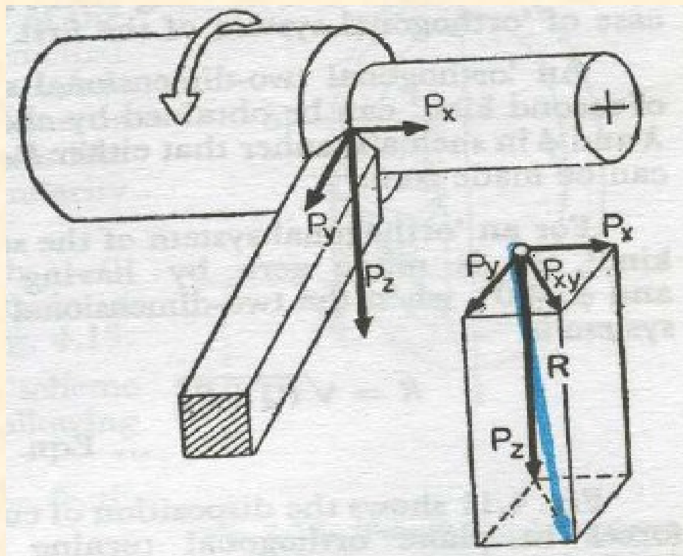
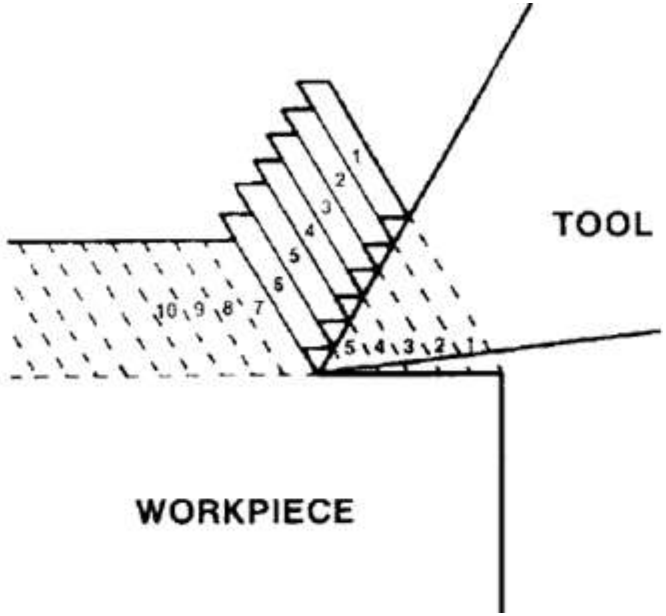
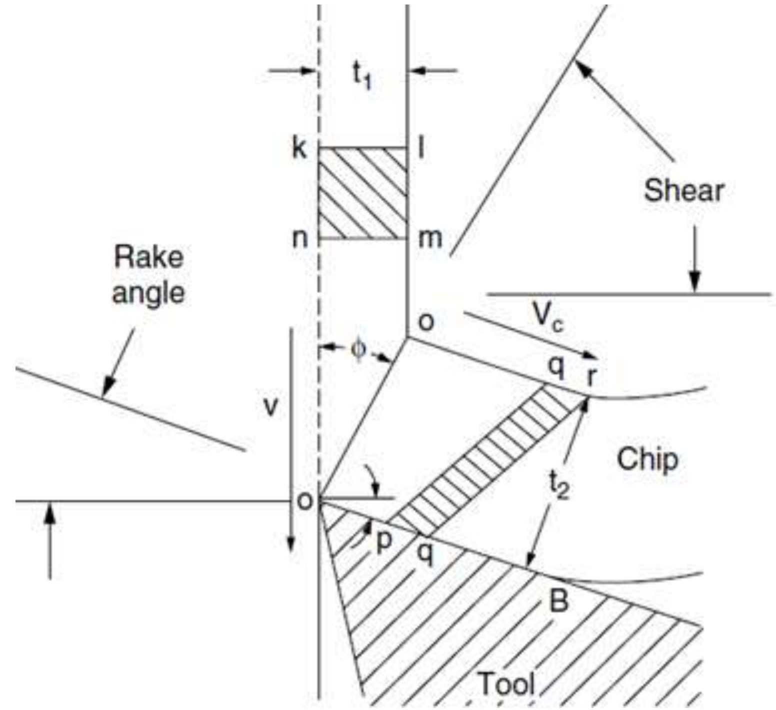
MECHANICS OF METAL CUTTING



Mechanics of Metal Cutting



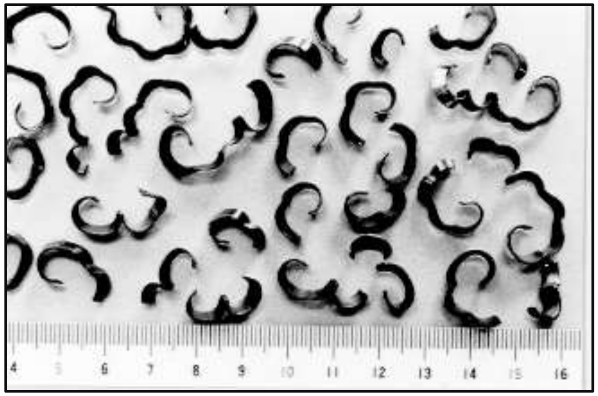


- Plastic Deformation
- The outer surface is usually smooth due to the burnishing effect of the tool
- Shear Plane
- The angle formed by the shear plane and the direction of the tool travel is called the *shear angle*

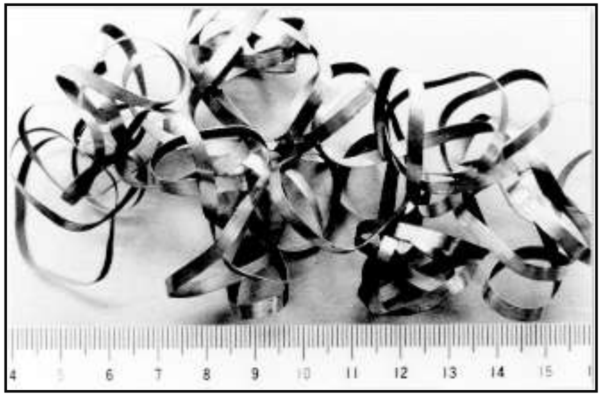
Mechanics of Metal Cutting

The type of chip produced depends upon workpiece material, tool geometry, and operating conditions.

- *Discontinuous chips*
  - Individual segments
  - Fracture of the metal
  - Brittle materials (cast irons)
  - No plastic deformation



- *Continuous chips*
  - Machining ductile materials like steel and Al
  - Continuous deformation without fracture
  - Chip breakers are required
  - Tool wear increases with sliding



Mechanics of Metal Cutting

- Compressive deformation will cause it to be thicker and shorter than the layer of workpiece material removed
- The work required to deform this material usually accounts for the largest portion of forces and power involved in a metal removal operation
- The ratio of chip thickness, to the un-deformed chip thickness (effective feed rate) is called the *chip thickness ratio. The* lower the chip thickness ratio, the lower the force and heat, and the higher the efficiency of the operation

$$\frac{t_2}{t_1} = \frac{\cos(\phi - \sigma)}{\sin\phi}$$

where t_1 = undeformed chip thickness
t_2 = chip thickness after cutting
θ = shear angle
σ = true rake angle

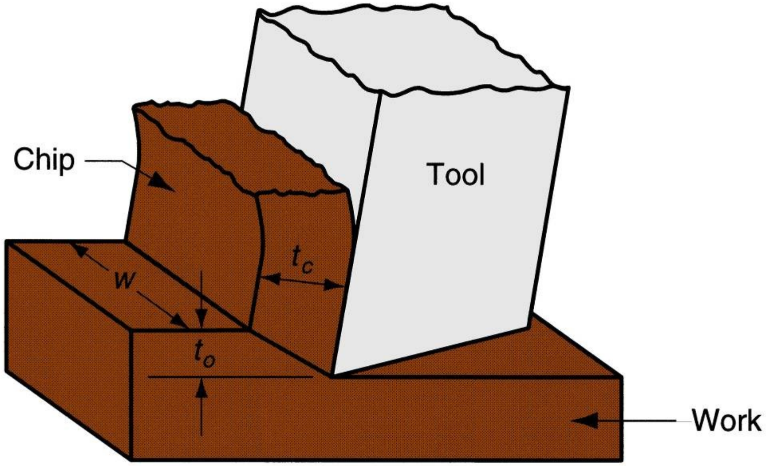
Chip Thickness Ratio

$$r = \frac{t_o}{t_c}$$

where r = *chip thickness ratio*; t_o = thickness of the chip prior to chip formation; and t_c = chip thickness after separation

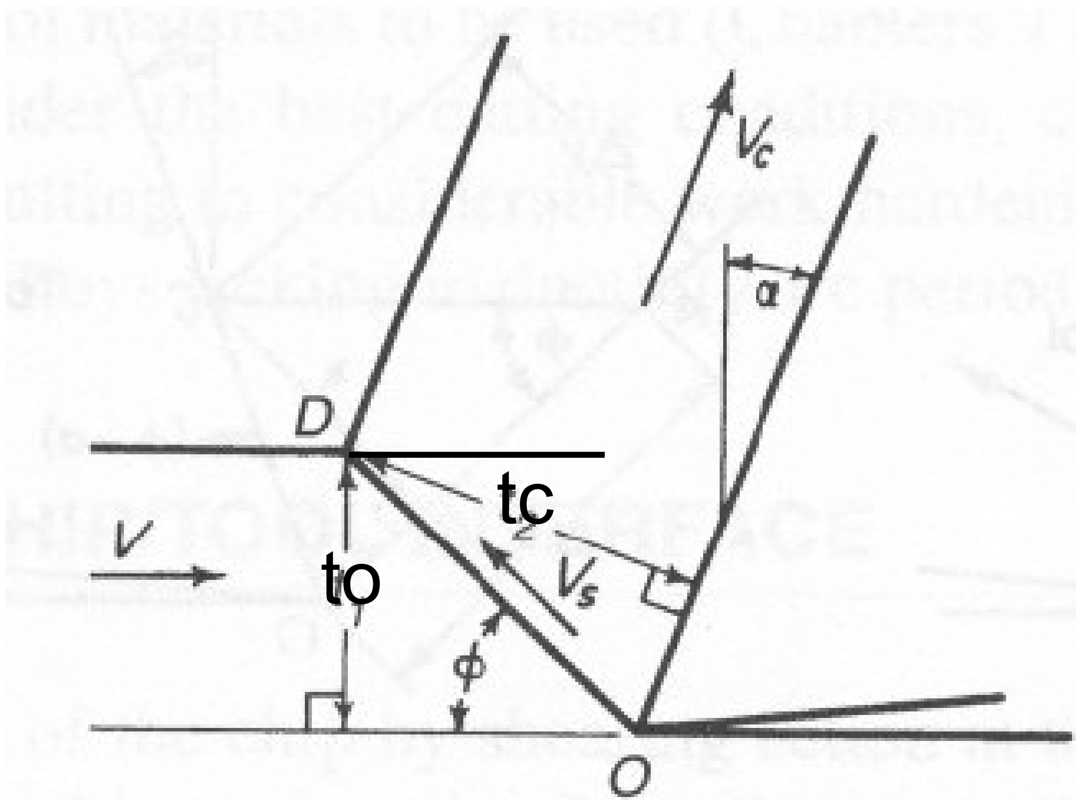
- Chip thickness after cut is always greater than before, so chip ratio always

an 1.0



(a)

Determining Shear Plane Angle



Determining Shear Plane Angle

- Based on the geometric parameters of the orthogonal model, the shear plane angle ϕ can be determined as:

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

where r = chip ratio, and α = rake angle

Shear Strain in Chip Formation

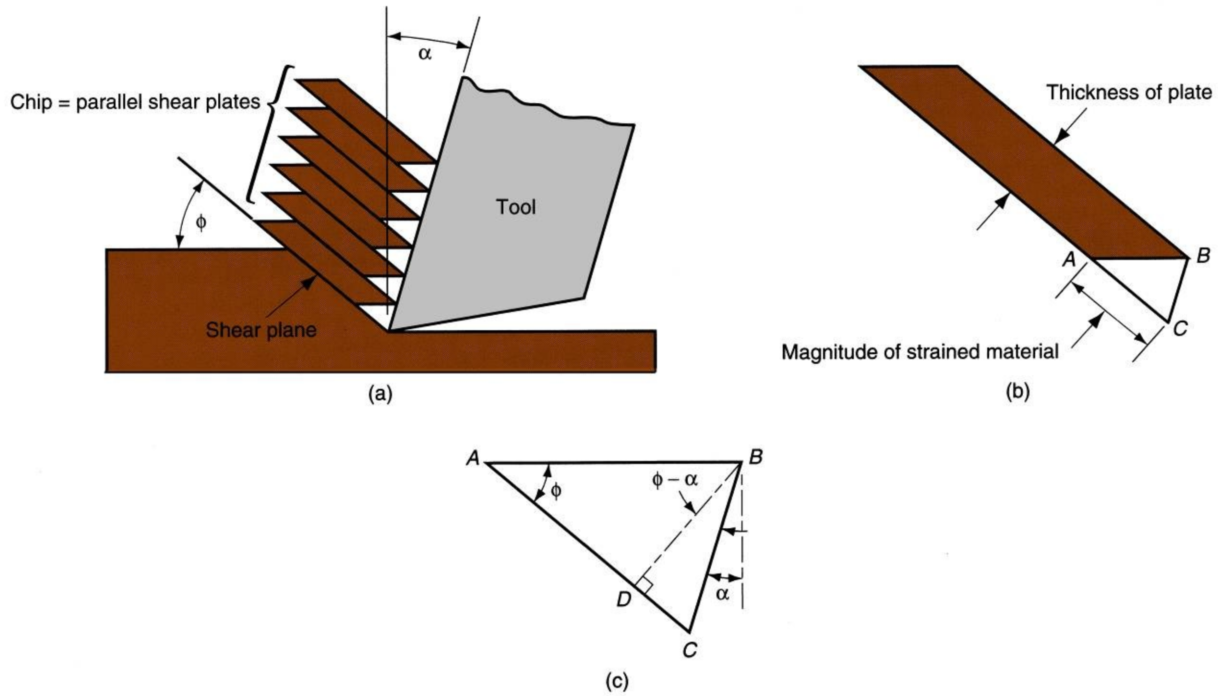


Figure 21.7 Shear strain during chip formation: (a) chip formation depicted as a series of parallel plates sliding relative to each other, (b) one of the plates isolated to show shear strain, and (c) shear strain triangle used to derive strain equation.

Shear Strain

Shear strain in machining can be computed from the following equation, based on the preceding parallel plate model:

$$\gamma = \tan(\phi - \alpha) + \cot \phi$$

where γ = shear strain, ϕ = shear plane angle, and α = rake angle of cutting tool

Mechanics of Metal Cutting –Power Consumption

- Method based on the MRR

$$Q = 12 \times V_t \times F_r \times d$$

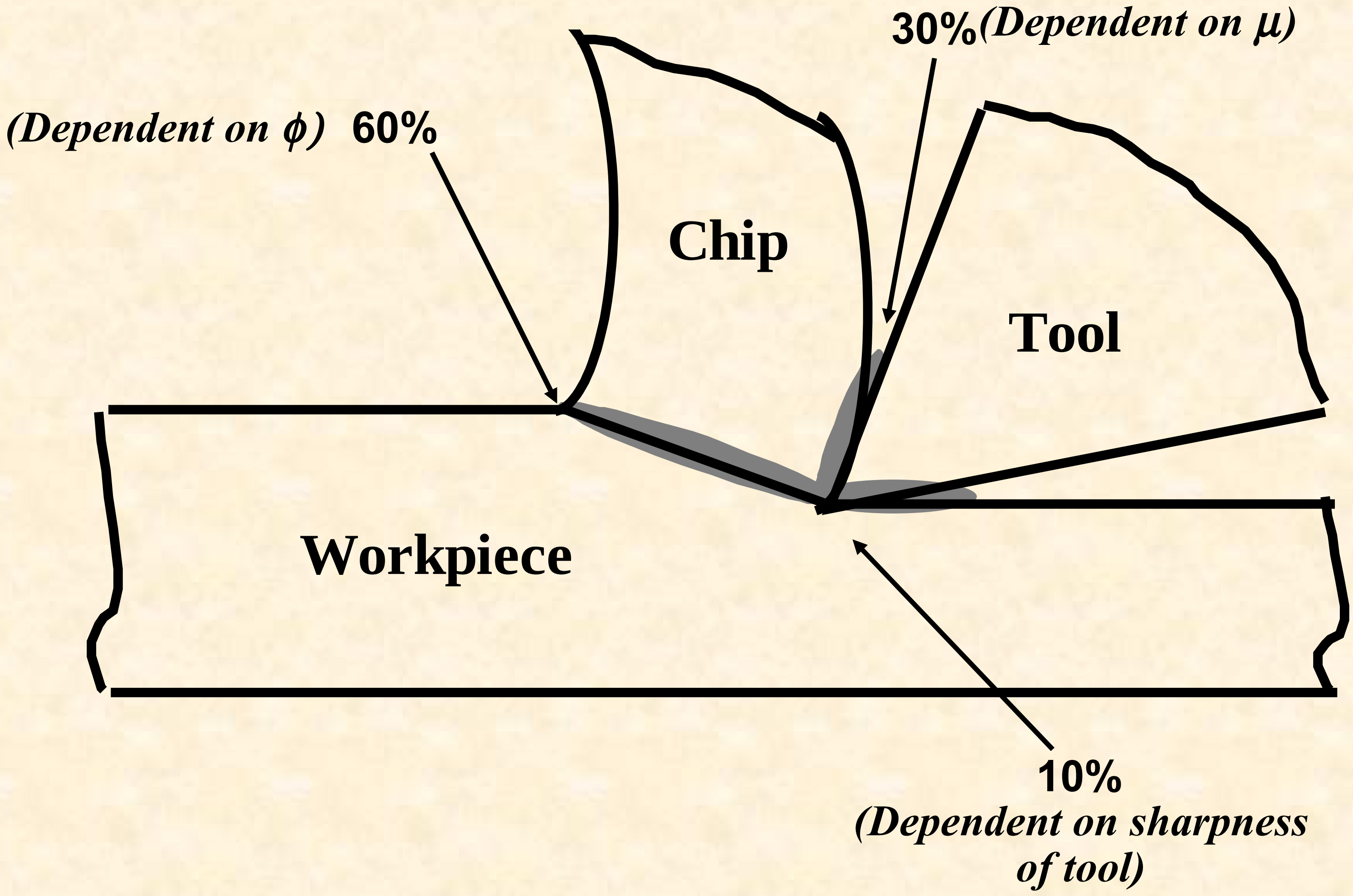
where Q = metal removal rate (cubic inches per minute)
V_t = cutting speed (surface feet per minute)
F_r = feed rate (inches per revolution)
D = depth of cut (inches)

- Unit Horse Power

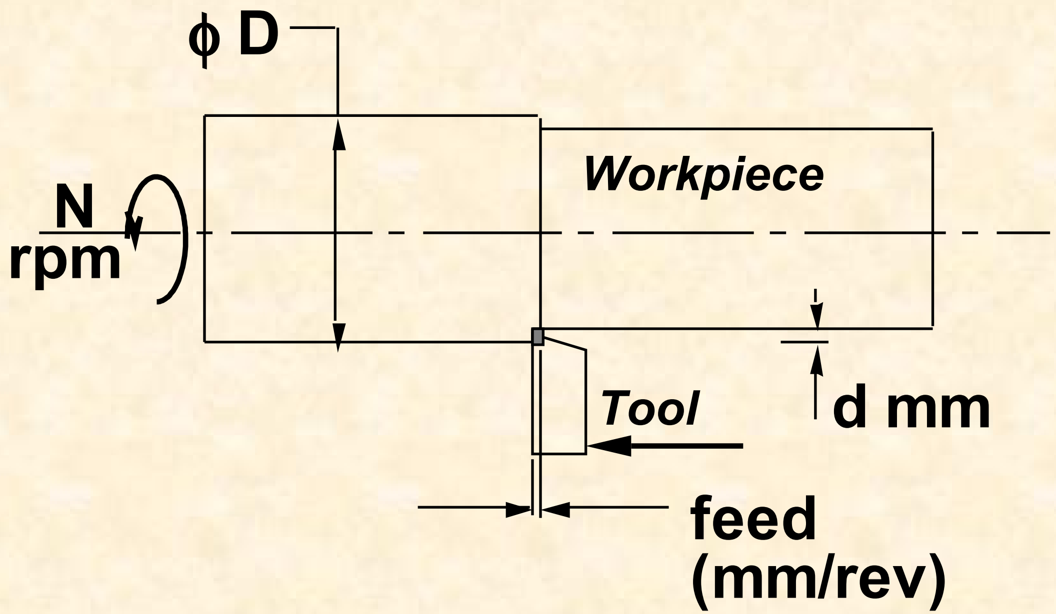
The unit horsepower factor (P) is the approximate power required at the spindle to remove 1 in3/min of a certain material.

Nonferrous metals and alloys	
Brass	P
Hard	83
Medium	50
Soft	33
Free machining	25
Bronze	
Hard	83
Medium	50
Soft	33
Copper	
Pure	90
Aluminum	
Cast	25
Hard (rolled)	33
Monel	
Rolled	1
Zinc alloy	
Die cast	25

Heat Generation Zones



'Turning' Terminology

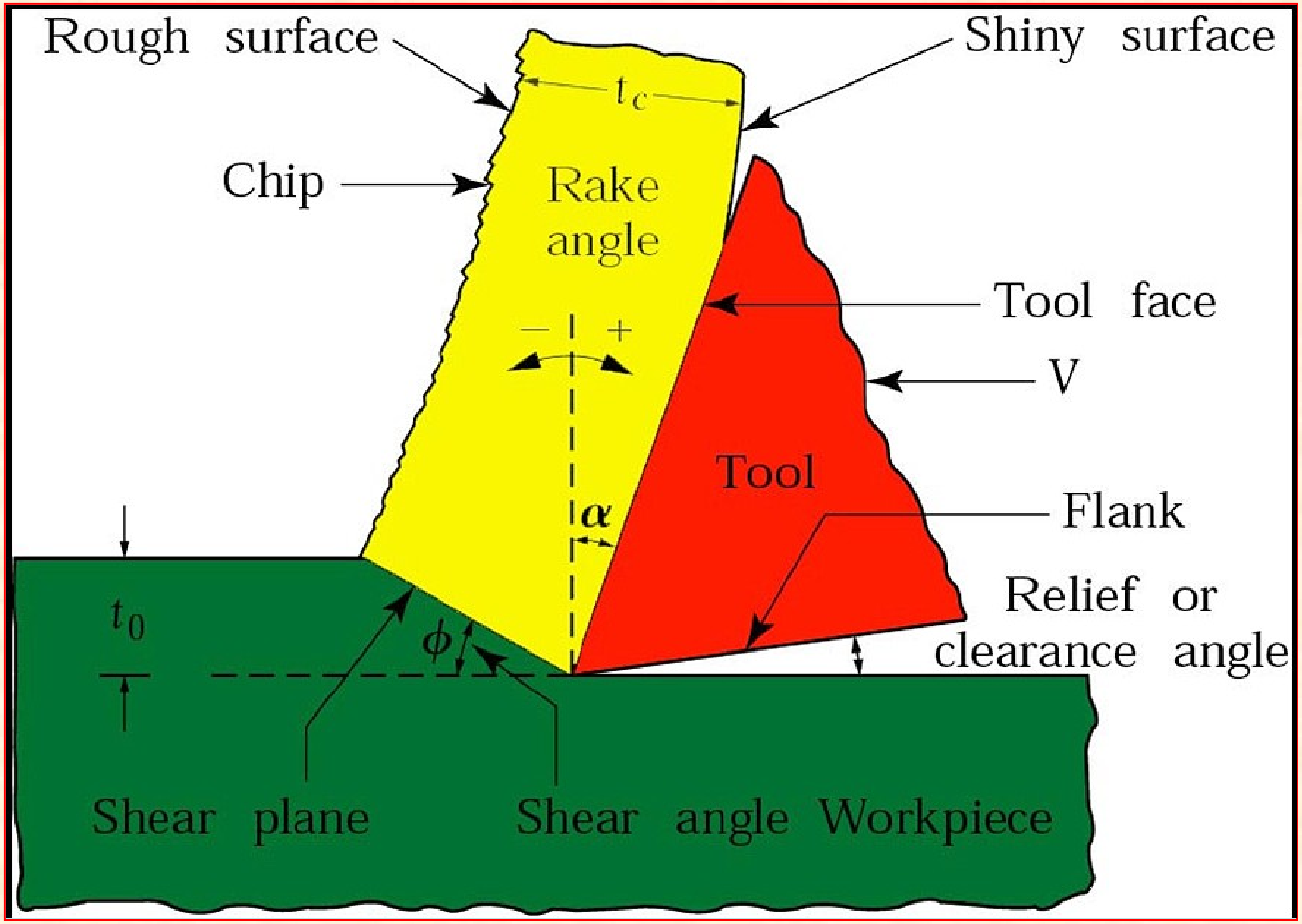


Standard Terms

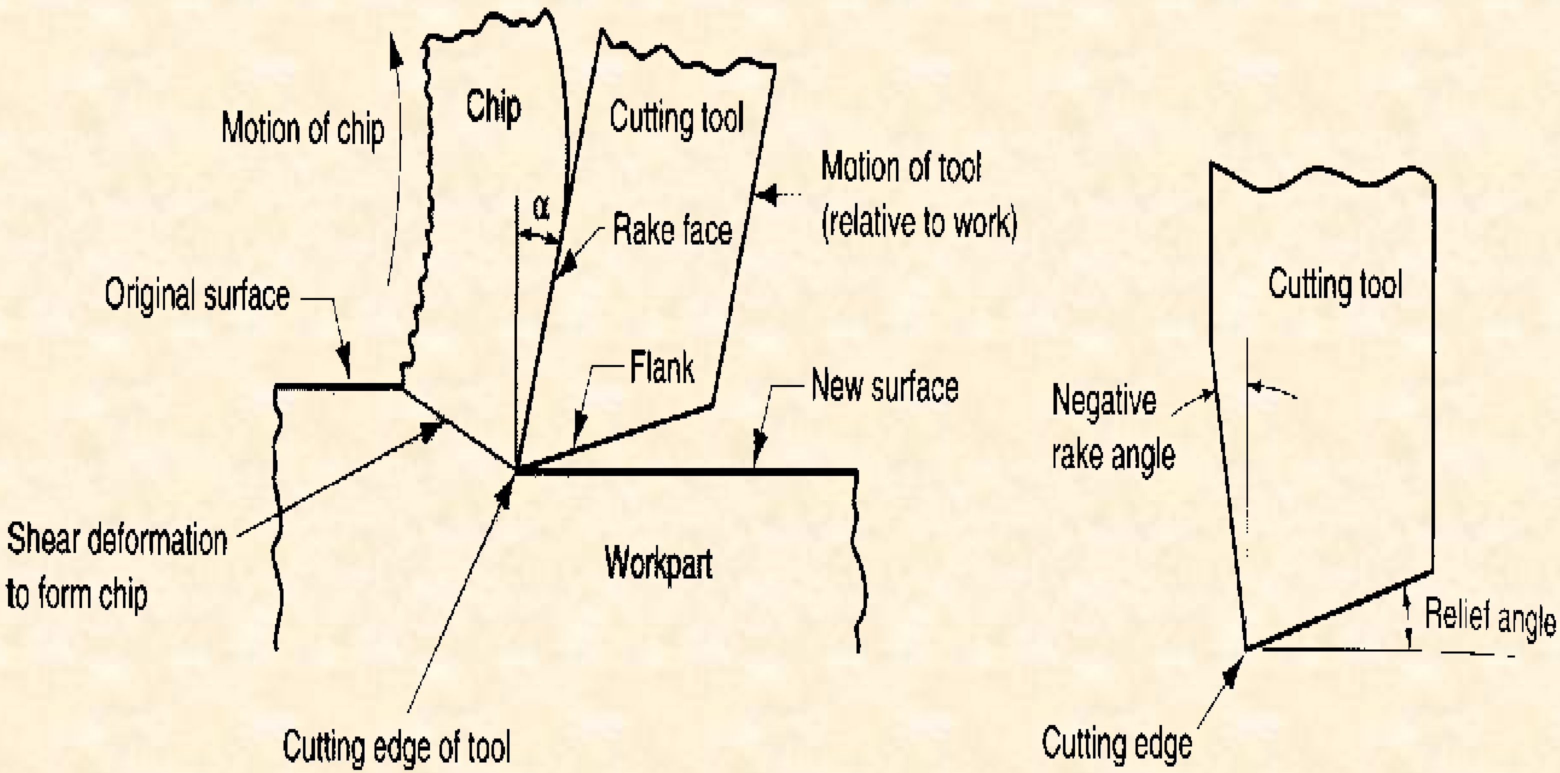
N	is the speed in rpm
D	is the diameter of the workpiece
f	is the feed (linear distance/rev)
d	is the depth of cut
V	is the surface speed $= \pi DN$

Beware**, for turning: In the generalized orthogonal model depth of cut (to) is f (the feed), and width of cut (w) is d (the depth of cut)**

Elements of Metal Cutting

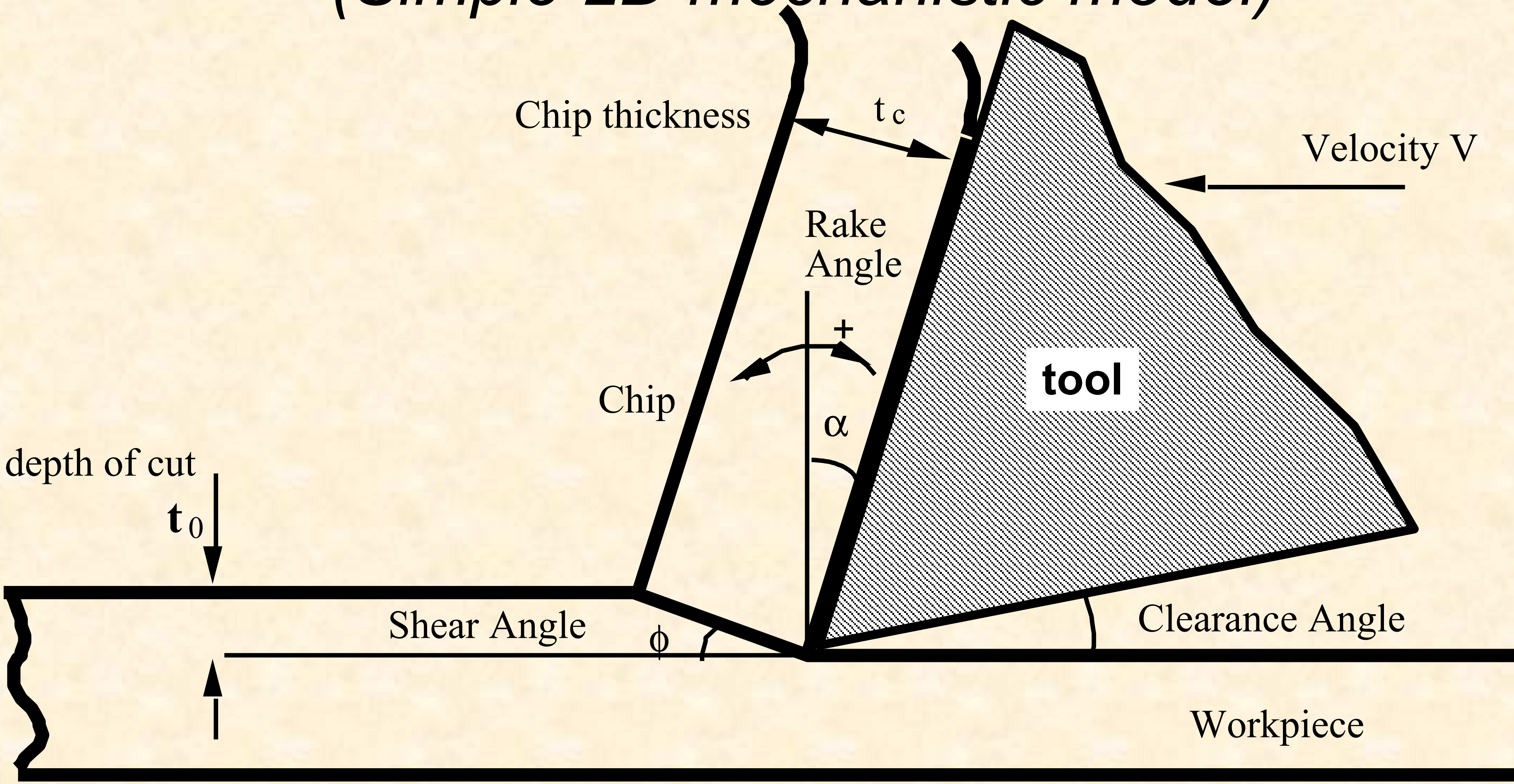


Cutting Geometry



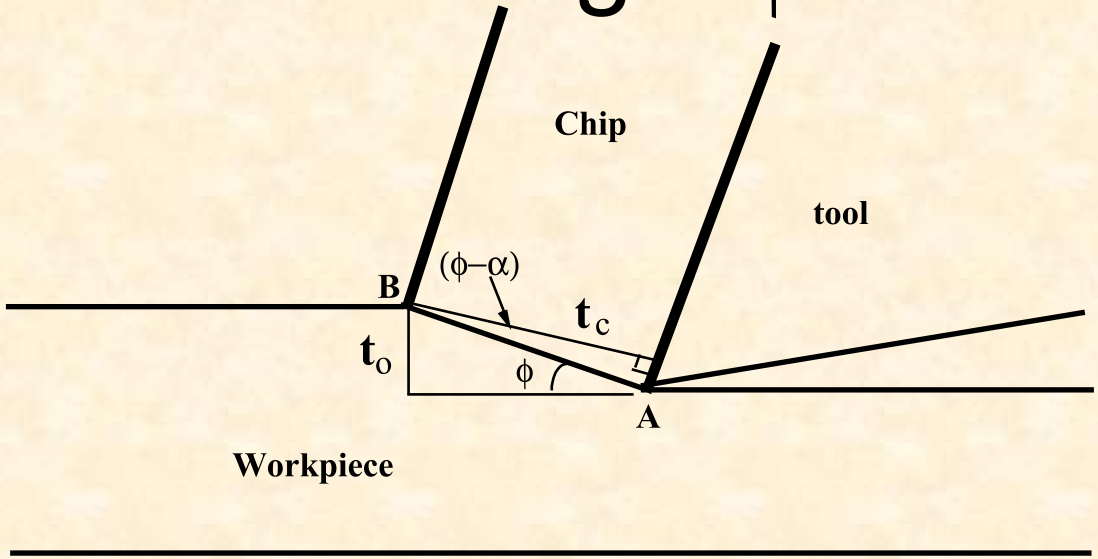
Orthogonal Cutting Model

(Simple 2D mechanistic model)



Mechanism: Chips produced by the shearing process along the shear plane

Shear Plane Length and Angle ϕ

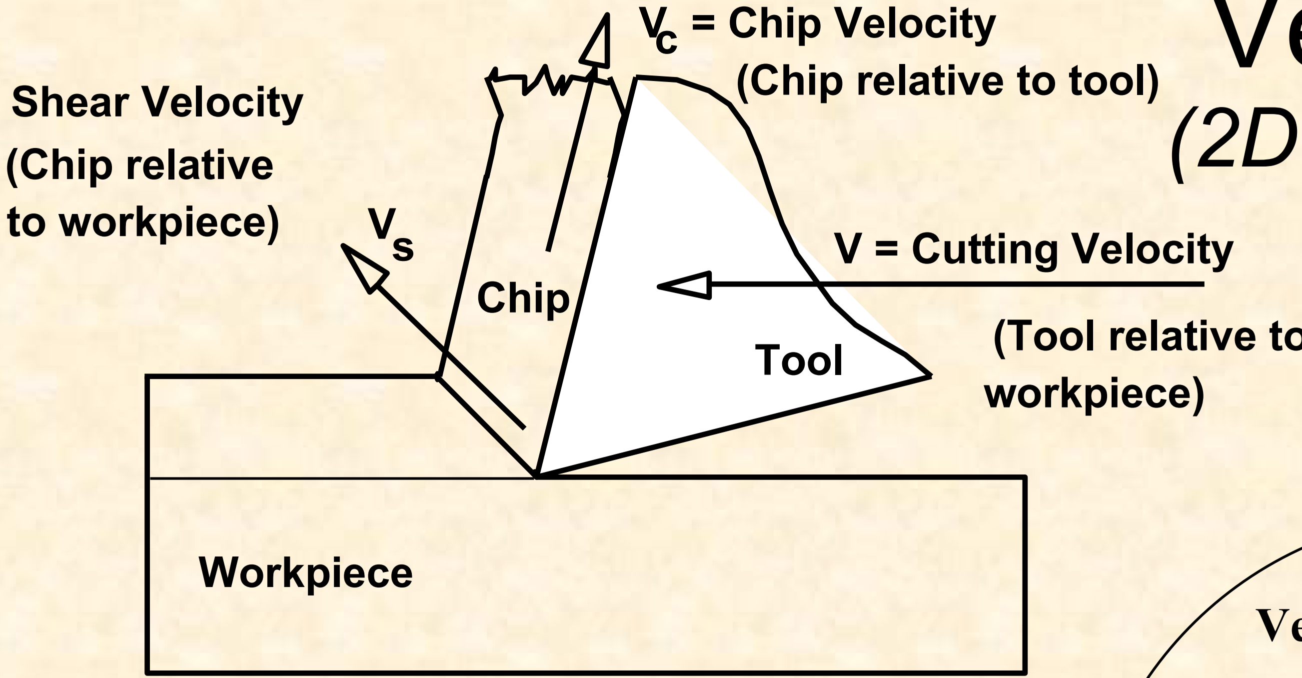


Shear plane length AB $= \dfrac{t_0}{\sin\phi}$

Shear plane angle $(\phi) = \mathbf{Tan}^{-1}\left[\dfrac{r\cos\alpha}{1 - r\sin\alpha}\right]$

or make an assumption, such as ϕ adjusts to minimize cutting force: $\phi = 45^0 + \alpha/2 - \beta/2$ **(Merchant)**

Velocities
(2D Orthogonal Model)



From mass continuity: $Vt_o = V_c t_c$

$$V_c = Vr \text{ and } \quad V_c = V\frac{\sin\phi}{\cos(\phi-\alpha)}$$

From the Velocity diagram:

$$V_s = V\frac{\cos\alpha}{\cos(\phi-\alpha)}$$