Milling Processes

Topics

- Milling Processes
- Material Removal Rate
- Design Considerations
- Milling Machines
- Thread Cutting

Week 3 check in... how are we feeling ?

Total Results: 135

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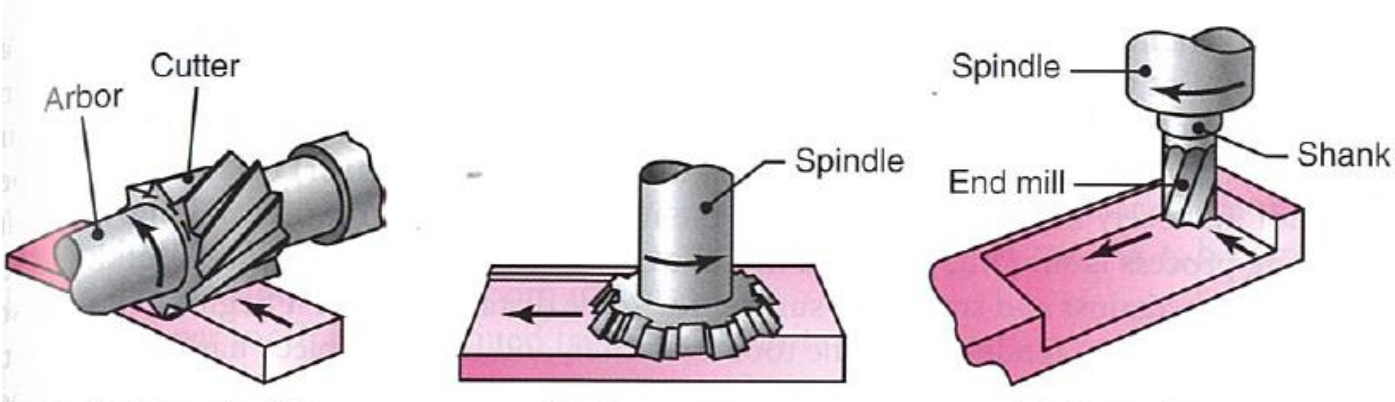
Milling Processes

- Milling has a special place in our hearts at MMAN1130
- The assessment that you work on is done with a CNC Mill
  - Remember, we livestream everything!
- So, we don't want to see this…
  - https://www.youtube.com/watch?v=CGKLG4XB_7Y

Your part. Soon. The Hammer of Destiny is coming.

Milling Processes

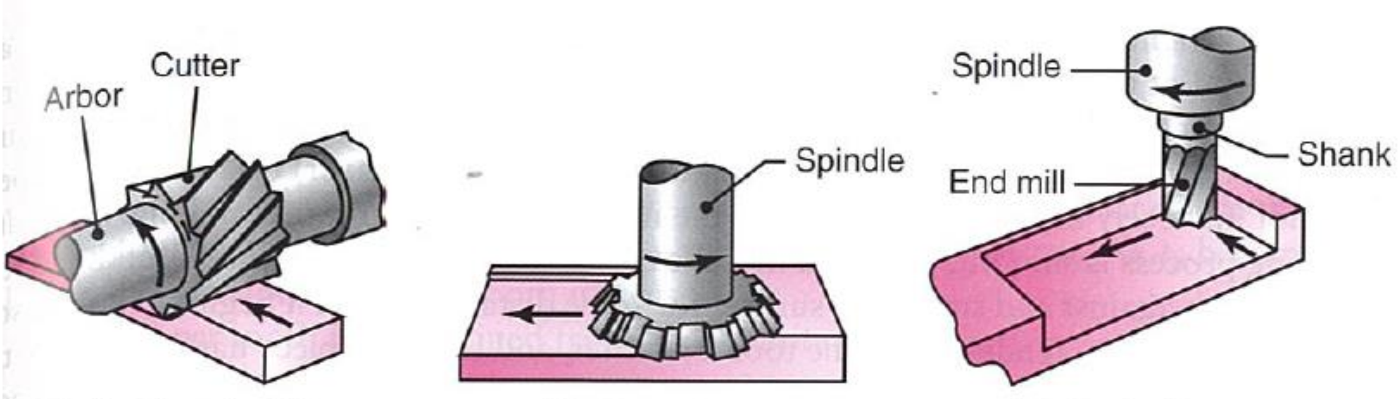
- Milling is one of the most versatile processes available to us in metalworking.
- The milling cutter is a multitooth tool that produces a number of chips per revolution.
  - Depending on the mount they are arbor or shank cutters.



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

Milling Processes

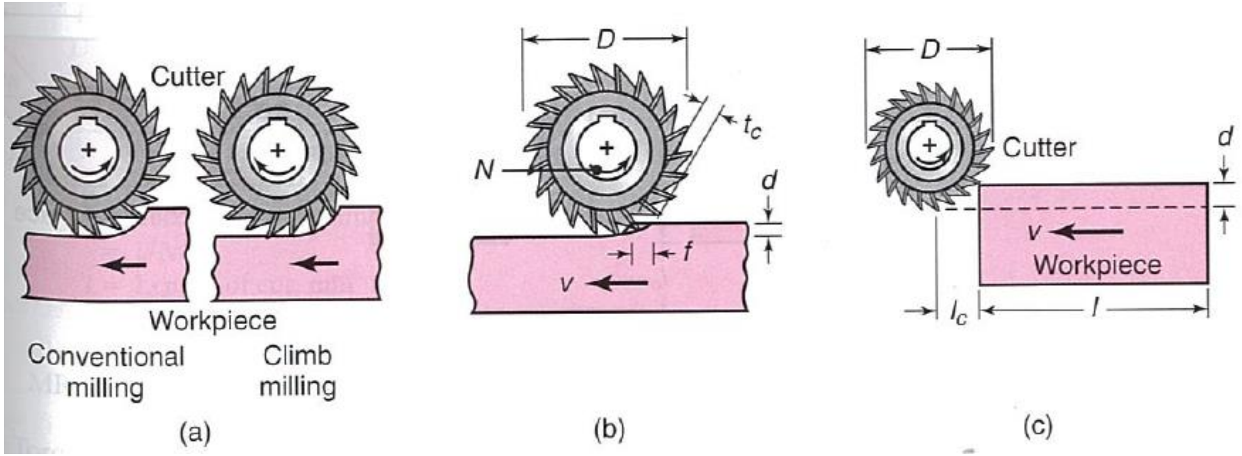
- The various machining operations take place in a variety of configurations
  - Rotating cutter stationary with material being moved
  - Rotating cutter moving through stationary material



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

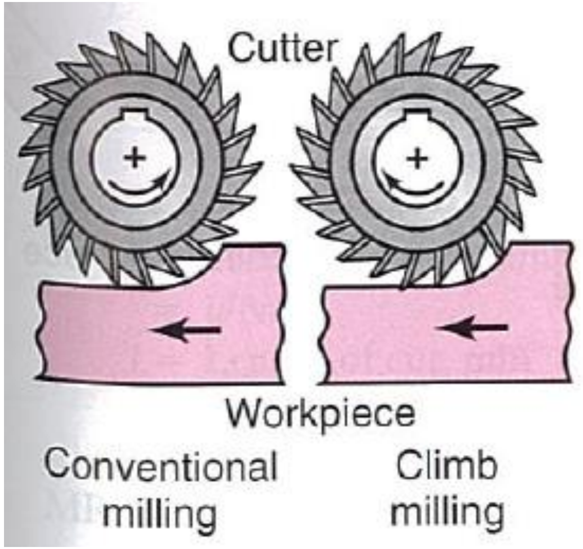
Peripheral Milling

- Peripheral (plain) milling is when the cutter axis of rotation is parallel to the workpiece surface.'
- If the cutter width is larger than the material width, this is known as slab milling
- Peripheral cutters may have straight or helical teeth.



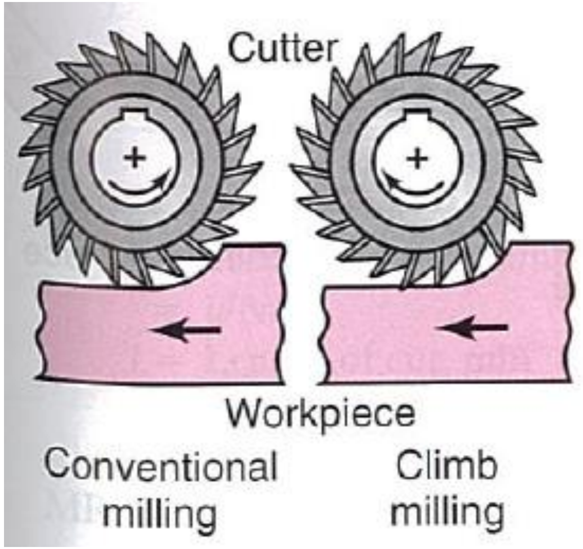
Peripheral Milling

- The cutter rotation dictates the type of cutting process.
- Conventional (up) milling is when the cutter rotation is the opposite direction to the material travel.
- The maximum chip thickness is at the end of the cut resulting in heat increase in the stock.
- Chips are thrown in front of the cutter path.
  - Re-cutting of chips and can affect finish.
- Cutting forces tend to “pull” the workpiece away from the clamp.

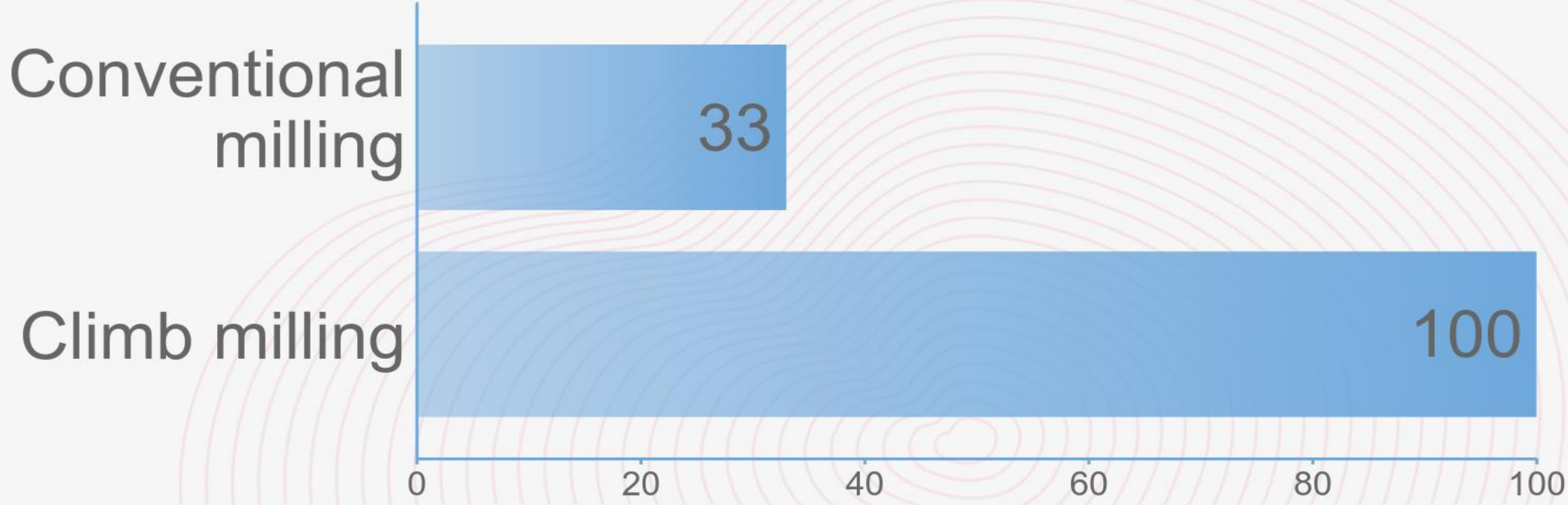


Peripheral Milling

- The cutter rotation dictates the type of cutting process.
- Climb (down) milling is when the cutter rotation is the same direction as the material travel.
- The maximum chip thickness is at the beginning of the cut resulting in heat being transfer to the chip instead of the workpiece.
- Chips are thrown behind the cutter path.
- Cutting forces tend to “push” the workpiece into the clamp.
- https://www.youtube.com/watch?v=2y_OJv-K0E8



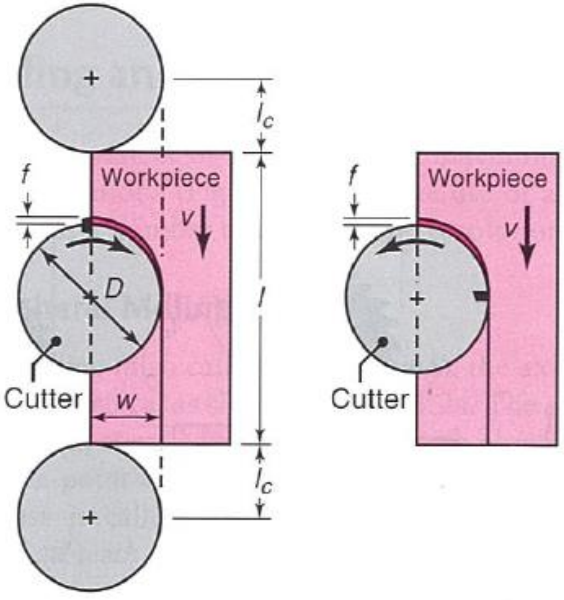
To maximise quality, is conventional or climb milling better?



Total Results: 133

Face Milling

- In face milling, the cutter’s axis of rotation is perpendicular to the workpiece surface.
- Similar to before, the milling is classified as conventional or climb milling depending on the cutter rotation relative to the workpiece travel.

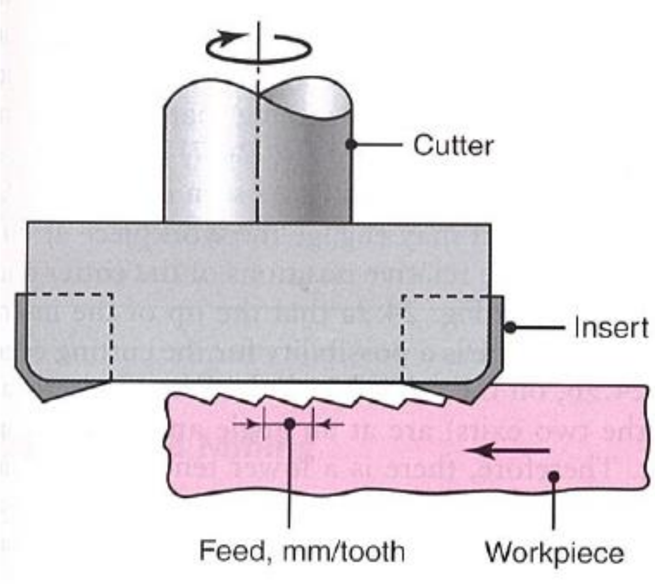


(b)

(c)

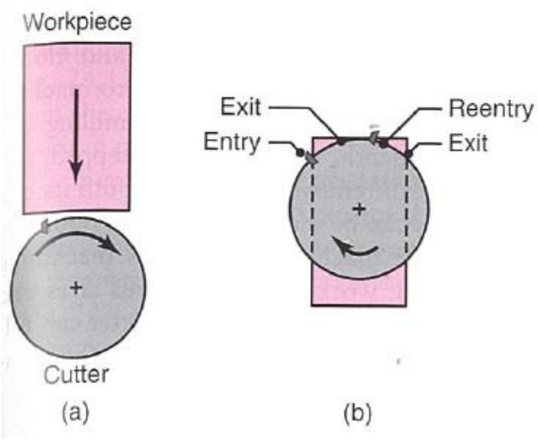
Face Milling

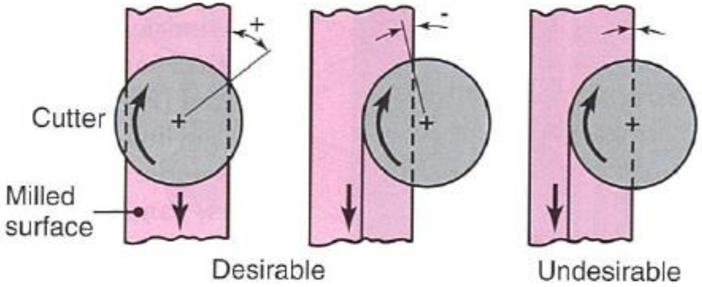
- A face cutter typically has cutting teeth inserts mounted into the cutter body.
- The relative motion between the workpiece and cutter teeth leaves feed marks on the machined surface.
  - This is similar to turning processes.



Face Milling

- How the cutter enters and exits the workpiece is very important in milling.
- Depending on the diameter of the cutter and workpiece geometry, there may be multiple entry and exit points.
- We always have positive or negative entry/exit angles.
  - Zero degrees is undesirable and can result reduced tool life.
- https://www.youtube.com/watch?v=9OsNUi_o6C4

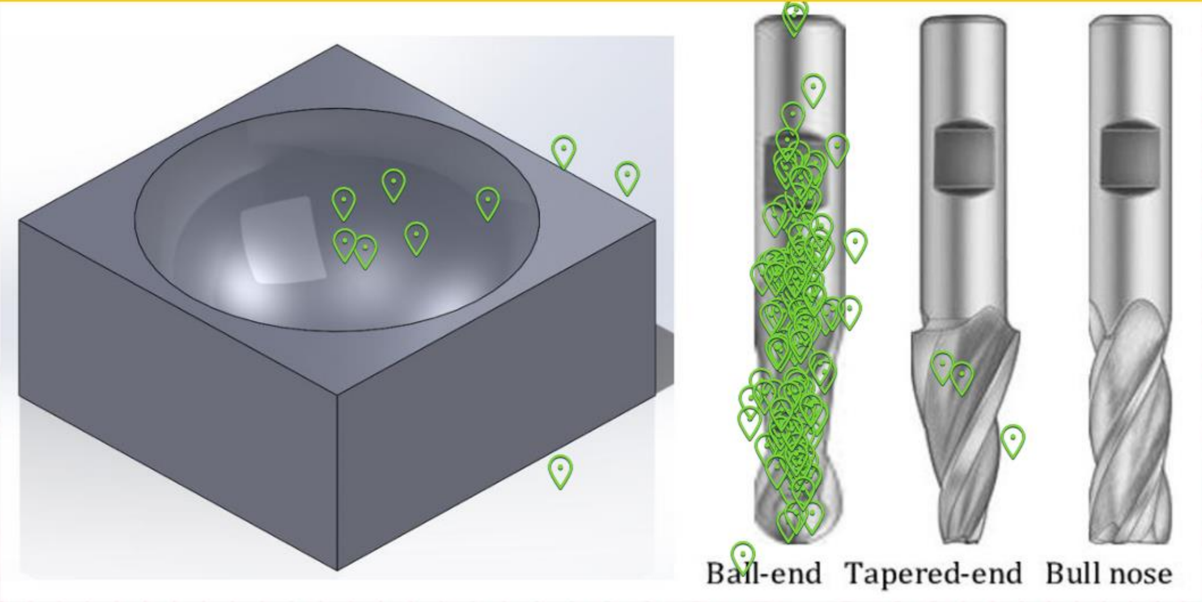




End Milling

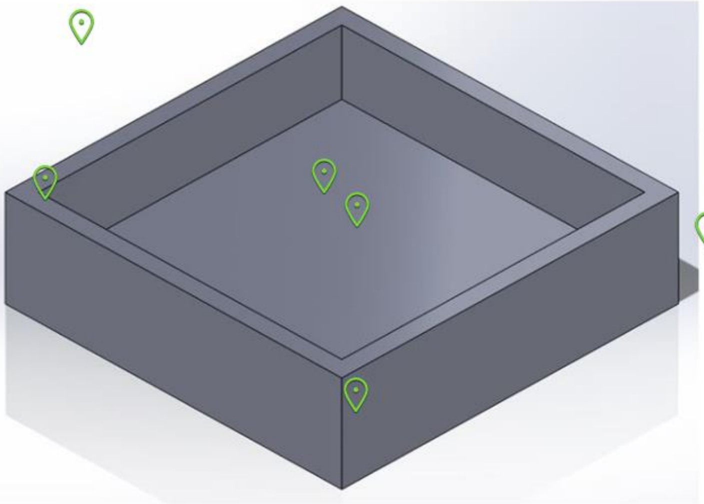
- End milling is a very important operation due to its ability to produce various profiles and curved surfaces.
- End mills tend to be made of high-speed steels or carbide inserts.
- The cutter typically rotates on an axis perpendicular to the workpiece surface.
  - It can also be tilted to create tapered or curved surfaces.
- https://www.youtube.com/watch?v=HfIaISnqHOk

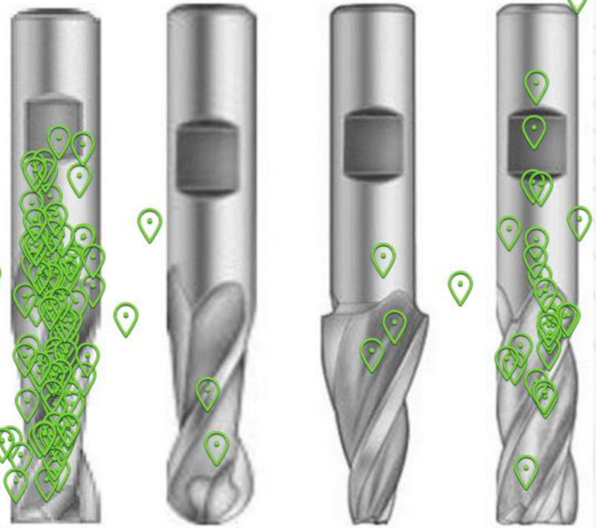
What type of end mill would be able to create this spherical pocket?



Total Results: 135

What type of end mill would be able to create this rectangular pocket?





Total Results: 124

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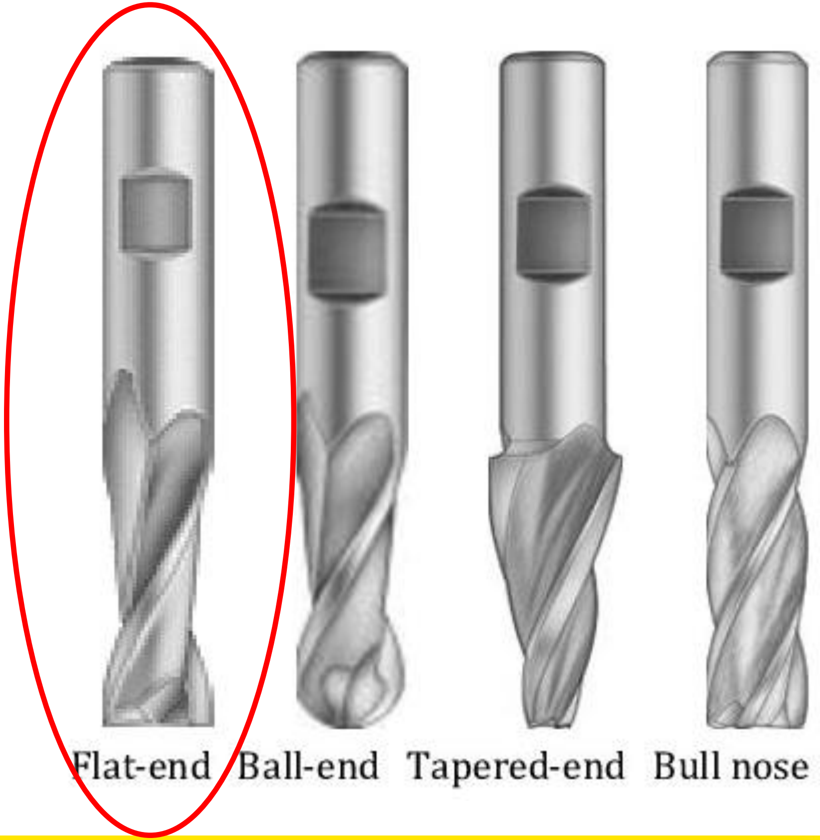
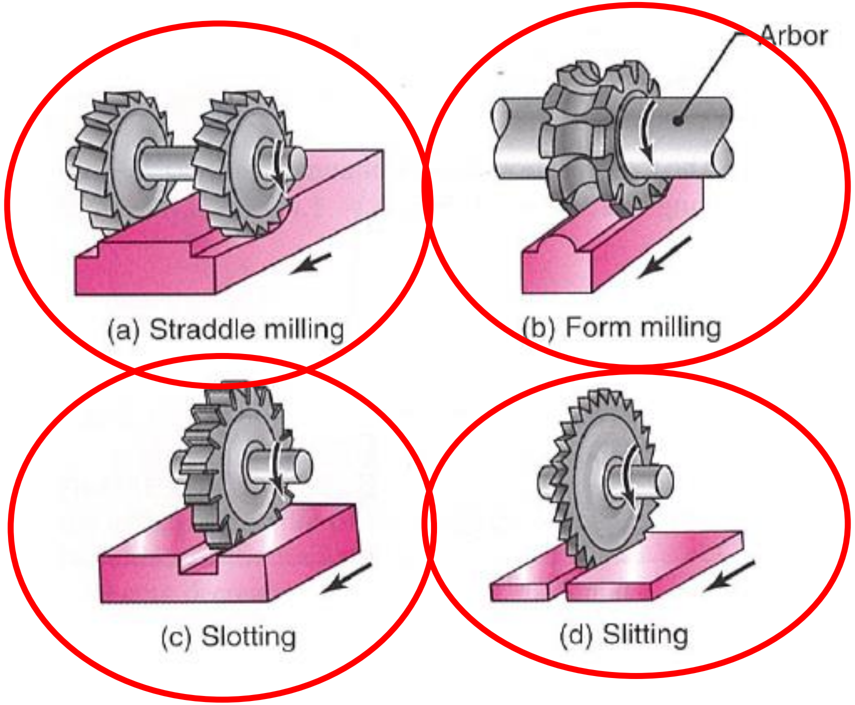
Types of End Mills

- Our ability to produce these varied and complex surfaces comes down to the types of end mills.
- These are some of the most common:
  - Flat-end
  - Ball-end
  - Tapered-end
  - Bull nose



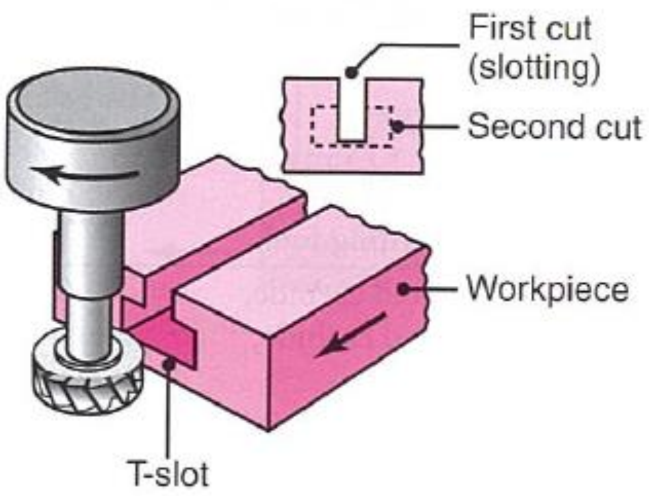
Other Milling Processes

- There are also a range of special milling processes such as:
  - Straddle milling
  - Form milling
  - Slotting
  - Slitting



Other Milling Processes

- There are also a range of special milling processes such as:
  - Straddle milling
  - Form milling
  - Slotting
  - Slitting
  - T-slot cutters
    - » https://youtu.be/nsBJ3dIx3-w
  - Key seat cutters

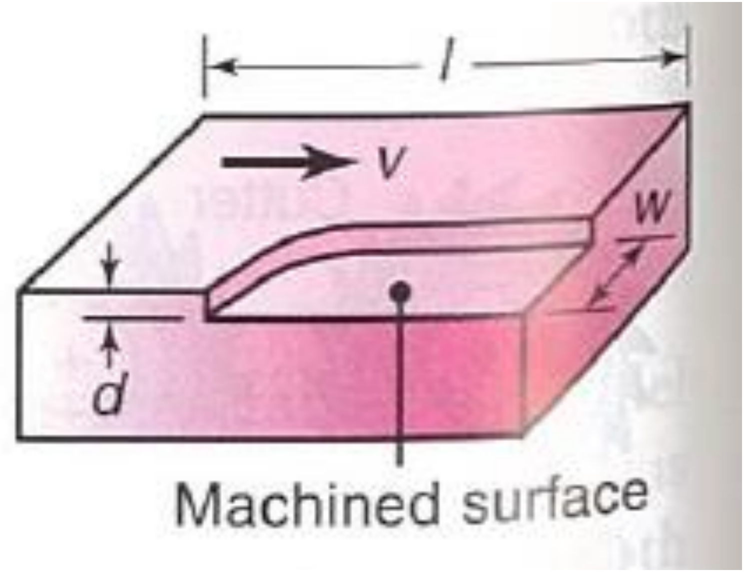


Material Removal Rate

- The material removal rate for milling operations is the simplest we have encountered.

$$MRR = wdv$$

- w – width of the cut
- d – depth of cut
- v – feed speed (linear speed of tool along workpiece)



Milling Process Capabilities

General Recommendations for Milling Operations

		General-purpose starting conditions		Range of conditions	
Material	Cutting tool	Feed mm/tooth	Speed m/min	Feed mm/tooth	Speed m/min
Low-carbon and free-machining steels	Uncoated carbide, coated carbide, cermets	0.13–0.20	120–180	0.085–0.38	90–425
Alloy steels					
Soft	Uncoated, coated, cermets	0.10–0.18	90–170	0.08–0.30	60–370
Hard	Cermets, PcBN	0.10–0.15	180–210	0.08–0.25	75–460
Cast iron, gray					
Soft	Uncoated, coated, cermets, SiN	0.10–10.20	120–760	0.08–0.38	90–1370
Hard	Cermets, SiN, PcBN	0.10–0.20	120–210	0.08–0.38	90–460
Stainless steel, Austenitic	Uncoated, coated, cermets	0.13–0.18	120–370	0.08–0.38	90–500
High-temperature alloys Nickel based	Uncoated, coated, cermets, SiN, PcBN	0.10–0.18	30–370	0.08–0.38	30–550
Titanium alloys	Uncoated, coated, cermets	0.13–0.15	50–60	0.08–0.38	40–140
Aluminum alloys					
Free machining	Uncoated, coated, PCD	0.13–0.23	610–900	0.08–0.46	300–3000
High silicon	PCD	0.13	610	0.08–0.38	370–910
Copper alloys	Uncoated, coated, PCD	0.13–0.23	300–760	0.08–0.46	90–1070
Plastics	Uncoated, coated, PCD	0.13–0.23	270–460	0.08–0.46	90–1370

Source: Based on data from Kennametal Inc.
Note: Depths of cut, *d*, usually are in the range of 1 to 8 mm. PcBN: polycrystalline cubic-boron nitride. PCD: polycrystalline diamond. See also Table 23.4 for range of cutting speeds within tool material groups.

Milling Process Capabilities

General Troubleshooting Guide for Milling Operations

Problem	Probable causes
Tool breakage	Tool material lacks toughness, improper tool angles, machining parameters too high
Excessive tool wear	Machining parameters too high, improper tool material, improper tool angles, improper cutting fluid
Rough surface finish	Feed per tooth too high, too few teeth on cutter, tool chipped or worn, built-up edge, vibration and chatter
Tolerances too broad	Lack of spindle and work-holding device stiffness, excessive temperature rise, dull tool, chips clogging cutter
Workpiece surface burnished	Dull tool, depth of cut too low, radial relief angle too small
Back striking	Dull cutting tools, tilt in cutter spindle, negative tool angles
Chatter marks	Insufficient stiffness of system; external vibrations; feed, depth of cut, and width of cut too large
Burr formation	Dull cutting edges or too much honing, incorrect angle of entry or exit, feed and depth of cut too high, incorrect insert shape
Breakout	Lead angle too low, incorrect cutting-edge geometry, incorrect angle of entry or exit, feed and depth of cut too high

Design Considerations

- In general, many design considerations for turning also apply to milling.
- Some milling specific considerations are:
  - Design features should avoid requiring bespoke tooling, inserts and toolholders.
  - Chamfers should be used instead of fillets as it is difficult to smoothly match intersecting radii.
  - Internal cavities and pockets with sharp corners should be avoided. Why?

Why should internal cavity and pocket design avoid sharp corners?

“ dangerours ”

“ creates stress in the material ”

“ Increases the stress concentratio[n …]
weak point in the piece ”

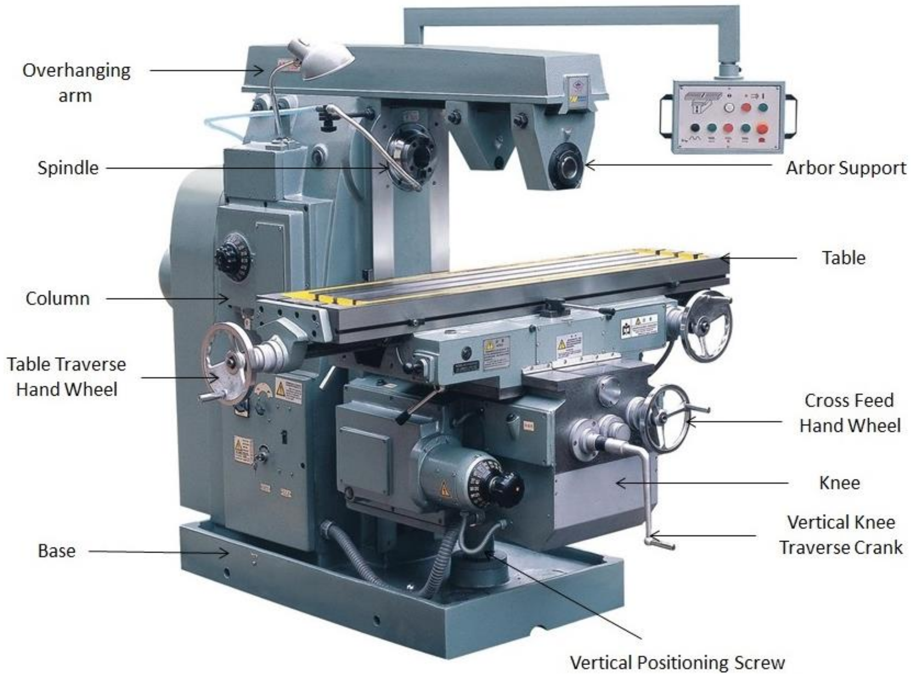
Total Results: 141

Design Considerations

- In general, many design considerations for turning also apply to milling.
- Some milling specific considerations are:
  - Design features should avoid requiring bespoke tooling, inserts and toolholders.
  - Chamfers should be used instead of fillets as it is difficult to smoothly match intersecting radii.
  - Internal cavities and pockets with sharp corners should be avoided. Why?
  - Small milling cutters can produce any surface but are more susceptible to machine chatter. Proper clearance should be provided to accommodate the most appropriate milling cutter.

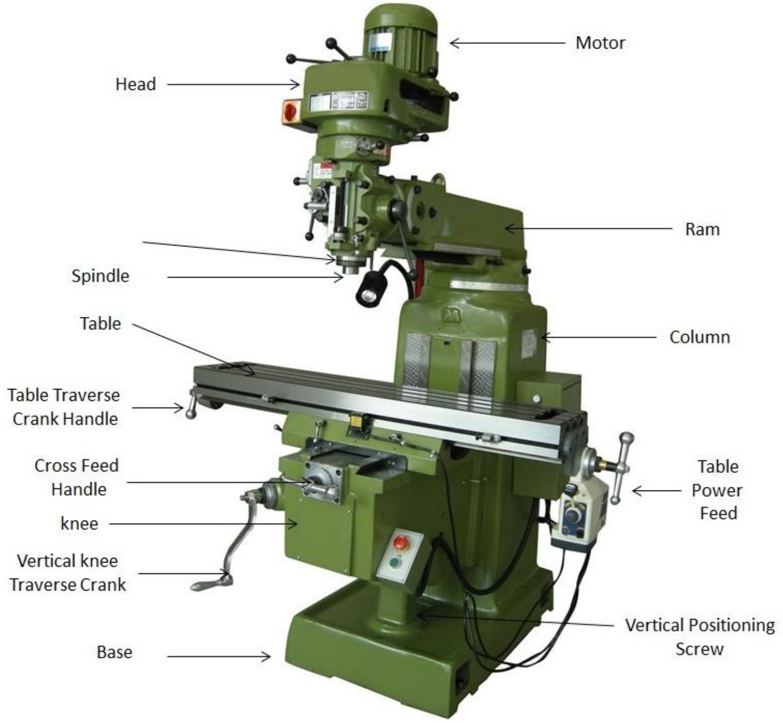
Milling Machines

- The most common type of milling machine is the column-and-knee type machine. These come in either horizontal or vertical variants.
- Horizontal variants are typically for peripheral milling.



Milling Machines

- Vertical variants are much more versatile and can perform face and milling, boring and drilling operations.
- The work piece is moved in three directions as follows
  - Worktable: longitudinal movement
  - Saddle: Transverse movement
  - Knee: Vertical movement



Milling Machines

- Bed-type milling machines replace the knee with a bed platform.
- The worktable is directly mounted to the bed and can move longitudinally only.
- Although not as versatile, they have high stiffness and are great for high-volume production.
- Some models allow for duplex or triplex spindle types to facilitate simultaneous machining of multiple surfaces.

Milling Machines

- CNC Milling machines tool paths are controlled by a computer.
- Contain automatic tool changers (ATCs).
- Reliably repetitive, maintain desired dimensional accuracy, requires less skill to operate.
- CNC milling machines have replaced manual milling machines for all but the lowest of production requirements.
- This is our CNC milling machine in the Makerspace that you will use for your CNC assessment.

Thread cutting on a mill

- We learnt about tapping and threading in hole making.
  - We know it is possible to cut threads using a lathe.
- However, it is also possible to cut threads using a CNC mill
  - https://www.youtube.com/watch?v=p6nzSpqGsxI (internal tap milling)
  - https://www.youtube.com/watch?v=a43S2y7Ccy8 (internal thread milling)
  - https://www.youtube.com/watch?v=2Bzvi_zX2lM (external thread milling)