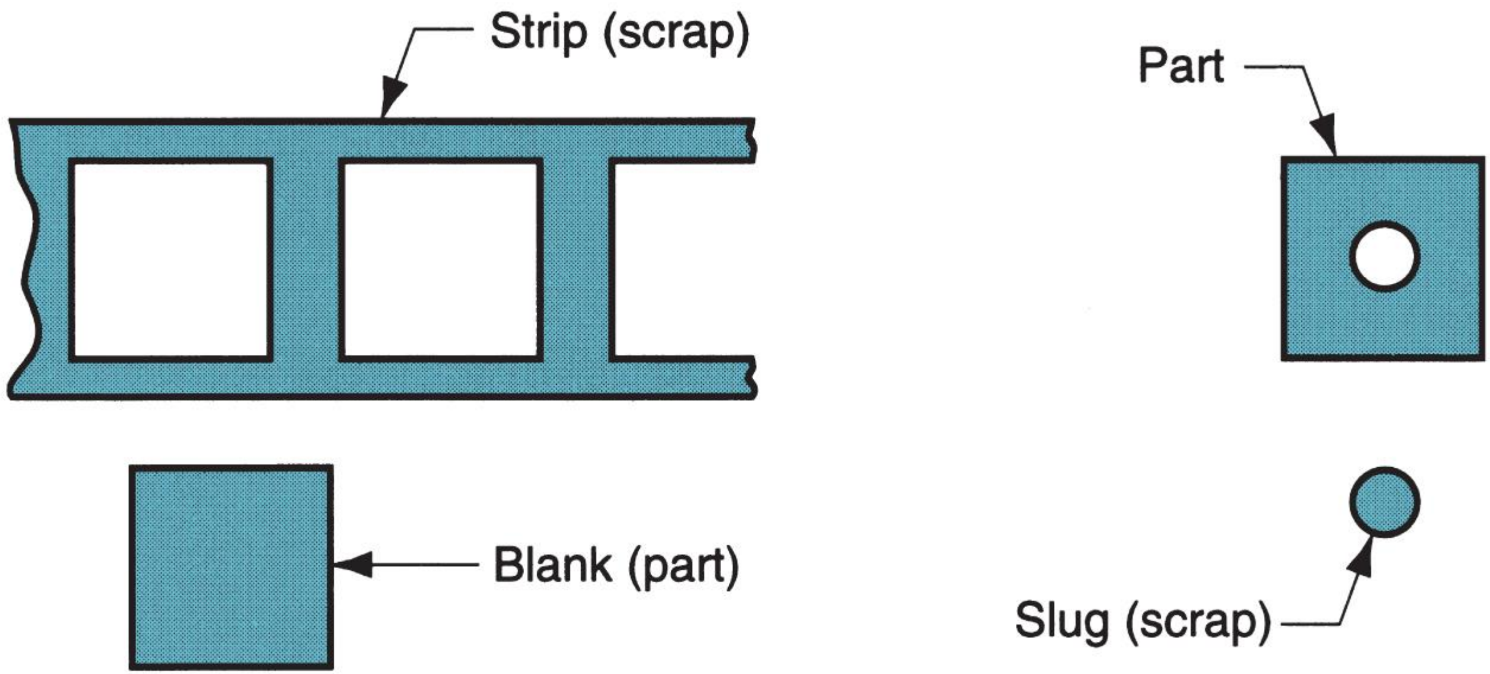
Star sheet

www.pinterest.com

5.1 Stamping: shearing







(a) (b)

Shearing analysis: force F? power P?

$$P = FV \qquad (\text{since } F//V)$$

Fs: shearing force

As: sheared area

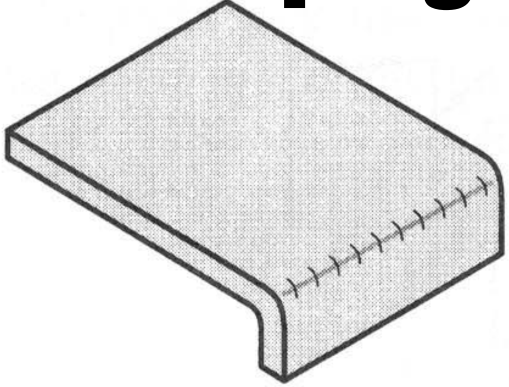
Ss: shear strength

Su: tensile strength

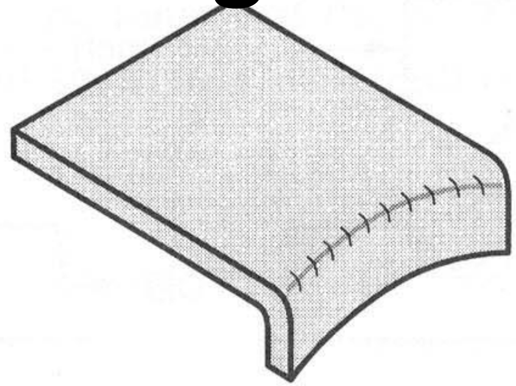
P: power

v: speed

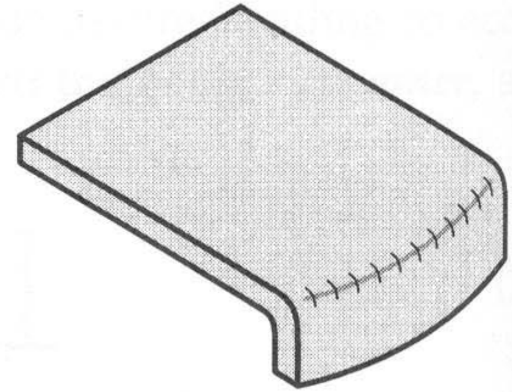
5.2 Stamping: bending



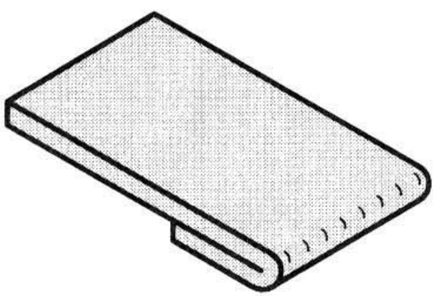
Straight flanging



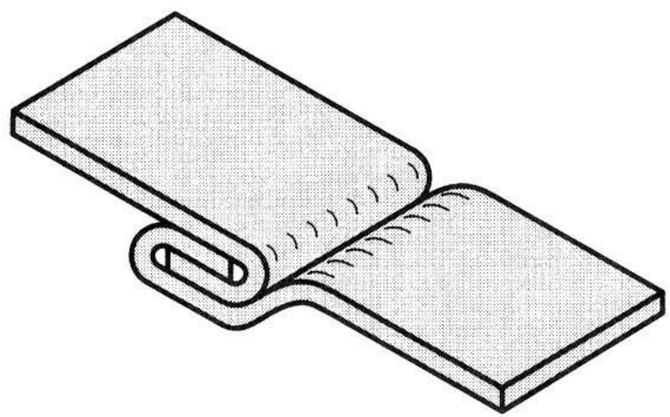
stretch flanging



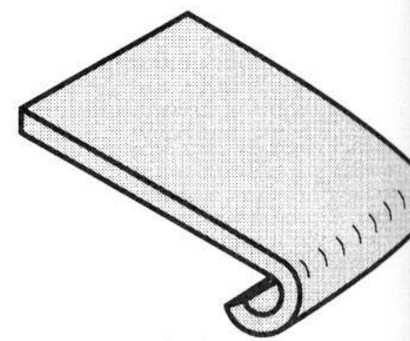
shrink flanging



Hemming

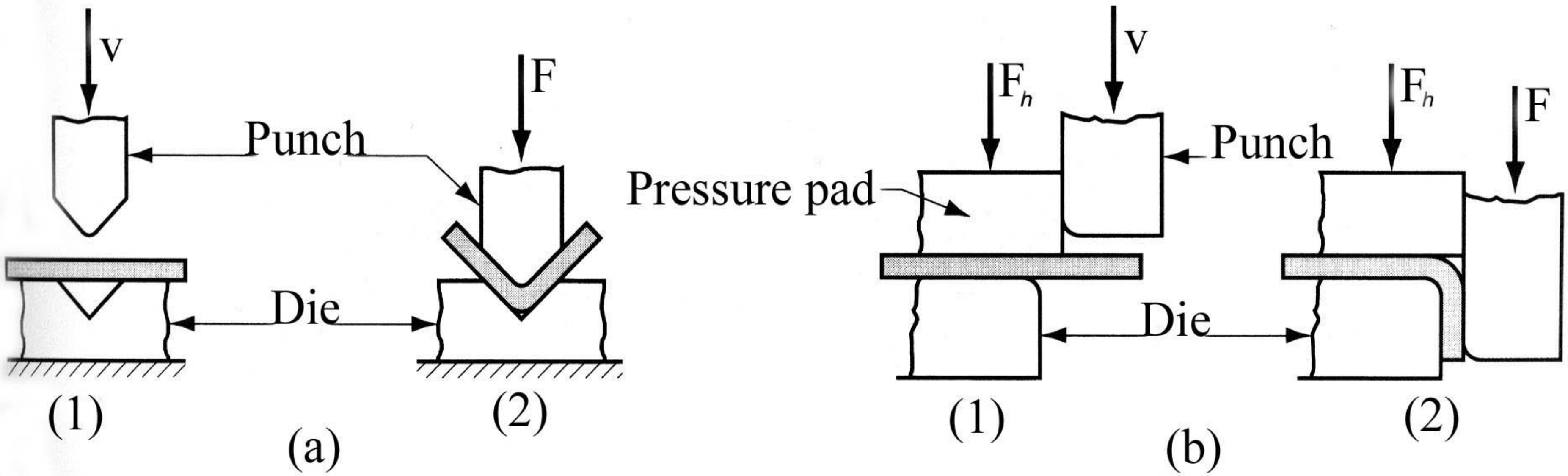


seaming



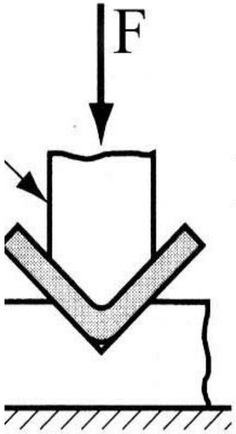
curling

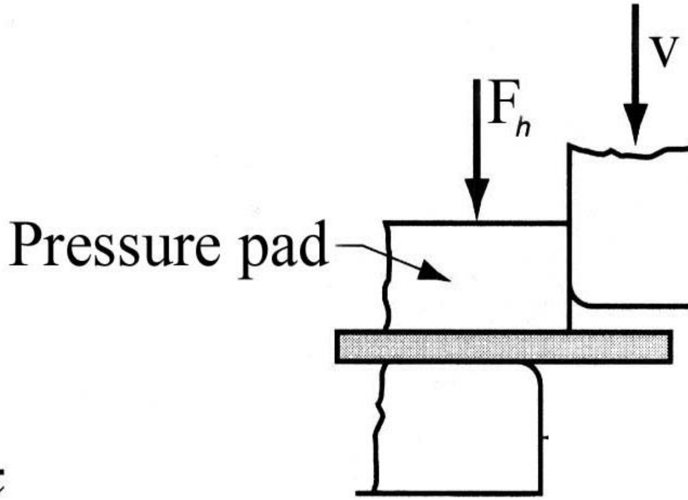
5.2 Stamping: bending



Bending analysis:

shearing force F, power P?





$$P = FV \quad \text{(since F//V)}$$

$$F = \frac{K S_u w t^2}{D}$$

F: bending force

S_u: tensile strength

w: sheet width

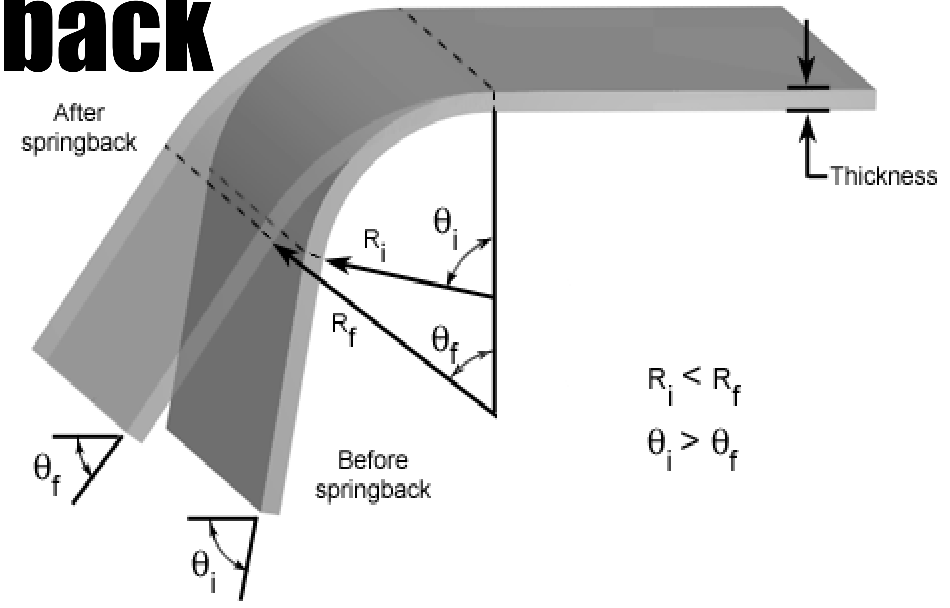
t: sheet thickness

D: die opening

K: constant

5.2 Stamping: spring back

http://riiskadesign.com/spring-back-bankers-chair



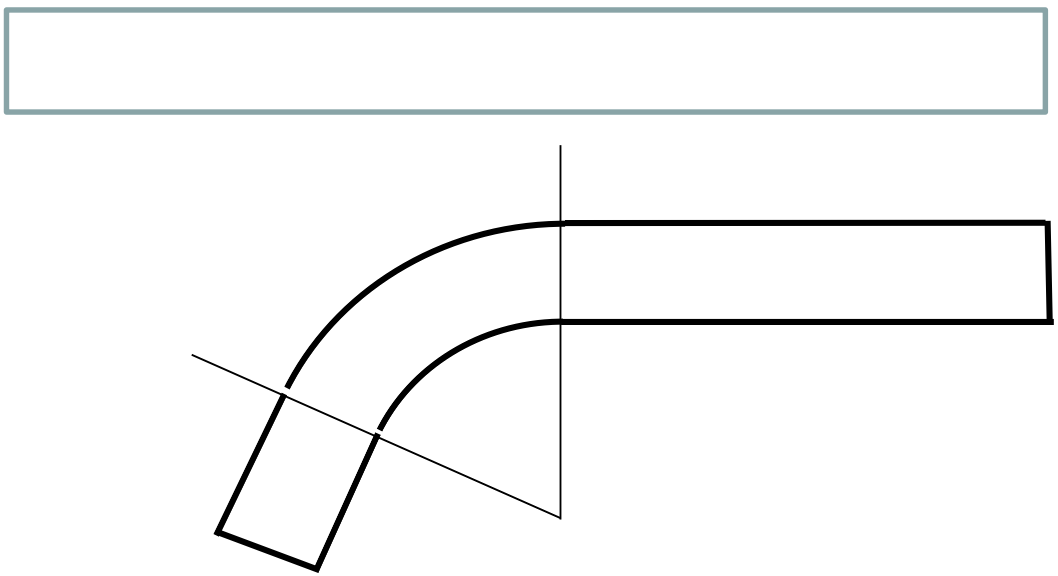
http://www.custompartnet.com/wu/sheet-metal-forming

Springback
- Elastic recovery
- Unavoidable
- Correctable

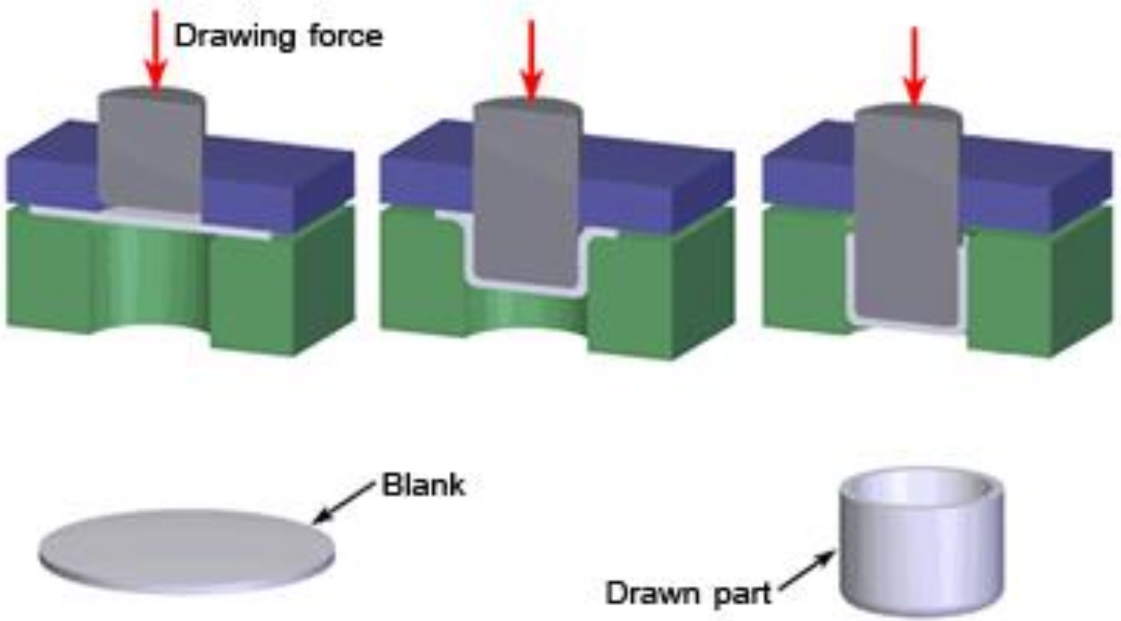
Correction
- Overbending
- Bottoming
- Annealing

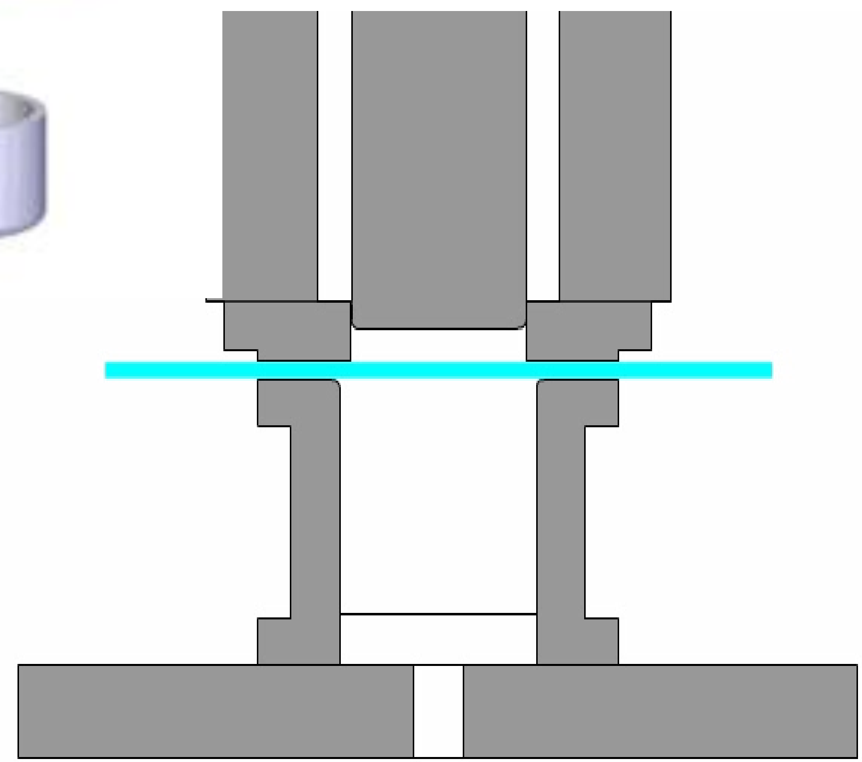
5.2 Stamping: bend allowance

- Starting dimension before bending
- Small bending radius→ stretching rod/sheet
- Correct with bending allowance



5.3 Stamping: (cup) drawing





http://technote-ashok.blogspot.com/2011_01_01_archive.html

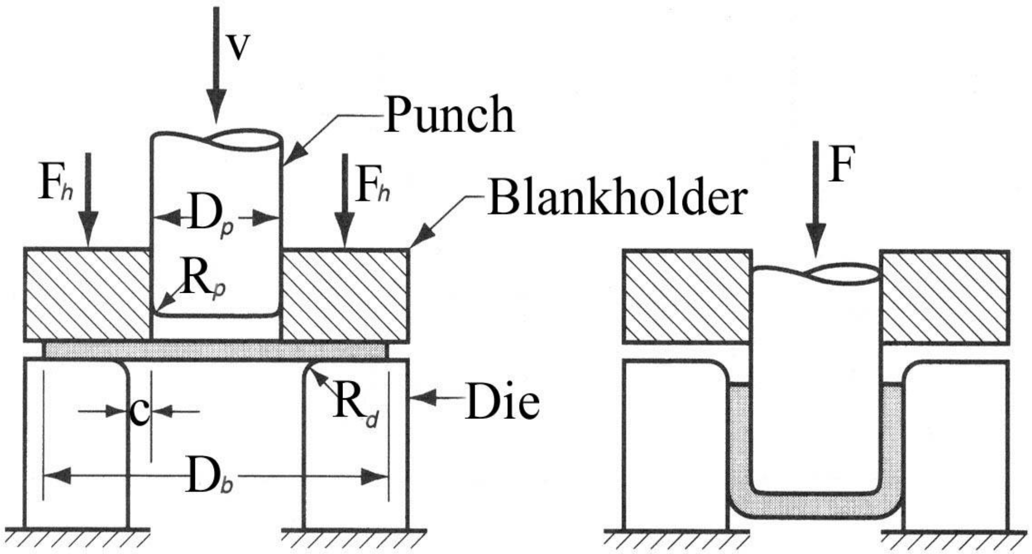
Cup drawing analysis: force F? power P?

$$F_h = 0.015\pi S_y \left[D_b^2 - \left(D_p + 2.2t + 2R_d\right)^2\right]$$

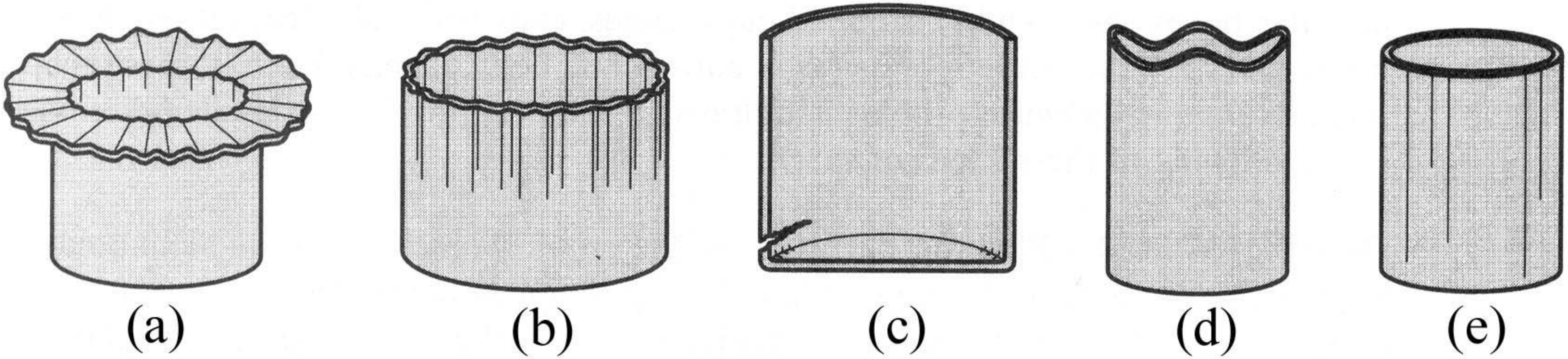
$$F = \pi D_p t S_u \left(\frac{D_b}{D_p} - 0.7\right)$$

$$P = FV \qquad \text{(since F//V)}$$

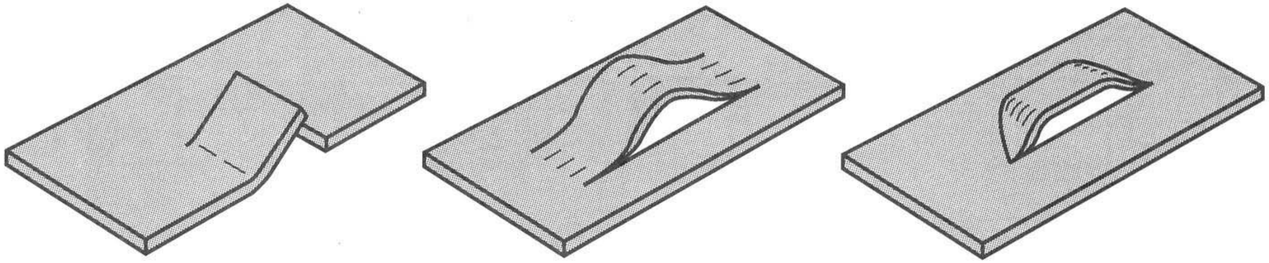
F: drawing force
F_h: holding force
S_y, S_u: yield, tensile strength
D_b, D_p: blank, punch diameter
t: sheet thickness
R_d: die radius

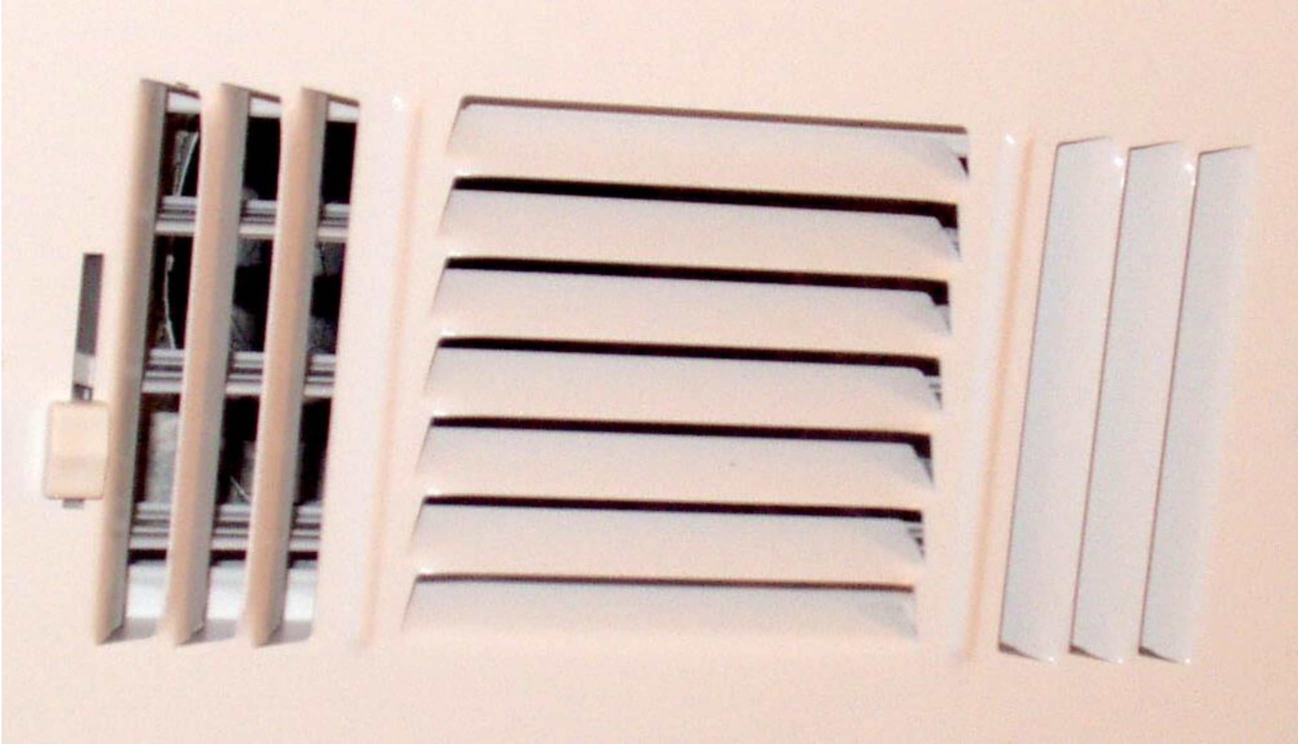


Cup drawing defects



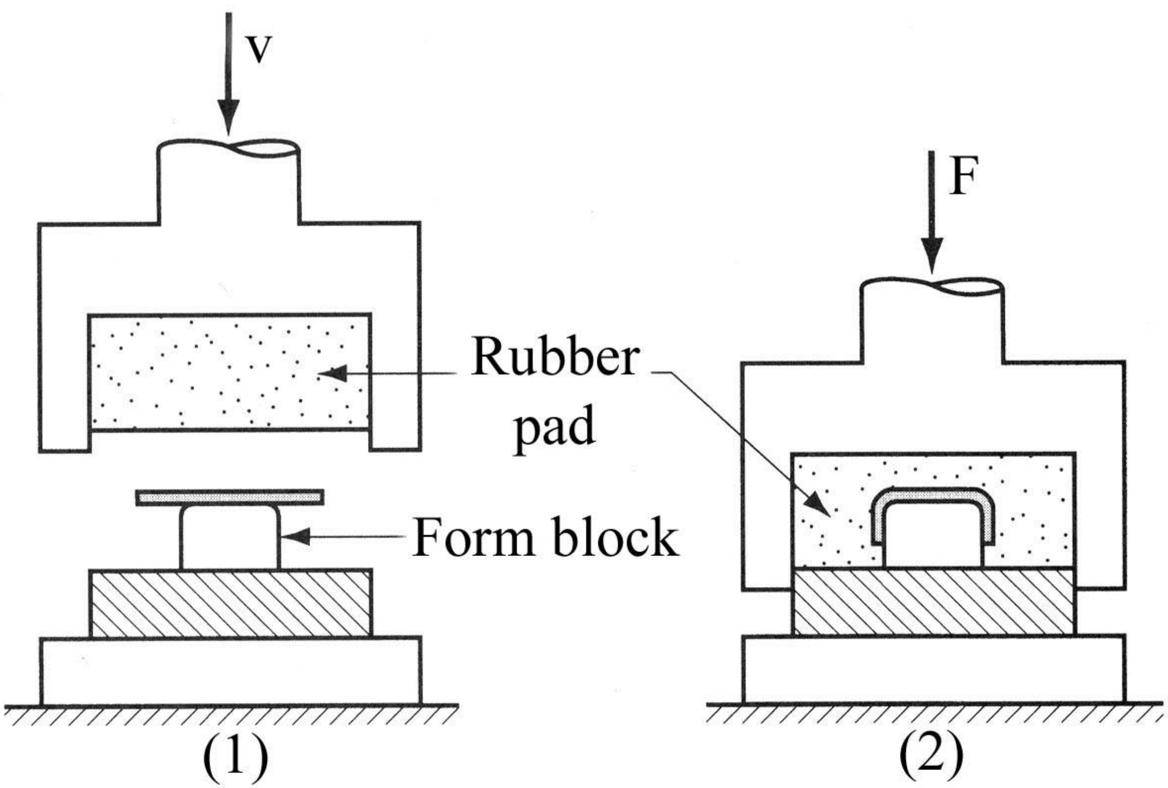
5.4 Stamping: lancing





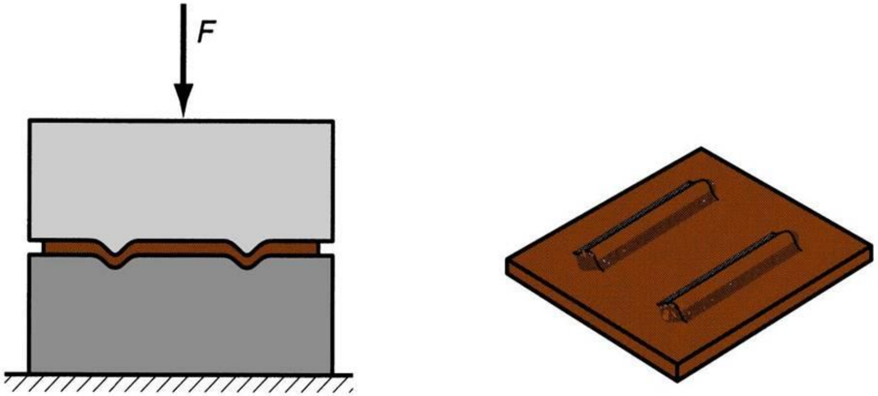
5.5 Stamping: rubber (Guerin) forming

- ✓ Simpler than cup drawing, forging, lower cost, prototyping
- – Wear/tear of rubber, simple shape only, thin sheet only

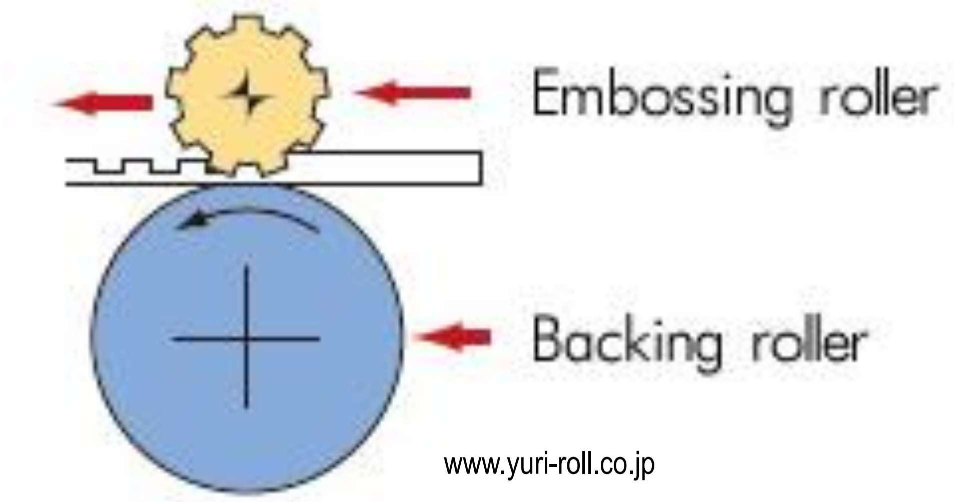


5.6 Stamping: embossing

- To deform and form raised/indented features on thin sheet.
- Another version of forging, rolling, or cup drawing



(a) www.quia.com (b)



Lec 5: Material Removal Processes

A. Traditional techniques

A1. Overview and machining theory
- A1.1 Chip formation
- A1.2. Mechanics of machining

A2. Processes
- A2.1. Lathe operations
- A2.2. Mill and drill operations
- A2.3. Other operations
- A2.4. Process planning
- A2.5. Cutting tools and cutting fluids

B. Nontraditional techniques

B1. Overview

B2. Processes
- B2.1. Water jet and abrasive water jet
- B2.2. Electrochemical machining
- B2.3. Electrical discharge machining
- B2.4. Energy beam machining
- B2.5. Chemical etching and photochemical etching

C. Finishing techniques

C1. Overview

C2. Processes
- C2.1. Grinding and honing
- C2.2. Lapping
- C2.3. Polishing
- C2.4. Deburring
- C2.5. Surface treatment processes

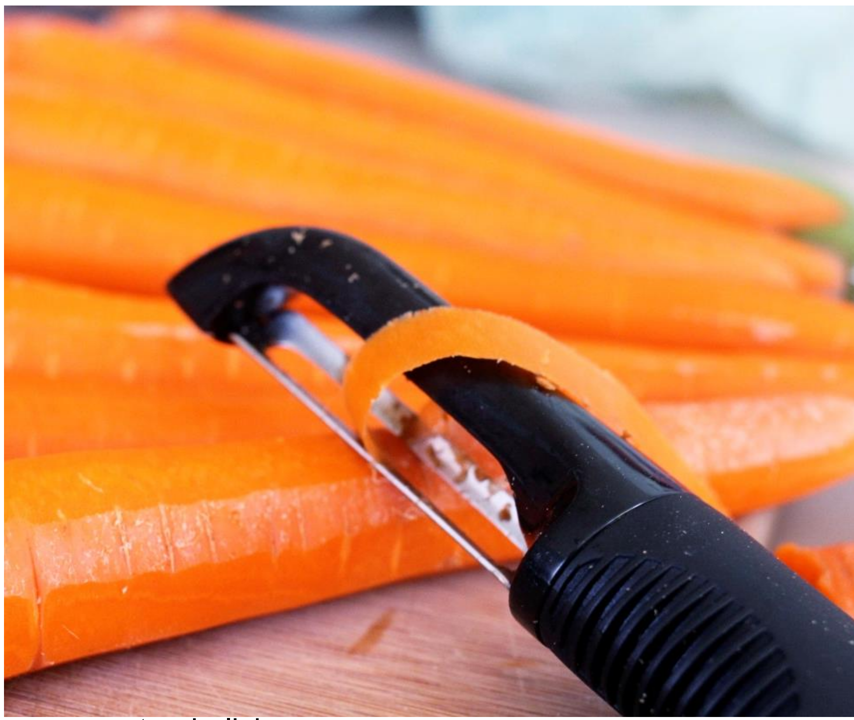
A. Classification

- **Traditional**
  - Turning, facing, grooving, threading…
  - Milling, tapping, boring…
  - Sawing, drilling…
- **Non-traditional**
  - Laser, ion beam, electron beam machining…
  - Electrochemical, electrical discharge …
  - Water jet, chemical etching plasma cutting…
- **Finishing**
  - Grinding, honing
  - Lapping, polishing, deburring…
  - Chemical mechanical polishing, sputtering…

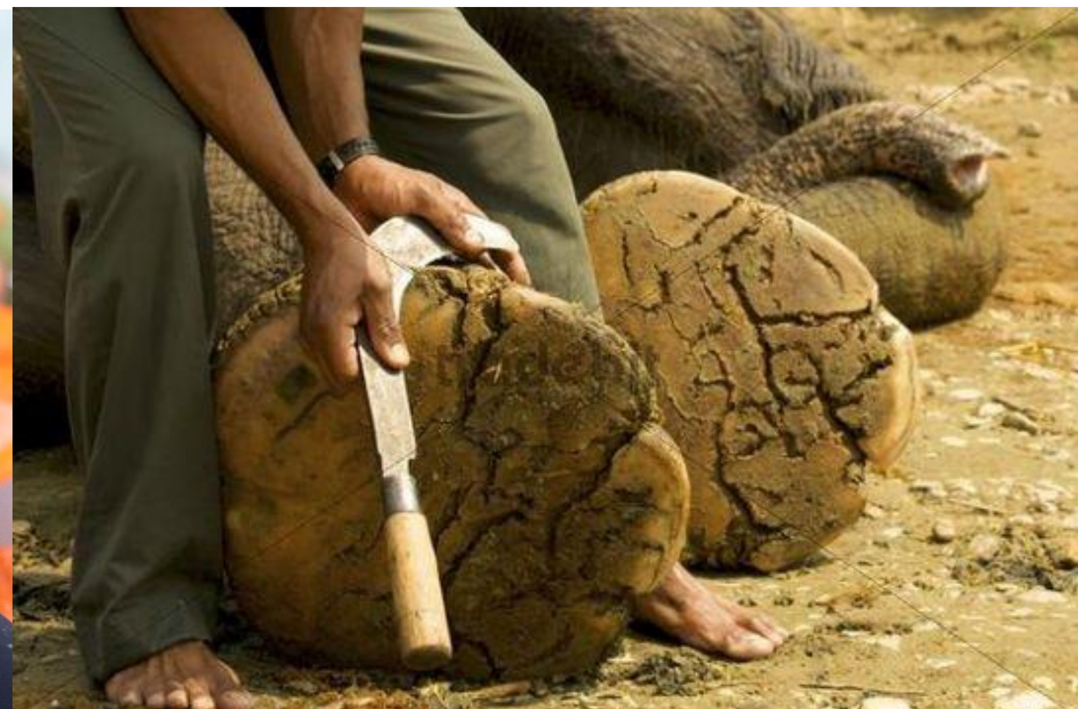
A1. Theory

Orthogonal cutting

- 2D
- Straight cutting edge
- Cutting edge ⊥ cutting direction

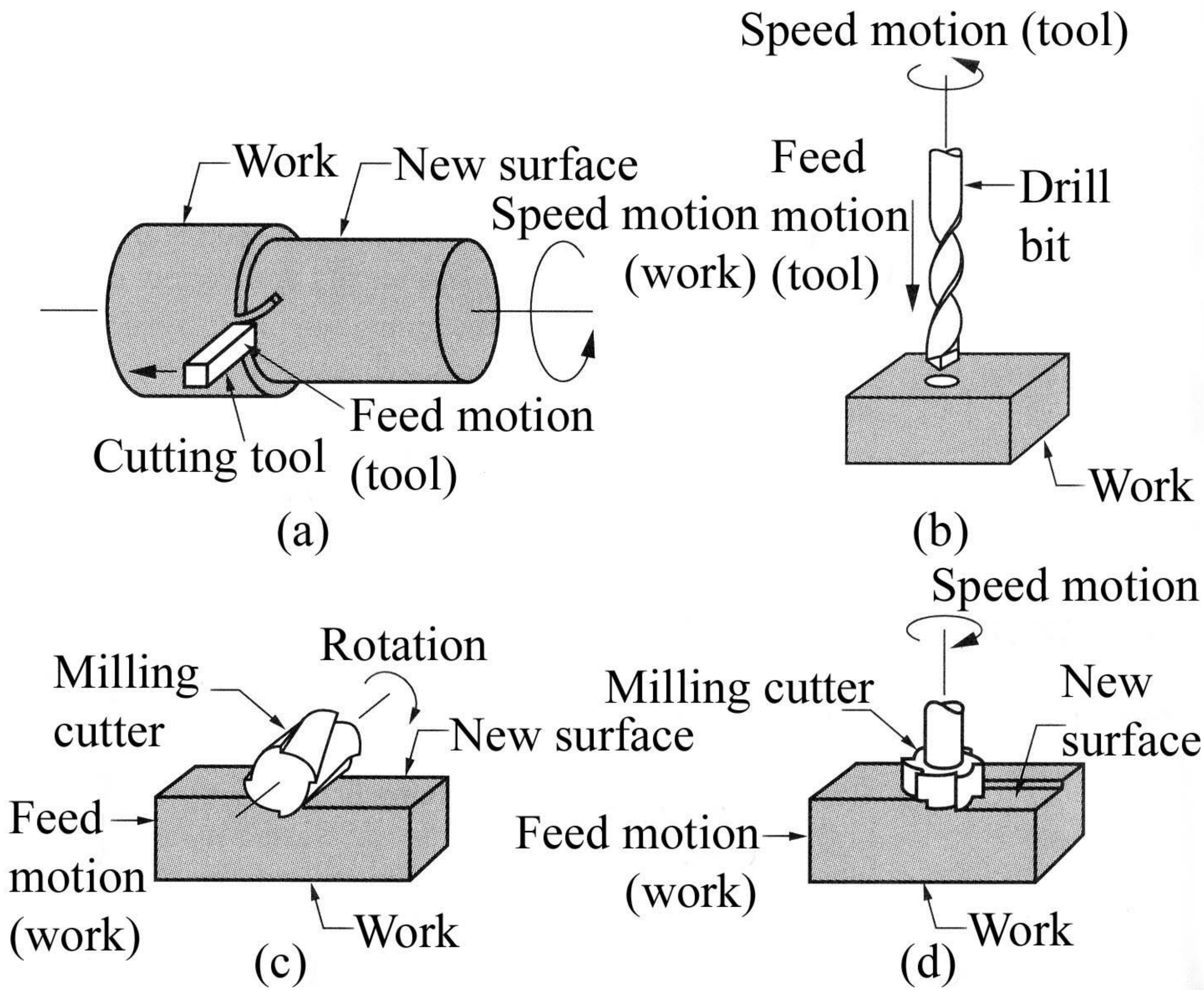


eatandrelish.com

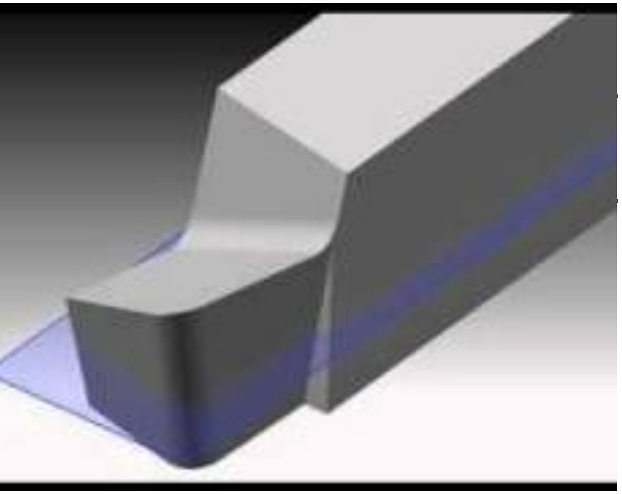


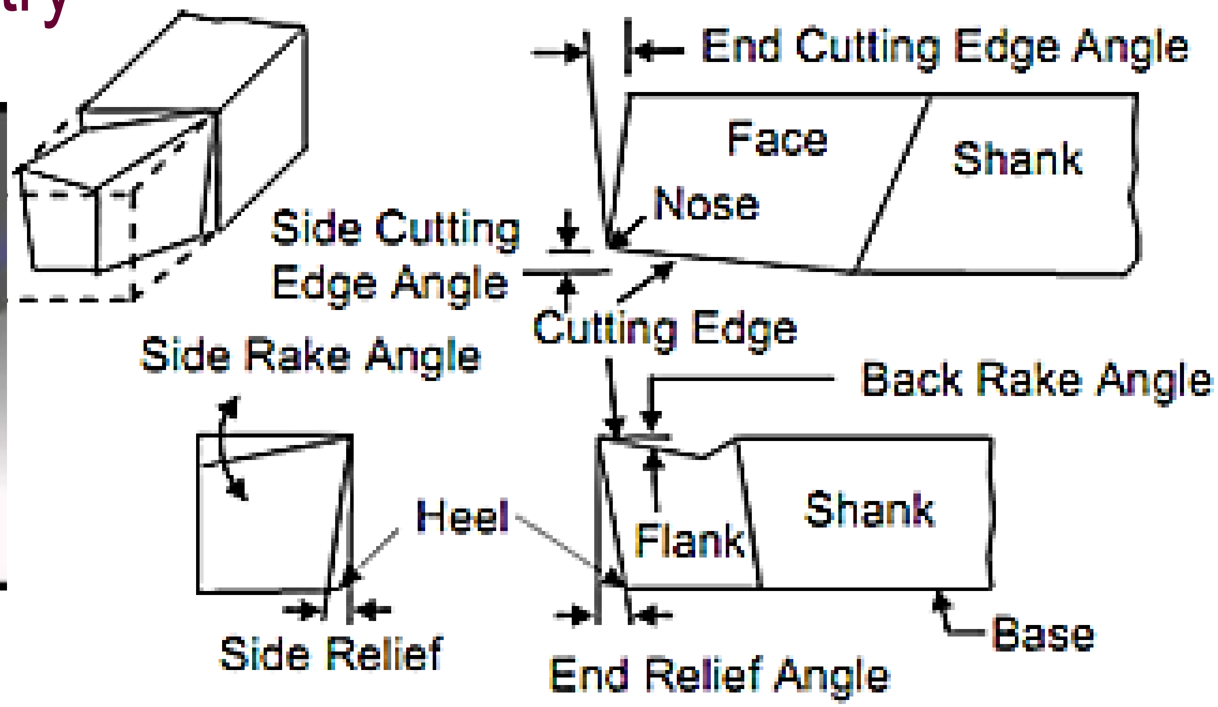
www.tradebit.com

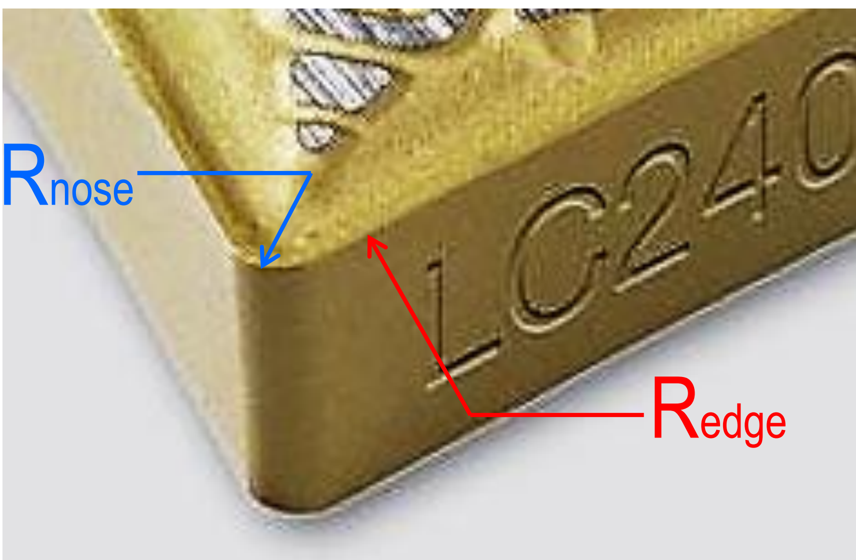
A. Traditional technique

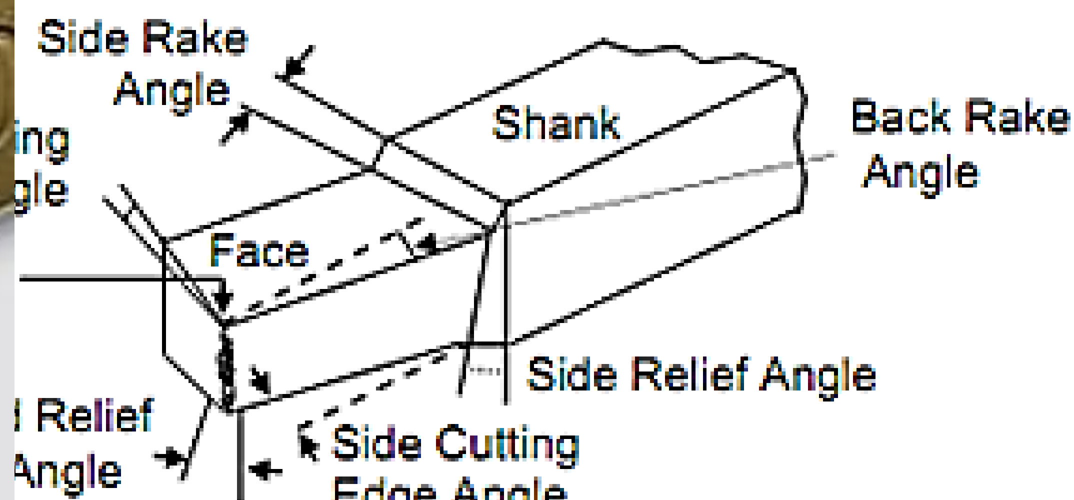


Cutting tool geometry



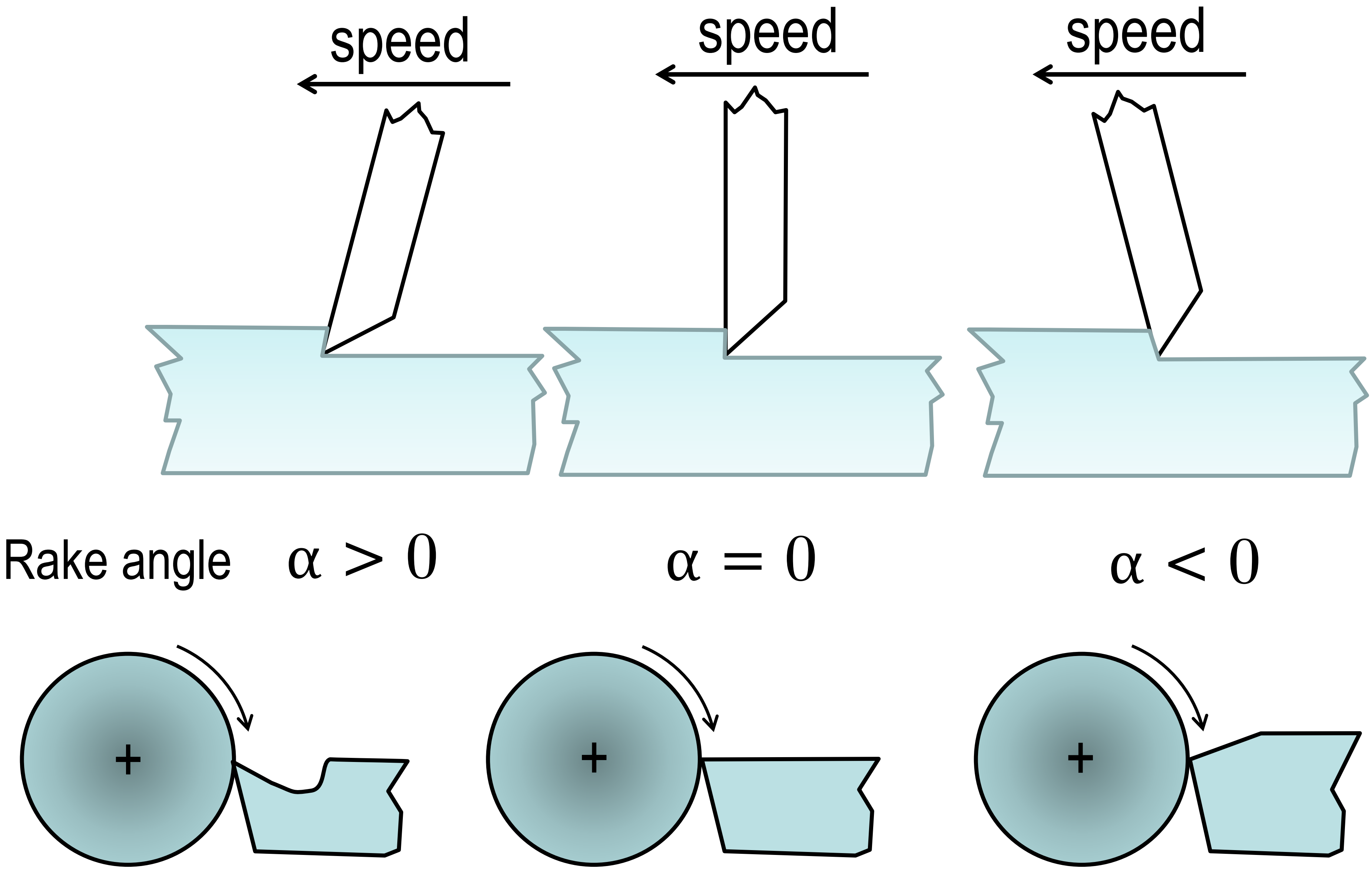






https://i.ytimg.com/vi/Mn9jpqI8rao/mqdefault.jpg

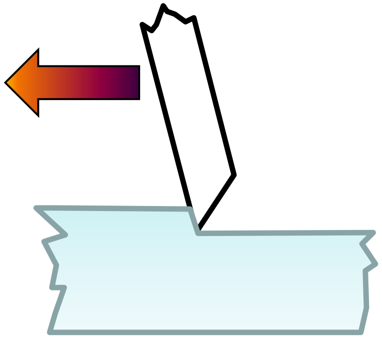
www.expertsmind.com


speed
speed
speed
Rake angle
$\alpha > 0$
$\alpha = 0$
$\alpha < 0$

EFFECT OF (back) RAKE ANGLE

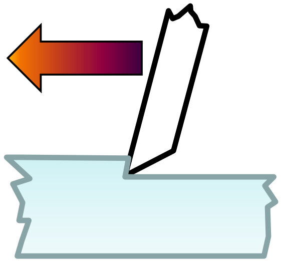
<u>Tool with negative rake:</u>

- Has blunt but strong cutting edge
- Deforms material in front and below the tool
- Produces low shear angle



<u>Tool with positive rake:</u>

- Has sharp yet fragile cutting edge
- Produces high shear angle
- Produces uniform chip



Chip formation and BUE

0° rake

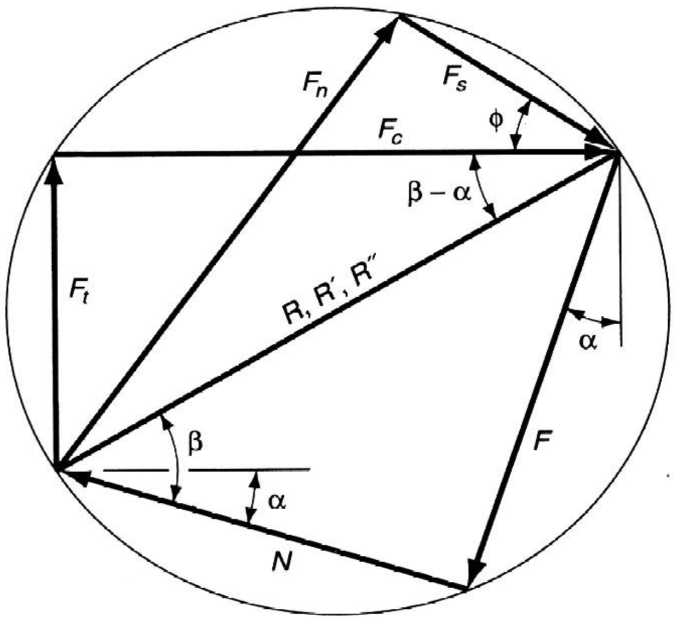
+45° rake

-20° rake

[Chip formation.wmv](http://www.youtube.com/watch?v=mRuSYQ5Npek) by Rick Steinard (Iscar)
http://www.youtube.com/watch?v=mRuSYQ5Npek

[Built up edge.mpg](http://www.youtube.com/watch?v=uwh3ouvzSLk) by Phuc Pheo
http://www.youtube.com/watch?v=uwh3ouvzSLk

A1.2. Mechanics: Merchant's circle and equation



- Orthogonal machining
- Cutting force
- Cutting power

$$\vec{R} = \overrightarrow{F_c} + \overrightarrow{F_t}$$
$$= \overrightarrow{F_s} + \overrightarrow{F_n}$$
$$= \vec{F} + \vec{N}$$

$$\mu = tan\beta = \frac{F}{N}$$

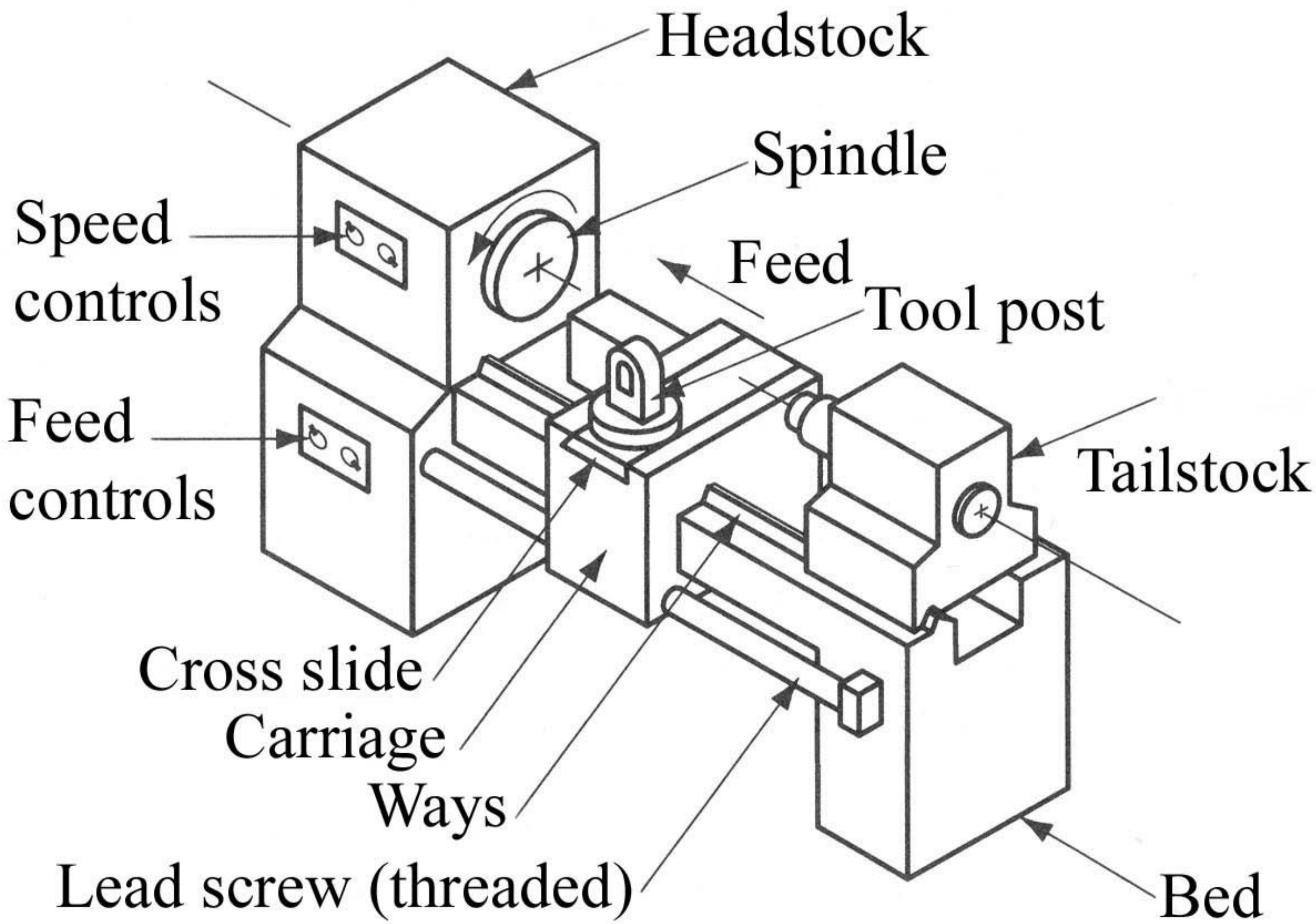
$$\emptyset = 45° + \frac{\alpha}{2} - \frac{\beta}{2}$$

Cutting force measurement

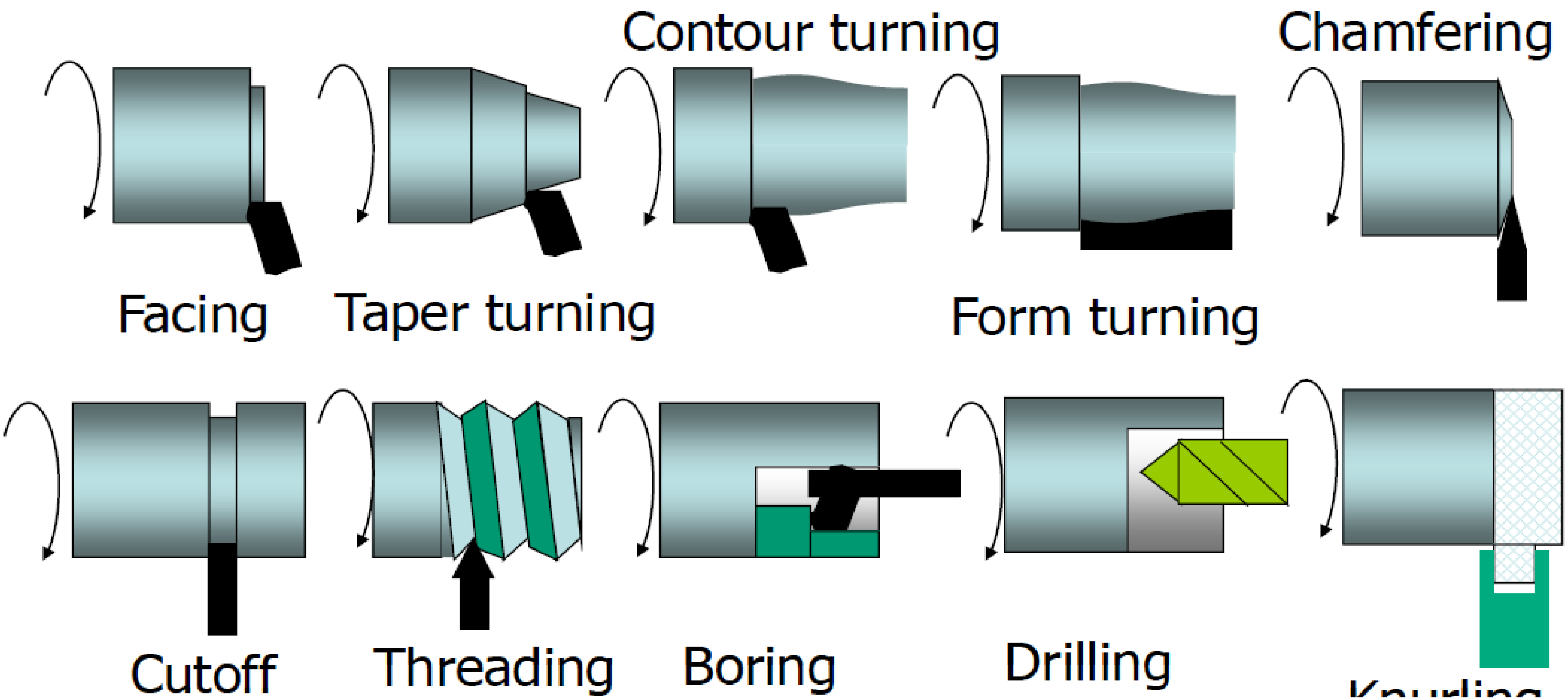
Piezzo-dynamometer

www.kistler.com

A2.1. Lathe operations



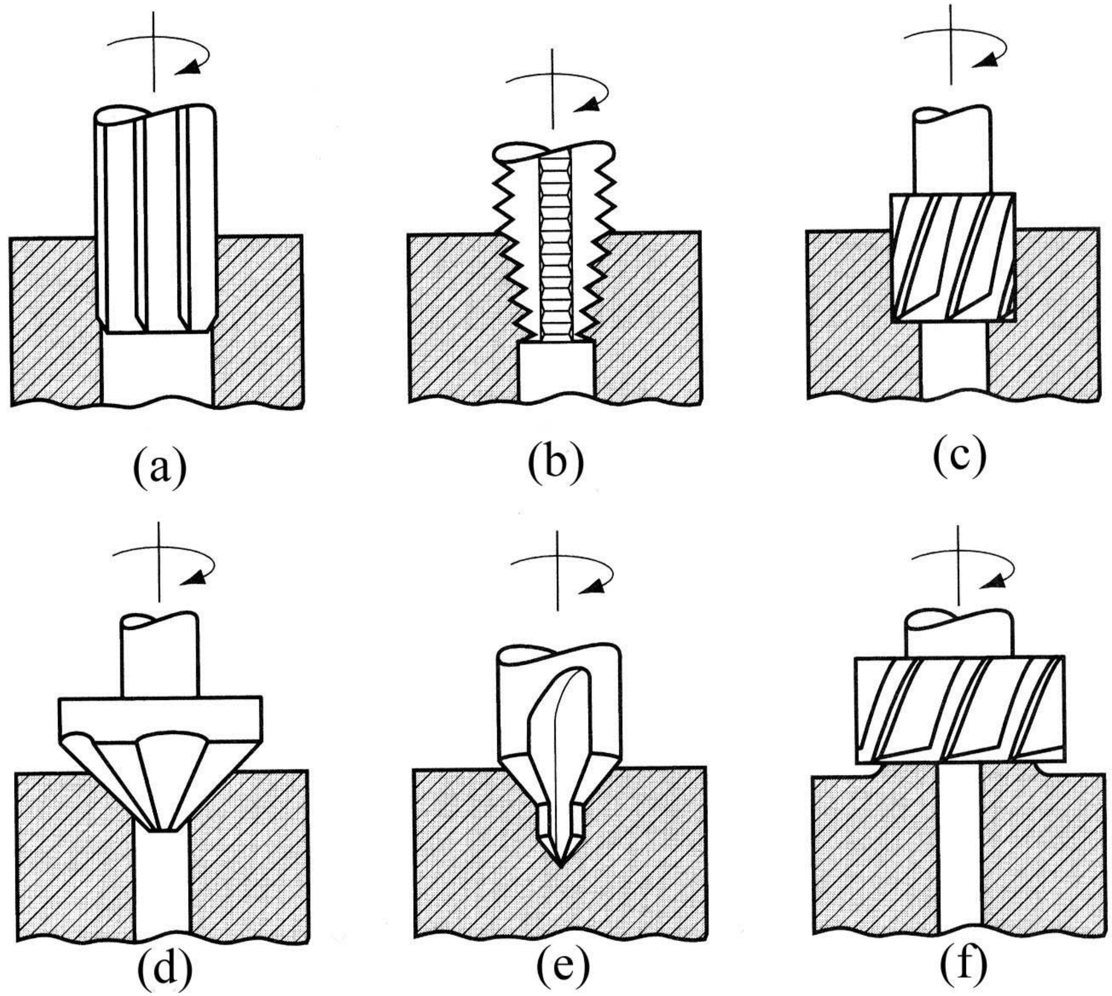
Operations related to Turning



A2.2. Similar processes

Hole making:

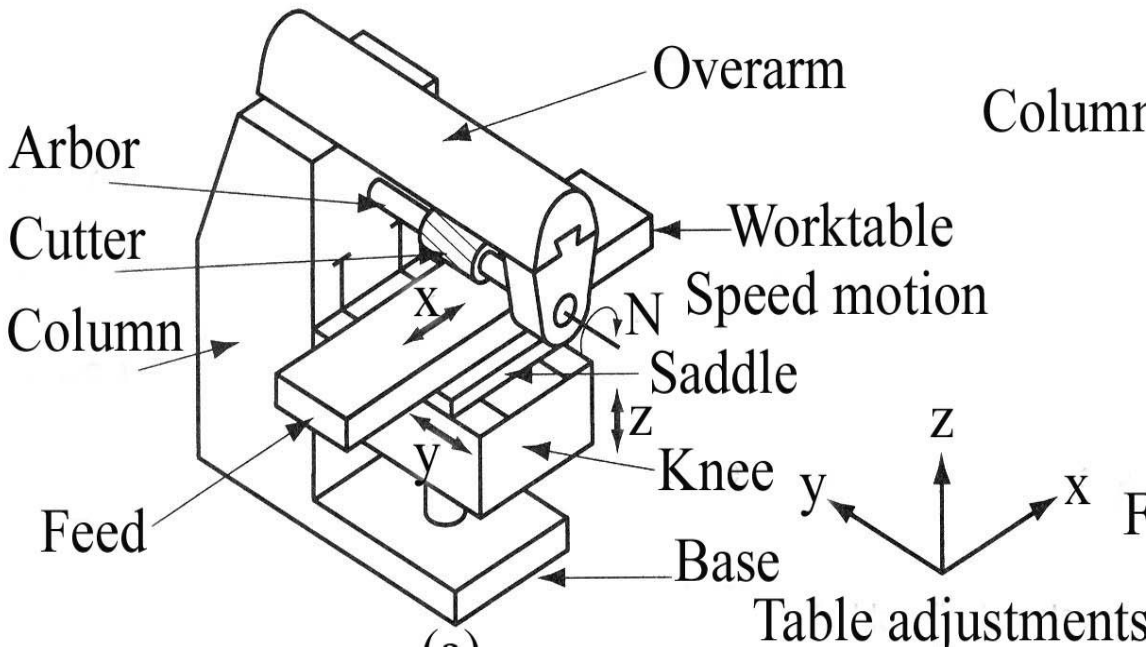
1. Center drill
2. Drill
3. Bore to size
4. Ream
5. Hone
6. Deburr

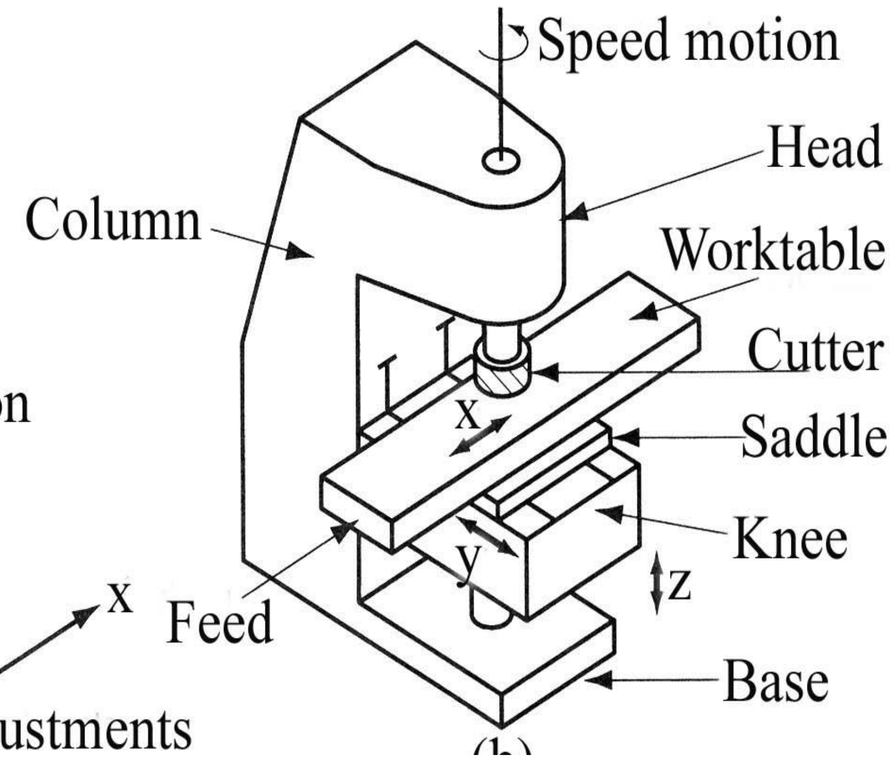


Drill tap chart

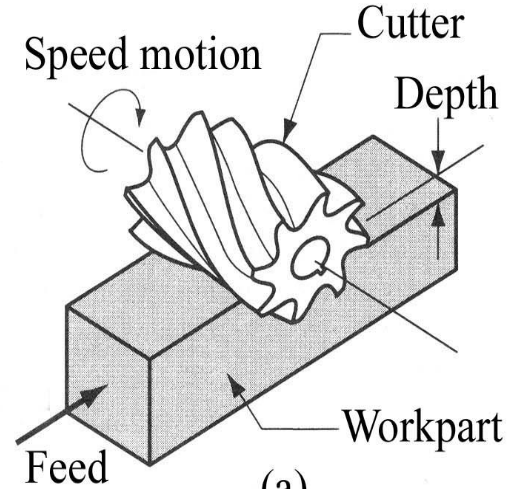
Thread Size	Threads Per Inch	Thread Designation	Tap Drill Size	Decimal Equiv.	Theoretical % Thread Engagement	Major Diameter (inches)	Pitch Diameter (inches)	Minor Diameter (inches)	Stress Area of Installed Fastener (sq. in.)
12	**24**	**UNC**	**16**	0.1770	72%	0.2160	0.1889	0.171	0.0242
	28	**UNF**	**14**	0.1820	73%		0.1928	0.177	0.0258
	32	UNEF	3/16	0.1875	70%		0.1957	0.182	0.0270
1/4	**20**	**UNC**	**7**	0.2010	75%	0.2500	0.2175	0.196	0.0318
	28	**UNF**	**3**	0.2130	80%		0.2268	0.211	0.0364
	32	UNEF	7/32	0.2188	77%		0.2297	0.216	0.0379
5/16	**18**	**UNC**	**F**	0.2570	77%	0.3125	0.2764	0.252	0.0524
	20	UN	17/64	0.2656	72%		0.2800	0.258	0.0547
	24	**UNF**	**I**	0.2720	75%		0.2854	0.267	0.0581
	28	UN	J	0.2770	77%		0.2893	0.274	0.0606
	32	UNEF	9/32	0.2813	77%		0.2922	0.279	0.0625
3/8	**16**	**UNC**	**5/16**	0.3125	77%	0.3750	0.3344	0.307	0.0775
	20	UN	21/64	0.3281	72%		0.3425	0.321	0.0836
	24	**UNF**	**Q**	0.3320	79%		0.3479	0.330	0.0878
	28	UN	R	0.3390	78%		0.3518	0.336	0.0909
	32	UNEF	11/32	0.3438	77%		0.3547	0.341	0.0932

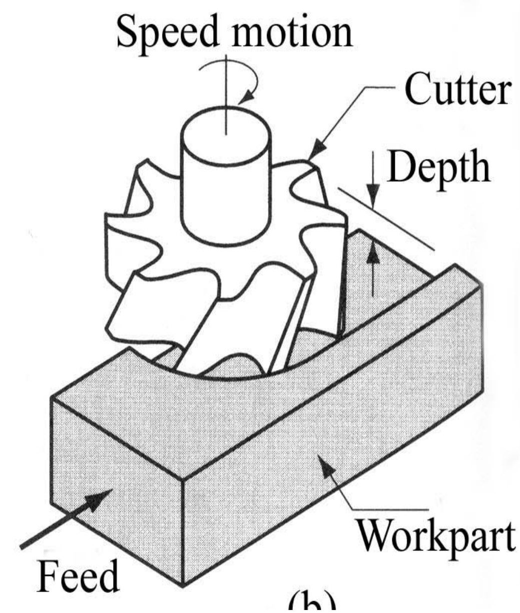
A2.2. Milling





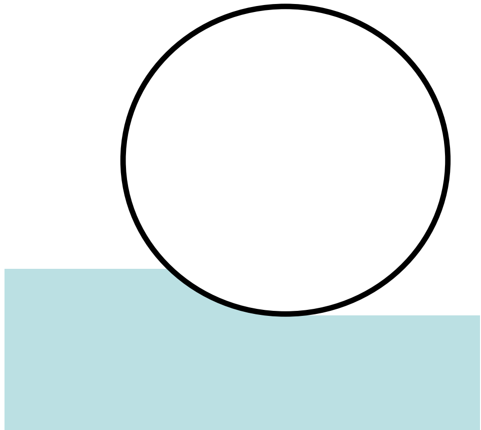
Horizontal Peripheral /side milling



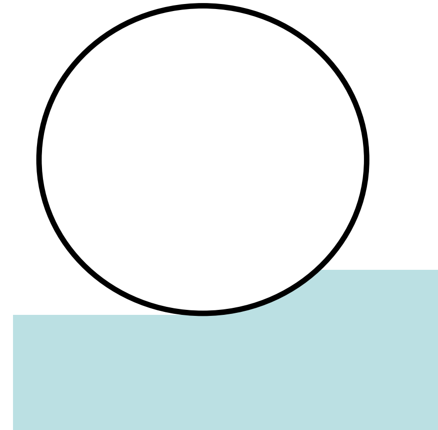


Vertical Face /end milling

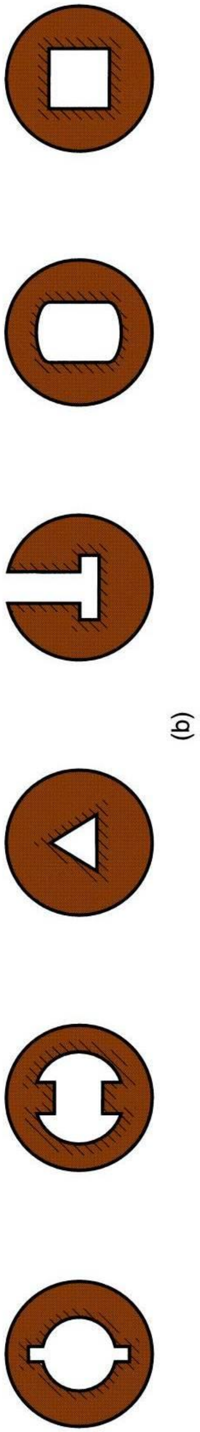
Milling analysis



Up milling
(conventional milling)

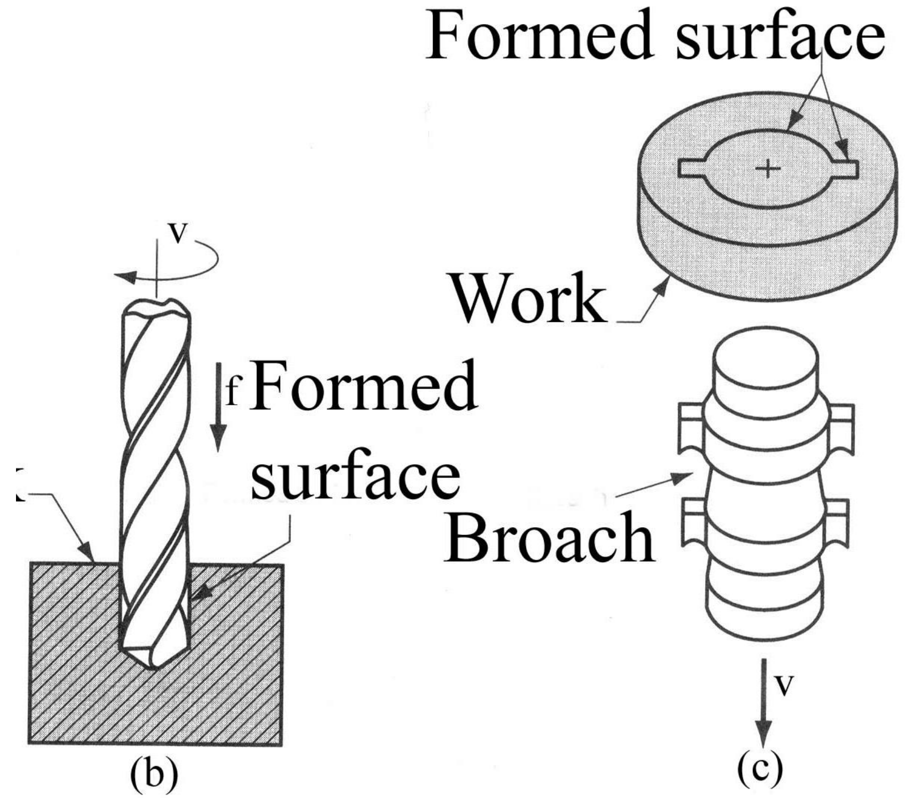


Down milling
(climb milling)



A2.3. Broaching

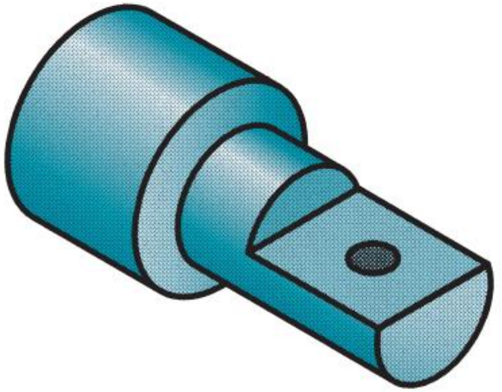
- Add features to a drilled hole
- Make non-circular hole

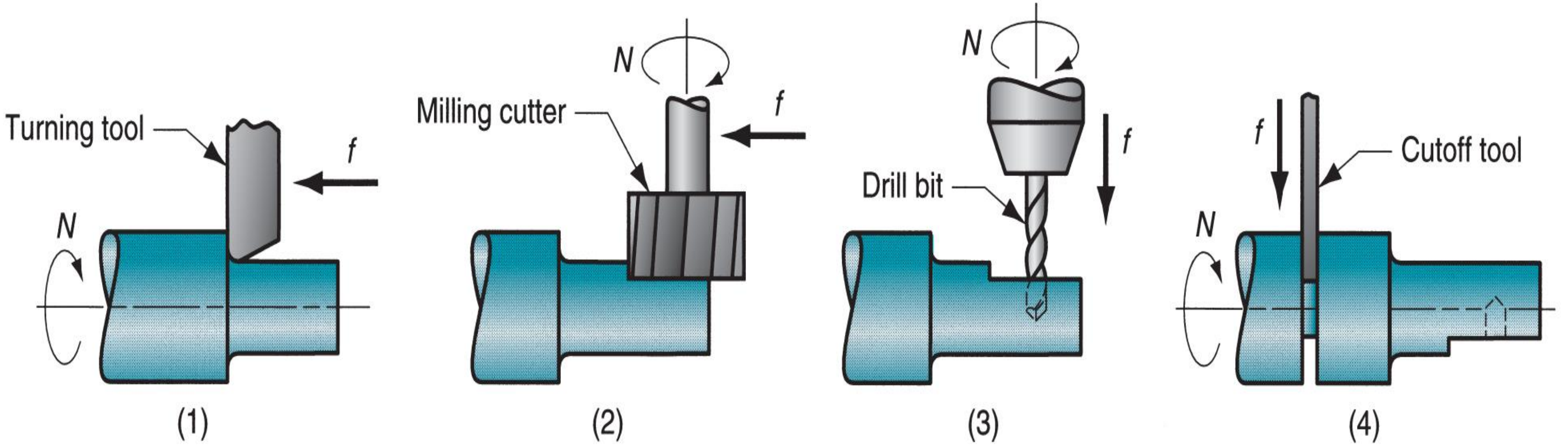


A2.4. Process plan

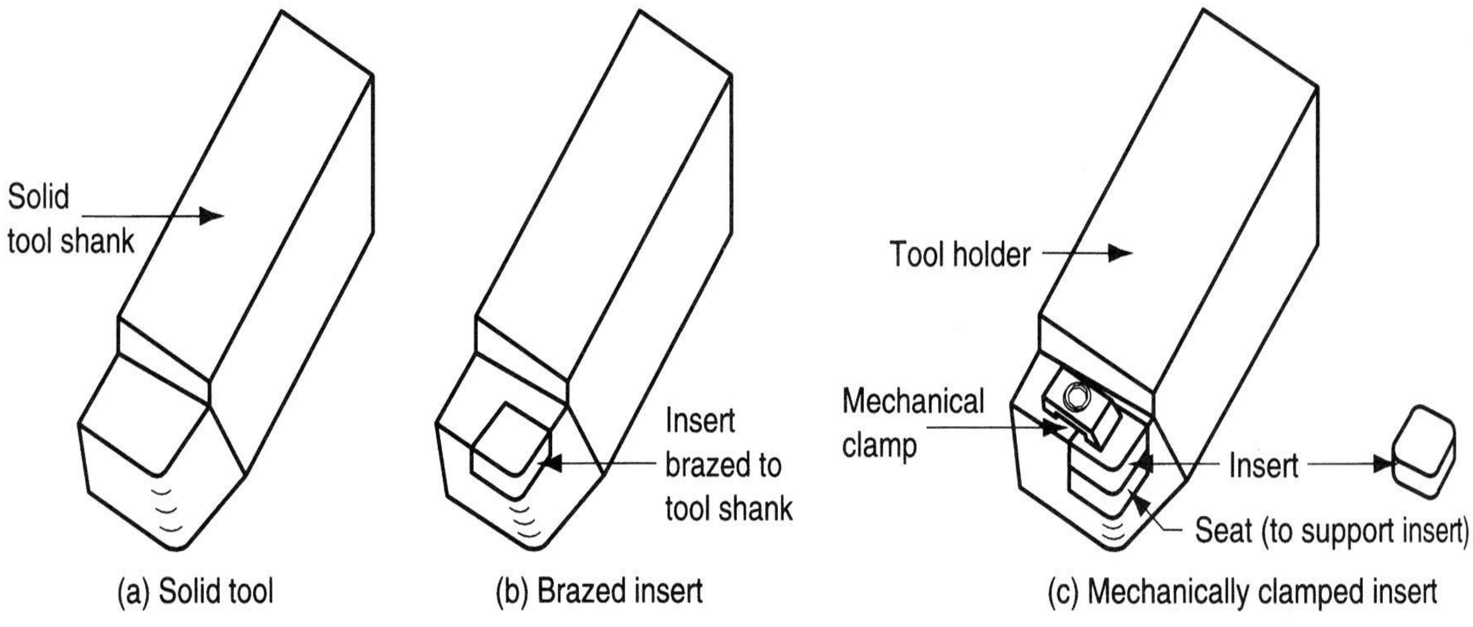
Step-by-step instructions to fabricate a part:

- Graphical illustration
- Tools, tool offset, tool sequence…
- Cutting speed, feed, depth of cut…
- Coolant / lubricant
- Deburring, packaging



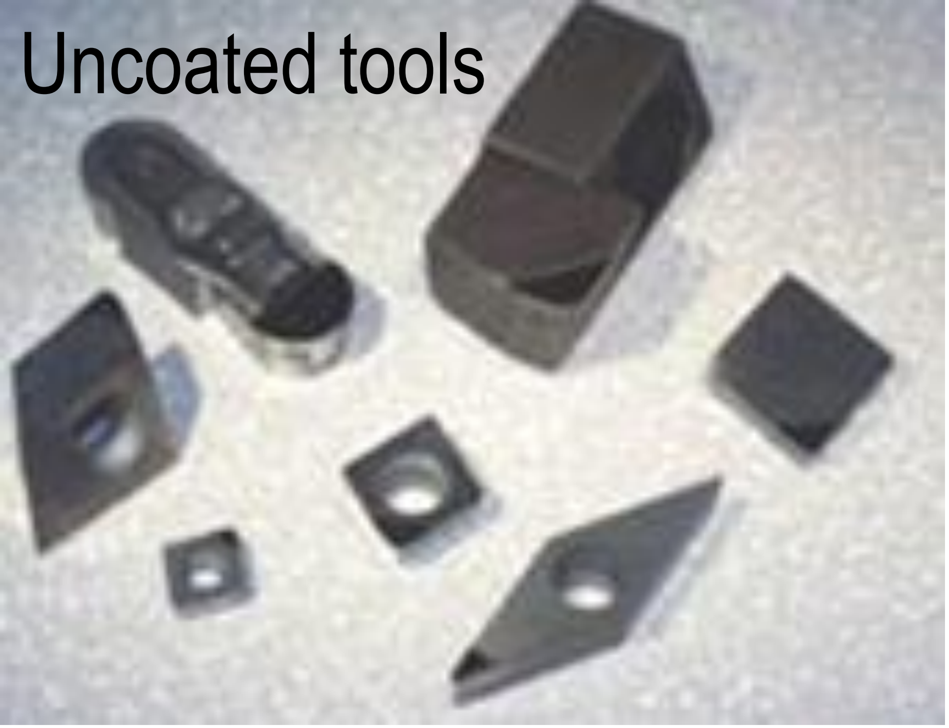


A2.5a. Cutting tools

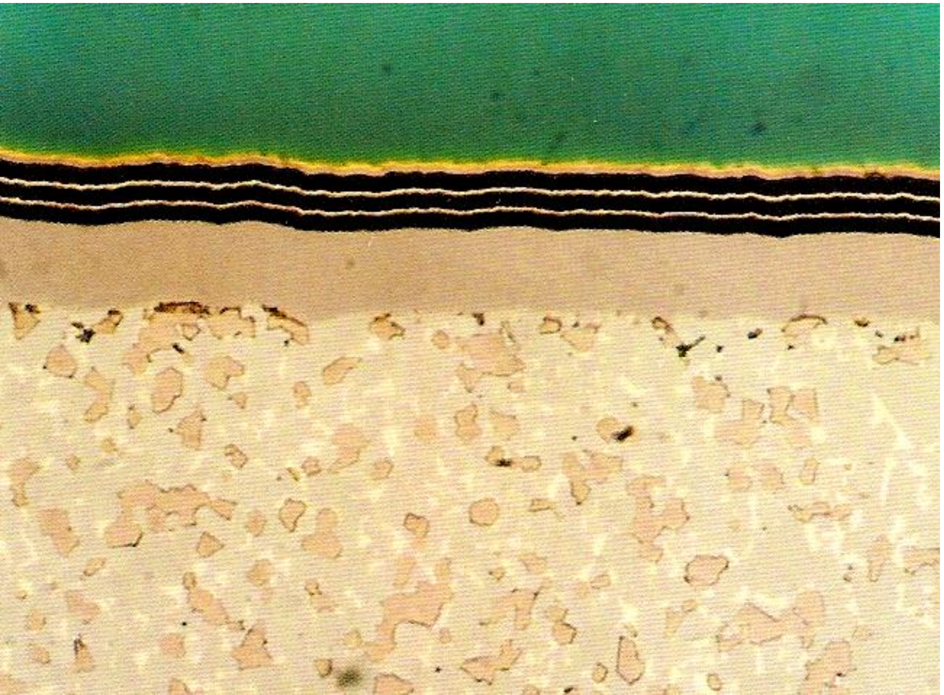


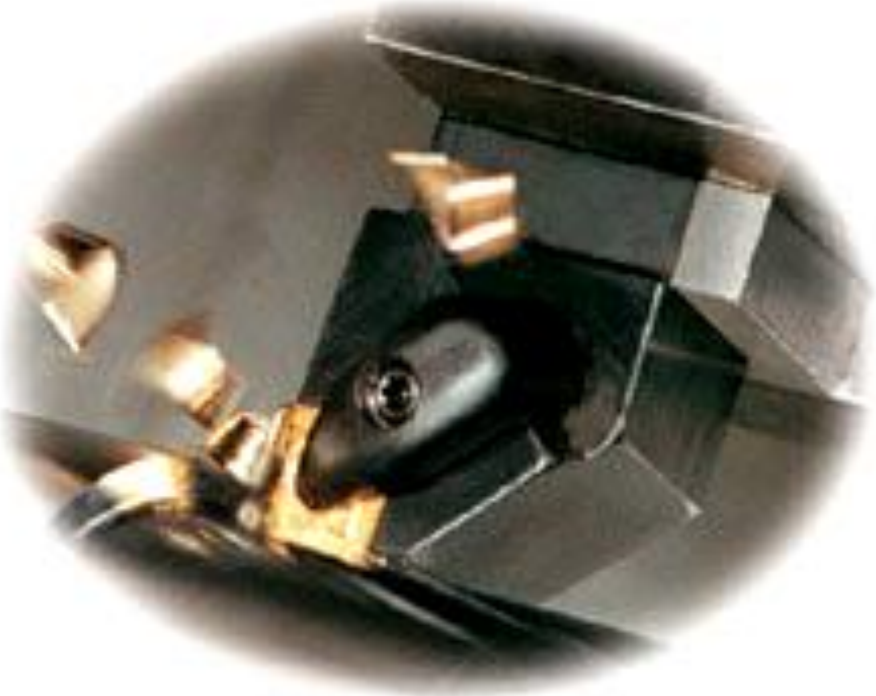
- Tool failure: wear, fracture, burnt…
- Tool life: machining distance, or time to replace a worn-out cutting tool

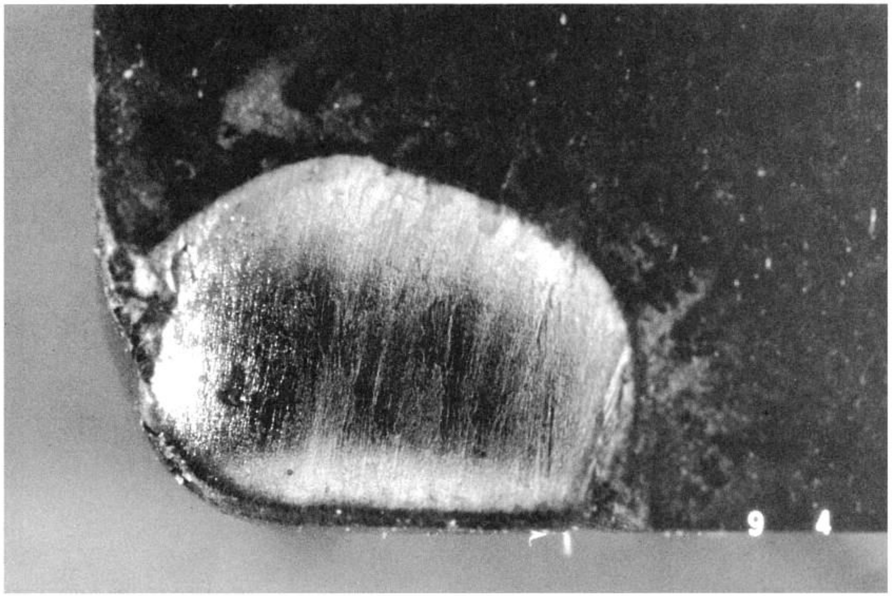
Uncoated tools



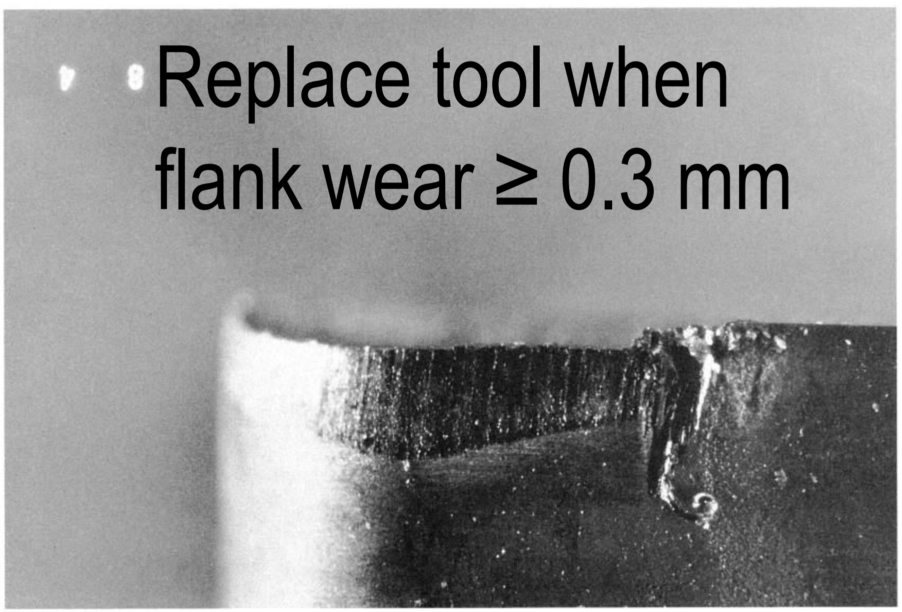
Coated tools

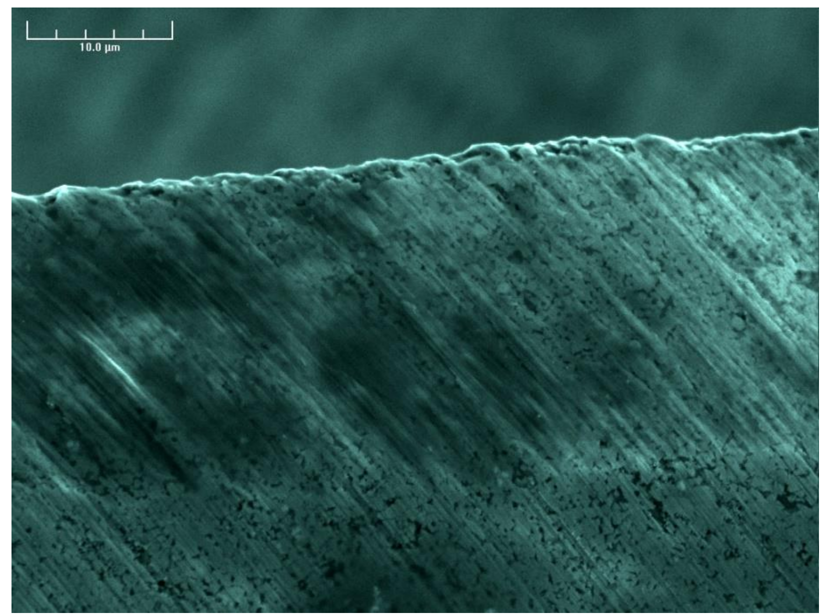






Crater wear (top view)





Flank wear (side view)

Tool materials

Selection criteria: crack resistance (toughness)
hardness
wear resistance
chemical resistance
geometry
cost, etc…

- HSS (high speed steel)
- WC (tungsten carbide)
- Coated WC
- CBN (cubic boron nitride)
- Diamond

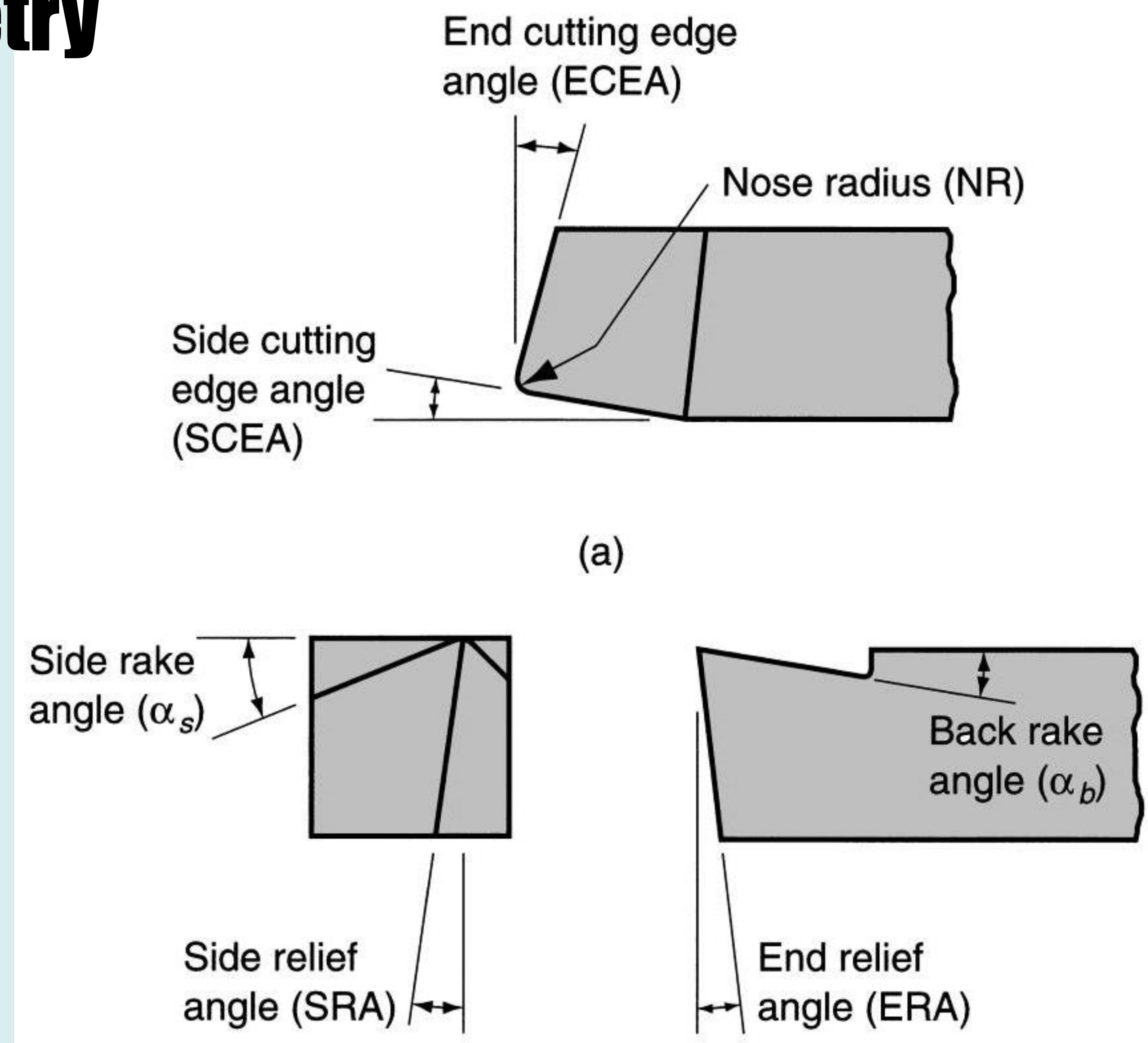
8.3 Tool geometry

Important

- Nose radius
- Back rake angle

Effects

- Chip flow
- Surface integrity
- Tool life

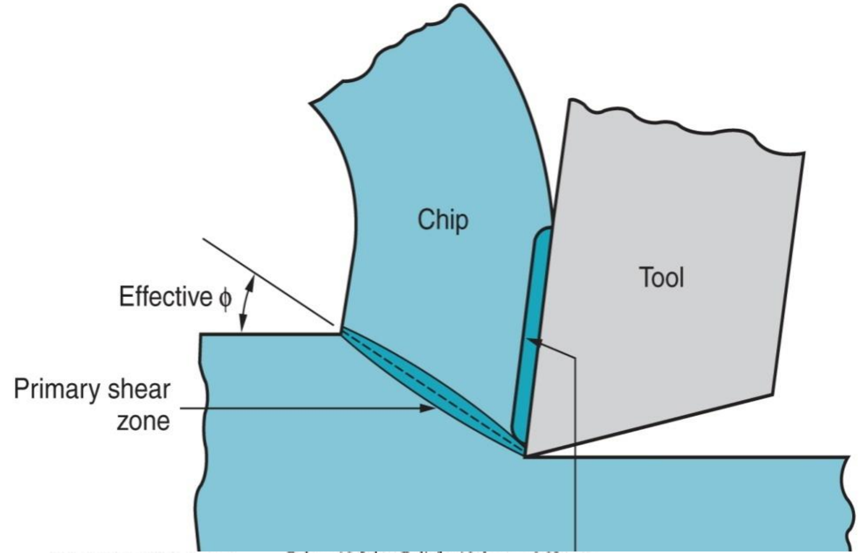


(b) Tool signature: α_b, α_s, ERA, SRA, ECEA, SCEA, NR

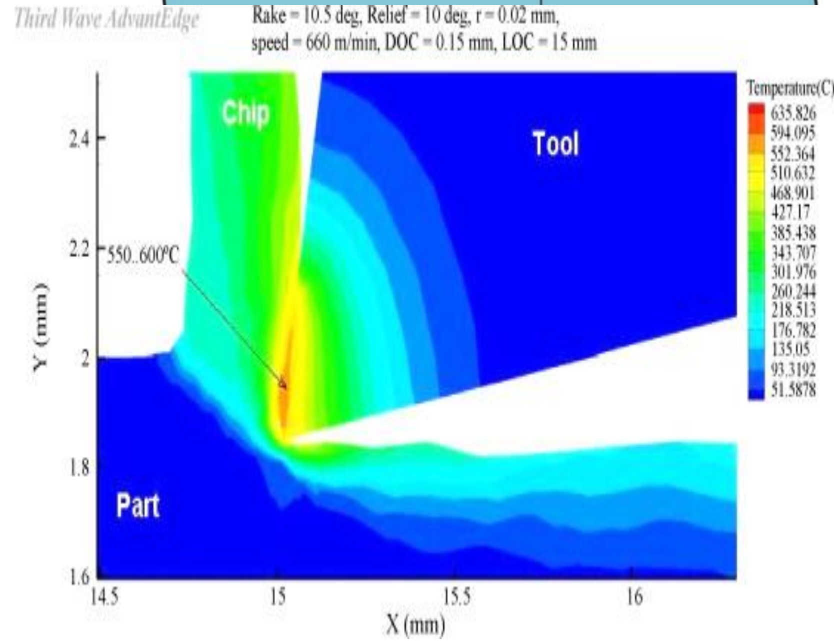
Table 3. Cutting Feeds and Speeds for Turning Stainless Steels

Material	Brinell Hardness	Tool Material: Uncoated HSS — Speed (fpm)		Uncoated Carbide — Hard — Opt.	Uncoated Carbide — Hard — Avg.	Uncoated Carbide — Tough — Opt.	Uncoated Carbide — Tough — Avg.	Coated Carbide — Hard — Opt.	Coated Carbide — Hard — Avg.	Coated Carbide — Tough — Opt.	Coated Carbide — Tough — Avg.	Cermet — Opt.	Cermet — Avg.
				f = feed (0.001 in./rev), s = speed (ft/min)									
Free-machining stainless steel (Ferritic): 430F, 430FSe	135–185	110	f s	20 480	10 660	36 370	17 395	17 755	8 945	28 640	13 810	7 790	3 995
(Austenitic): 203EZ, 303, 303Se, 303MA, 303Pb, 303Cu, 303 Plus X	135–185 225–275	100 80	f s	13 520	7 640	36 310	17 345			28 625	13 815	7 695	3 875
(Martensitic): 416, 416Se, 416 Plus X, 420F, 420FSe, 440F, 440FSe	135–185 185–240	110 100	f s	13 520	7 640	36 310				28 625	13 815	7 695	3 875
	275–325 375–425	60 30	f s	13 210	7 260	36 85	17 135			28 130	13 165		
Stainless steels (Ferritic): 405, 409 429, 430, 434, 436, 442, 446, 502	135–185	90	f s	20 480	10 660	36 370	17 395	17 755	8 945	28 640	13 810	7 790	3 995
(Austenitic): 201, 202, 301, 302, 304, 304L, 305, 308, 321, 347, 348	135–185 225–275	75 65	f s	13 520	7 640	36 310	17 345			28 625	13 815	7 695	3 875
(Austenitic): 302B, 309, 309S, 310, 310S, 314, 316, 316L, 317, 330	135–185	70											
(Martensitic): 403, 410, 420, 501	135–175 175–225	95 85											
	275–325 375–425	55 35	f s	13 210	7 260	36 85	17 135			28 130	13 165	13 200†	7 230
(Martensitic): 414, 431, Greek Ascoloy, 440A, 440B, 440C	225–275 275–325 375–425	55–60 45–50 30											
(Precipitation hardening): 15-5PH, 17-4PH, 17-7PH, AF-71, 17-14CuMo, AFC-77, AM-350, AM-355, AM-362, Custom 455, HNM, PH13-8, PH14-8Mo, PH15-7Mo, Stainless W	150–200 275–325	60 50	f s	13 520	7 640	36 310	17 345			28 625	13 815	13 695	7 875
	325–375 375–450	40 25	f s	13 195	7 240	36 85	17 155						

A2.5.b. Cutting fluid



Why
- Heat generates at shear zone
- Friction at tool/chip interface



Cutting fluid
- Coolant: water base + additives
- Lubricant: oil base + additives

Latest technology: micromist
- Minimum fluid
- Most effective for external micromachining
- Environmental concern

http://www.fabricatingandmetalworking.com/2013/04/fea-optimizes-cutting-processes-machining-strategies/

Dry