ME338 – Manufacturing Process II

Lecture 1 : Overview of Machining Processes

Prof. Pradeep Dixit

Course Objective and Text Books

- Understanding of Material Removal Processes and Metrology
  - Basic mechanism of Machining, Single point cutting tool, Tool life
  - Conventional contact-based processes: Turning, Grinding, Milling
  - Non-conventional machining : USM, ECM, EDM, Laser etc
- Text Book:
  - Manufacturing Processes for Engineering Materials, S. Kalpakjian and S. R. Schmid, 4th edition; Prentice Hall, 2003: Chapter 4, 9, 10
  - Manufacturing Science, A. Ghosh and A. Mallick, 2nd edition
  - Engineering Metrology: RK Jain
- Reference:
  - Fundamentals of Machining and Machine Tools, G. Boothroyd and W.A. Knight. 2nd edition, Marcel Dekker, Inc., 1989.

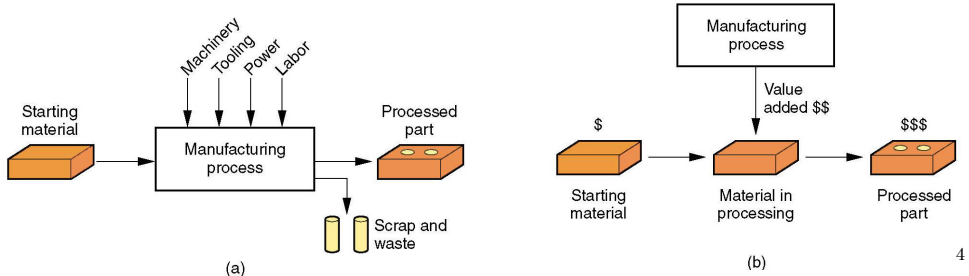
Grading Policy

- Slot 4 (Mon: 11:30-12:30, Tue: 8:30 – 9:30, Thu: 9:30 – 10:30)
- Multiple Quizes : 10%
- Project/Term paper: 20% (group project
- Home assignment: 10% (group assignment)
- Midsem + End-semester exam: 60% (20% Midsem + 40% Endsem)

- Please form a team of 4 persons
  - Will be same for assignments and projects
- Minimum attendance > 80% required for appearing in end-sem exam
- Lecture slides will be provided in advance
- If any doubt, you can contact me any time:
  - S11 office, ME department,7393 (ext), 9819707393 (m)
  - Electrochemical Microfabrication lab (on library road)

What is Manufacturing ?

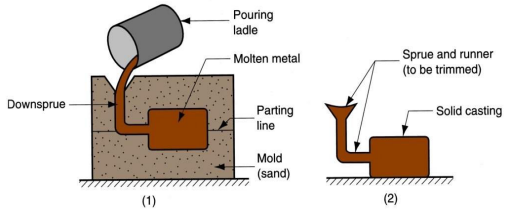
- Application of physical and chemical processes to change the geometry, properties, and appearance of a starting material to make parts or products for a given application
- Manufacturing results in transformation of materials into items of greater value
  - Profit is achieved by minimize defects and increasing yield
- Manufacturing : Man (woman), Machine, Materials, Money and Management
  - Controlling the five M's is the key behind successful (profitable) manufacturing
- Materials: metal, non-metals, plastic, ceramic, composite



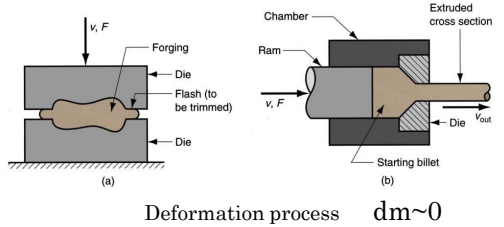
Classification of Manufacturing Processes

- Materials: Metals, ceramic, polymers, composites
  - This course will deal with metals only
- Shaping operations - alter the geometry of the starting work material
  - Metal casting, forming, machining, joining processes
  - Machining : Conventional (turning, milling, drilling),
  - Non-conventional (ECM, EDM, Laser ablation etc)
- Property-enhancing operations - improve physical properties of the material <u>without changing its shape</u>
  - Annealing, hardening..
- Surface processing operations - clean, treat, coat, or deposit material onto the exterior surface of the work
  - Surface oxidation

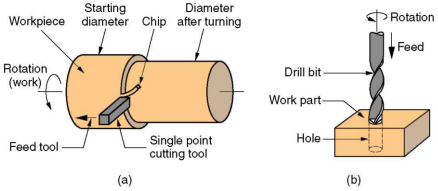
Shaping Processes – Main Categories



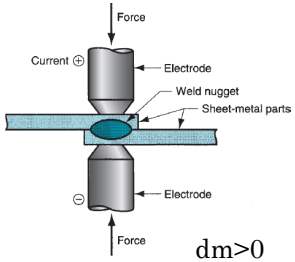
Solidification process dm~0



Deformation process dm~0



Metal removal processes dm<0



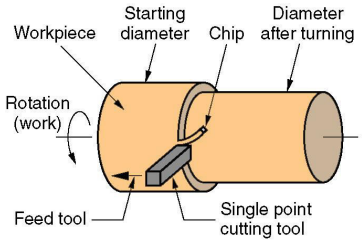
dm>0

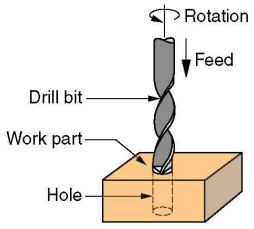
Assembly process: Welding

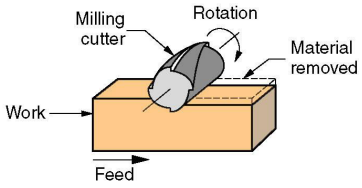
Further sub-classification is possible based on processing energy and workpiece state considerations

Material Removal Processes

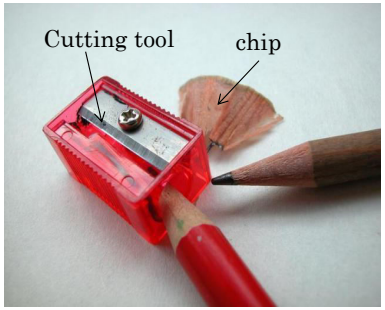
- Excess material removed from the starting work piece so what remains is the desired geometry
- Two types: Based on contact between tool and work piece
  - Direct contact : turning, drilling, and milling, grinding
  - Non-contact: Non-traditional methods ECM, EDM, USM
- Direct contact is the most popular (>90% high MRR)
  - Tool hardness > work piece hardness. Physical contact
- Material removal is expensive process because more energy is consumed, and also a lot of waste material is generated in the process





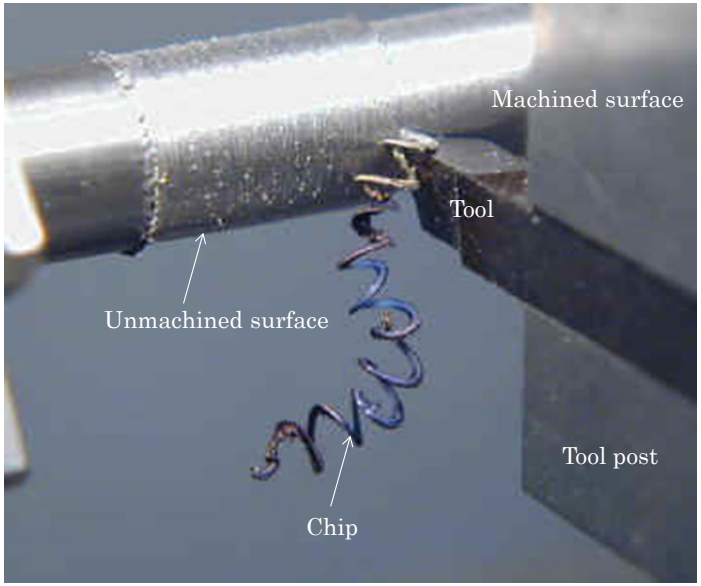


Machining during school time ?



- What did we learn from our school time ?
  - Effective machining process for wooden pencil
- Can we use plastic pen instead of wooden pencil ? How about metal rod?
- What if the blade is not sharp? Need more efforts
- Workpiece must be softer than blade material.
  - What should be the ratio of tool hardness to workpiece hardness
- Blade edge must be sharp (to reduce the cutting effort)

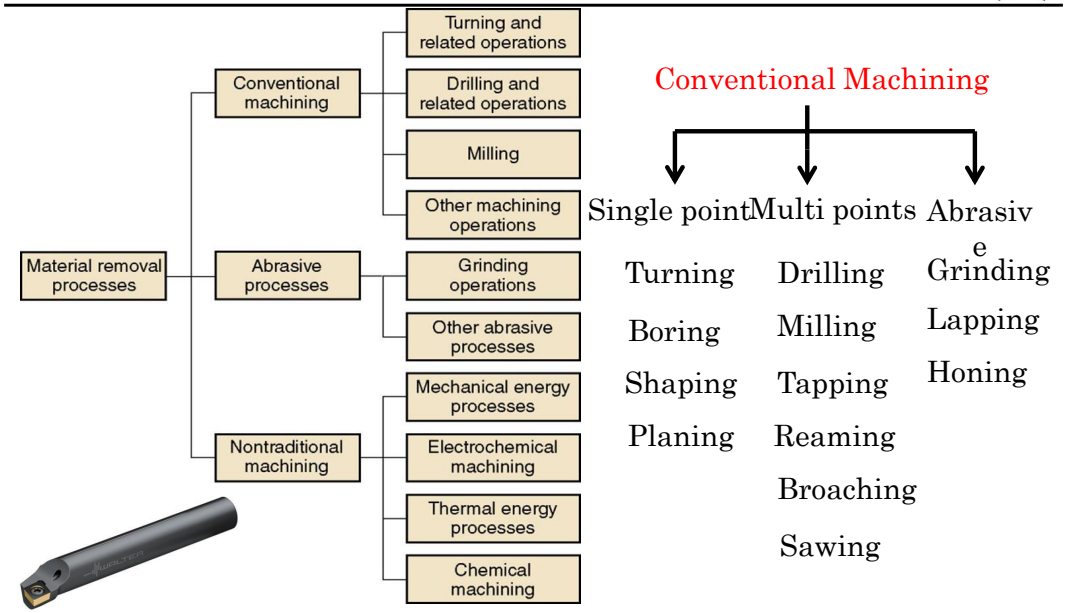
Machining Process in IIT B' workshop



Single point cutting tool - video

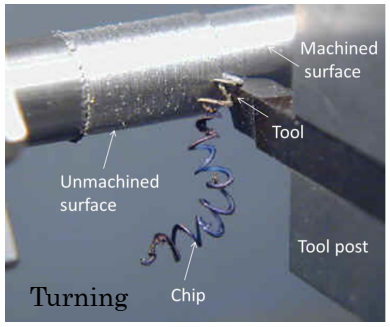
https://www.youtube.com/watch?v=H0AyVUfl8-k&list=PLff2PAVk5xaxcIz93_xgC30yFa03w0loa

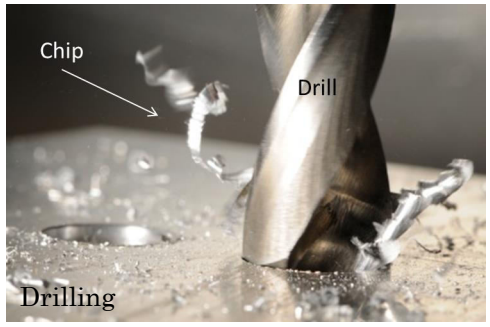
Various machining process

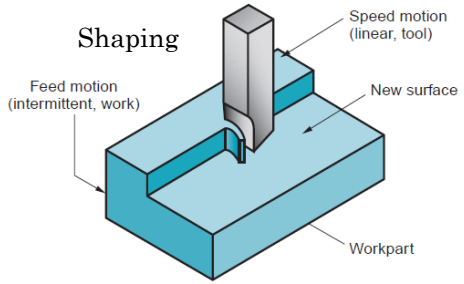


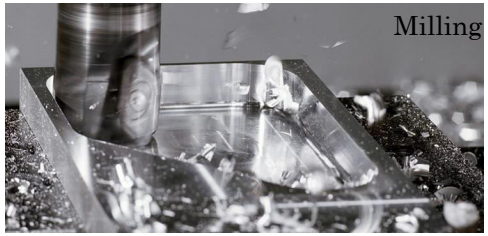
Single/Multi point operations involve geometrically well defined cutting edges; However abrasive operations have random cutting edges

Conventional Machining Processes



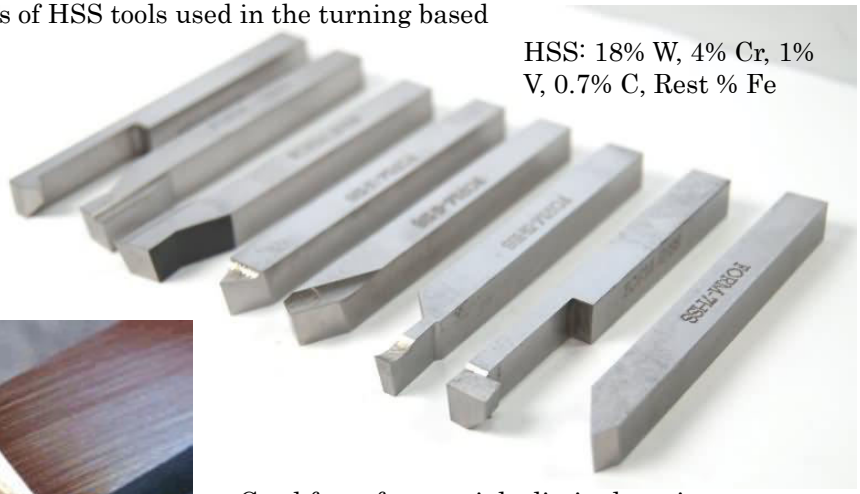




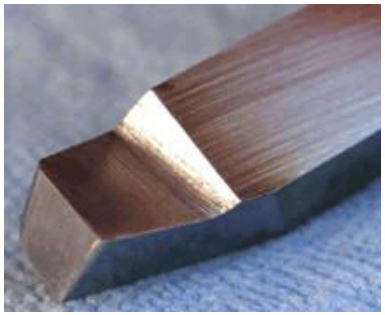


Cutting tool – HSS tool

Different types of HSS tools used in the turning based processes

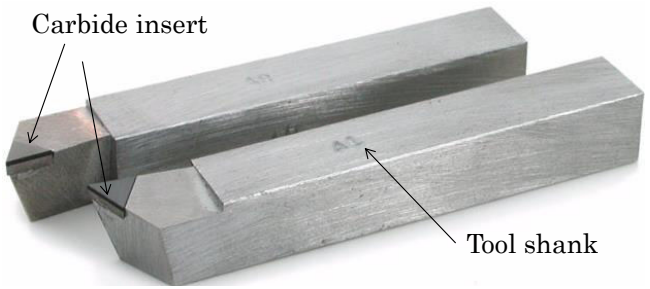


HSS: 18% W, 4% Cr, 1% V, 0.7% C, Rest % Fe



- Good for soft materials, limited cutting speed
- High tool wear, Need to sharpen by grinding wheel
- Required tool angles are created by the grinding process

Carbide brazed tipped single cutting tool



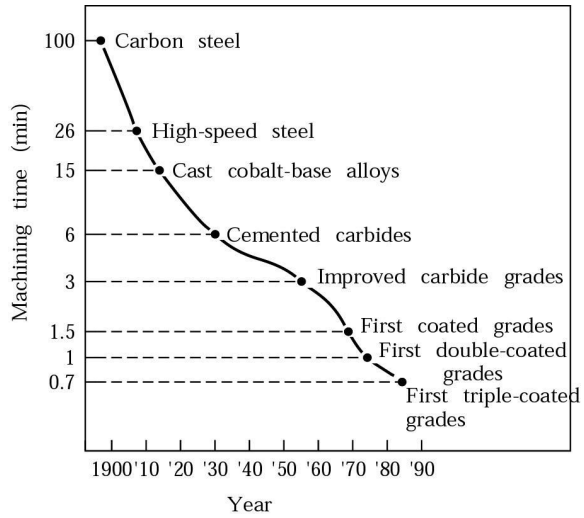
- WC: A fine gray powder, Pressed and sintered into various cutting shapes
- Carbide insert is attached to tool shank by brazing (permanent joining)
  - >2 times stiffer than steel, Young's modulus 530–700 GPa
- Due to WC, Highly abrasion resistance, temperature resistance,
- Used in machining hard materials at higher speed, less tool wear than HSS

Insert cutting tool – PCD

Insert is mounted on tool shank

Cutting tool materials

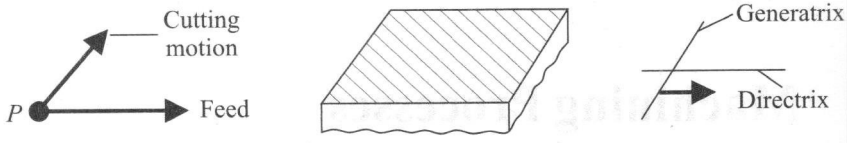
- Steel: Alloy of Fe and C
- Steel: upto 2% C,
- LCS: < 0.3% C
- MCS: 0.3 – 0.6% C
- HCS : 0.6-1.7% C
- Cast-iron: 2- 6% C
- HSS: 18% W, 4% Cr, 1% V, 0.7% C, Rest % Fe
- Ceramics: Alumina, SiO2
  Carbide: WC
- Cemented carbide: WC + Co



How is the machined surface generated

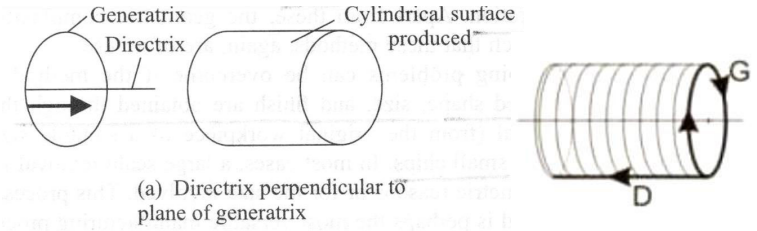
- Final machined surfaces can be planer (as in shaping), cylindrical (turning), tapered or free form
- Desired machined surface is obtained by combination of cutting motion and feed motion
  - Cutting motion : for material removal
  - Feed motion : for providing new (fresh) surface to be cut
- Generatix: Lines generated by the cutting motion of the tool
- Directrix: Lines generated by the feed motion of tool/workpiece

Generatix : Cutting direction, Directrix : Feed direction



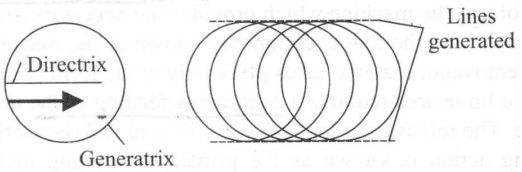
(a) Motions of cutting point (b) Production of surface (c) Generatrix and directrix

Surface formation in machining

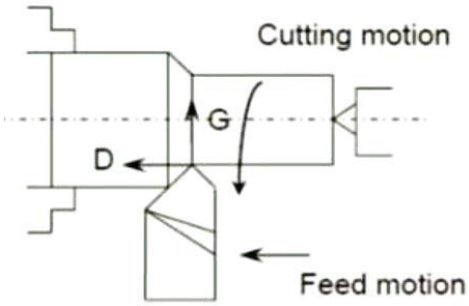


(a) Directrix perpendicular to plane of generatrix

This kind of surface is obtained during turning, grinding

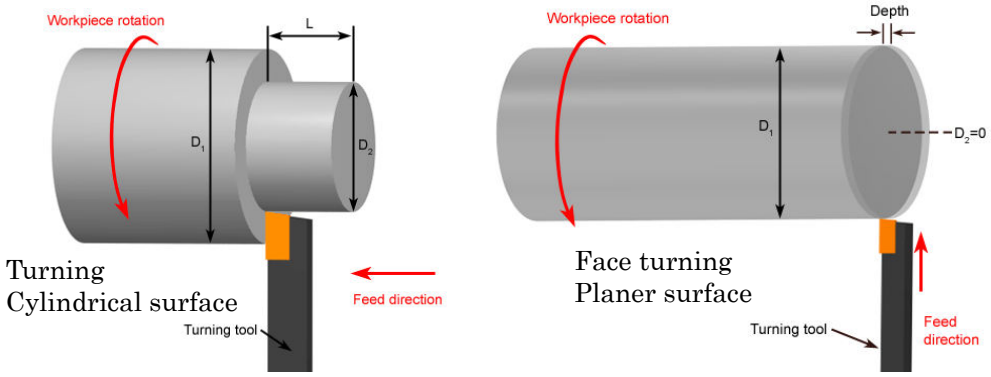


(b) Directrix in the plane of generatrix



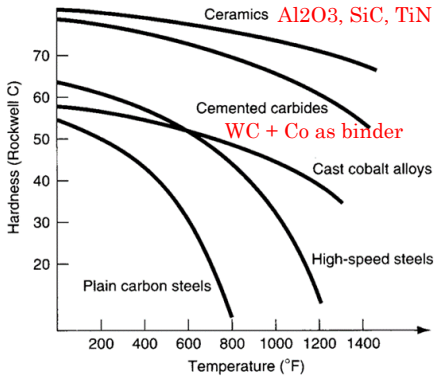
This kind of surface is obtained during milling

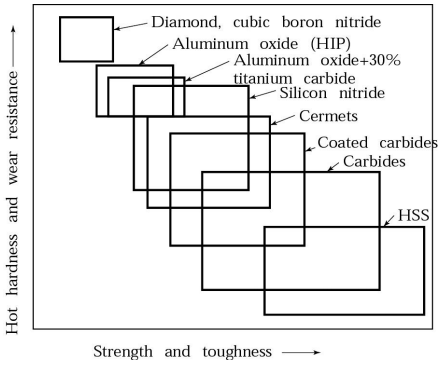
Surface formation in machining



Generatrix	Directrix	Process	Surface obtained
Straight line	Straight line	Tracing	Plain
Circular	Straight line	Tracing	Cylindrical
Plain curve	Circular	Tracing	Surface of revolution
Circular	Straight line	Generation	Straight line (plain surface in practice)

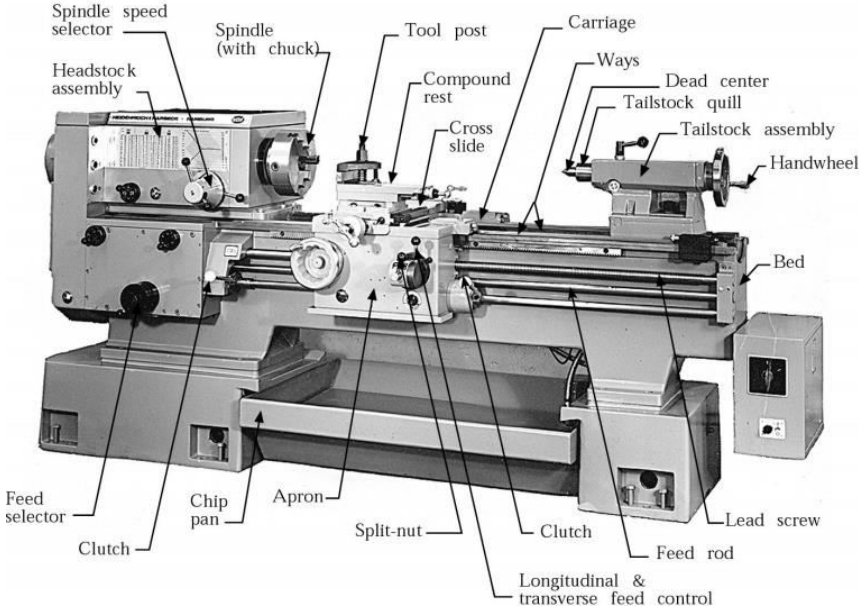
Properties for Groups of Tool Materials





- Tool material hardness > work piece hardness. But how much ?
- Hardness of tool material reduces at elevated temperature
- Hot hardness : ability of material to maintain its hardness at higher temperature
- Higher cutting speed >> higher temperature generation in machining >> higher loss in the hardness value

Material removal machine : Lathe

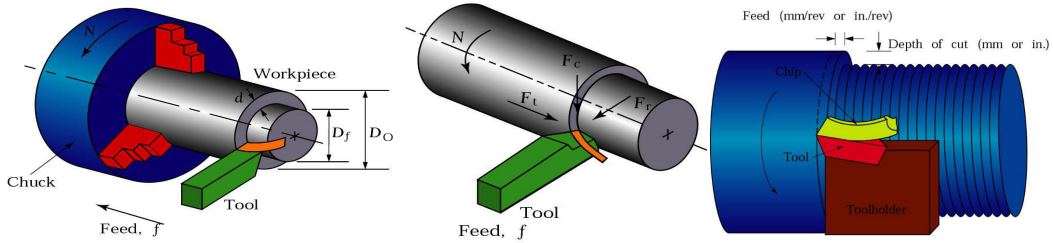


Cutting speed, feed and depth of cut

- Material removal rate depends on following parameters
- Cutting speed is the surface speed of the workpiece (mm/min, m/min)
  - Size of workpiece, rotation speed
- Feed speed : to get fresh material to cut (mm/rev)
- Depth of cut
- How to find machining time ?

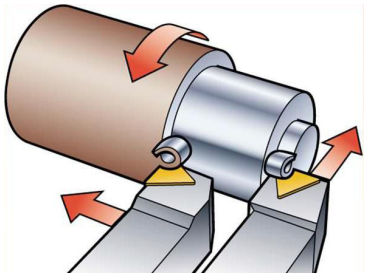
Machining operations

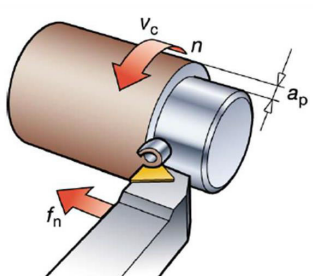
Turning process



- Turning : Workpiece is rotated, while cutting tool is fixed to tool post
- Cutting tool: HSS, WC Carbide
- Material removal rate: Speed of rotation (cutting speed), depth of cut, feed rate
- Cutting speed is the surface speed of the workpiece
  - F_c is the cutting force,
  - F_t is the thrust or feed force (in the direction of feed),
  - F_r is the radial force that tends to push the tool away from the workpiece being machined.

Machining Parameters





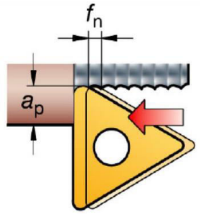
n = spindle speed (rpm)

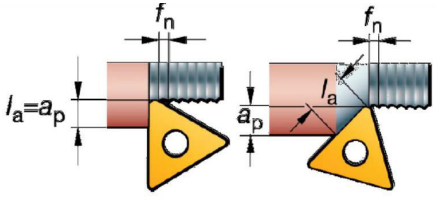
v_c = cutting speed (ft/min)

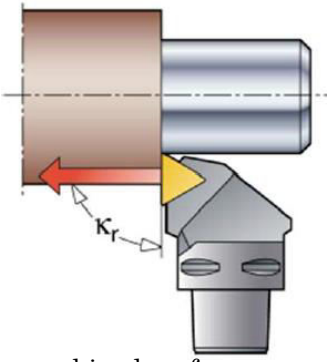
f_n = cutting feed (in/rev)

a_p = depth of cut (in)

K_r = entering angle





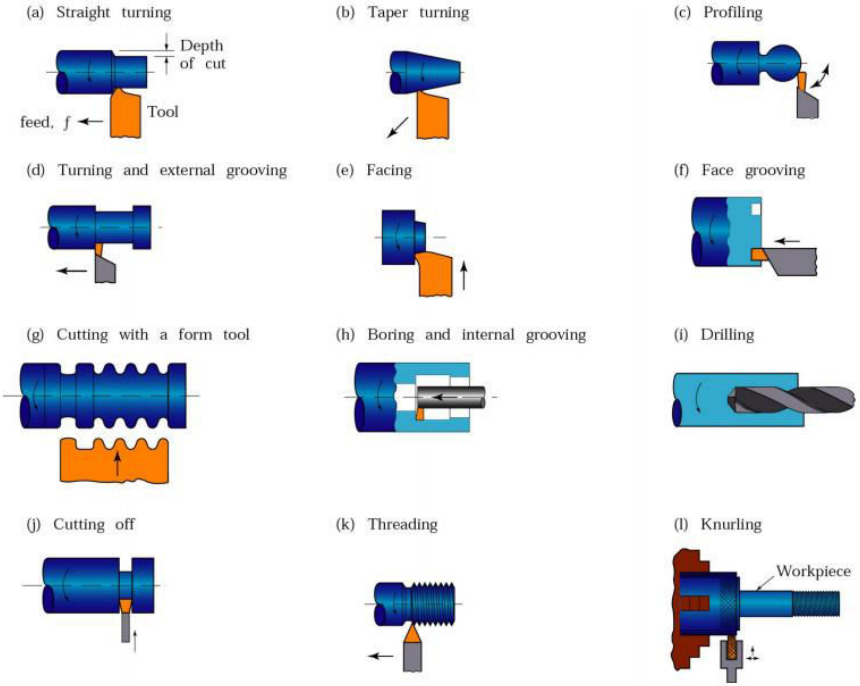


The feed rate f_n is the distance the edge moves along the cut per revolution

- Effective cutting edge length l_a relates to cutting depth and entering angle

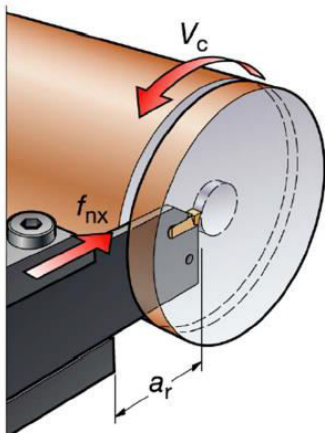
Due to finite size of nose radius, there is roughness on the machined surface

Turning-based processes



Parting & Grooving processes

Parting process



n = spindle speed (rpm)

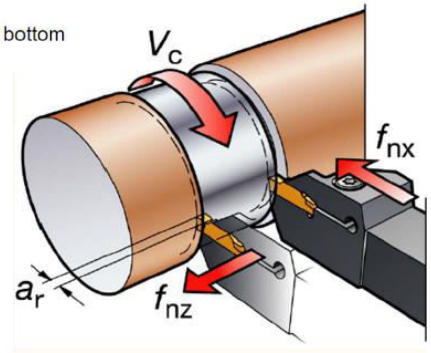
v_c = cutting speed (ft/min)

f_{nz} = axial cutting feed (in/rev)

f_{nx} = radial cutting feed (in/rev)

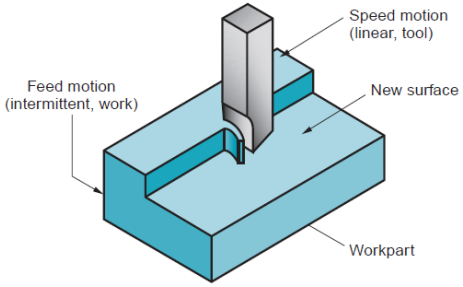
a_r = depth of cut (in) outer diameter to center or bottom of groove

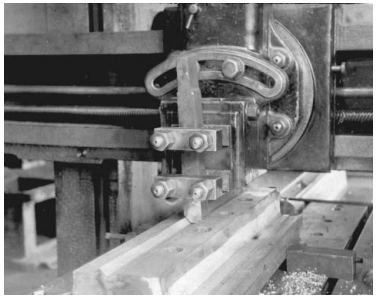
Grooving process



https://www.sandvik.coromant.com/en-gb/knowledge/machining-formulas-definitions/pages/parting-grooving.aspx

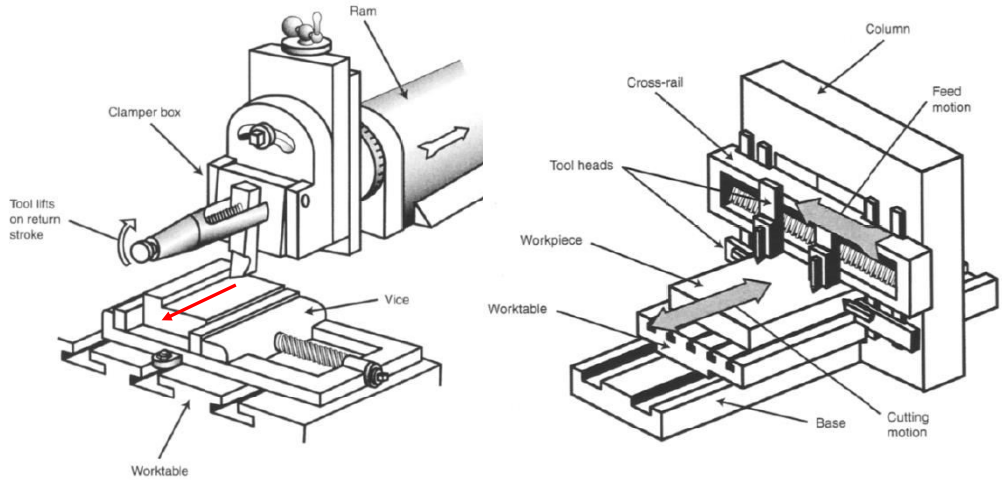
Shaping and Planing process



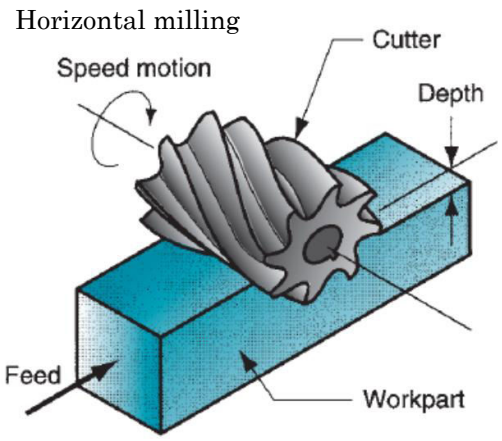


- Shaping and Planing: very similar, produces planer surfaces
- Shaping:
  - Cutting tool moves forward/backward,
  - Work piece is moved laterally during the reverse stroke
- Planing:
  - Work piece moves in linear direction, while cutting tool is fed
  - Suitable for long work pieces

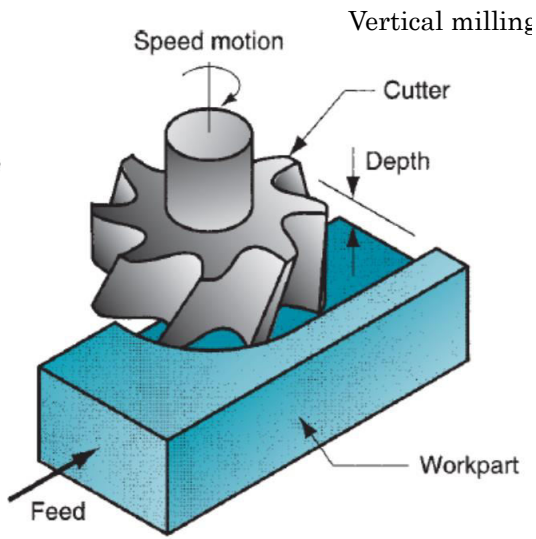
Shaping/Planning



Milling process : Classification

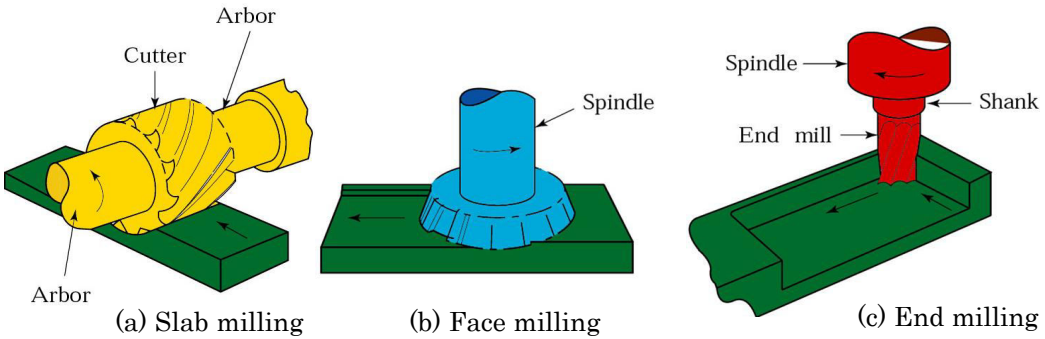


Cutter axis and workpiece axis in the same plane (parallel to workpiece axis)



Cutter axis is perpendicular to workpiece axis

Milling process : different types

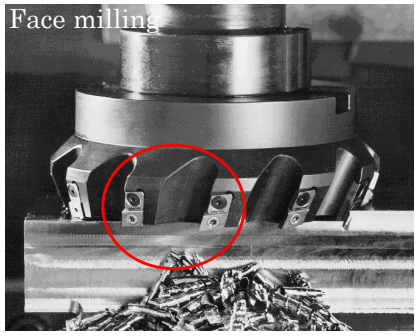


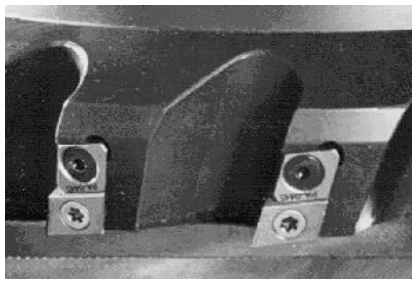
(a) Slab milling (b) Face milling (c) End milling

- Both slab milling and face milling will produce flat surface
- End milling cutter has teeth both on the end face as well as on the peripheral surface
- Milling cutter can be of HSS or can have multiple PCD (poly-crystalline diamond inserts)

PCD milling cutt

Face and End milling process



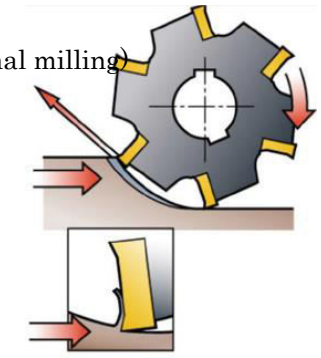


End milling

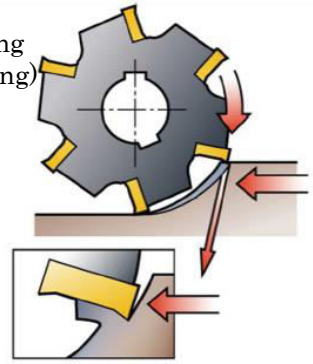
- End milling process is extensively used in the manufacturing industry
- Can create variety of the features

Up or down milling

Up milling
(conventional milling)



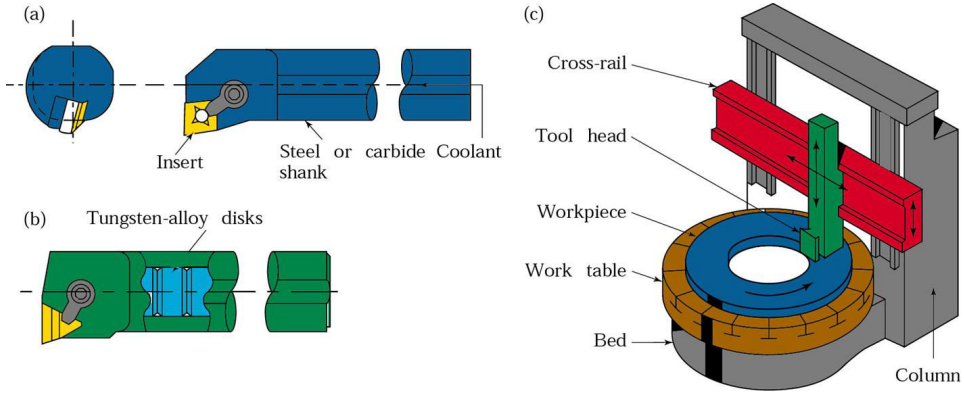
Down milling
(climb milling)



- Directions of cutter rotation and the table feed is opposite
- Chip thickness starts at zero and slowly increases.
- The cutting chips fall behind the cutting tool which results in better surface finish.
- Tool wear is more as tool runs against the feed.

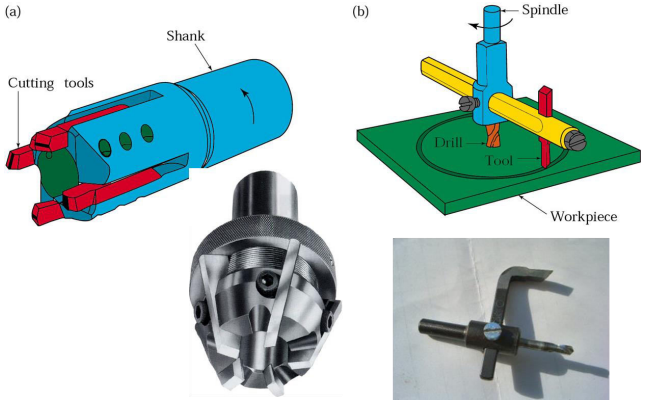
- Directions of cutter rotation and the table feed is same
- The insert starts its cut with a large chip thickness and slowly reduces to zero
- The cutting chips fall in front of the cutting tool which causes less surface finish.
- Tool wear is less as the cutter rotates with the feed.

Boring process



- Boring process is similar to vertical turning process
- Performed on the internal surfaces for diameter enlargement
- Drills are normally of fixed size (say 50 mm), so only holes with fixed diameters can be formed (can not make 50.75 mm holes)
- Boring process is used to enlarge the diameters upto the required size

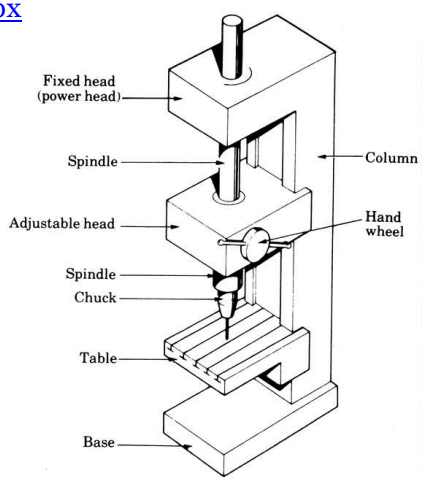
Trepanning process



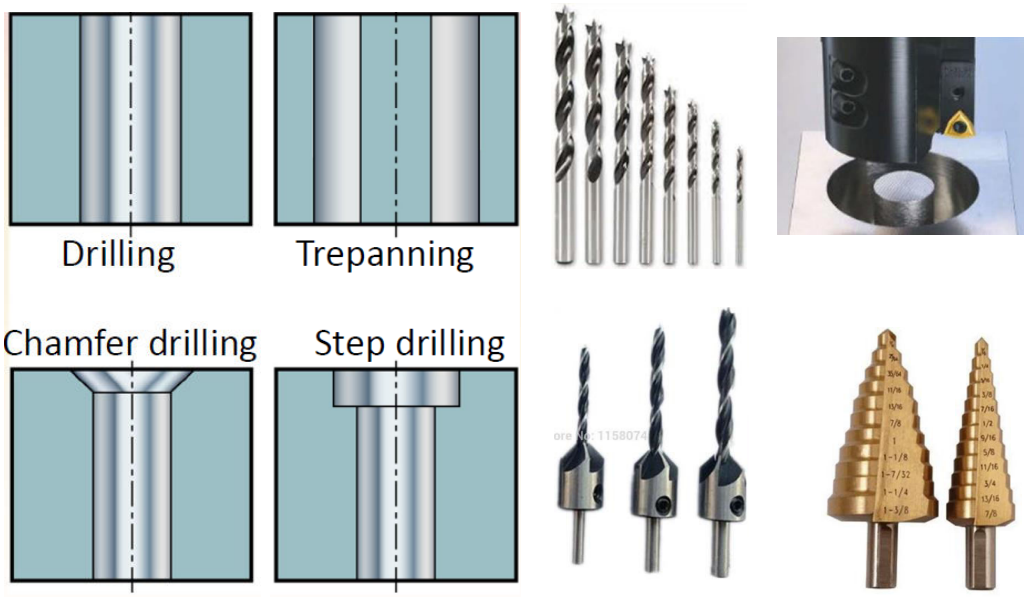
- Trepanning is used for drilling larger through-holes where machine power is limited
- Trepanning tool does not machine the whole diameter, only a ring at the periphery.
- Instead of removing all the material in the form of chips, a core is left at the centre of the hole. Consequently, this method is for through-hole applications.

Drilling process

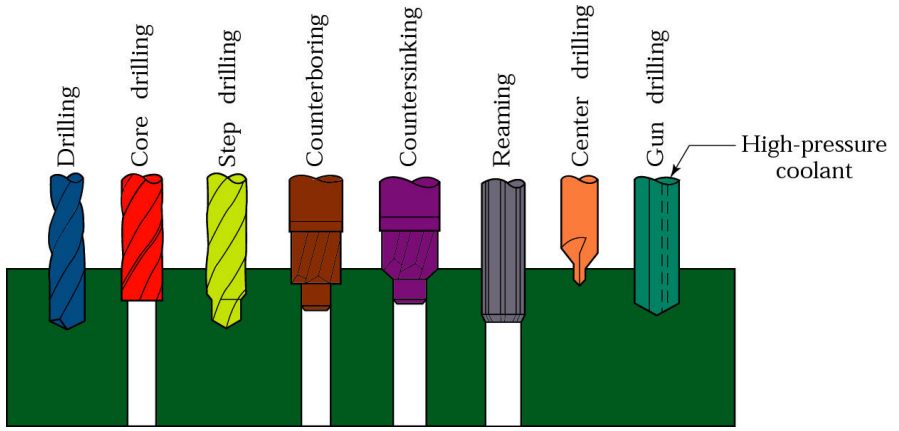
https://www.sandvik.coromant.com/en-gb/products/Pages/drilling-tools.aspx



Various drilling process



Drilling and Reaming Operations



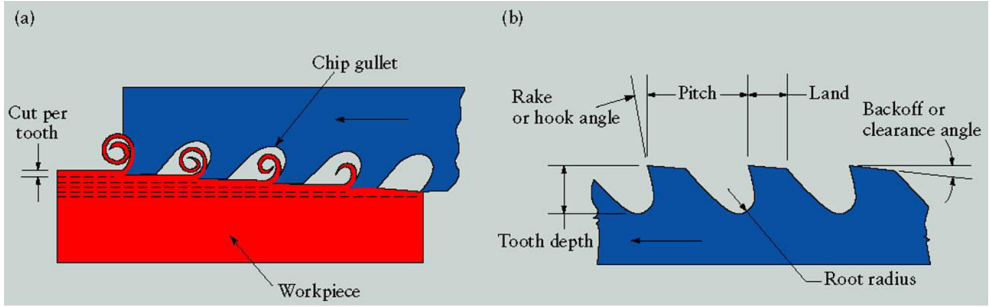
- Reaming is a cutting process that involves the use of a rotary cutting tool to create smooth interior walls in an existing hole in a workpiece.
- Gun drilling is a deep hole drilling process that uses a long, thin cutting tool to produce holes in metal at high depth-to-diameter ratios. It is effective in diameters from 1 – 50 mm

Broaching : Parts made

Broaching tool

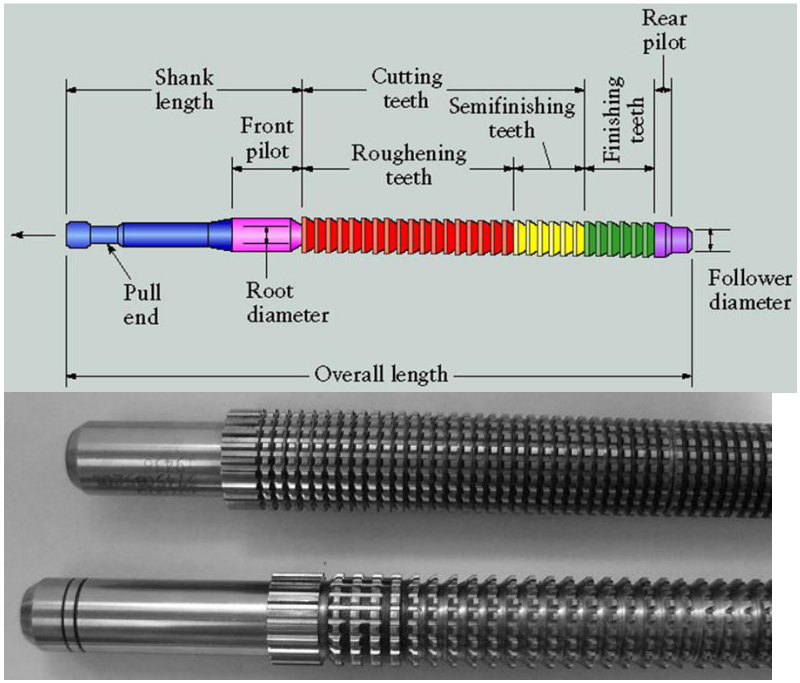
Internal teeth formation in gears

Broaching process

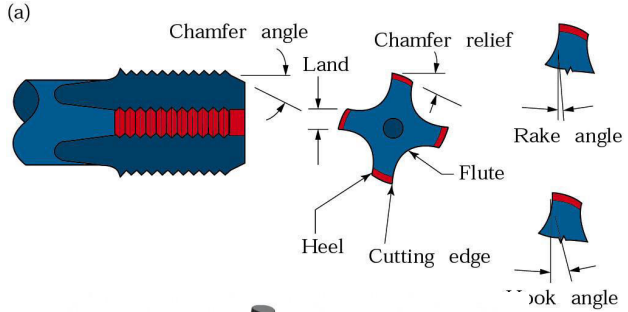


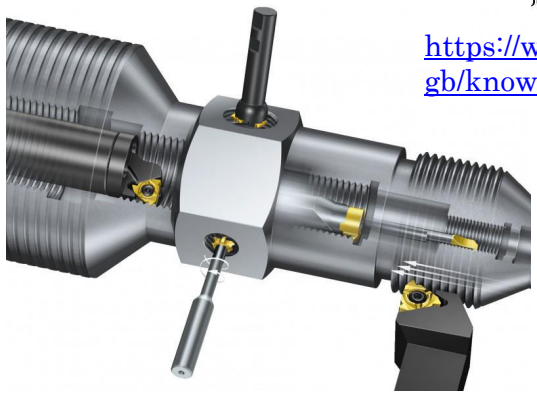
- Broaching uses a toothed tool (broach), to remove material.
- Types: linear and rotary.
- The broach is run linearly against a surface of the workpiece to effect the cut.
- Mainly used for machining internal surface (internal gears)
- Vertical broaching machine is more popular

Broaching process



Tapping and Taps

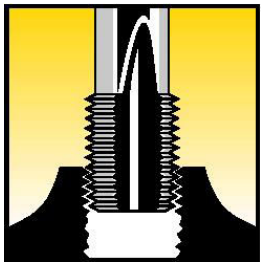




https://www.sandvik.coromant.com/en-gb/knowledge/threading/Pages/default.aspx

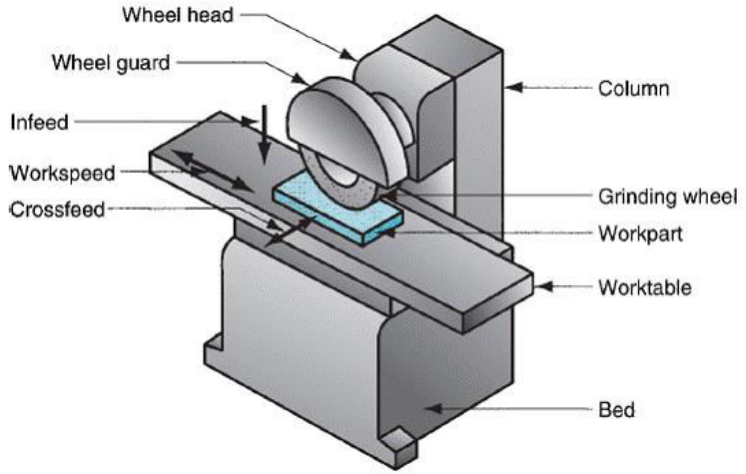
Threading Tap and Die

External threads



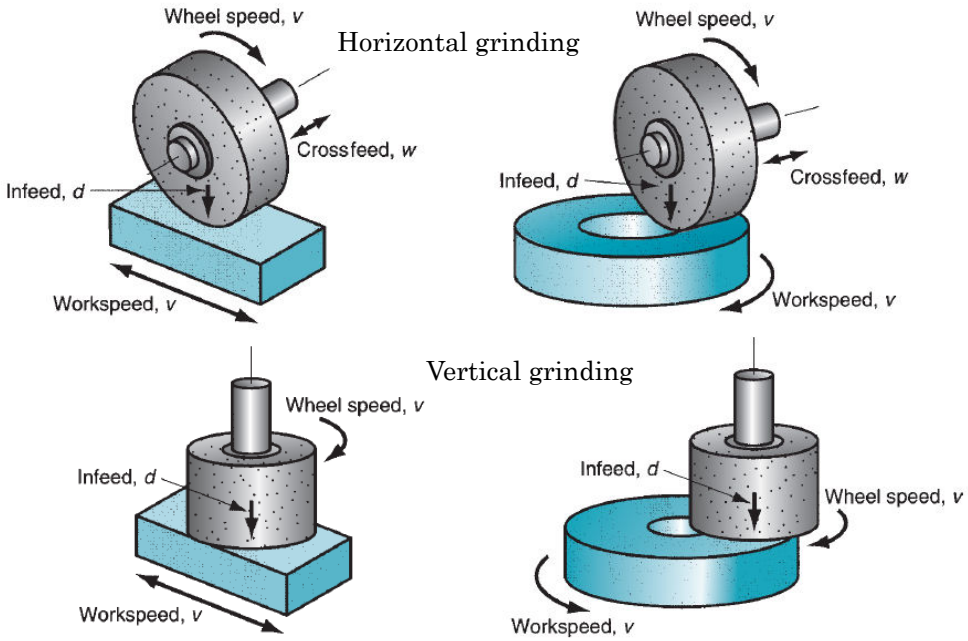
Internal threads

Grinding Process

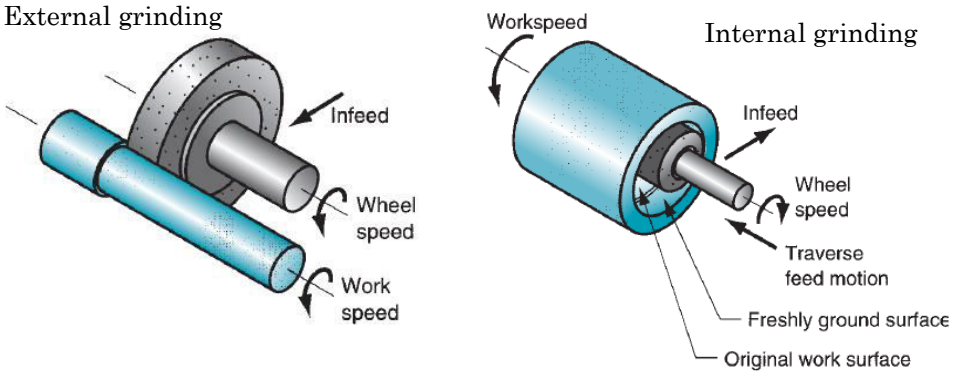


- Grinding wheels: Alumina, SiC, Diamonds are used as abrasive grains
- Surface finishing, polishing

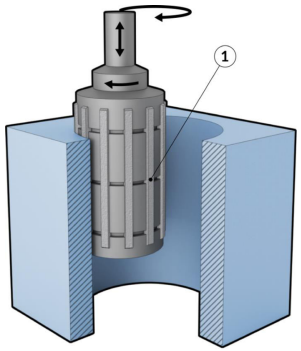
Grinding types

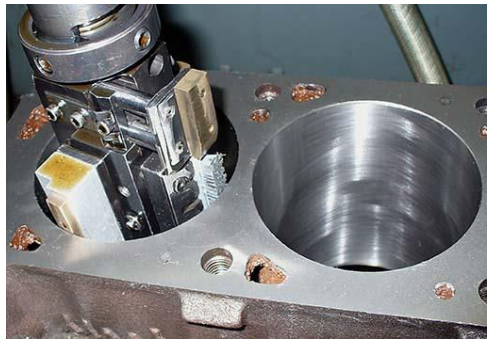


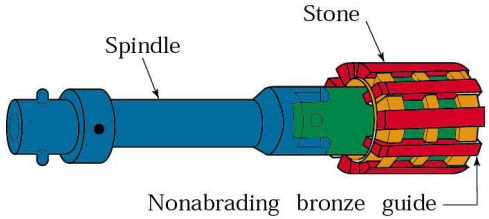
Grinding Process



Honing (surface finishing)

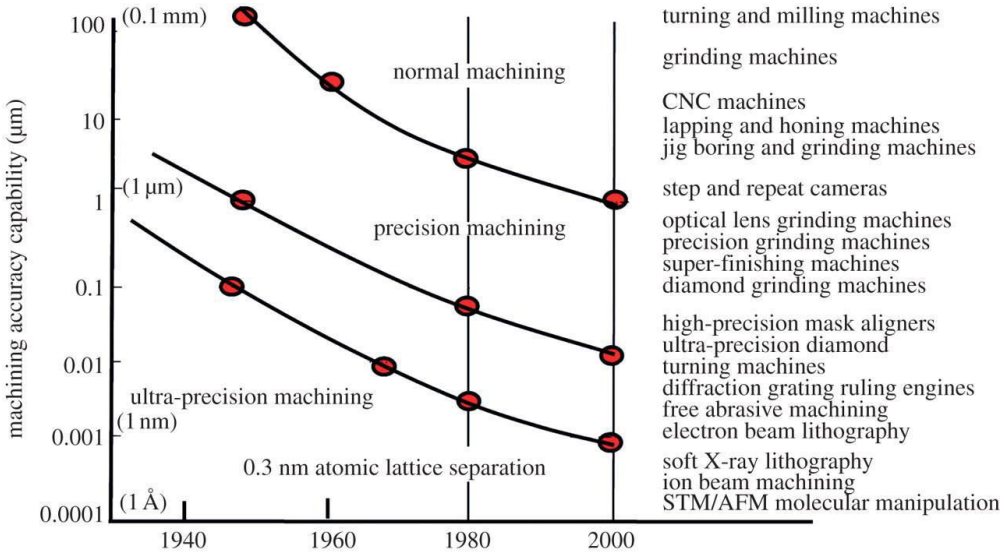






- Abrasive machining process that produces a precision surface on a metal workpiece by scrubbing an abrasive grinding stones against it along a controlled path.
- Primarily used to make the internal surface smooth (cylinder block)

Machining Accuracy: Taniguchi Curve



The required dimensional accuracy (1nm – 100 um) depends on the processes

Problem

What are these process (A, B, C) called? What are the cutting, feed directions in these processes?