ME338 – Manufacturing Process II
Lecture 4 : Analysis of Shaping and Turning

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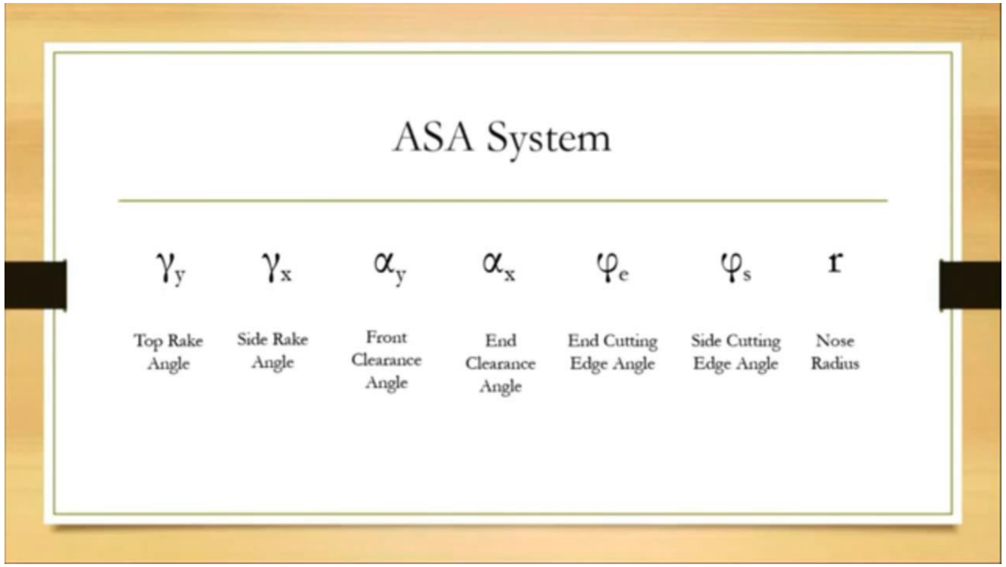
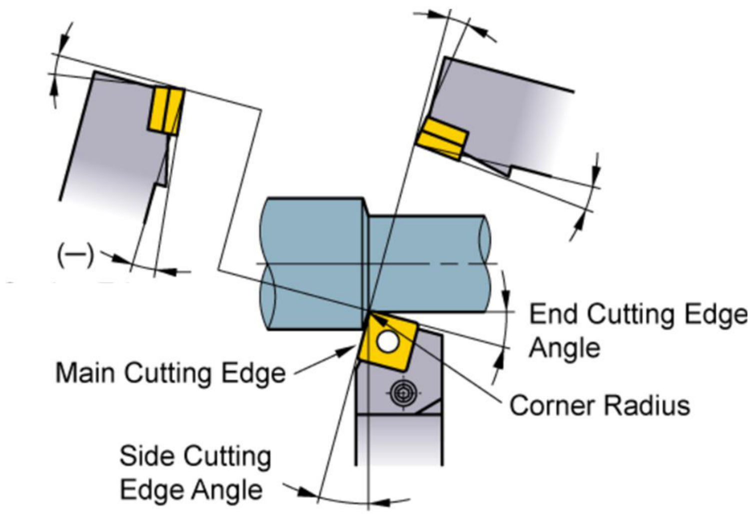
https://www.youtube.com/watch?v=bbMbFvsRTJo
http://www.mitsubishicarbide.com/en/technical_information
http://www.mitsubishicarbide.com/en/technical_information/tec_turning_tools/tec_external_turning

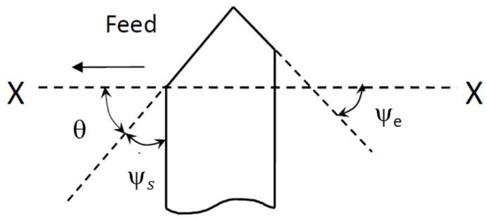
Recap : ASA system



Recap : Machining process

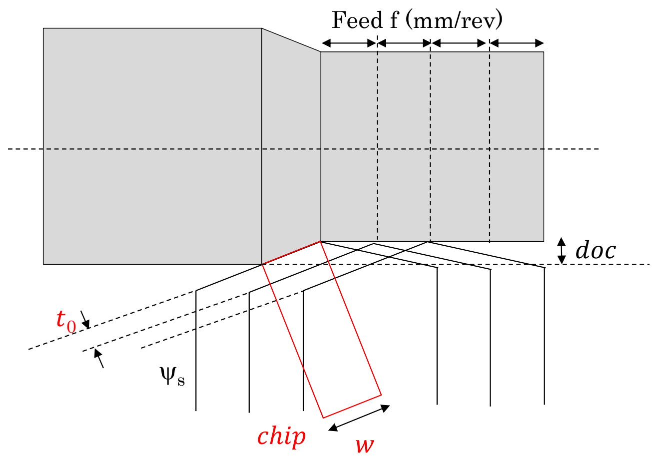


Recap: Side cutting edge



θ = Plain approach angle
ψ_s = Side cutting edge angle
ψ_e = End cutting edge angle

$$\theta = 90° - \psi_s$$



$t_0 = f\cos\psi_s$

$w = d/\cos\psi_s$

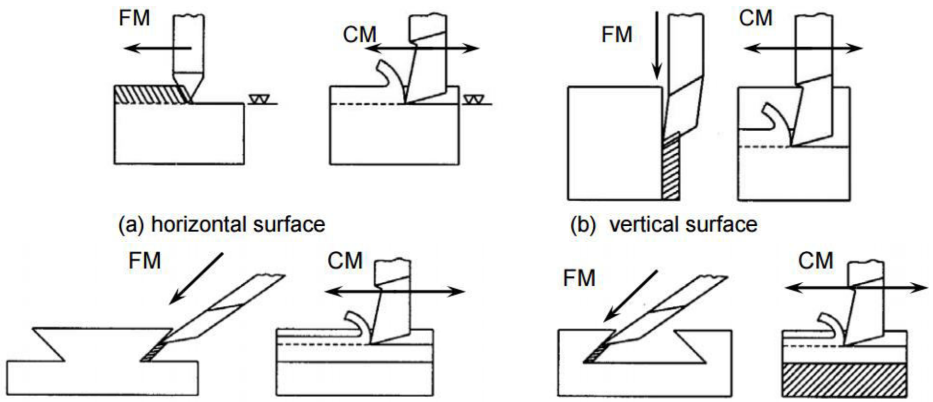
Orthogonal Machining : condition

- 2D Orthogonal machining:
  - Cutting edge has to be perpendicular to the cutting velocity vector
- Condition for Orthogonal machining:
  - $tan\alpha_b . cos\psi_s = tan\alpha_s . sin\psi_s$
  - $\tan\alpha_b = \tan\alpha_s \tan\psi_s$
- If $tan\alpha_b . cos\psi_s - tan\alpha_s . sin\psi_s = 0$, the process will be a perfect Orthogonal machining
  - Angle between cutting edge and cutting velocity vector = 90°
- $tan\alpha_b . cos\psi_s - tan\alpha_s . sin\psi_s \neq 0$, the process will be oblique machining
  - Any deviation of $(tan\alpha_b . cos\psi - tan\alpha_s . sin\psi)$ from zero indicates the degree of non-orthogonality.

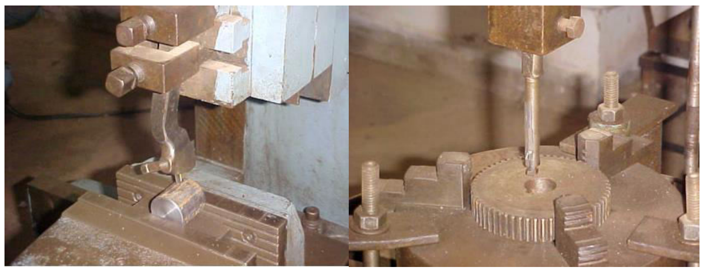
Normal rake angle (α)

- In analysis, rake or normal rake angle (α) is been used
- The cutting tool has only back rake angle (α_b) and side rake angle (α_s)
  - Side cutting edge angles (ψ_s)
  - End cutting edge angle (ψ_e)
- In ASA system, Normal rake angle can be calculated from the tool signature in the following manner:
- Normal rake angle (α)
  - $tan\alpha = \dfrac{tan\alpha_b . sin\psi_s + tan\alpha_s . cos\psi_s}{\sqrt{1 + (tan\alpha_b . cos\psi_s - tan\alpha_s . sin\psi_s)^2}}$
- In case of orthogonal machining:
  - $tan\alpha = tan\alpha_b sin\psi_s + tan\alpha_s cos\psi_s$
- Example: tool signature 6°-10°-7°-7°-10°-20°-0.5
- Normal rake angle will be ???

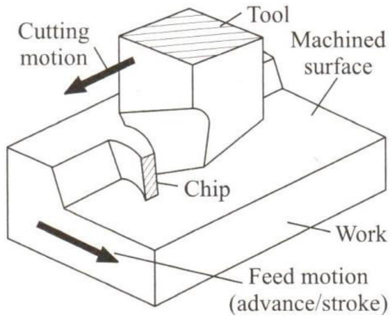
Shaping : Different surfaces machined

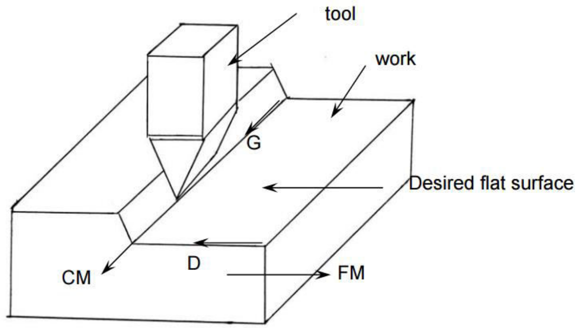


Keyway formation by Shaping



Analysis of Shaping



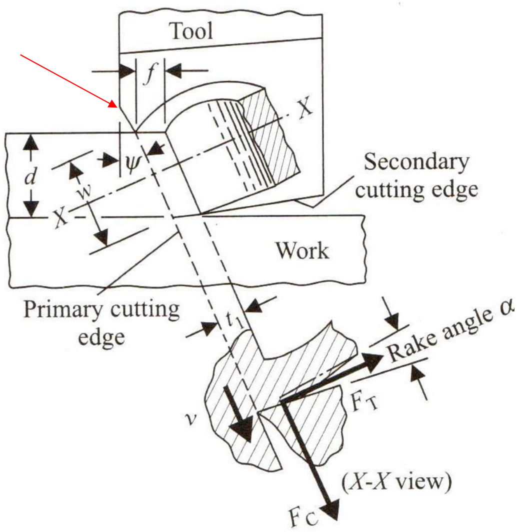


- Tool moves forward and backwards but cutting is only in forward stroke
- Speed in return stroke is more than in forward stroke for increased productivity
- Quick return ratio (R) = speed in return stroke/speed in forward stroke
- Stroke length is higher than length of job (Approach distance + overtravel)
- Major parameters:
  - strokes per unit time (N), stroke length (S), quick return ratio (R) (displacement/stroke), depth of cut (d), tool angles

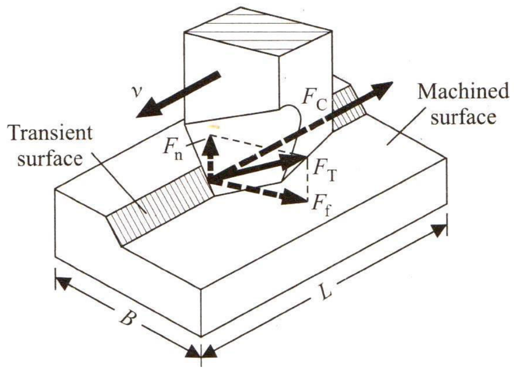
Orthogonal analysis of shaping process

- Input : Feed per stroke (f), depth of cut (d)
- Tool: Side cutting edge angle (ψ_s), Normal rake angle (α)
- Output: Uncut chip thickness t_1 width of cut w

- Uncut chip thickness $t_1 = f\cos\psi_s$,
- width of cut $w = d/\cos\psi_s$
- ψ_s is primary (side) cutting edge angle



Orthogonal analysis of shaping process

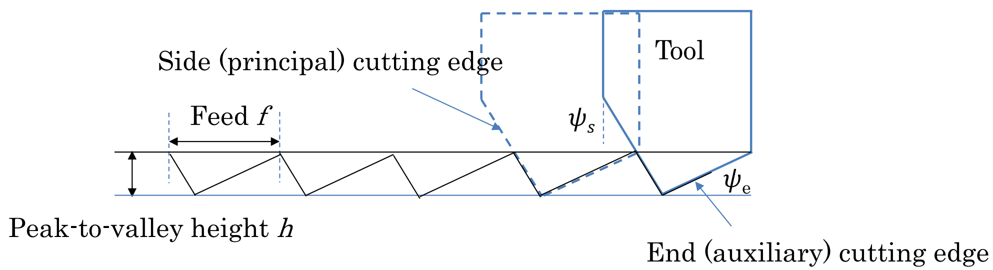


- Due to the side cutting edge angle (ψ_s), the 'transient' surface is inclined
- Cutting force F_c will be along the cutting direction
- F_t force will be ⊥ to the transient surface
  - It can be broken in two components
  - F_f Feed component, F_n (normal to the machined surface)
- $F_f = F_t.Cos\,\psi$, $F_n = F_t.Sin\,\psi$

Important relationships

- Quick return ratio :
  - Ratio of the durations of the forward stroke and the return stroke
- Metal removal rate $MRR = LdfN$
  - L = Overall length of job (including overtravel + approach distance),
  - d = depth of cut,
  - f = feed per stroke,
  - N = no of strokes per unit time
- If B is breadth of job, then total time taken to reduce the work surface has to be lowered (H), depth of cut (d), feed (f), cutting stroke per unit time (N)
  - $t_c = (H/d).(B/f).(1/N)$
- Average cutting speed can be expressed as
  - $v = NS(1+R)/2$,
  - S = stroke length, R = quick return ratio, N = no of strokes per unit time

Surface finish in shaping/planing



Side cutting edge angle (ψ_s),

End cutting edge angle (ψ_e),

Max peak-to-valley height h_{max} for shaping/planing with a sharp tool

$$h_{max} \approx \frac{f}{\tan\psi_s + \cot\psi_e}$$

Numeric problem : Shaping

Determine the three components of the machining force when shaping a cast iron block with depth of cut = 4 mm, feed = 0.25 mm/stroke, normal rake angle of the tool = 10°, principle cutting edge angle = 30°, coefficient of friction between chip and tool is 0.6. Assume ultimate shear strength of cast iron is 400 N/mm2.

- Coefficient of friction is known, friction angle ß is known
- Assume any relationship lee-shaffer equation
- Rake angle is known. Shear angle ϕ can be calculated
- Shear strength τ, width w, depth d, uncut chip thickness t1 is known
  - Width w = depth of cut d/cos ψ,
  - Uncut chip thickness t_1 = feed f.Cos ψ
- Cutting force Fc, Ft can be calculated
- Feed force and normal to feed force components can be calculated

$$F_c = \frac{\tau w t_0 \cos(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$$

$$F_t = \frac{\tau w t_0 \sin(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$$

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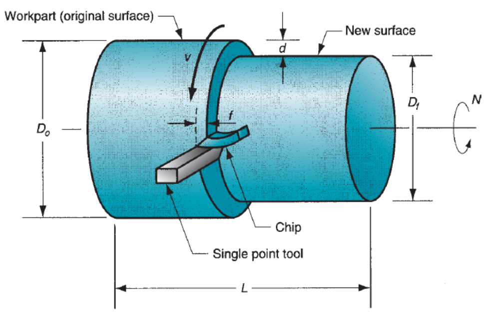
- Shear strength τ, width w, depth d, uncut chip thickness t_0 is known
  - Width w = depth of cut d/cos ψ,
  - Uncut chip thickness t_0 = feed f.Cos ψ
- Cutting force F_c, F_t can be calculated
- Feed force and normal to feed force components can be found too

$$F_c = \frac{\tau w t_0 \cos(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$$

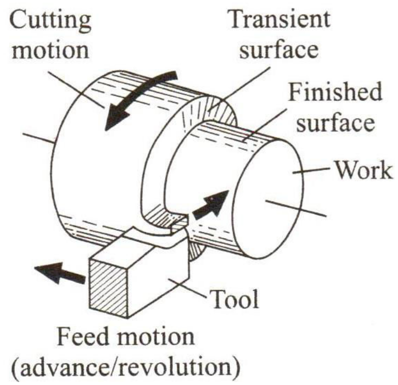
$$F_t = \frac{\tau w t_0 \sin(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$$

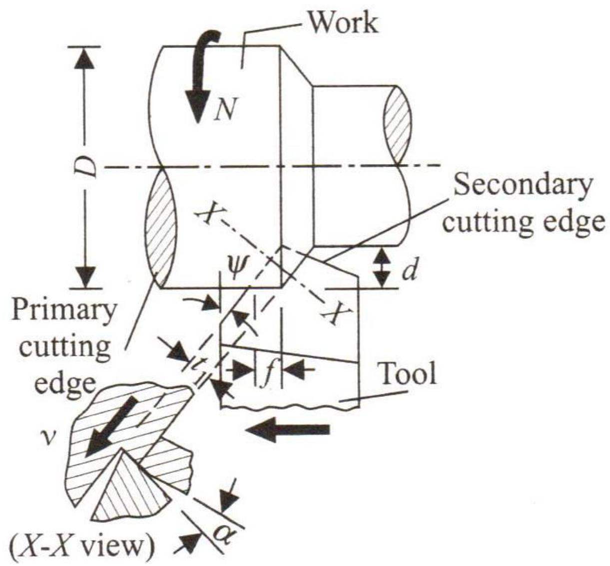
Turning process

- Turning – external surfaces
- Boring – internal surfaces
- Desired cutting speed v = $\pi D_0 N$
- If depth of cut is d, Final diameter $D_f = D_0 - 2d$
- Feed in turning process can be expressed in mm/rev (in rev)
- Feed can be converted into a linear travel feed rate in mm/min,
  - $f_r = Nf$
- The time to machine from one end of a cylindrical work part to the other
  - $T_m = L / f_r$



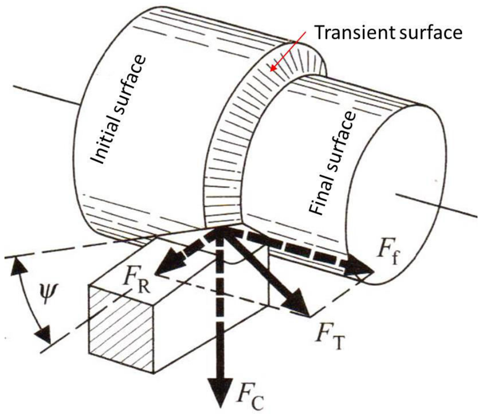
Analysis of Turning process



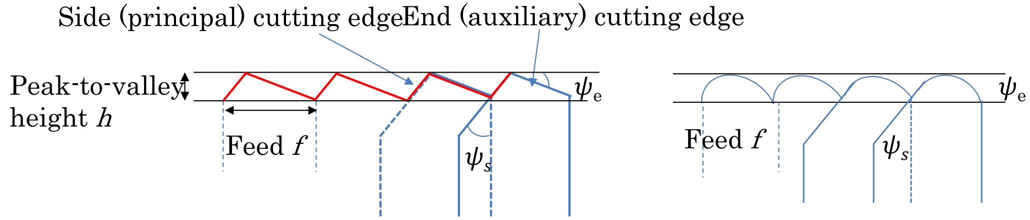


Basic force components in turning

- Uncut chip thickness $t_1 = f.Cos\,\psi$,
- Width of cut $w = d/Cos\,\psi$
  - f feed, d depth of cut, ψ side cutting edge angle
- Due to the side cutting edge angle (ψ), the ‘transient’ surface is inclined
- Thrust force F_t can be divided in two components
  - Feed force $F_f = F_t\,Cos\,\psi$,
  - Radial component $F_R = F_t\,Sin\,\psi$



Surface finish in turning



Side cutting edge angle (ψ_s),

End cutting edge angle (ψ_e),

Peak-to-valley height h_{max} for turning with a sharp tool

$$h_{max} \approx \frac{f}{\tan\psi_s + \cot\psi_e}$$

Peak-to-valley roughness h for turning with tool having nose radius r, when only nose is cutting

$$h = \frac{f^2}{8r}$$

Problem 3

A mild steel bar of 100 mm diameter is being turned with a tool with the specification 6°–10°–5°–7°–10°–30°–0.55 mm. The depth of cut is 2.5 mm and the feed is 0.125 mm/revolution. The rpm of the job is 300. Determine the components of the machining force and the power consumption. The ultimate shear stress of the work material is 400 N/mm^2 and the coefficient of friction between the tool and the chip is 0.6.

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- Coefficient of friction is known, friction angle β is known
- Rake angle is known. Shear angle ϕ can be calculated
- Shear strength τ, width w, depth d, uncut chip thickness t_0 is known
  - Width $w = d/Cos\,\psi_s$
  - Uncut chip thickness $t_0 = f\,Cos\,\psi_s$
- Cutting force F_c, F_t can be calculated

$$F_c = \frac{F_s\,Cos(\beta-\alpha)}{Cos(\phi+\beta-\alpha)}$$

$$F_c = \frac{\tau w t_0\,Cos(\beta-\alpha)}{\sin\phi\,Cos(\phi+\beta-\alpha)}$$

$$F_t = \frac{\tau w t_0\,Sin(\beta-\alpha)}{\sin\phi\,Cos(\phi+\beta-\alpha)}$$