Fundamental of Machining

1-The Machine Tool selected to perform the process
2-The Cutting Tool selected (Geometry & Material)
3-Properties and Parameters of the workpiece
4-The Cutting Parameters selected (Speed, Feed, Depth of Cut)

Example: In Turning Operation

*Speed (V) = The speed of the cutting tool relative to workpiece meter/ min

*Feed (f_r) = The amount of material removed per revolution mm/rev

*Depth of Cut (d) = The distance of the Tool is plunged into the workpiece surface

$d = (D1-D2)/2$

$V = (\pi DN)/1000$

Material Removal Rate

MRR = $1000*V*f_r*d$ = mm^3/min

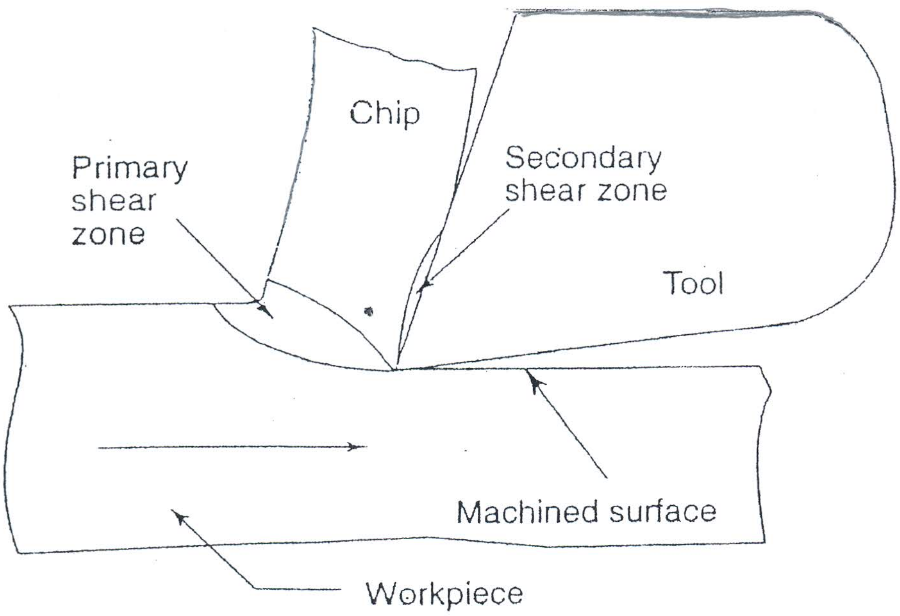
Volume of Metal Removed = $MRR*T_m$ mm^3

Machining Time = T_m = $(L + Allowance)/f_r*N$

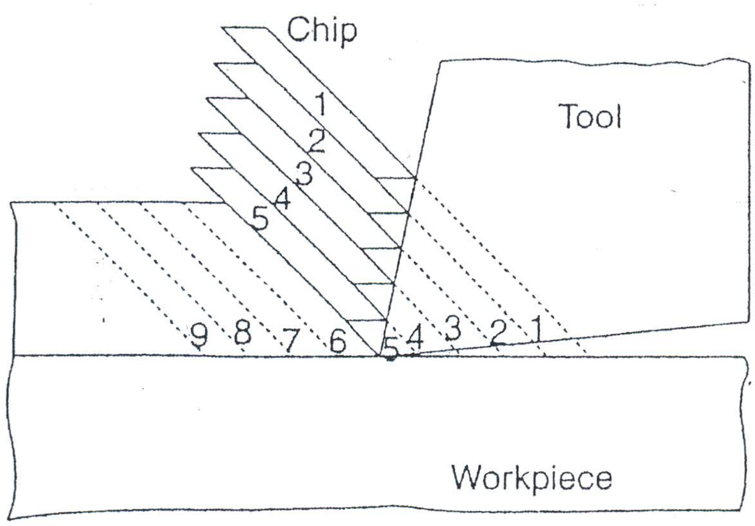
Chip Formation

- **Metal cutting process is a very complex process, the below figure shows the basic material removal operation schematically The metal in front of the tool rake face gets immediately compressed, first elastically and then plastically. This zone is traditionally called shear zone.**
- **The actual separation of the metal cutting starts as a yielding or fracture depending upon the cutting conditions, starting from the cutting tool tip. Then the deformed metal (called chip) flow over the tool (rake) face.**
- **If the friction between the tool rake face and the underside of the chip (deformed material) is considerable, then the gets further deformed, which is termed as secondary deformation.**

• Piispanen presented interesting mechanism to account for the deformation process taking place at the cutting edge. He considered the un-deformed metal as a stack of cards which would slide over one another as wedge shaped tools moved under these cards as shown in below figure



The possible deformations in metal cutting



Piispanen's model of metal cutting

Chip formation in metal cutting could be categorized into three types:

1- Discontinuous chip

2- Continuous chip

3- Continuous chip with BUE

2.1.1 Discontinuous Chip

- When brittle materials like cast iron are cut, the deformed material gets fractured very easily

- The chips produced is in the form of discontinuous segments

- The cutting forces become unstable

2.1.2 Continuous Chip

- **Continuous chips are normally produced when machining steel or ductile metals at high cutting speeds**

- **Some ideal conditions that promote continuous chips in metal cutting:**

  - Sharp cutting edge

  - Small chip thickness (fine feed)

  -Large rake angle

  -Ductile work material

Advantages

- Good surface finish

- Higher tool life

- Lower power consumption

2.1.3 Continuous chip with bue

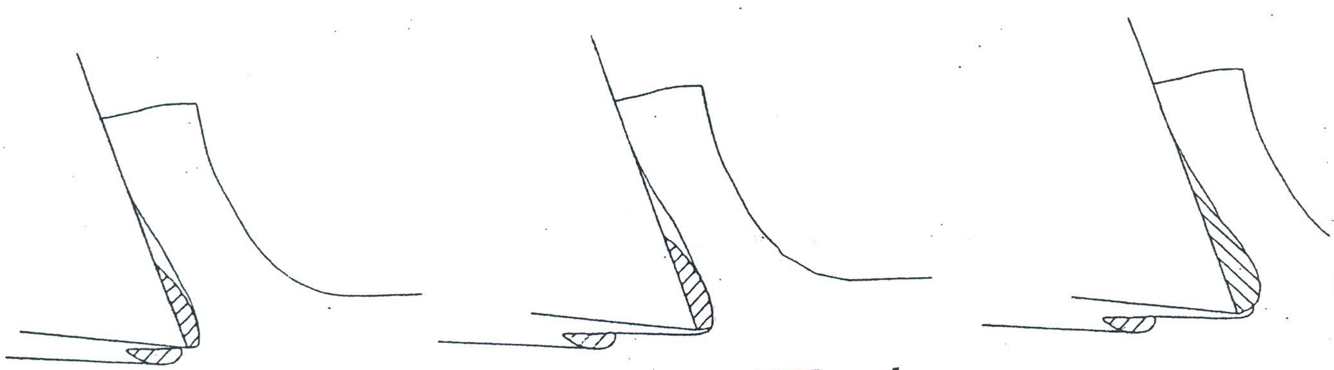
When the friction between tool and chip is high while machining ductile materials, some particles of chips adhere to the tool rake face near the tool tip. It acts as a cutting edge in place of the actual cutting edges.

- This termed as built up edge.

-BUE is harder than the parent material.

- This causes the finished surface to be rough

- The life of the cutting tool increases



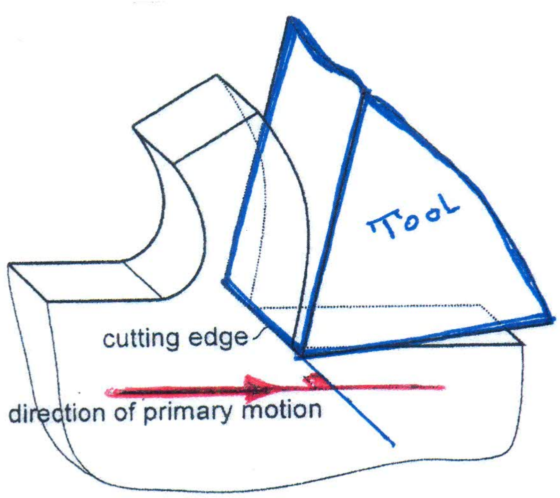
BUE cycle

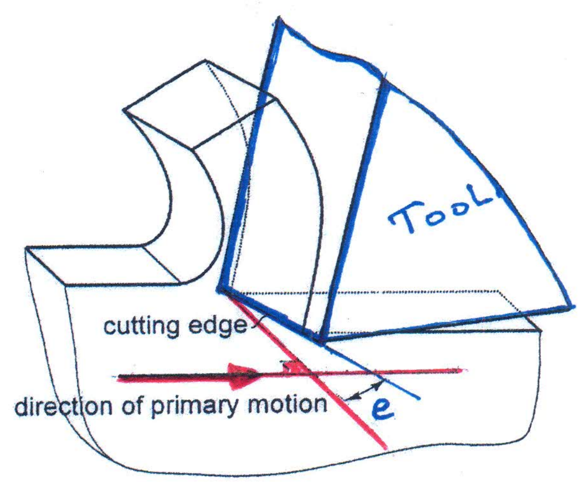
Orthogonal Cutting

The edge of Cutting Tool is straight and parallel to the workpiece surface and perpendicular to the direction of cutting

Oblique Cutting

The edge of Cutting Tool is straight and parallel to the original plane surface of the workpiece and inclined angle(e)with perpendicular to the direction of cutting





Energy and Power in Machining

Orthogonal Cutting

Two Model Forces

Oblique Cutting

Three Model Forces

1- F_c = Primary Cutting Force acting in the direction of the Cutting Velocity
2- F_f = Feed Force acting in the direction of the Tool feed
3- F_r = Radial or thrust force acting perpendicular to the machined surface

*Power Required = $P = FV$

*Power Required at Spindle

$P_c = F_c * V/60$ Watt = (N. m/S)

*Specific Power (P_s)= $P_c * 60000/MRR$ (N/mm^2)

*Motor Power (P_m) = $P_s * MRR * CF/E$

Where: E= Efficiency of the machine = 80%

CF = Correction factor =1.25 used for dull tool

Merchant's Model

- Mechanics of Orthogonal Metal Cutting As has been mentioned previously, there are two schools of thoughts with regard to plastic deformation at the cutting zone.
- The thin zone model is more useful for analytical purposes. The current analysis is based on Merchant s thin shear plane model which considers the minimum energy principle. This model is applicable at very high cutting speeds which are generally practiced in production.

The assumptions with regard to this model are:

1- The tool is perfectly sharp and there is no contact along the clearance face.

2. The surface where the shear occurs is a plane.

3. The cutting edge is a straight line which extends perpendicular to the direction of motion and generates a plane surface as are work moves past it.

4. The chip does not flow to either side, or there is no side spread.

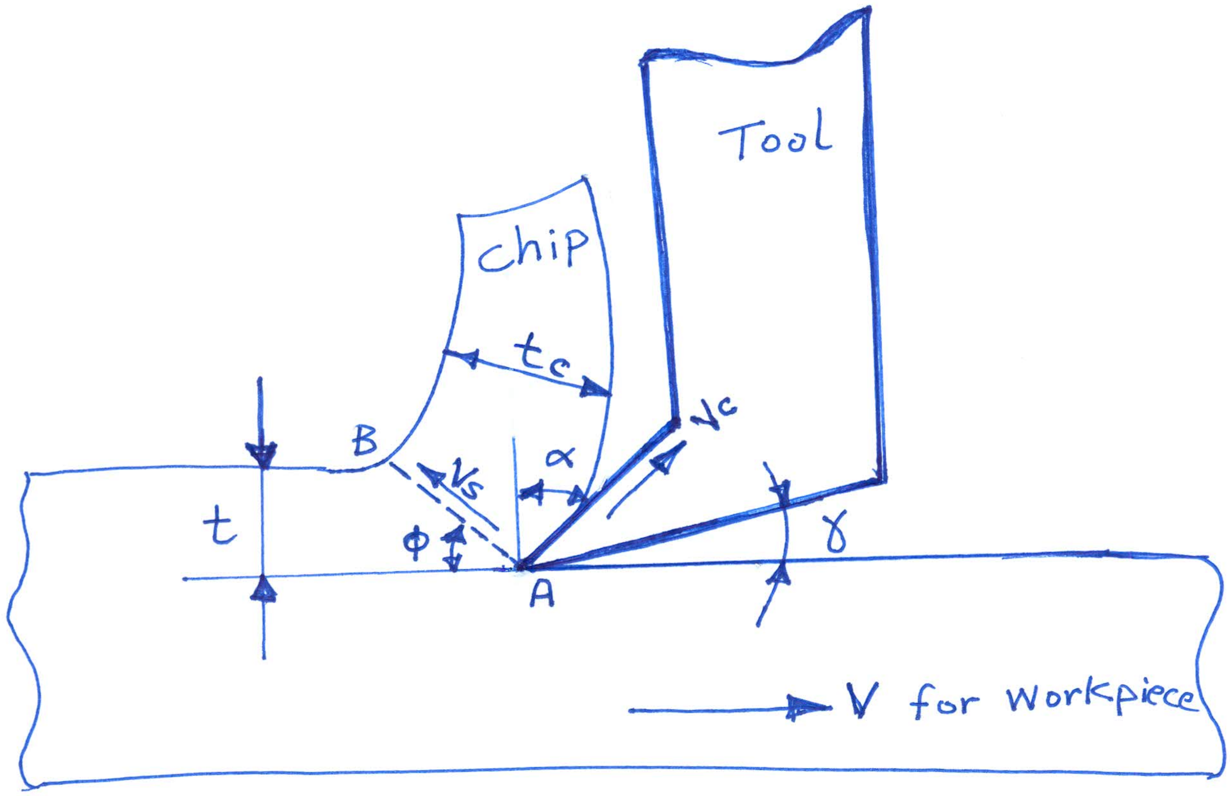
5. Uncut chip thickness is constant.

6. Width of the tool is greater than the width of the work.

7. A continuous chip is produced without any BUE.

8. Work moves with a uniform velocity

9. The stresses on the shear plane are uniformly distributed.



t =undeformed chip thickness

t_c = deformed chip thickness

α =rake angle, ϕ = Shear Angle

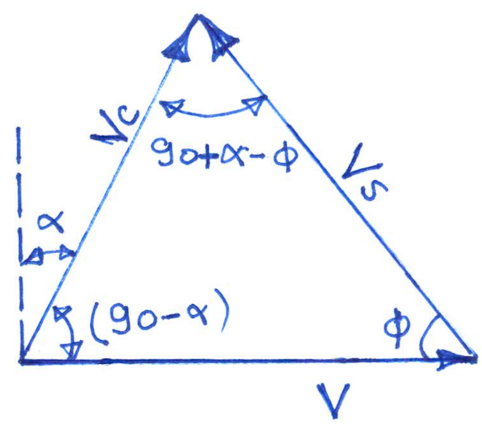
V =Velocity of workpiece, V_c = Velocity of Chip

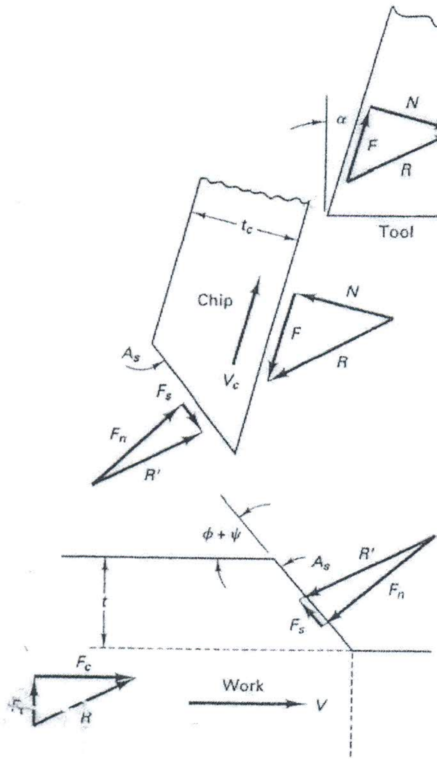
V_s =Velocity of Shear, $V_s / V = \cos\phi / \cos(\phi - \alpha)$

r_c = Chip Thickness Ratio = $t/t_c = AB \sin\phi / AB \cos(\phi - \alpha)$

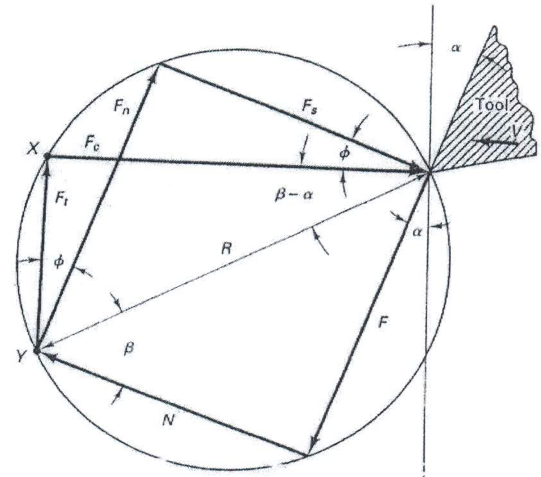
$r_c = \sin\phi / \cos(\phi - \alpha) = V_c / V$

$\tan\phi = r_c \cos\alpha / (1 - r_c \sin\alpha)$





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



Merchant's circular force diagram used to derive equations for F_s, F_r, F_t, and N as functions of F_c, F_t, φ, α, and β.

- F_c= Cutting Force,
- F_s= Shear Force,
- F= Friction Force,

F_t =Normal Force

F_n= Normal Force

N =Normal Force

β=Friction Angle,

μ=Friction Coefficient

$\beta = \tan^{-1}\mu = \tan^{-1}(F/N)$,

$R = \sqrt{F_c^2 + F_t^2}$

$F = F_c \sin\alpha + F_t \cos\alpha$ and $N = F_c \cos\alpha - F_t \sin\alpha$

$F_s = F_c \cos\phi - F_t \sin\phi$ and $F_n = F_c \sin\phi + F_t \cos\phi$

Shear Stress $\tau = F_s/A_s$, Where: $A_s = t*w/\sin\phi$

t=uncut ship thickness, w=width of workpiece