ME 355

NOTES ON MACHINING PROCESSES.

Ch. 16 (TEXT).

<u>MINIMUM</u> READING:

§ 16.1 (p. 617-645)

16.2-1 (p. 646)

16.3.1 (p. 652-653)

16.7.1, 16.7.2 { p. 684-690 }

16.7-5 (p. 694- 696)

<u>PLUS</u>: ANYTHING NEEDED TO DO HOMEWOR ASSIGNED.

Vipin Kumar

MACHINING PROCESSES

CASTING & FORMING INVOLVE MATERIAL FLOW - EITHER AS LIQUID OR AS SOLID. BOTH HAVE LIMITATIONS:

CASTING: MATERIAL PROPERTIES, DIMENSIONAL ACCURACY

FORMING: LARGE JOB → HUGE MACHINE
GEOMETRIC COMPLEXITIES

THESE PROBLEMS OVERCOME IN MACHINING WHERE EXCESS MATERIAL IS REMOVED IN THE FORM OF SMALL CHIPS

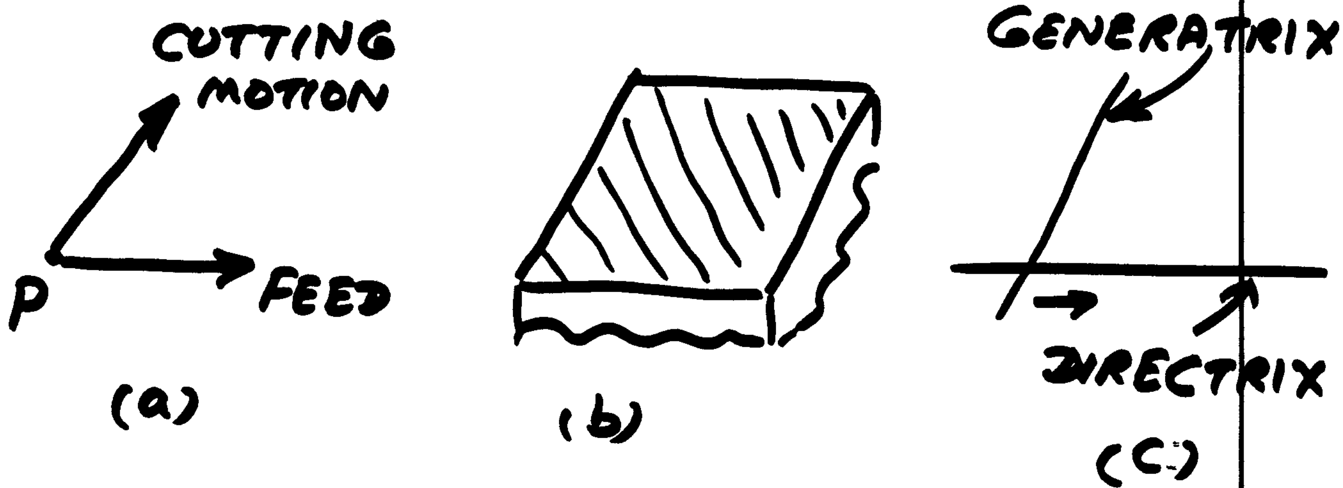
MACHINING TERMINOLOGY

CUTTING TOOL REMOVES MATERIAL

MACHINE TOOL PROVIDES RELATIVE MOTIONS

PRIMARY CUTTING MOTION

SECONDARY CUTTING MOTION (FEED)



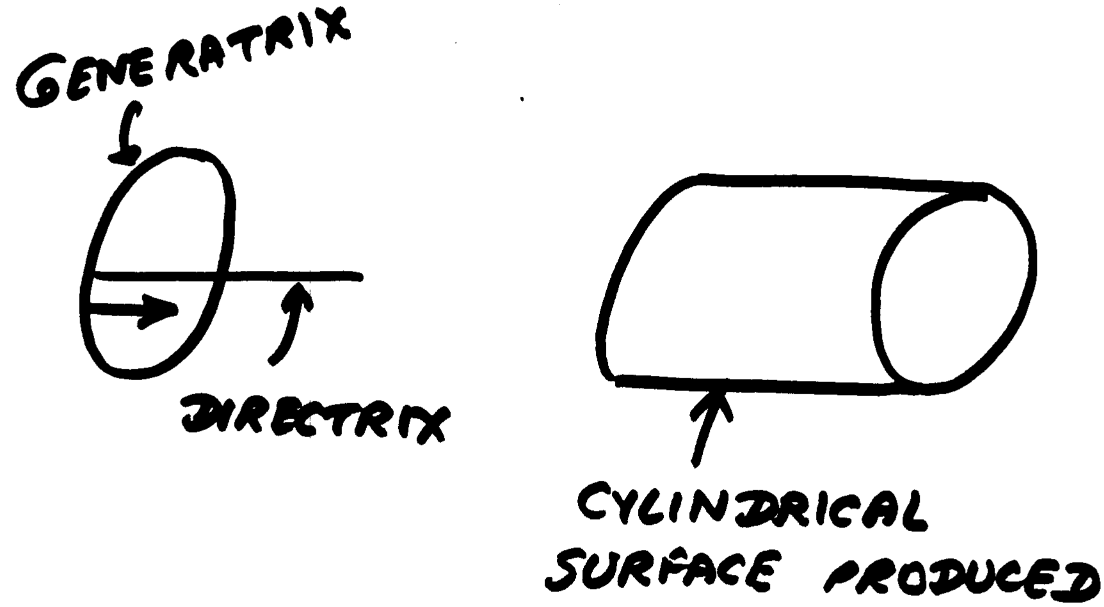
(a): MOTIONS OF THE CUTTING PT.

(b): SURFACE PRODUCED

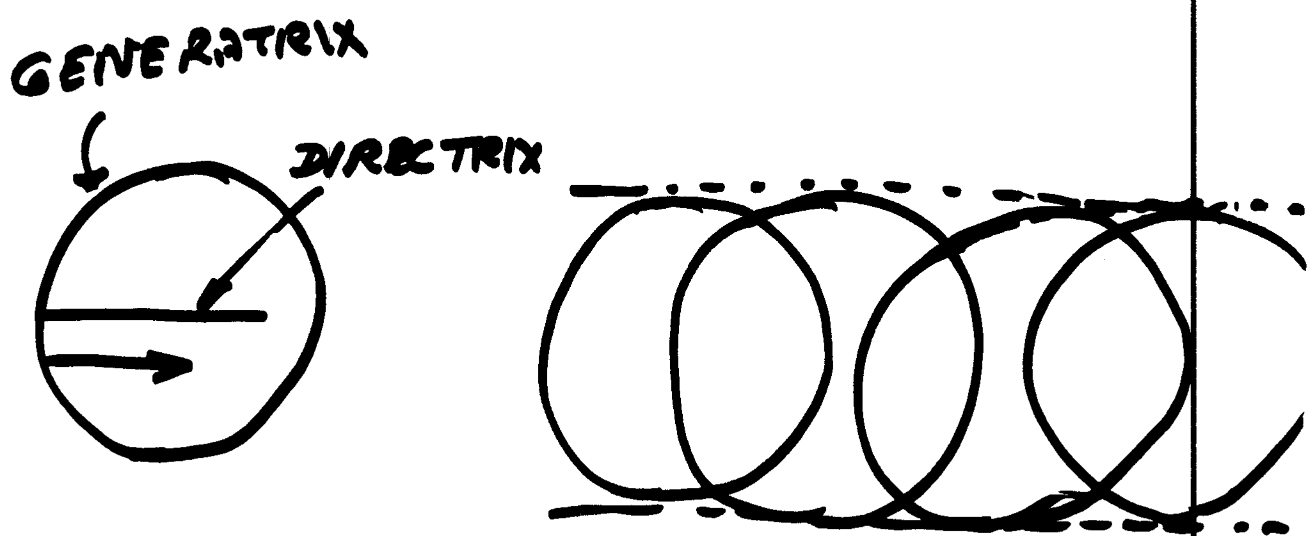
(c): GENERATRIX & DIRECTRIX

GENERATRIX ↓ LINE GENERATED BY CUTTING MOTION

DIRECTRIX ↓ BY FEED MOTION



DIRECTRIX ⊥ TO PLANE OF GENERATRIX



DIRECTRIX IN THE PLANE OF GENERATRIX

COMMON MACHINING PROCESSES

- SHAPING & PLANNING
- TURNING
- DRILLING
- MILLING
- GRINDING

COMMON MACHINING OPERATIONS

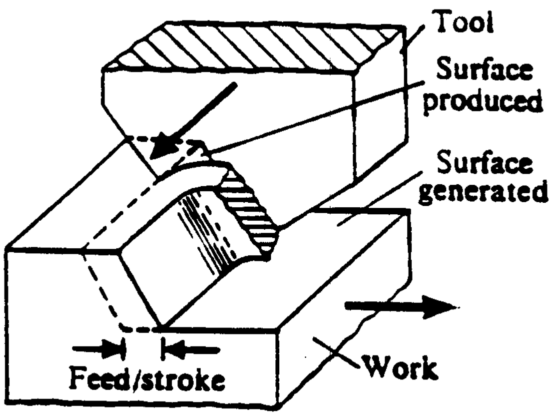


Fig. 4.3 Shaping operation.

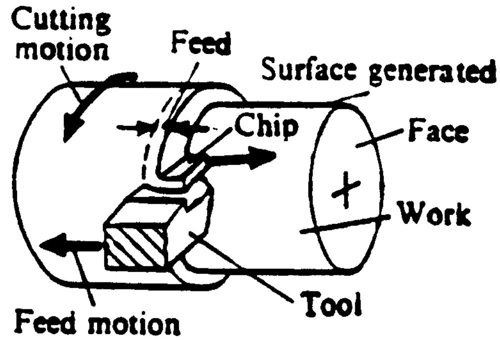


Fig. 4.4 Turning operation.

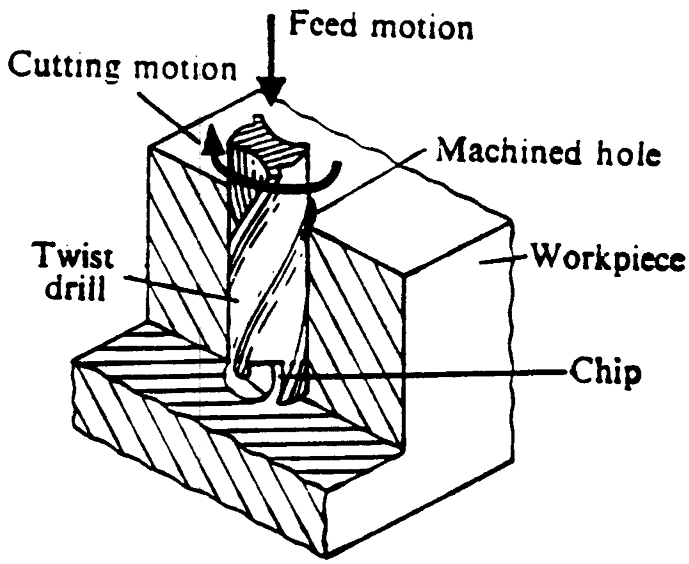
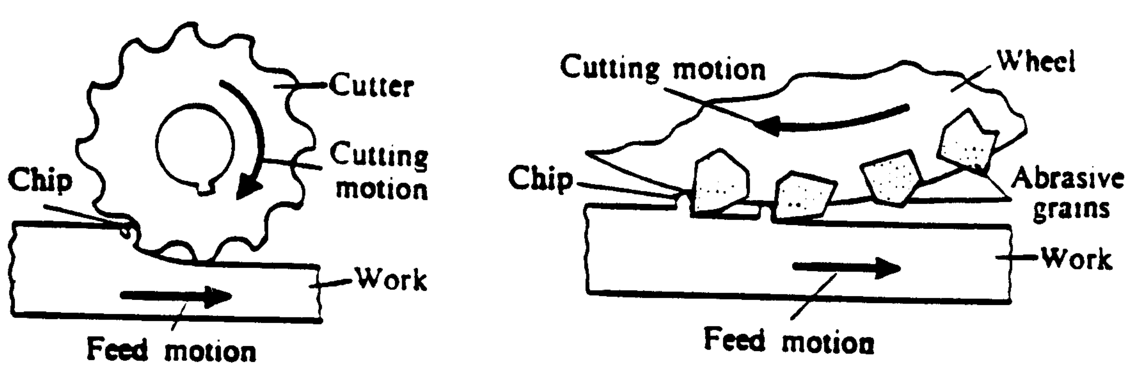


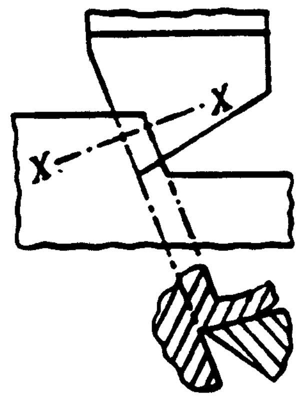
Fig. 4.5 Drilling operation.



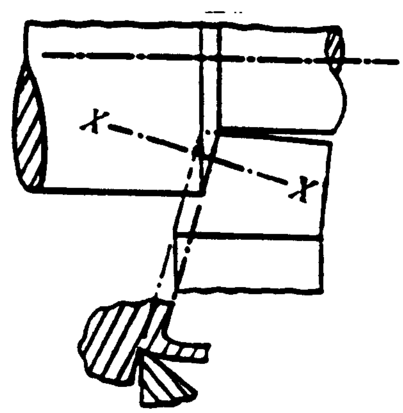
(a) Scheme of milling operation (b) Scheme of grinding operation

Fig. 4.6 Machining with multipoint tools.

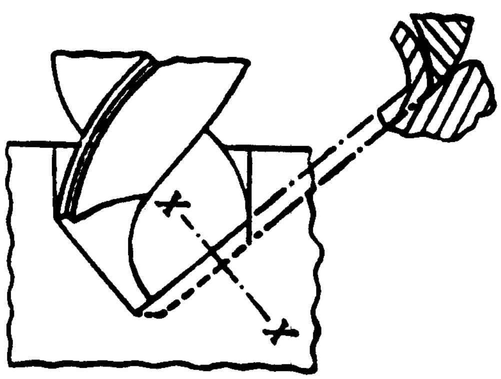
SIMILARITY IN THE MATERIAL REMOVAL PROCESSES



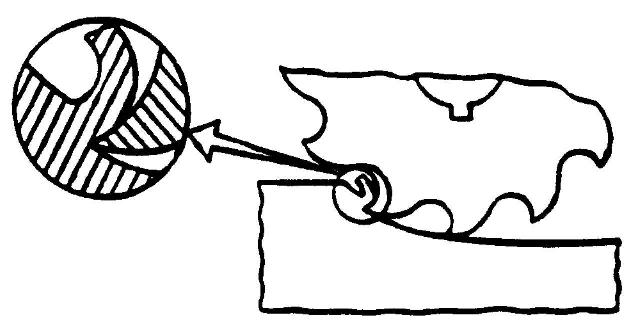
(a) Shaping



(b) Turning

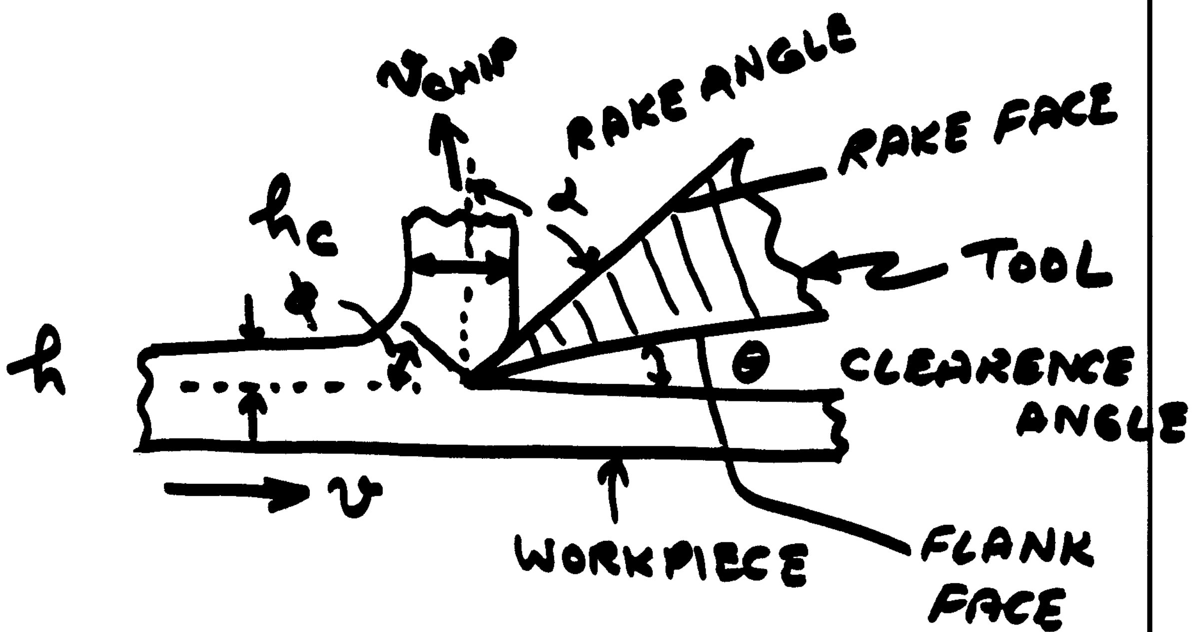


(c) Drilling



(d) Milling

Fig. 4.7 Simulation of actual machining processes.



h : UNCUT CHIP THICKNESS

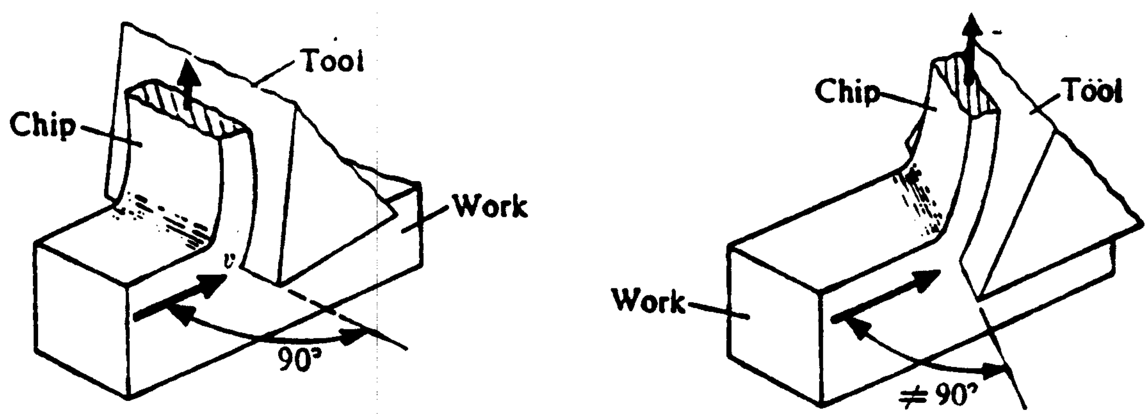
h_c : CHIP THICKNESS

BASIC OPERATION AND PARAMETERS.

VARIABLES

<u>INDEPENDENT</u>	<u>DEPENDENT</u>
TOOL MAT'L, α, θ	SHEAR ANGLE ϕ
TOOL GEOMETRY	CHIP FORMATION
WORKPC. MAT'L + GEOM.	& MORPHOLOGY
TEMP. OF WORKPC.	FORCES ; ENERGY
SPEED, FEED, etc.	WEAR
CUTTING FLUID	TEMP. RISE
MACHINE TOOL: POWER, STIFFNESS, etc.	SURFACE FINISH

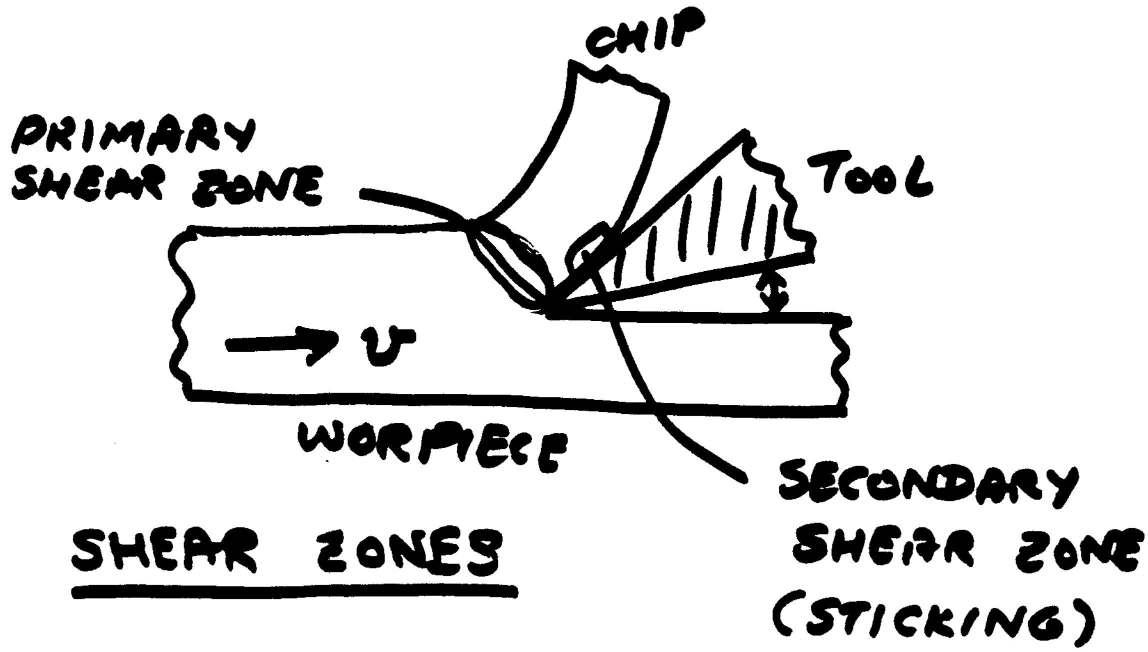
ORTHOGONAL VS OBLIQUE CUTTING OPERATIONS



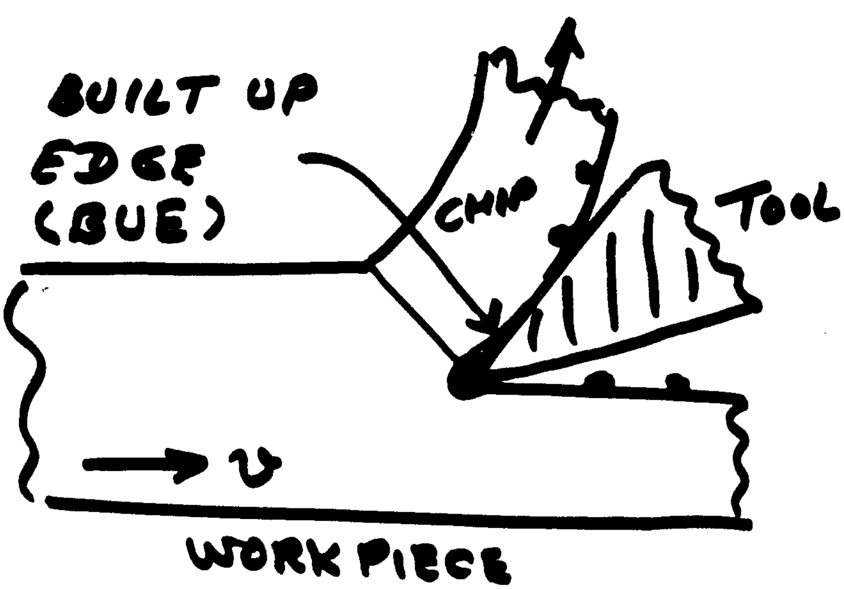
(a) Orthogonal (b) Oblique

Fig. 4.9 Types of machining operations.

MECHANISM OF CHIP FORMATION



SHEAR ZONES



BUE FORMATION

HIGH EFFECTIVE α : ENERY CONSUMPTION ↓

BUT DIMENSIONAL CONTROL & SURFACE FINISH LOST

CHIP FORMATION;

BUILT-UP-EDGE (BUE);

EFFECT OF CUTTING SPEED.

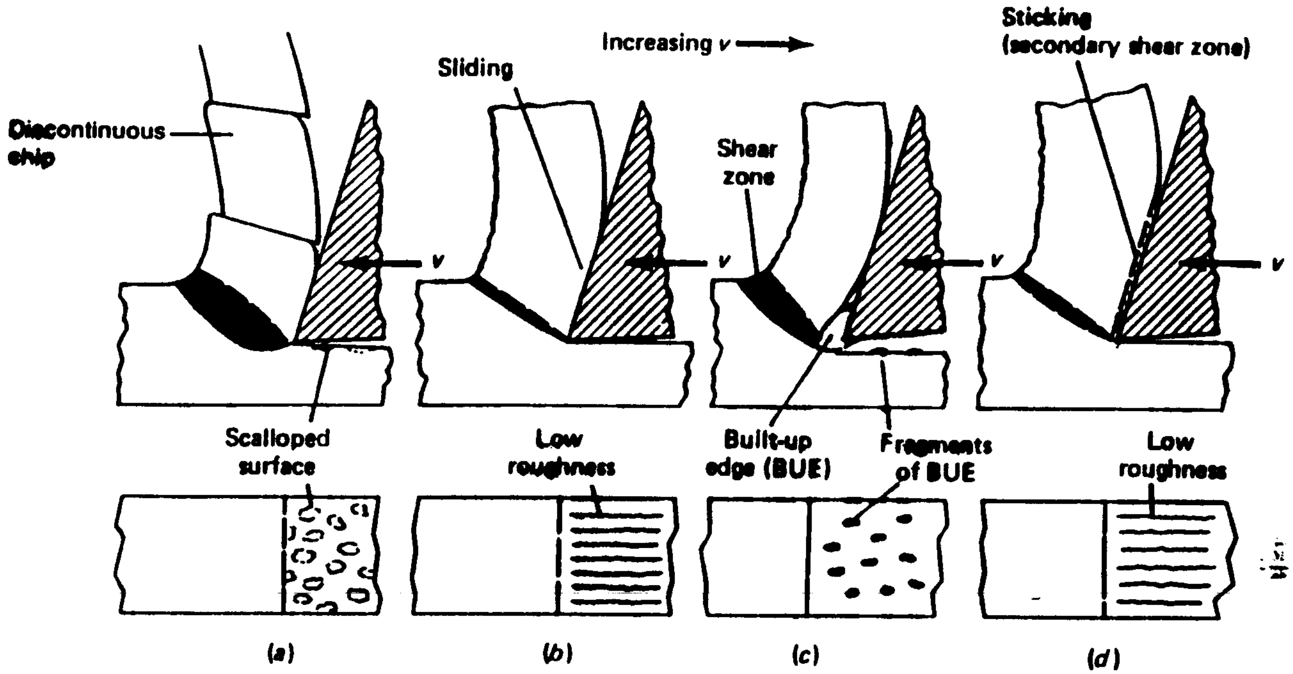


FIGURE 8-4 The process of chip formation changes with cutting speed. When cutting steel, the chip (*a*) is discontinuous at speeds below 2 m/min, (*b*) is continuous and slides on the rake face at 7 m/min, (*c*) forms with a built-up edge at 20 m/min, and (*d*) develops a secondary shear zone at 40 m/min. (*After M. C. Shaw, in Machinability, Spec. Rep. 94, The Iron and Steel Institute, London, 1967, pp. 1–9.*)

VARIOUS KINDS OF CHIPS

1. CONTINUOUS WITHOUT BUE

   DUCTILE MATERIAL

   SMALL UNCUT THICKNESS

   HIGH CUTTING SPEED

   SUITABLE CUTTING FLUID

2. CONTINUOUS WITH BUE

   STRONG ADHESION BETWEEN CHIPS & TOOL FACE

   LOW RAKE ANGLE

   LARGE UNCUT THICKNESS

3. DISCONTINUOUS CHIPS

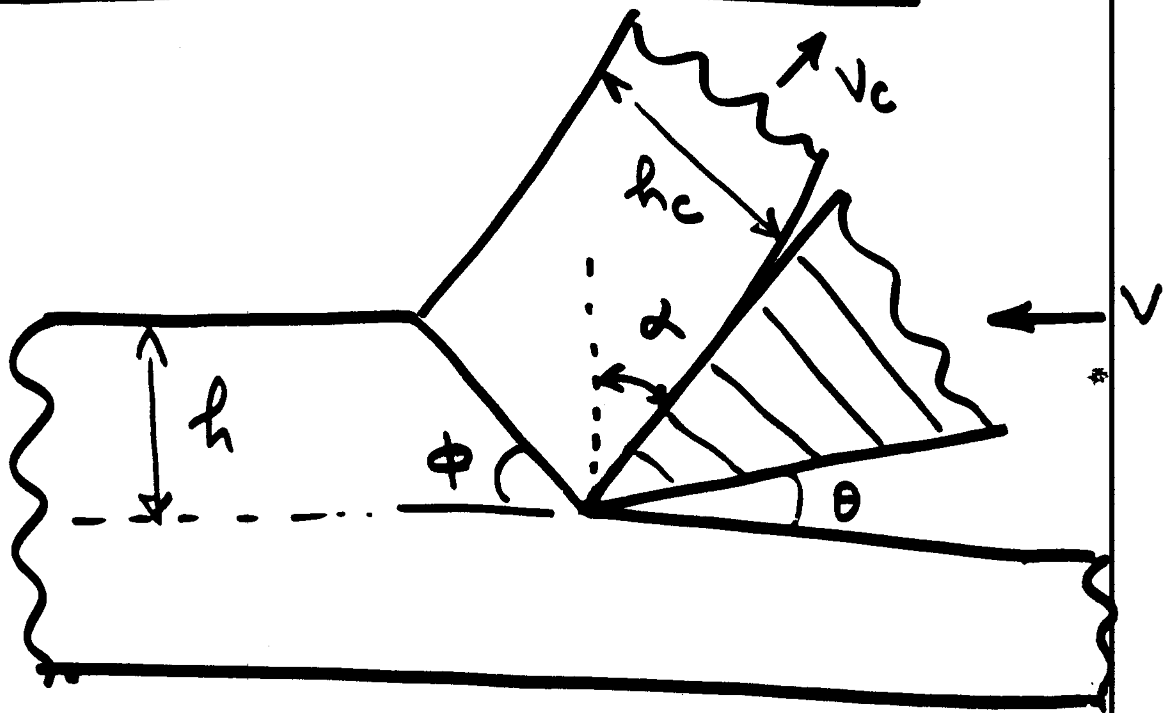
   LOW CUTTING SPEED

   BRITTLE WORK MATERIAL

   SMALL RAKE ANGLE

   LARGE UNCUT THICKNESS

ORTHOGONAL CUTTING



h = uncut chip thickness

h_c = chip thickness

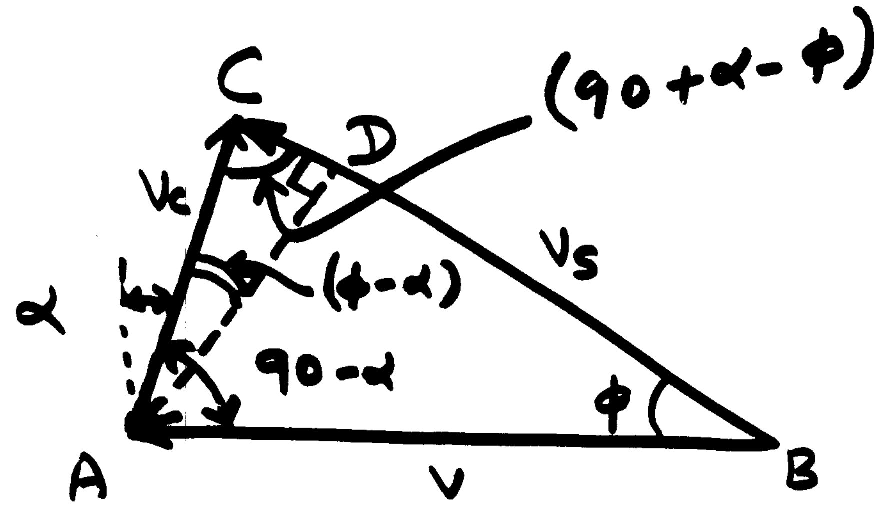
V_c = chip speed

V = cutting speed

ϕ = shear angle

α = rake angle

θ = clearance angle



from △ ACB

$$\phi + (90-\alpha) + \angle ACB = 180^\circ$$

$$\therefore \angle ACB = 180 - (90-\alpha) - \phi$$

$$= 90 + \alpha - \phi$$

from △ ACD

$$\angle DAC = 90 - (90 + \alpha - \phi)$$

$$= (\phi - \alpha)$$

Now from ΔABC

(using $\frac{\sin A}{A} = \frac{\sin B}{B} = \frac{\sin C}{C}$

↑ length of side opposite to angle A)

$$\frac{V_c}{\sin\phi} = \frac{V}{\sin(90+\alpha-\phi)} = \frac{V_s}{\sin(90-\alpha)}$$

Cutting ratio

$$r_c = \frac{h}{h_c} = \frac{l_c}{l} = \frac{v_c}{V}$$

$$r_c = \frac{V_c}{V} = \frac{\sin\phi}{\sin(90-(\phi-\alpha))}$$

or $$r_c = \frac{\sin\phi}{\cos(\phi-\alpha)} \quad \text{(Eq. ~~16.3~~ 16.3)}$$

NOTE, as $\Phi\uparrow$, $r_c\uparrow$ Thus $h_c\downarrow$ and $V_c\uparrow$

⇒ CHIP BECOMES THINNER AND COMES OFF FASTER

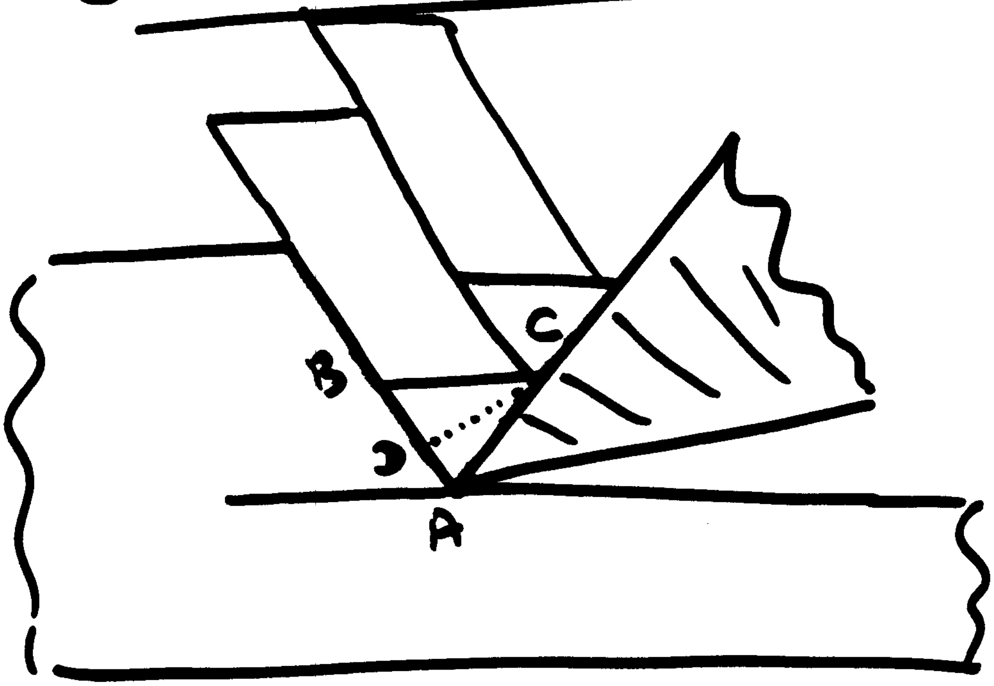
$$r_c = \frac{\sin\phi}{\cos\phi\cos\alpha + \sin\phi\sin\alpha}$$

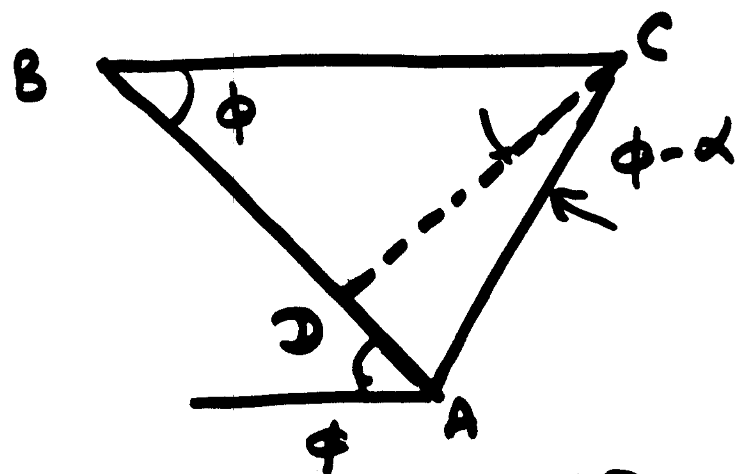
or, $\sin\phi = r_c\cos\phi\cos\alpha + r_c\sin\phi\sin\alpha$

or, $\sin\phi(1 - r_c\sin\alpha) = r_c\cos\phi\cos\alpha$

or, $$\tan\phi = \frac{r_c\cos\alpha}{1 - r_c\sin\alpha} \quad \text{(Eq. 16.2)}$$

Shear Strain





$$\gamma = \frac{AB}{CD} = \frac{AD}{CD} + \frac{BD}{CD} = \tan(\phi - \alpha) + \cot\phi$$

Shear rate

$$\dot{\gamma} = \frac{V_s}{\Delta y} = \frac{V_s}{V}\,\frac{V}{\Delta y}$$

where Δy = thickness of shear zone ($\simeq .001$ in.)

$$\dot{\gamma} = \left(\frac{\sin(90-\alpha)}{\sin(90-(\phi-\alpha))}\right)\cdot\frac{V}{\Delta y}$$

or $$\dot{\gamma} = \frac{\cos\alpha}{\cos(\phi-\alpha)}\cdot\frac{V}{\Delta y} \quad \text{(Eq. ~~8.5~~ 16.5)}$$

$\dot{\gamma}$ CAN EASILY BE $10^3 - 10^4$/sec.

FORCES IN orthogonal cutting

P_c : Cutting force } on tool holder (measured)
P_t : Thrust force }

P_n : Normal force } on tool
F : Frictional force }

{ P_h : Hydrostatic (Compressive) force
{ F_s : Shearing force
on workpiece.

$$P_n = P_c \cos\alpha - P_t \sin\alpha$$

$$F = P_c \sin\alpha + P_t \cos\alpha$$

Friction angle ψ

$$\tan\psi = \mu = \frac{F}{P_n}$$

$$\tan\psi = \frac{P_t + P_c \tan\alpha}{P_c - P_t \tan\alpha}$$

ϕ depends on the process itself.

For minimum energy

$$\phi = 45^\circ - \frac{1}{2}(\psi - \alpha)$$

Thus if $\psi \uparrow$ or $\alpha \downarrow \Rightarrow \phi \downarrow$

$\Rightarrow$ larger energy consumption.

$\therefore$ for min. energy, use high α and low ψ.

Forces and Energy

Experimental material constants

Specific cutting pressure

1. $p_c = \frac{P_c}{hw}$ $\left[\frac{N}{m^2}\right]$ (not a true stress)

hw = cross section of undeformed chip

2. Specific cutting energy (See Table 16-1)

$$E_1 = \frac{P_c \cdot l}{h w \cdot l} \left[\frac{J}{m^3}\right] \text{ or } \left[\frac{N}{m^2}\right]$$

= Energy required to remove a unit vol.

(l = length of uncut chip)

3. Material removal factor

$$K_1 = \frac{1}{E_1} = \left[\frac{m^3}{J}\right]$$ material removed per unit power.

Adjusted Specific Cutting Energy

$$E = E_1 \left(\frac{h}{h_{ref}} \right)^{-a}$$

$$h_{ref} = 1\,mm$$

$$E = E_1 h^{-a}$$

$$a \simeq 0.2 \text{ to } 0.4$$

(Take $a = 0.3$ for MOST MATERIALS.)

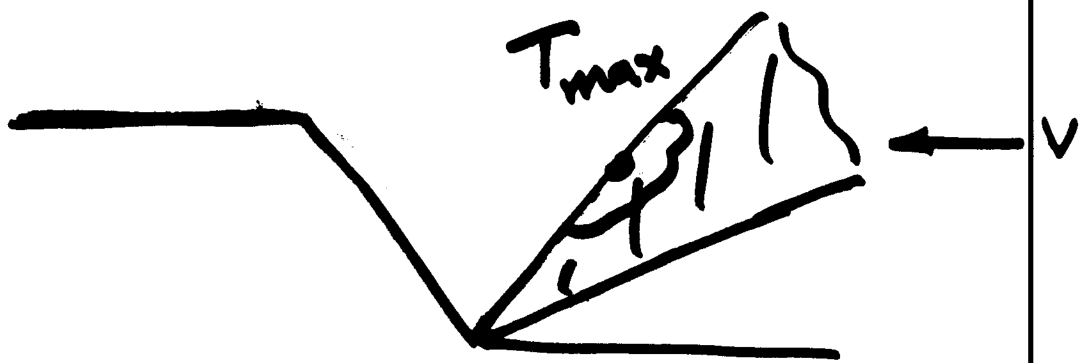
$$\text{Power req'd} = \frac{E V_t}{\eta}$$

where V_t = material removal rate.

$$\text{Cutting force} \quad P_c = \frac{\text{Power}}{V}$$

TOOL TEMPERATURES

(depend on V)



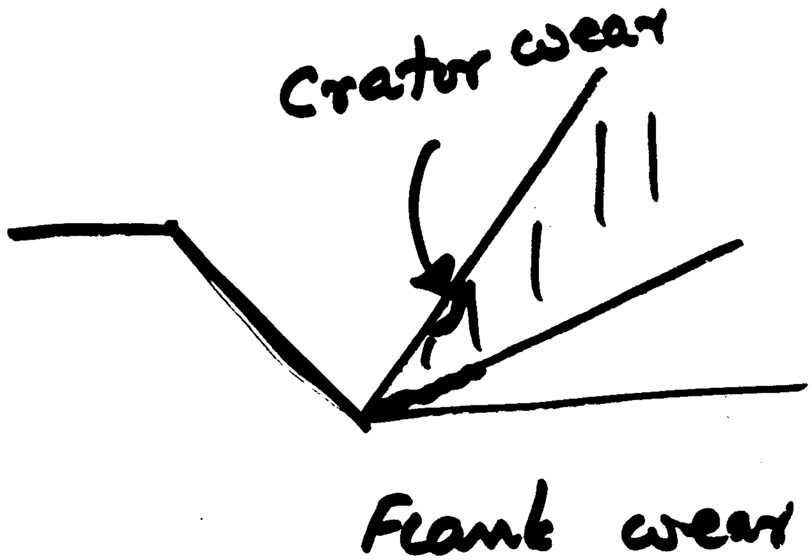
Mean tool face temp. T_T

$$T_T = E\left(\frac{vh}{k\rho c}\right)^{1/2}$$

k = heat conductivity
ρ = density
c = Specific heat

} workpc. mat'l

TOOL LIFE



Taylor

$$V t^{n} = C \qquad t = \left(\frac{C}{V}\right)^{1/n}$$

V = Cutting speed

t = tool life

C = Cutting speed for life of 1 min.

Refinement :

$$t = \frac{K}{v^{1/n_1} \, f^{1/n_2} \, W^{1/n_3}}$$

f : feed rate

W = depth of cut