TA 202A

Lecture 3

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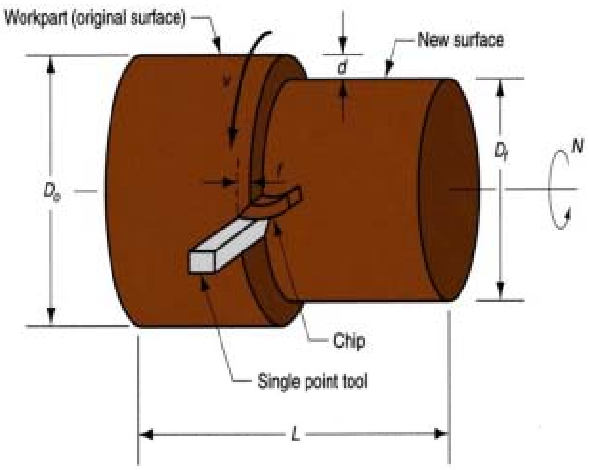
Machining

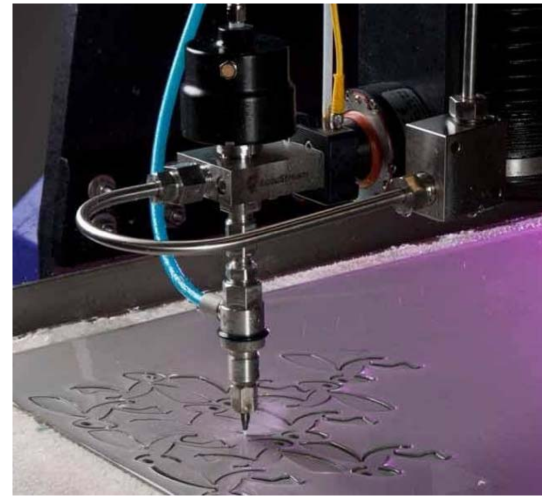
- In MACHINING, the shape, size, finish and accuracy are obtained by removing the excess material from the workpiece surface.
- Various surfaces are obtained as an interaction between a workpiece and a cutting tool with the help of a contrivance known as MACHINE TOOL.



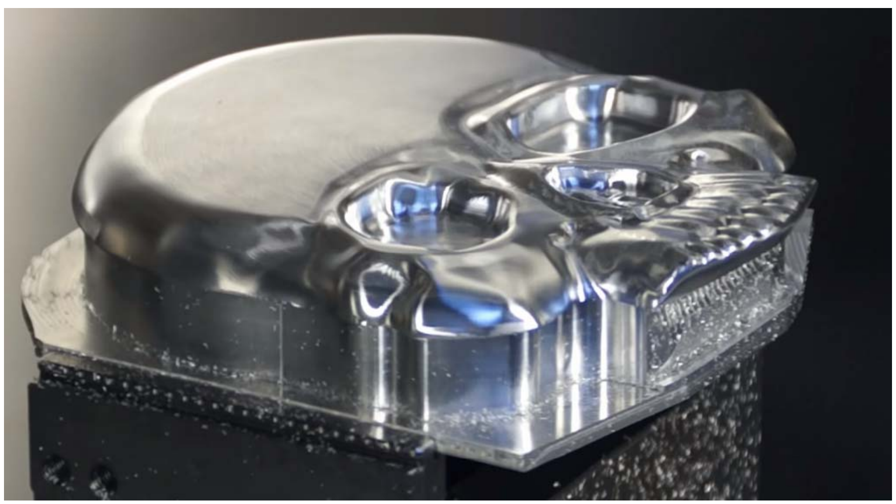
Ancient Tools & Structures

Modern Machining Practice

5 axis



High speed



Complex part

New configurations

Modern Machining Practice

Conventional lathe

Abrasive water jet machine

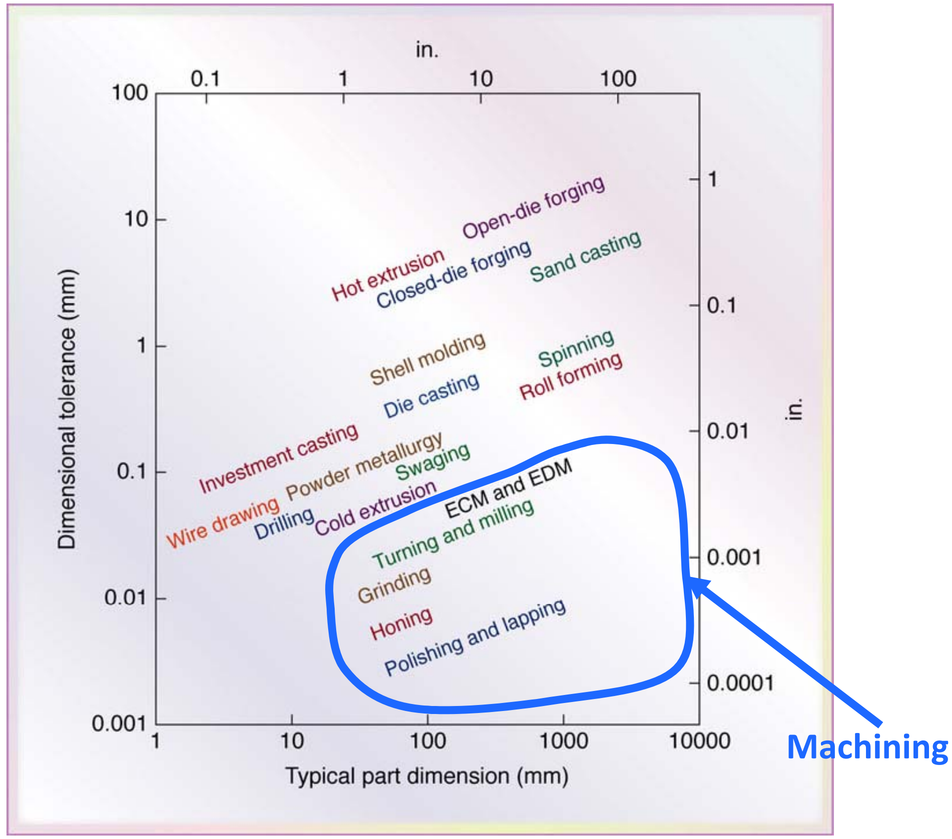
CNC lathe

CNC milling

CNC Drilling

Why machining is important

- Variety of work materials can be machined
  - Most frequently used to cut metals
- Variety of part shapes and special geometric features possible:
  - Screw threads
  - Accurate round holes
  - Very straight edges and surfaces
- Good dimensional accuracy and surface finish



Dimensional tolerances as a function of part size for various manufacturing processes

Note that because many factors are involved, there is a broad range for tolerances.

Disadvantages with Machining

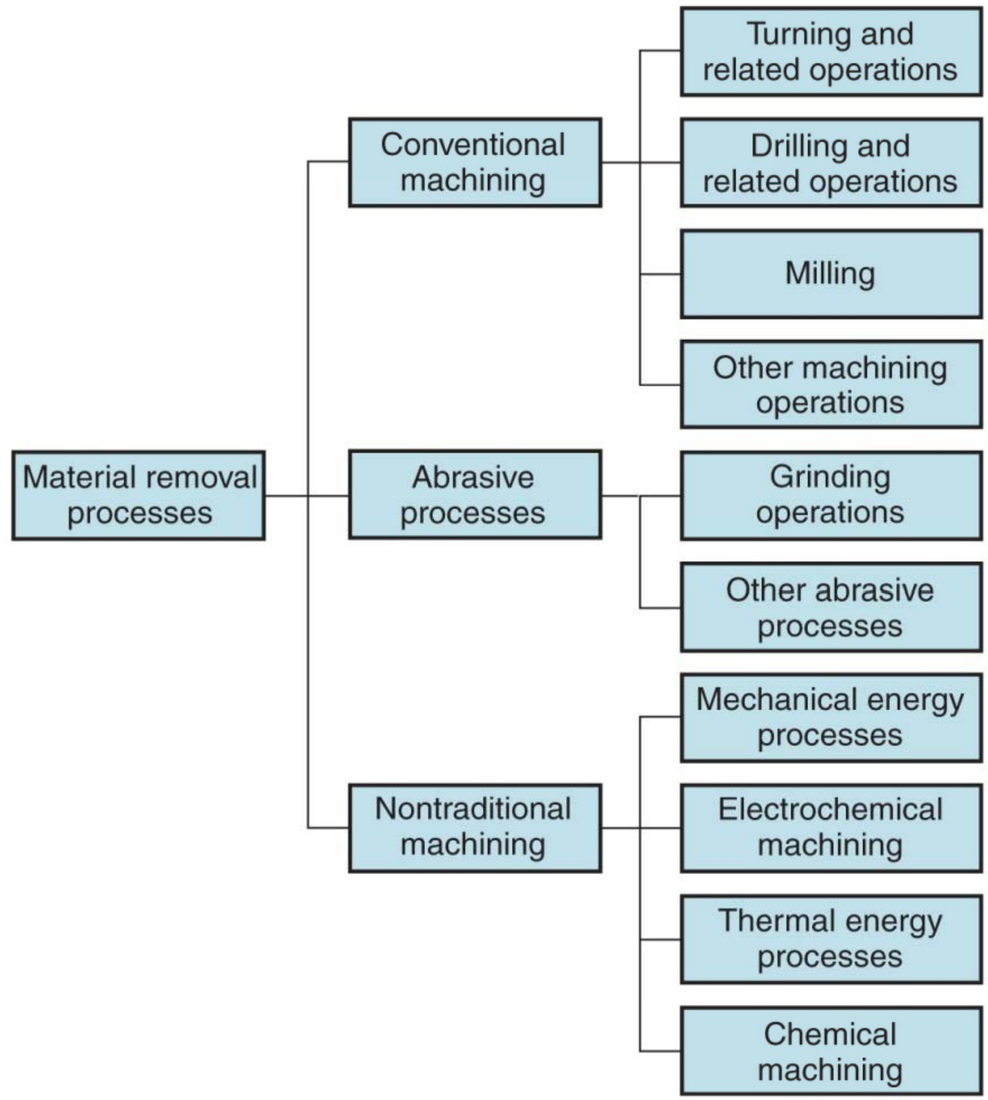
- Wastage of material
  - Chips generated in machining are wasted material
    - At least in the unit operation
- Time consuming
  - A machining operation generally takes longer to shape a given part than alternative shaping processes

Machining in the Manufacturing Sequence

- Generally performed after other manufacturing processes, such as casting, forging, and bar drawing
  - Other processes create the general shape of the starting workpart
  - Machining provides the final shape, dimensions, finish, and special geometric details that other processes cannot create

Material Removal Processes

- The family tree

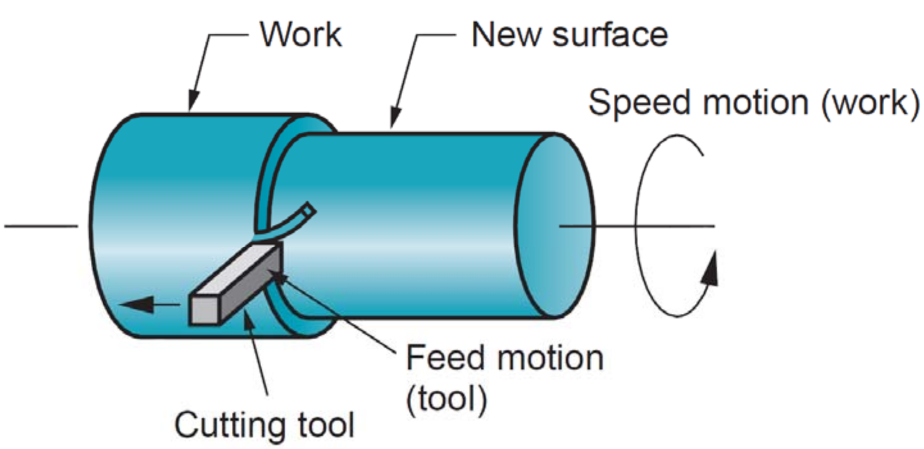


Machining Operations

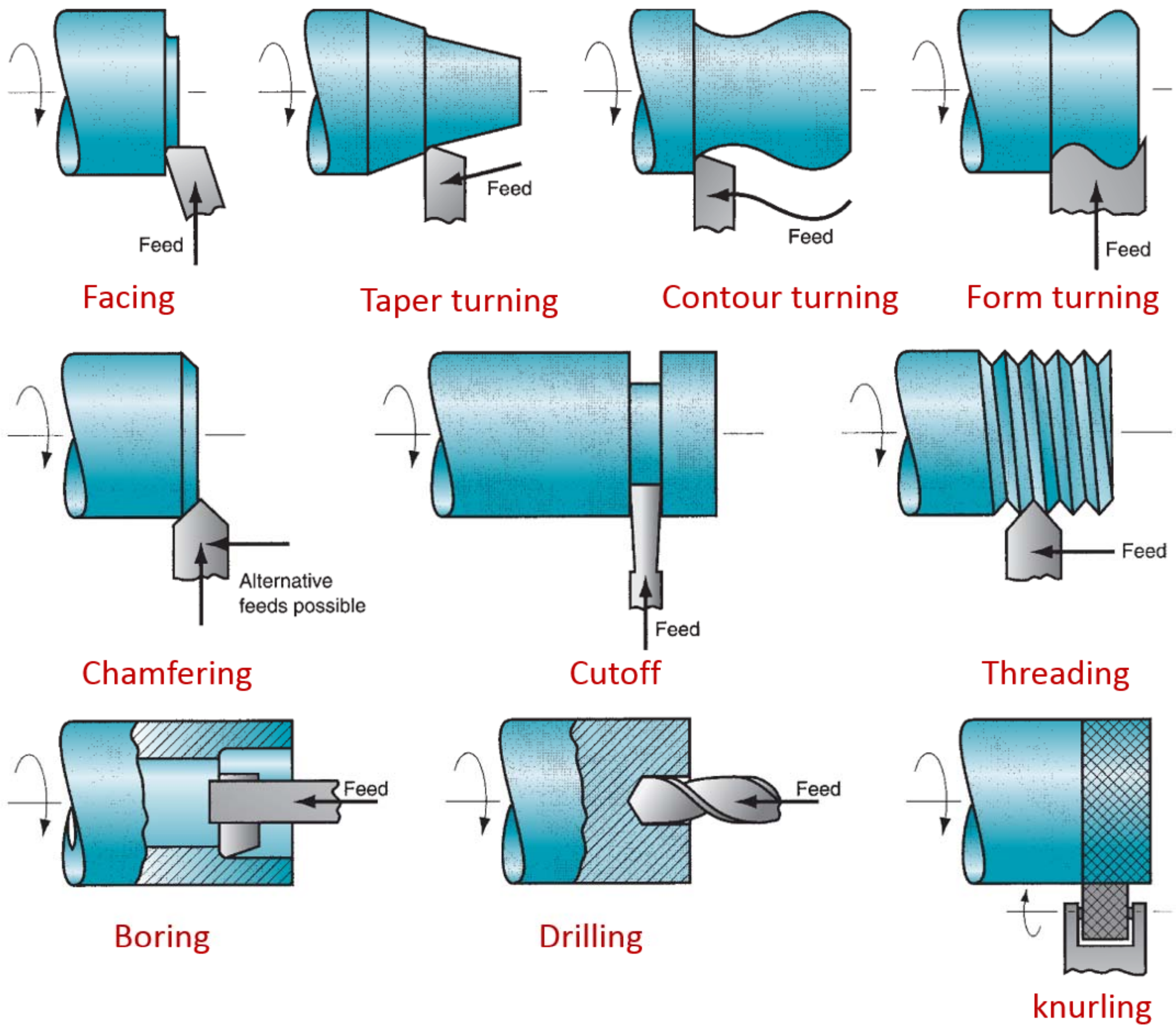
- Most important machining operations:
  - Turning
  - Drilling
  - Milling
- Other machining operations:
  - Shaping and planing
  - Broaching
  - Sawing

Turning

Single point cutting tool removes material from a rotating workpiece to form a cylindrical shape

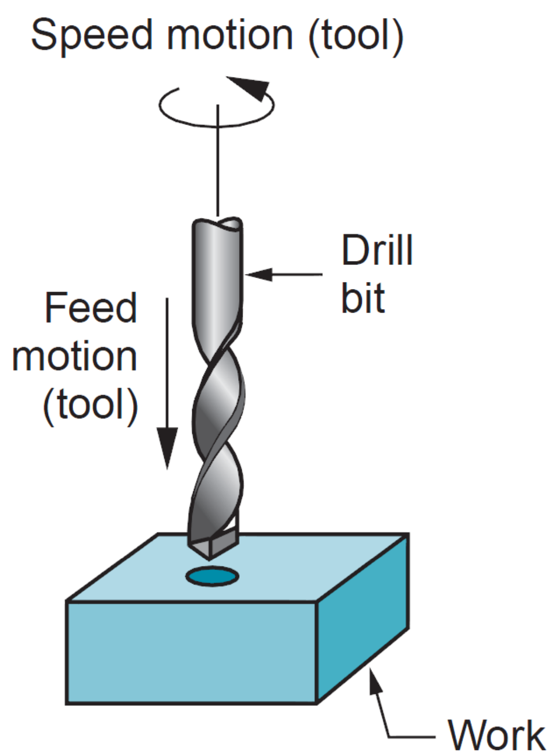


Turning related operations



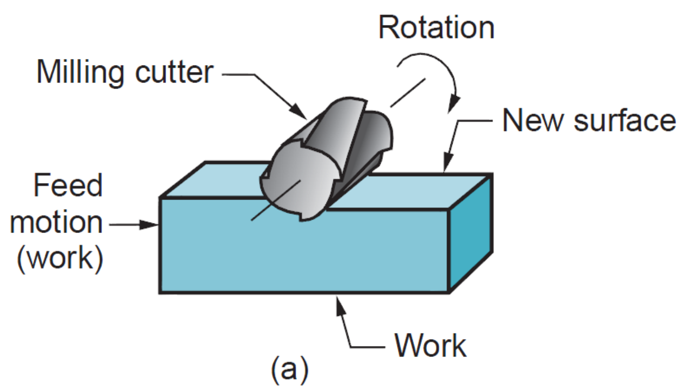
Drilling

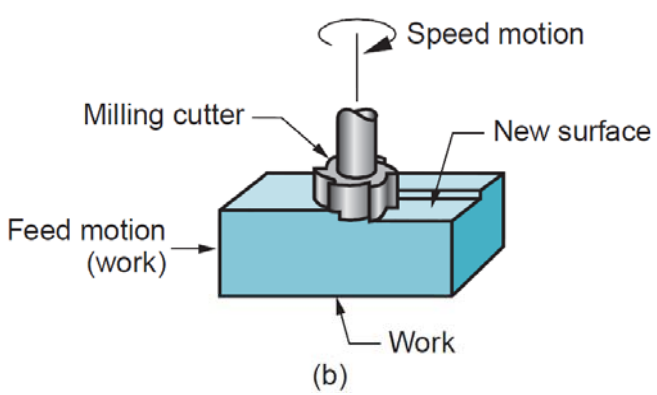
Used to create a round hole, usually by means of a rotating tool (drill bit) with two cutting edges



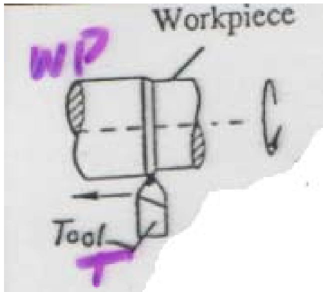
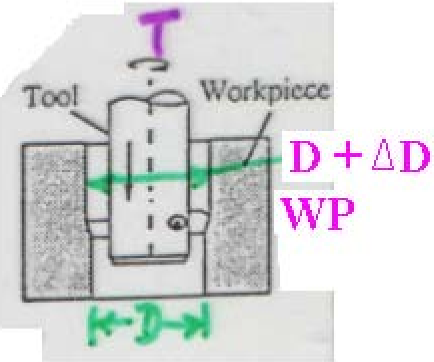
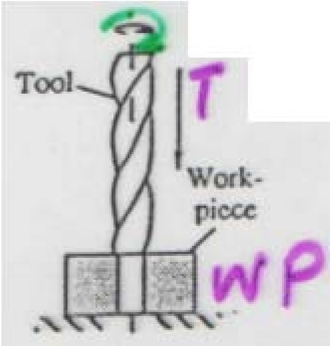
Milling

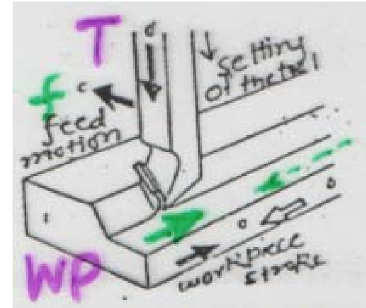
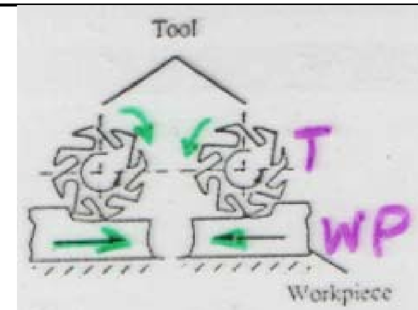
- Rotating multiple-cutting-edge tool is moved across work to cut a plane or straight surface
- Two forms: (a) peripheral milling and (b) face milling





Nature of relative motion between the tool and workpiece

Operation	Motion of job	Motion of cutting tool	Figure of operation
Turning	Rotary	Translatory (Forward)	
Boring	Rotation	Translation (forward)	
Drilling	Fixed (no motion)	Rotation as well as translatory feed	

Planing	**Translatory**	**Intermittent translation**	
Milling	**Translatory**	**Rotation**	
Grinding	**Rotary / Translatory**	**Rotary**	

What is the basic difference between ?

Turning
Boring
Planing
Single point

and

Drilling
Milling
Grinding
Multi points

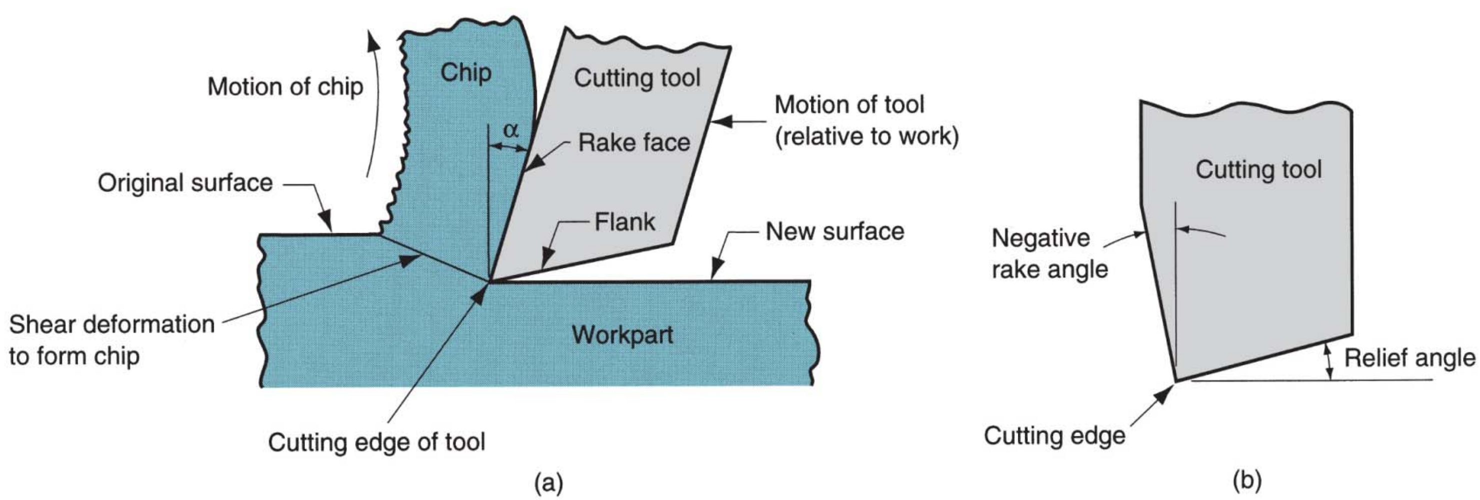
- Single vs multi Points
- Continuous and Intermittent

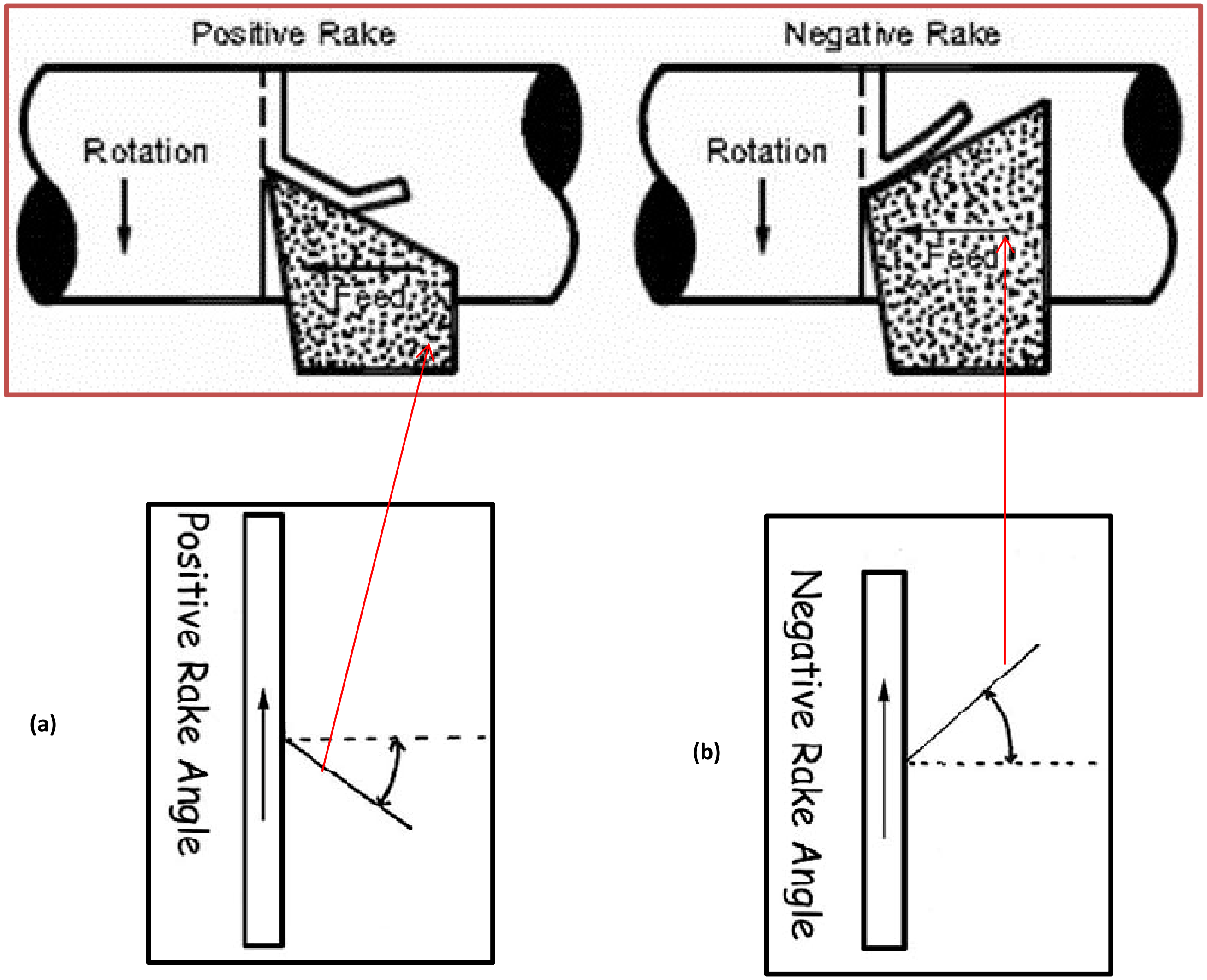
Basic Mechanics Issues

- Shear strain
- Power, Plastic work
- Friction, Forces
- Temperature rise
- Tool materials, Rate limits

Cutting action

- Cutting action involves shear deformation of work material to form a chip, and as chip is removed, new surface is exposed: (a) positive and (b) negative rake tools




Positive Rake
Negative Rake
Rotation
Feed
Rotation
Feed
Positive Rake Angle
Negative Rake Angle

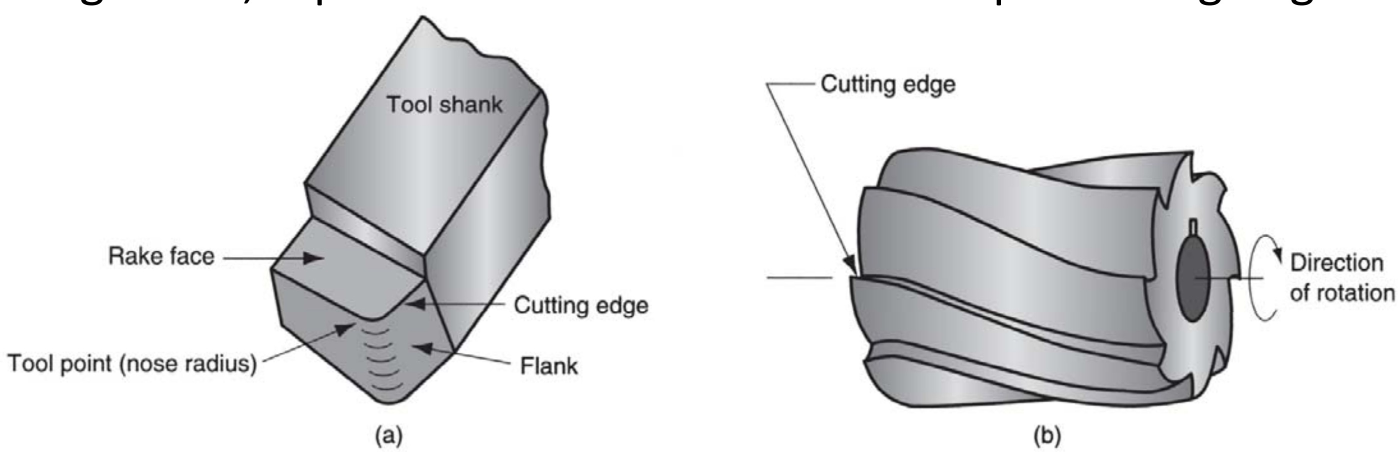
(a)

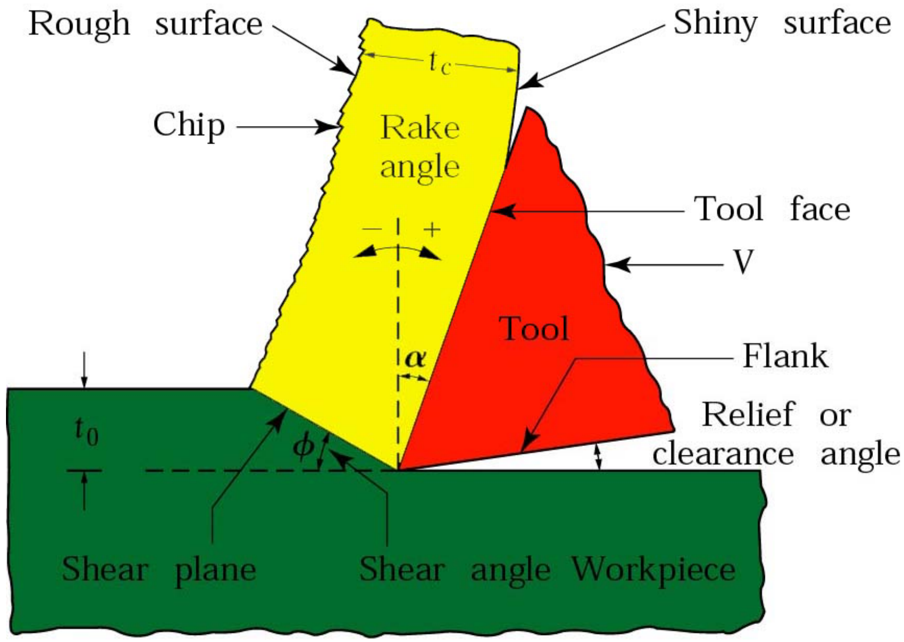
(b)

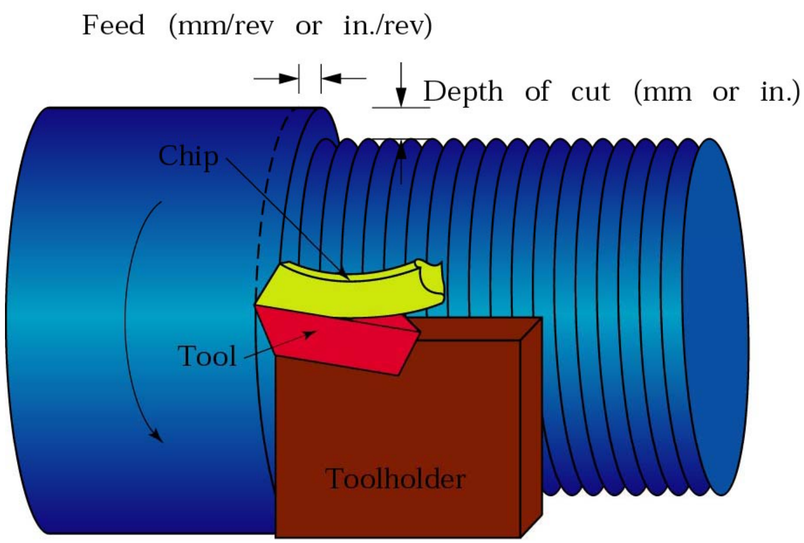
Cutting Tool Classification

1. Single-Point Tools
   – One dominant cutting edge
   – Point is usually rounded to form a nose radius
   – Turning uses single point tools
2. Multiple Cutting Edge Tools
   – More than one cutting edge
   – Motion relative to work achieved by rotating
   – Drilling and milling use rotating multiple cutting edge tools

(a) Single-point tool showing rake face, flank, and tool point; and (b) a helical milling cutter, representative of tools with multiple cutting edges



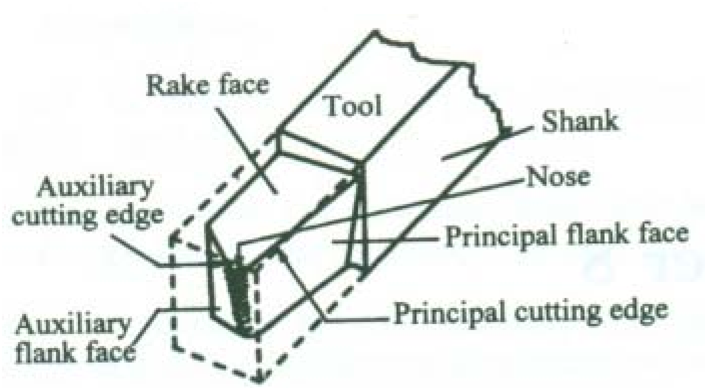




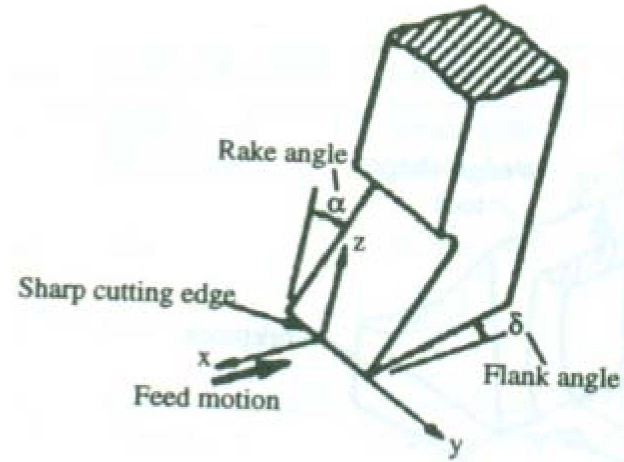
Two-dimensional cutting process, also called orthogonal cutting. Note that the tool shape and its angles, depth of cut, t_o, and the cutting speed, V, are all independent variables.

Dependent Variables (Responses): Forces, Temperature (workpiece, tool, chip), tool wear, etc.

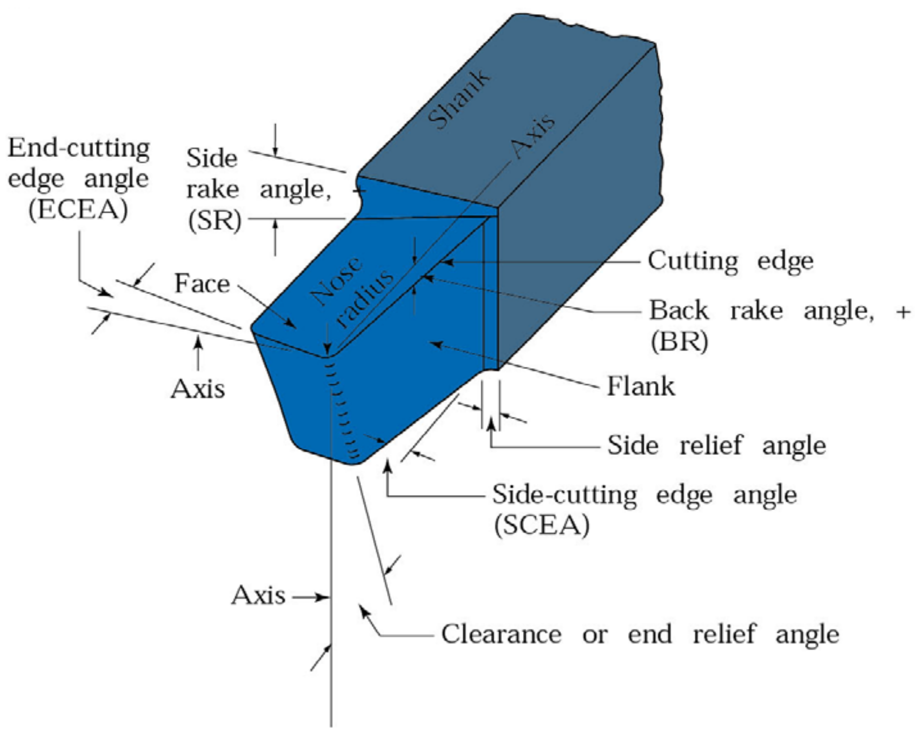
Cutting Tools and Types of Machining

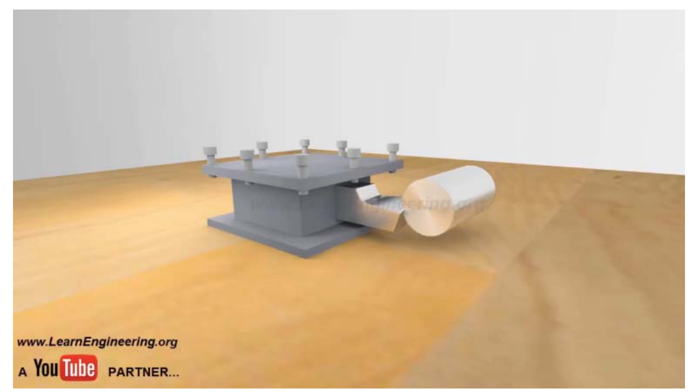


A Typical Lathe Tool

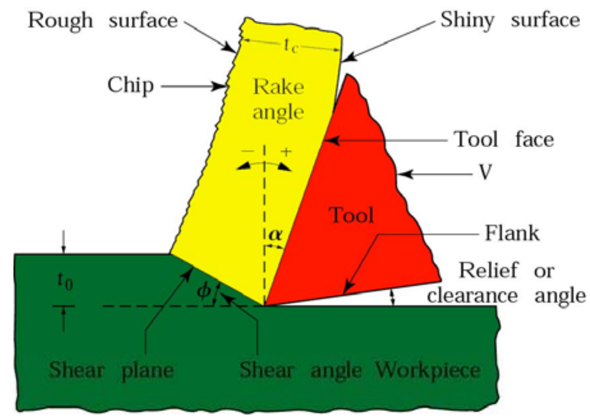


Wedge-Shaped tool





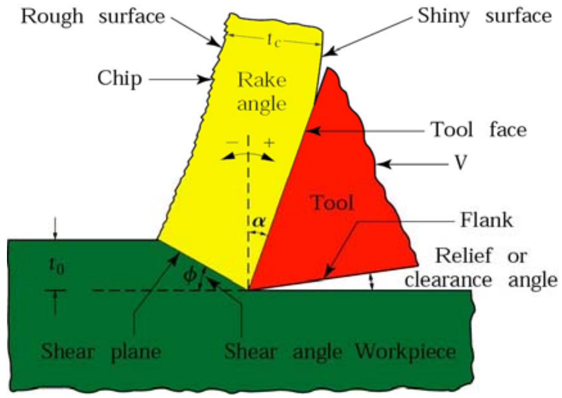
Tool Angles



Rake Angle (α)

- Influence cutting forces, power and surface finish
- Large α
  - lowers forces and improves surface finish
  - In general, power consumption ↓ by ~ 1% for 1 degree change in α
  - Has adverse effect on tool strength because less metal is available to support the tool
  - Greatly reduced capacity to conduct heat away from the cutting edge
  - Increases tool forces, but keeps the tool in compression and provides added support to the cutting edge

- 0 or negative rake angles employed on carbide, ceramic and similar "hard" tools
- Particularly important in making intermittent cuts and in absorbing impact during initial tool - workpiece contact
- Rake angles: 5 – 15 degrees for HSS; Lower for harder materials



Flank Angle

- Minimizes rubbing of flank faces with the machined surface
- Higher values of flank angle will reduce rubbing but also weaken the tool
- Flank angles have no influence on cutting forces and power. So angles large enough to avoid rubbing is generally chosen
- Angle: 5 – 12 degrees for HSS; higher for softer and lower for brittle material

Cutting Edge Angle

- Provided to clear the cutting edge from the machined surface
- To Reduce tool chatter
- Affects tool life as well as surface finish

Tool Parameter

Nose radius

- ➢ Improves tool life and surface finish

- Large nose radius
  - Increases cutting forces and power
  - Causes chatter (self-excited vibration)

- ➢ Recommended value: 1 – 3 mm

❖ Orthogonal Cutting (2-D Cutting):

Cutting edge is:

(1) straight

(2)parallel to the original plane surface on the work piece and

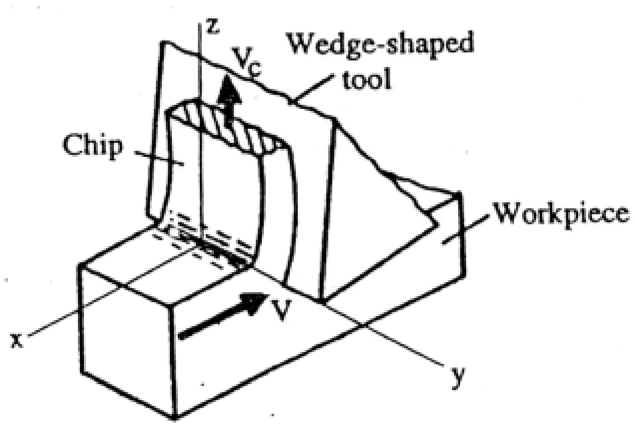
(3)perpendicular to the direction of cutting. For example:

Operations: Lathe cut-off operation, Straight milling, etc.

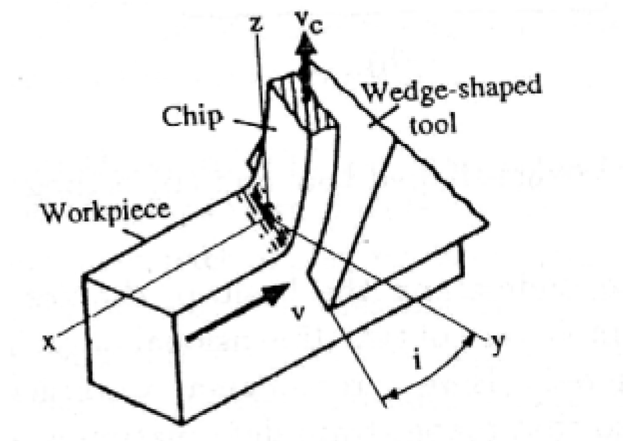
❖ Oblique Cutting (3-D Cutting):

Cutting edge of the tool is inclined to the line normal to the cutting direction.

In actual machining, Turning, Milling etc., cutting operations are oblique cutting(3-D)



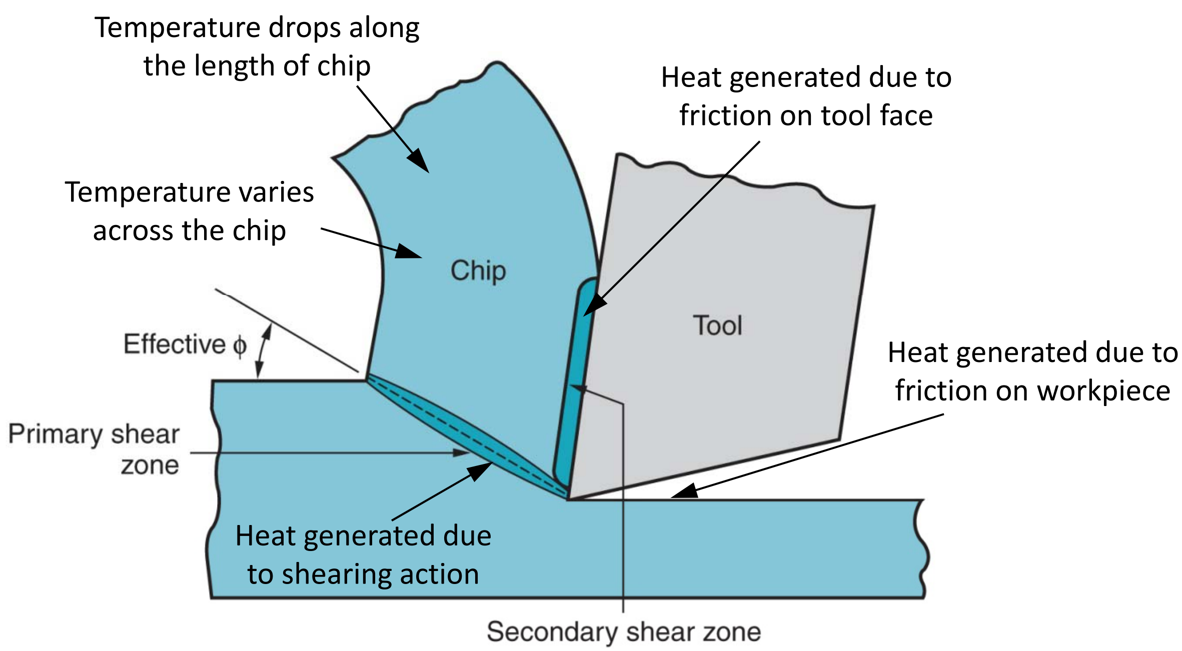
Orthogonal Cutting



Oblique Cutting

Chip Formation

- More realistic view of chip formation, showing shear zone rather than shear plane
- Also shown is the secondary shear zone resulting from tool-chip friction

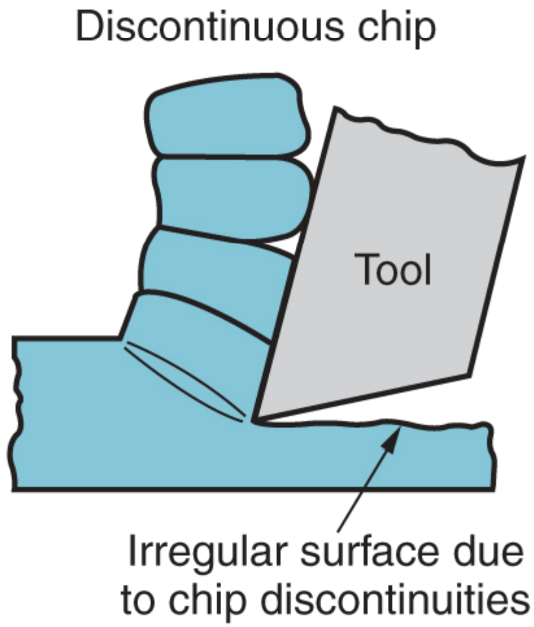


Schematic of chip formation

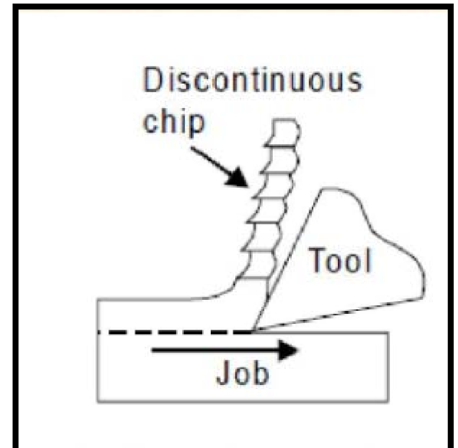
Four Basic Types of Chip in Machining

1. Discontinuous chip
2. Continuous chip
3. Continuous chip with Built-up Edge (BUE)
4. Serrated chip

Discontinuous Chip



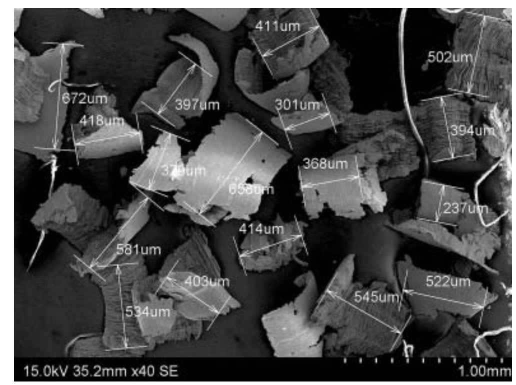
(a)



(b) Discontinuous chips

Conditions

- Brittle work materials
- Low cutting speeds
- Large feed and depth of cut
- Small rake angle
- High tool-chip friction



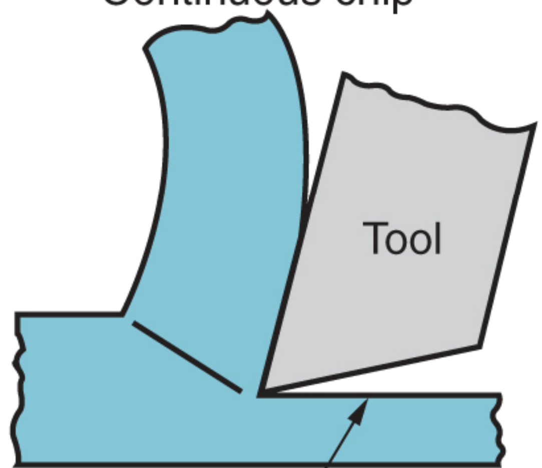
Chip in the form of discontinuous segments:

- **Easy disposal**
- **Good surface finish**

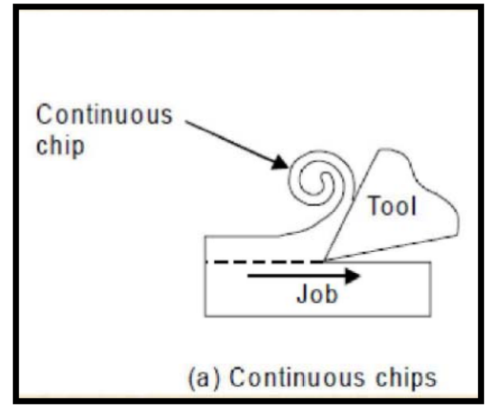
Continuous Chip

Conditions

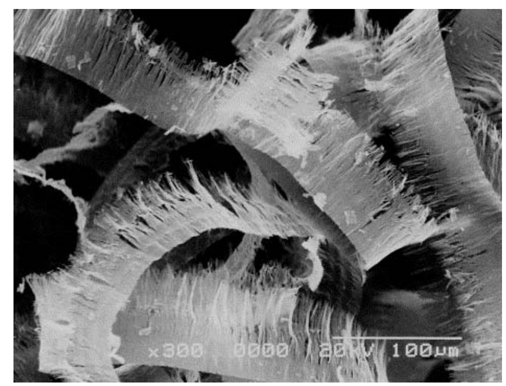
- Ductile work materials
- High cutting speeds
- Small feeds and depths
- Large rake angle (+ve)
- Sharp cutting edge
- Low tool-chip friction



(b)



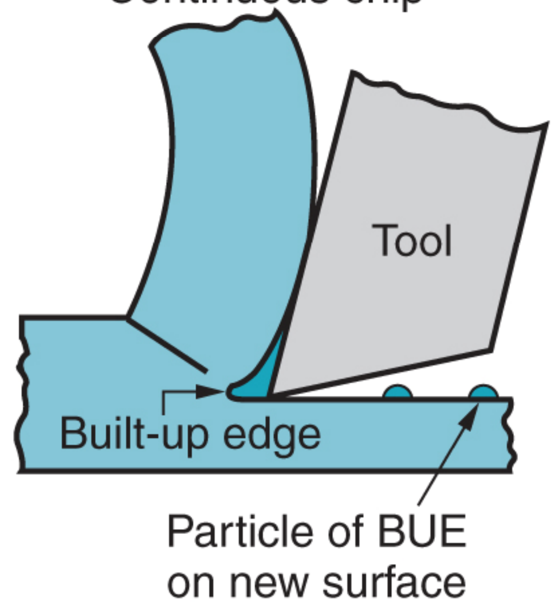
(a) Continuous chips



Continuous chip results in:

- **Good surface finish**
- **High tool life**
- **Low power consumptions**

Continuous with BUE



(c)

Conditions

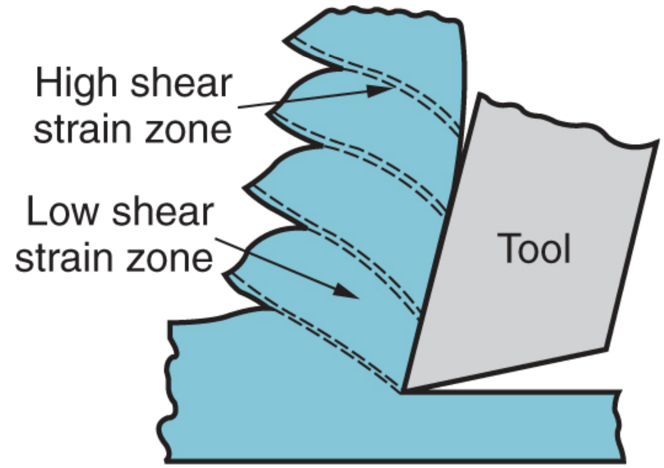
- Ductile materials
- Low-to-medium cutting speeds
- Large feed
- Small rake angle
- Tool-chip friction causes portions of chip to adhere to rake face
- BUE forms, then breaks off, cyclically

Built up Edge:

- High friction between Tool & Chip
- Particles of chip adhere to the rake face of the tool near cutting edge
- Some part of BUE get adhered to the machined surface hence poor surface finish

Serrated Chip

- Semi-continuous - saw-tooth appearance
- Cyclical chip forms with alternating high shear strain then low shear strain
- Associated with difficult-to-machine metals at high cutting speeds



(d)

Types of Chips

(a) Continuous chip with narrow, straight primary shear zone

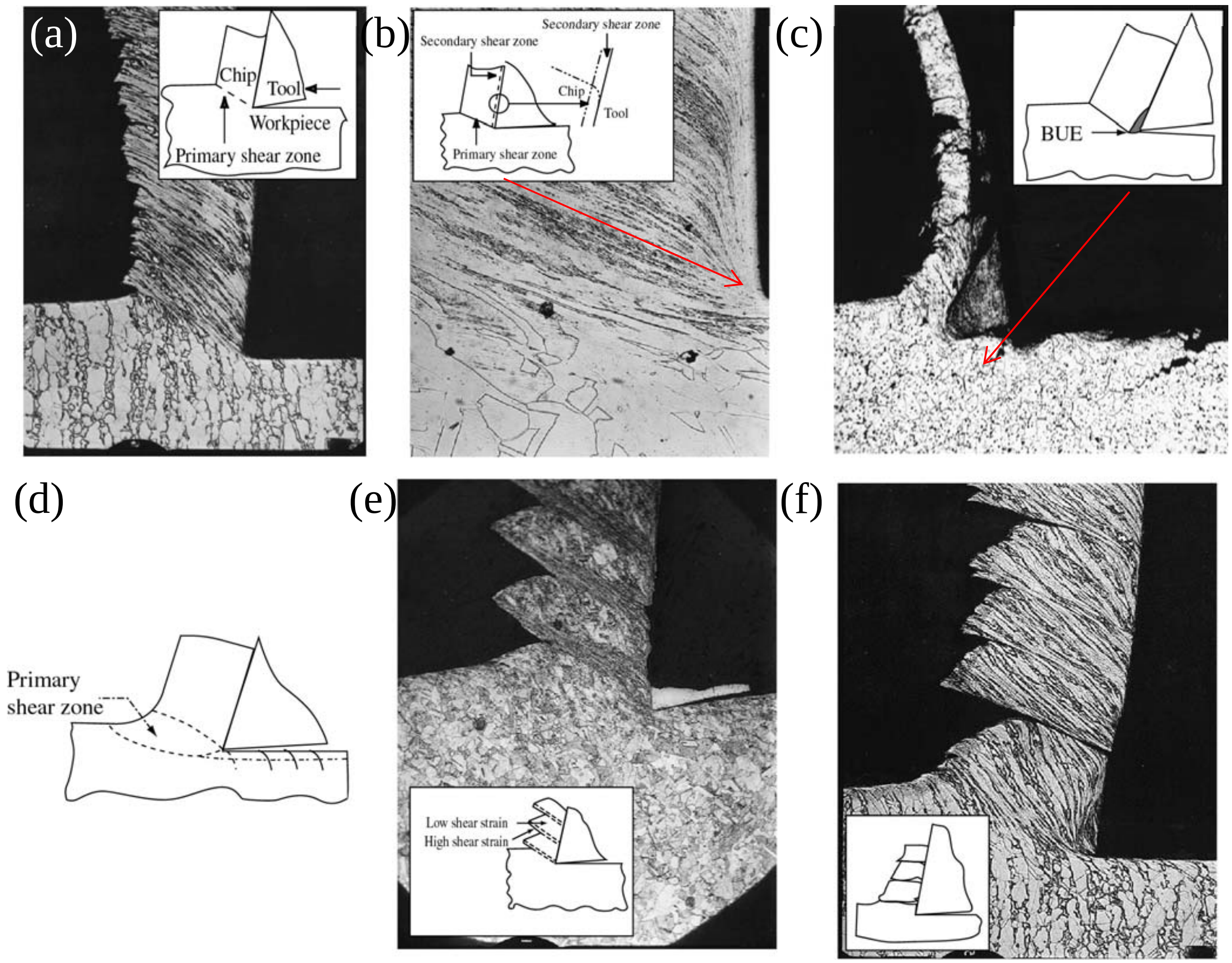
(b) Secondary shear zone at the chip-tool interface

(c) Continuous chip with built-up edge

(d) Continuous chip with large primary shear zone

(e) Segmented (Serrated) or nonhomogeneous chip and

(f) Discontinuous chip



Source: After M. C. Shaw, P. K. Wright, and S. Kalpakjian

Chip-Breaking

- **The chip breaker breaks the produced chips into small pieces.**
- **The work hardening of the chip makes the job of the chip breakers easy.**
- **When a strict chip control is desired, some sort of chip breaker has to be employed.**

- The following types of chip breakers are commonly used:

  a) Groove type
  b) Step type
  c) Secondary Rake type
  d) Clamp type

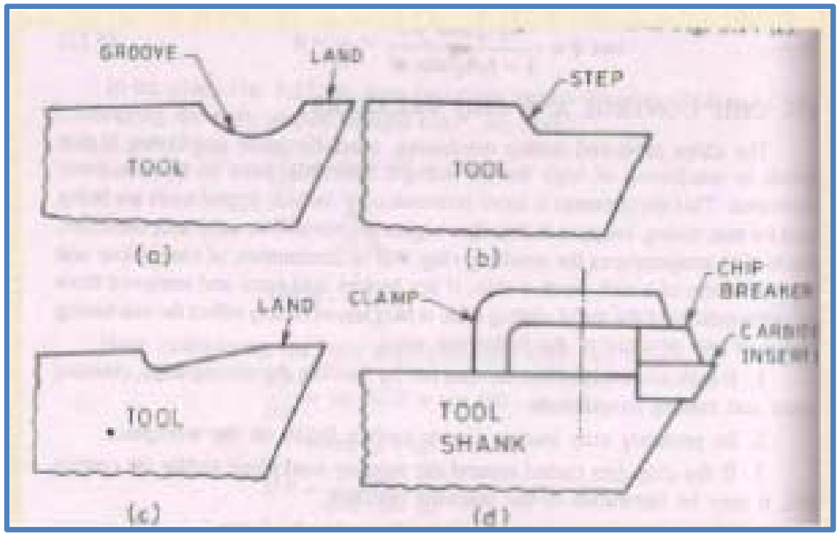
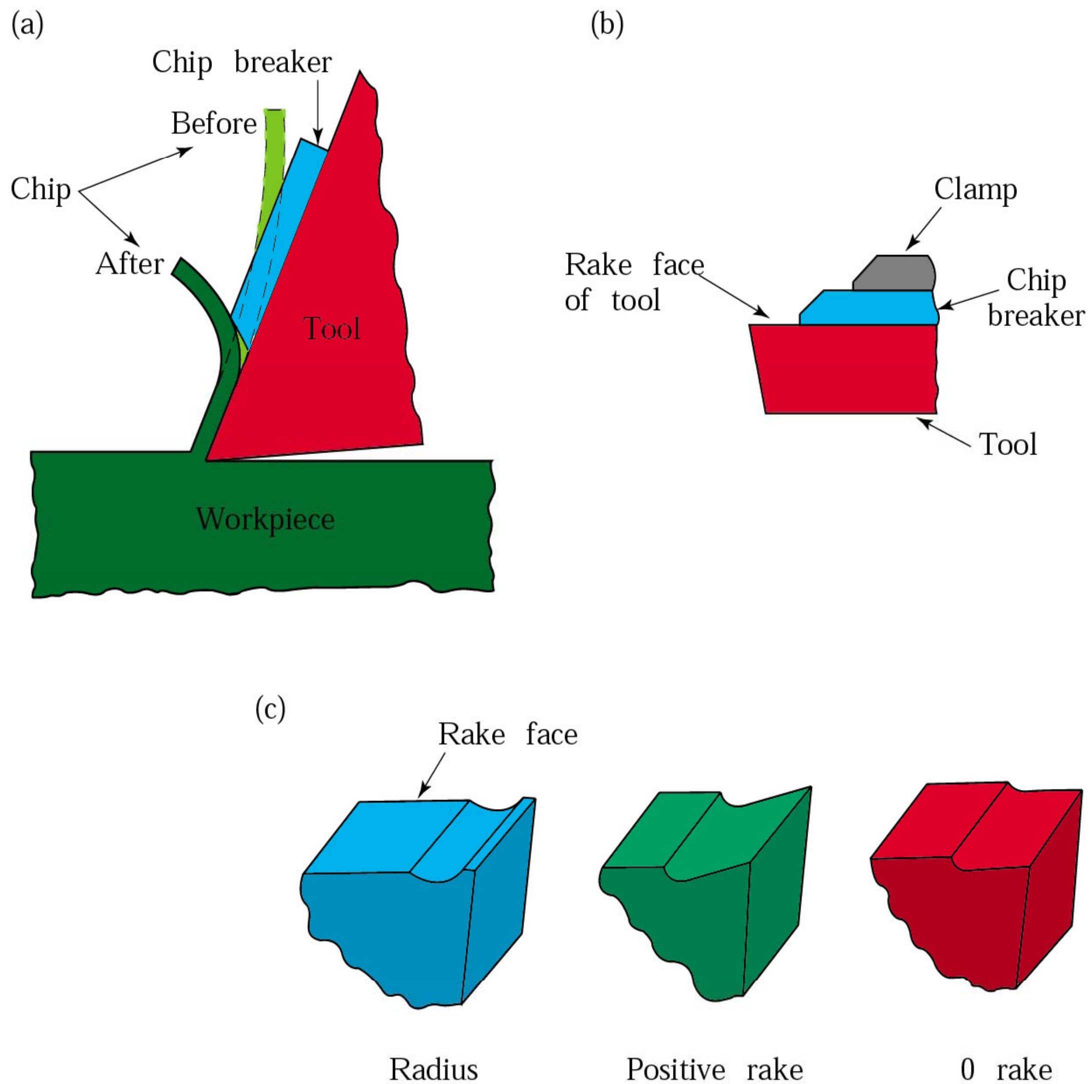


Fig: Schematics of different types of chip breakers



(a) Schematic illustration of the action of a chip breaker. Note that the chip breaker decreases the radius of curvature of the chip. (b) Chip breaker clamped on the rake face of a cutting tool. (c) Groove in a cutting tool acts as a chip breaker.

Recap of the Lecture

- Introduction to machining
- Classification of material removal processes
- Cutting tool classification
- Chip formation and types of chips
- Chip-breaking tools

Next Lecture

Mechanics of metal cutting