Introduction to Manufacturing, AGE-1320

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Spring-2026

Fundamentals of Machining
part 1 (Chapter 21):
Introduction, Types of Chips, and Tool Life

Manufacturing Engineering Technology in SI Units, 6th Edition

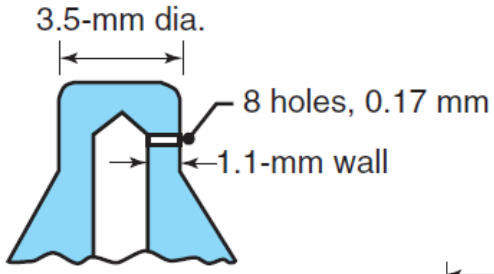
Chapter Outline

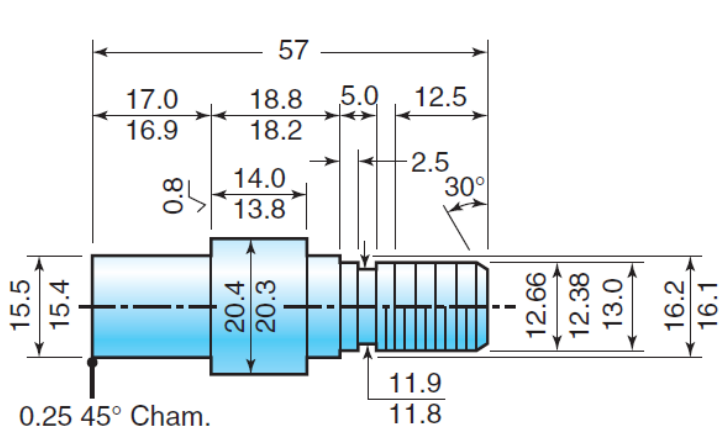
1. **Introduction**
2. **Types of Chips Produced in Metal Cutting**
3. **Tool Life: Wear and Failure**
4. **Cutting Tool Materials**
5. **Cutting Fluids**

1. Introduction

Introduction

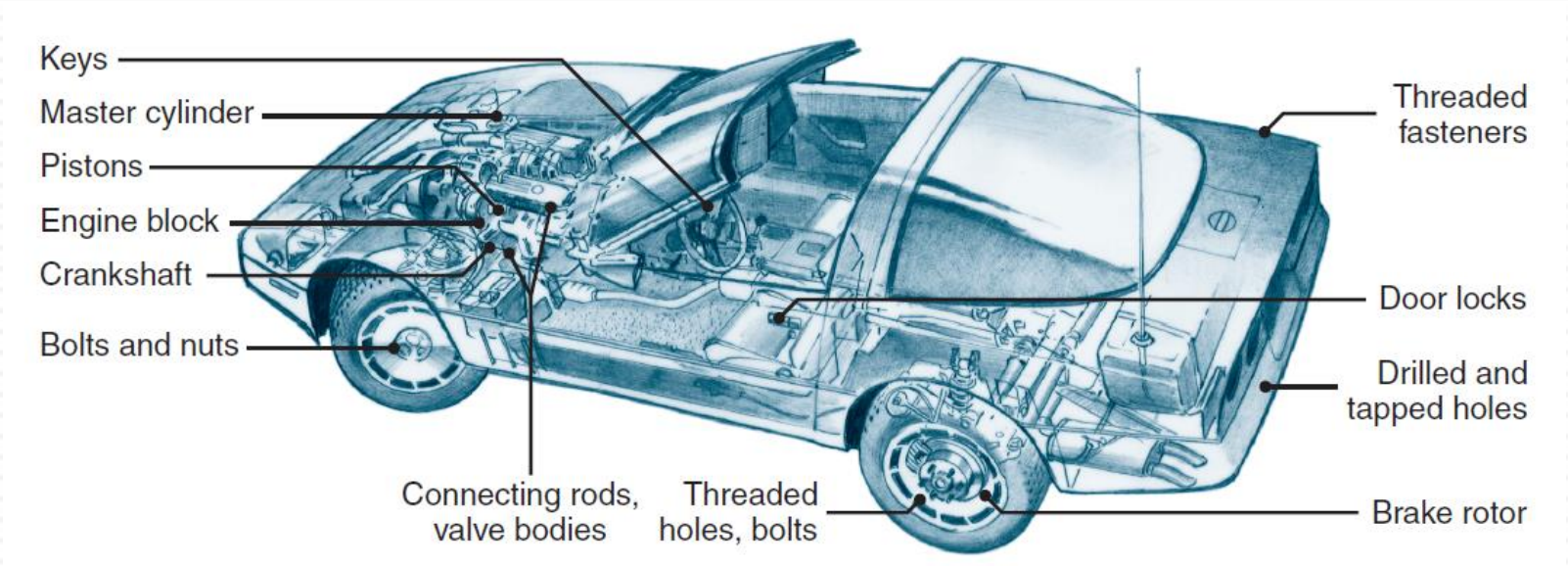
- Parts can be manufactured by casting, forming and shaping processes
- They often require further operations before the product is ready for use





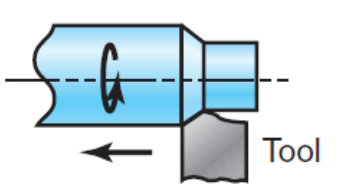
Introduction

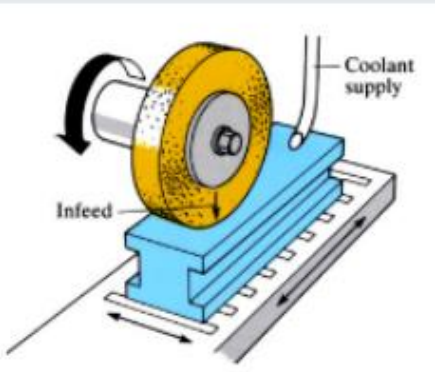
- **Machining** is the *removal* of material and *modification* of the surfaces of a workpiece
- Machining involves *secondary* and *finishing* operations



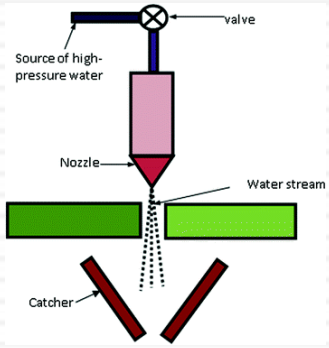
Introduction

- Major types of material removal processes:
1. **Cutting**
2. **Abrasive processes**
3. **Advanced machining processes**





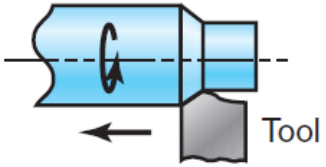
- Machining operations is a *system* consisting of the:
1. *Workpiece*
2. *Cutting tool*
3. *Machine tool*
4. *Production personnel*



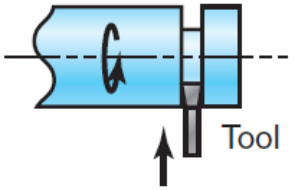
Introduction

- Cutting processes remove material from the surface of a workpiece by producing **chips**
- Common cutting processes:

1. **Turning** (workpiece rotates; tool moves left, removes layer of material)

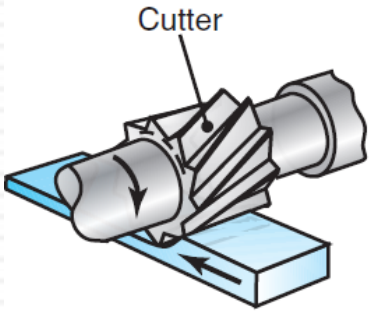


(a) Straight turning



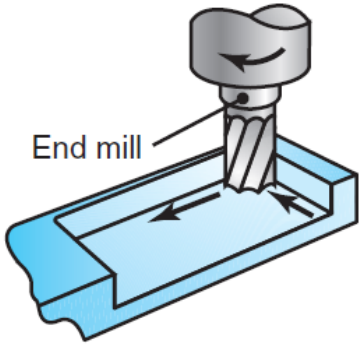
(b) Cutting off

2. **Cutting off** (cutting tool moves radially inward)
3. **Slab milling** (rotating cutting tool removes material from workpiece)



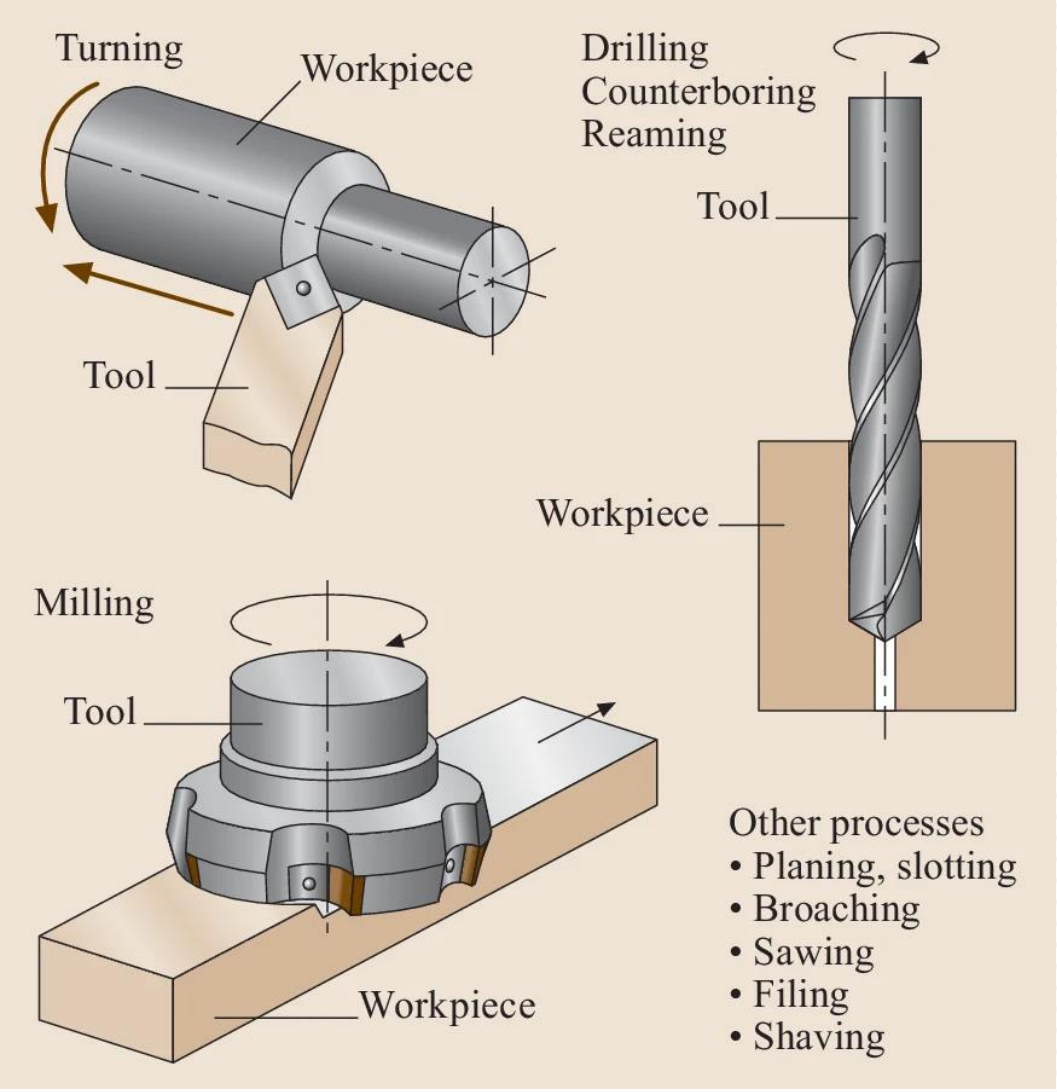
(c) Slab milling

4. **End milling** (rotating cutter; produces cavity)



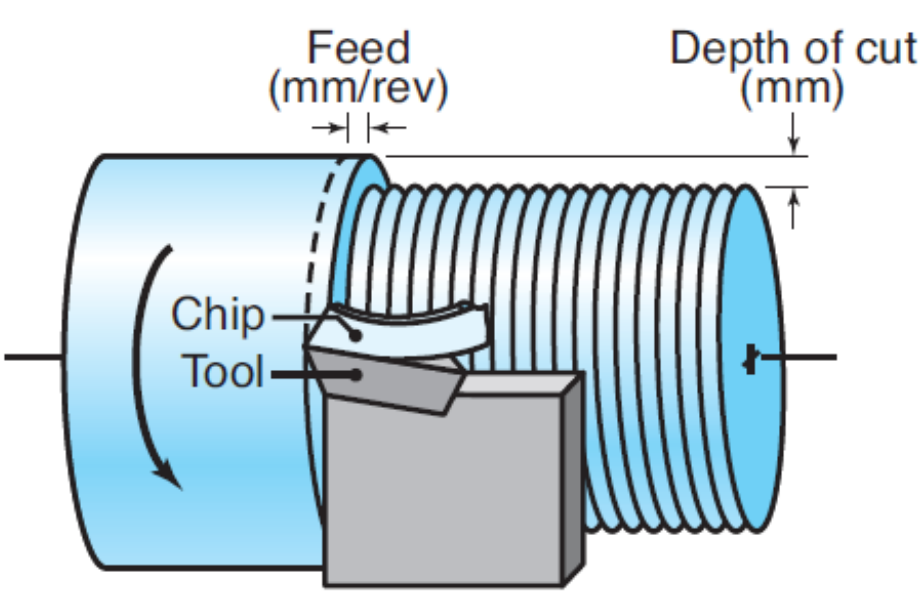
(d) End milling

Introduction

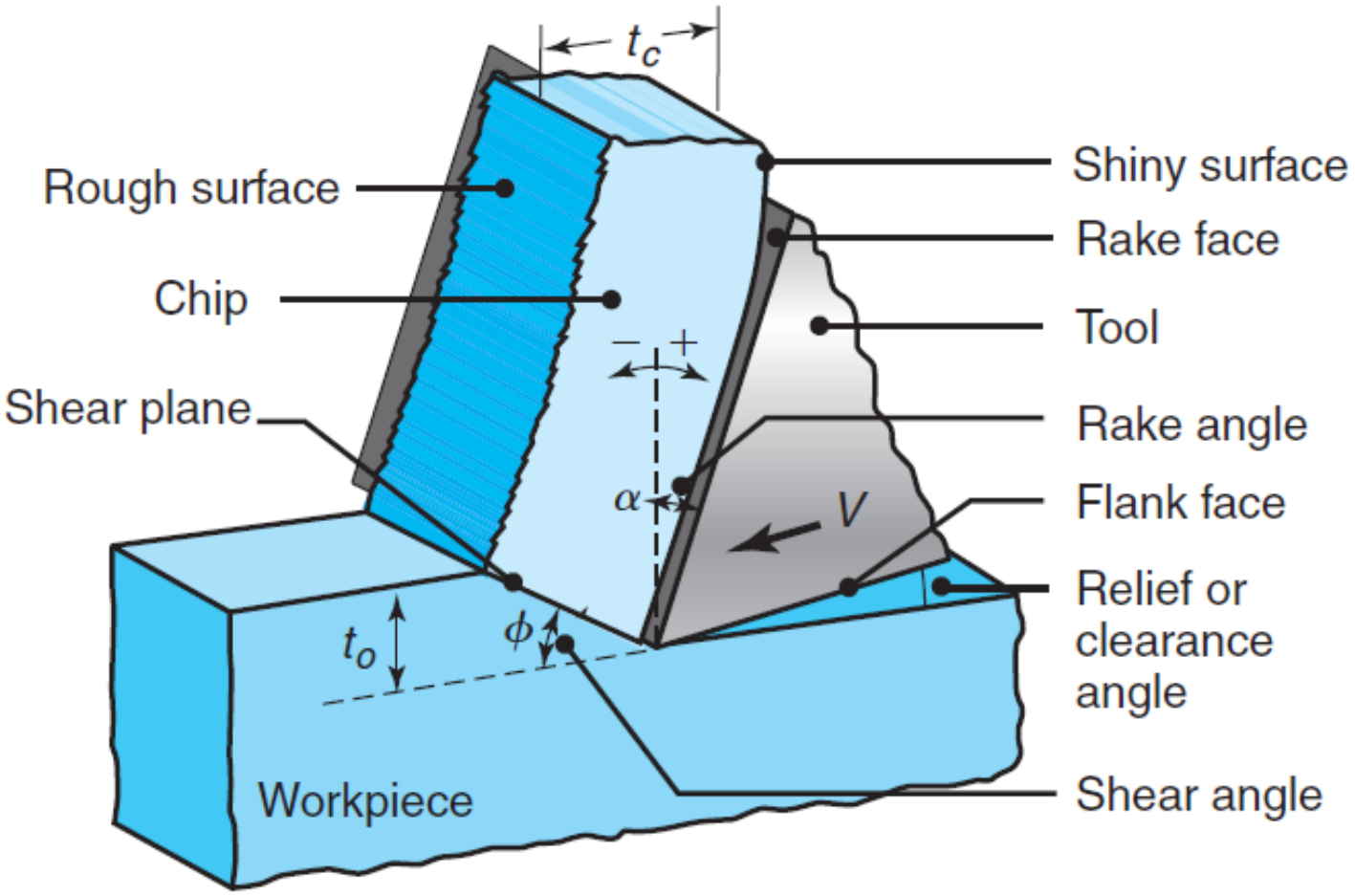


Introduction

- In the **turning process**, the cutting tool is set at a certain *depth of cut* [mm] and travels to the left (with a certain velocity) as the workpiece rotates
- *Feed*, or *feed rate*, is the distance the tool travels horizontally per unit revolution of the workpiece [mm/rev]
  - This tool movement produces chips, which move up the face of the tool



Introduction



Introduction

Factors Influencing Machining Operations

Parameter	Influence and interrelationship
Cutting speed, depth of cut, feed, cutting fluids	Forces, power, temperature rise, tool life, type of chip, surface finish and integrity
Tool angles	As above; influence on chip flow direction; resistance to tool wear and chipping
Continuous chip	Good surface finish; steady cutting forces; undesirable, especially in automated machinery
Built-up edge chip	Poor surface finish and integrity; if thin and stable, edge can protect tool surfaces
Discontinuous chip	Desirable for ease of chip disposal; fluctuating cutting forces; can affect surface finish and cause vibration and chatter
Temperature rise	Influences tool life, particularly crater wear and dimensional accuracy of workpiece; may cause thermal damage to workpiece surface
Tool wear	Influences surface finish and integrity, dimensional accuracy, temperature rise, forces and power
Machinability	Related to tool life, surface finish, forces and power, and type of chip

Introduction

- Major *independent variables* in the cutting process:

1. Tool material and coatings
2. Tool shape, surface finish, and sharpness
3. Workpiece material and condition
4. Cutting speed, feed, and depth of cut
5. Cutting fluids
6. Characteristics of the machine tool
7. Work holding and fixturing

Introduction

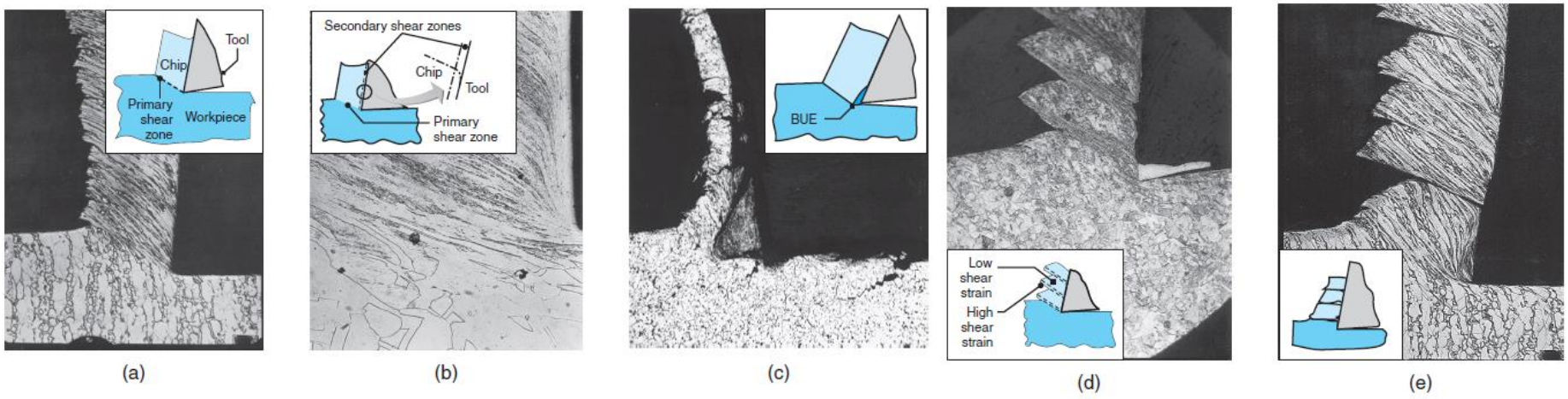
- *Dependent variables* in cutting (influenced by changes in independent variables):

1. Type of chip produced (studied since early 1940's)
2. Tool wear and failure
3. Surface finish and surface integrity of the workpiece
4. Force and energy dissipated during cutting
5. Temperature rise in the workpiece, the tool and the chip

2. Types of Chips Produced in Metal Cutting

Types of Chips Produced in Metal Cutting

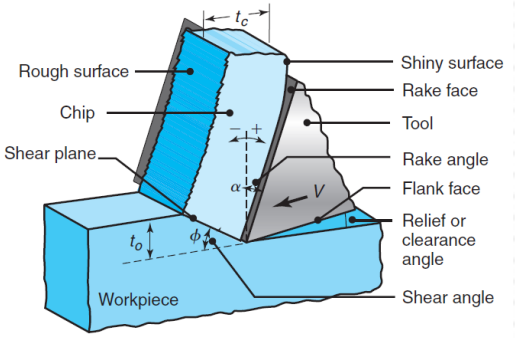
- Types of metal chips commonly observed in practice (orthogonal metal cutting)
- There are 4 main types:



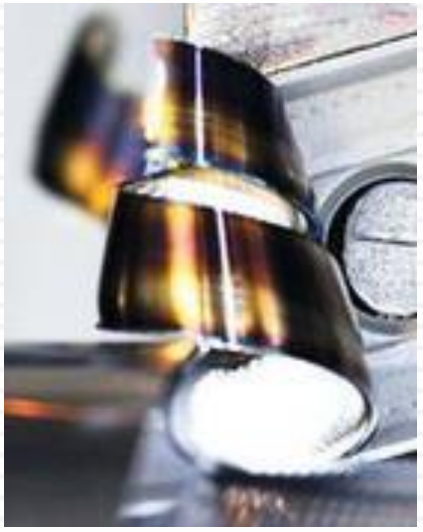
a) Continuous chip (with narrow, straight, primary shear zone)
b) Continuous chip with secondary shear zone at the tool-chip interface
c) Built-up edge, BUE chip
d) Serrated or segmented or non-homogenous chip
e) Discontinuous chip

Types of Chips Produced in Metal Cutting

All Chips



- Chip has two surfaces:
- Surface in contact with rake face
  - Shiny and polished
  - Caused by rubbing of the chip on the tool surface
- Outer surface from the original surface of the workpiece
  - Jagged, rough appearance
  - Note, this surface remains exposed to the environment, and does not come into contact with any other surface

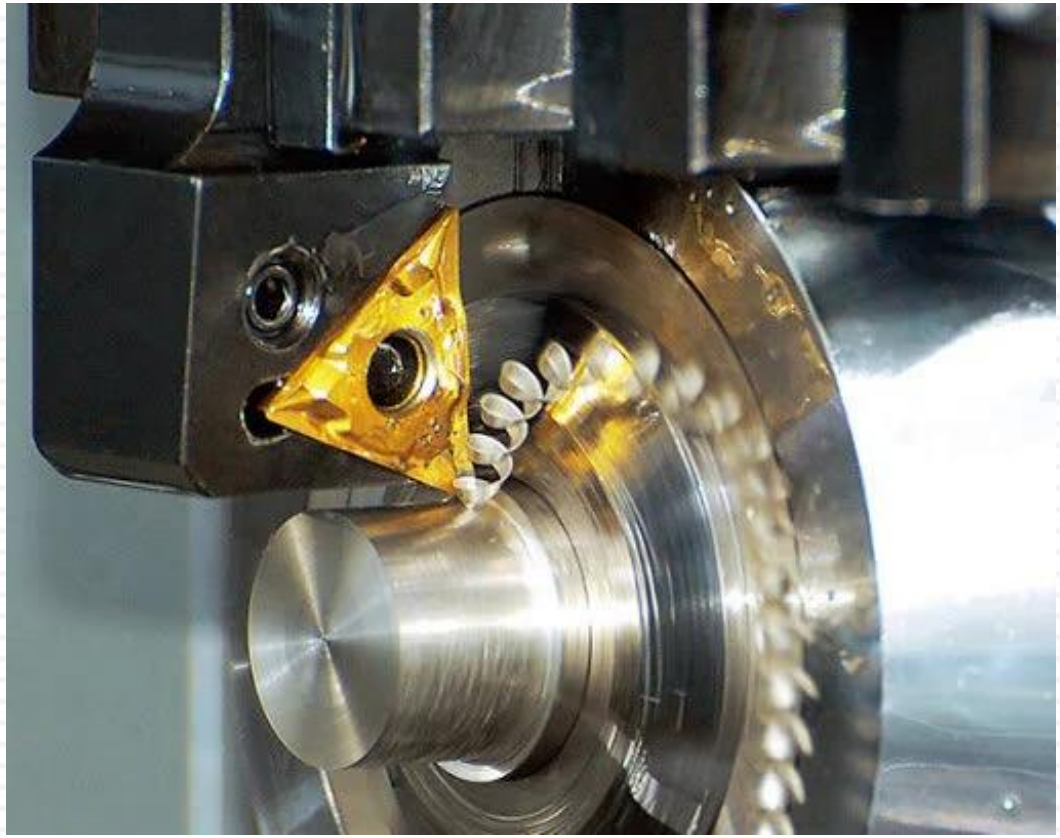


Types of Chips Produced in Metal Cutting

Types of Chips Produced in Metal Cutting

1. Continuous Chips

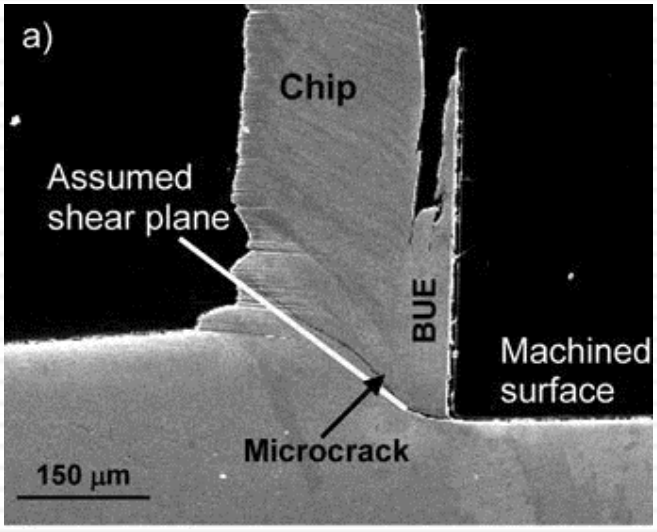
- Formed with ductile materials machined at high cutting speeds
- Watch this video:

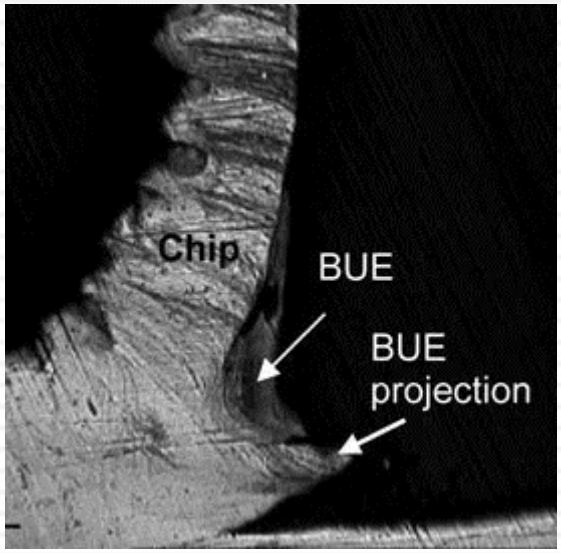


Types of Chips Produced in Metal Cutting

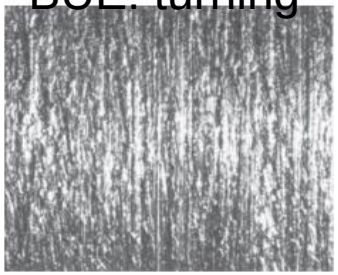
2. Built-up Edge (BUE) Chips

- Consists of layers of material from the workpiece that are deposited on the tool tip (affects surface finish) ↓
- As it grows larger, the BUE becomes unstable and eventually breaks apart
  - BUE: partly removed by tool, partly deposited on workpiece





BUE: turning

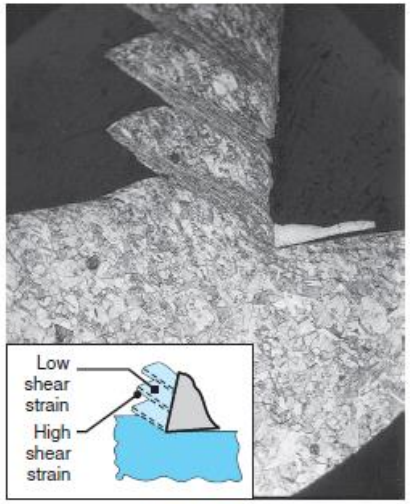


BUE: milling

Types of Chips Produced in Metal Cutting

3. Serrated Chips

- Also called *segmented* or *nonhomogeneous* chips
- Formed in metals with low thermal conductivity
- Chips have a sawtooth-like appearance



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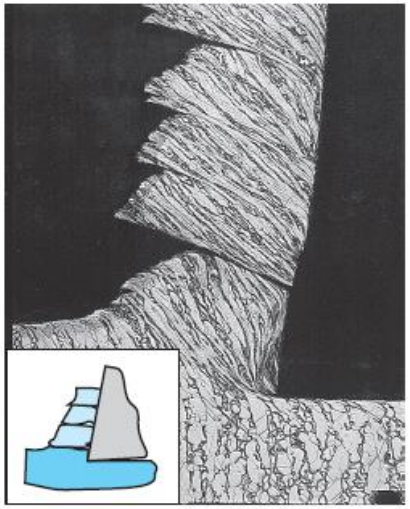


(e)

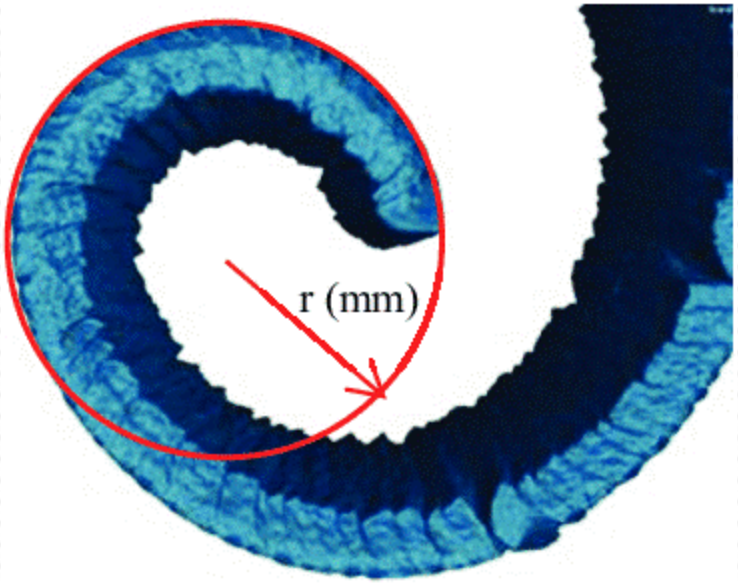
4. Discontinuous Chips

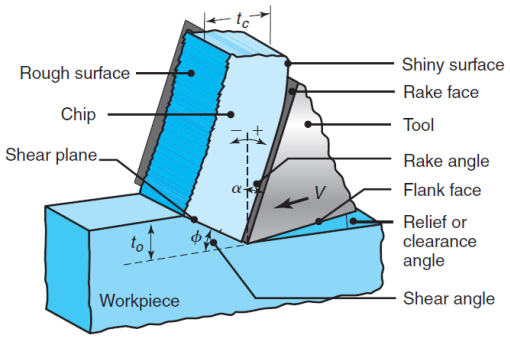
- Consist of segments that are attached firmly or loosely to each other
- Formed with brittle workpiece materials

Types of Chips Produced in Metal Cutting

Chip Curl

- Chips will develop a curvature (*chip curl*) as they leave the workpiece surface
- Note, as cutting depth ↓, chip radius ↓ (i.e. curlier)



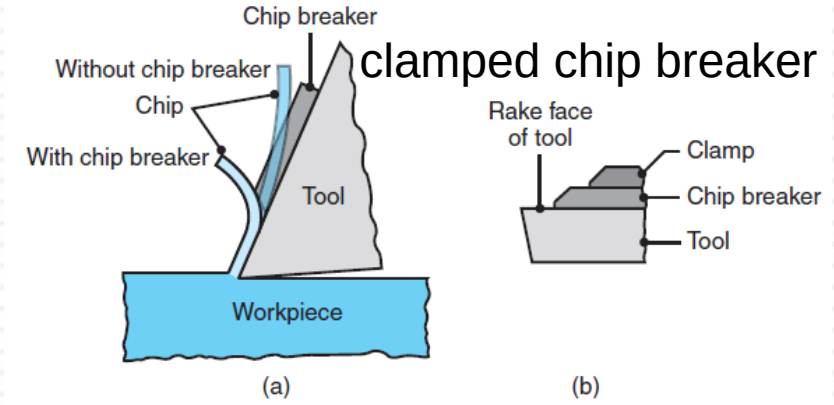


Types of Chips Produced in Metal Cutting

Chip Breakers

- Long, continuous chips are undesirable since:
  - become entangled and greatly interfere with machining
  - potential safety hazard
- *chip-breaker:* breaks chips intermittently with cutting tools

action of chip breaker



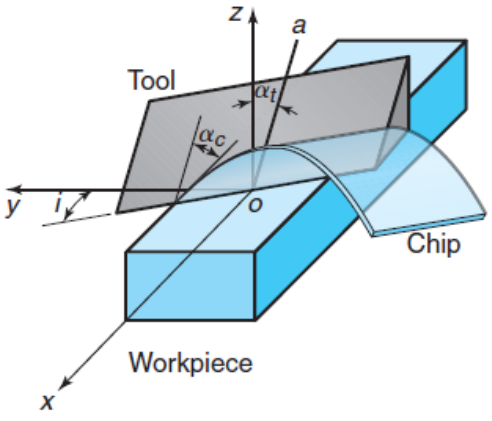
Chip hits tool shank (body) and breaks off

Types of Chips Produced in Metal Cutting: Oblique Cutting

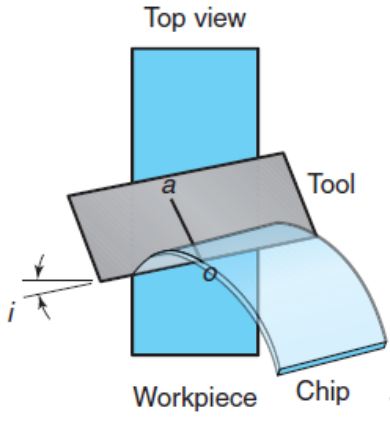
- Majority of machining operations involve tool shapes that are 3-D where the cutting is said to be *oblique*
- Difference between oblique and orthogonal cutting can be seen in chip movement and shape
- Orthogonal cutting: chip slides directly up face of tool
- Oblique cutting:

  - Chip movement is like snow from snowplow blade: sideways
    - i.e. helical chips don't interfere with cutting zone, unlike orthogonal cutting

Cutting with an Oblique Tool
(note the direction of chip movement)



Top view, showing inclination angle, *i*



Types of Chips Produced in Metal Cutting: Oblique Cutting

Shaving and Skiving

- Thin layers of material can be removed from straight or curved surfaces (similar to shaving wood with a plane)
- *Shaving* can improve the surface finish
- Parts that are long or combination of shapes are shaved by *skiving*
  - A specially shaped cutting tool is moved tangentially across the length of the workpiece

3. Tool Life: Wear and Failure

Tool Life: Wear and Failure

- **Tool wear** is gradual process; created due to:

1. Sliding of the chip along the rake face
2. Sliding of the tool along the newly cut workpiece surface
3. High temperatures (especially along rake face)

- The rate of tool wear depends on
  - tool and workpiece materials
  - tool geometry
  - process parameters
  - cutting fluids
  - characteristics of the machine tool

Tool Life: Wear and Failure

- Tool wear and the changes in tool geometry are classified as:

a) *Flank wear*

b) *Crater wear*

c) *Nose wear*

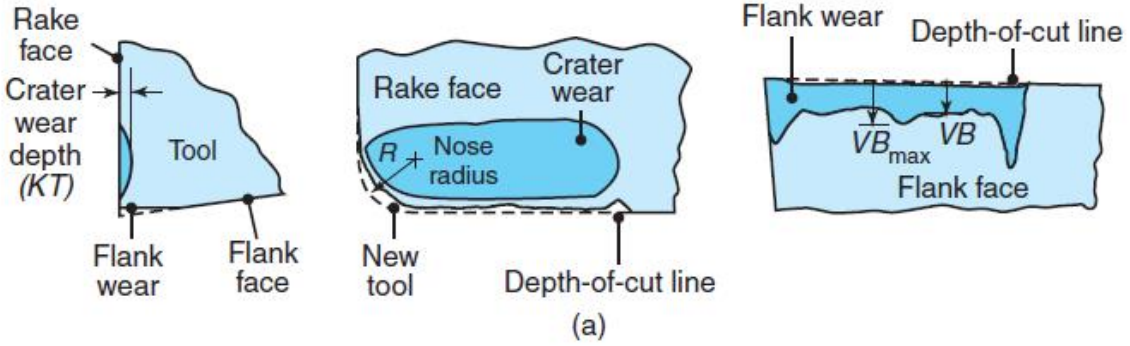
d) *Notching*

e) *Plastic deformation of the tool tip*

f) *Chipping and Gross fracture*

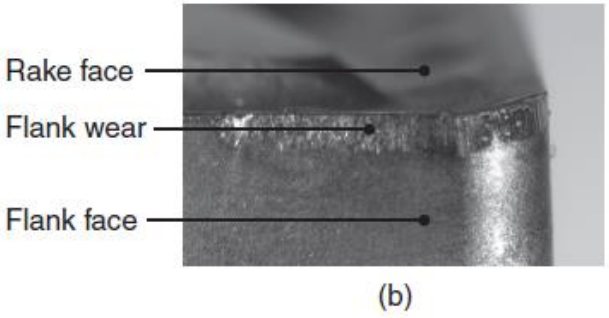
Tool Life: Wear and Failure

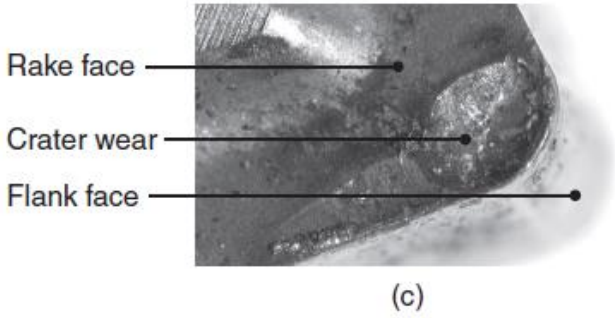
a) **Features of tool wear** in a turning operation. **VB**: indicates average flank wear



b) – e) **Examples of wear in cutting tools**

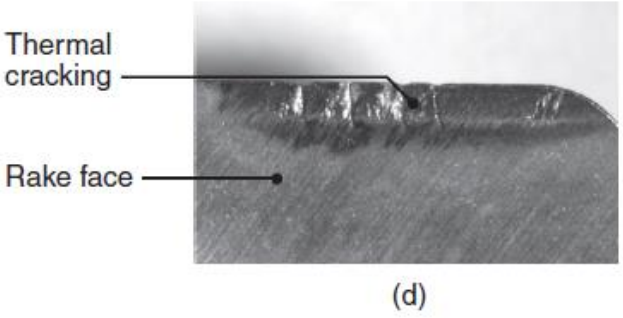
b) **Flank wear**

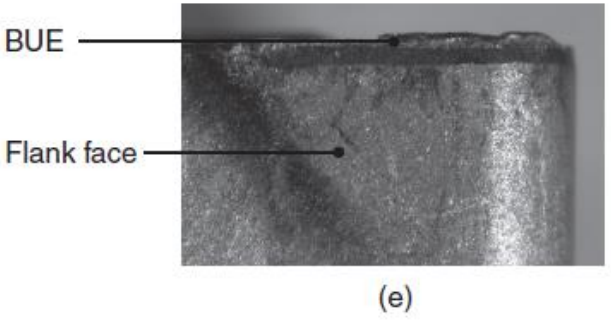




c) **Crater wear**

d) **Thermal cracking**

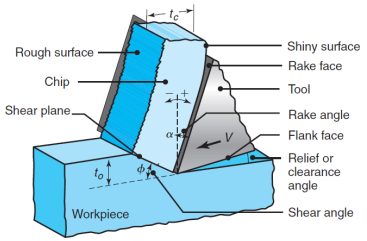


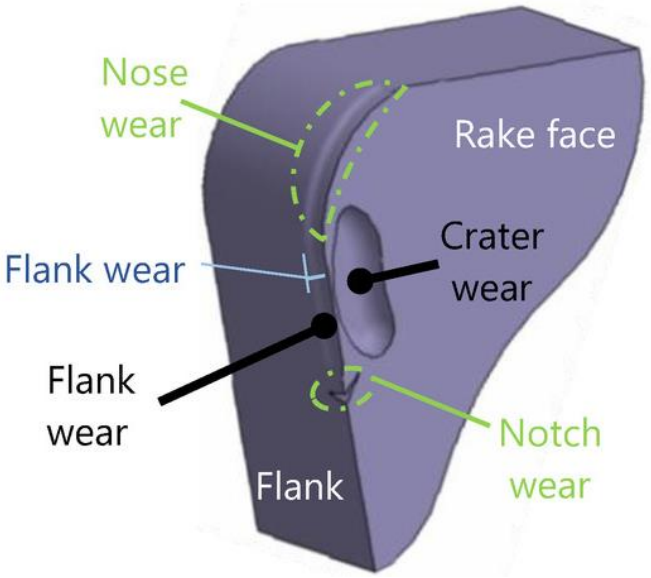


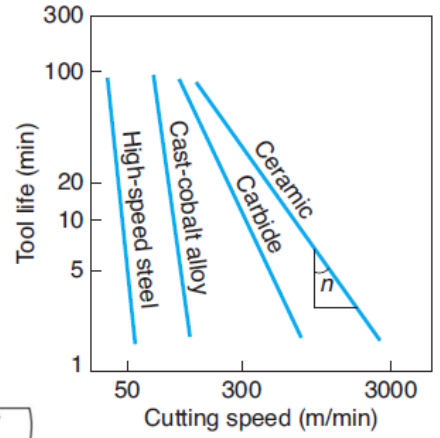
e) **Flank wear** and built-up edge (**BUE**)

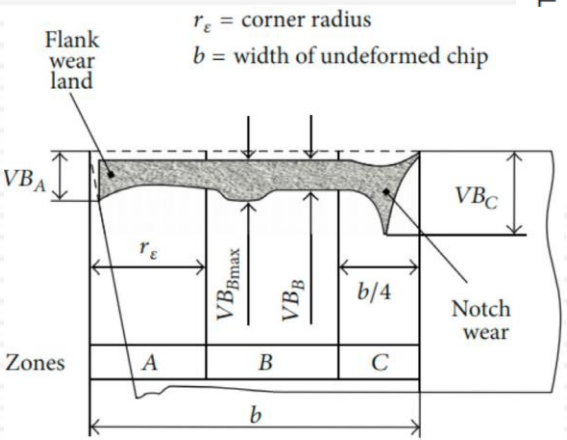
Tool Life: Wear and Failure: Flank Wear

- Flank wear occurs on the relief (flank) face of the tool
- It is due to
  - rubbing of the tool along machined surface
  - high temperatures (adversely affecting tool-material properties)
- as V increases ⇒ tool life decreases faster



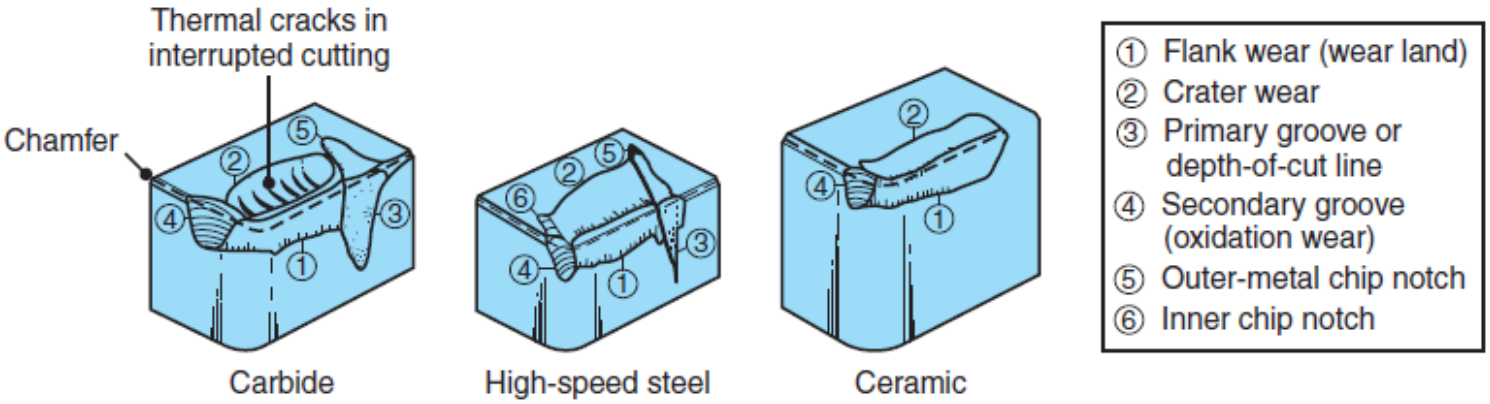




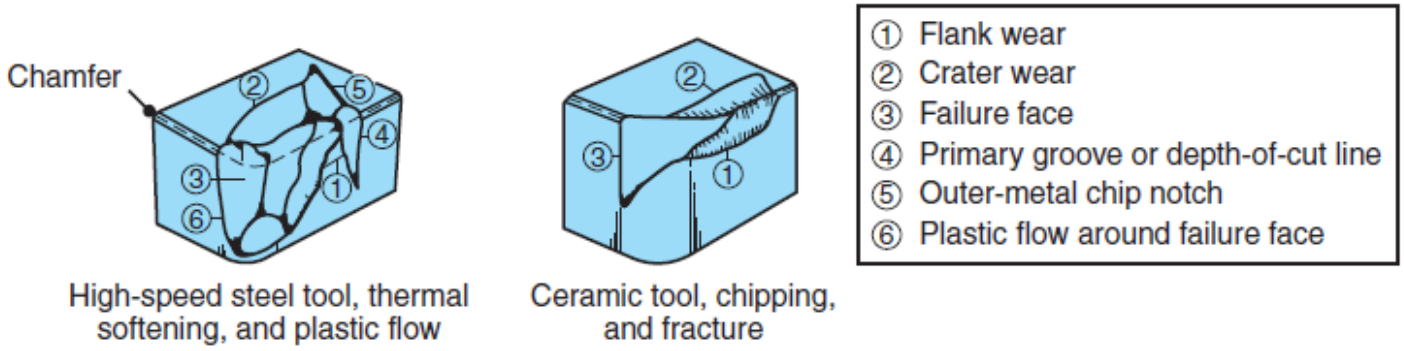


Tool Life: Wear and Failure: Crater Wear

- *Crater wear* occurs on the rake face of the tool



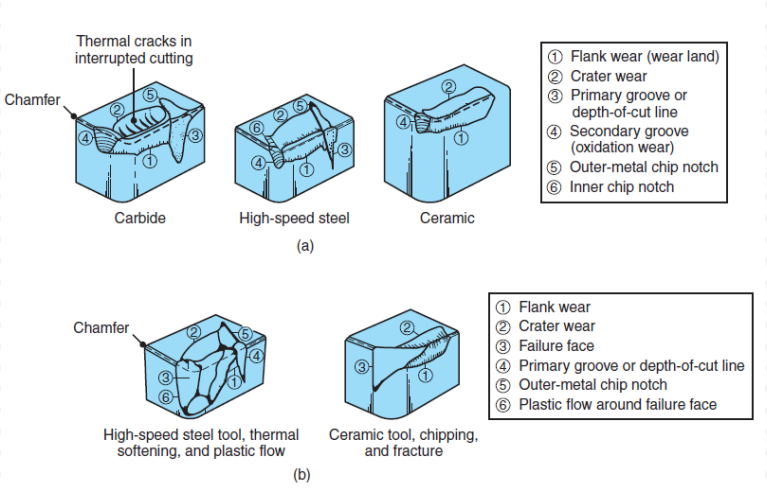
(a) Types of wear associated with various cutting tools



(b) Catastrophic tool failures (many variables involved)

Tool Life: Wear and Failure: Other Types of Wear, Chipping, and Fracture

- ***Nose wear*** is the rounding of a sharp tool due to mechanical and thermal effects
- Tools also may undergo ***plastic deformation*** because of temperature rises in the cutting zone
- ***Notches*** or ***grooves*** occur at boundary where chip no longer touches tool
- Tools may undergo ***chipping***, where small fragment from the cutting edge of the tool breaks away



Tool Life: Wear and Failure: Machinability

- *Machinability:* how easily material can be cut by a tool
- It depends on:

1. Surface finish of machined part
2. Tool life
3. Cutting conditions (e.g. speed)
4. The level of difficulty in chip control

- Good machinability indicates:
  - good surface finish
  - a long tool life
- Note, continuous chips should be avoided for good machinability