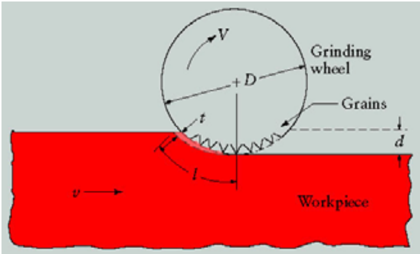
Outline

- Grinding
- Tool Life
- Tool Materials
- Tool Geometry
- Cutting Fluids

Grinding

FIGURE 9.7 *(Kalpakjian)* Variables in surface grinding. In actual grinding, the wheel depth of cut *d*, and contact length, *l*, are much smaller than the wheel diameter, *D*. The dimension *t* is called the *grain depth of cut*.



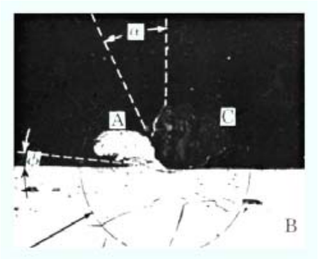


FIGURE 9.6 *(Kalpakjian)* Grinding chip being produced by a single abrasive grain: (A) chip, (B) workpiece, (C) abrasive grain.

Note the large negative rake angle of the grain, the low shear angle, and the small size of the chip.

Grinding

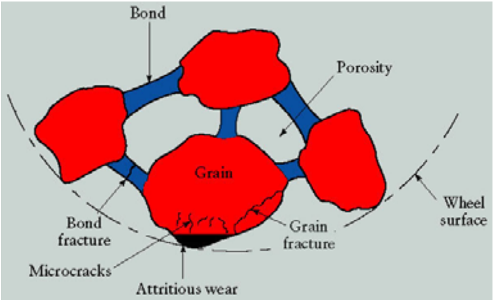
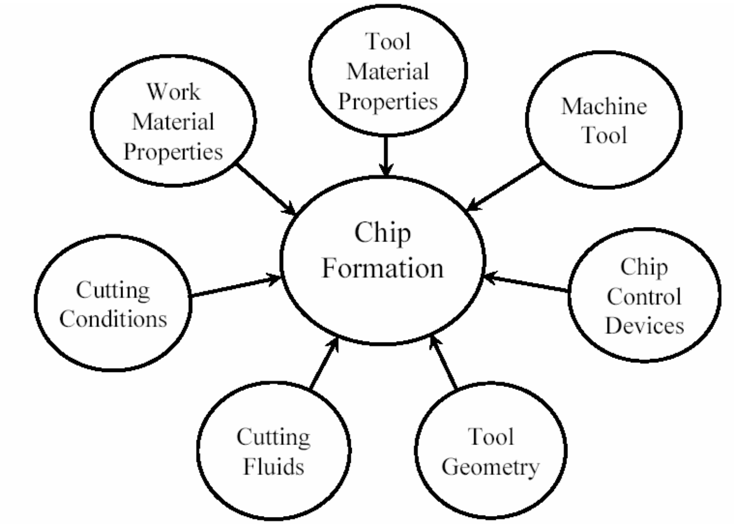


FIGURE 9.1 (*Kalpakjian*) Schematic illustration of a physical model of a grinding wheel, showing its structure and wear and fracture patterns.

Conventional abrasives
- *Aluminum oxide*
- *Silicon carbide*

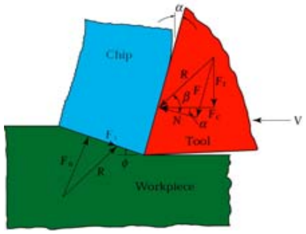
Superabrasives
- *Cubic boron nitride*
- *Diamond*

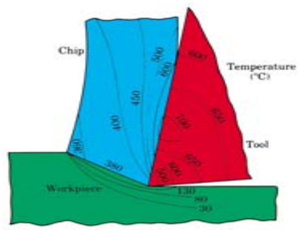
Factors Influencing the Chip Formation Process



Tool Life: *Wear and Failure*

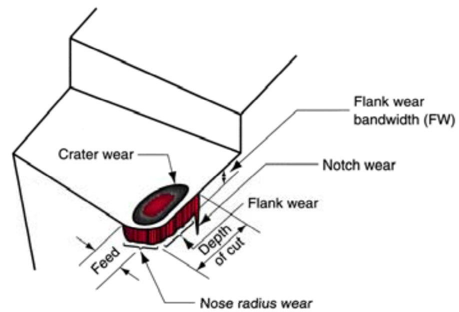
- Cutting tools subjected to
  - *High forces*
  - *High temperatures*
  - *Sliding of the chip along the rake face*
  - *Sliding of the tool along the freshly cut surface*
- *Fracture failure*
  - *Cutting force becomes excessive and/or dynamic, leading to brittle fracture*
- *Temperature failure*
  - *Cutting temperature is too high for the tool material*
- *Gradual wear*
  - *Gradual wearing of the cutting tool*
- Induce tool wear affects:
  - *Tool life , Surface quality and Dimensional accuracy*
  - *Economics of cutting operations*

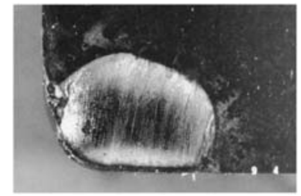




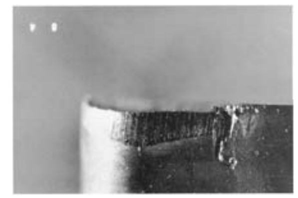
Preferred Mode of Tool Failure: *Gradual Wear*

- Fracture and temperature failures are ……….. failures
- Gradual wear is preferred because it leads to the longest possible use of the tool
- Gradual wear occurs at two locations on a tool:
  - *…….. wear* – occurs on top rake face
  - *…….. wear* – occurs on flank (*side of tool*)





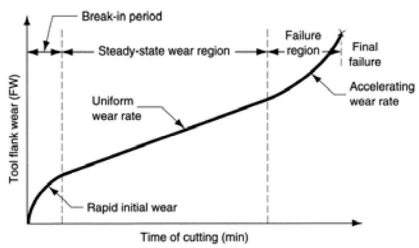
Crater wear



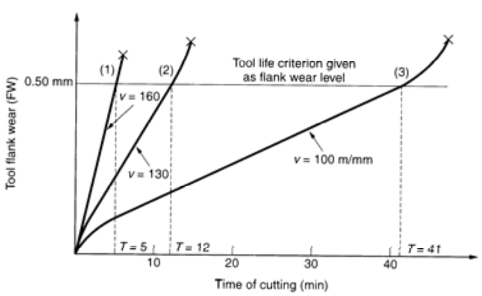
flank wear

Wear in Cutting Tools

Tool wear as a function of cutting time. Flank Wear is used here as the measure of tool wear. ***Crater Wear follows a similar*** *growth curve*



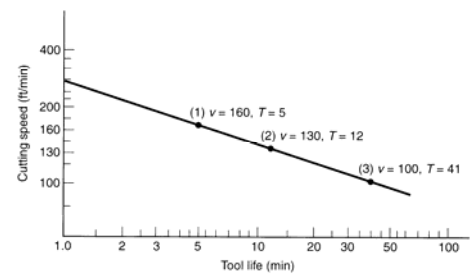
Effect of cutting speed on tool flank wear for three cutting speeds, using a tool life criterion of ***0.50 mm*** *flank wear*



Taylor Tool Life Equation

$$vT^n = C$$

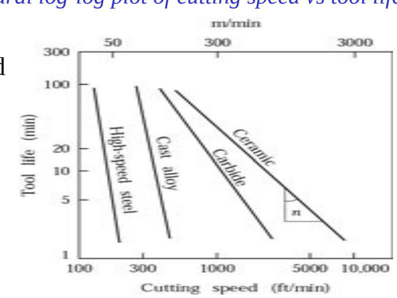
This relationship is credited to F. W. **Taylor** (~1900)



Natural log-log plot of cutting speed vs tool life

where v = cutting speed; T = tool life; and n and C are parameters that depend on feed, depth of cut, work material, tooling material, and the tool life criterion used

- n is the slope of the plot
- C is the intercept on the speed axis



Taylor's Equation

- Generalized Taylor's Equation

$$vT^n f^m d^p = C$$

- In practice,
  - Complete failure of cutting edge
  - Visual inspection
  - Finger nail testing
  - Sound
  - Power consumption
  - Work piece count or Cumulative time

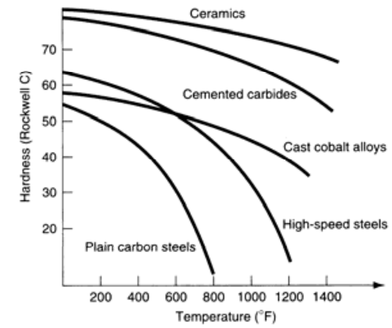
Tool Materials

- Tool failure modes identify the important properties that a tool material should possess:
  - ………… - to avoid fracture failure
  - ………… - ability to retain hardness at high temperatures
  - ………… - hardness is the most important property to resist abrasive wear

✓ Plain carbon steel shows a rapid loss of hardness as temperature increases.

✓ High speed steel is substantially better

✓ cemented carbides and ceramics are significantly harder at elevated temperatures.



Typical hot hardness for selected tool materials

High Speed Steel (HSS)

- Highly alloyed tool steel capable of maintaining hardness at elevated temperatures better than high carbon and low alloy steels
- One of the most important cutting tool materials
- Especially suited to applications involving complicated tool geometries, such as drills, taps, milling cutters, and broaches
- Two basic types (AISI)
  1. *Tungsten*-type, designated T- grades
  2. *Molybdenum*-type, designated M-grades
- Typical composition:
  - Grade T1: 18% W, 4% Cr, 1% V, and 0.9% C

Cemented Carbides

- Class of hard tool material based on tungsten carbide (WC) using powder metallurgy techniques with cobalt (Co) as the binder
- High compressive strength but low-to-moderate tensile strength
- High hardness (90 to 95 HRA)
- Good hot hardness
- Good wear resistance
- High thermal conductivity
- High elastic modulus - 600 x 10^3 MPa (90 x 10^6 lb/in^2)
- Toughness ……… than high speed steel

- Two basic types:
  1. Non-steel cutting grades - only WC-Co
  2. Steel cutting grades - TiC and TaC added to WC-Co

Non-steel Cutting Carbide Grades

- Used for nonferrous metals and gray cast iron
- Properties determined by grain size and cobalt content
  - *As **grain size** ………, hardness and hot hardness …………., but <u>toughness</u> ………….*
  - *As **cobalt content** increases, toughness improves at the expense of hardness and wear resistance*

Steel Cutting Carbide Grades

- Used for low carbon, stainless, and other alloy steels
  - *For these grades, TiC and/or TaC are substituted for some of the WC*
  - *This composition increases <u>crater wear resistance</u> for steel cutting, but adversely affects <u>flank wear resistance</u> for non-steel cutting applications*

Cermets

- Combinations of TiC, TiN, and titanium carbonitride (TiCN), with nickel and/or molybdenum as binders.
- Some chemistries are more complex
- Applications: high speed finishing and semifinishing of steels, stainless steels, and cast irons
  - *Higher speeds and lower feeds than steel-cutting carbide grades*
  - *Better finish achieved, often eliminating need for grinding*

Coated Carbides

- Cemented carbide insert coated with one or more thin layers of wear resistant materials, such as TiC, TiN, and/or Al_2O_3
- Coating applied by CVD or PVD
- Coating thickness = 2.5 - 13 μm (0.0001 to 0.0005 in)
- Applications: cast irons and steels in turning and milling operations
- Best applied at high speeds where dynamic force and thermal shock are minimal

Ceramics

- Primarily fine-grained Al_2O_3, pressed and sintered at high pressures and temperatures into insert form with no binder
- Applications: high speed turning of cast iron and steel
- Not recommended for heavy interrupted cuts (e.g. rough milling) due to low toughness

Synthetic Diamonds

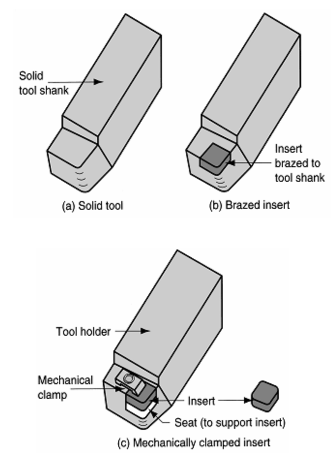
- *Sintered polycrystalline diamond* (SPD) - fabricated by sintering very fine-grained diamond crystals under high temperatures and pressures into desired shape with little or no binder
- Usually applied as coating (0.5 mm thick) on WC-Co insert
- Applications: high speed machining of nonferrous metals and abrasive nonmetals such as fiberglass, graphite, and wood
  - *Not for machining of steel or titanium alloys.*

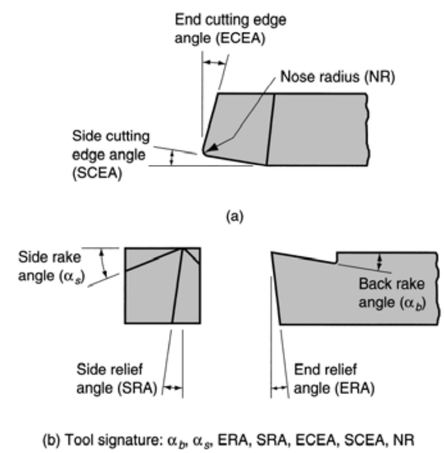
Cubic Boron Nitride

- Next to diamond, *cubic boron nitride* (cBN) is hardest material known
- Fabrication into tool inserts same as SPD: coatings on WC-Co inserts
- Applications: machining steel and nickel-based alloys

Tool Geometry

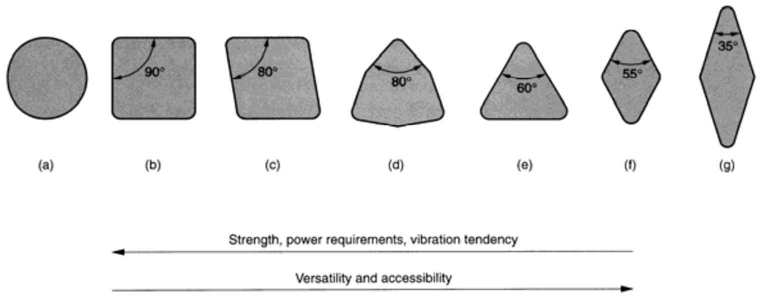
- Single point tools
  - *Used for turning, boring, shaping, and planing*





Single-Point Tool Geometry

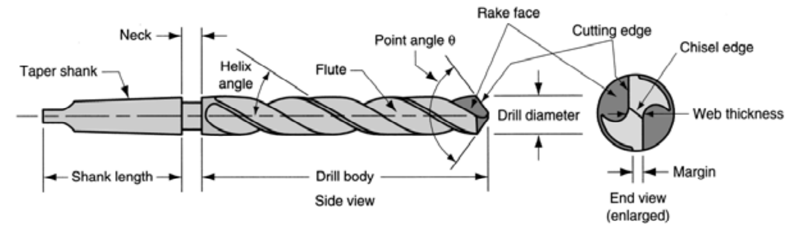
Tool Geometry: *Single Point*



Common insert shapes: (a) round, (b) square, (c) rhombus with two 80° point angles, (d) hexagon with three 80° point angles, (e) triangle (equilateral), (f) rhombus with two 55° point angles, (g) rhombus with two 35° point angles. Also shown are typical features of the geometry.

Tool Geometry: *Twist Drills*

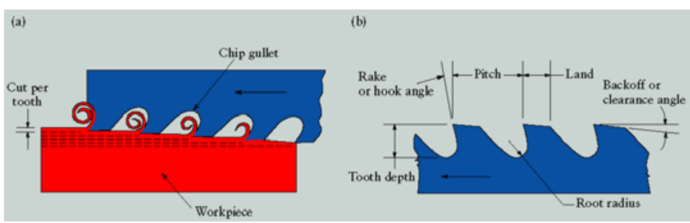
- By far the most common cutting tools for hole-making
- Usually made of high speed steel



Standard geometry of a twist drill

- Chip removal
  - *Flutes must provide sufficient clearance to allow chips to be extracted from bottom of hole*
- Friction makes matters worse
  - *Rubbing between outside diameter of drill bit and newly formed hole*
  - *Delivery of cutting fluid to drill point to reduce friction and heat is difficult because chips are flowing in the opposite direction*

Tool Geometry: *Broach*



Each tooth is successively higher than the previous tooth. In broaching, one stroke or cycle of the machine produces a finished part.

- Tooling cost can be high
- In some cases not suited for low production rates
- Parts to be broached must be ……… enough to withstand the forces of the process
- Surface to be broached must be accessible

Tool Geometry: *Broach*

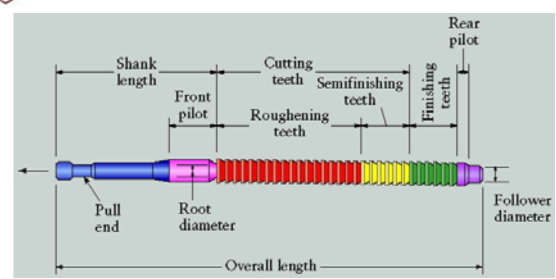
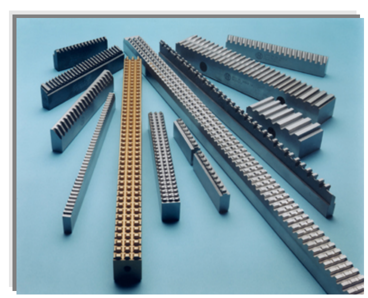


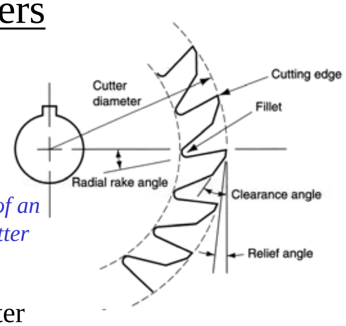
FIGURE 8.62 *(Kalpakjian)* Terminology for a pull-type internal broach used for enlarging long holes.



Milling Cutters

Plain Milling Cutter:

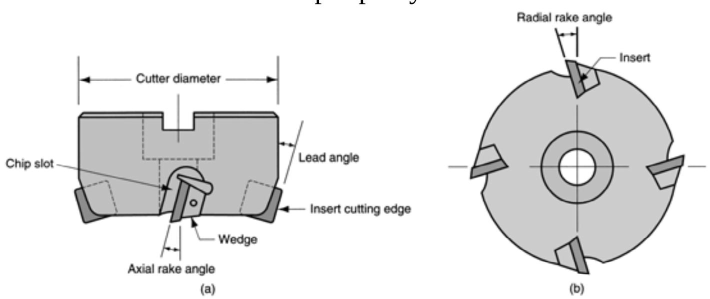
- Used for peripheral or slab milling



Tool geometry elements of an 18-tooth plain milling cutter

Face Milling Cutter:

- Teeth cut on side and periphery of the cutter



Tool geometry elements of a four-tooth face milling cutter: (a) side view and (b) bottom view

Cutting Fluids

- Any liquid or gas applied directly to machining operation to improve cutting performance
- Two main problems addressed by cutting fluids:
  1. Heat generation at shear zone and friction zone
  2. Friction at the tool-chip and tool-work interfaces
- Other functions and benefits:
  - Wash away chips (e.g., grinding and milling)
  - Reduce temperature of workpart for easier handling
  - Improve dimensional stability of workpart

- Cutting fluids can be classified according to function:
  - *Coolants* - designed to reduce effects of heat in machining
  - *Lubricants* - designed to reduce tool-chip and tool-work friction

Coolants

- Water used as base in coolant-type cutting fluids
- Most effective at high cutting speeds where heat generation and high temperatures are problems
- Most effective on tool materials that are most susceptible to temperature failures (e.g., HSS)

Lubricants

- Usually oil-based fluids
- Most effective at lower cutting speeds
- Also reduces temperature in the operation

Dry Machining

- No cutting fluid is used
- Avoids problems of cutting fluid contamination, disposal, and filtration
- Problems with dry machining:
  - *Overheating of the tool*
  - *Operating at lower cutting speeds and production rates to prolong tool life*
  - *Absence of chip removal benefits of cutting fluids in grinding and milling*

Next Time:

Different Examples