# Global Manufacturing

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Mechanical Engineering Department – POLI/COPPE/UFRJ

# Study Plan - Review

| Class# | Date | Planning |
|---|---|---|
| 1 | 10/8 | Global Manufacturing? |
| 2 | 12/8 | Manufacturing Processes (Begin project) |
| 3 | 17/8 | Steel Making |
| 4 | 19/8 | Casting Processes |
| 5 | 24/8 | Fabrication of Plastic, Ceramics and Composites |
| 6 | 26/8 | Powder Metallurgy |
| 7 | 31/8 | Additive Manufacturing |
| 8 | 02/9 | Metal Forming Processes |
| 9 | 09/9 | Forming Processes |
| 10 | 14/9 | CSA Visit |
| 11 | 16/9 | Metal Cutting (Machining) Processes |
| 12 | 21/9 | Joining (and Welding) Processes and Surface Engineering [HW #6] |
| 13 | 23/9 | Measurement and Inspection / Quality [HW# 7] |
| 14 | 28/9 | Presentation – Project – Part A |
| 15 | 30/9 | Presentation – Project – Part B |

# Metal Cutting [#9]

# Metal Cutting

- Shear Processes (Sheet Forming Process)
- Machining Processes
  - Traditional Machining
    - Rotational work part
    - Non-rotational/prismatic work part
  - Non-traditional Machining

- Oxygen Cutting

  (Related to welding Process)

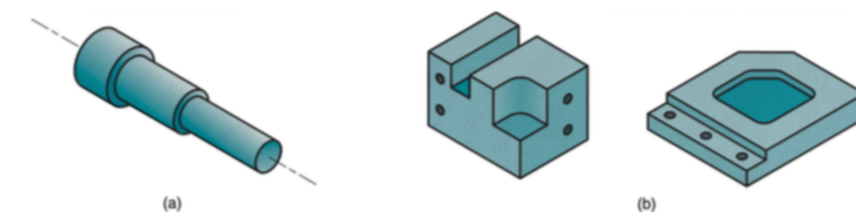
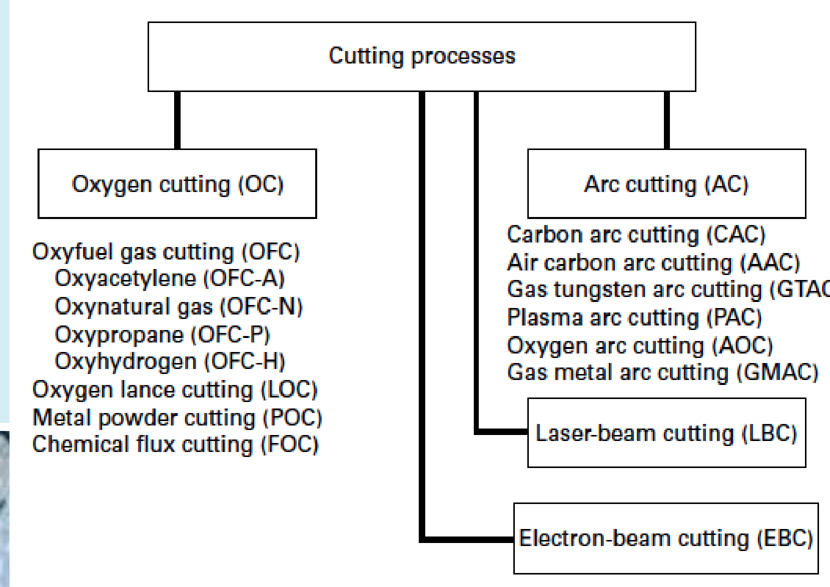



**FIGURE 16.1** Machined parts are classified as (a) rotational, or (b) nonrotational, shown here by block and flat parts. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



# Machining

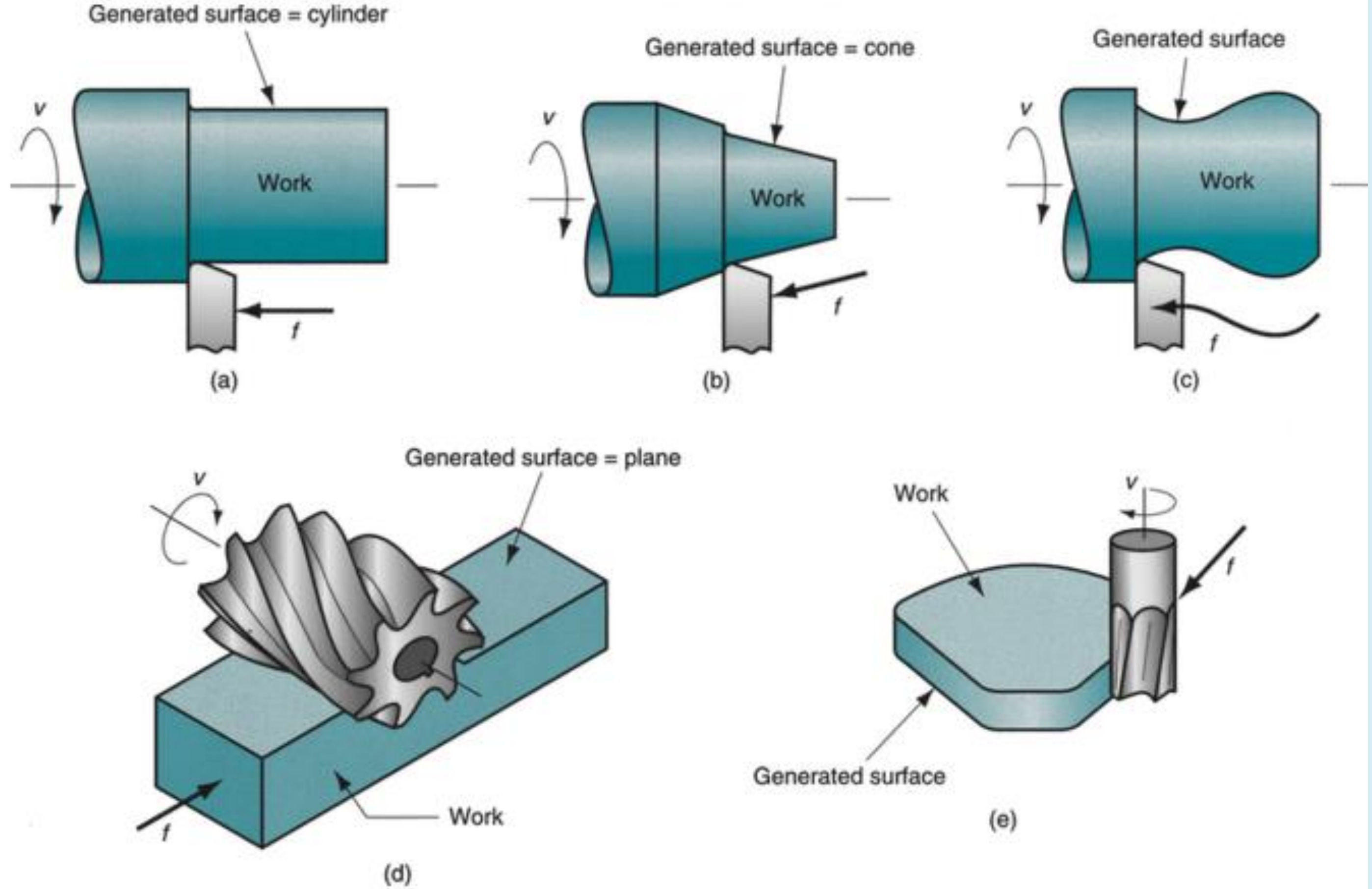



**FIGURE 16.2** Generating shape in machining: (a) straight turning, (b) taper turning, (c) contour turning, (d) plain milling, and (e) profile milling. (Credit: *Fundamentals of Modern Manufacturing,* 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

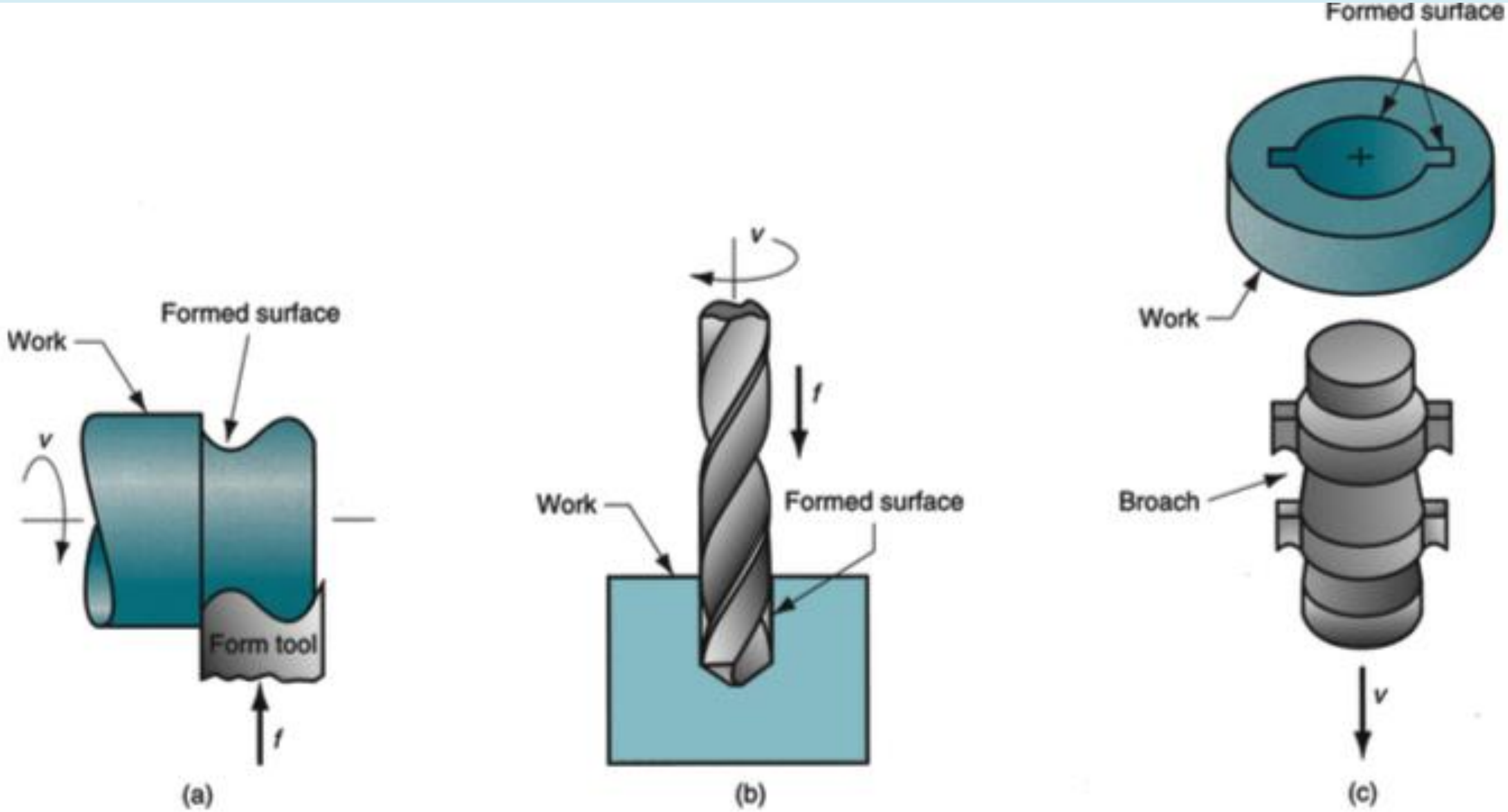



**FIGURE 16.3** Forming to create shape in machining: (a) form turning, (b) drilling, and (c) broaching. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

# TURNING

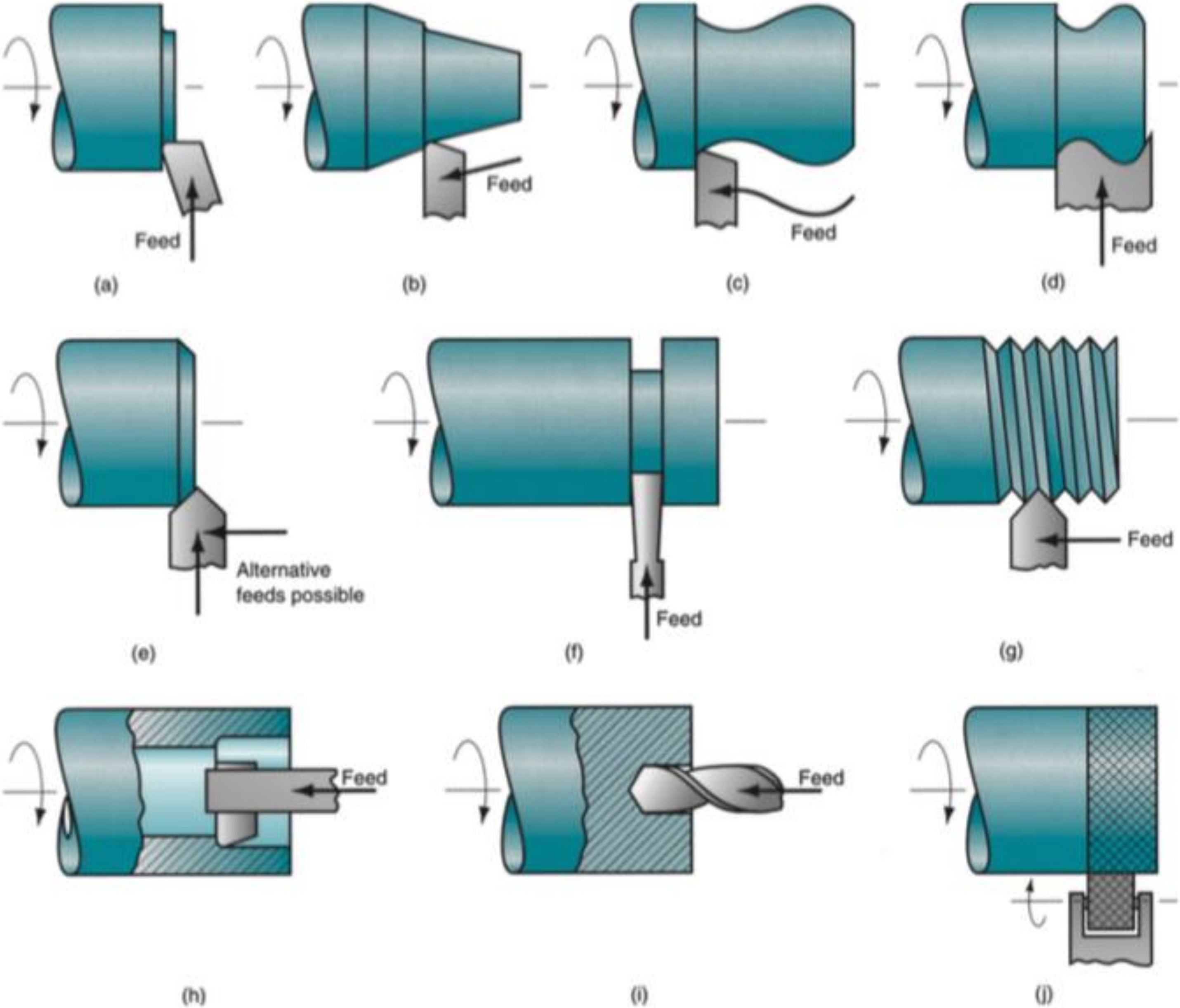



**FIGURE 16.6** Machining operations other than turning that are performed on a lathe: (a) facing, (b) taper turning, (c) contour turning, (d) form turning, (e) chamfering, (f) cutoff, (g) threading, (h) boring, (i) drilling, and (j) knurling. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

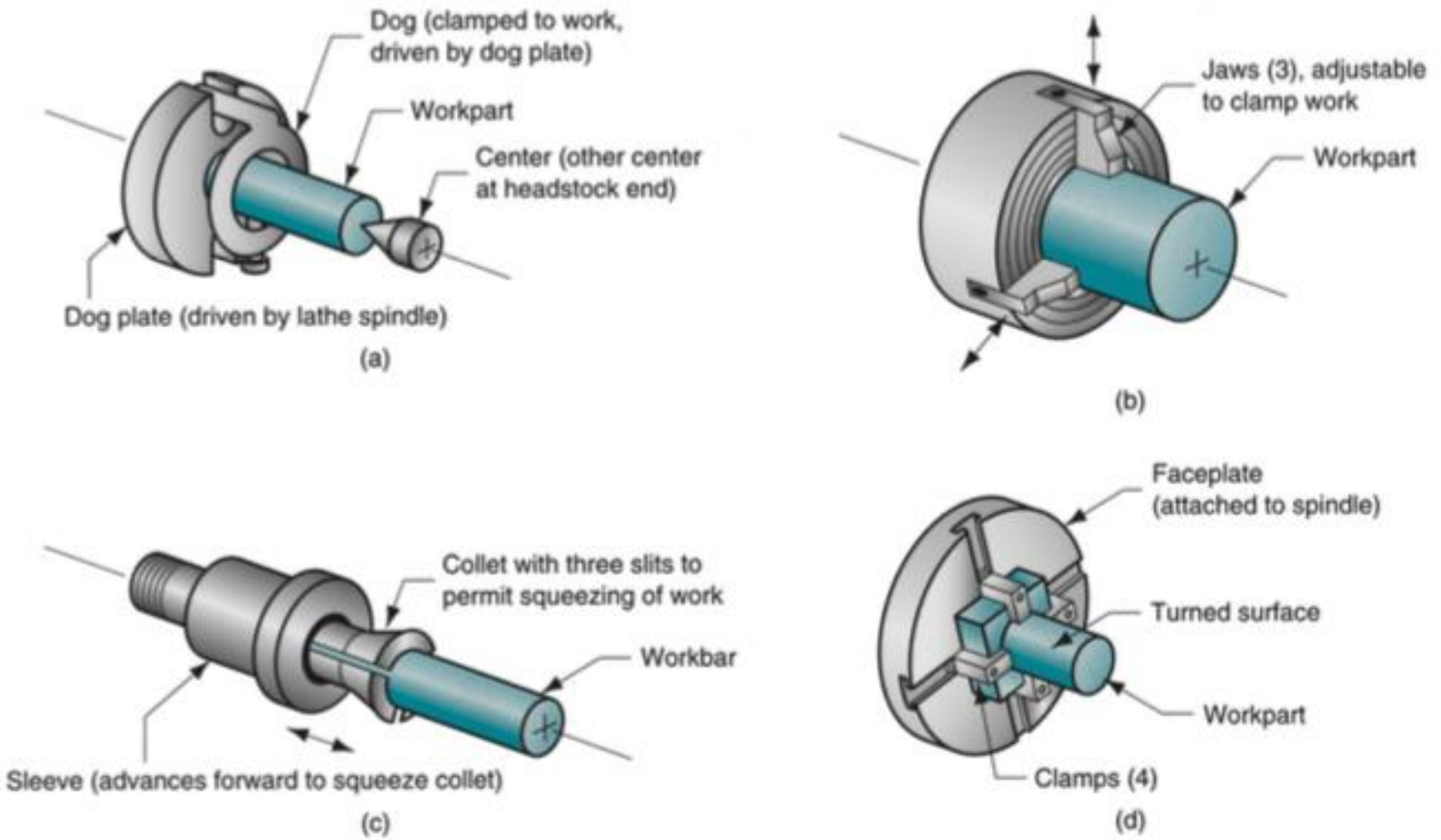



**FIGURE 16.8** Four workholding methods used in lathes: (a) mounting the work between centers using a dog, (b) three-jaw chuck, (c) collet, and (d) faceplate for noncylindrical workparts. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

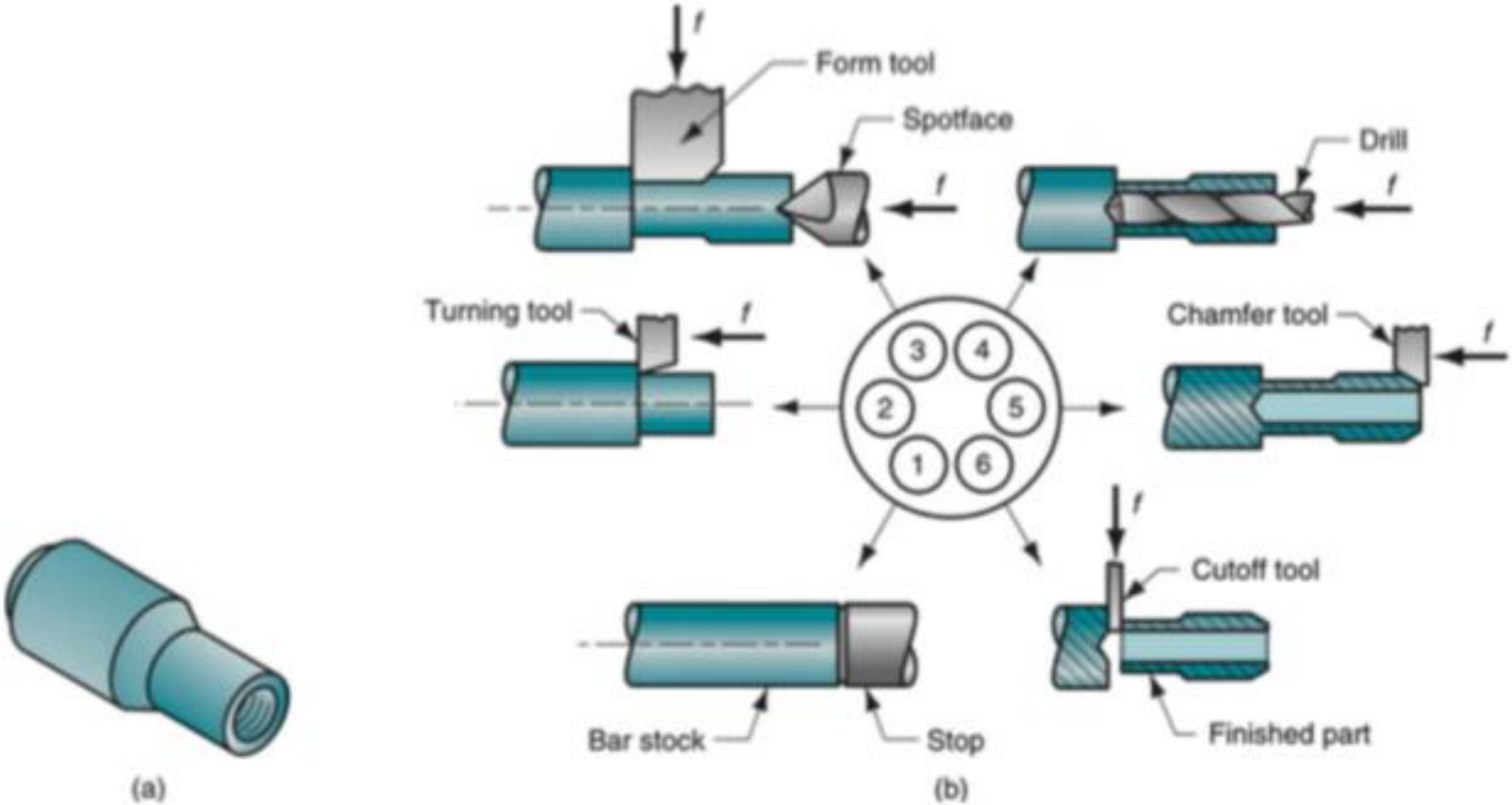



**FIGURE 16.9** (a) Type of part produced on a six-spindle automatic bar machine; and (b) sequence of operations to produce the part: (1) feed stock to stop, (2) turn main diameter, (3) form second diameter and spotface, (4) drill, (5) chamfer, and (6) cutoff. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

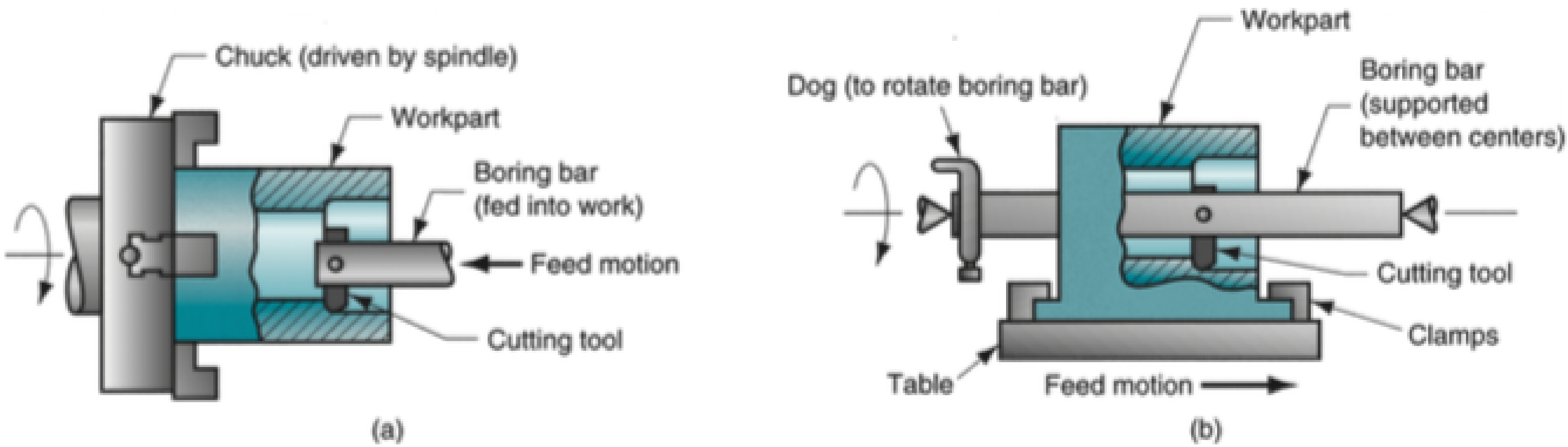



**FIGURE 16.10** Two forms of horizontal boring: (a) boring bar is fed into a rotating workpart, and (b) work is fed past a rotating boring bar. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

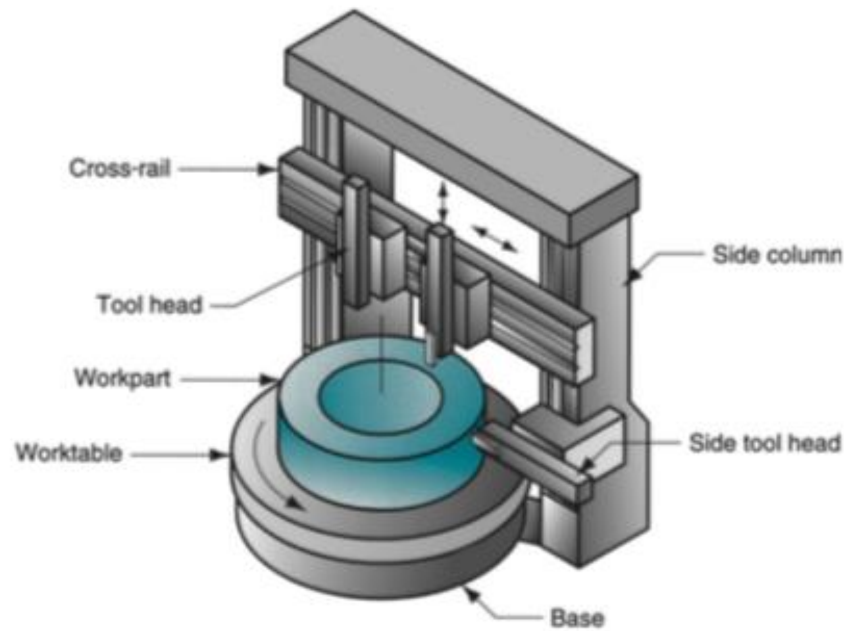



**FIGURE 16.12** A vertical boring mill. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

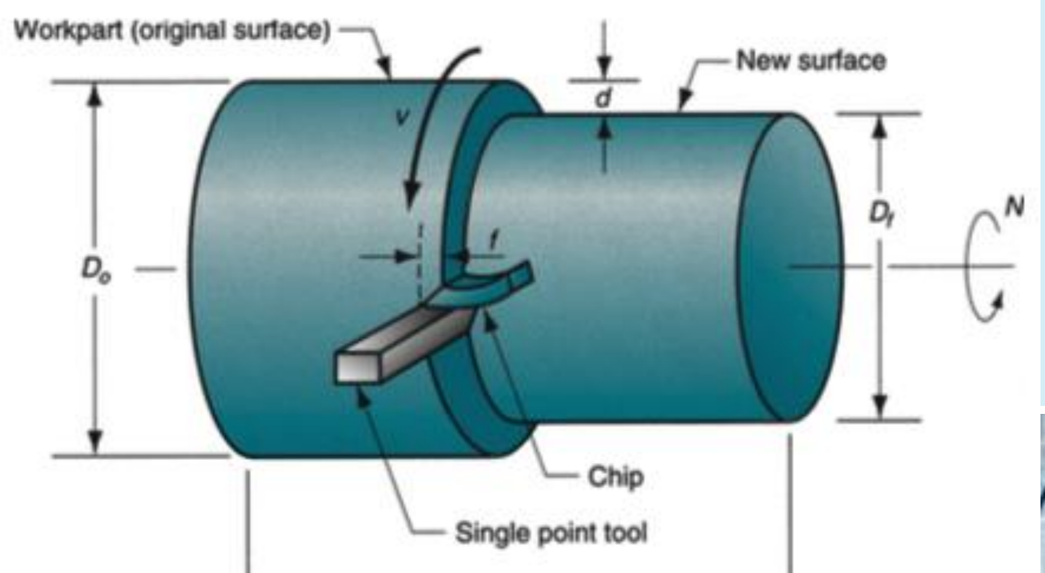
## Turning

Cutting Parameters:
d => Depth of Cut
V => Cutting Velocity
*f* => feed per revolution

$$D_f = D_i - 2d$$

$$N = \frac{V(mm/min)}{2\pi R(mm/rev)} = \frac{1000V(m/min)}{2\pi R(mm/rev)}[rpm]$$

$$V_f = N(rpm).f(mm/rev)[mm/min]$$



# CUTTING TIME

$$T_m = \frac{\pi D_o L}{f v}$$

$$\Delta t_u(min) = \frac{L(mm)}{V_f(mm/min)}$$

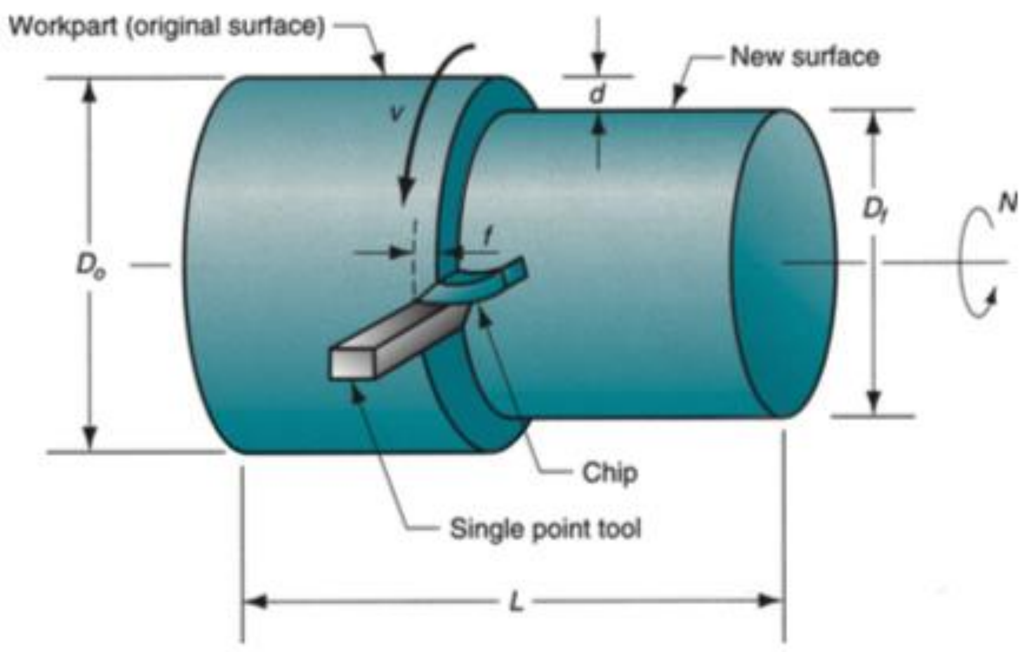



**FIGURE 16.5** Turning operation. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

# Volumetric Rate Material Removal

The volumetric rate of material removal can be most conveniently determined by the following equation:

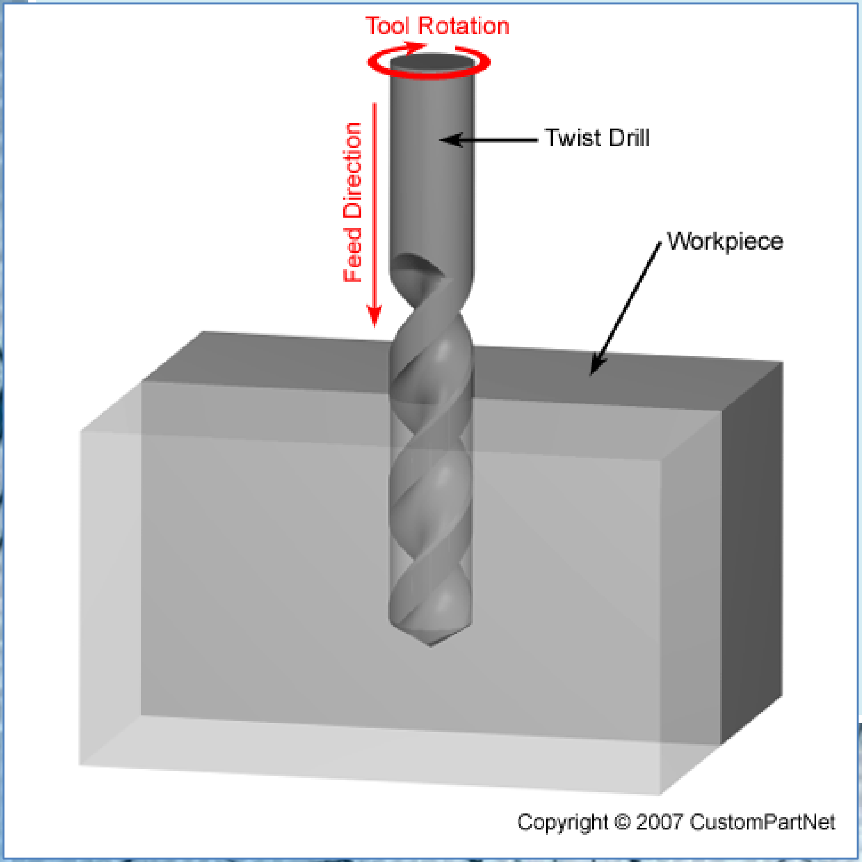
$$R_{MR} = vfd \tag{16.6}$$

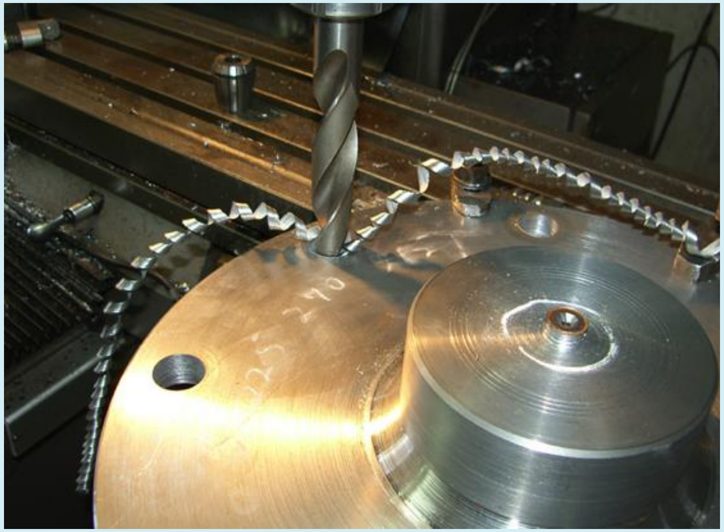
where $R_{MR}$ = material removal rate, $mm^3/min$ ($in^3/min$). In using this equation, the units for $f$ are expressed simply as mm (in), in effect neglecting the rotational character of turning. Also, care must be exercised to ensure that the units for speed are consistent with those for $f$ and $d$.

# DRILLING

$$N = \frac{1000.V_c(m/min)}{\pi D(mm)}$$

$$V_f = N(rpm).f(mm/rev)[mm/min]$$



## CUTTING TIME

$$\Delta t_u(min) = \frac{t + A}{V_f}$$

$$\Delta t_u(min) = \frac{p + A}{V_f}$$

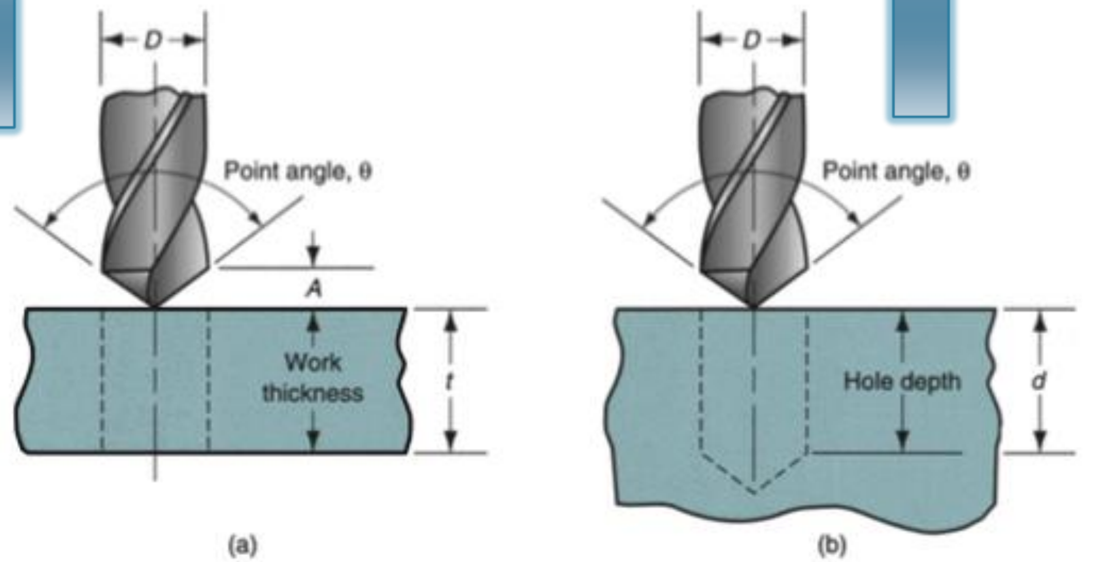



**FIGURE 16.13** Two hole types: (a) through hole and (b) blind hole. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

$$R_{MR} = \frac{\pi D^2 f_r}{4}$$

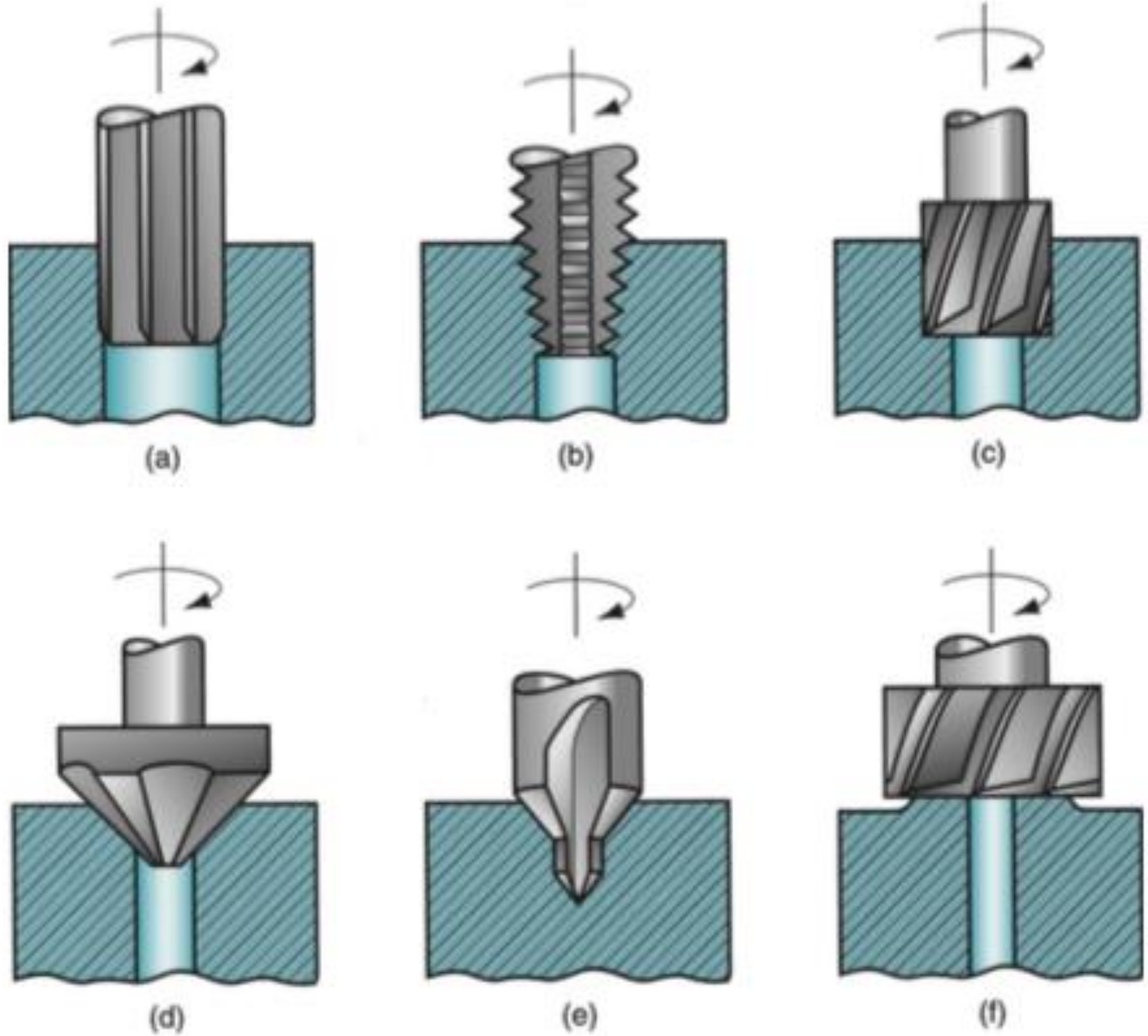
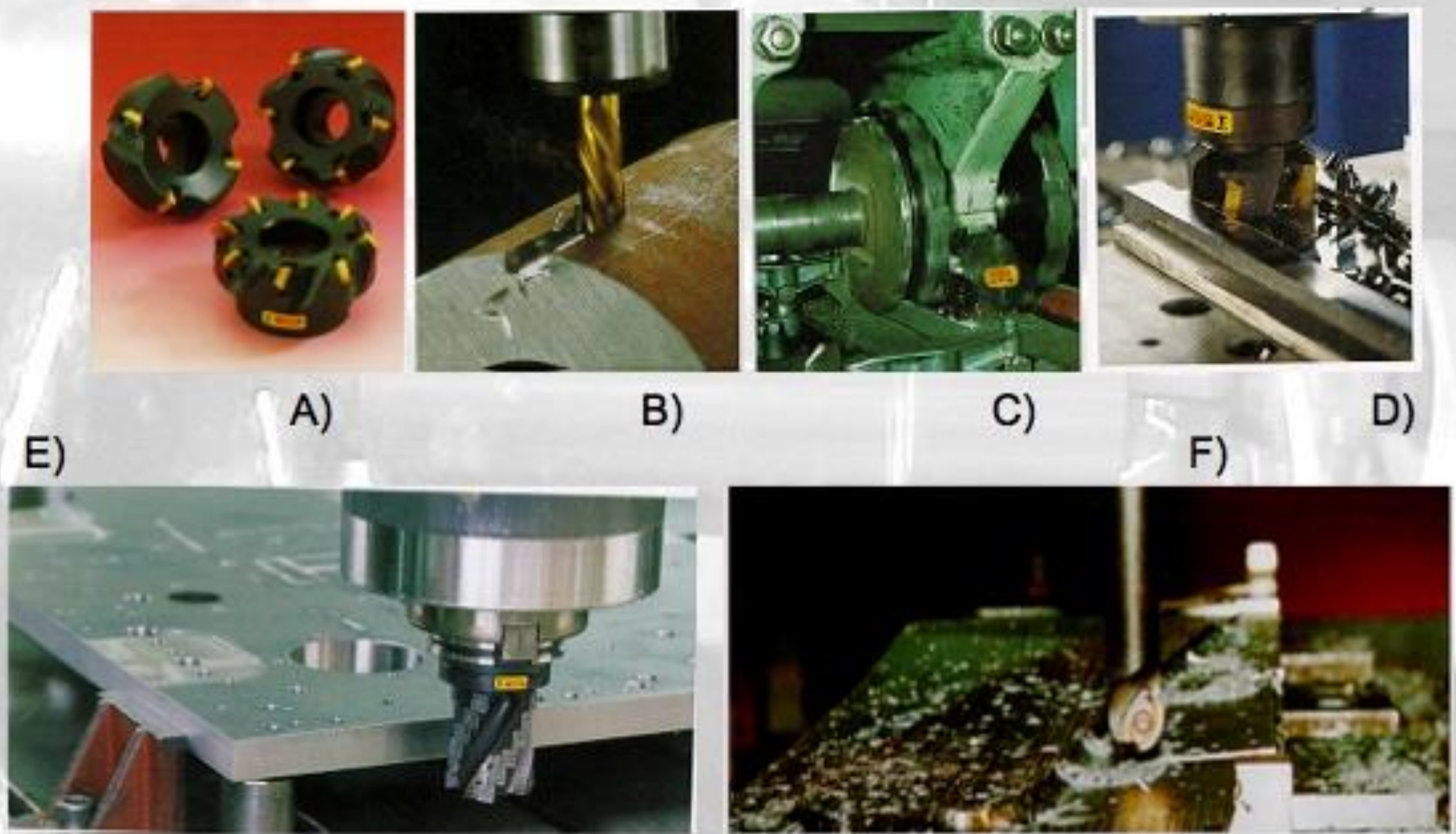



**FIGURE 16.14**
Machining operations related to drilling: (a) reaming, (b) tapping, (c) counterboring, (d) countersinking, (e) center drilling, and (f) spot facing. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

# Milling



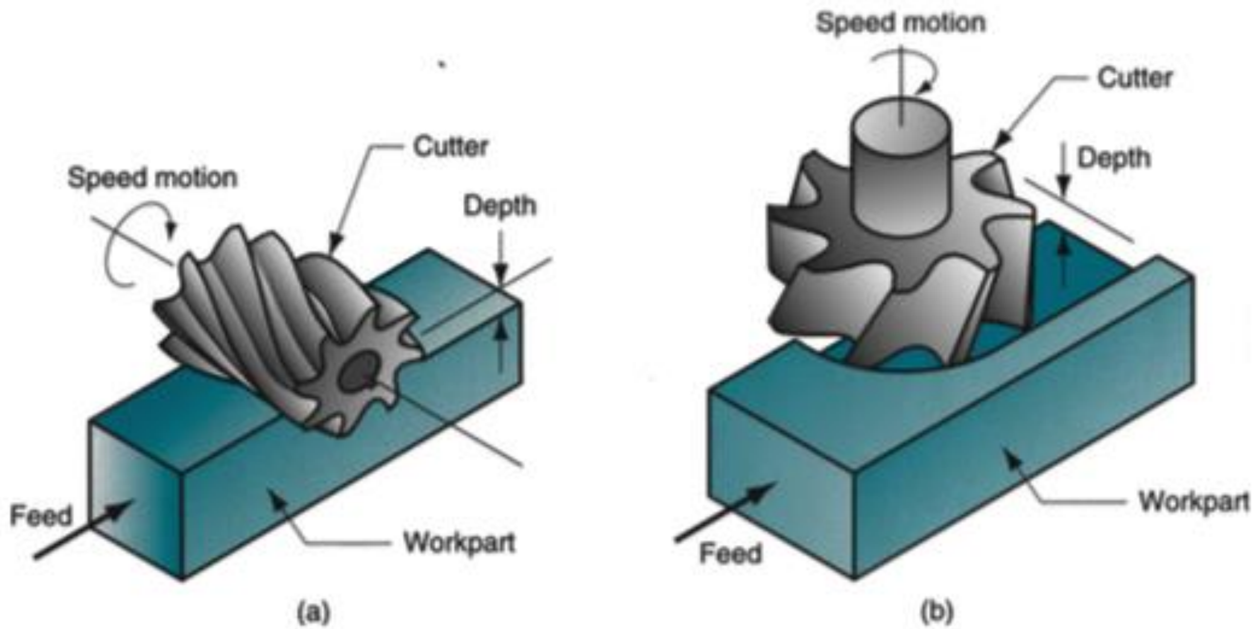



**FIGURE 16.17** Two basic types of milling operations: (a) peripheral or plain milling and (b) face milling. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

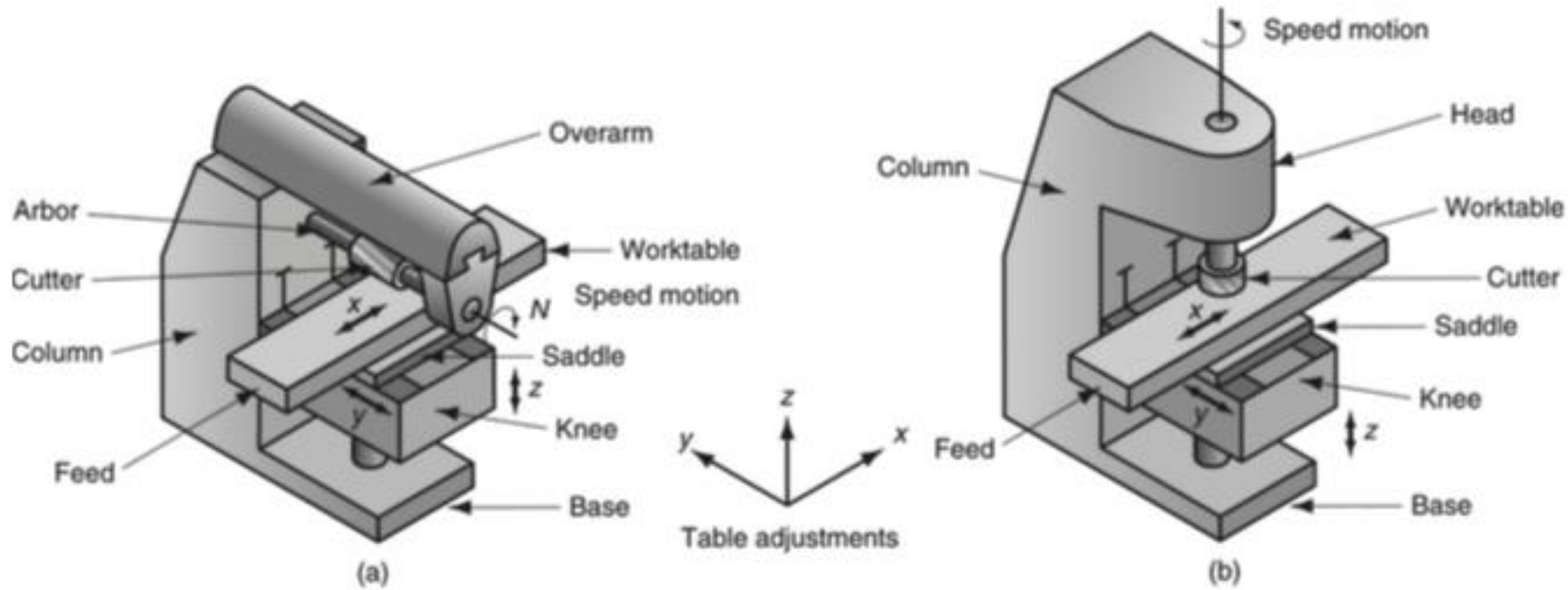
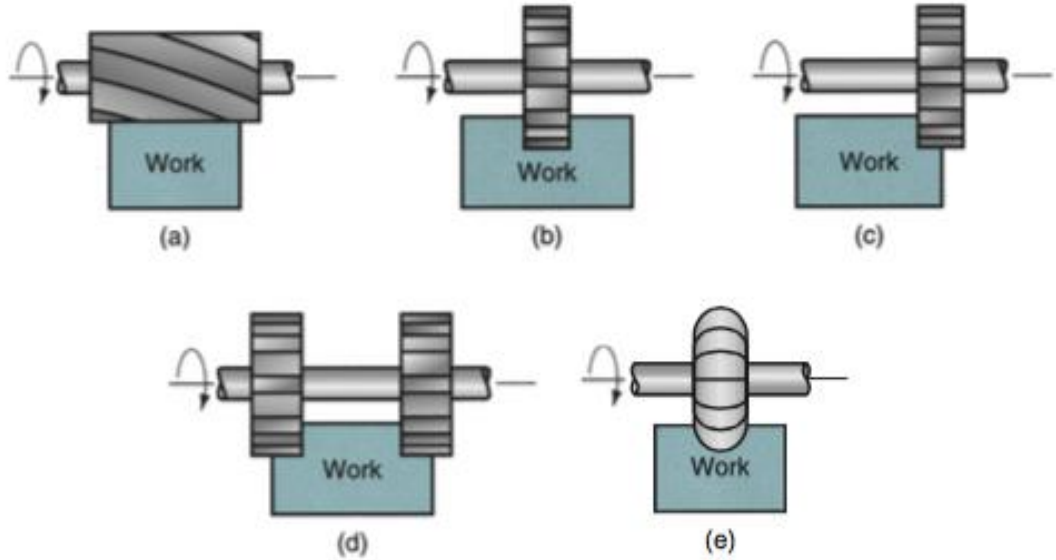
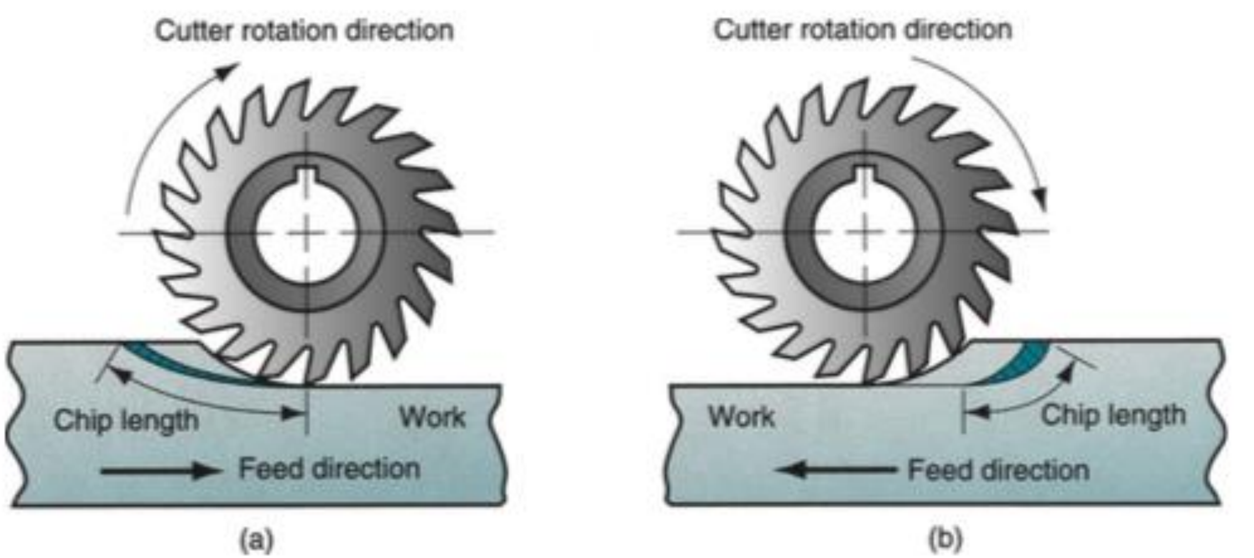



**FIGURE 16.23** Two basic types of knee-and-column milling machine: (a) horizontal and (b) vertical. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

**FIGURE 16.18**
Peripheral milling: (a) slab milling, (b) slotting, (c) side milling, (d) straddle milling, and (e) form milling. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



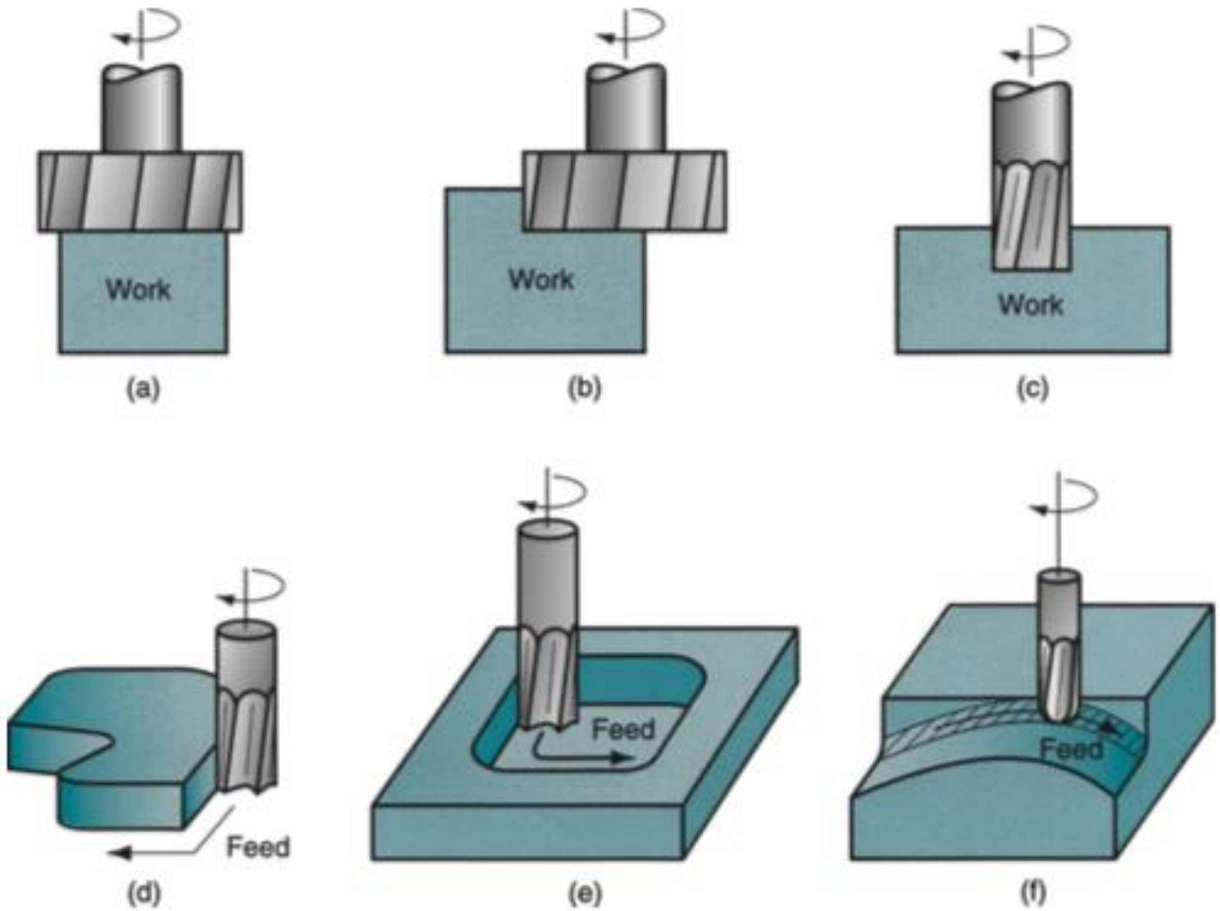
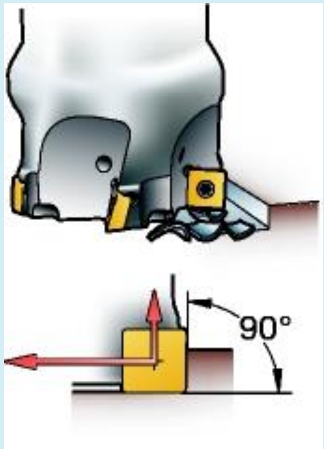
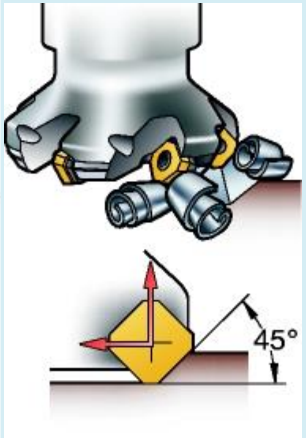



**FIGURE 16.20** Face milling: (a) conventional face milling, (b) partial face milling, (c) end milling, (d) profile milling, (e) pocket milling, and (f) surface contouring. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

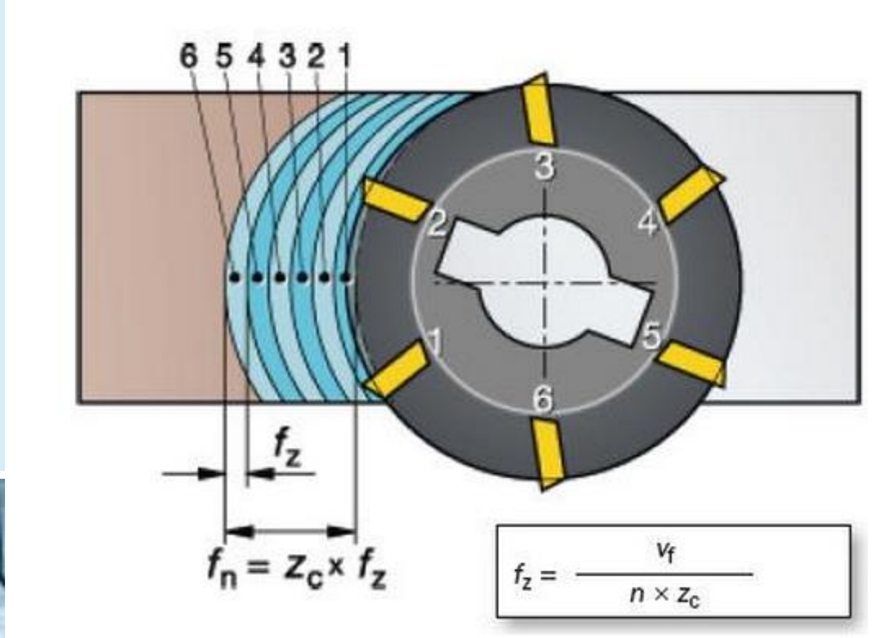
# CUTTING VELOCITIES

$$N = \frac{1000.V_c(m/min)}{\pi D(mm)}$$




$$V_f = N(rpm).Z(teeth).f_t(mm/teeth)[mm/min]$$



# Cutting Velocities in Milling (Conventional Speed and HSC)

**TABLE 16.1 Comparison of cutting speeds used in conventional versus high-speed machining for selected work materials.**

| | Solid Tools (end mills, drills)[a] | | | | Indexable Tools (face mills)[a] | | | |
|---|---|---|---|---|---|---|---|---|
| | Conventional Speed | | High Cutting Speed | | Conventional Speed | | High Cutting Speed | |
| Work Material | m/min | ft/min | m/min | ft/min | m/min | ft/min | m/min | ft/min |
| Aluminum | 300+ | 1000+ | 3000+ | 10,000+ | 600+ | 2000+ | 3600+ | 12,000+ |
| Cast iron, soft | 150 | 500 | 360 | 1200 | 360 | 1200 | 1200 | 4000 |
| Cast iron, ductile | 105 | 350 | 250 | 800 | 250 | 800 | 900 | 3000 |
| Steel, free machining | 105 | 350 | 360 | 1200 | 360 | 1200 | 600 | 2000 |
| Steel, alloy | 75 | 250 | 250 | 800 | 210 | 700 | 360 | 1200 |
| Titanium | 40 | 125 | 60 | 200 | 45 | 150 | 90 | 300 |

[a]Solid tools are made of one solid piece, indexable tools use indexable inserts. Appropriate tool materials include cemented carbide and coated carbide of various grades for all materials, ceramics for all materials, polycrystalline diamond tools for aluminum, and cubic boron nitride for steels (see Section 17.2 for discussion of these tool materials).

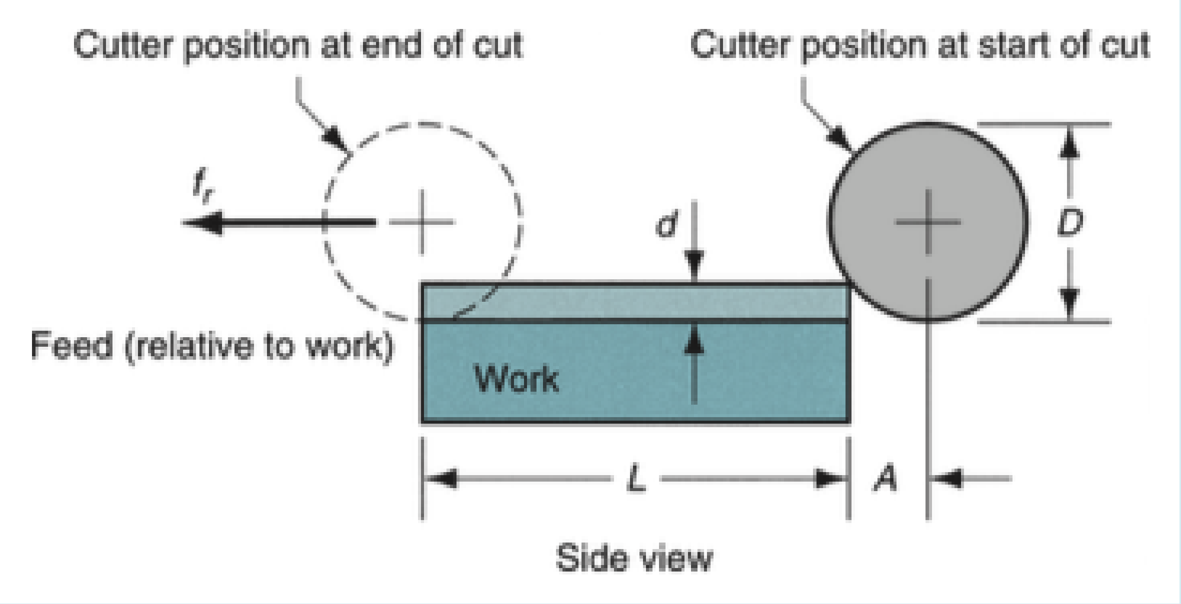
*Source:* Kennametal Inc. [3].

# Cutting Time

$$R_{MR} = w.d.V_f$$

$$\boxed{\Delta t_u(min) = \frac{L + A}{V_f}}$$

$$A = \sqrt{d(D - d)}$$



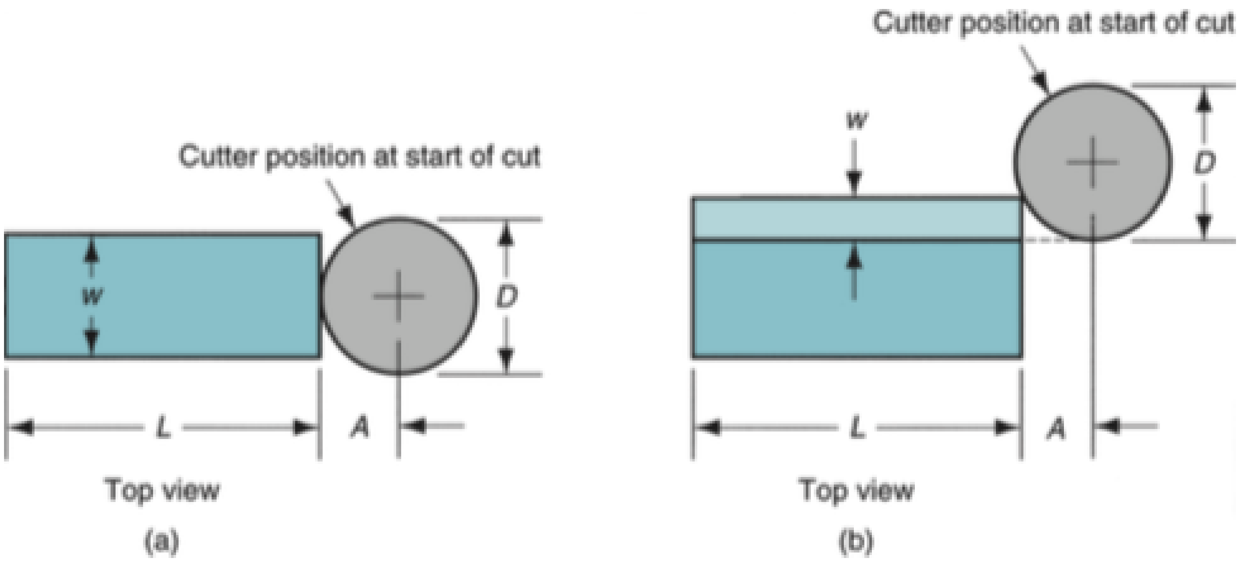
# Cutting Time

$$\Delta t_u(min) = \frac{L + A}{V_f}$$

$$A = 0.5\left(D - \sqrt{D^2 - w^2}\right)$$

$$R_{MR} = w.d.V_f$$

**FIGURE 16.22** Face milling showing approach and overtravel distances for two cases: (a) when cutter is centered over the workpiece, and (b) when cutter is offset to one side over the work. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



# Shapping and Planning

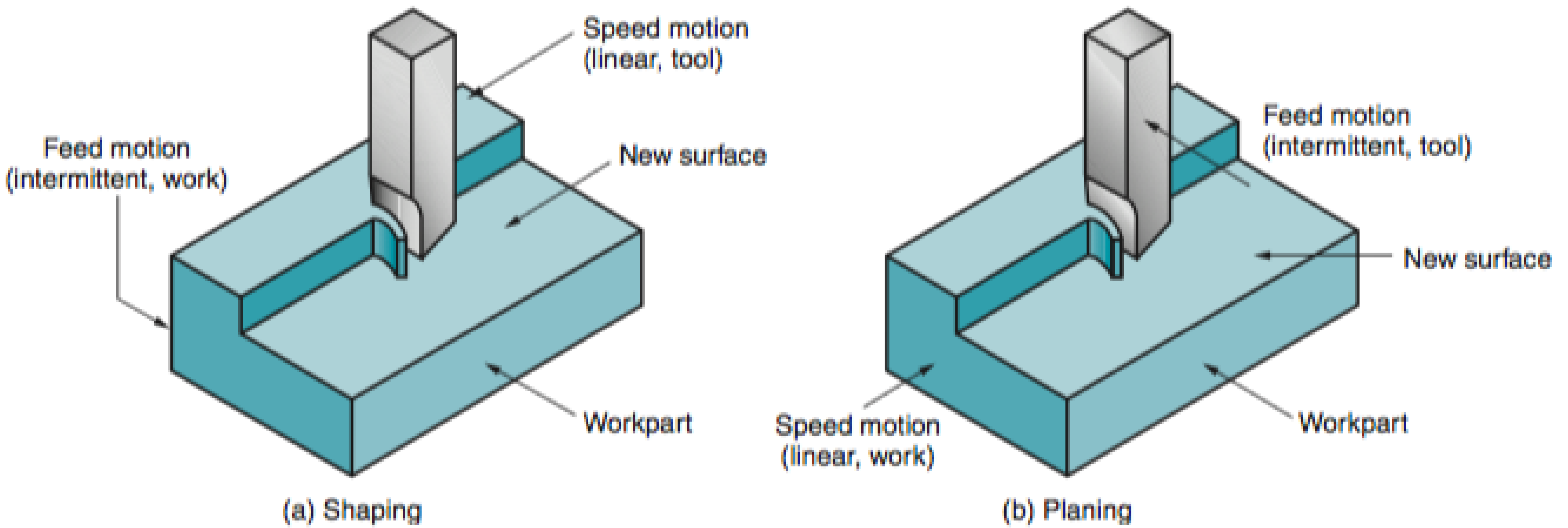



**FIGURE 16.29** (a) Shaping, and (b) planing. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010.

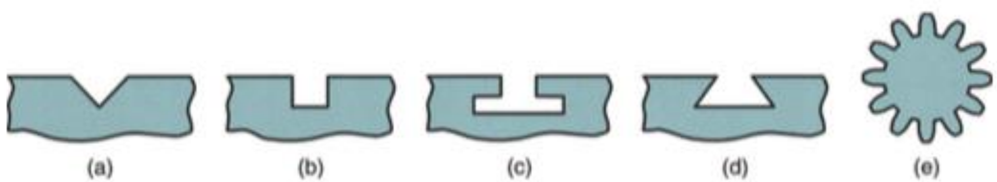



**FIGURE 16.32** Types of shapes that can cut by shaping and planing: (a) V-groove, (b) square groove, (c) T-slot, (d) dovetail slot, and (e) gear teeth. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

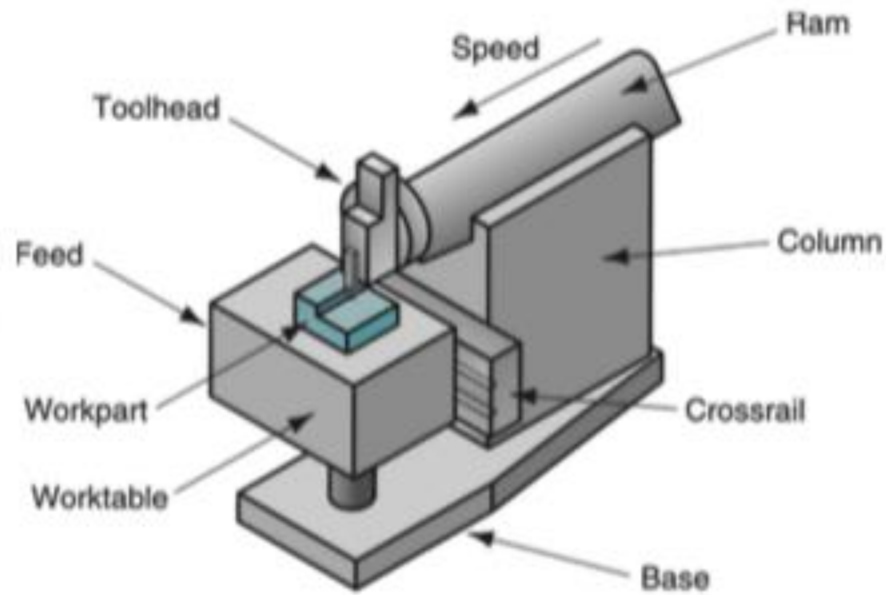



**FIGURE 16.30** Components of a shaper. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

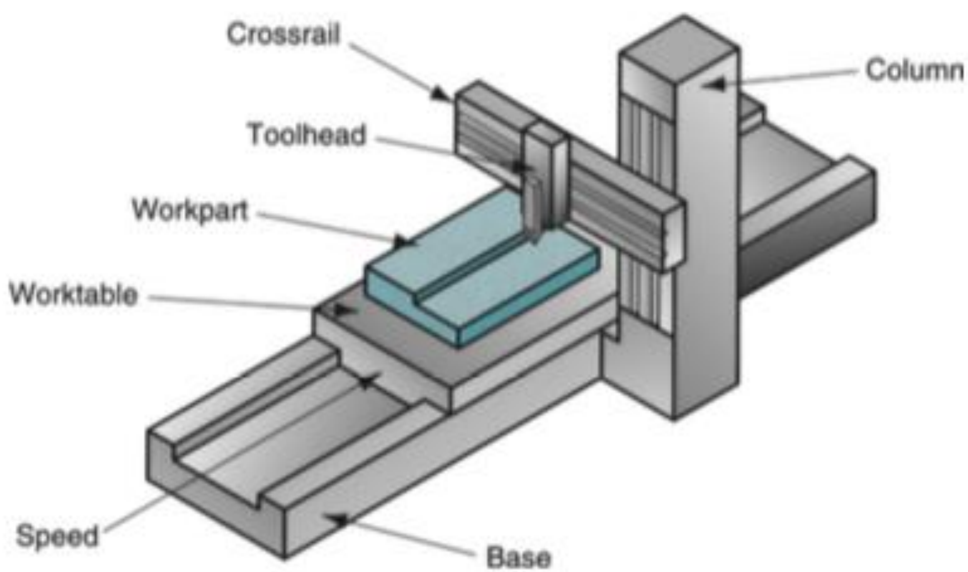



**FIGURE 16.31** Open side planer. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

# Broaching

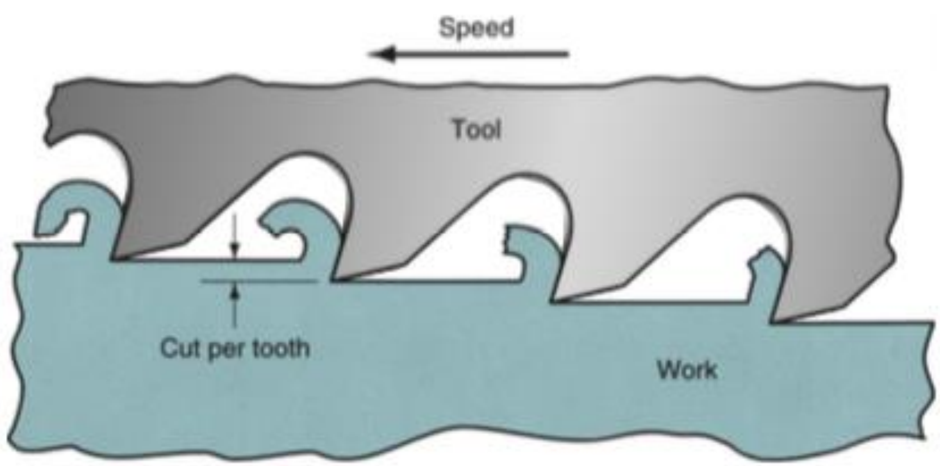



**FIGURE 16.33** The broaching operation. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

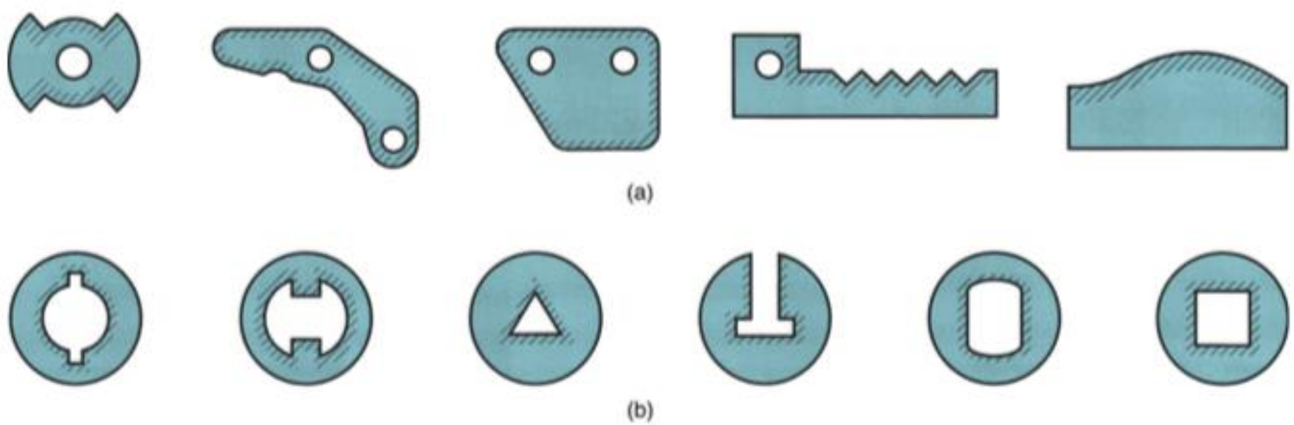
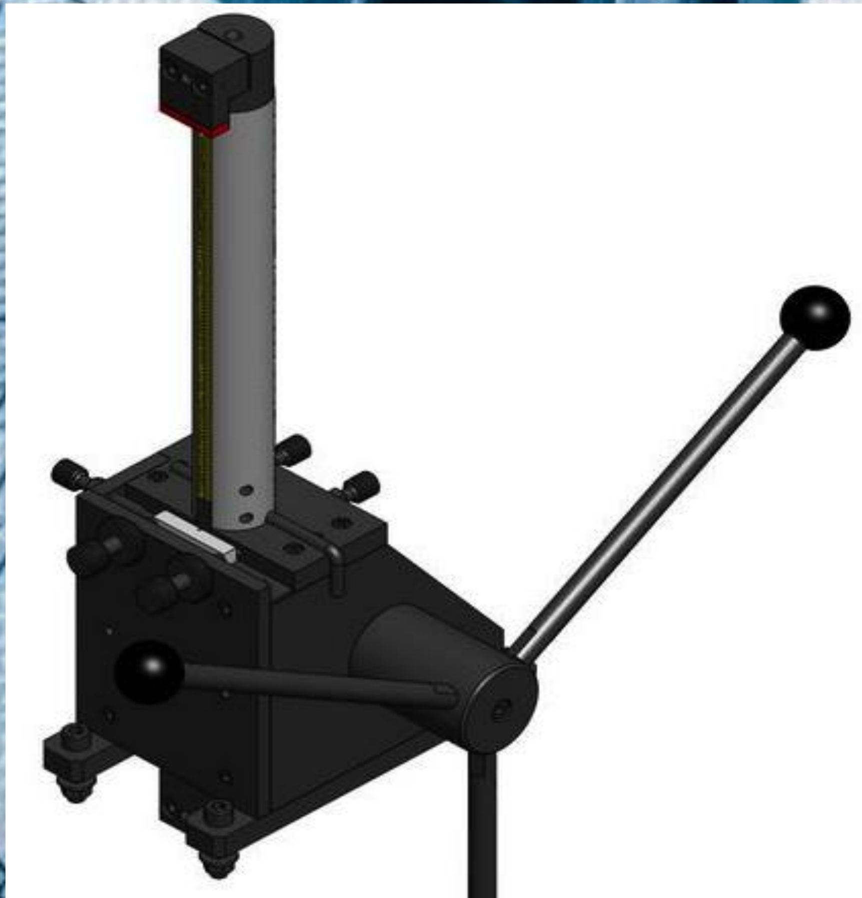



**FIGURE 16.34** Work shapes that can be cut by: (a) external broaching, and (b) internal broaching. Cross-hatching indicates the surfaces broached. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



# SAWING

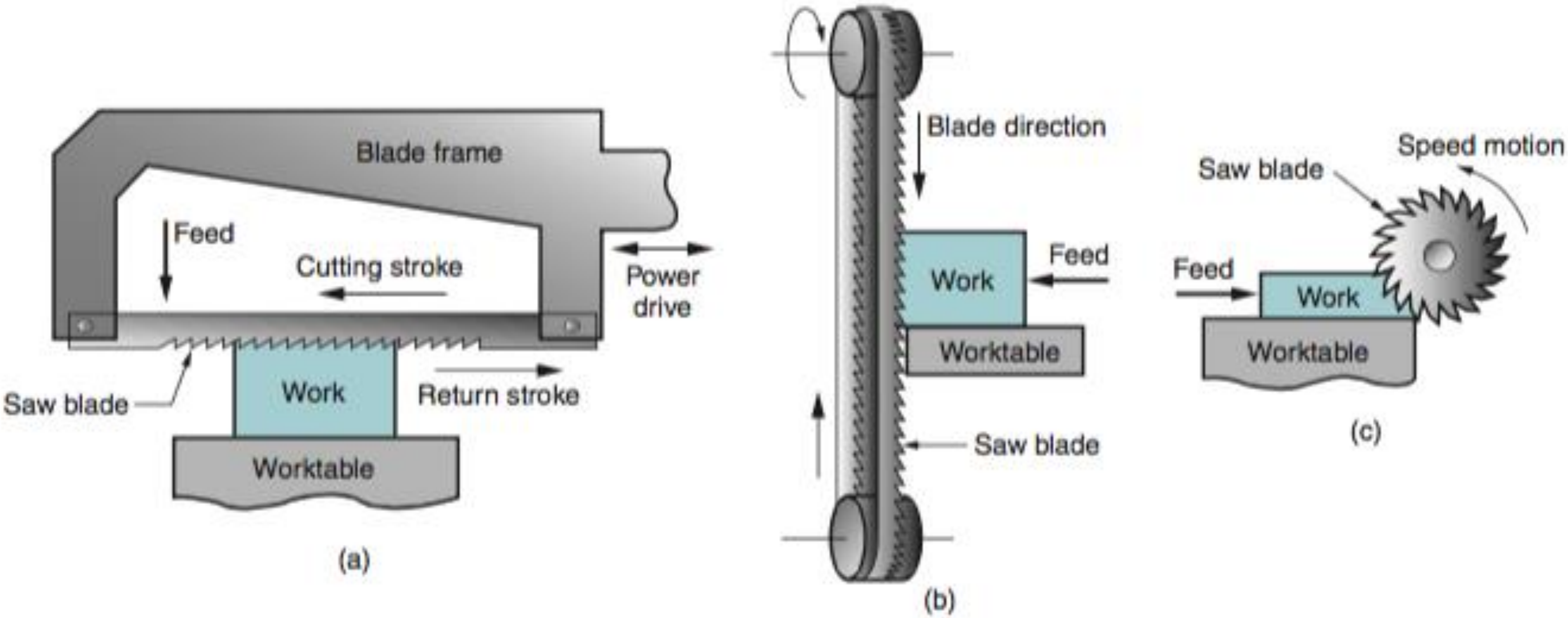



**FIGURE 16.35** Three types of sawing operations: (a) power hacksaw, (b) bandsaw (vertical), and (c) circular saw. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)


MINI ARCO DE SERRA


Starrett


PEGAMO


Einhell


COSEN
CAUTION
MH-812LC


SCM-4


14"
350mm
48T

# MACHINING TOLERANCES

**TABLE 16.2 Typical tolerances and surface roughness values (arithmetic average) achievable in machining operations**

| Machining Operation | Tolerance Capability —Typical mm | Tolerance Capability —Typical in | Surface Roughness AA—Typical μm | Surface Roughness AA—Typical μ-in | Machining Operation | Tolerance Capability —Typical mm | Tolerance Capability —Typical in | Surface Roughness AA—Typical μm | Surface Roughness AA—Typical μ-in |
|---|---|---|---|---|---|---|---|---|---|
| Turning, boring | | | 0.8 | 32 | Reaming | | | 0.4 | 16 |
| Diameter $D < 25$ mm | ±0.025 | ±0.001 | | | Diameter $D < 12$ mm | ±0.025 | ±0.001 | | |
| 25 mm $< D <$ 50 mm | ±0.05 | ±0.002 | | | 12 mm $< D <$ 25 mm | ±0.05 | ±0.002 | | |
| Diameter $D > 50$ mm | ±0.075 | ±0.003 | | | Diameter $D > 25$ mm | ±0.075 | ±0.003 | | |
| Drilling* | | | 0.8 | 32 | Milling | | | 0.4 | 16 |
| Diameter $D < 2.5$ mm | ±0.05 | ±0.002 | | | Peripheral | ±0.025 | ±0.001 | | |
| 2.5 mm $< D <$ 6 mm | ±0.075 | ±0.003 | | | Face | ±0.025 | ±0.001 | | |
| 6 mm $< D <$ 12 mm | ±0.10 | ±0.004 | | | End | ±0.05 | ±0.002 | | |
| 12 mm $< D <$ 25 mm | ±0.125 | ±0.005 | | | Shaping, slotting | ±0.025 | ±0.001 | 1.6 | 63 |
| Diameter $D > 25$ mm | ±0.20 | ±0.008 | | | Planing | ±0.075 | ±0.003 | 1.6 | 63 |
| Broaching | ±0.025 | ±0.001 | 0.2 | 8 | Sawing | ±0.50 | ±0.02 | 6.0 | 250 |

*Drilling tolerances are typically expressed as biased bilateral tolerances (e.g., + 0.010/– 0.002). Values in this table are expressed as closest bilateral tolerance (e.g., ±0.006).
Compiled from various sources, including [8], [9], [10], [21], and other sources.

# Tool Life

FIGURE 17.1 Diagram of worn cutting tool, showing the principal locations and types of wear that occur. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

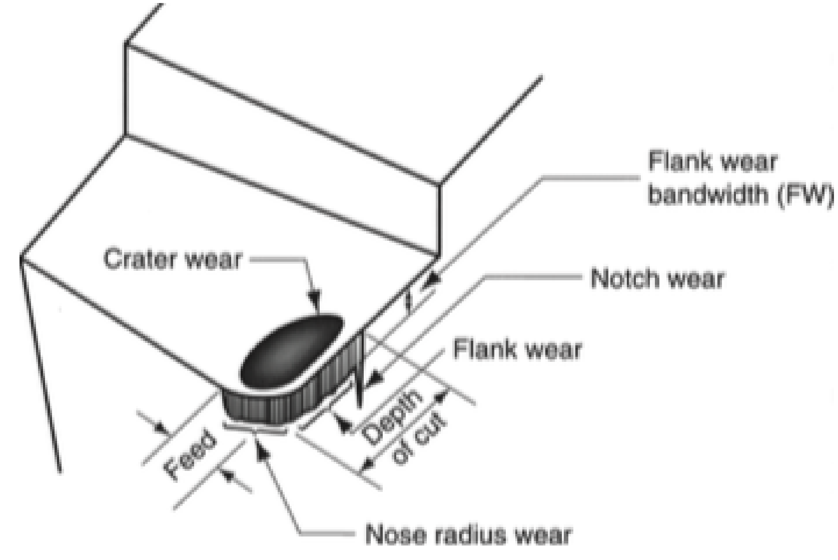



FIGURE 17.2 Tool wear as a function of cutting time. Flank wear (FW) is used here as the measure of tool wear. Crater wear follows a similar growth curve. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

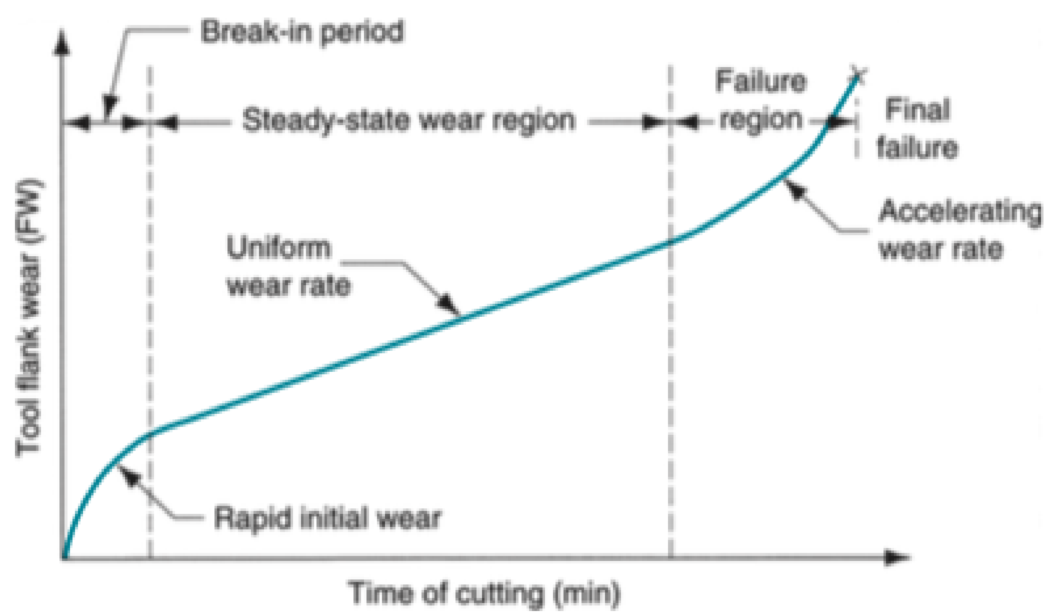
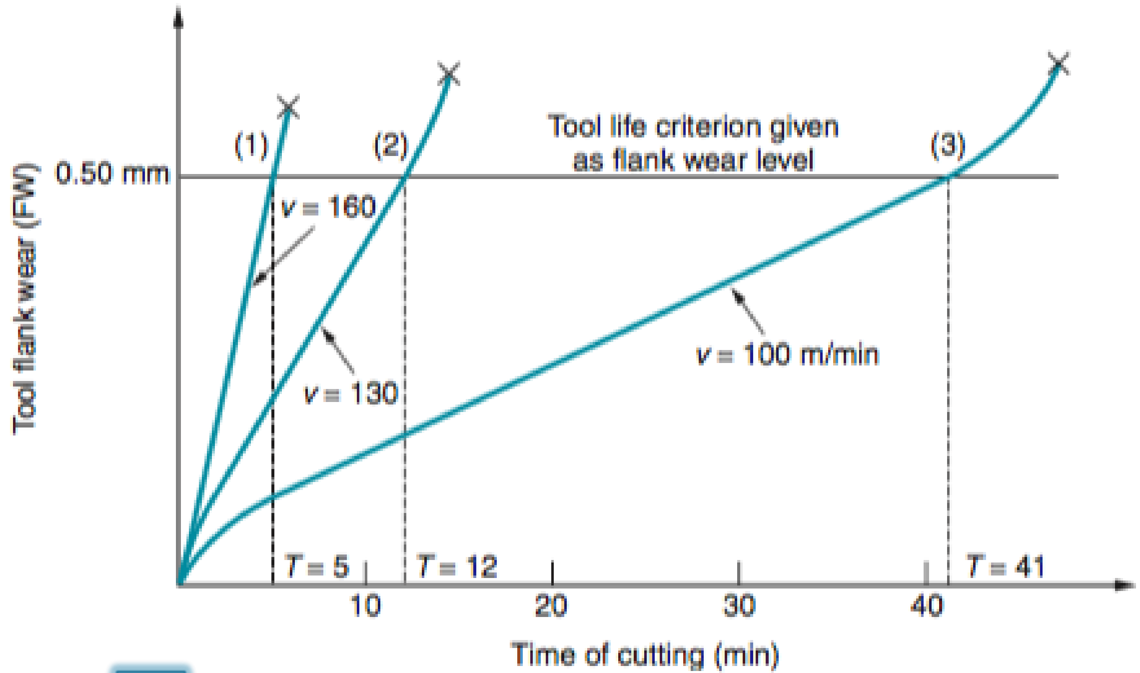
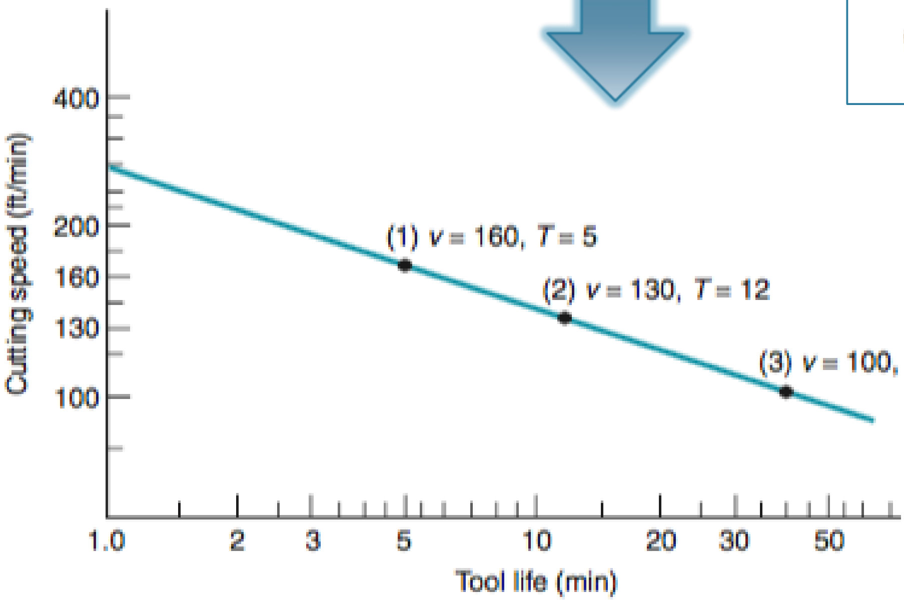


**FIGURE 17.3** Effect of cutting speed on tool flank wear (FW) for three cutting speeds. Hypothetical values of speed and tool life are shown for a tool life criterion of 0.50-mm flank wear. (Credit: *Fundamentals of Modern Manufacturing,* 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)




$$vT^n = C$$

**TABLE 17.2** Representative values of *n* and *C* in the Taylor tool life equation, Eq. (17.1), for selected tool materials

| | | *C* | | | |
|---|---|---|---|---|---|
| | | Nonsteel Cutting | | Steel Cutting | |
| **Tool Material** | ***n*** | **m/min** | **(ft/min)** | **m/min** | **ft/min** |
| Plain carbon tool steel | 0.1 | 70 | (200) | 20 | 60 |
| High-speed steel | 0.125 | 120 | (350) | 70 | 200 |
| Cemented carbide | 0.25 | 900 | (2700) | 500 | 1500 |
| Cermet | 0.25 | | | 600 | 2000 |
| Coated carbide | 0.25 | | | 700 | 2200 |
| Ceramic | 0.6 | | | 3000 | 10,000 |

# Tool Materials

**TABLE 17.1 Typical hardness values (at room temperature) and transverse rupture strengths for various tool materials.[a]**

| Material | Hardness | Transverse Rupture Strength MPa | Transverse Rupture Strength lb/in$^2$ |
|---|---|---|---|
| Plain carbon steel | 60 HRC | 5200 | 750,000 |
| High-speed steel | 65 HRC | 4100 | 600,000 |
| Cast cobalt alloy | 65 HRC | 2250 | 325,000 |
| Cemented carbide (WC) | | | |
| Low Co content | 93 HRA, 1800 HK | 1400 | 200,000 |
| High Co content | 90 HRA, 1700 HK | 2400 | 350,000 |
| Cermet (TiC) | 2400 HK | 1700 | 250,000 |
| Alumina ($Al_2O_3$) | 2100 HK | 400 | 60,000 |
| Cubic boron nitride | 5000 HK | 700 | 100,000 |
| Polycrystalline diamond | 6000 HK | 1000 | 150,000 |
| Natural diamond | 8000 HK | 1500 | 215,000 |

Compiled from [7], [12], [20], and other sources.

[a]*Note*: The values of hardness and TRS are intended to be comparative and typical. Variations in properties result from differences in composition and processing.

# CUTTING SPEED X CUTTING TOOL MATERIAL

**TABLE 17.3** Cutting-tool materials with their approximate dates of initial use and allowable cutting speeds

| Tool Material | Year of Initial Use | Allowable Cutting Speed[a] Nonsteel Cutting m/min | Nonsteel Cutting ft/min | Steel Cutting m/min | Steel Cutting ft/min |
|---|---|---|---|---|---|
| Plain carbon tool steel | 1800s | Below 10 | Below 30 | Below 5 | Below 15 |
| High-speed steel | 1900 | 25–65 | 75–200 | 17–33 | 50–100 |
| Cast cobalt alloys | 1915 | 50–200 | 150–600 | 33–100 | 100–300 |
| Cemented carbides (WC) | 1930 | 330–650 | 1000–2000 | 100–300 | 300–900 |
| Cermets (TiC) | 1950s | | | 165–400 | 500–1200 |
| Ceramics ($Al_2O_3$) | 1955 | | | 330–650 | 1000–2000 |
| Synthetic diamonds | 1954, 1973 | 390–1300 | 1200–4000 | | |
| Cubic boron nitride | 1969 | | | 500–800 | 1500–2500 |
| Coated carbides | 1970 | | | 165–400 | 500–1200 |

# Cutting Speed Range

[V_max Production; V_min Cost]

**FIGURE 17.14** Cost components in a machining operation plotted as a function of cutting speed. Total cost per piece is minimized at a certain value of cutting speed. This is the speed for minimum cost per piece. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

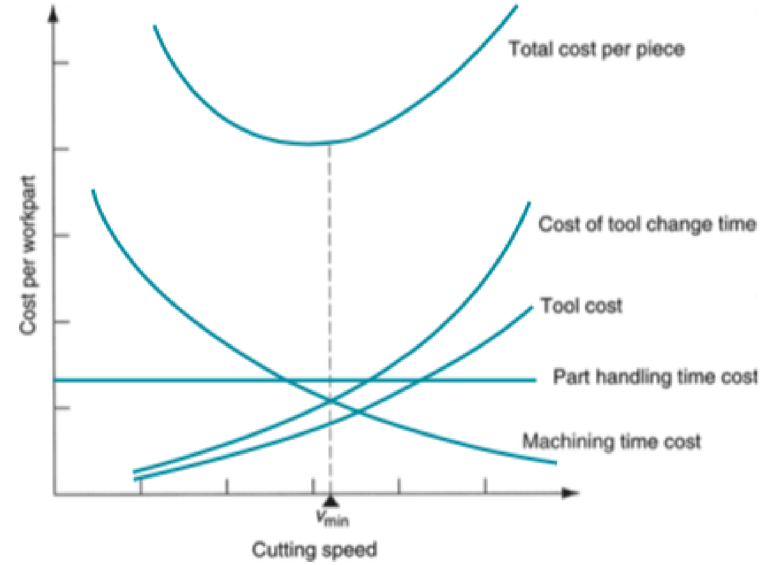
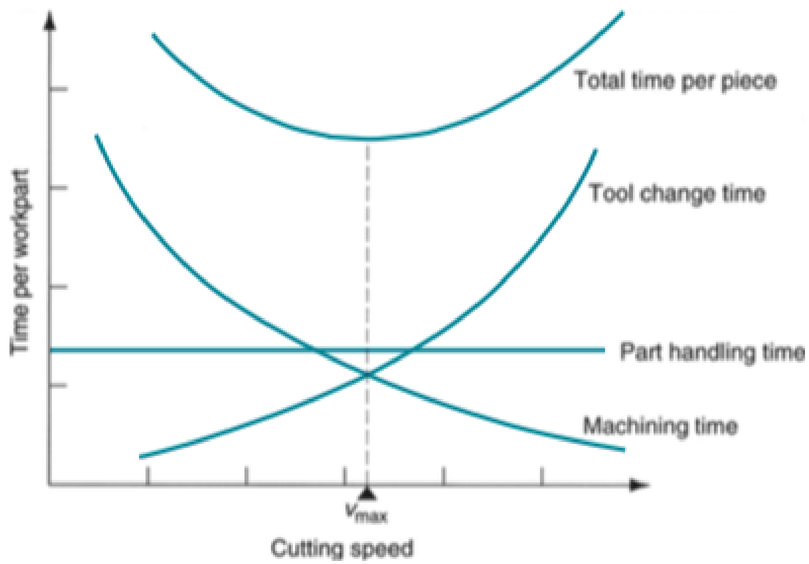



**FIGURE 17.13** Time elements in a machining cycle plotted as a function of cutting speed. Total cycle time per piece is minimized at a certain value of cutting speed. This is the speed for maximum production rate. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)




ning operation is to be performed with HSS tooling on mild steel, with Taylor tool arameters $n = 0.125$, $C = 70$ m/min (Table 17.2). Workpart length = 500 mm and eter = 100 mm. Feed = 0.25 mm/rev. Handling time per piece = 5.0 min, and tool ge time = 2.0 min. Cost of machine and operator = \$30/hr, and tooling cost = \$3 per ing edge. Find: (a) cutting speed for maximum production rate, and (b) cutting speed minimum cost.

**lution:** (a) Cutting speed for maximum production rate is given by Eq. (17.9):

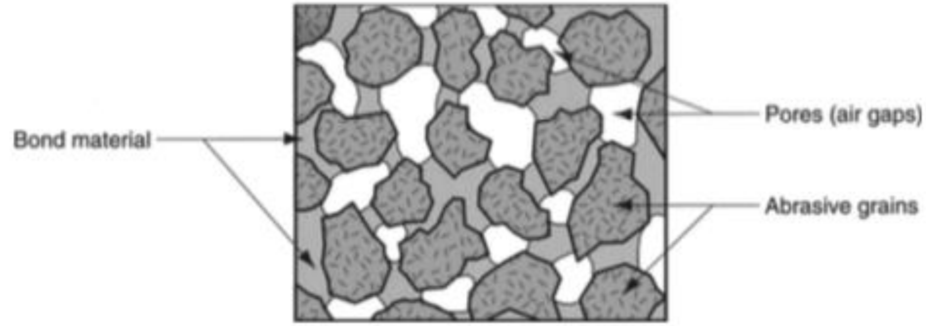
$$v_{max} = 70\left(\frac{0.125}{0.875}\cdot\frac{1}{2}\right)^{0.125} = 50\,\text{m/min}$$

b) Converting $C_o$ = \$30/hr to \$0.5/min, minimum cost cutting speed is given Eq. (17.15):

$$v_{min} = 70\left(\frac{0.125}{0.875}\cdot\frac{0.5}{0.5(2)+3.00}\right)^{0.125} = 42\,\text{m/min}$$

# GRINDING

**FIGURE 18.1** Typical structure of a grinding wheel. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)



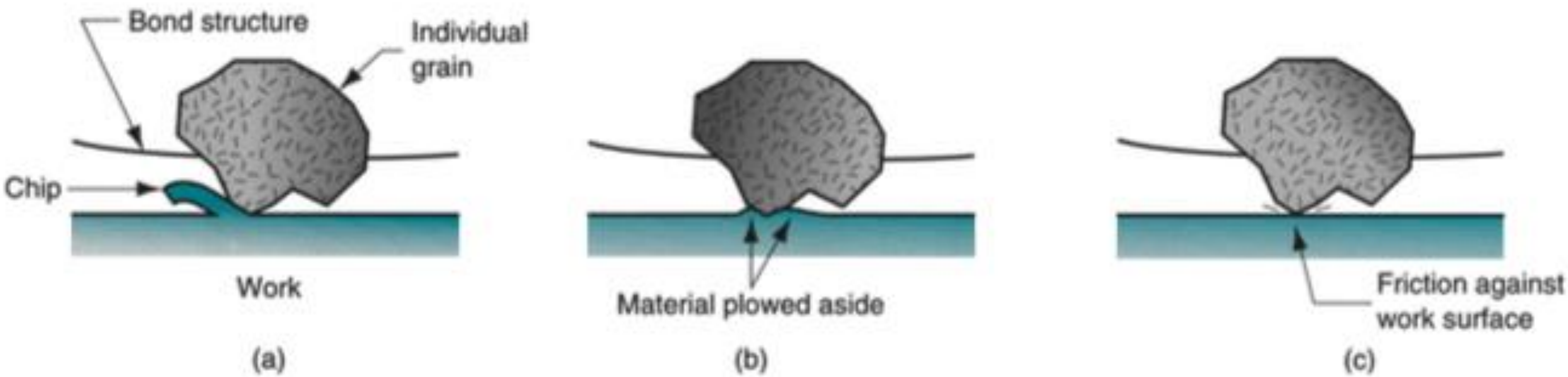
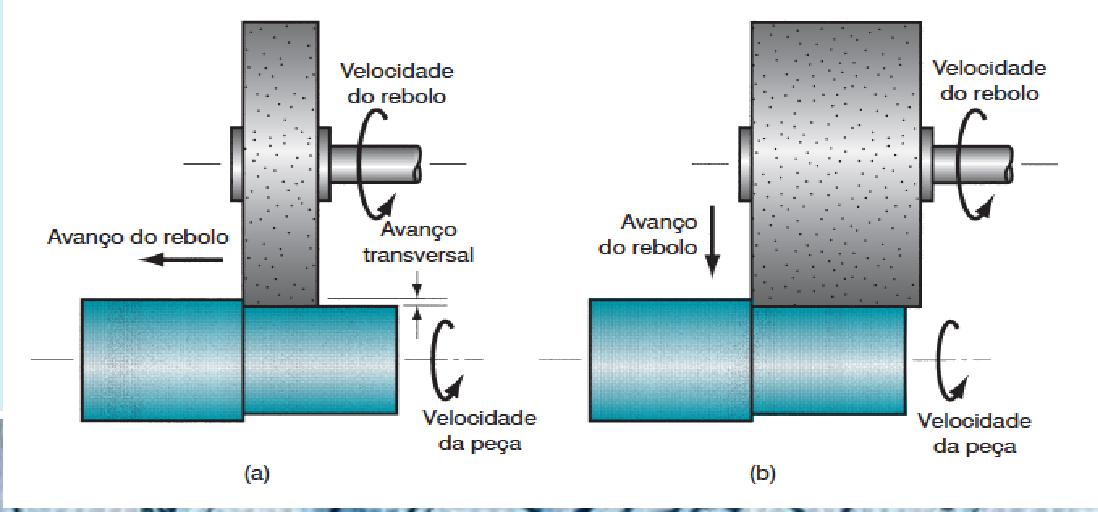




**FIGURE 18.4** Three types of grain action in grinding: (a) cutting, (b) plowing, and (c) rubbing. (Credit: *Fundamentals of Modern Manufacturing*, 4th Edition by Mikell P. Groover, 2010. Reprinted with permission of John Wiley & Sons, Inc.)

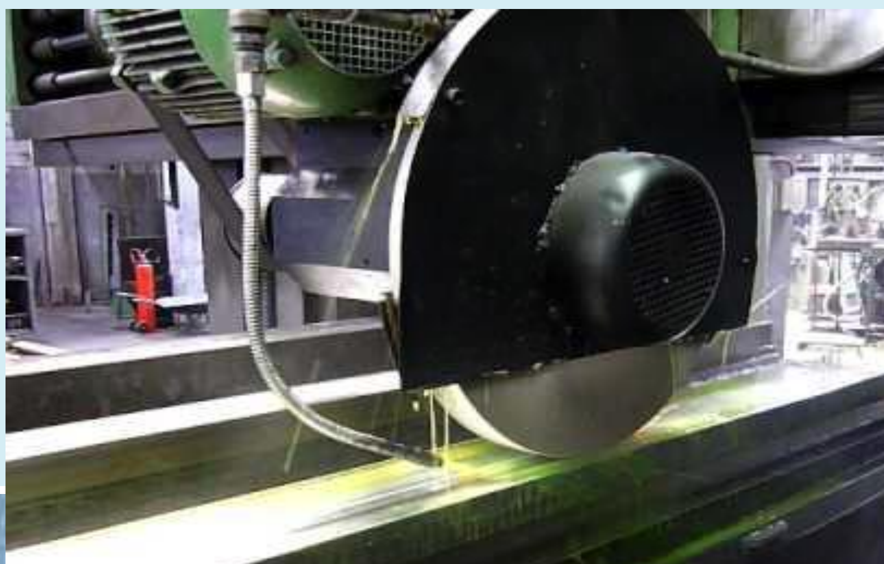

ICDER


SoloStocks
NORTON



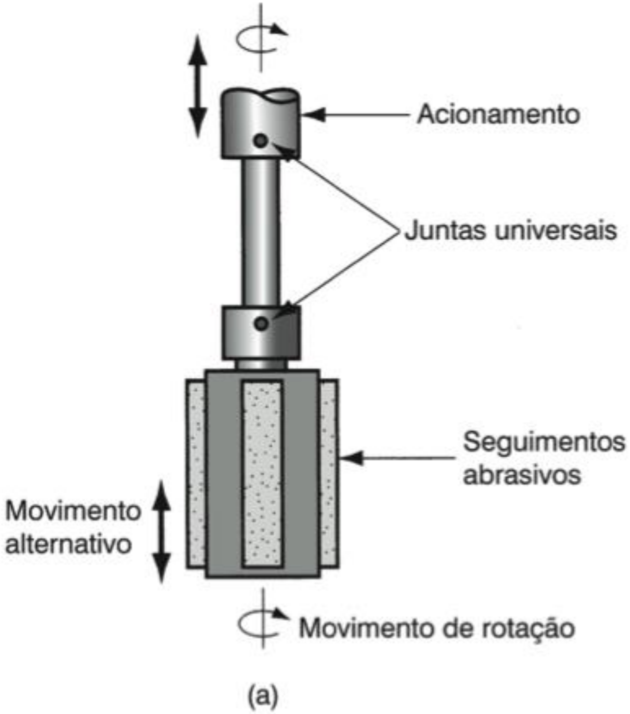
Velocidade
do rebolo
Avanço do rebolo
Avanço
transversal
Velocidade
da peça
(a)
Velocidade
do rebolo
Avanço
do rebolo
Velocidade
da peça
(b)

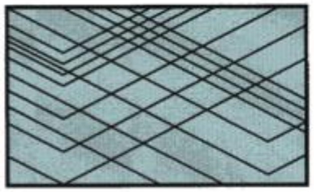


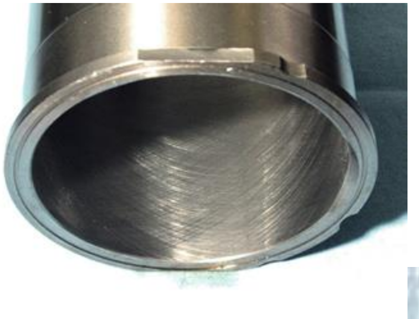



# HONING

superfície com riscos diagonais-padrão criada pela ação da ferramenta de brunir. (Crédito: *Fundamentals of Modern Manufacturing*, 4ª Edição por Mikell P. Groover, 2010. Reimpresso com permissão de John Wiley & Sons, Inc.)





# NONTRADITIONAL MACHINING

- Mechanical Energy Processes
  - Ultrasonic Machining
  - Processes Using Water Jets
  - Other Nontraditional Abrasive Processes
- Electrochemical Machining Processes
  - Electrochemical Machining
  - Electrochemical Deburring and Grinding
- Thermal Energy Processes
  - Electric Discharge Processes
  - Electron Beam Machining
  - Laser Beam Machining
- Chemical Machining

# Non Traditional Machining Processes

1. Mechanical. Mechanical energy in some form other than the action of a conventional cutting tool is used in these nontraditional processes. Erosion of the work material by a high velocity stream of abrasives or fluid (or both) is a typical form of mechanical action in these processes.

2. Electrical. These nontraditional processes use electrochemical energy to remove material; the mechanism is the reverse of electroplating.

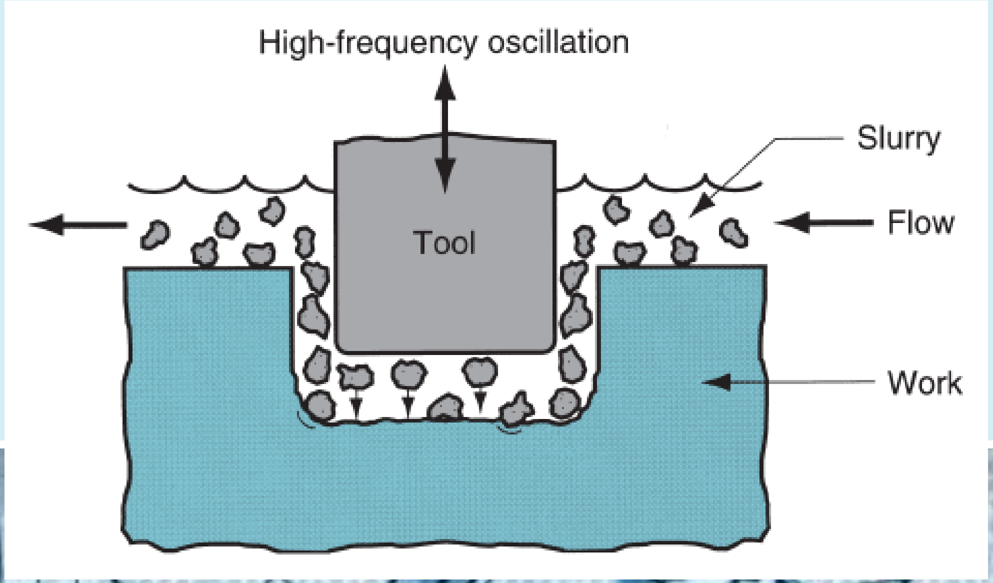
3. Thermal. These processes use thermal energy to cut or shape the workpart. The thermal energy is generally applied to a very small portion of the work surface, causing that portion to be removed by fusion and/or vaporization. The thermal energy is generated by the conversion of electrical energy.

4. Chemical. Most materials (metals particularly) are susceptible to chemical attack by certain acids or other etchants. In chemical machining, chemicals selectively remove material from portions of the workpart, while other portions of the surface are protected by a mask.

# Ultrasonic Machining

Ultrasonic machining (USM) is a nontraditional machining process in which abrasives contained in a slurry are driven at high velocity against the work by a tool vibrating at low amplitude and high frequency.

The amplitudes are around 0.075 mm (0.003 in), and the frequencies are approximately 20,000 Hz. The tool oscillates in a direction perpendicular to the work surface, and is fed slowly into the work, so that the shape of the tool is formed in the part.

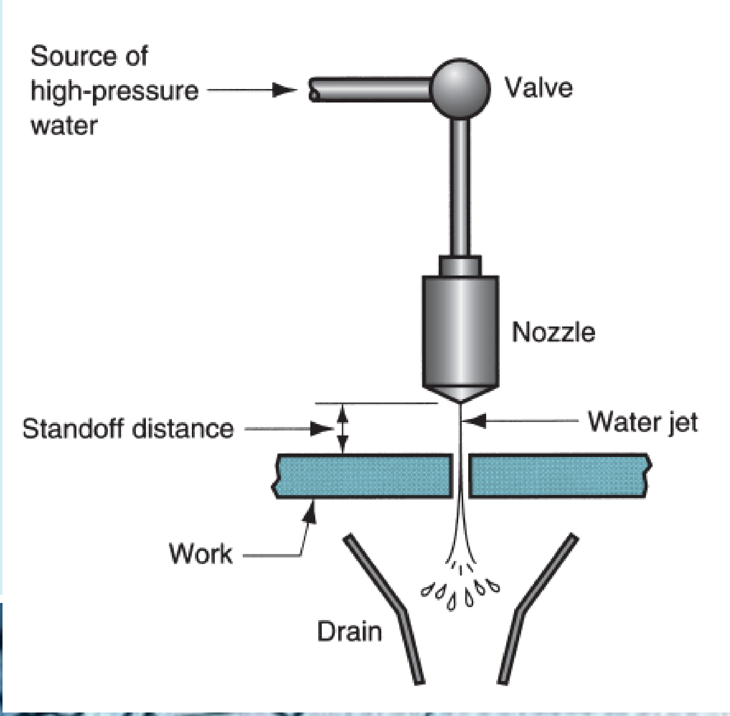


# Water Jet Cutting (WJC)


Water jet cutting (WJC) uses a fine, high-pressure, high-velocity stream of water directed at the work surface to cause cutting of the work.

To obtain the fine stream of water, a small nozzle opening of diameter 0.1 to 0.4mm(0.004 to 0.016 in) is used. To provide the stream with sufficient energy for cutting, pressures up to 400 MPa (60,000 lb/in2) are used, and the jet reaches velocities up to 900 m/s (3,000 ft/sec).

The fluid is pressurized to the desired level by a hydraulic pump.



# Abrasive Water Jet Cutting

When WJC is used on metallic workparts, abrasive particles must usually be added to the jet stream to facilitate cutting.

Introduction of abrasive particles into the stream complicates the process by adding to the number of parameters that must be controlled. Among the additional parameters are abrasive type, grit size, and flow rate.

Aluminum oxide, silicon dioxide, and garnet (a silicate mineral) are typical abrasive materials, at grit sizes ranging between 60 and 120.

The abrasive particles are added to the water stream at approximately 0.25 kg/min (0.5 lb/min) after it has exited the WJC nozzle.

# Usinagem por jato abrasivo

Processo de remoção de material devido à ação de uma corrente de gás em alta velocidade, contendo pequenas partículas abrasivas

Os gases usados: ar seco, nitrogênio, dióxido de carbono e hélio

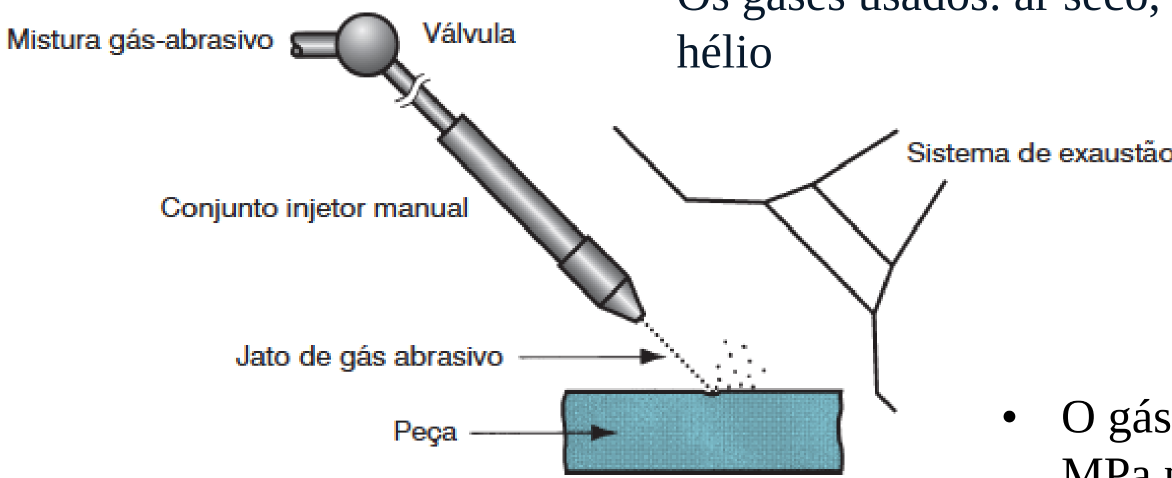
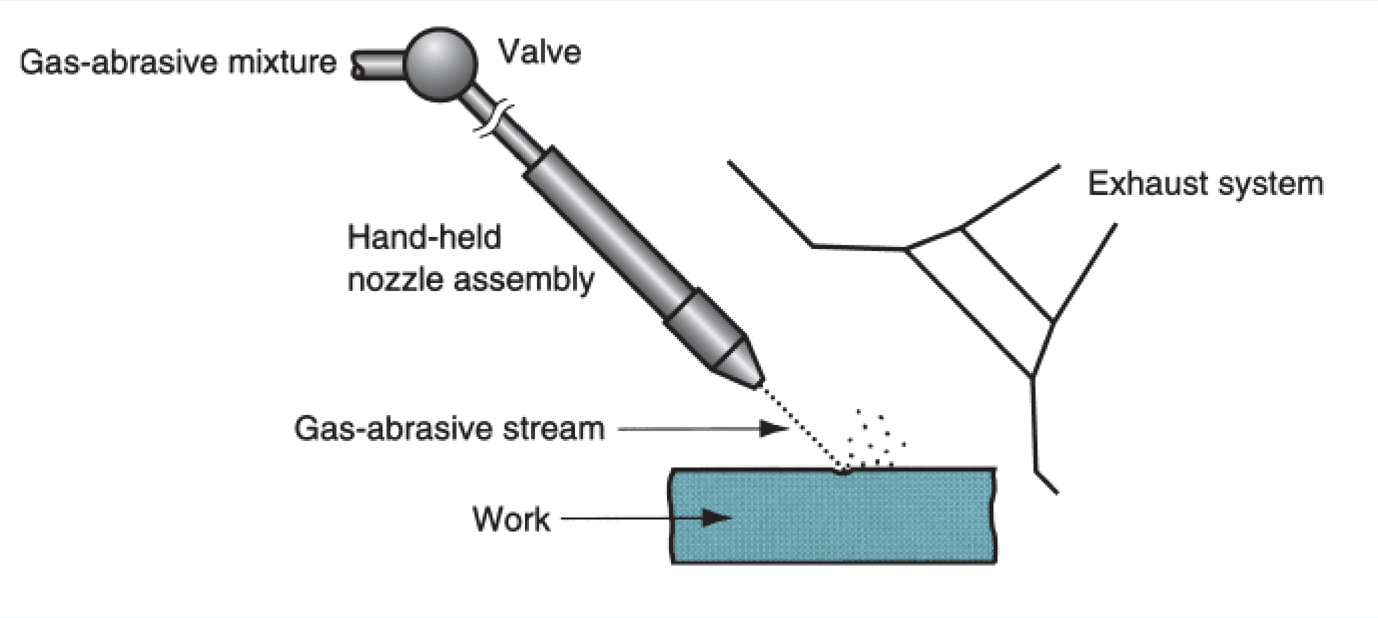



FIGURA 19.3 Usinagem por jato abrasivo. (Crédito: *Fundamentals of Modern Manufacturing*, 4ª Edição, por Mikell P. Groover, 2010. Reimpresso com permissão de John Wiley & Sons, Inc.)

materiais duros e frágeis

- O gás é seco com pressões de 0,2 a 1,4 MPa para empurrá-lo através dos orifícios dos bocais.
- O diâmetro varia entre de 0,075 a 1,0 mm
- Velocidades de 2,5 a 5,0 m/s
- Distância entre a ponta do bocal e a superfície da peça: entre 3 mm e 75 mm

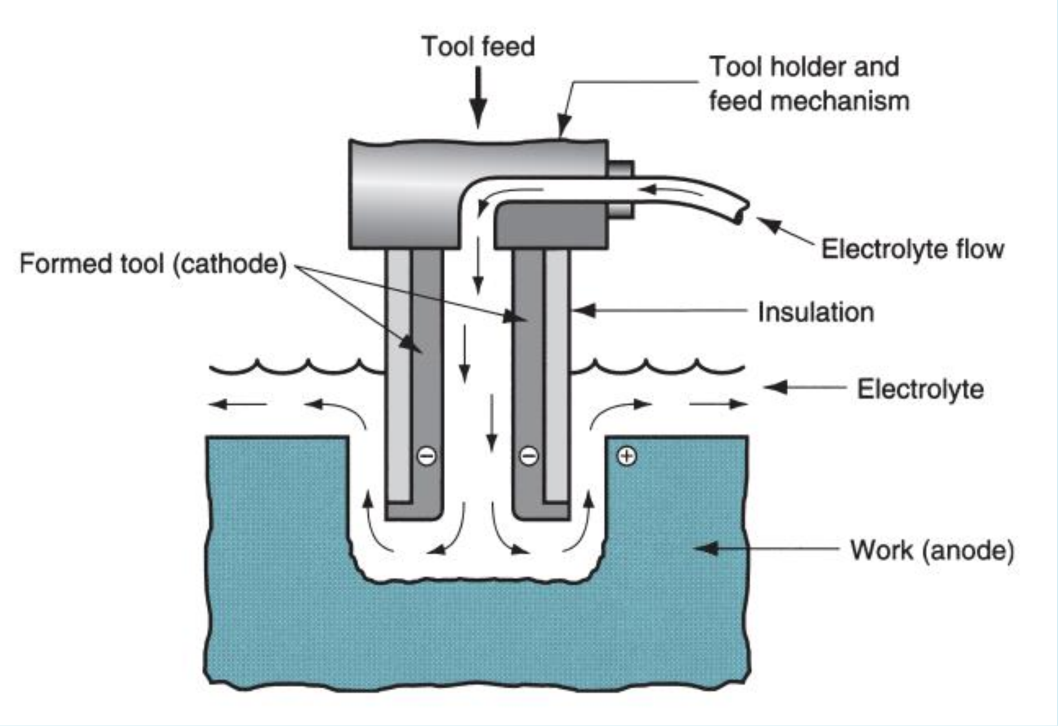
# Abrasive Jet Machining




The gas is dry, and pressures of 0.2 to 1.4 MPa (25 to 200 lb/in2) are used to propel it through nozzle orifices of diameter 0.075 to 1.0mm(0.003 to 0.040 in) at velocities of 2.5 to 5.0 m/s (500 to 1000 ft/ min). Gases include dry air, nitrogen, carbon dioxide, and helium.

# Electrochemical Machining processes

The basic process in this group is electrochemical machining (ECM). Electrochemical machining removes metal from an electrically conductive workpiece by anodic dissolution, in which the shape of the workpiece is obtained by a formed electrode tool in close proximity to, but separated from, the work by a rapidly flowing electrolyte.

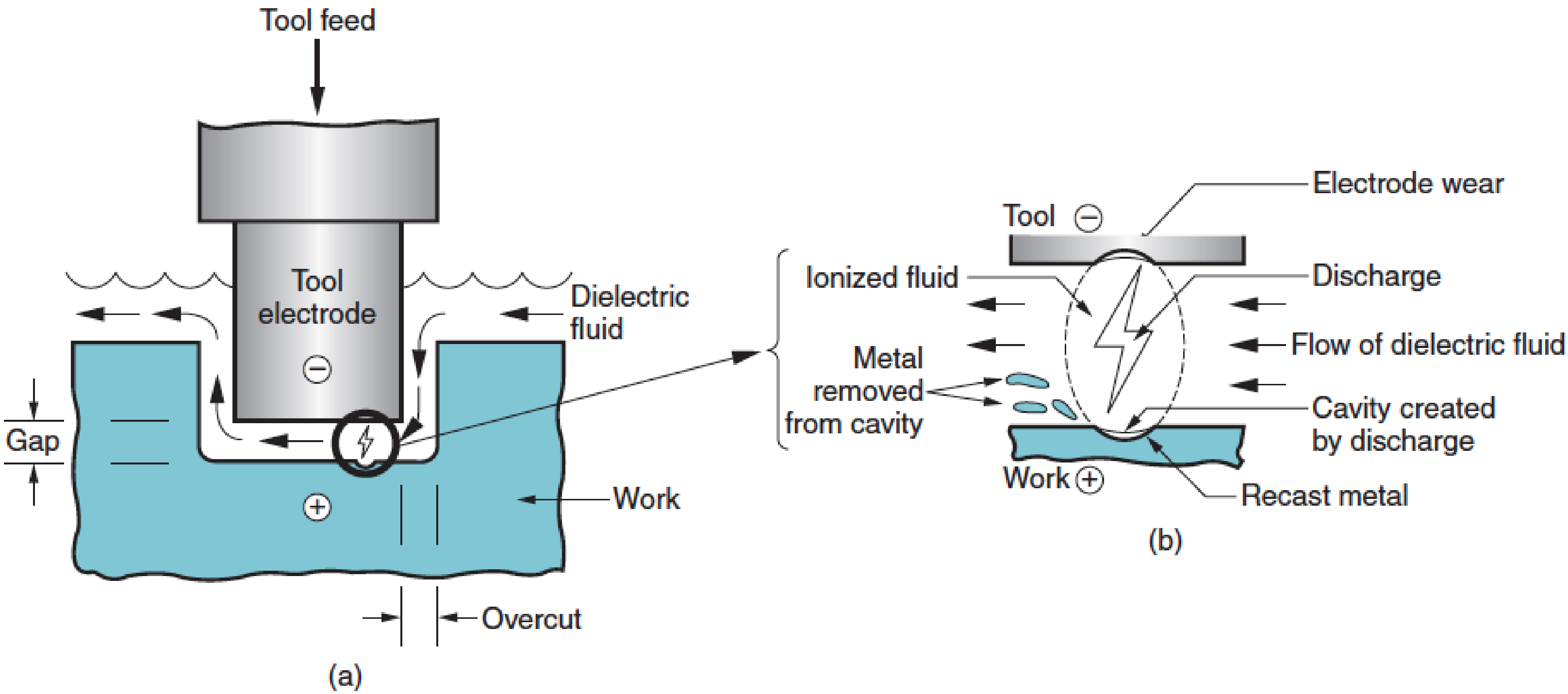


# Electric Discharge Machining

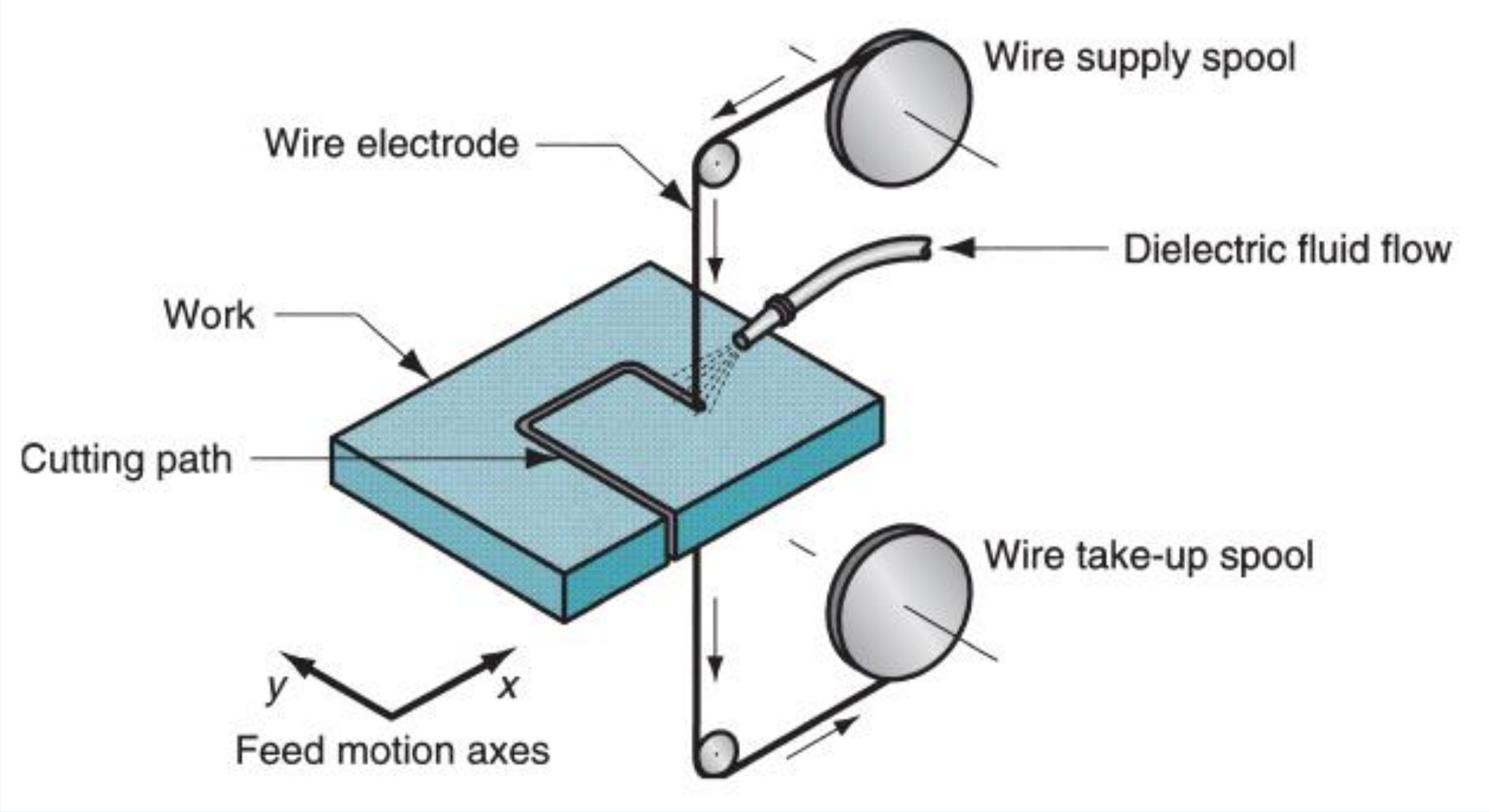
The shape of the finished work surface is produced by a formed electrode tool. The sparks occur across a small gap between tool and work surface.

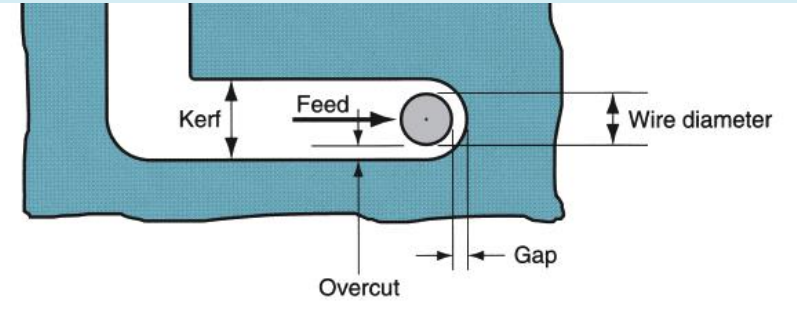
The EDM process must take place in the presence of a dielectric fluid, which creates a path for each discharge as the fluid becomes ionized in the gap.

The discharges are generated by a pulsating direct current power supply connected to the work and the tool.



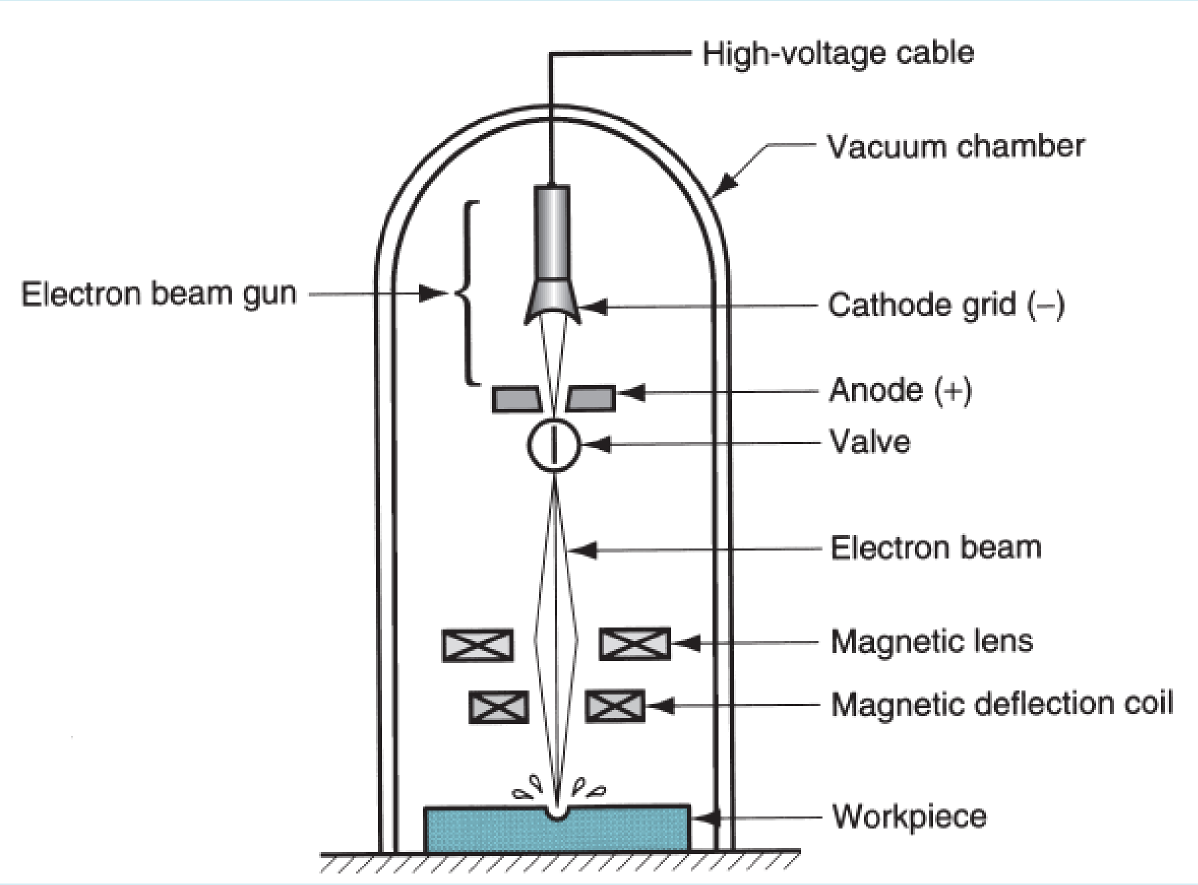
# Electric discharge wire cutting



# Electron beam machining

Electron beam machining (EBM) is one of several industrial processes that use electron beams. In addition to machining, other applications of the technology include heat treating and welding. Electron beammachining uses a high-velocity streamof electrons focused on the workpiece surface to remove material by melting and vaporization.

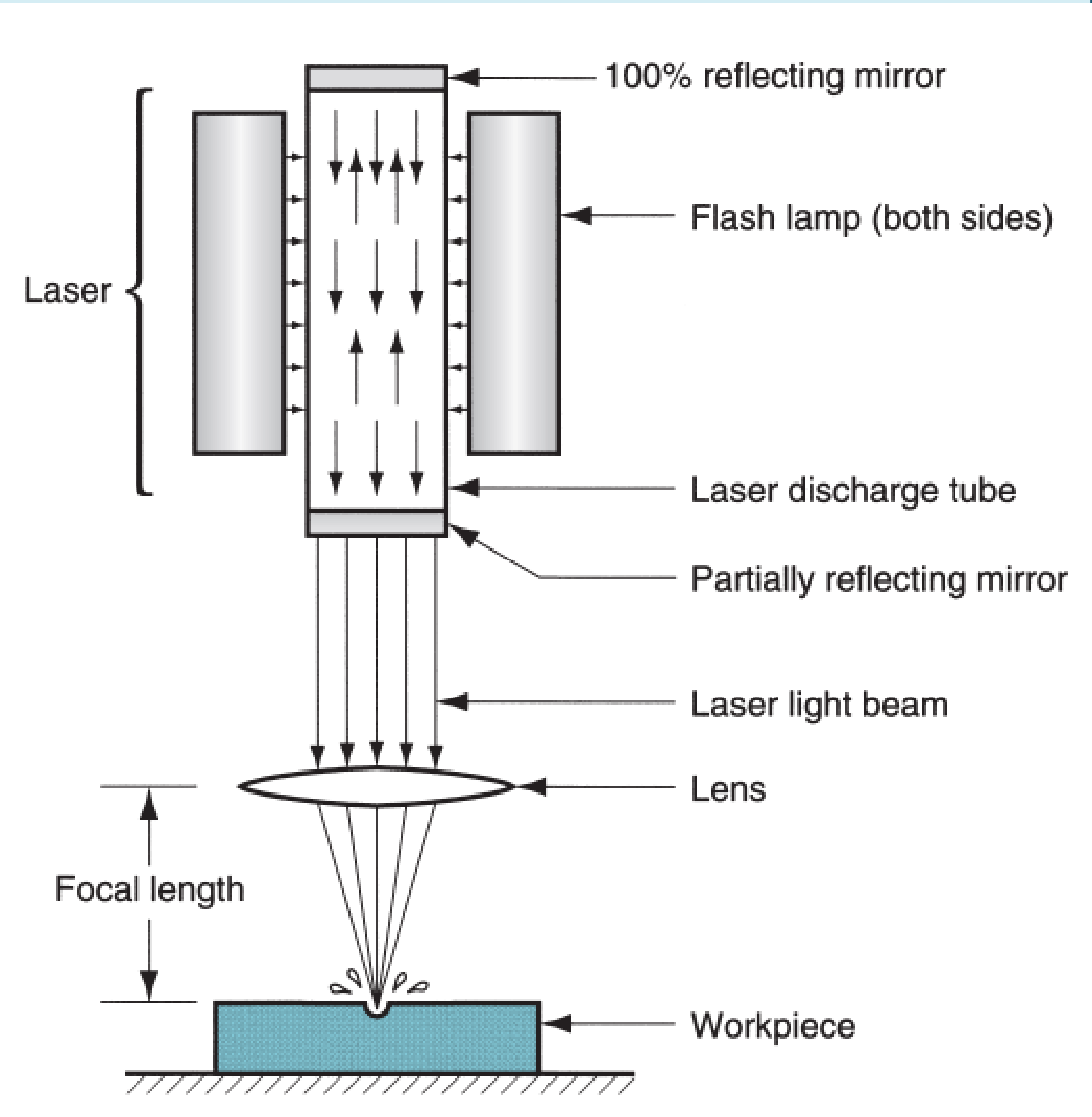


# Laser beam machining

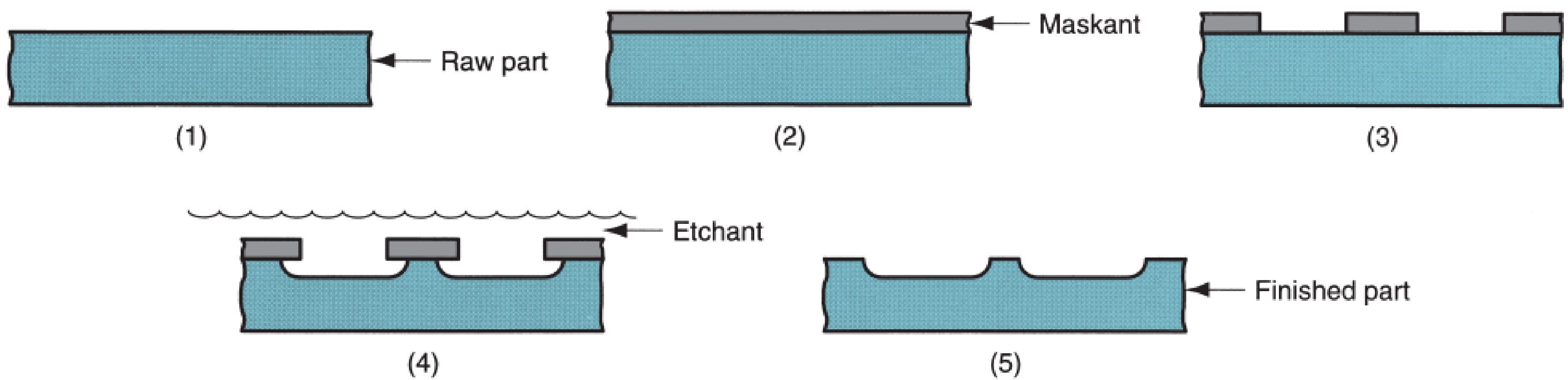
Laser beam machining (LBM) uses the light energy from a laser to remove material by vaporization and ablation.

The types of lasers used in LBM are carbon dioxide gas lasers and solid-state lasers (of which there are several types).

In laser beam machining, the energy of the coherent light beam is concentrated not only optically but also in terms of time. The light beam is pulsed so that the released energy results in an impulse against the work surface that produces a combination of evaporation and melting, with the melted material evacuating the surface at high velocity.



# Chemical Machining

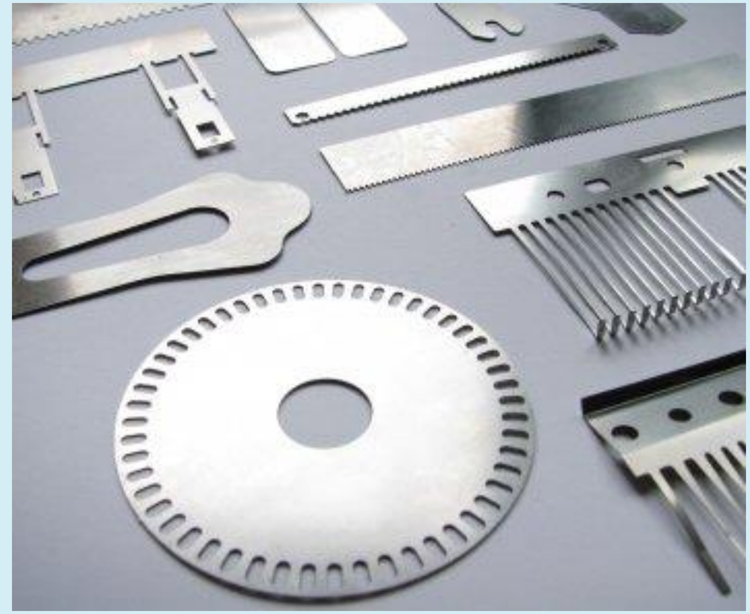


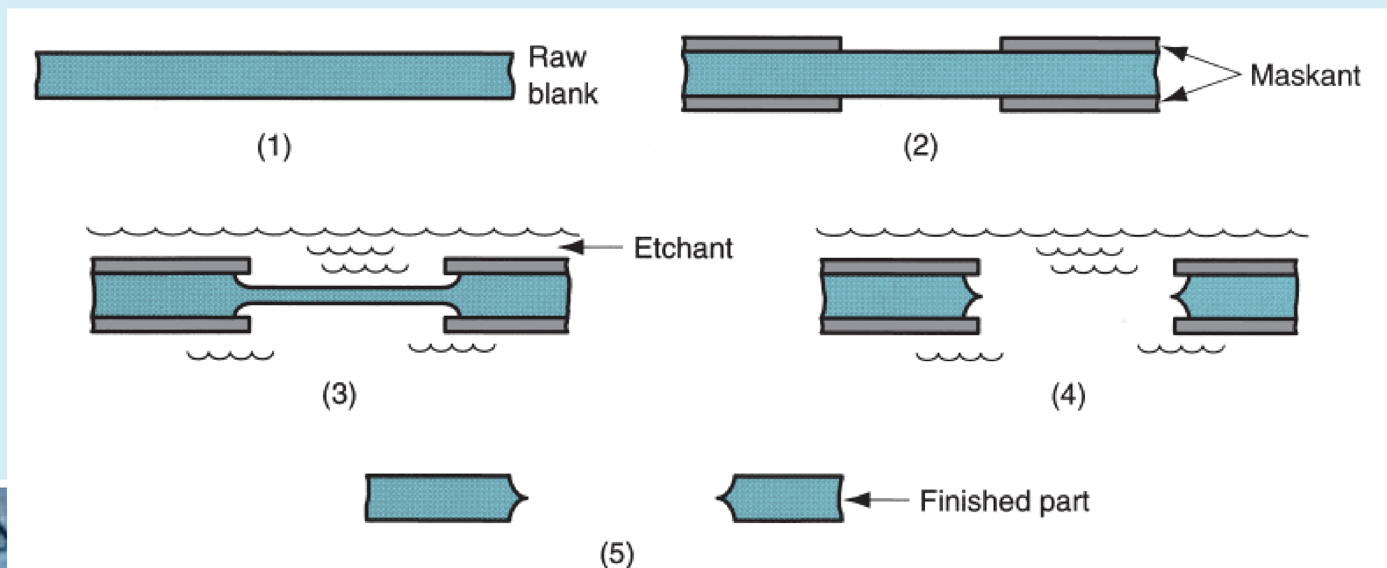

1. Cleaning. The first step is a cleaning operation to ensure that material will be removed uniformly from th surfaces to be etched.

2. Masking. A protective coating called a maskant is applied to certain portions of the part surface. Thi maskant is made of a material that is chemically resistant to the etchant (the term resist is used for thi masking material). It is therefore applied those portions of the work surface that are not to be etched.

3. Etching. This is the material removal step. The part is immersed in an etchant that chemically attacks thos portions of the part surface that are not masked. The usual method of attack is to convert the work materi (e.g., a metal) into a salt that dissolves in the etchant and is thereby removed from the surface. When th desired amount of material has been removed, the part is withdrawn from the etchant and washed to stop th process.

4. Demasking. The maskant is removed from the part.




Raw blank
(1)
Maskant
(2)
Etchant
(3)
(4)
Finished part
(5)

## Home Work # 7

- There will be no HM#7.
- On the other hand, machining Parameters should be calculated in the Final Project. Which means: find recommended parameters as feed per revolution (of per tooth), depth of cut and cutting velocity and calculate feed velocity Vf and spindle speed N.