FUNDAMENTALS OF MACHINING

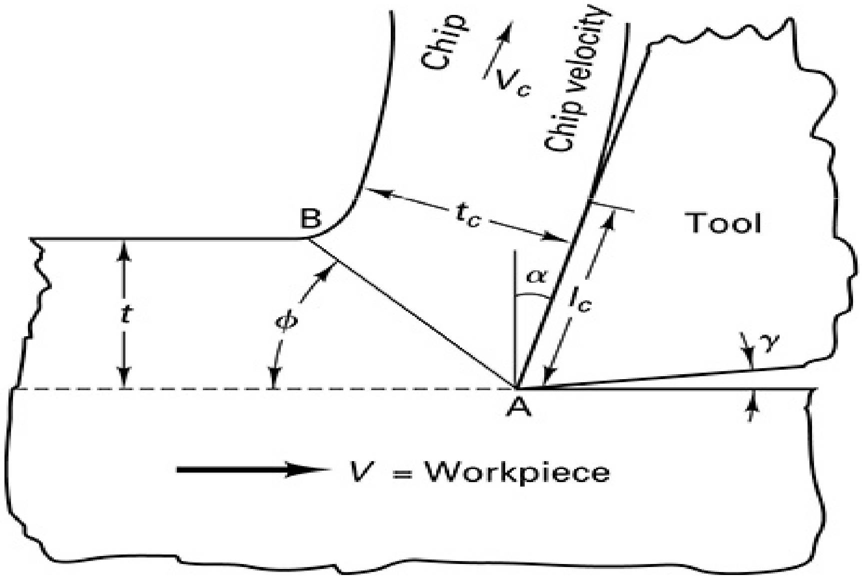
MODULE CONTENT

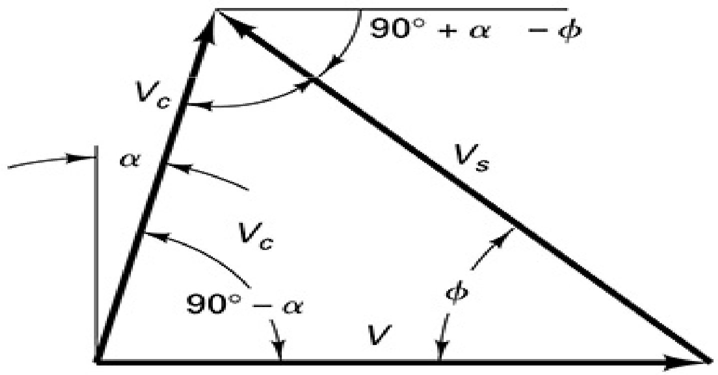
- Material removal
- Orthogonal Machining
- Basic Machining Processes
- Turning
- Milling

MATERIAL REMOVAL

- Mass production vs an individual part
- Shape generation
- Material separation and removal of separated material

DIAGRAM OF ORTHOGONAL MACHINING

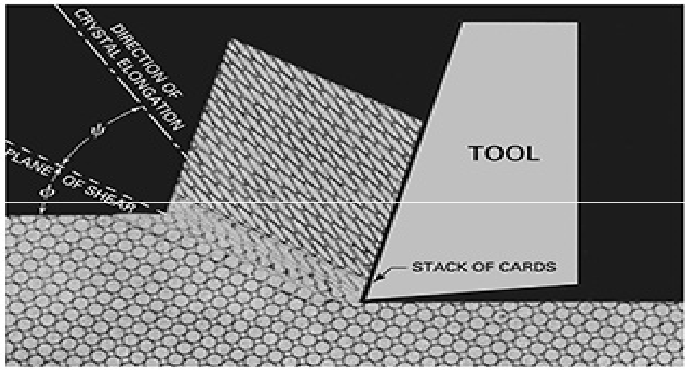




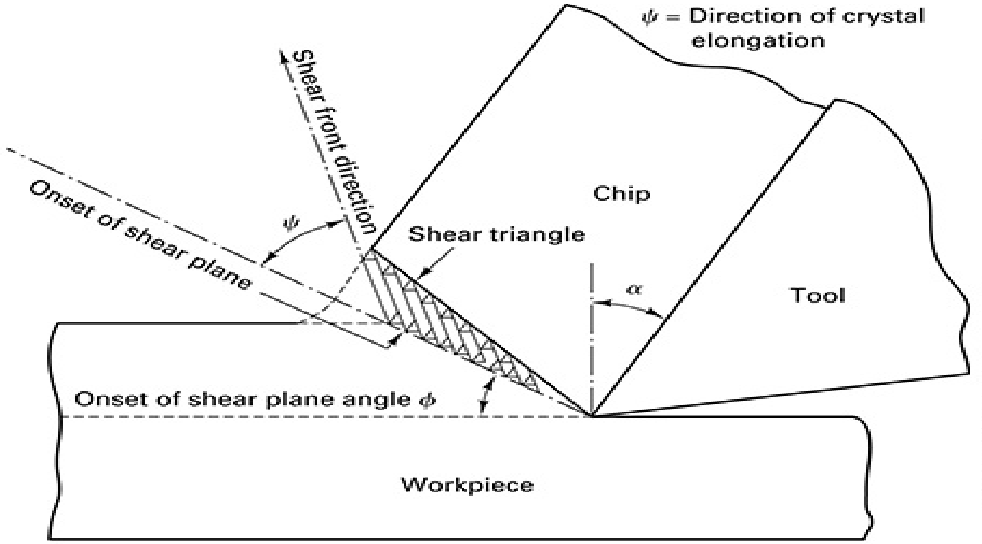
CHIP FORMATION

$$r_c = \frac{t}{t_c} = \frac{AB\sin\phi}{AB\cos(\phi - \alpha} = \frac{V_c}{V}$$

“STACK OF CARD” MODEL OF MATERIAL REMOVAL

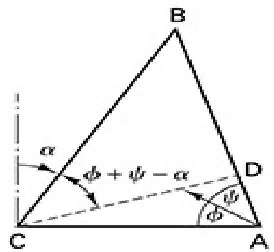


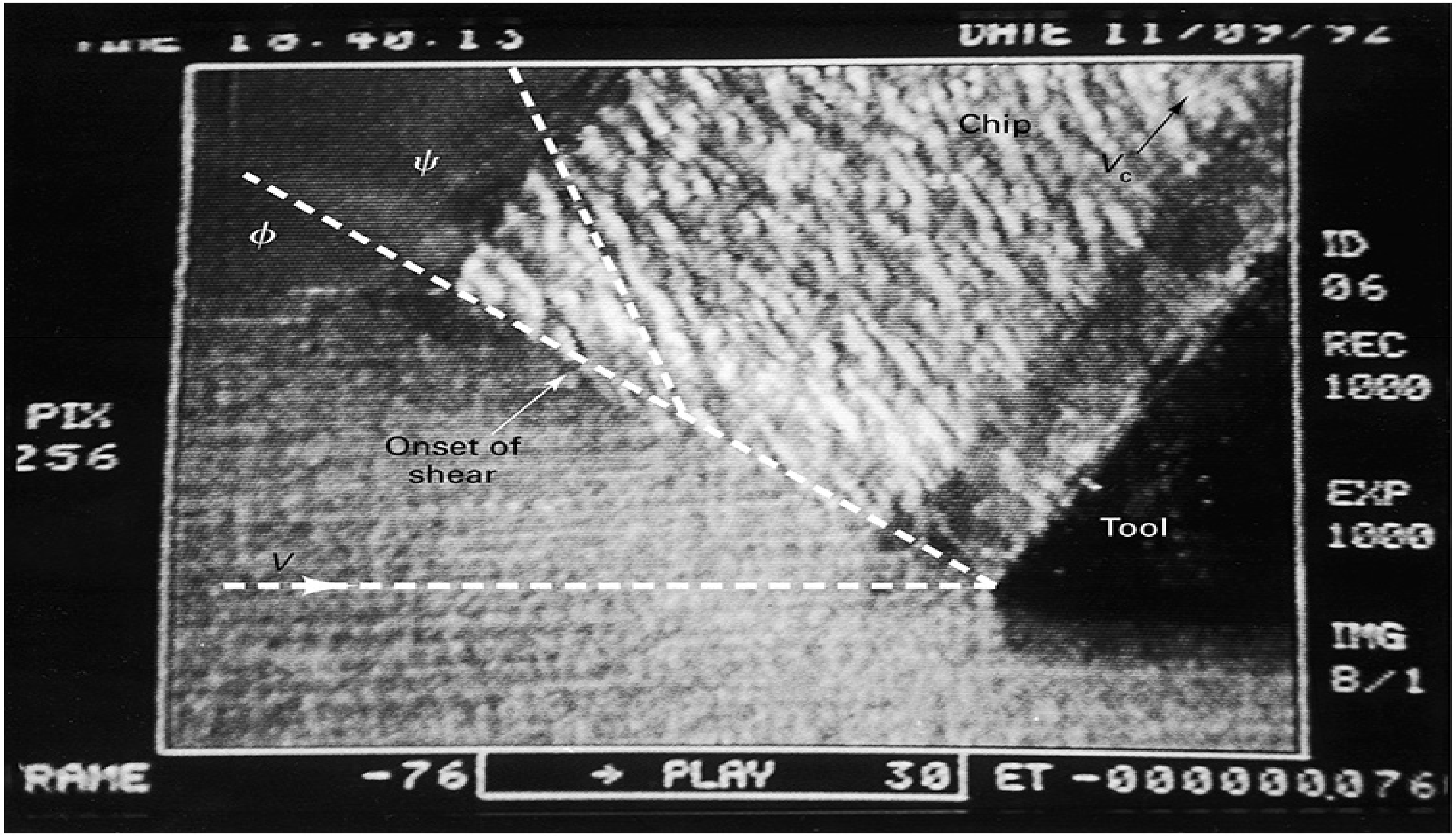
Mechant's bubble model of chip formation



Black-Huang stack-of-cards model

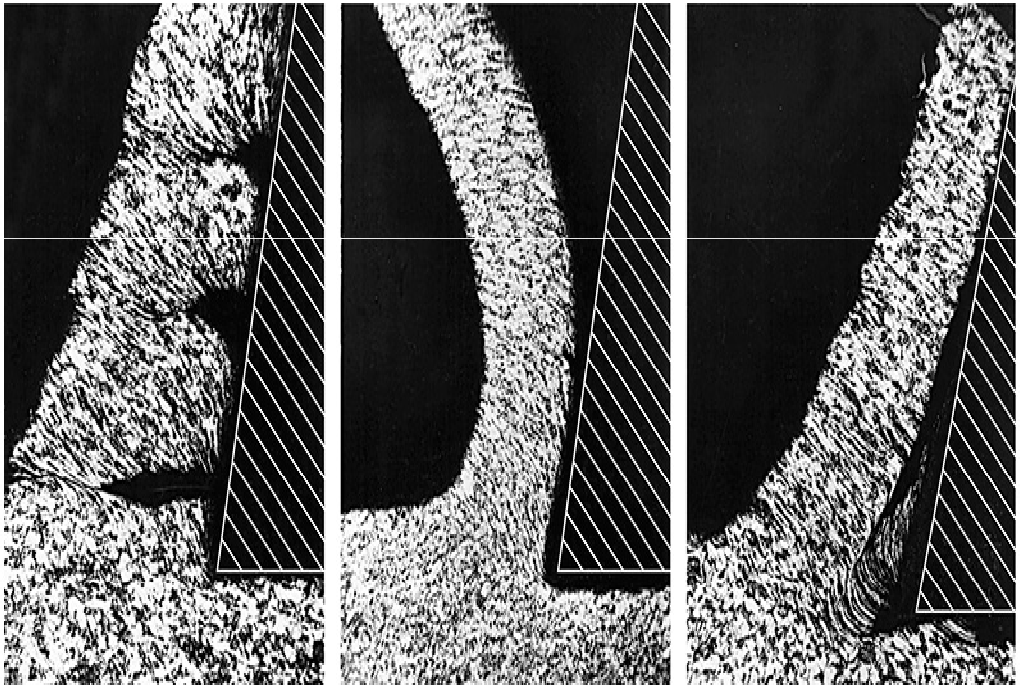
The shaded shear triangle on the right is used to develop the basic equation for shear strain, γ.



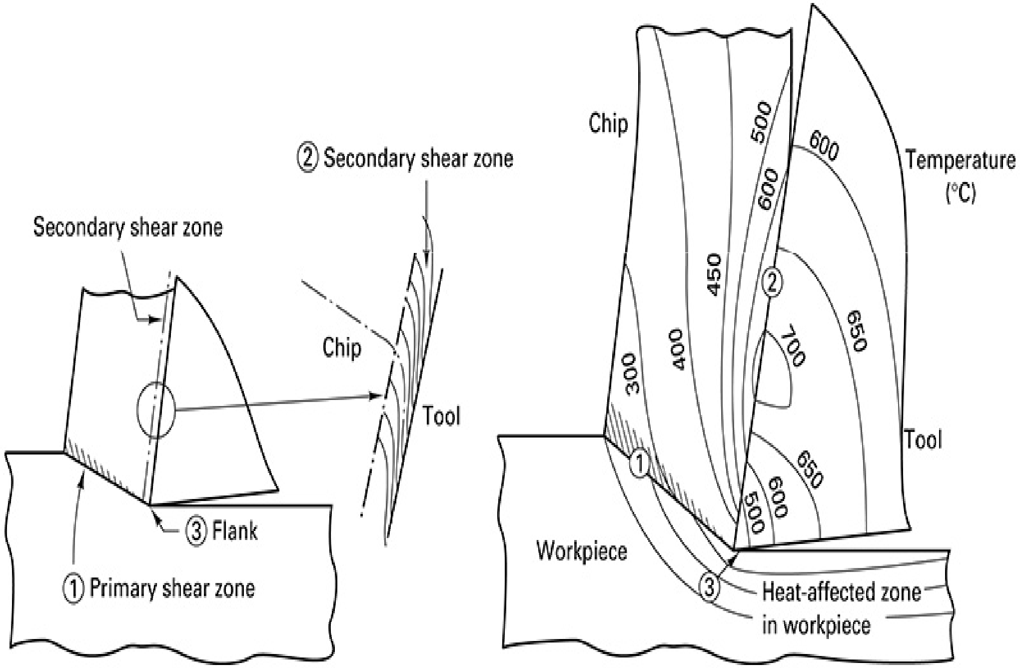


Chip
V_c
ψ
ϕ
Onset of shear
V
Tool
ID
06
REC
1000
EXP
1000
IMG
8/1
PIX
256
-76
PLAY
30

CHIPS SHAPE



TEMPERATURE FIELD



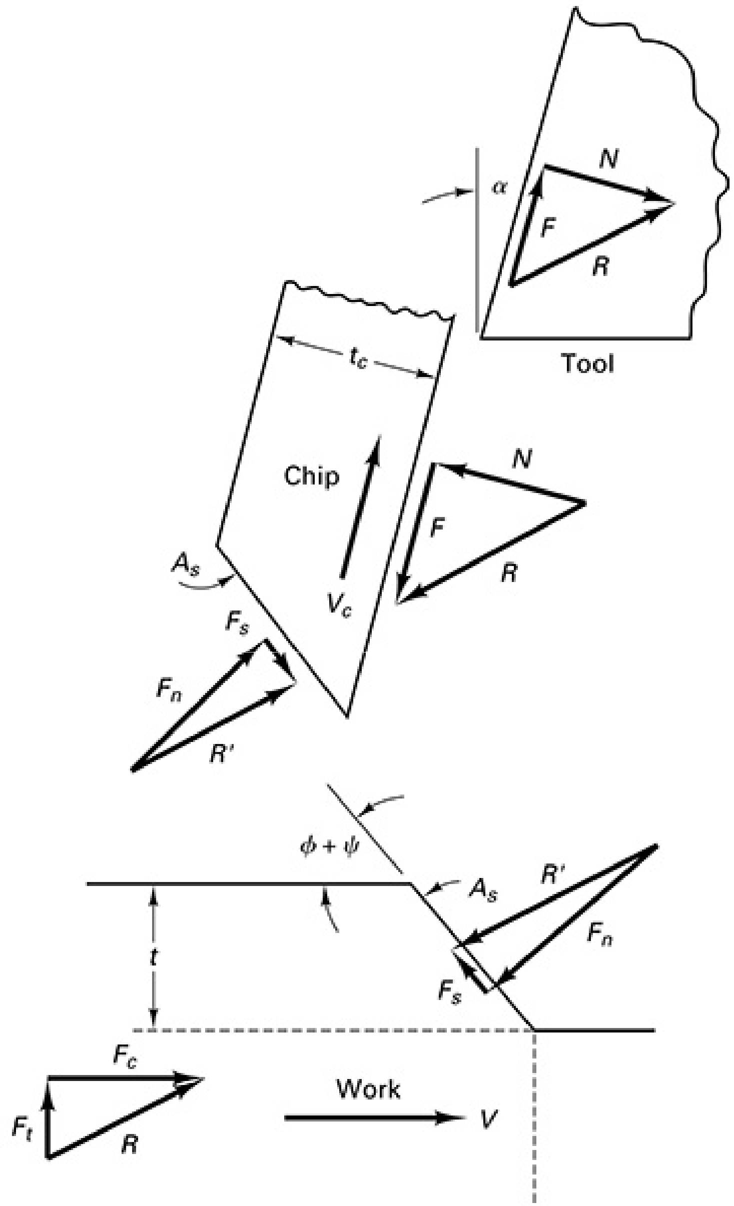
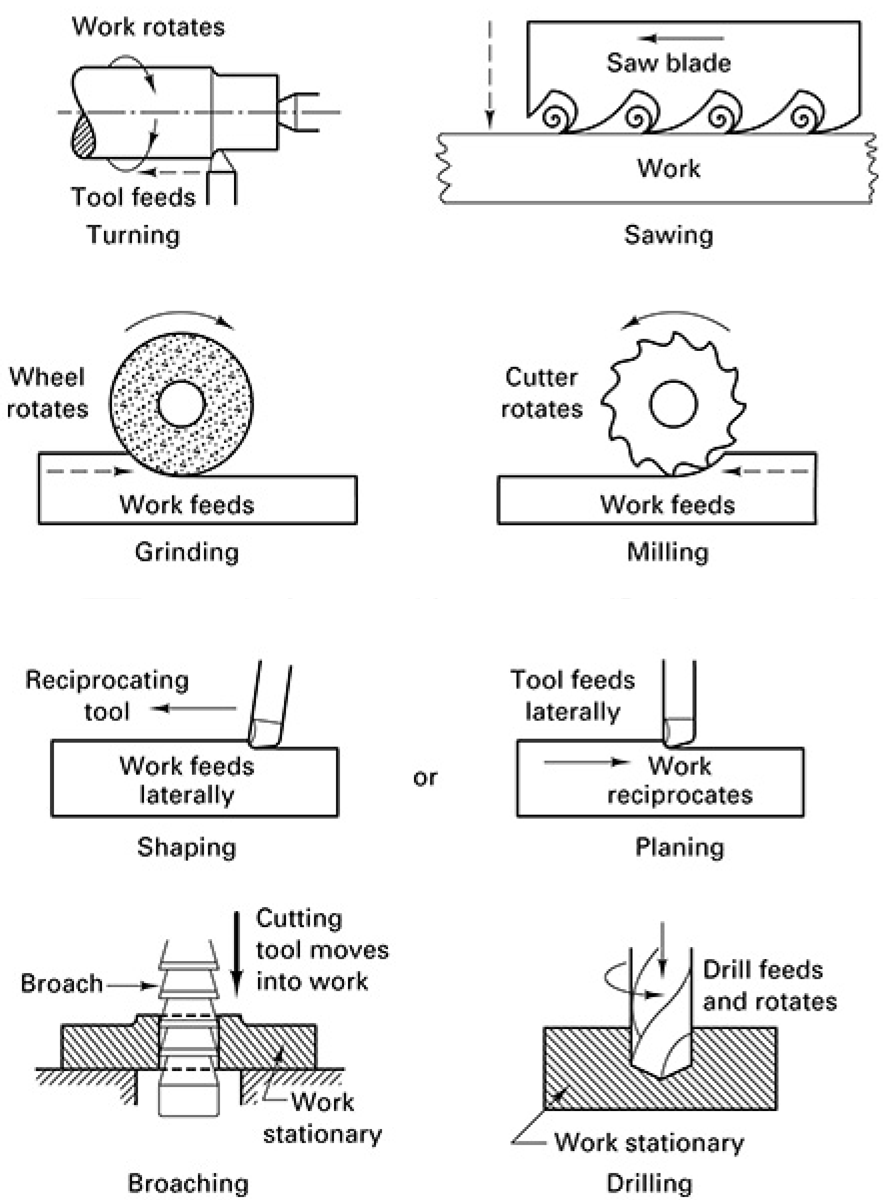


FIGURE 20-20 Free-body diagram of orthogonal chip formation process, showing equilibrium condition between resultant forces *R* and *R*.

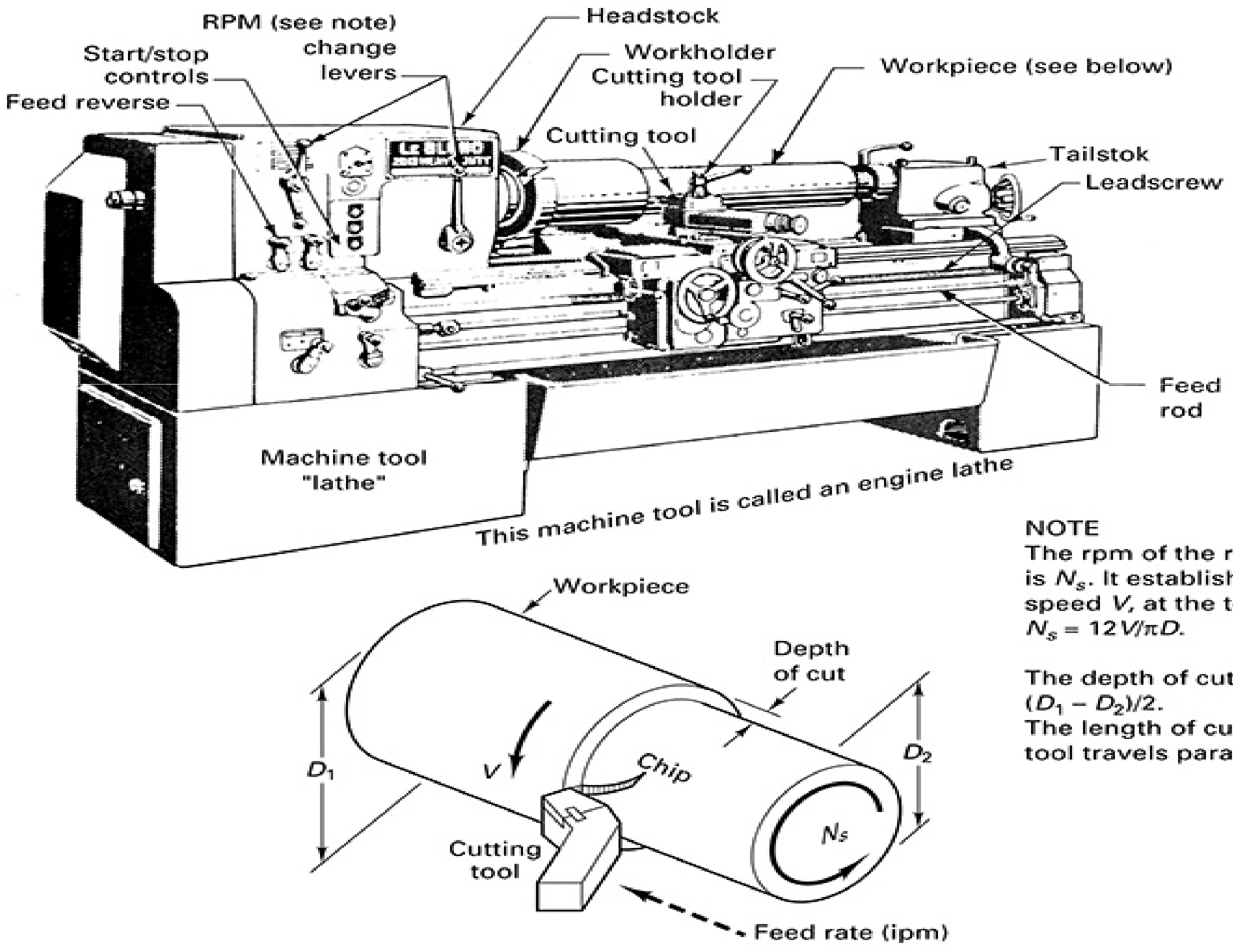


Work rotates
Tool feeds
Turning
Saw blade
Work
Sawing
Wheel rotates
Work feeds
Grinding
Cutter rotates
Work feeds
Milling
Reciprocating tool
Work feeds laterally
Shaping
or
Tool feeds laterally
Work reciprocates
Planing
Cutting tool moves into work
Broach
Work stationary
Broaching
Drill feeds and rotates
Work stationary
Drilling

BASIC MACHINING PROCESSES

- Turning
- Milling
- Sawing
- Grinding
- Shaping
- Planning
- Broaching
- Drilling

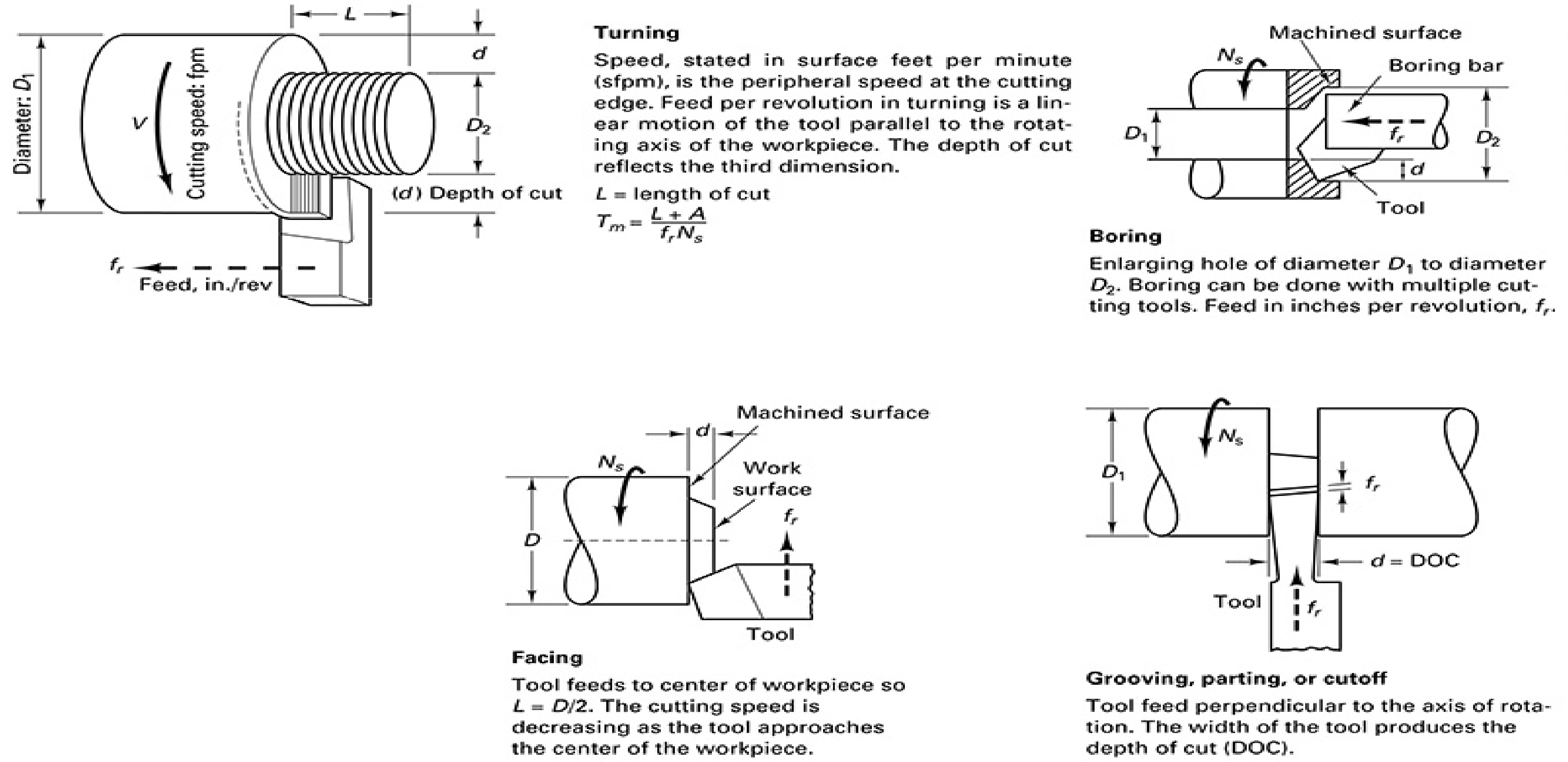
TURNING MACHINING

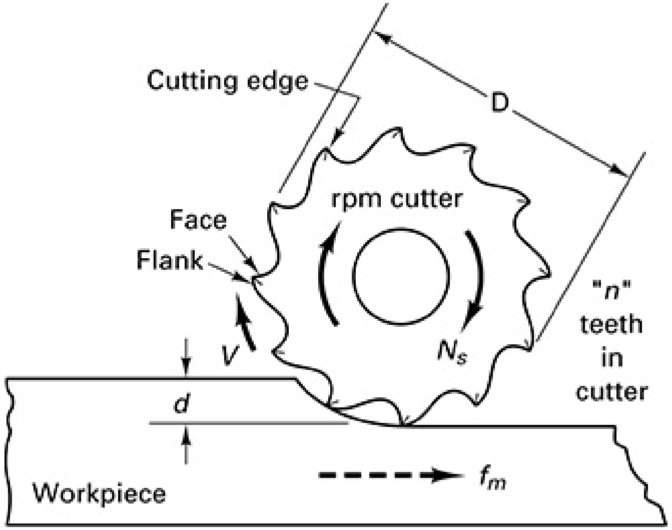


NOTE
The rpm of the rotating workpiece is N_s. It establishes the cutting speed V, at the tool, according to $N_s = 12V/\pi D$.

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.

LATH OPERATION





Slab milling – multiple tooth

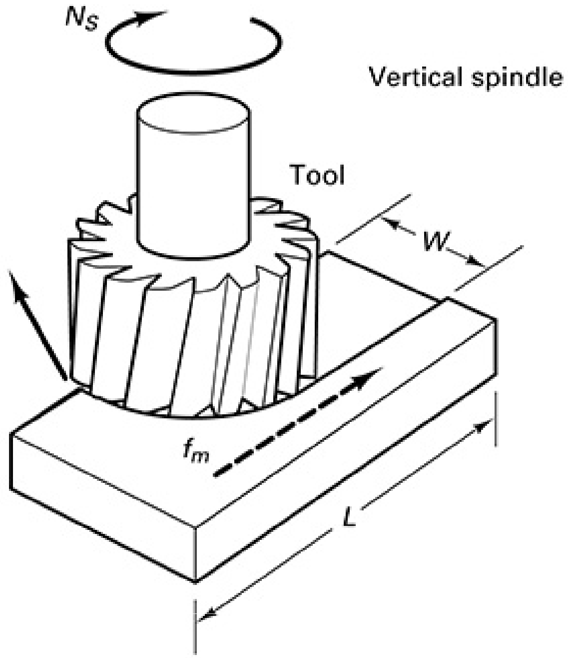
Slab milling is usually performed on a horizontal milling machine.
Equations for T_m and MRR derived in Chapter 25.

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,

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

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

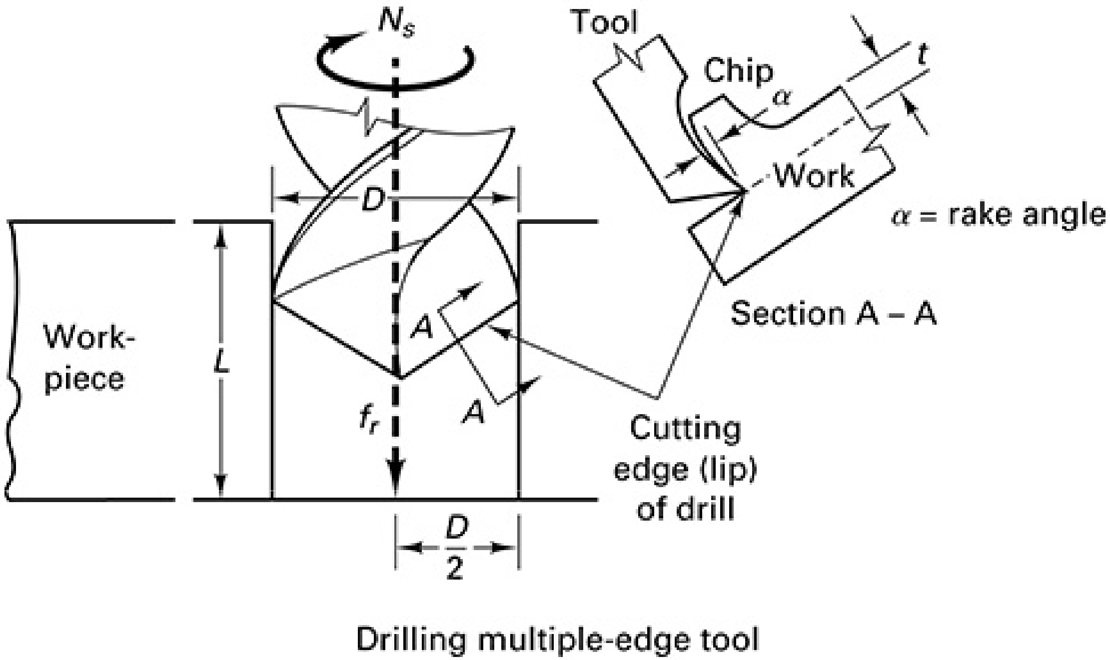
The MRR = Wdf_m where W = width of the cut and d = depth of cut.



Face milling
Multiple-tooth cutting

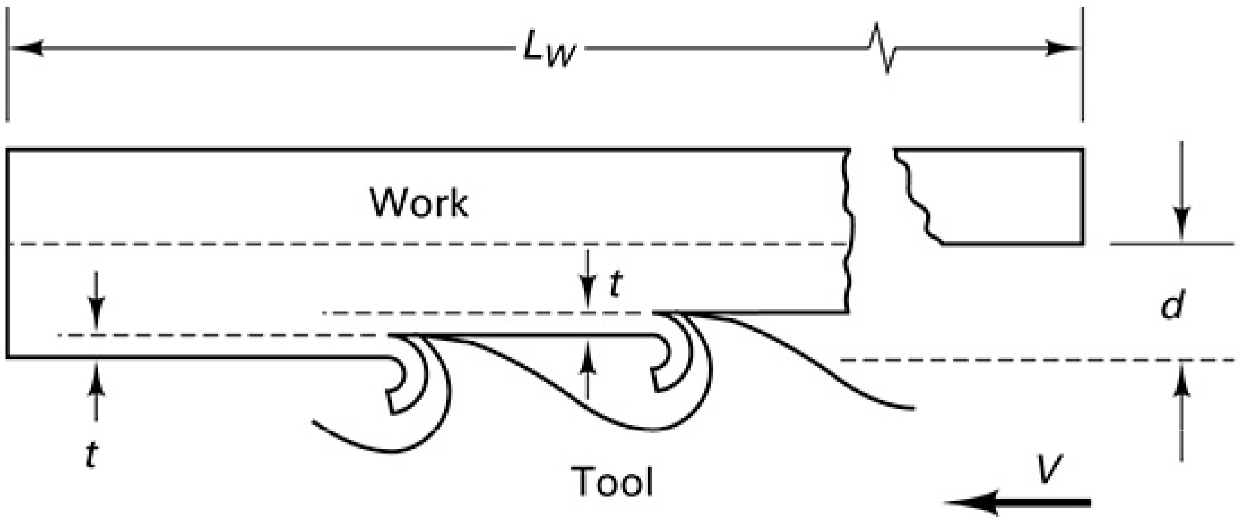
Given a selected cutting speed V and a feed per tooth f_t, the rpm of the cutter is $N_s = 12V/\pi D$ for a cutting of diameter D. The table feed rate is $f_m = f_t n N_s$ for a cutter with n teeth.
The cutting time, $T_m = (L + L_A + L_o)/f_m$
where $L_o = L_A = \sqrt{W(D - W)}$ for $W < D/2$
or $L_o = L_A = D/2$ for $W \geqslant D/2$.
The MRR = Wdf_m where d = depth of cut.

FIGURE 20-6 Basics of milling processes (slab, face, and end milling) including equations for cutting time and metal removal rate (MRR).



Select cutting speed V, fpm and feed, f_r, in./rev. Select drill.
D = diameter of the drill which rotates 2 cutting edges at rpm N_s. V = velocity of outer edge of the lip of the drill.
$N_s = 12V/\pi D$. T_m = cutting time = $(L + A)/f_r N_s$ where f_r is the feed rate in in. per rev. The allowance $A = D/2$.
The MRR = $(\pi D^2/4) f_r N_s$ in.^{3} /min which is approximately $3DVf_r$.

FIGURE 20-7 Basics of the drilling (hole-making) processes, including equations for cutting time and metal removal rate (MRR).

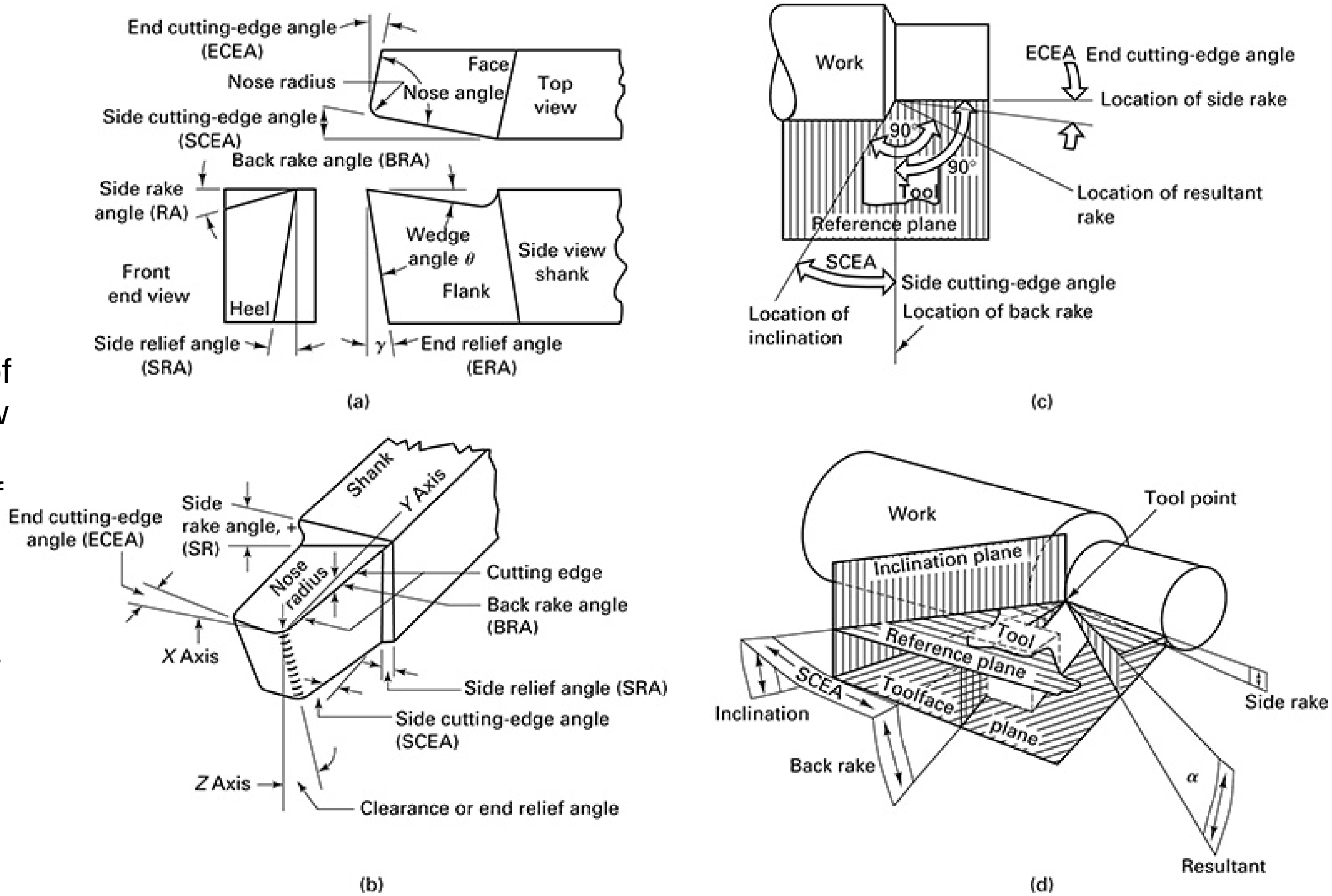


The T_m for broaching is $T_m = L/12V$. The MRR (per tooth) is $12tWV$ in.^{3}/min where V = cutting velocity in fpm, W is the width of cut, t = rise per tooth.

FIGURE 20-8 Process basics of broaching. Equations for cutting time and metal removal rate (MRR) are developed in Chapter 26

Tool Geometry Terminology

FIGURE 21-11 Standard terminology to describe the geometry of single-point tools: (a) three dimensional views of tool, (b) oblique view of tool from cutting edge, (c) top view of turning with single-point tool, (d) oblique view from shank end of single-point turning tool.



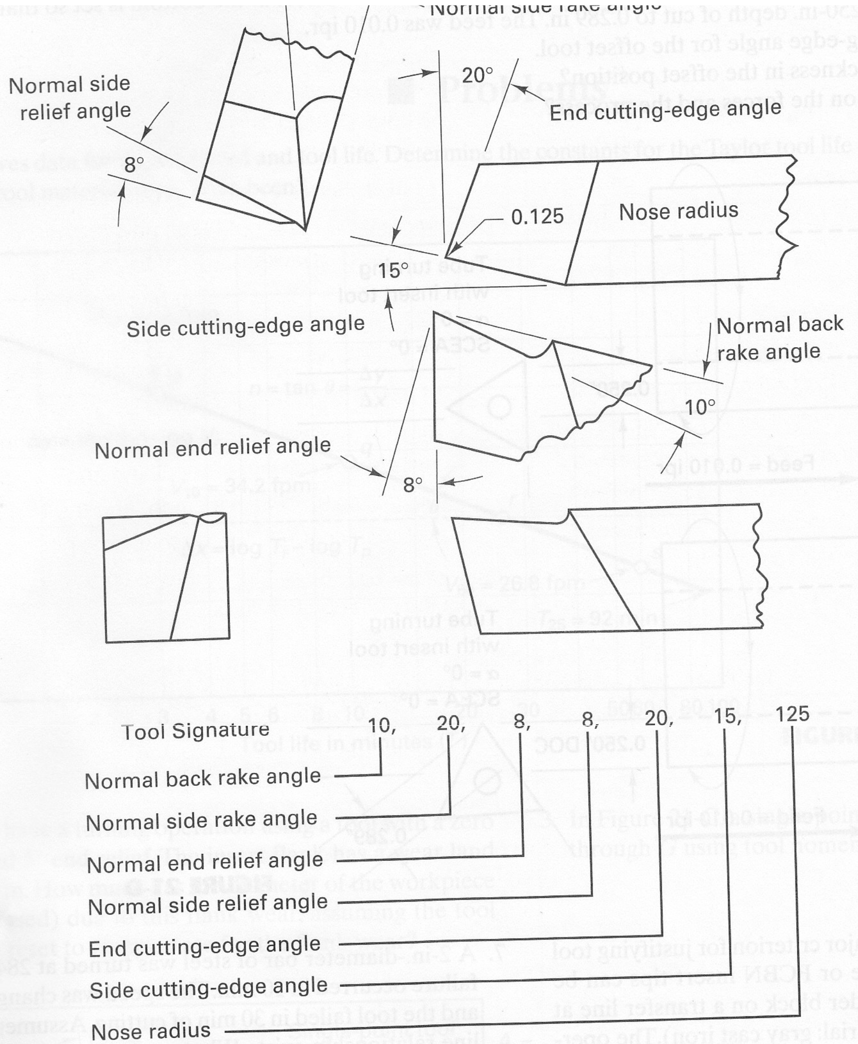
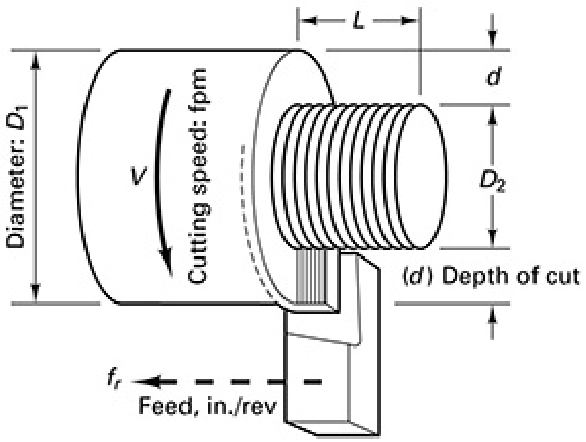

Normal side rake angle
Normal side
relief angle
8°
20°
End cutting-edge angle
0.125
Nose radius
15°
Side cutting-edge angle
Normal back
rake angle
10°
Normal end relief angle
8°
Tool Signature
10,
20,
8,
8,
20,
15,
125
Normal back rake angle
Normal side rake angle
Normal end relief angle
Normal side relief angle
End cutting-edge angle
Side cutting-edge angle
Nose radius

FIGURE 21-E

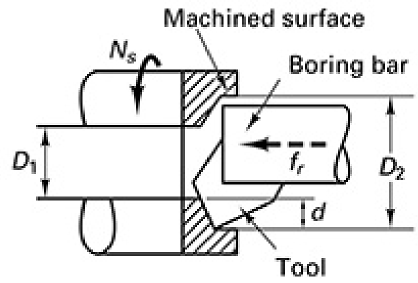


Turning

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.

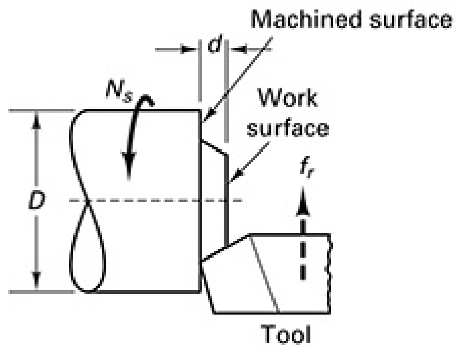
L = length of cut

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



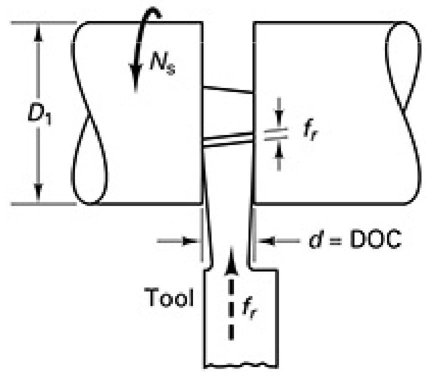
Boring

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

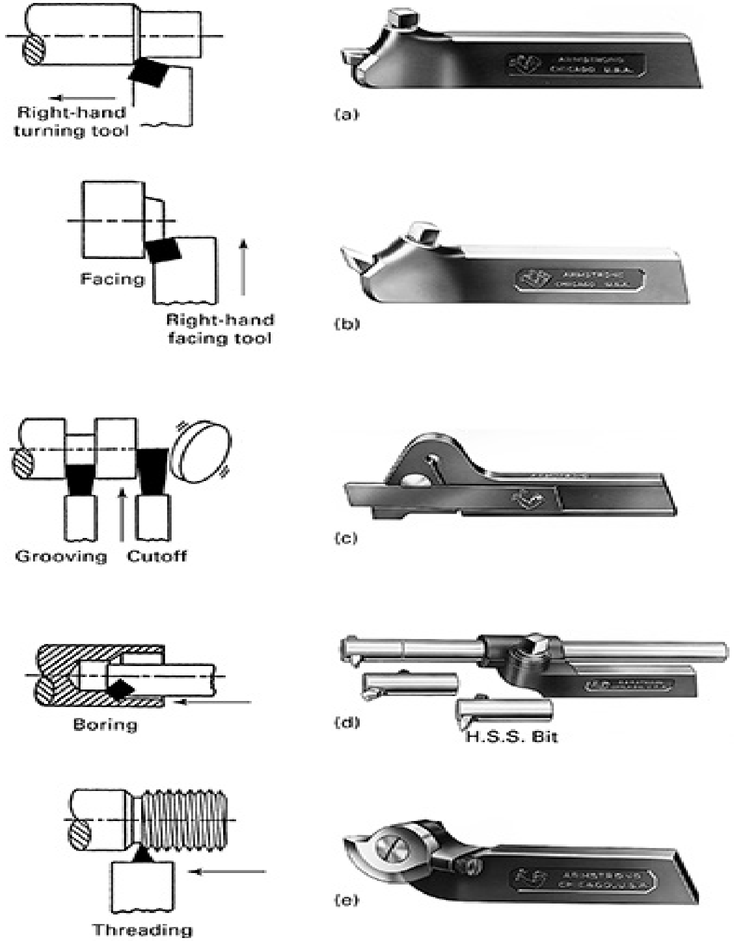
Tool feeds to center of workpiece so $L = D/2$. The cutting speed is decreasing as the tool approaches the center of the workpiece.

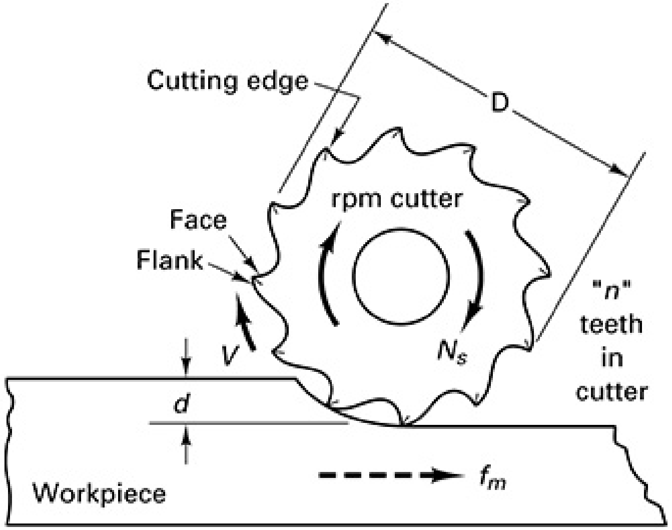


Grooving, parting, or cutoff

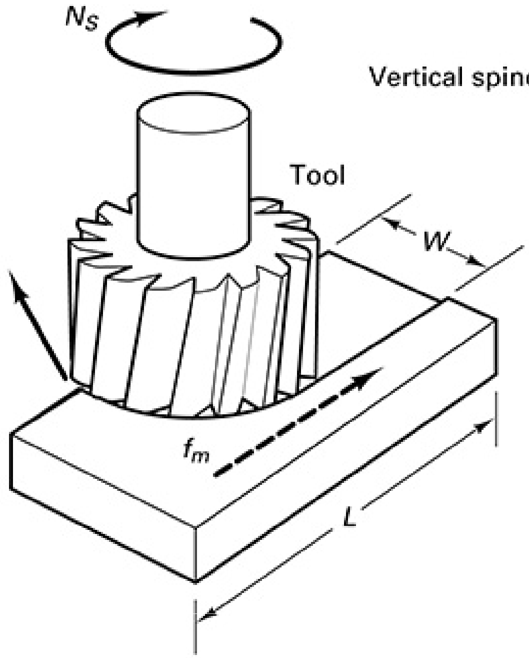
Tool feed perpendicular to the axis of rotation. The width of the tool produces the depth of cut (DOC).

TURNING TOOLS





Slab milling – multiple tooth



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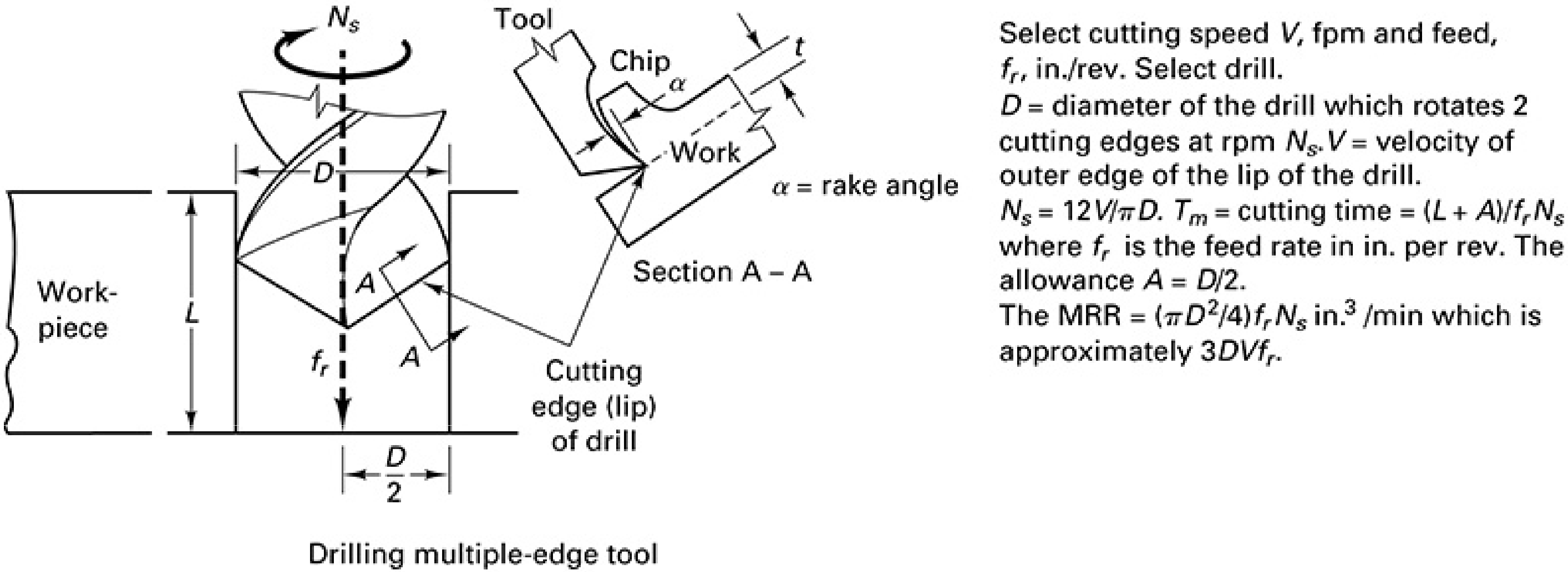
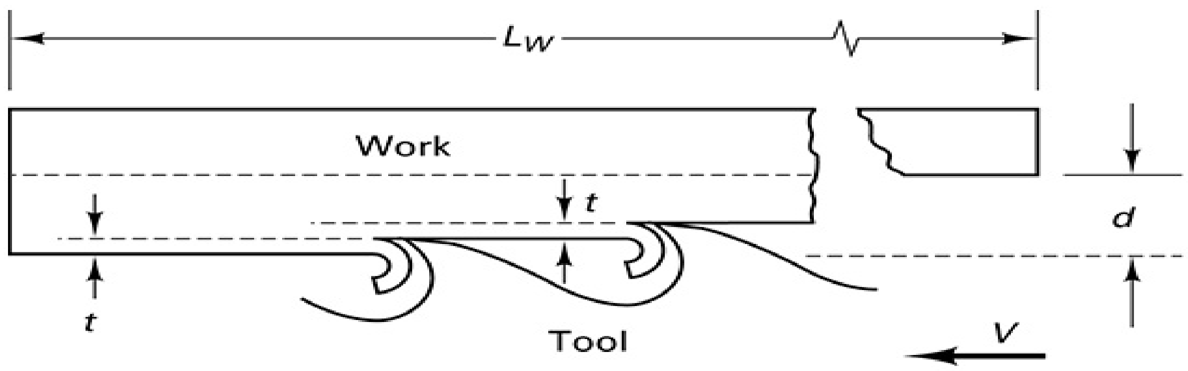


FIGURE 20-7 Basics of the drilling (hole-making) processes, including equations for cutting time and metal removal rate (MRR).



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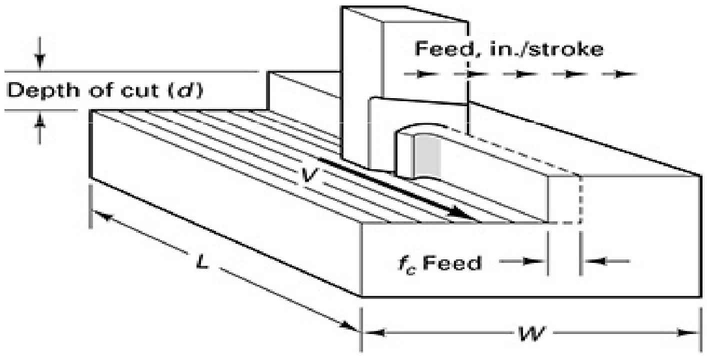
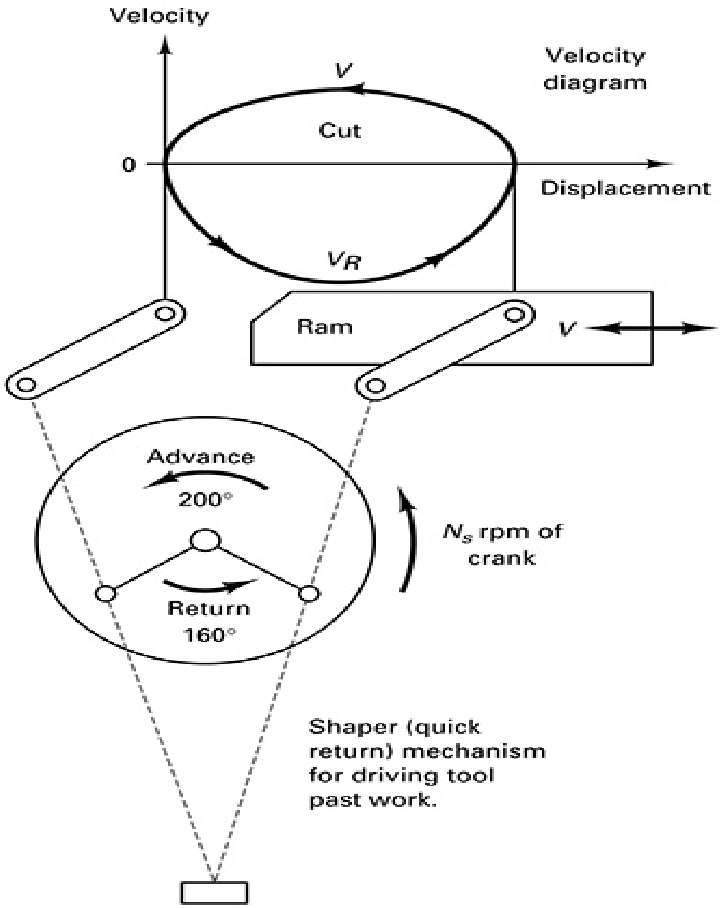


(a)

The tool cuts at velocity V with a return velocity of V_R dictated by the rpm of the crank, N_s. The cutting speed $V = (l + A)N_s/12R_s$ where R_s = stroke ratio = 200°/360° and the length of stroke is $l = L$ + ALLOW. The tool feed is f_c inches per stroke.

$T_m = W/N_s f_c$

MRR = $L d N_s f_c$ in^3/min



(b)