Óbuda University
Bánki Donát Faculty of Mechanical and Safety Engineering
Institute of Material Science and Manufacturing Engineering

Manufacturing Engineering 2

BAGGT23NEC

2013/14 I.

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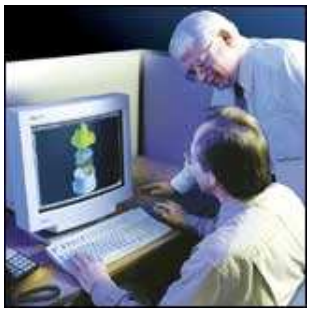




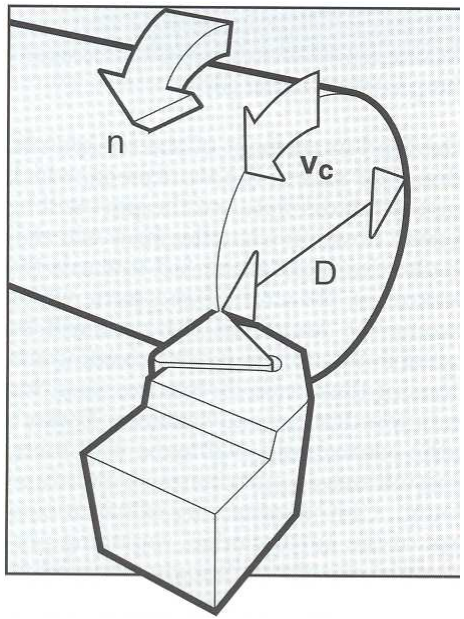
03

CUTTING METHODS

- Turning
- Milling
- Drilling
- Reaming

- Grinding
- Planning
- Shaping
- Broaching

Turning



Primary motion:
- continuous
- rotating
- workpiece

Feed motion:
- continous
- tool

$$v_c \Rightarrow known$$

$$n = \frac{1000 \cdot v_c}{D \cdot \Pi}$$

$$f \Rightarrow known$$

$$or$$

$$f \Rightarrow R_t = 4 \cdot R_a = \frac{f^2}{8 \cdot r_\varepsilon}$$

$$f = \sqrt{4 \cdot R_a \cdot 8 \cdot r_\varepsilon}$$

$$v_f = n \cdot f$$

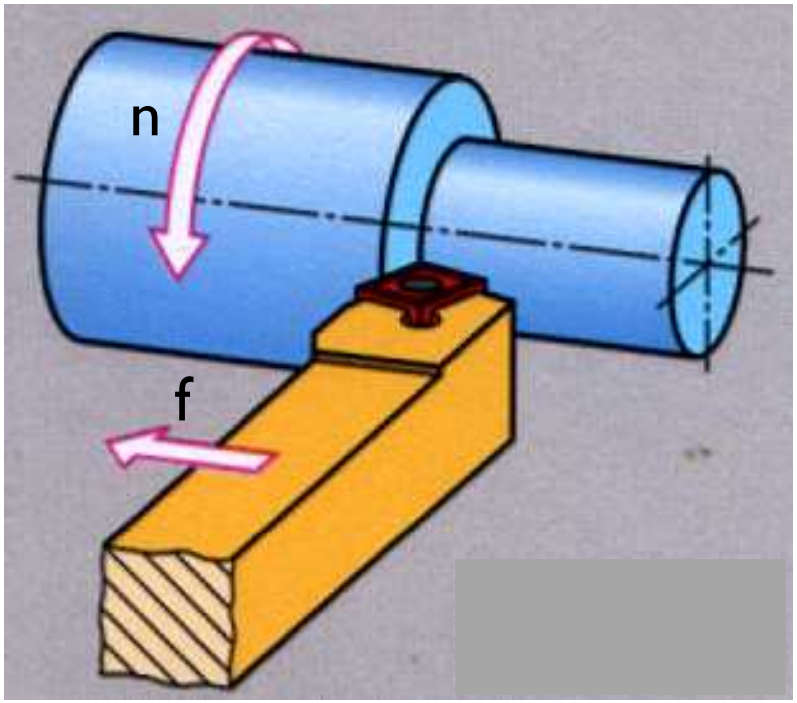
$$t_c = \frac{L}{v_f} = \frac{L_{pre} + L_c + L_{post}}{v_f}$$

Ra: 0.8 – 6.3 µm
IT: (7) 8 - 12

Operation steps

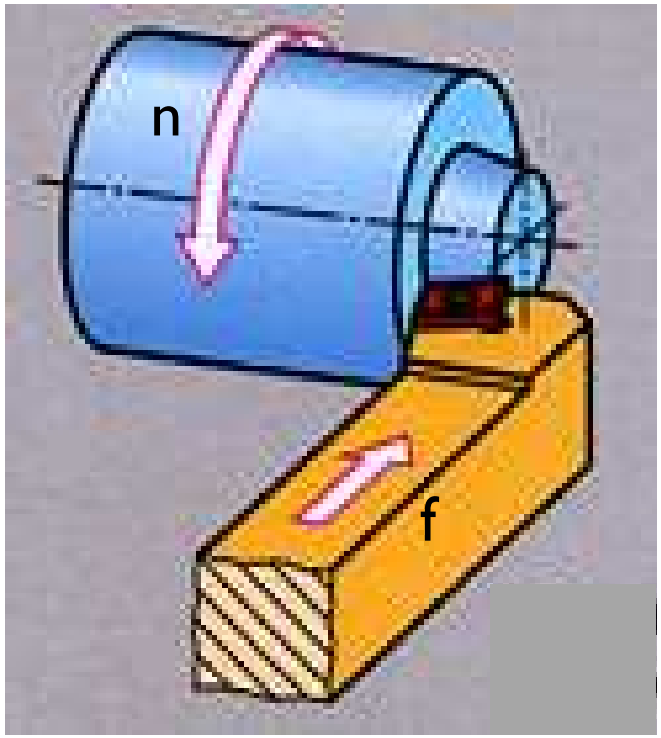
1) Turning
2) Facing
3) Grooving
4) Face grooving
5) Parting
6) Thread turning
7) Boring

Turning



Feed is parallel with the axis.

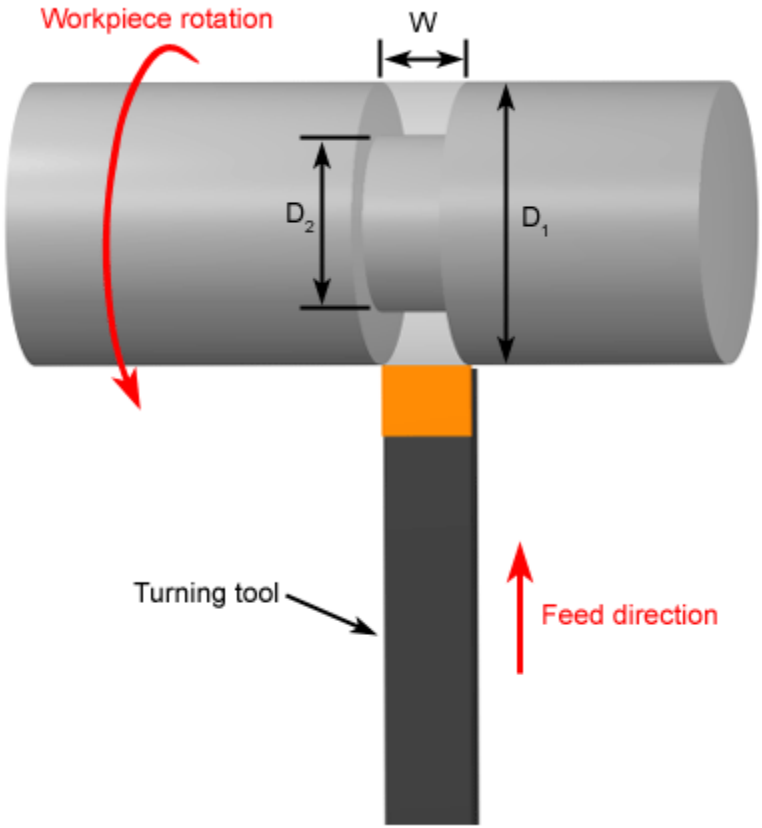
Facing



Feed is perpendicular to the axis.
D is changed continuously.

$v_{c\_facing} = v_{c\_turning}$

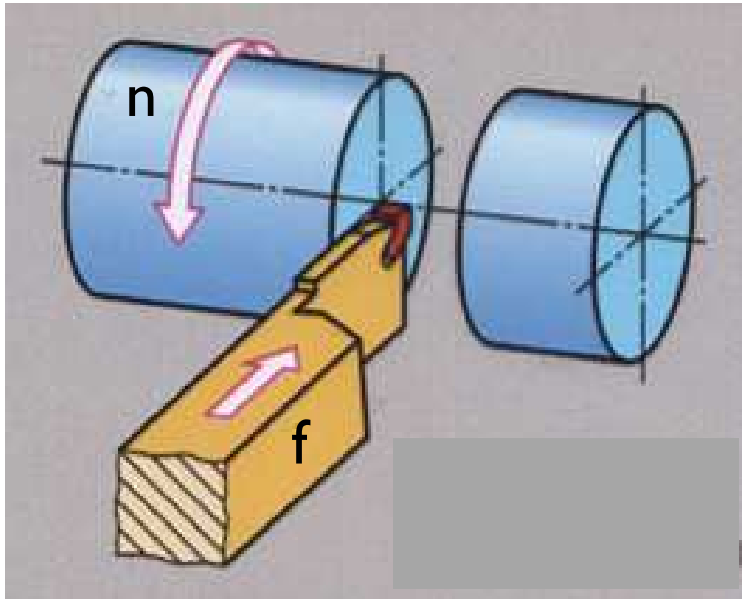
Grooving



Feed is perpendicular to the axis.
D is changed continuously.

$v_{c\_grooving} = v_{c\_turning}$

Parting

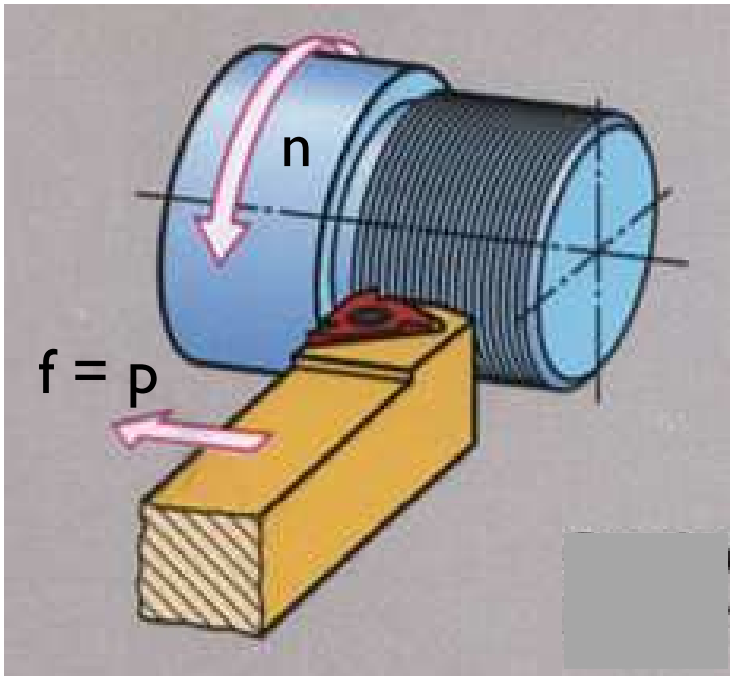


Feed is perpendicular to the axis.

D is changed continuously.

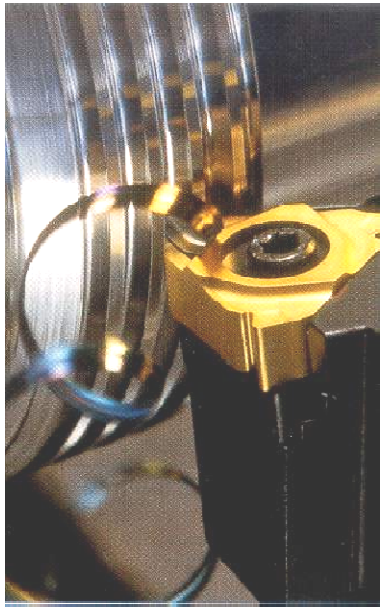
$v_{c\_parting} = (0.2…0.5)\ v_{c\_turning}$

Thread turning

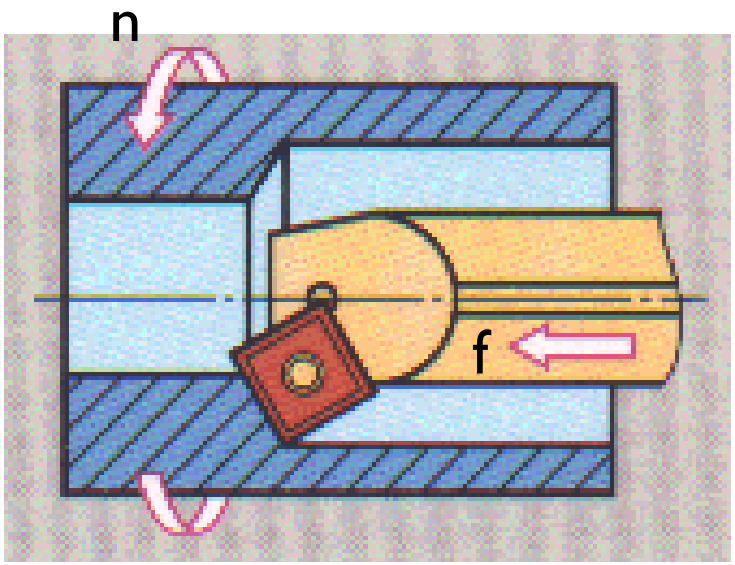


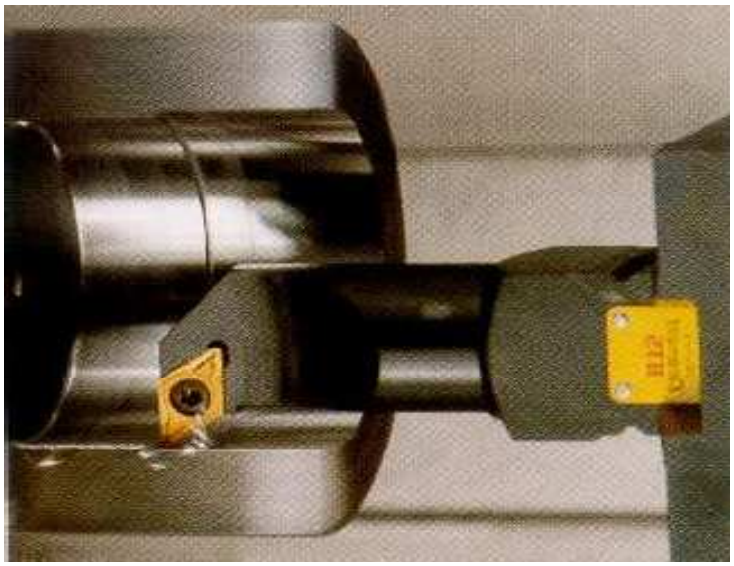
Feed is parallel with the axis.
Feed is equal to pitch.

$v_{c\_parting} = (0.4 \ldots 0.5)\ v_{c\_turning}$
But the v_f means constrain.



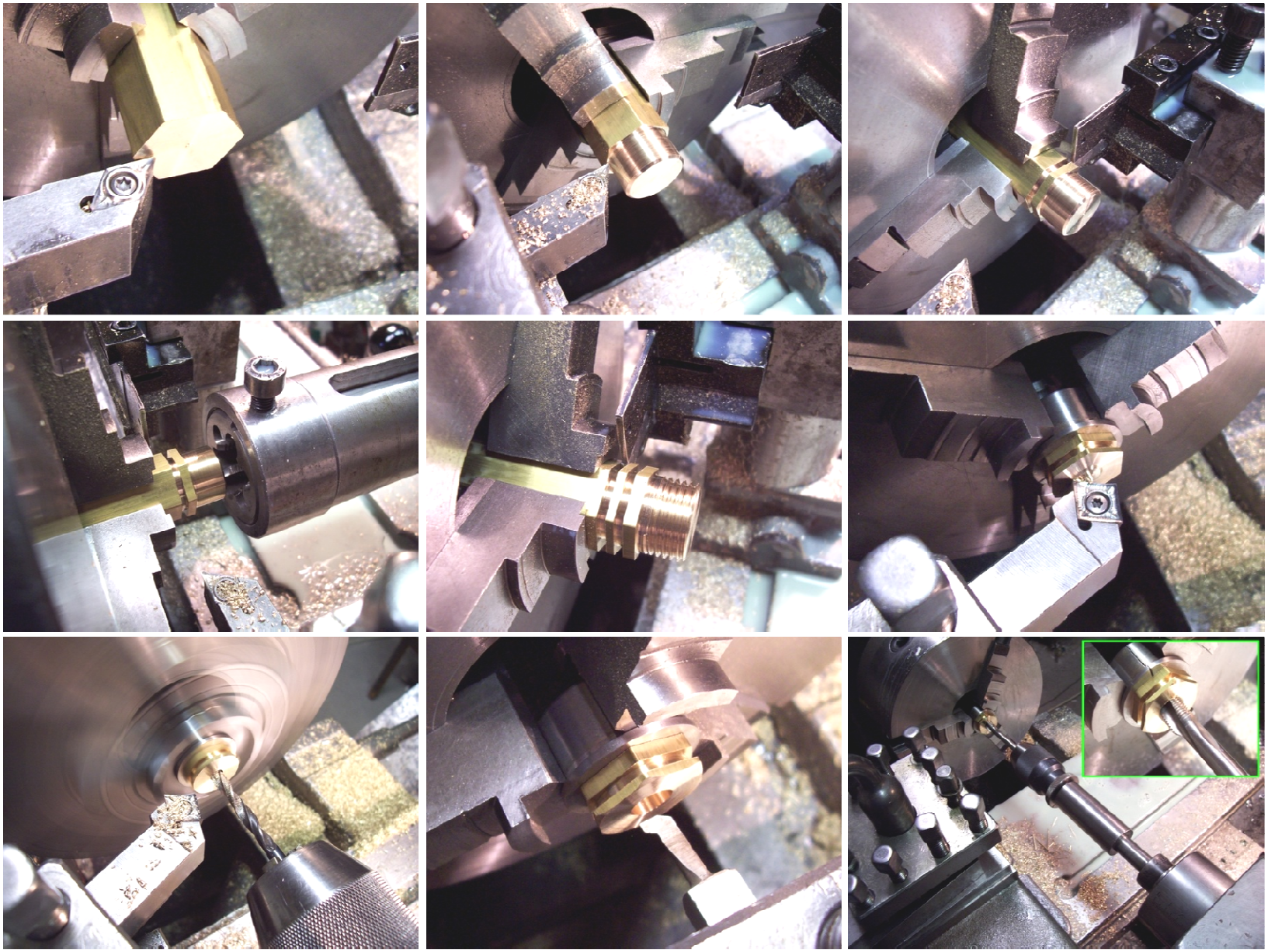
Boring





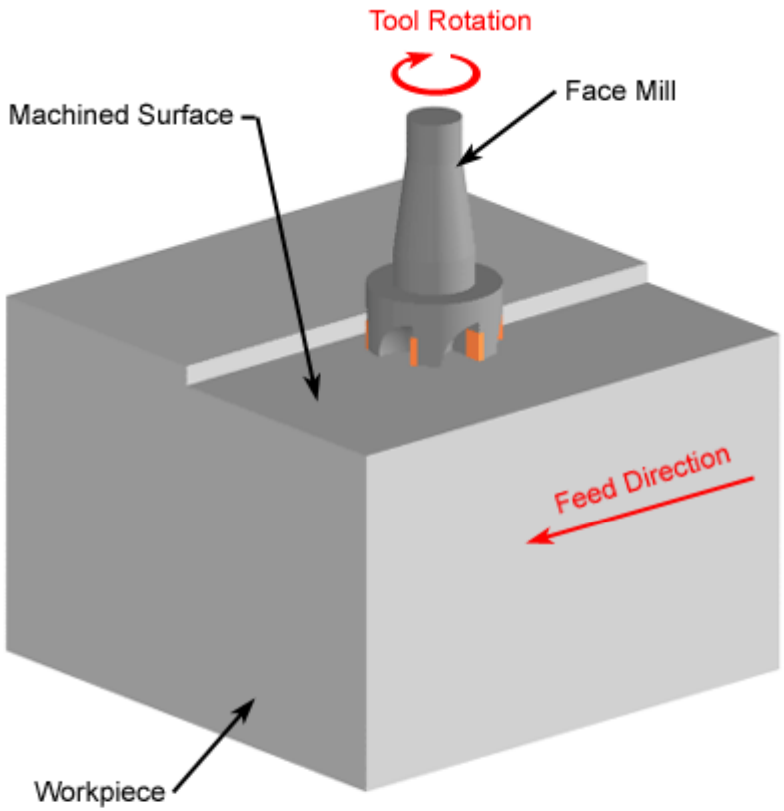
Feed is parallel with the axis.

$v_{c\_parting} = (0.7 \ldots 1.0)\ v_{c\_turning}$



http://turning.fw.hu

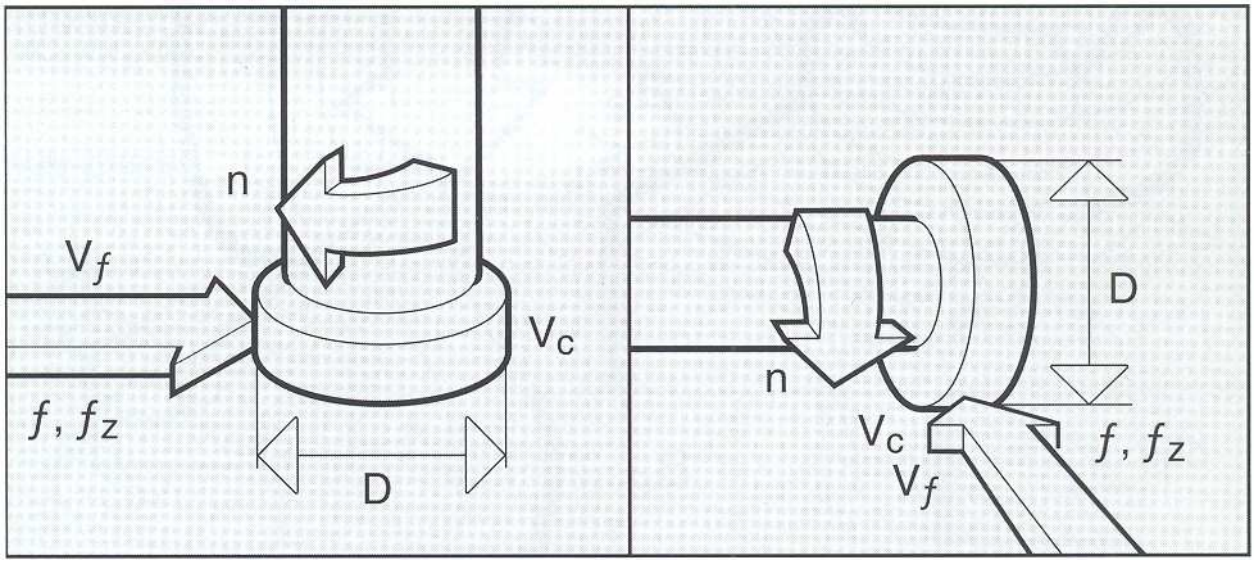
Milling



Primary motion:
- continuous
- rotating
- tool

Feed motion:
- continuous
- tool / workpiece

Ra:	0.8 – 6.3 µm
IT:	9 - 12



$$v_c \Rightarrow known$$

$$n = \frac{1000 \cdot v_c}{D \cdot \Pi}$$

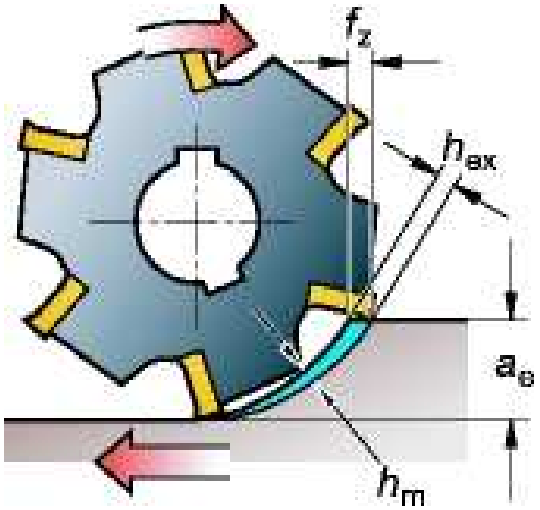
$$f_z \Rightarrow known$$

$$f = f_z \cdot z$$

$$v_f = n \cdot f$$

$$t_c = \frac{L}{v_f} = \frac{L_{pre} + L_c + L_{post}}{v_f}$$

Cutting forces – plain milling



Average chip thickness:

$$\bar{h} = f_z \cdot \sqrt{\frac{a_e}{d}} \quad [\text{mm}]$$

Chip cross section:

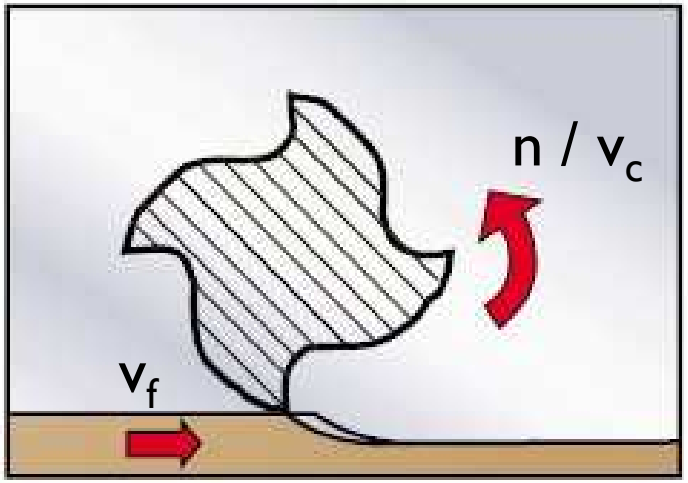
$$\bar{A}_1 = \bar{h} \cdot a_p = \sqrt{\frac{a_e}{d}} \cdot f_z \cdot a_p \quad [\text{mm}^2]$$

Average cutting force:

$$\bar{F}_c = \bar{k} \cdot a_e \cdot a_p \cdot f_z \cdot \frac{z}{d \cdot \pi} \quad [\text{N}]$$

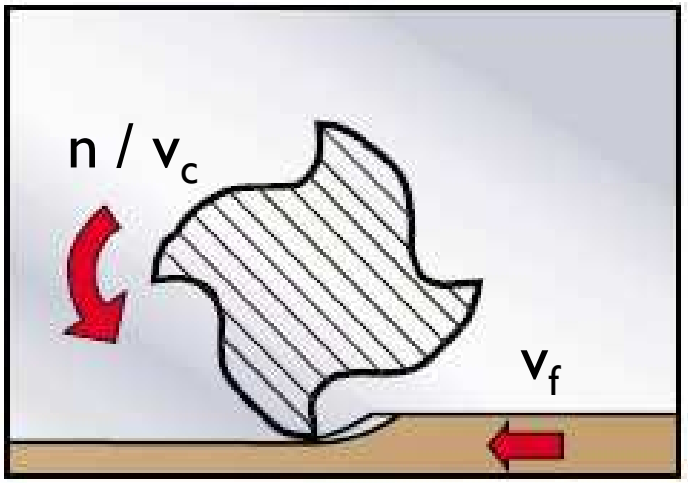
$$\bar{k} = \frac{k_{c1.1}}{\bar{h}^{q_c}} \quad [\text{N}]$$

As a general rule – use down milling tool paths.



Down milling

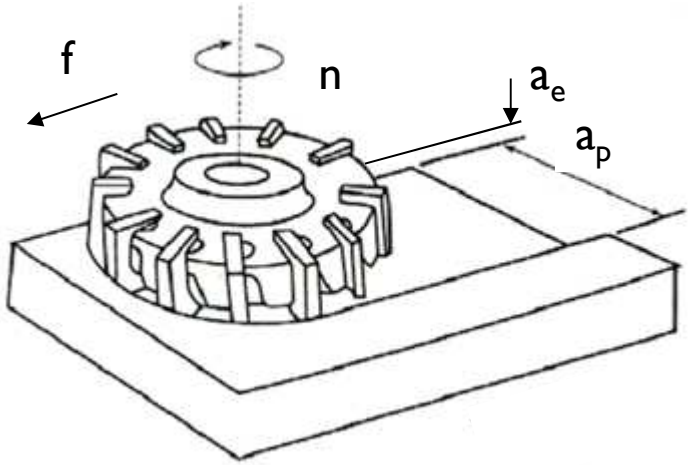
- Less heat generation.
- Compressive stresses favourable for the carbide edge.
- Longer tool life.
- Better surface finish.
- Better geometrical accuracy.
- More friendly to spindle bearings.

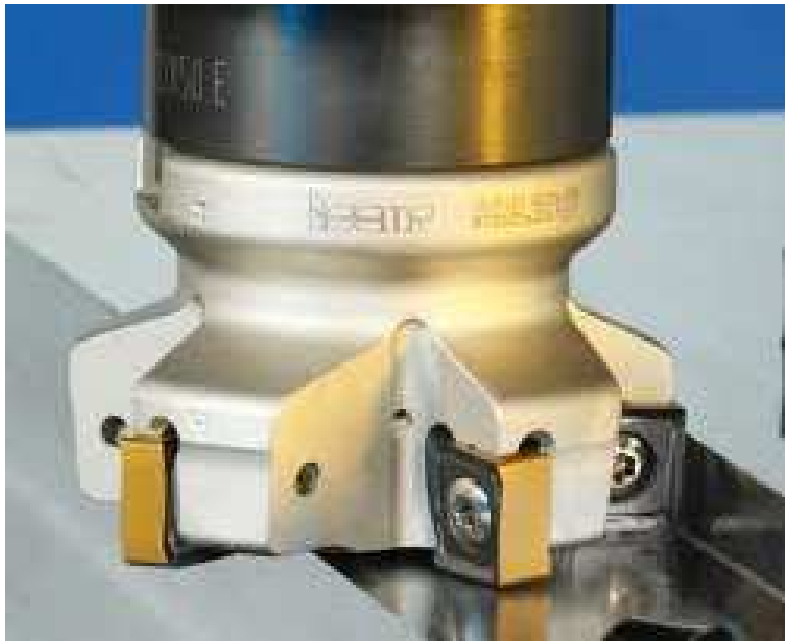


Up milling

- Better wall straightness and more accurate corner angle when side milling – finishing.
- Little or no mismatch between subsequent toolpaths.
- Makes somewhat worn manual machine tools perform better.

Cutting forces – face milling





Average cutting force:

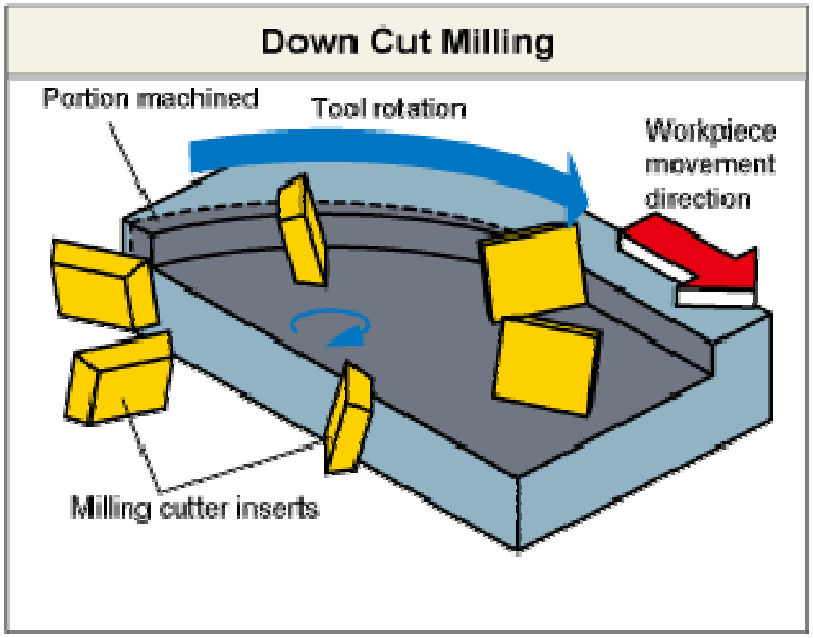
$$\overline{F}_c = \overline{k} \cdot a_e \cdot a_p \cdot f_z \cdot \frac{z}{d \cdot \pi} \ [\mathrm{N}]$$

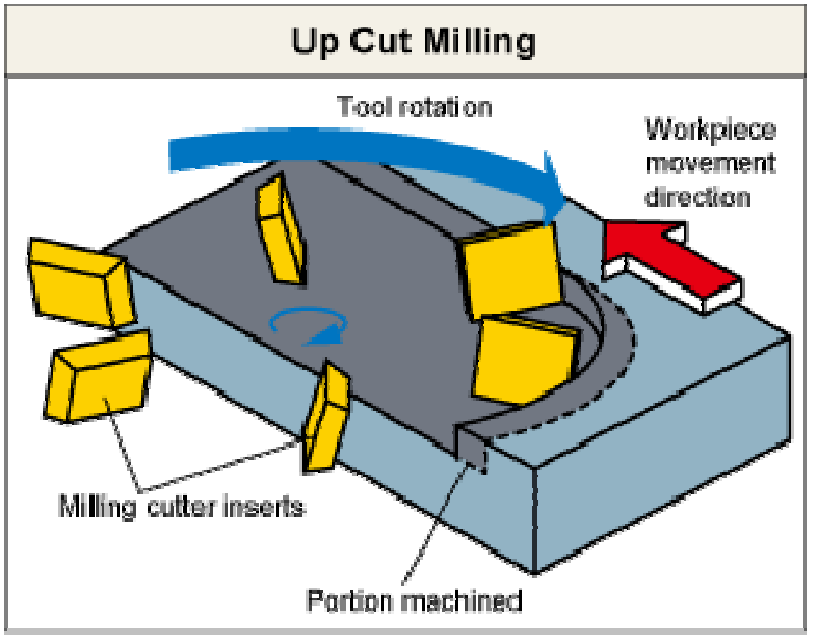
Cutting torque:

$$M_c = \frac{\overline{F}_c \cdot d}{2000} \ [\mathrm{Nm}]$$

Cutting power:

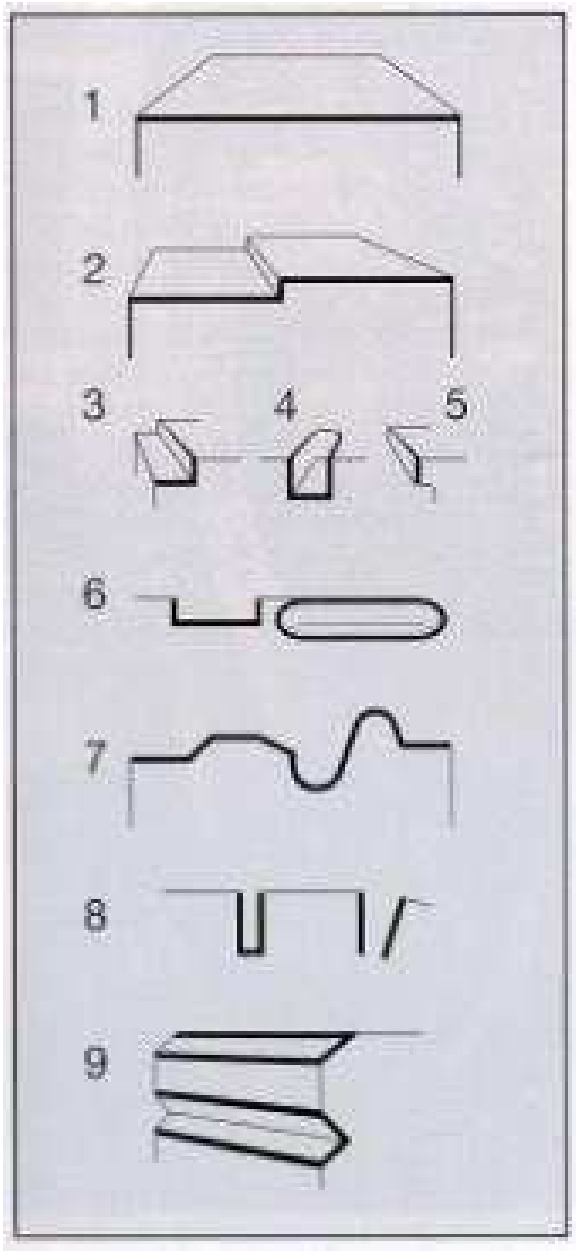
$$P_c = \frac{M_c \cdot n}{9550} \ [\mathrm{kW}]$$

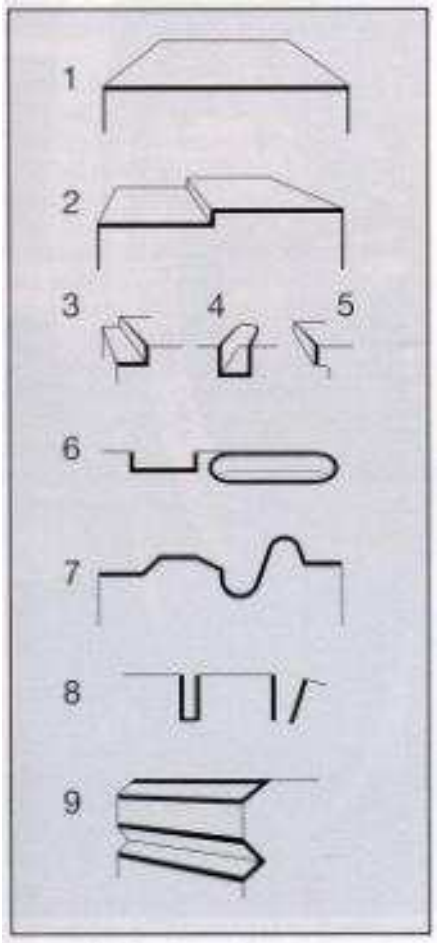

Down Cut Milling
Portion machined
Tool rotation
Workpiece movement direction
Milling cutter inserts


Up Cut Milling
Tool rotation
Workpiece movement direction
Milling cutter inserts
Portion machined

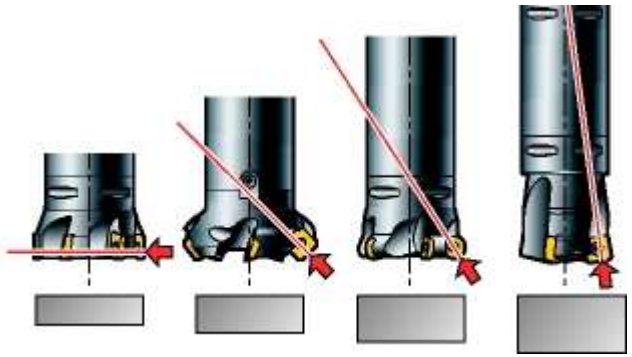
Operation steps

1. Plane or face milling
2. Shoulder milling
3. Shoulder milling
4. Groove or keyway milling
5. Edge milling
6. Pocket milling
7. Contour milling
8. Slot milling and cut off
9. Champfer milling

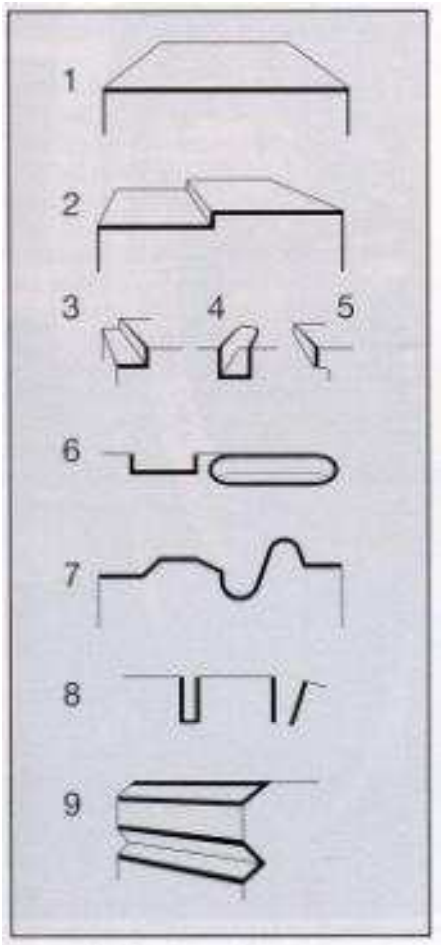




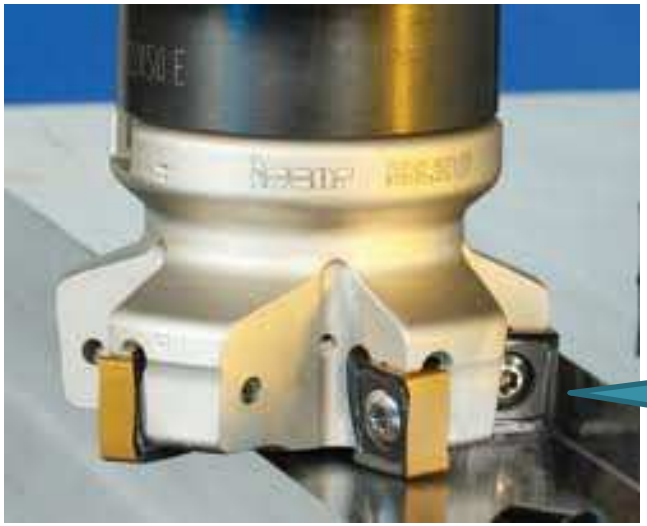
1. Plane or face milling



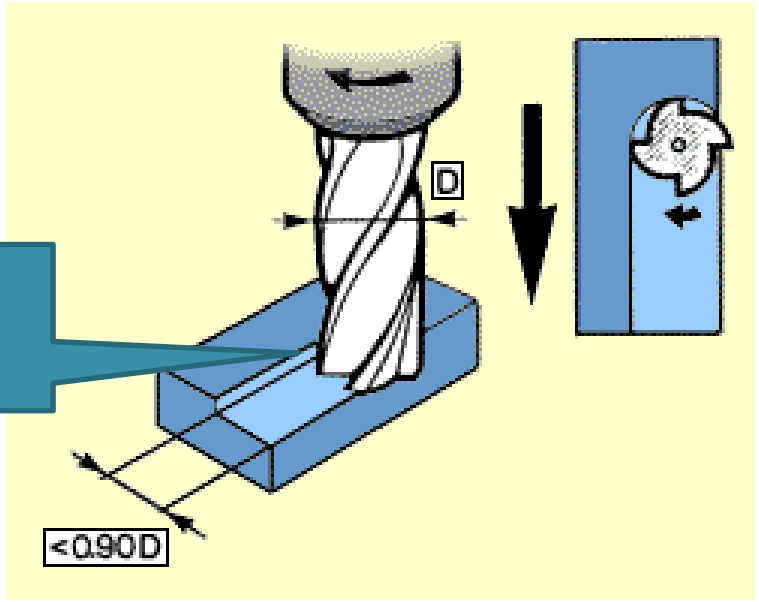
Lead angle < 90°



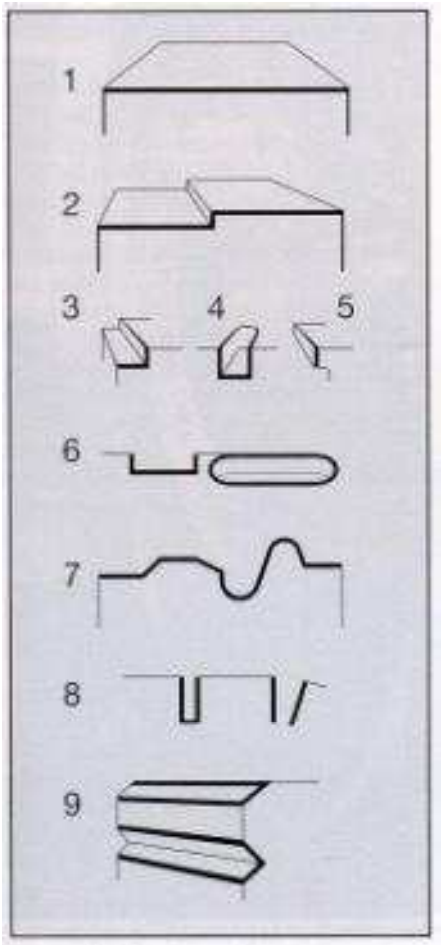
2. Shoulder milling with face mill



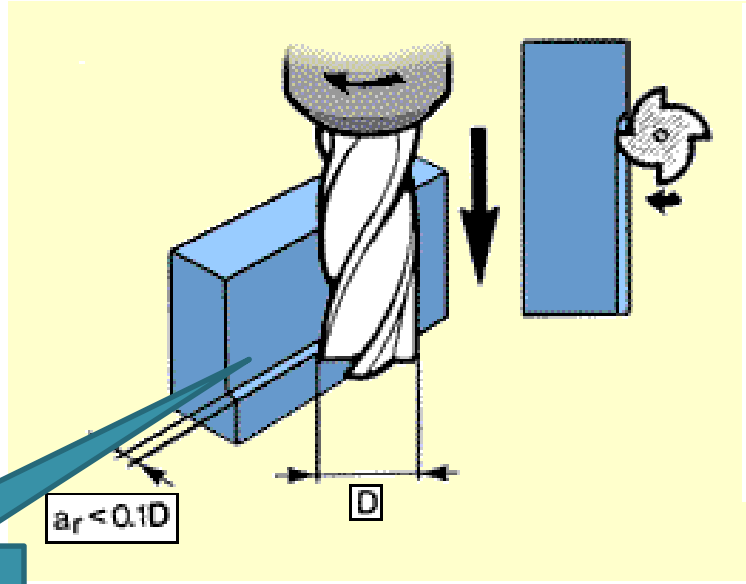
Lead angle = 90°



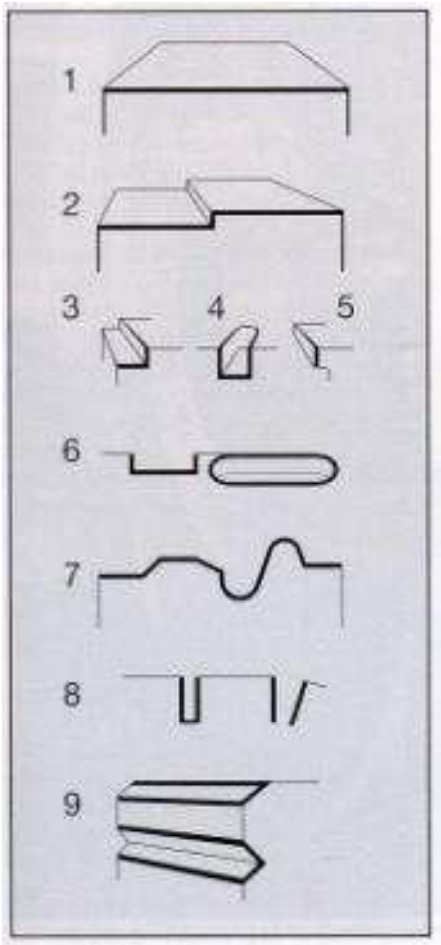
Short edge
Small a_p
Large a_e



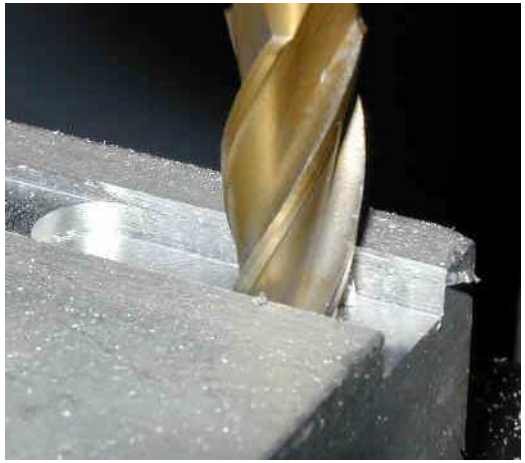
3. Shoulder milling with end mill

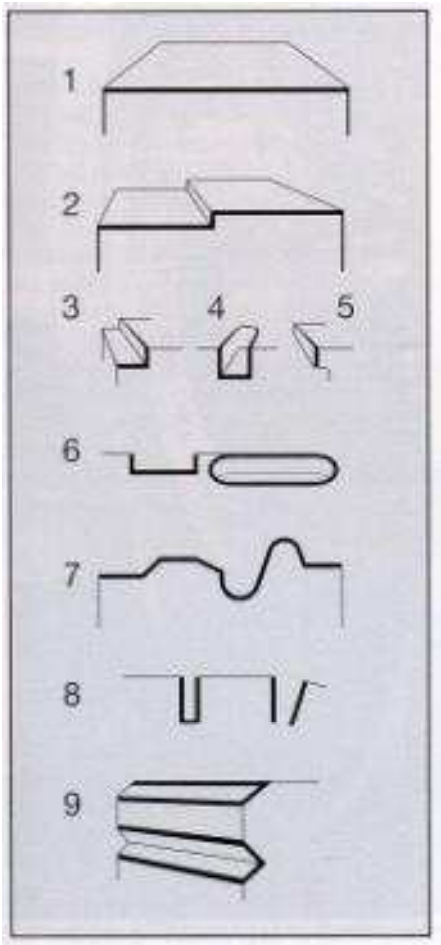


Long edge
Lagre a_p
Small a_e

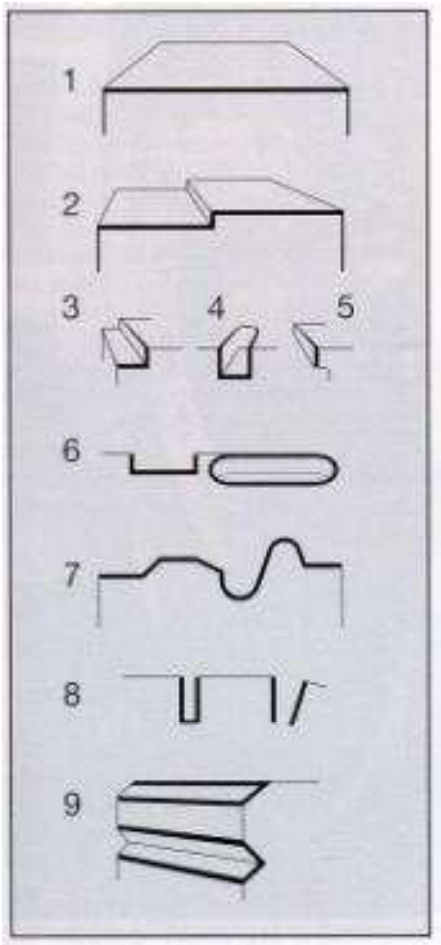


4. Groove or keyway / keyseat milling

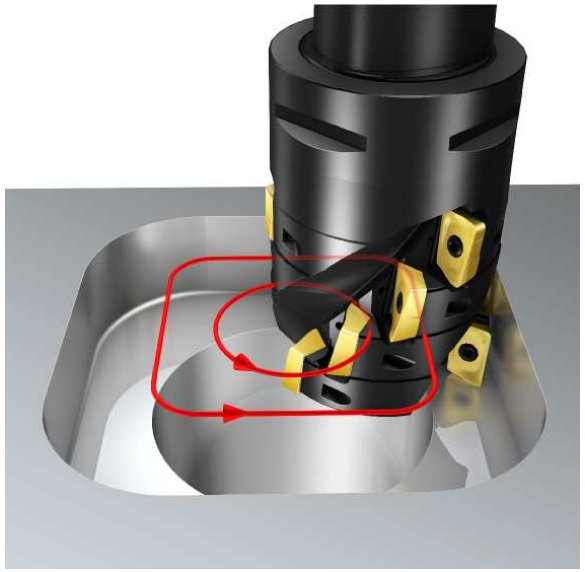


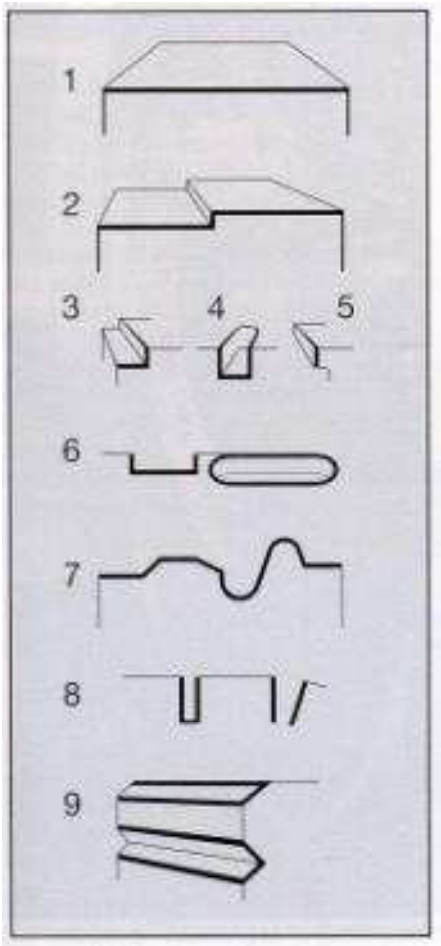


5. Edge milling

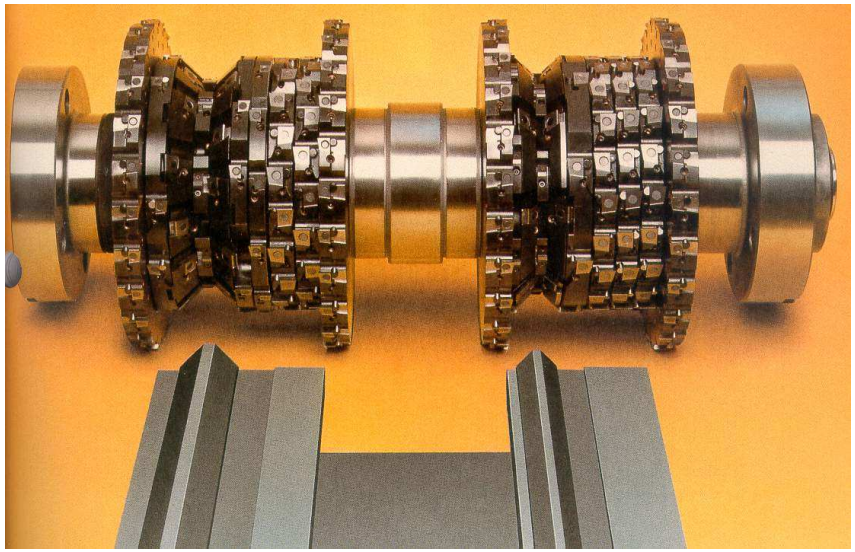


6. Pocket milling





7. Contour milling



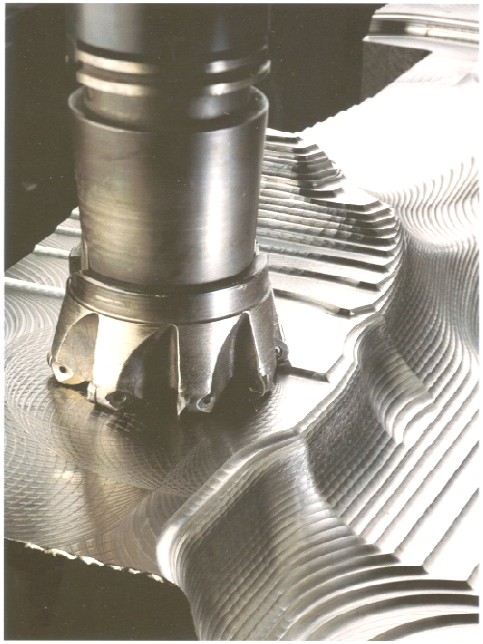
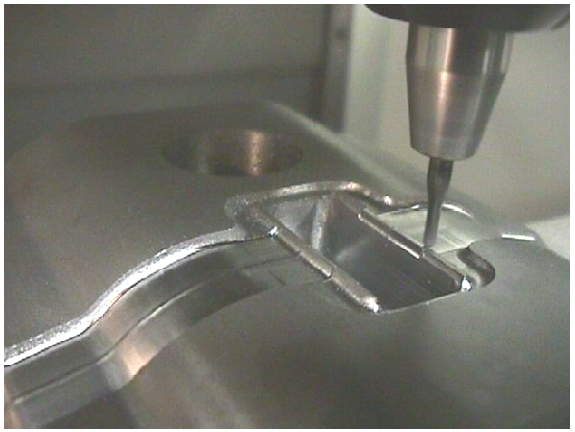
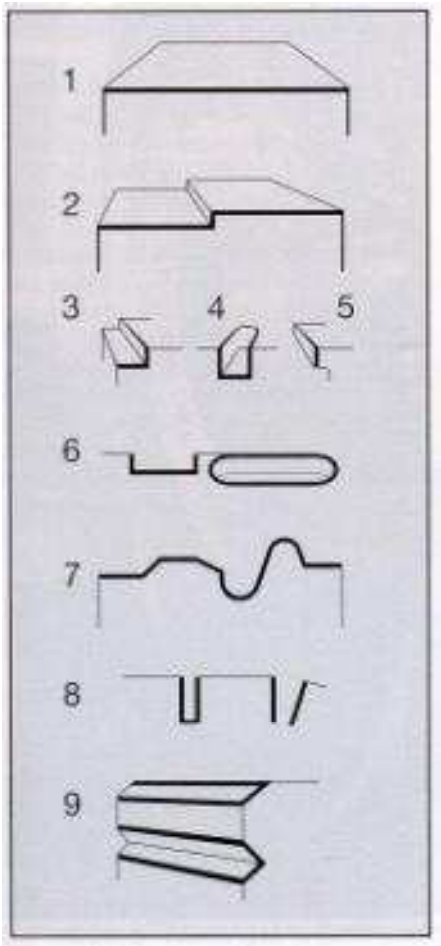
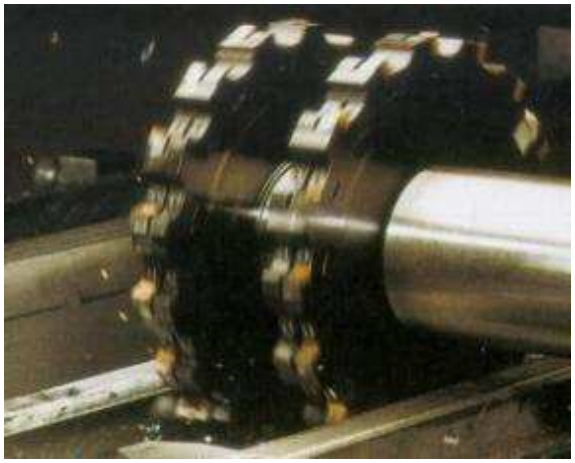


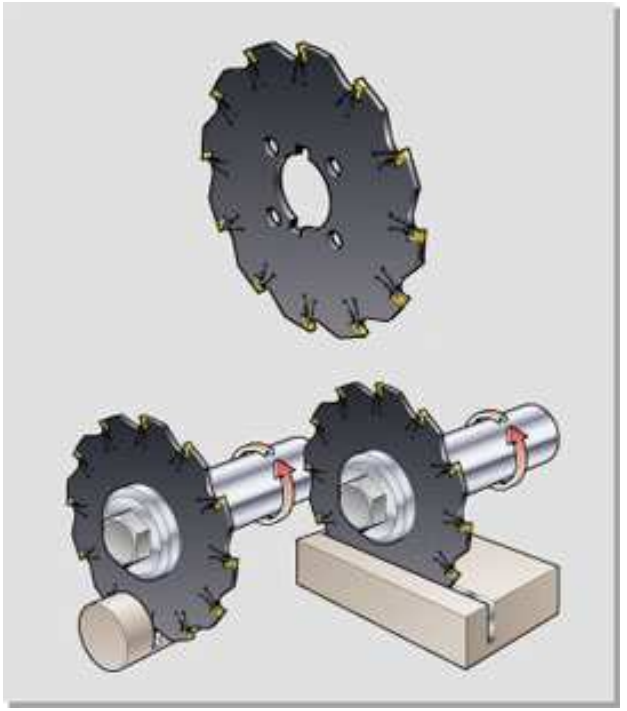
Bild 5.3: Fräsoperationen nehmen im Werkzeug- und Formenbau einen wesentlichen Stellenwert ein.

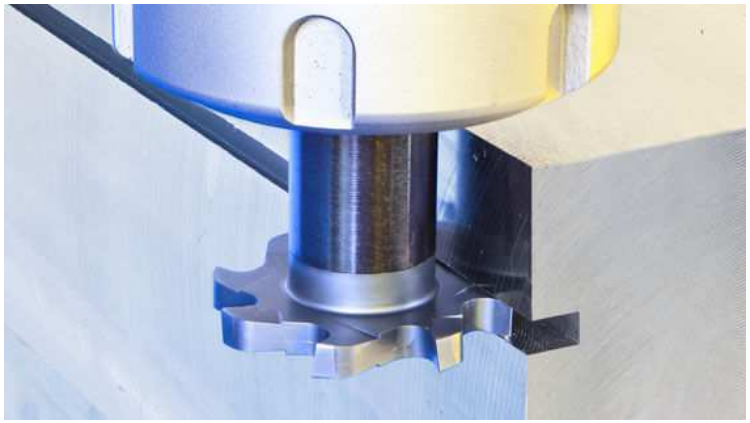


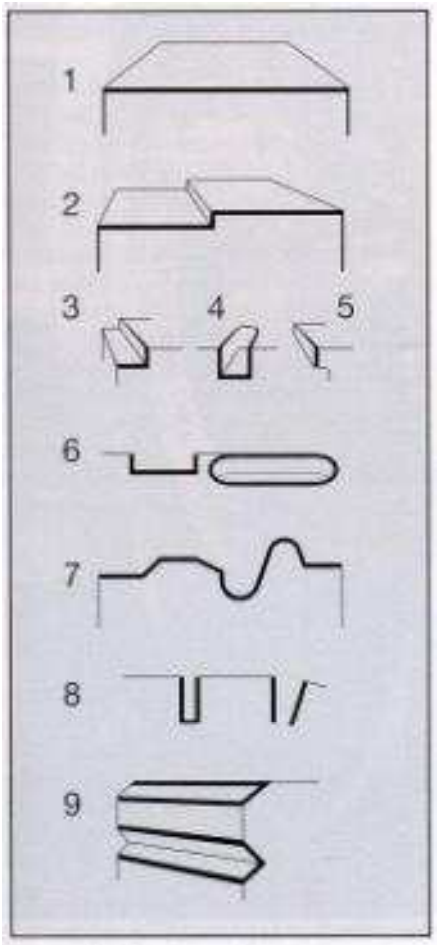


8. Slot milling and cut off

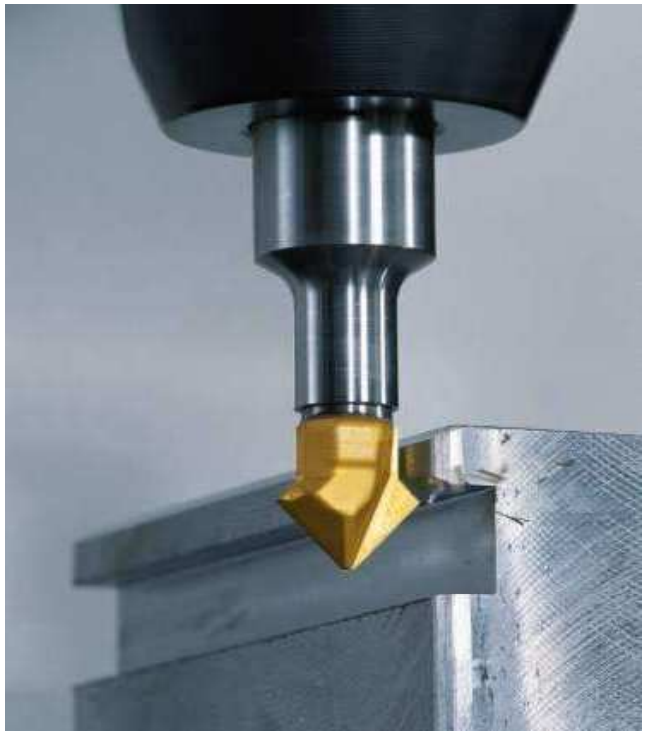




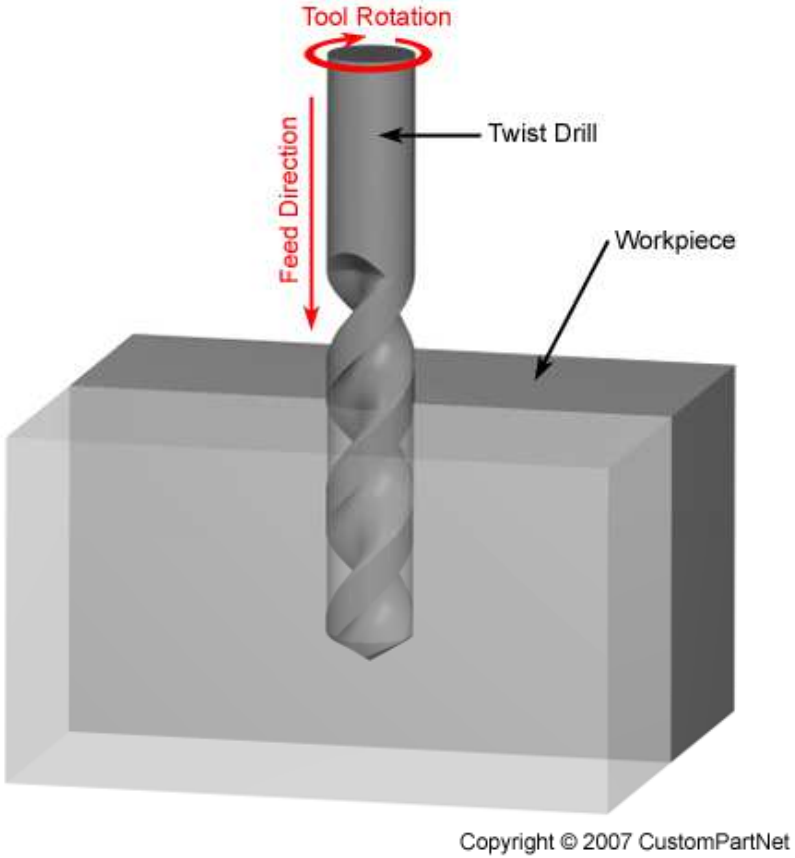


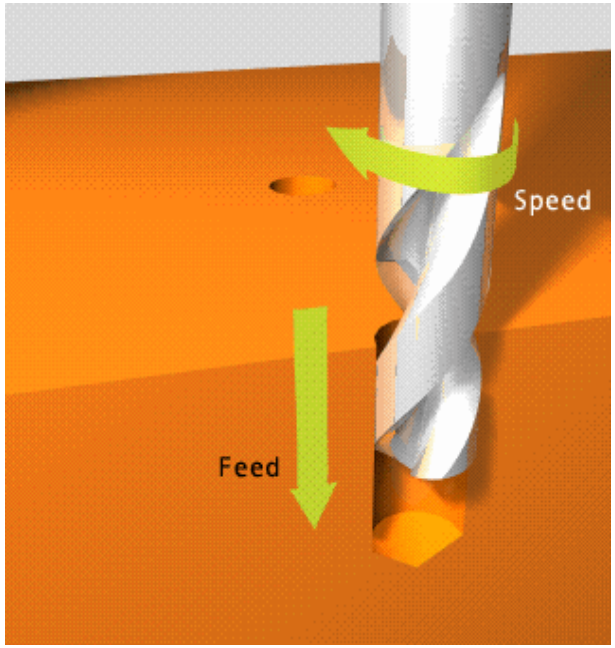


9. Chamfering



Drilling





Primary motion:
- continuous
- rotating
- tool

Feed motion:
- continuous
- tool

Ra: 3.2 – 25 µm
IT: 10 – 12
Max. diameter: 25 mm

$$v_c \Rightarrow known$$

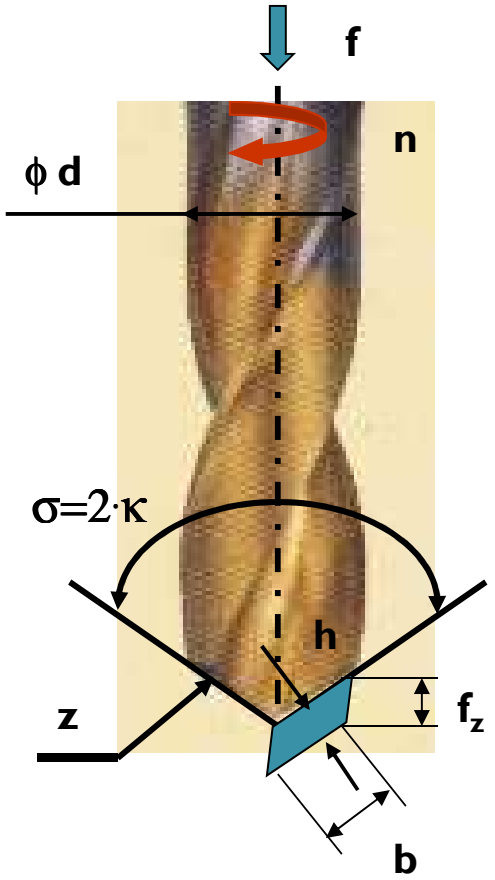
$$n = \frac{1000 \cdot v_c}{D \cdot \Pi}$$

$$f_z \Rightarrow known$$

$$f = f_z \cdot z$$

$$v_f = n \cdot f$$

$$t_c = \frac{L}{v_f} = \frac{L_{pre} + L_c \left(+ L_{post}\right)}{v_f}$$



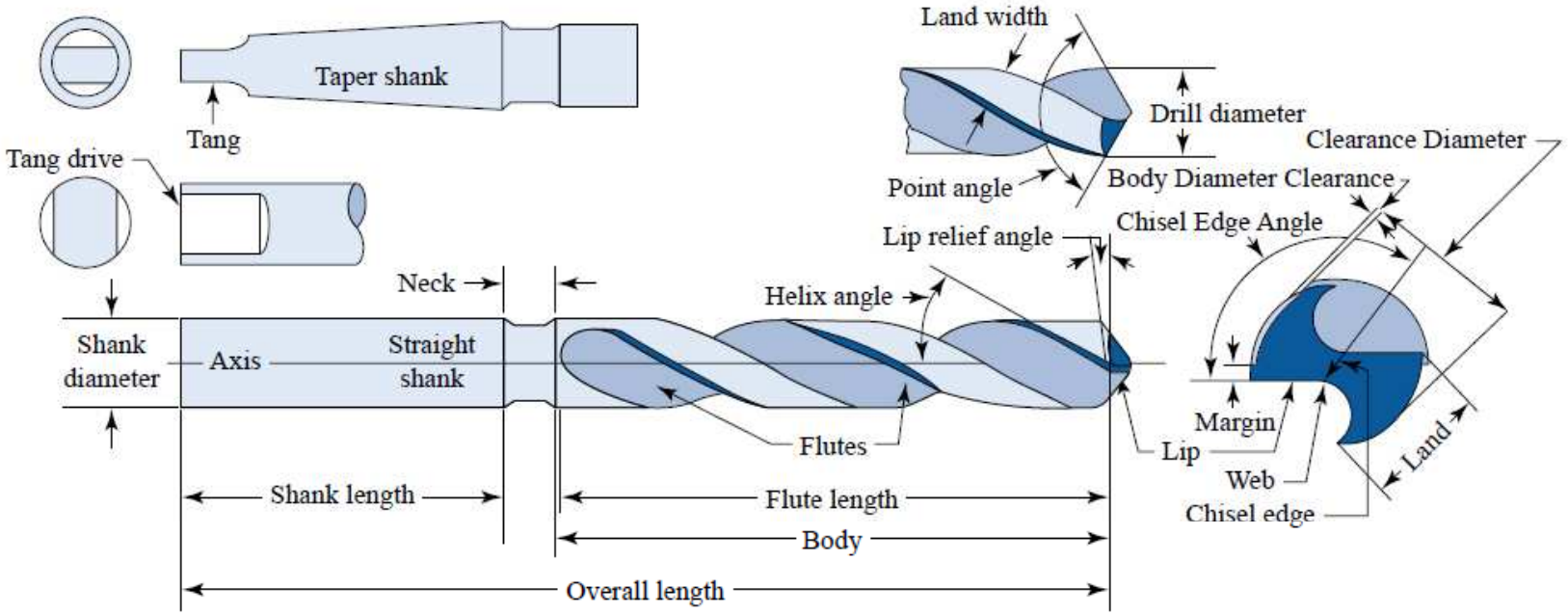
$$h = \frac{f}{2} \cdot \sin\frac{\sigma}{2} \quad [\text{mm}]$$

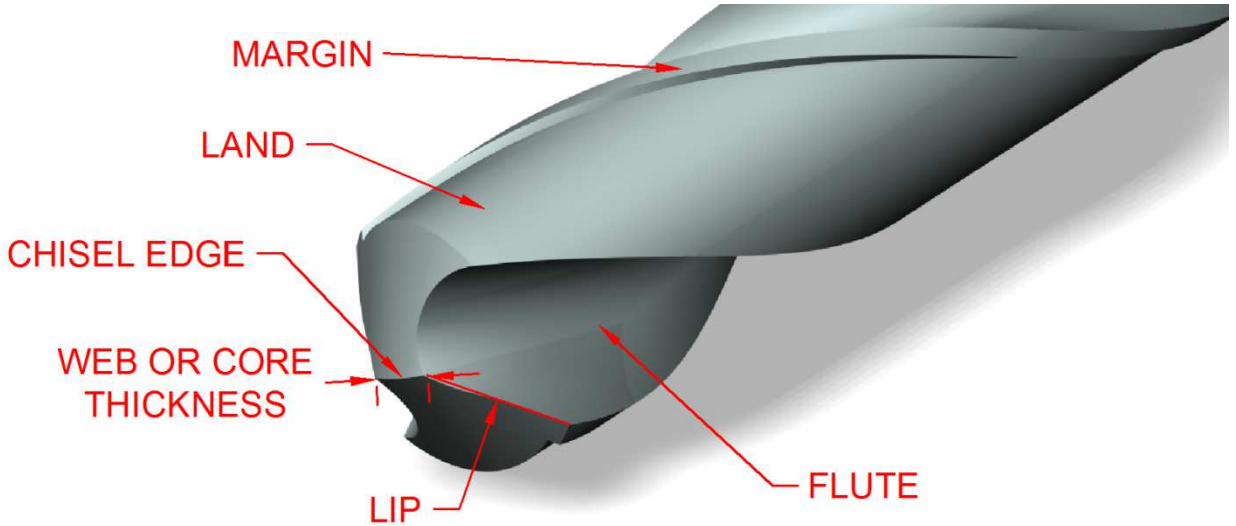
$$b = \frac{d}{2 \cdot \sin\frac{\sigma}{2}} \quad [\text{mm}]$$

σ:

118	- Steels
130	- High alloyed steels
130	- Aluminium

Twist drill


Taper shank
Tang
Tang drive
Land width
Drill diameter
Clearance Diameter
Point angle
Body Diameter Clearance
Chisel Edge Angle
Lip relief angle
Neck
Helix angle
Shank diameter
Axis
Straight shank
Flutes
Margin
Lip
Web
Land
Chisel edge
Shank length
Flute length
Body
Overall length


MARGIN
LAND
CHISEL EDGE
WEB OR CORE THICKNESS
LIP
FLUTE

Cutting force

Cutting force in one edge:

$$F_{c1} = \bar{k} \cdot A = \bar{k} \cdot h \cdot b = \bar{k} \cdot \frac{f \cdot d}{4} = \frac{k_{c1.1}}{h^{q_c}} \cdot \frac{f \cdot d}{4} \quad [\mathrm{N}]$$

Cutting force:

$$F_c = 2 \cdot F_{c1} = k \cdot \frac{f \cdot d}{2} = \frac{k_{c1.1}}{h^{q_c}} \cdot \frac{f \cdot d}{2} \quad [\mathrm{N}]$$

$$F_c = \frac{k_{c1.1}}{(0{,}5 \cdot \sin \sigma/2)^{q_c}} \cdot \frac{f^{1-q_c} \cdot d}{2} \quad [\mathrm{N}]$$

Cutting torque:

$$M_c = F_{c1} \cdot \frac{d}{2} = \frac{k \cdot f \cdot d^2}{4 \cdot 2 \cdot 1000} \quad [\mathrm{Nm}]$$

$$M_c = \frac{k_{c1.1}}{(0{,}5 \cdot \sin \sigma/2)^{q_c}} \cdot \frac{f^{1-q_c} \cdot d^2}{8000} \quad [\mathrm{Nm}]$$

Cutting power:

$$P_c = \frac{M_c \cdot n}{9550} \quad [\mathrm{kW}]$$

Hole making operations

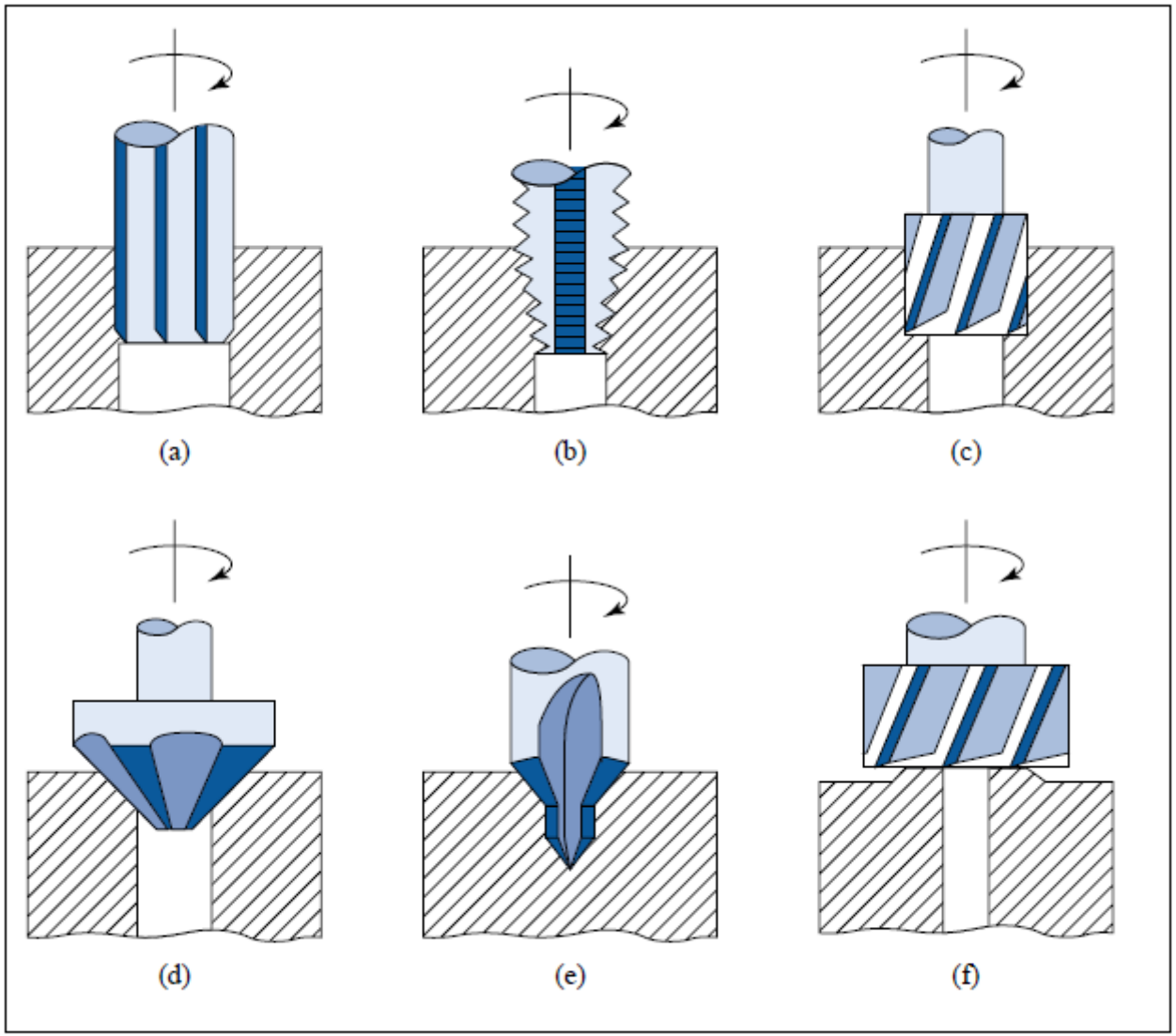
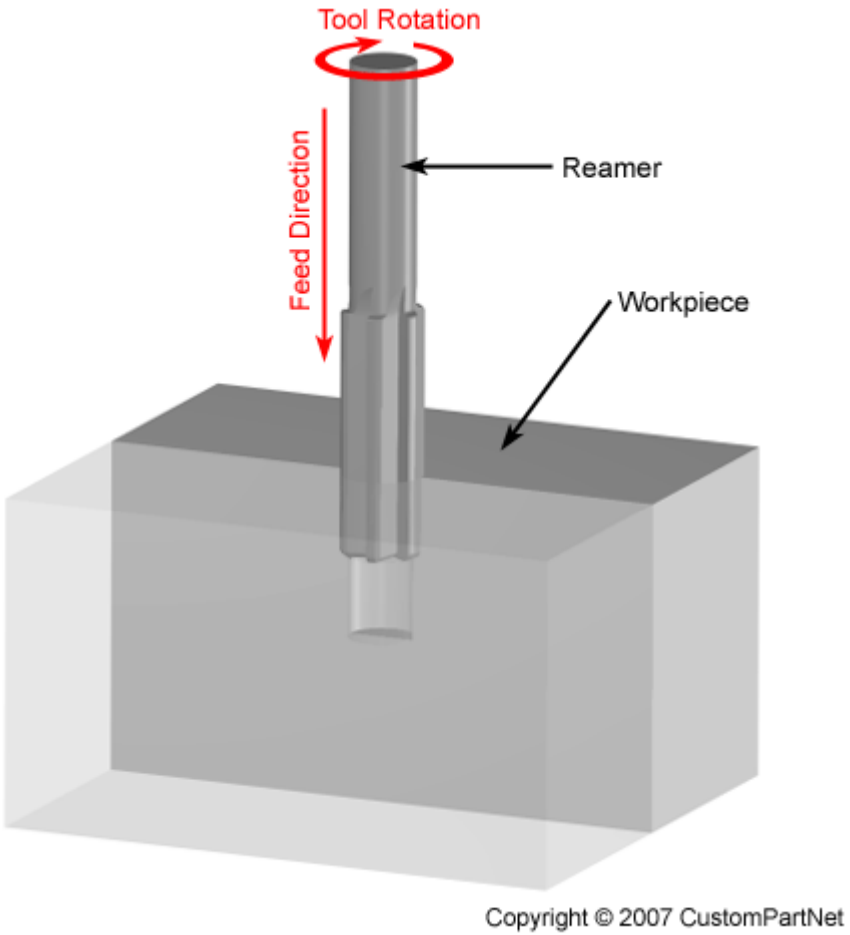
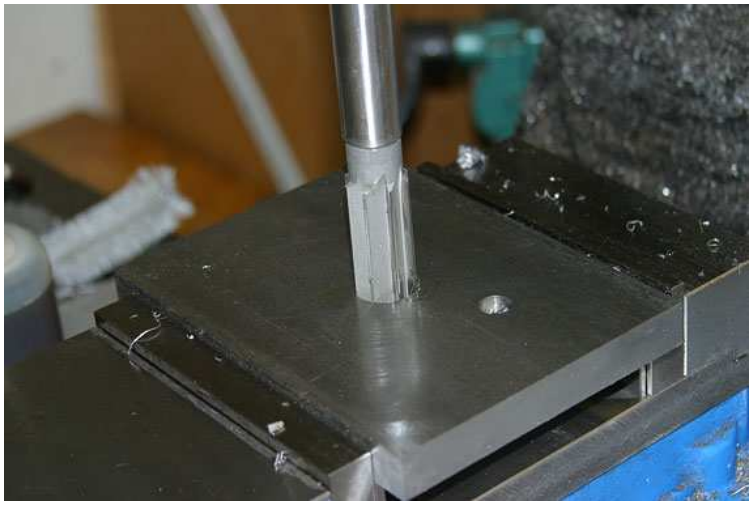


FIGURE 8.7: Related drilling operations: (a) reaming, (b) tapping, (c) counterboring, (d) countersinking, (e) centering, (f) spotfacing.

Reaming





Primary motion:
- continuous
- rotating
- tool

Feed motion:
- continuous
- tool

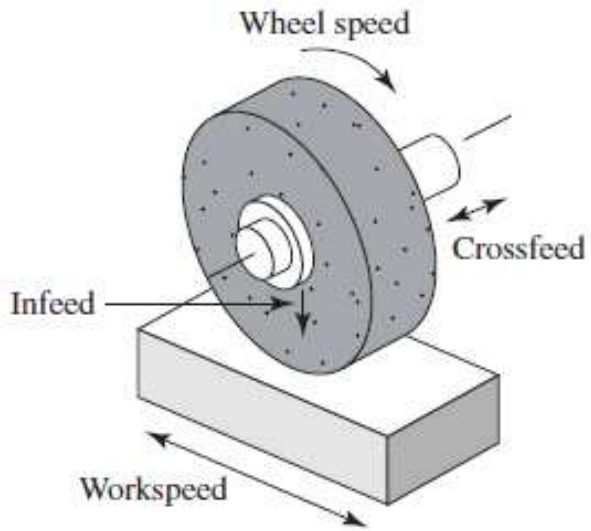
Ra: 0.2 – 1.6 µm
IT: 6 – 7
Max. diameter: 30 mm

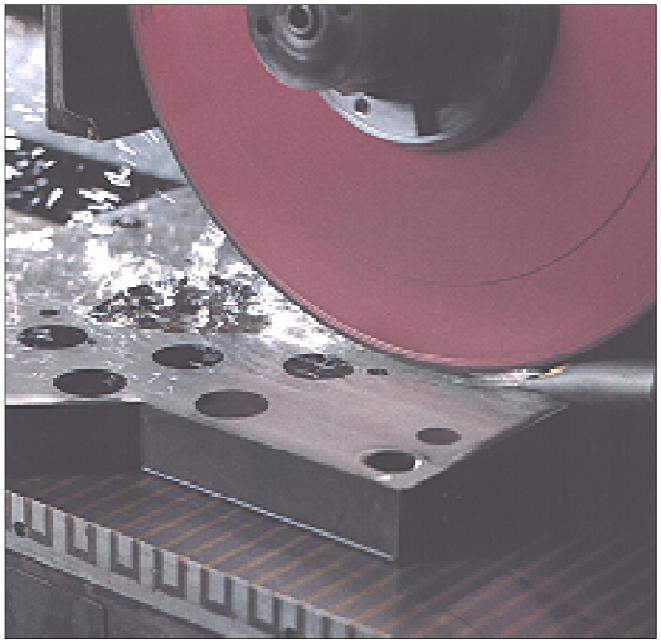
HSS reamer with taper shank

HSS TiN coated reamer with taper shank

HM TiN coated assembled reamer with cylindrical shank

Surface grinding



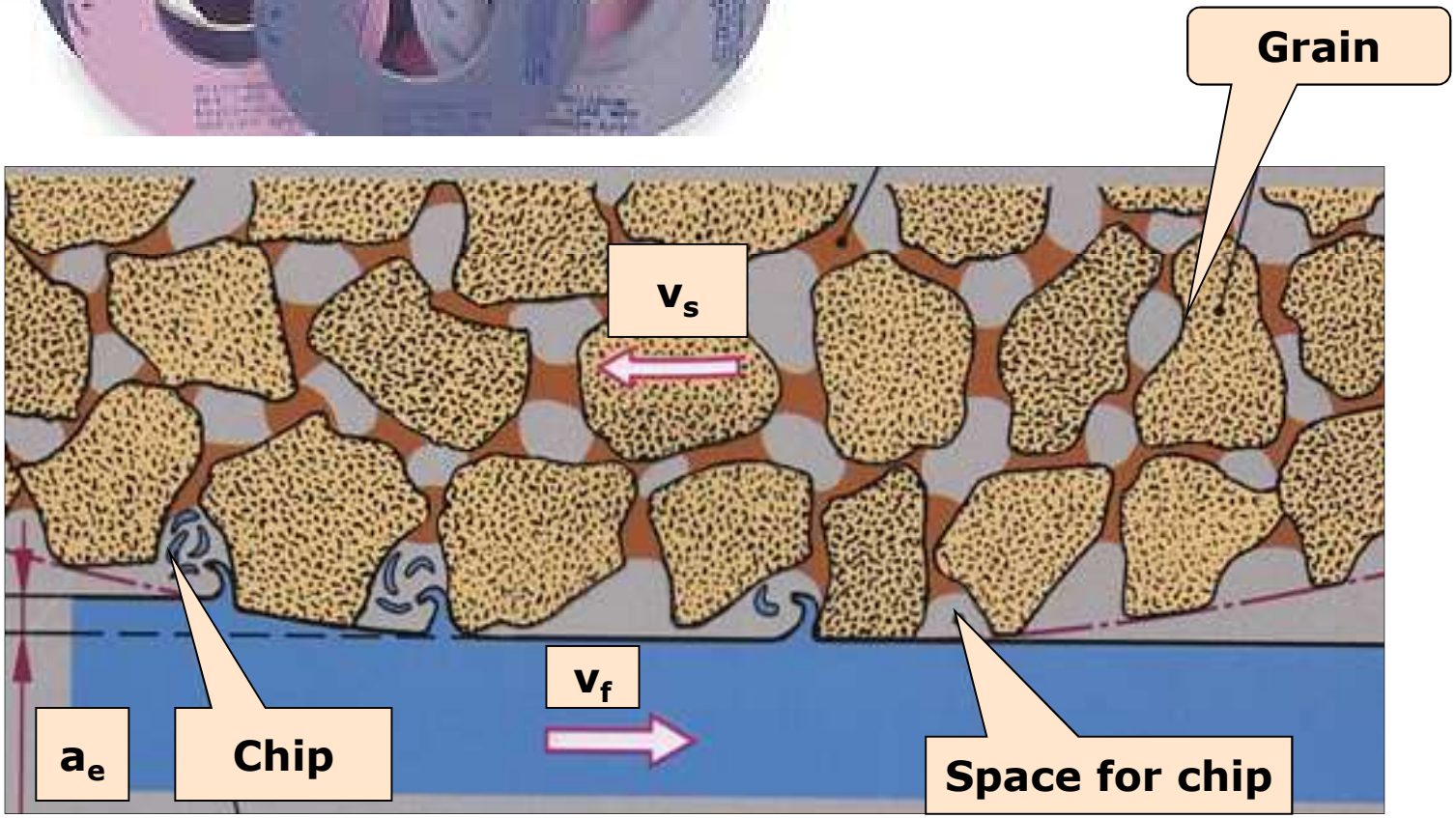


Primary motion:
- continuous
- rotating
- tool

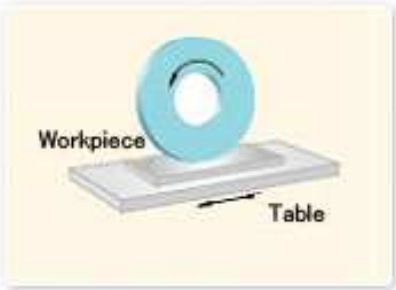
Feed motion:
- periaodical
- tool or workpiece

Ra: 0.1 – 0.8 µm
IT: 3 - 6


NORTON
NORTON
NORTON
NORTON
NORTON


Grain
v_s
v_f
a_e
Chip
Space for chip

- Surface grinding
  - Straight wheel
    - Horizontal spindle reciprocating table
    - Horizontal spindle rotary table
  - Cups · Cylinders · Segments
    - Vertical spindle reciprocating table
    - Vertical spindle rotary table
    - Horizontal spindle reciprocating table
  - Disc wheels (Double disc surface grinding)
    - Through feed type
    - Carrier type

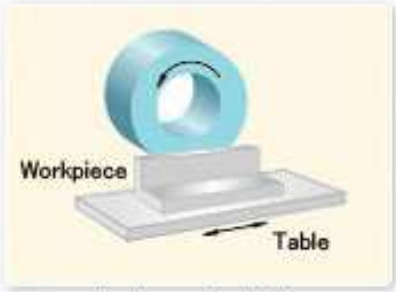


Horizontal spindle reciprocating table

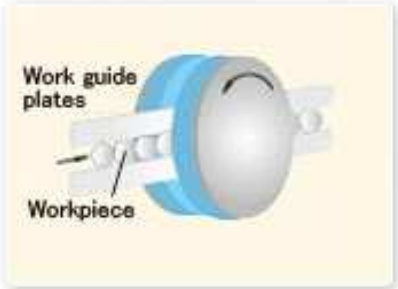
Horizontal spindle rotary table

Vertical spindle rotary table

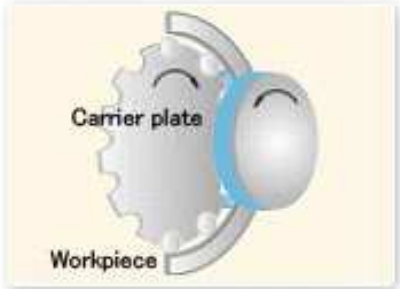
Vertical spindle reciprocating table



Horizontal spindle reciprocating table

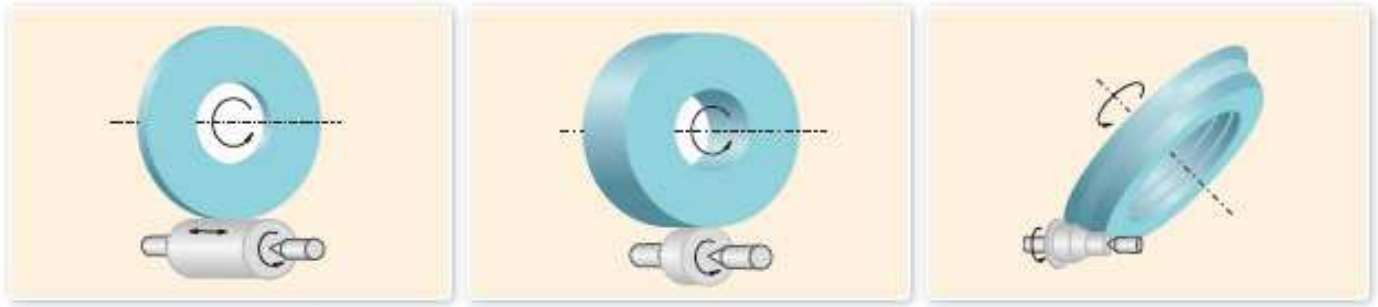


Through feed type



Carrier type

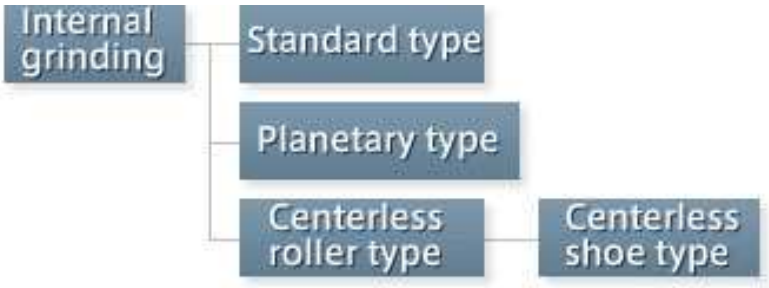
- Cylindrical grinding
  - Traverse grinding
  - Plunge grinding
    - Angular slide grinding



Traverse grinding　　Plunge grinding　　Angular slide grinding

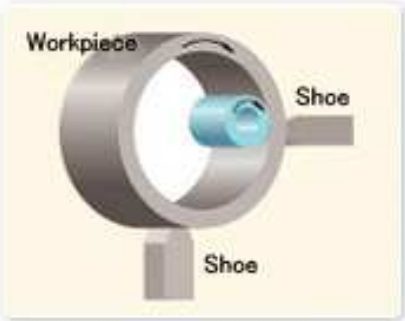
- Centerless grinding
  - Through feed grinding
  - Infeed grinding
  - Tangential feed grinding

Through feed grinding　　Infeed grinding

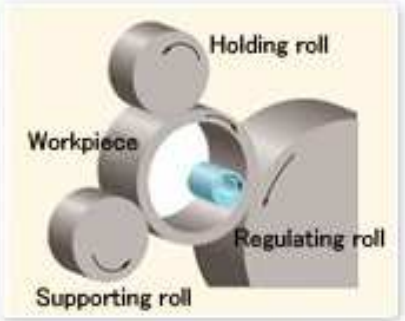


Standard type

Planetary type
(revolving grinding wheel axis)

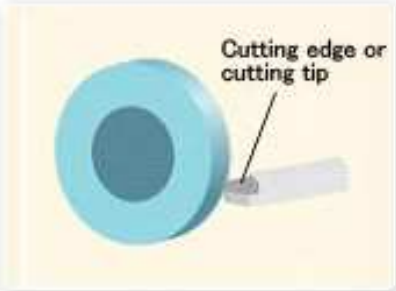


Centerless shoe type



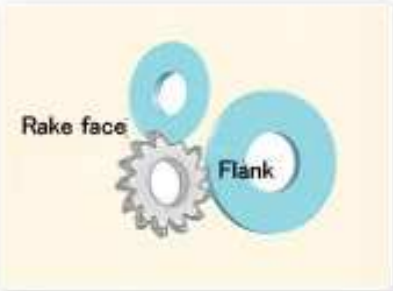
Centerless roller type

Tool grinding — Turning tool, Drill, Milling, Hob, Broach, Pinion cutter, End mill

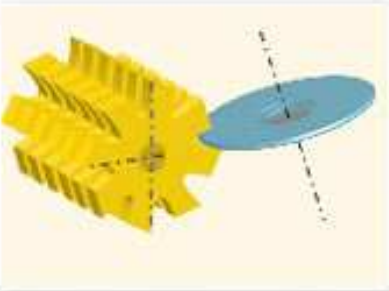


Turning tool grinding

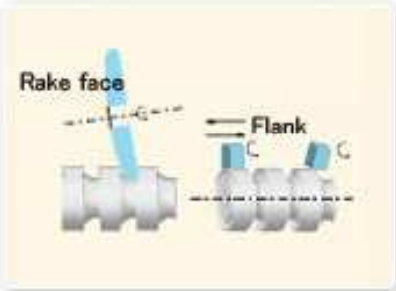
Drill grinding



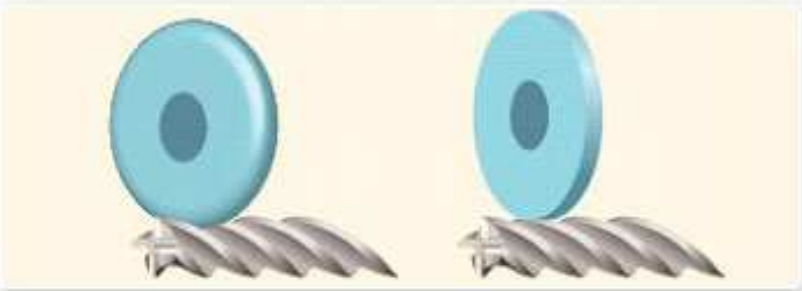
Milling cutter grinding



Hob grinding



Broach grinding



End mill grinding

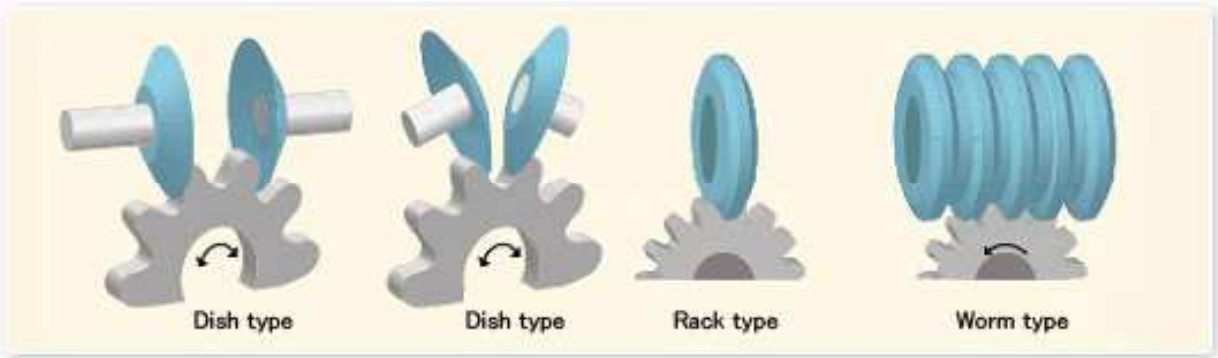
Machinery parts & other grinding

- Roll grinding
- Crank grinding
- Cam grinding
- Gear grinding
- Thread grinding

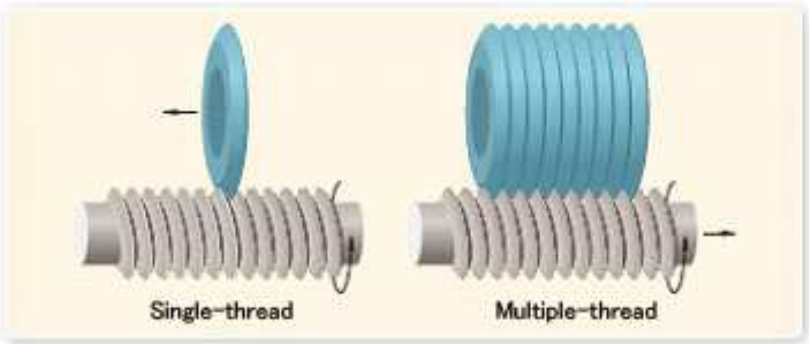
Roll grinding

Crankshaft grinding

Camshaft grinding

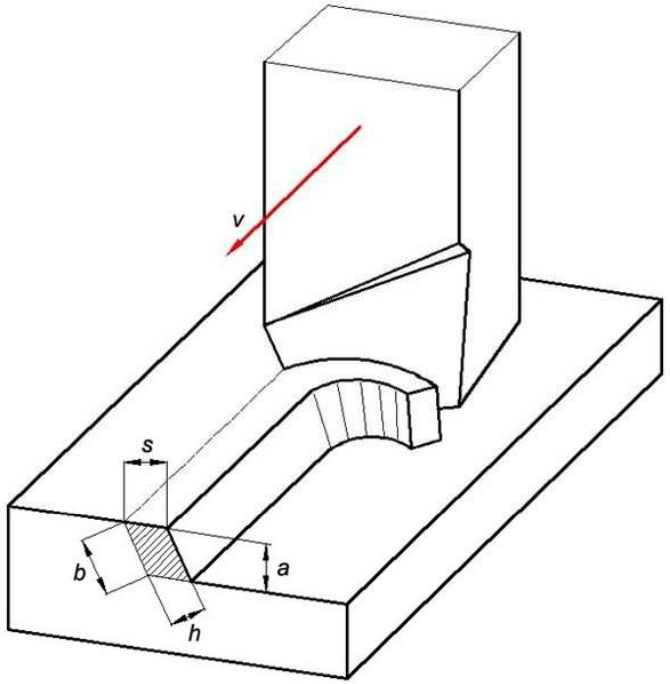


Gear grinding



Thread grinding

Planing



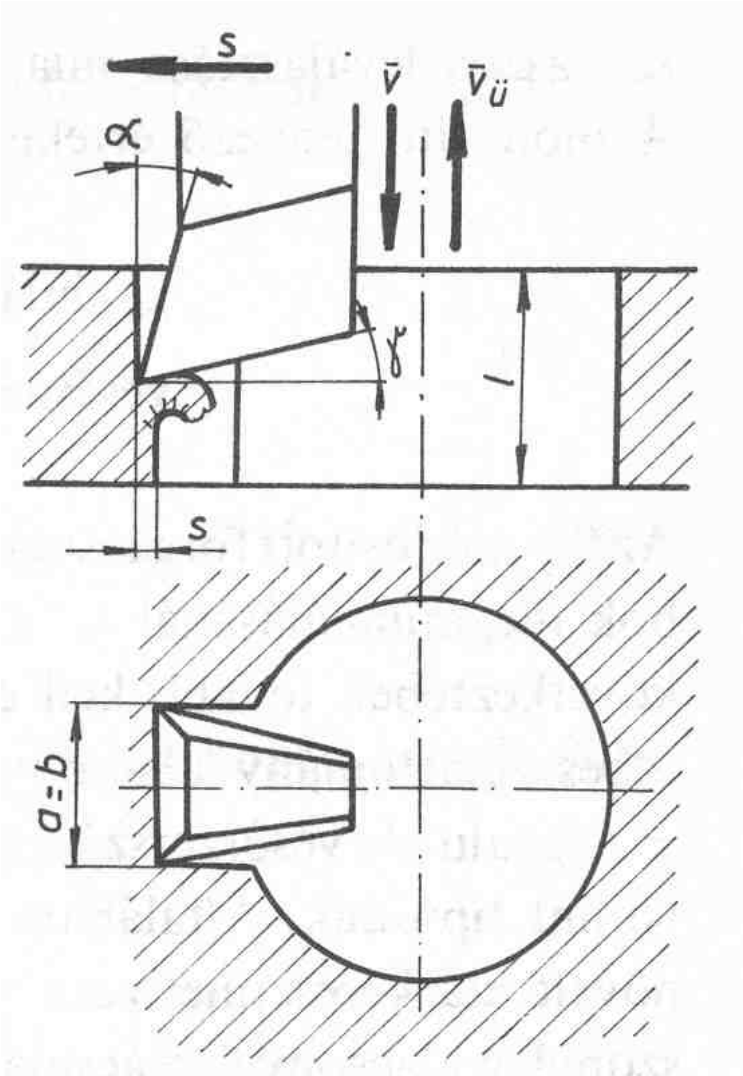
Primary motion:
- periodical
- linear
- tool OR workpiece

Feed motion:
- periaodical
- workpiece

Ra: 0.8 – 3.6 µm
IT: 9 - 12

(Turning, D = ∞)

Shaping

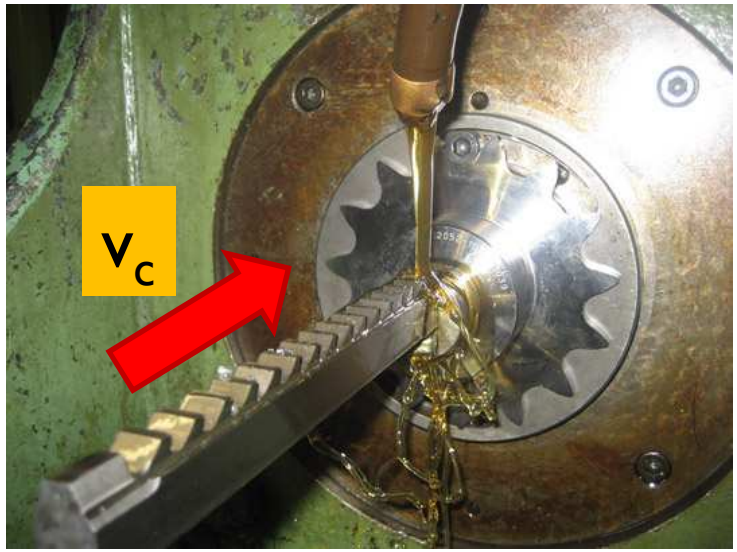


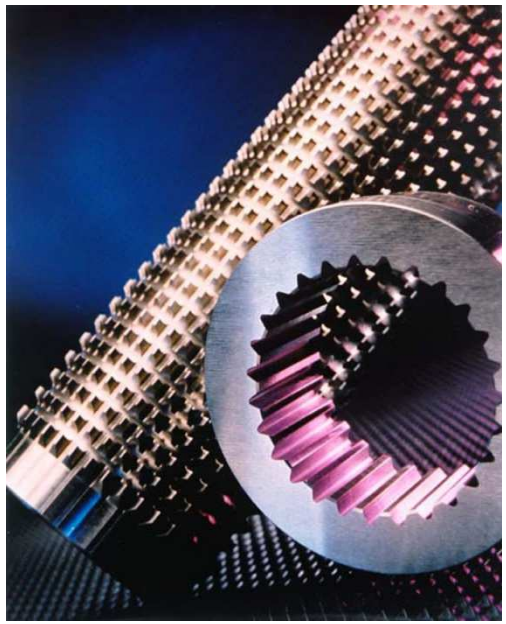
Primary motion:
- periodical
- linear
- tool

Feed motion:
- periaodical
- tool

Ra: 0.8 – 3.6 μm
IT: 9 - 12

Broaching

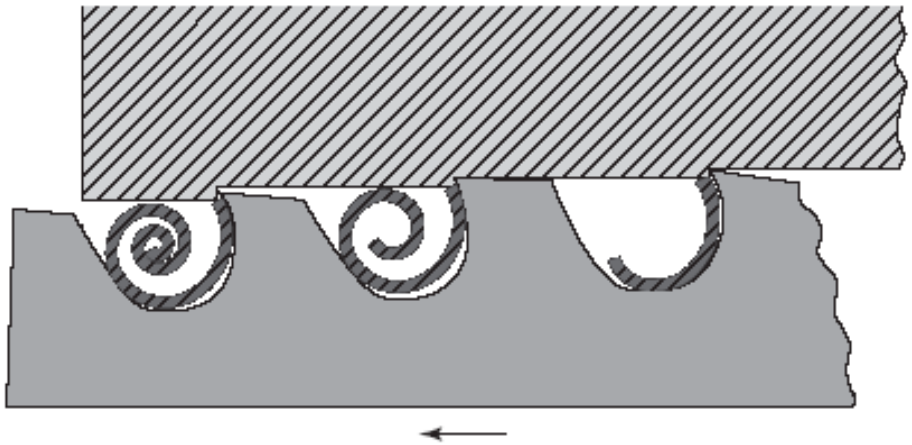


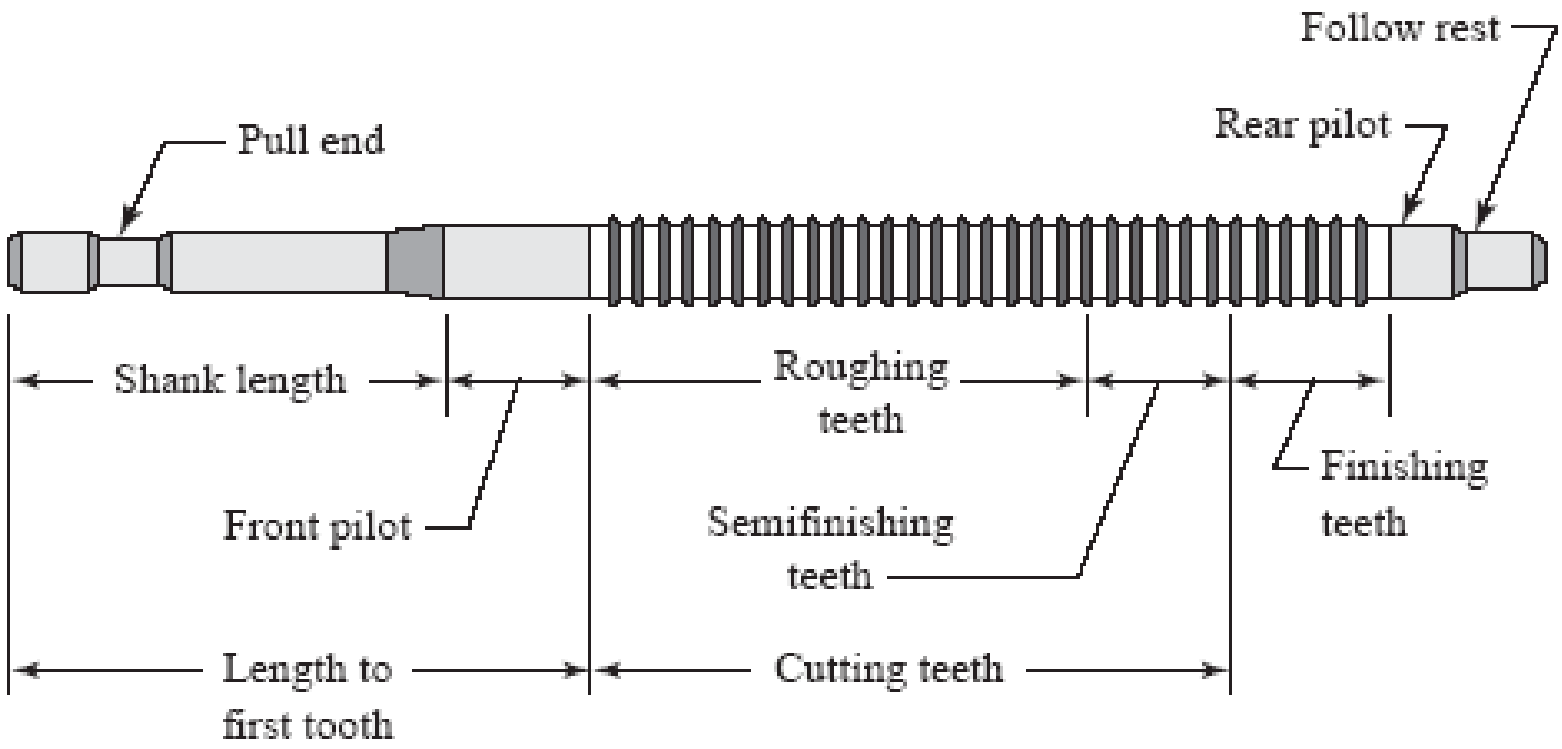


Primary motion:
- continuous
- linear
- tool

Feed motion:
- „periodical”
- tool

Ra: 0.2 – 0.8 µm
IT: 7 - 9




Follow rest
Rear pilot
Pull end
Shank length
Roughing teeth
Finishing teeth
Front pilot
Semifinishing teeth
Length to first tooth
Cutting teeth

	Primary motion			Feed motion	
Turning	Rot	Cont	WP	Cont	Tool
Milling	Rot	Cont	Tool	Cont	Tool/WP
Drilling	Rot	Cont	Tool	Cont	Tool/WP
Reaming	Rot	Cont	Tool	Cont	Tool/WP
Grinding - Plane	Rot	Cont	Tool	Per	WP
Grinding - Cylindrical	Rot	Cont	Tool	Cont/Per	Tool/WP
Planing	Lin	Per	Tool	Per	Tool
Shaping	Lin	Per	Tool	Per	Tool
Broaching	Lin	Cont	Tool		