

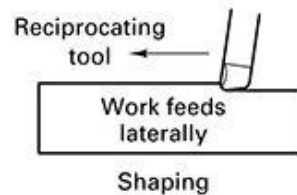
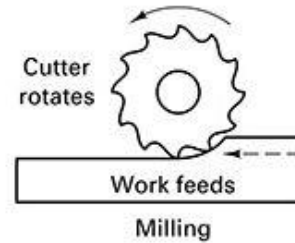
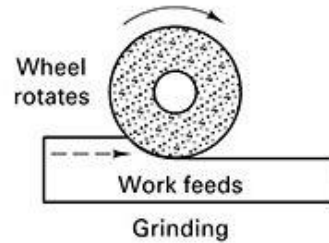
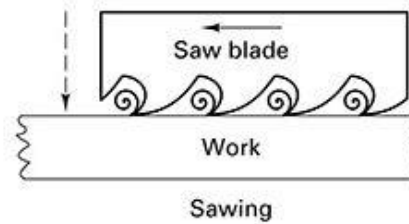
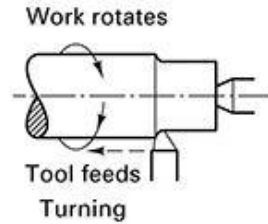
# Machining Processes

# Machining

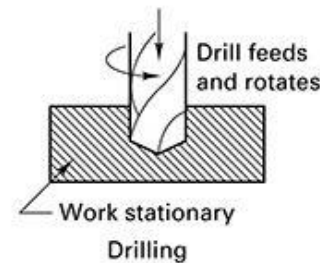
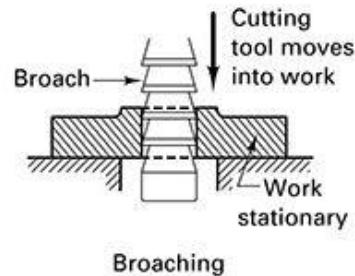
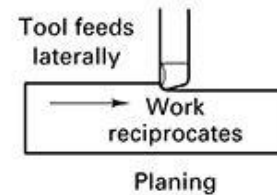
Removing unwanted material in the form of chips:

- Turning
- Sawing
- Grinding
- Milling
- Shaping or planing
- Broaching
- Drilling

# Seven Basic Machining Processes



or

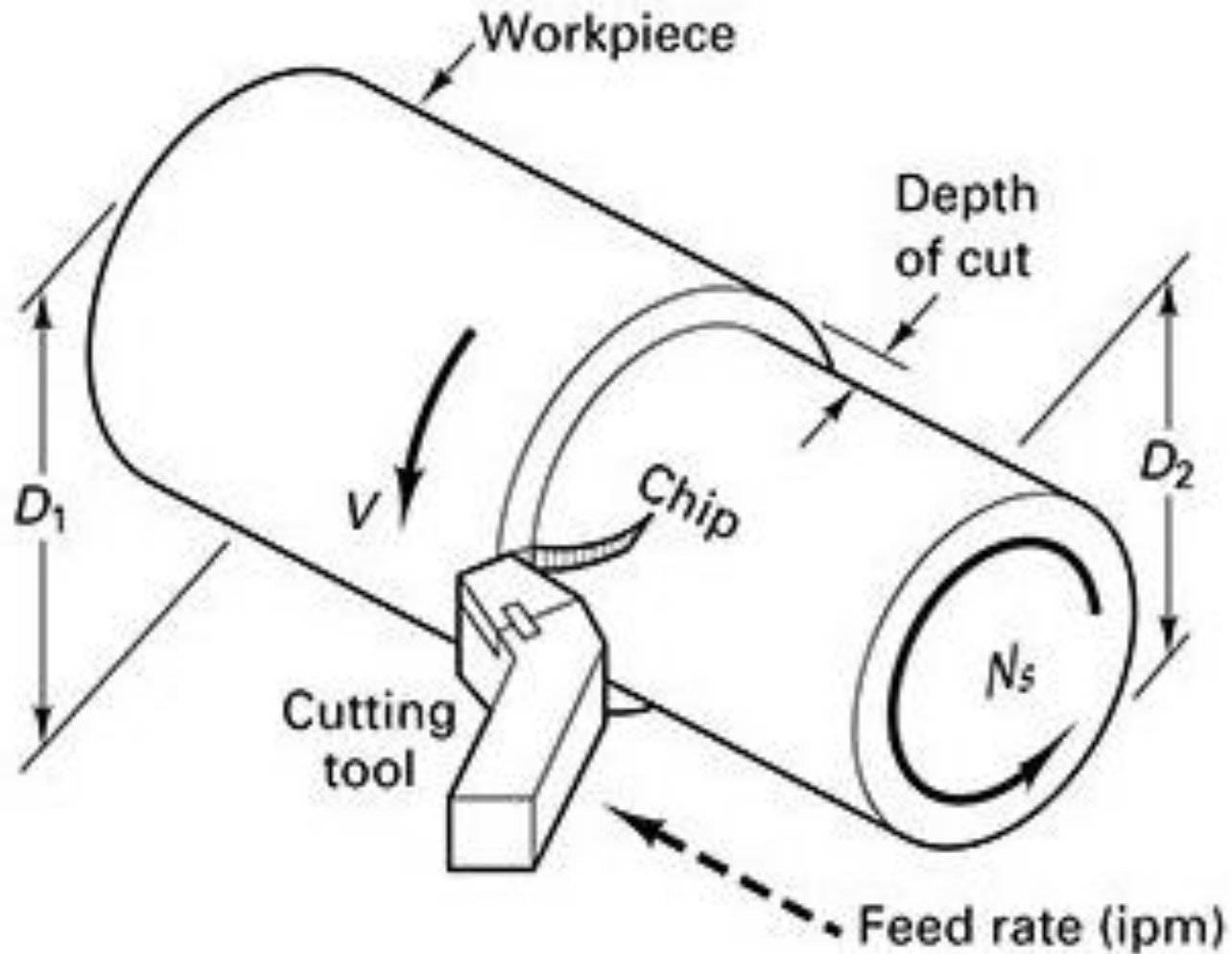


# Machining Process

Affected by:

- Machine tool (the machine itself)
- Cutting tool (geometry and material)
- Workpiece (properties and material)
- Cutting tool parameters
  - ❖ Speed
  - ❖ Feed
  - ❖ Depth of cut
- Workpiece holding devices

# Cutting Parameters



# Four Cutting Tool Parameters

- 1. Speed
- 2. Depth of Cut (DOC)
- 3. Feed Rate ( $f_r$ )
- 4. Material Removal Rate (MRR)

# Speed

Speed – velocity of workpiece relative to cutting tool; the **primary cutting motion**

- $V = \pi D_1 N_s / 12$ , in *ft/min*
- $D_1$  = original diameter, inches
- $N_s$  = angular velocity of workpiece, *RPM*
- $N_s \cong 3.8V / D_1$

# Depth of Cut

Depth of Cut (DOC) – distance tool plunged into workpiece

- $d = (D_1 - D_2)/2$ , inches



# Feed Rate

Feed Rate ( $f_r$ ) – amount of material removed per revolution (inches/rev)

# Material Removal Rate

## Material Removal Rate

$MRR = (\text{volume removed})/(\text{cutting time}), \text{ in}^3/\text{min}$

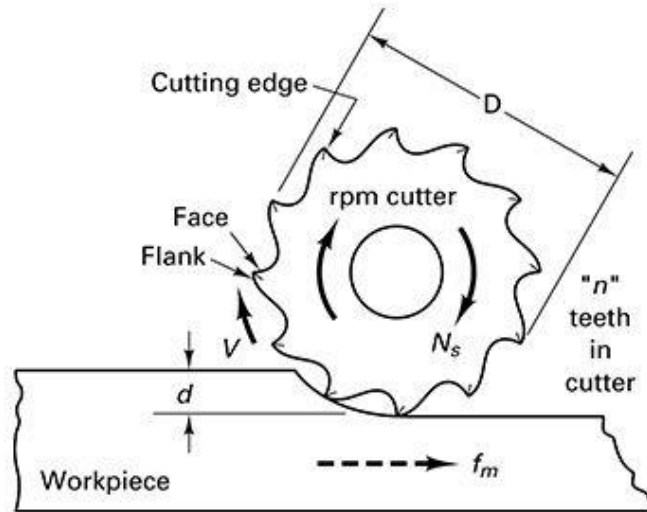
- $MRR \cong 12V f_r d, \text{ in}^3/\text{min}$
- $MRR \cong \pi D_1 N_s f_r d, \text{ in}^3/\text{min}$
- $d = \text{depth of cut}$

# Milling Material Removal Rate

Multiple-tooth cutter is used

- Table feed:  $f_m = f_t n N_s$
- $f_t$  = feed per tooth pass, inches/rev
- $n$  = number of teeth
- $N_s$  = angular velocity, RPM
- $MRR = W d f_m$ , in<sup>3</sup>/min

# Slab/Face Milling Basics



Slab milling – multiple tooth

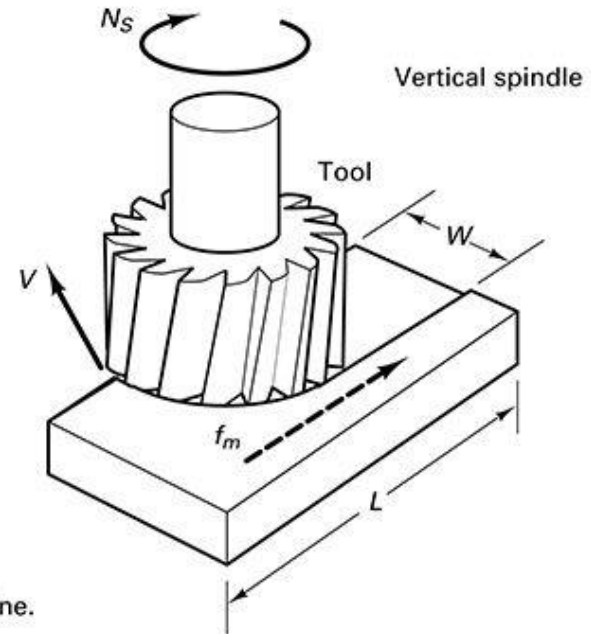
Slab milling is usually performed on a horizontal milling machine. Equations for  $T_m$  and MRR derived in Chapter 25.

The tool rotates at rpm  $N_s$ . The workpiece translates past the cutter at feed rate  $f_m$ , the table feed. The length of cut,  $L$ , is the length of workpiece plus allowance,  $L_A$ .

$$L_A = \sqrt{\frac{D^2}{4} - \left(\frac{D}{2} - d\right)^2} = \sqrt{d(D - d)} \text{ inches}$$

$$T_m = (L + L_A)/f_m$$

The MRR =  $Wdf_m$  where  $W$  = width of the cut and  $d$  = depth of cut.



Face milling  
Multiple-tooth cutting

Given a selected cutting speed  $V$  and a feed per tooth  $f_t$ , the rpm of the cutter is  $N_s = 12V/\pi D$  for a cutting of diameter  $D$ . The table feed rate is  $f_m = f_t n N_s$  for a cutter with  $n$  teeth.

The cutting time,  $T_m = (L + L_A + L_o)/f_m$  where  $L_o = L_A = \sqrt{W(D - W)}$  for  $W < D/2$  or  $L_o = L_A = D/2$  for  $W \geq D/2$ .

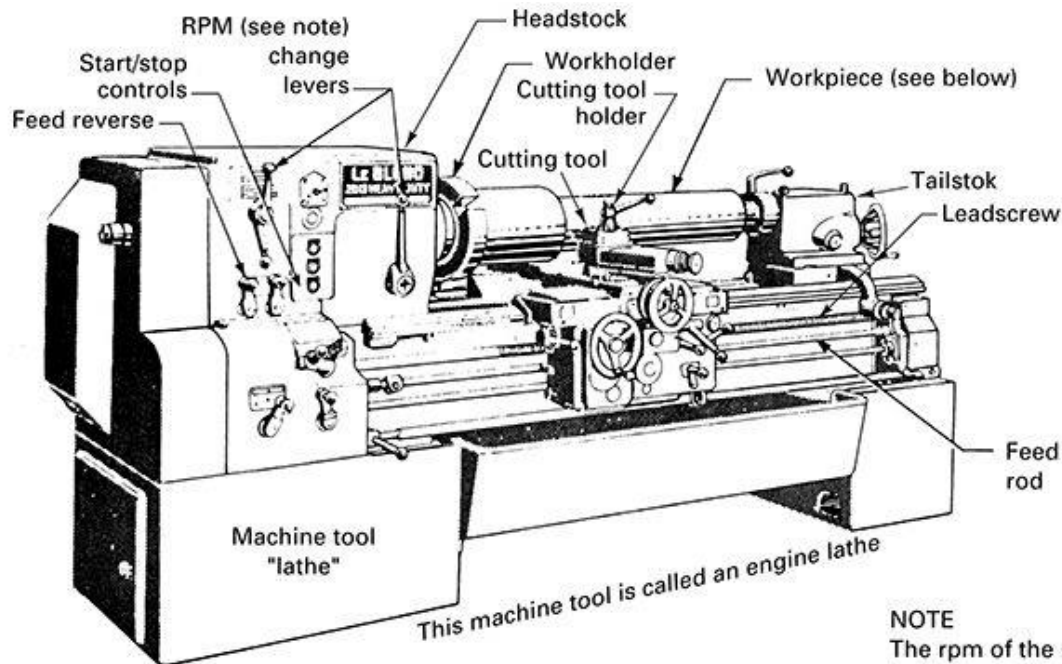
The MRR =  $Wdf_m$  where  $d$  = depth of cut.

# Shop Formulas for Various Processes

Shop Formulas for Turning, Milling, Drilling, and Broaching (English Units)

Parameter	Turning	Milling	Drilling	Broaching
Cutting speed, fpm	$V = 0.262 \times D_t \times \text{rpm}$	$V = 0.262 \times D_m \times \text{rpm}$	$V = 0.262 \times D_d \times \text{rpm}$	$V$
Revolutions per minute, $N_s$	$\text{rpm} = 3.82 \times V_c/D_t$	$\text{rpm} = 3.82 \times V_c/D_m$	$\text{rpm} = 3.82 \times V_c/D_d$	—
Feed rate, in./min Feed per rev tooth pass, in./rev	$f_m = f_r \times \text{rpm}$ $f_r$	$f_m = f_r \times \text{rpm}$ $f_t$	$f_m = f_r \times \text{rpm}$ $f_r$	— —
Cutting time, min, $T_m$	$T_m = L/f_m$	$T_m = L/f_m$	$T_m = L/f_m$	$T_m = L/12V$
Rate of metal removal, in. <sup>3</sup> /min	$\text{MRR} = 12 \times d \times f_r \times V_c$	$\text{MRR} = w \times d \times f_m$	$\text{MRR} = \pi D^2 d/4 \times f_m$	$\text{MRR} = 12 \times w \times d \times V$
Horsepower required at spindle	$\text{hp} = \text{MRR} \times \text{HP}_s$	$\text{hp} = \text{MRR} \times \text{HP}_s$	$\text{hp} = \text{MRR} \times \text{HP}_s$	—
Horsepower required at motor	$\text{hp}_m = \text{MRR} \times \text{HP}_s/E$	$\text{hp}_m = \text{MRR} \times \text{HP}_s/E$	$\text{hp}_m = \text{MRR} \times \text{HP}_s/E$	$\text{hp}_m = \text{MRR} \times \text{HP}_s/E$
Torque at spindle	$t_s = 63,030 \text{ hp/rpm}$	$t_s = 63,030 \text{ hp/rpm}$	$t_s = 63,030 \text{ hp/rpm}$	—
Symbols	$D_t$ = Diameter of workpiece in turning, inches $D_m$ = Diameter of milling cutter, inches $D_d$ = Diameter of drill, inches $d$ = Depth of cut, inches $E$ = Efficiency of spindle drive $f_m$ = Feed rate, inches per minute $f_r$ = Feed, inches per revolution $f_t$ = Feed, inches per tooth $\text{hp}_m$ = Horsepower at motor $\text{MRR}$ = Metal removal rate, in. <sup>3</sup> /min			$\text{hp}$ = horsepower at spindle $L$ = Length of cut, inches $n$ = Number of teeth in cutter $\text{HP}_s$ = Unit power, horsepower per cubic inch per minute, specific horsepower $N_s$ = Revolution per minute of work or cutter $t_s$ = Torque at spindle, inch-pound $T_m$ = Cutting time, minutes $V$ = Cutting speed, feet per minute $w$ = Width of cut, inches

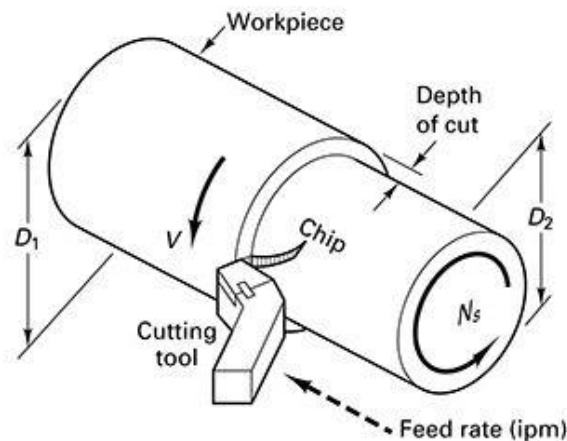
# Lathe Turning



## NOTE

The rpm of the rotating workpiece is  $N_s$ . It establishes the cutting speed  $V$ , at the tool, according to  $N_s = 12V/\pi D$ .

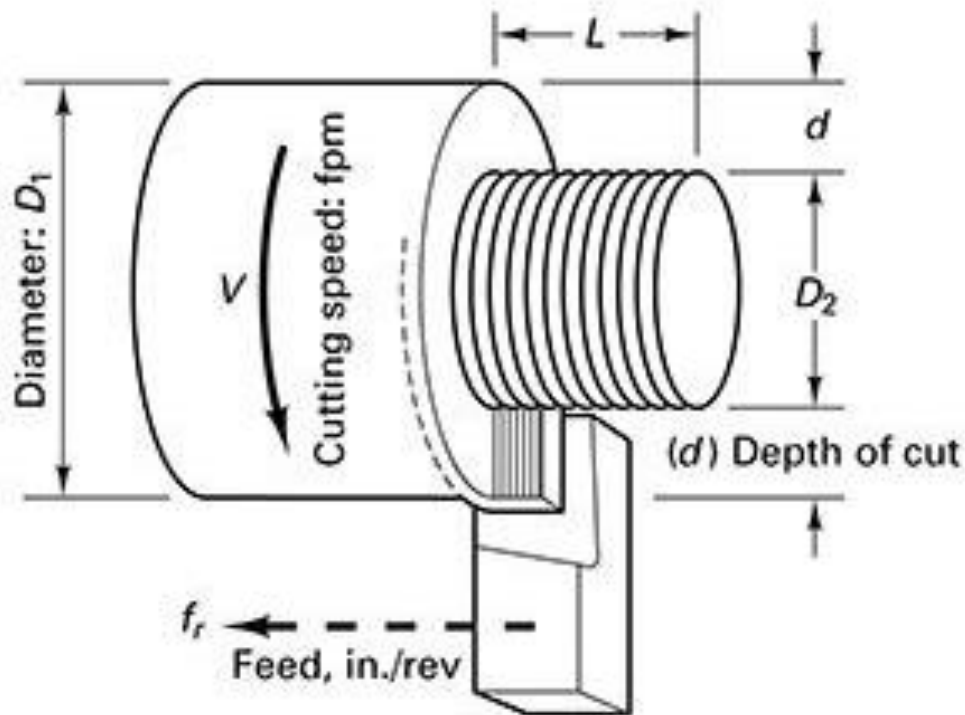
The depth of cut,  $d$ , is equal to  $(D_1 - D_2)/2$ .  
The length of cut is the distance the tool travels parallel to the axis,  $L$ .





[Watch Video Here](#)

# Lathe Turning



## Turning

Speed, stated in surface feet per minute (sfpm), is the peripheral speed at the cutting edge. Feed per revolution in turning is a linear motion of the tool parallel to the rotating axis of the workpiece. The depth of cut reflects the third dimension.

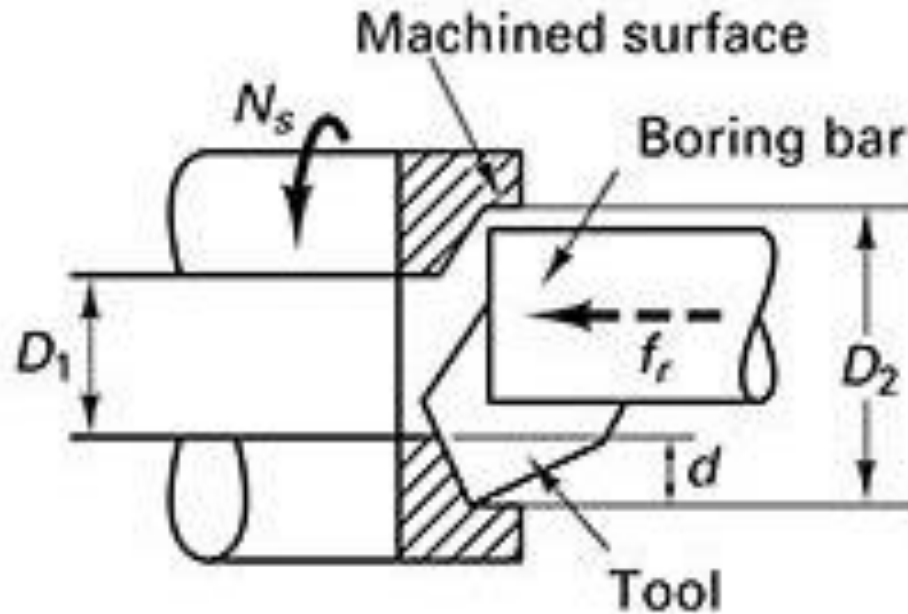
$L$  = length of cut

$$T_m = \frac{L + A}{f_r N_s}$$

$T_m$  = cutting time, minutes



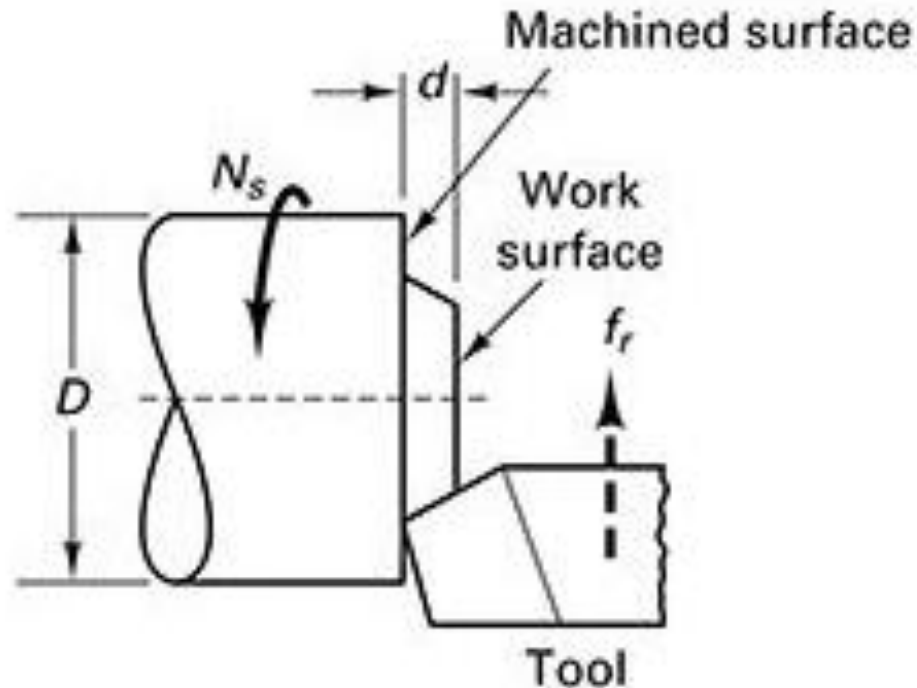
# Boring Basics



## Boring

Enlarging hole of diameter  $D_1$  to diameter  $D_2$ . Boring can be done with multiple cutting tools. Feed in inches per revolution,  $f_r$

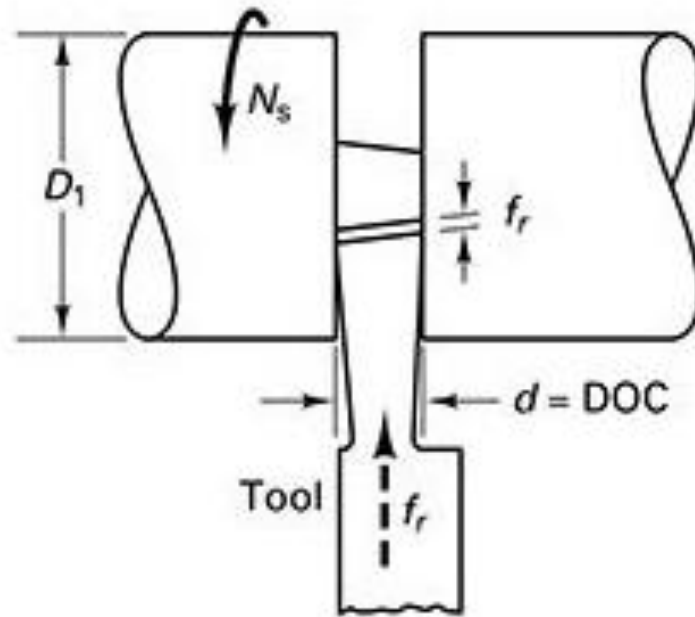
# Facing Basics



## Facing

Tool feeds to center of workpiece so  $L = D/2$ . The cutting speed is decreasing as the tool approaches the center of the workpiece.

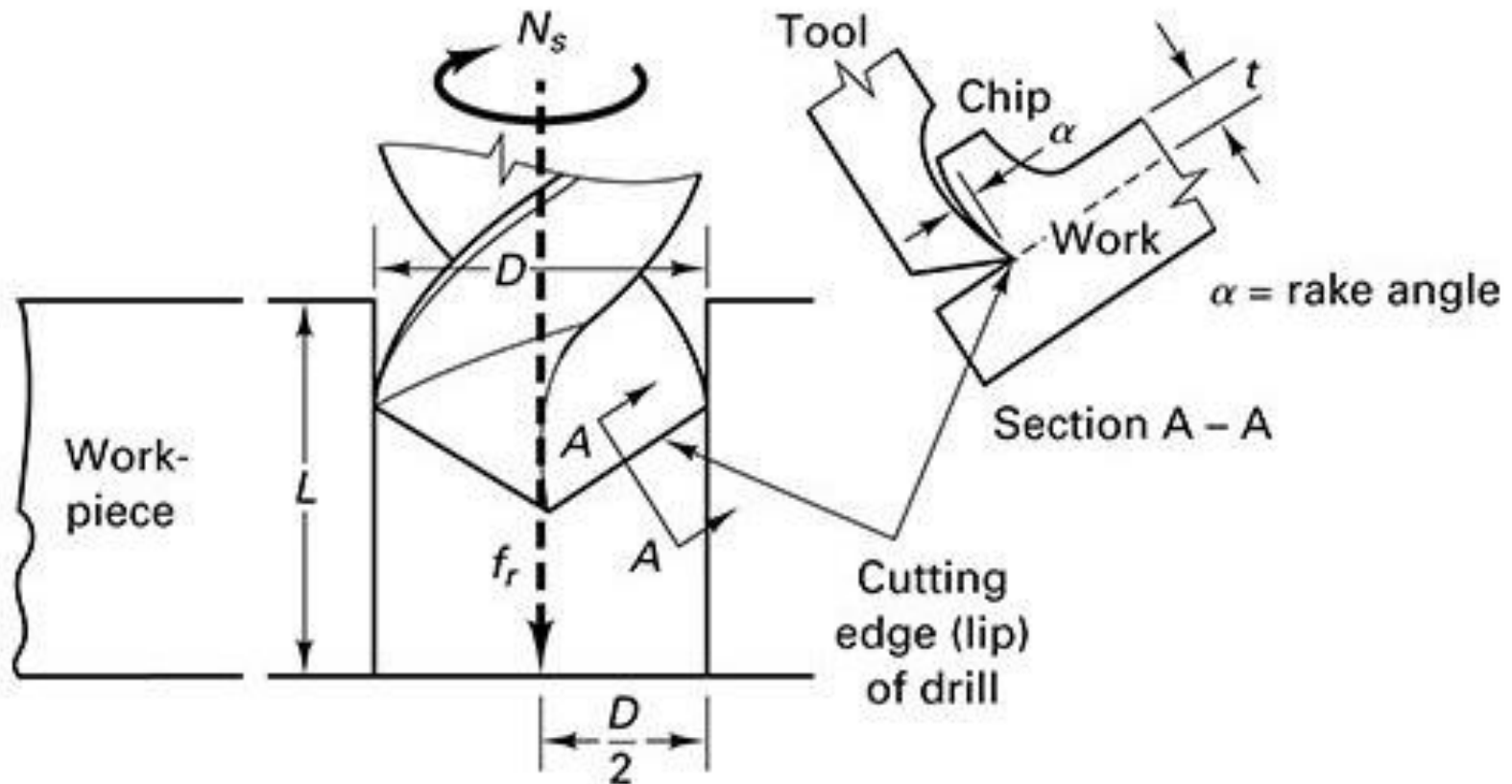
# Grooving, Parting, or Cut-off



## Grooving, parting, or cutoff

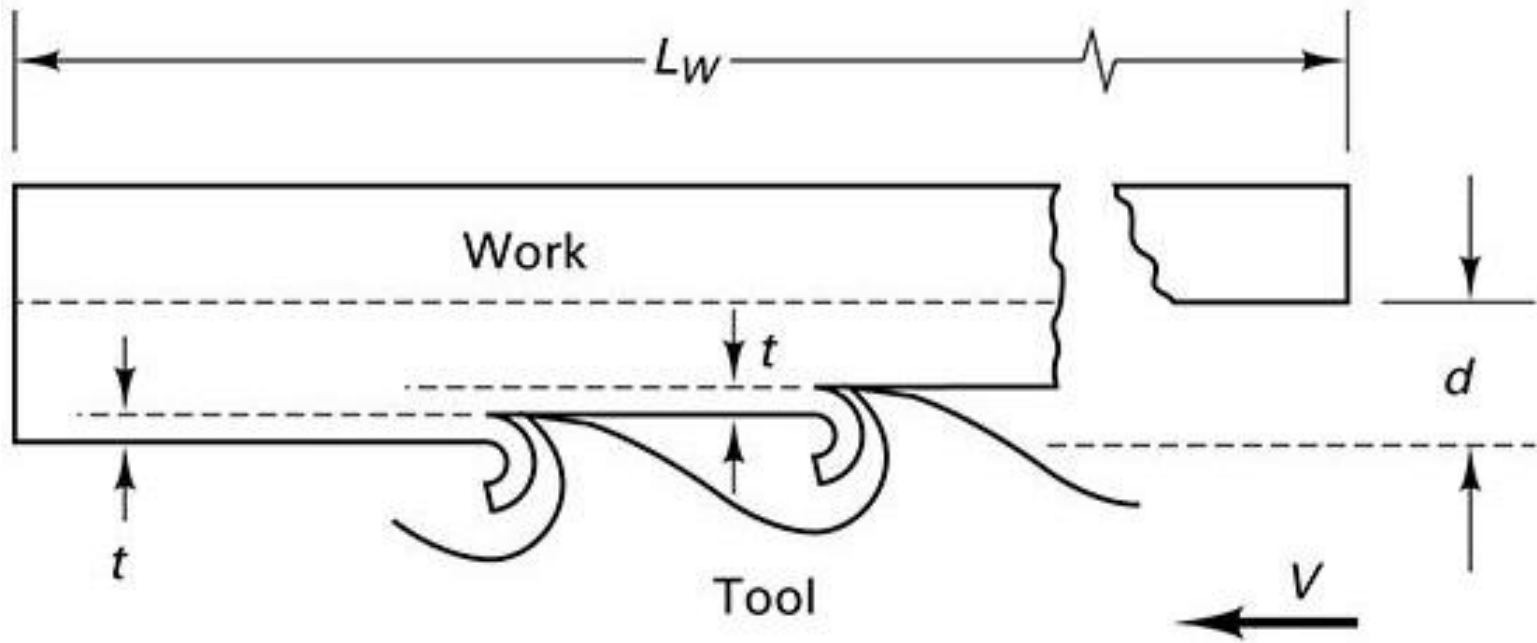
Tool feed perpendicular to the axis of rotation. The width of the tool produces the depth of cut (DOC).

# Drilling Basics

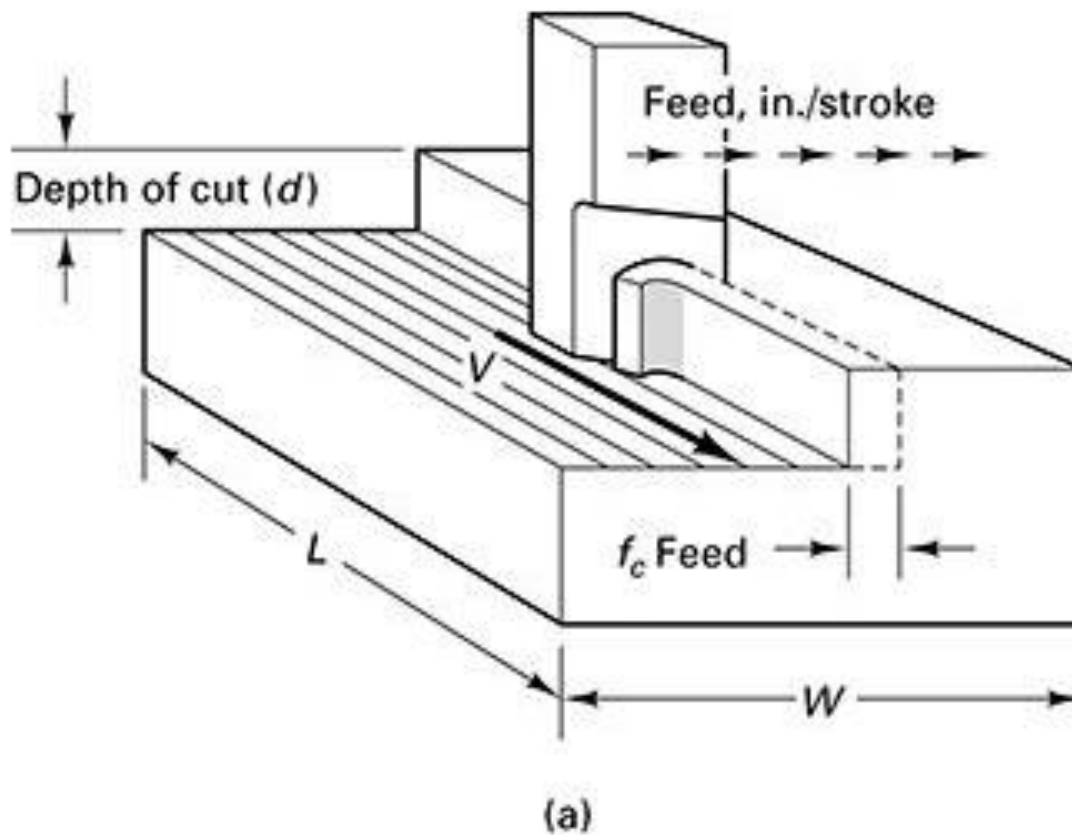


Drilling multiple-edge tool

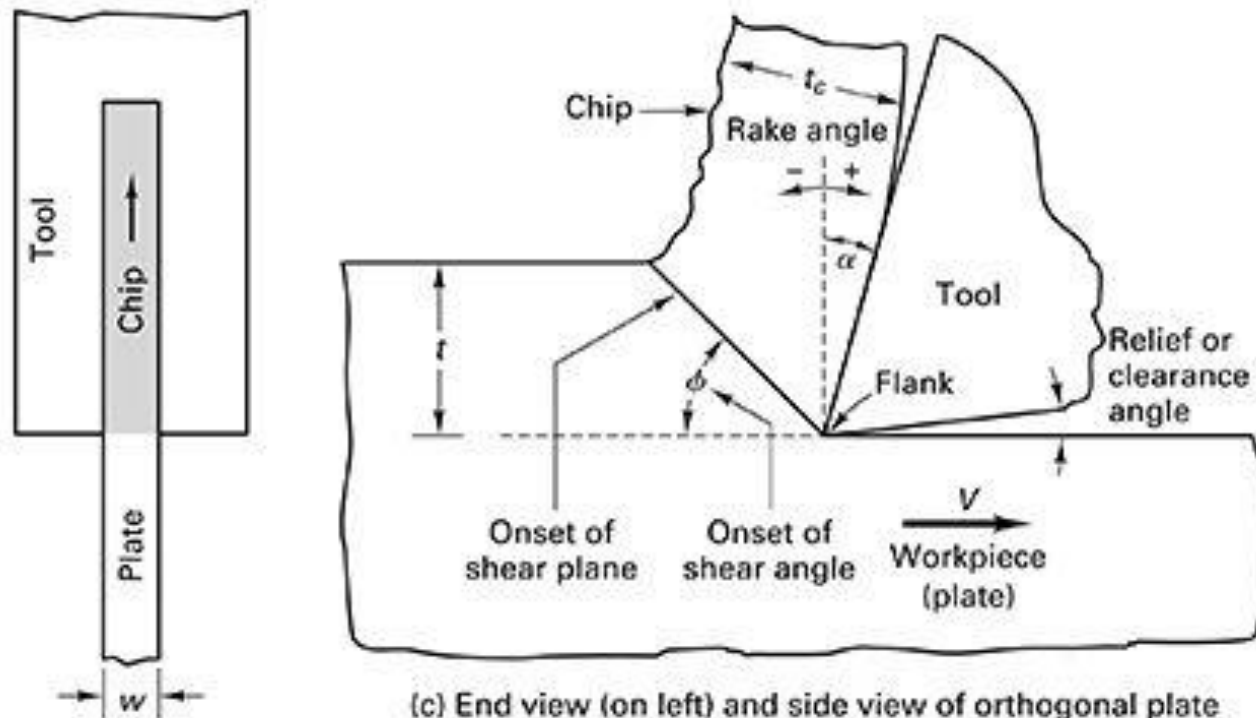
# Broaching Basics



# Shaping/Planing Basics

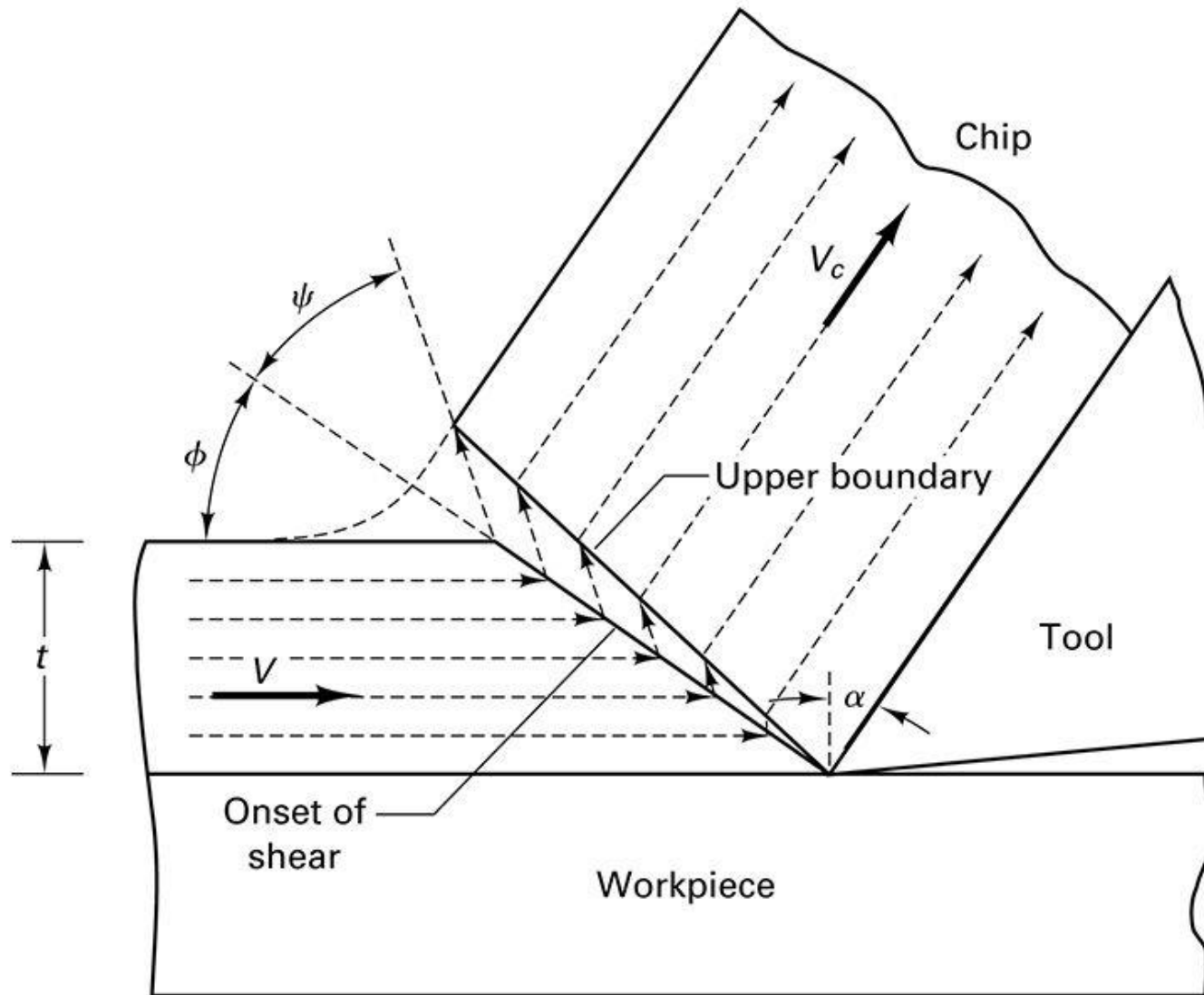


# Understanding Chip Formation



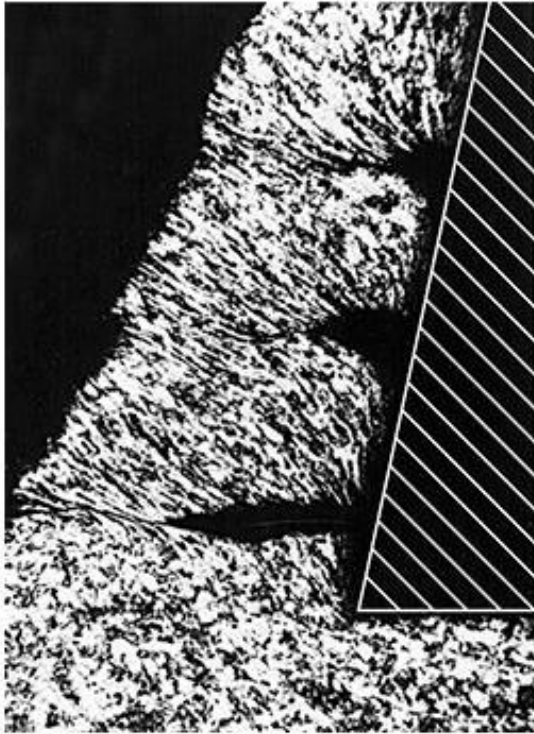
(c) End view (on left) and side view of orthogonal plate machining with fixed tool and moving plate.

# Removing a Chip

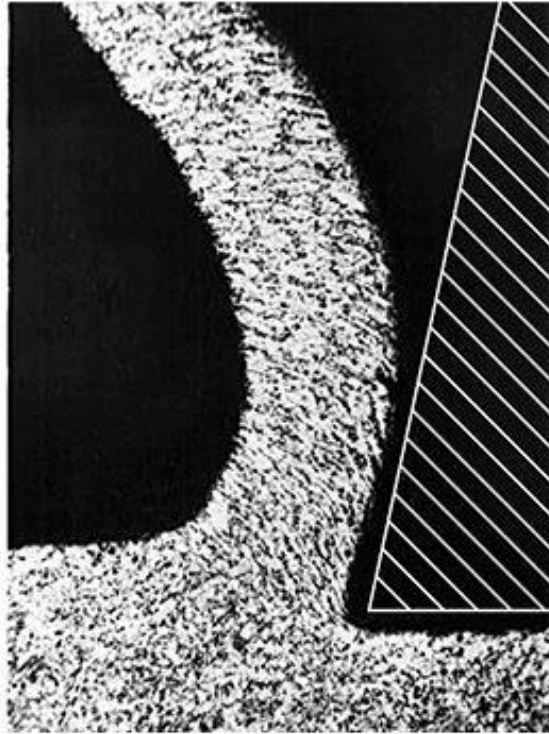




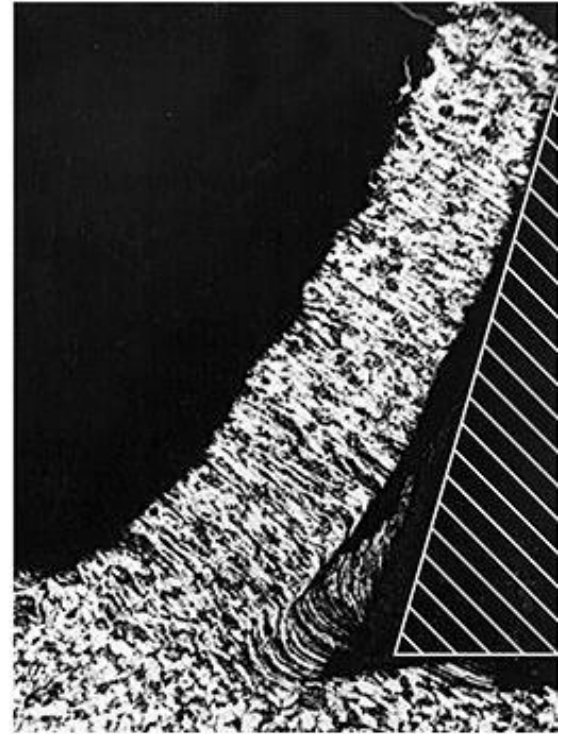
# Effect of Workpiece Material Properties



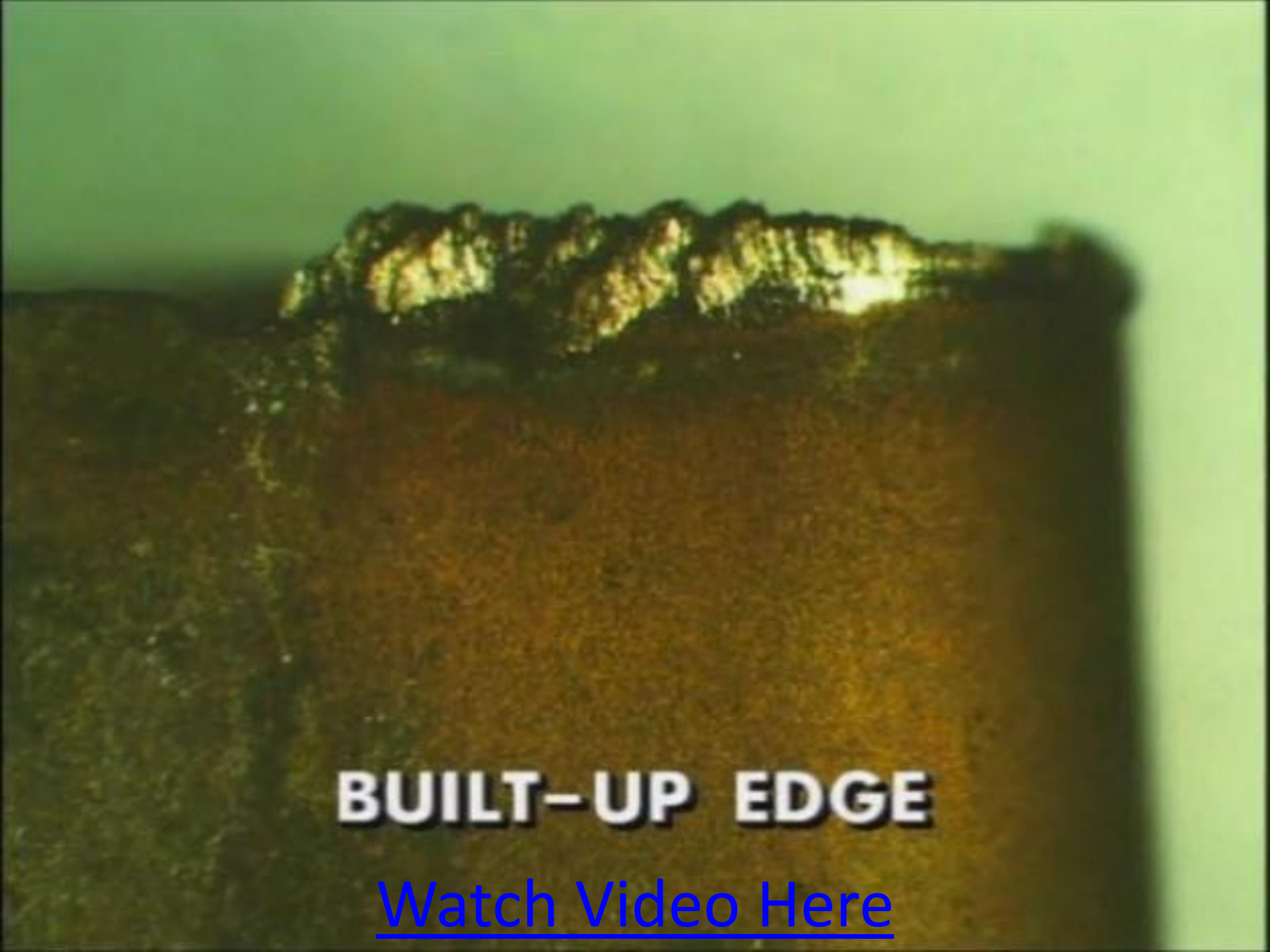
Discontinuous



Continuous



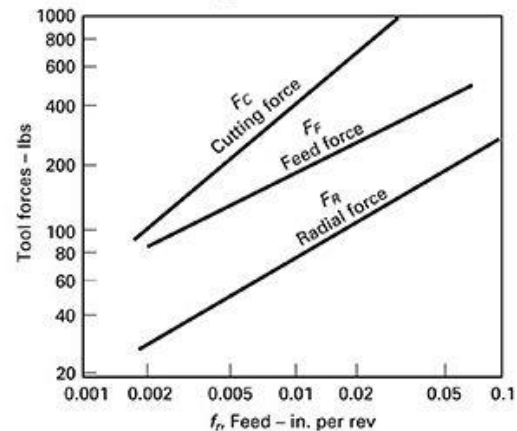
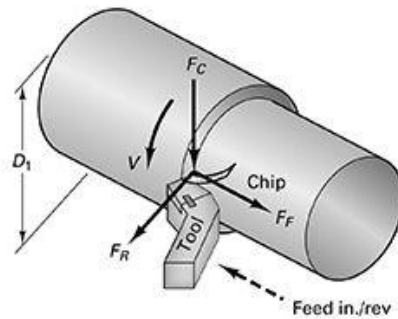
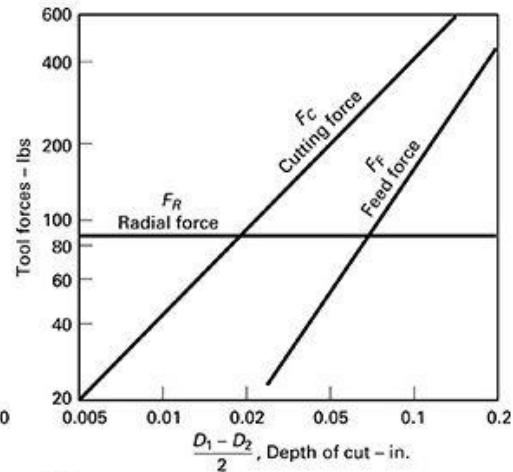
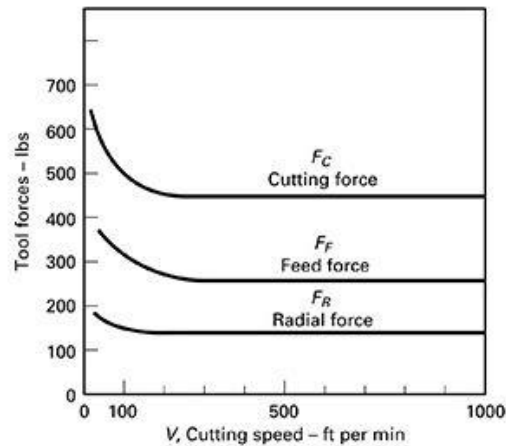
Continuous  
with built-up edge



**BUILT-UP EDGE**

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# Energy and Power in Machining



### 3 Force

$F_C$  = Cutting force (vertical)

$F_R$  = Radial force (thrust)

$F_F$  = Feed force

# Power

- $Power = F_c V$ , ft-lbs/min  
     $V$ , ft/min  
     $F_c$ , lbs
- $HP = F_c V / 33000$ , horsepower
- Specific horsepower  $HP_s = HP / MRR$ , ft-lbs/in<sup>3</sup>

# **TOOL FAILURE MODES**

[Watch Video Here](#)