Milling Cutters and Milling Operations

Figure 24.2 Some basic types of milling cutters and milling operations. (a) Peripheral milling. (b) Face milling. (c) End milling. (d) Ball-end mill with indexable coated-carbide inserts machining a cavity in a die block. (e) Milling a sculptured surface with an end mill, using a five-axis numerical control machine. *Source*: (d) Courtesy of Iscar. (e) Courtesy of The Ingersoll Milling Machine Co.

Milling and Milling Machines
Milling operations: Milling Parameters

- N = Rotational speed of the milling cutter, rpm
- f = Feed per tooth, mm/tooth (in/tooth) = υ /N n
- D = Cutter diameter, mm (in)
- n = Number of teeth on cutter
- υ = Linear speed of the workpiece or feed rate, mm/min (in/min)
- V = Surface speed of cutter, m/min (ft/min) = π D N
- l = Length of cut, mm (in)
- t = Cutting time, s or min=(l+lc) / υ
- lc =extent of the cutter's first contact with workpiece lc=$\sqrt{Dd}$
- MRR = mm3/min or in3/min = w d υ , where w is the width of cut
- Torque = N.m (lb.ft) =(Fc) (D/2)
- Power = kW (hp) = (Torque) (ω), where $\omega = 2\pi$ N radians/min

Milling and Milling Machines
Milling operations: Slab milling
Milling Parameters

- **EXAMPLE Material-removal Rate, Power, Torque, and Cutting Time in Slab Milling**
- A slab-milling operation is being carried out on a 300-mm-long, 100-mm-wide annealed mild-steel block at a feed f = 0.25 mrn/tooth and a depth of cut d = 3.0 mm. The cutter is D = 50 mm in diameter, has 20 straight teeth, rotates at N = 100 rpm, and, by definition, is wider than the block to be machined, Calculate the material-removal rate, estimate the power and torque required for this operation, and calculate the cutting time.
- **Solution:**

$$v = fNn = (0.25)(100)(20) = 500 \text{ mm/min.}$$

$$\text{MRR} = \frac{lwd}{t} = wdv,$$

$$\text{MRR} = (100)(3)(500) = 150{,}000 \text{ mm}^3\text{/min.}$$

From table 21.2 U=3 W.S/mm^3

Milling and Milling Machines
Milling operations: Slab milling
Milling Parameters-Example 24.2

$$\text{Power} = (3)(150{,}000)\left(\frac{1}{60}\right) = 7.5\ \text{kW}$$

$$\text{Torque} = \frac{\text{Power}}{\text{Rotational speed}}$$

$$= \frac{(7500)(60\ \text{N}\cdot\text{m/min}\cdot\text{W})}{(100\ \text{rpm})(2\pi)}$$

$$= 716\ \text{N}\cdot\text{m}$$

$$l_c = \sqrt{Dd} = \sqrt{(50)(3)} = 12.2\ \text{mm.}$$

Thus, the cutting time is

$$t = \frac{300 + 12.2}{500} = 0.62\ \text{min} = 37.2\ \text{s.}$$

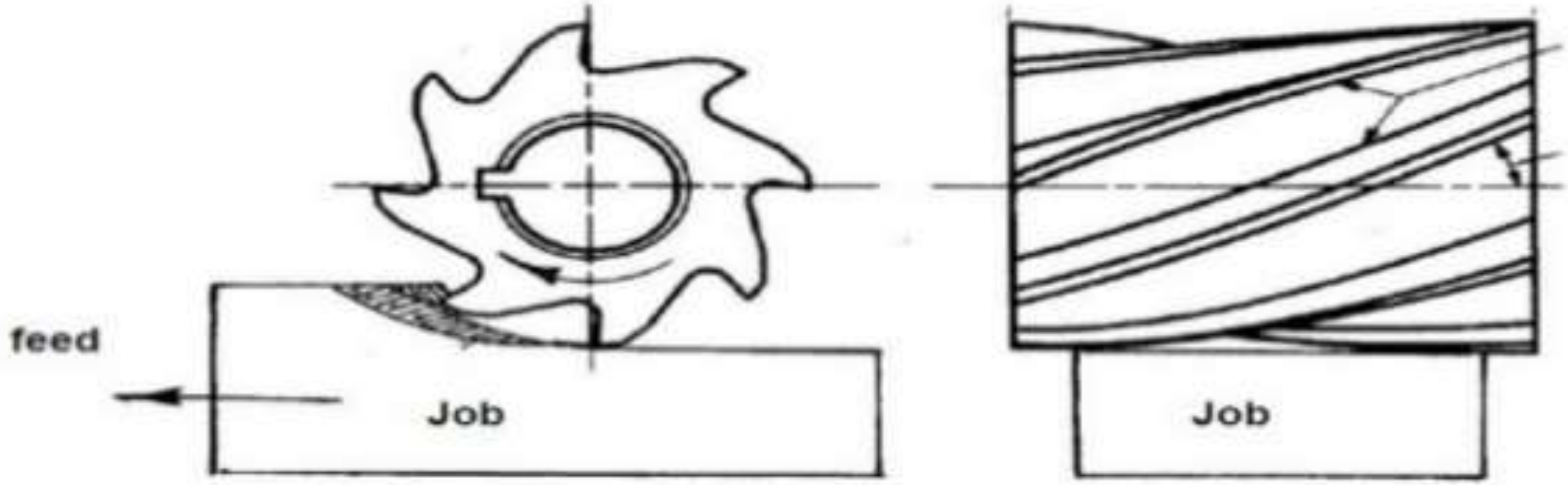
Milling Cutter

Profile sharpened cutters

- The profile sharpened cutters are inherently used for making flat surfaces or surface bounded by a number of flat surfaces only.

Slab or Plain milling cutters

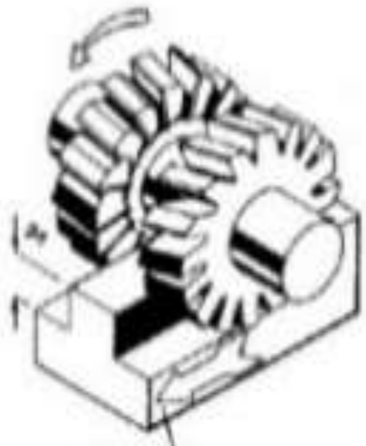
- Plain milling cutters are hollow straight HSS cylinder of 40 to 80 mm outer diameter having 4 to 16 straight or helical equi-spaced flutes or cutting edges and are used in horizontal arbour to machine flat surface



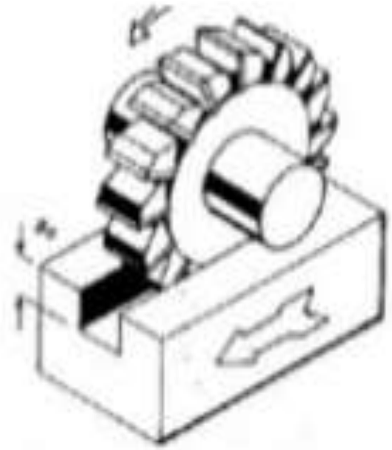
Machining flat surface by slab milling Cutter

Side and slot milling cutters

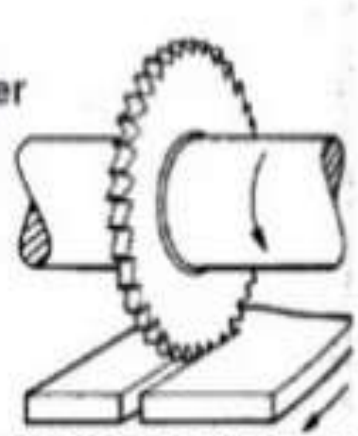
- These arbour mounted disc type cutters have a large number of cutting teeth at equal spacing on the periphery.



(a) parallel facing by two side (single) cutter



(b) slotting by side (double sided) milling cutter



(c) Parting by slitting saw

Side milling cutters

Cutters

a. Straddle: more cutters are used to machine two parallel surfaces on the workpiece

b. Form milling produces curved profiles using cutters that have specially shaped teeth

Slotting and slitting operations are performed with circular cutters. [T-slot cutters,

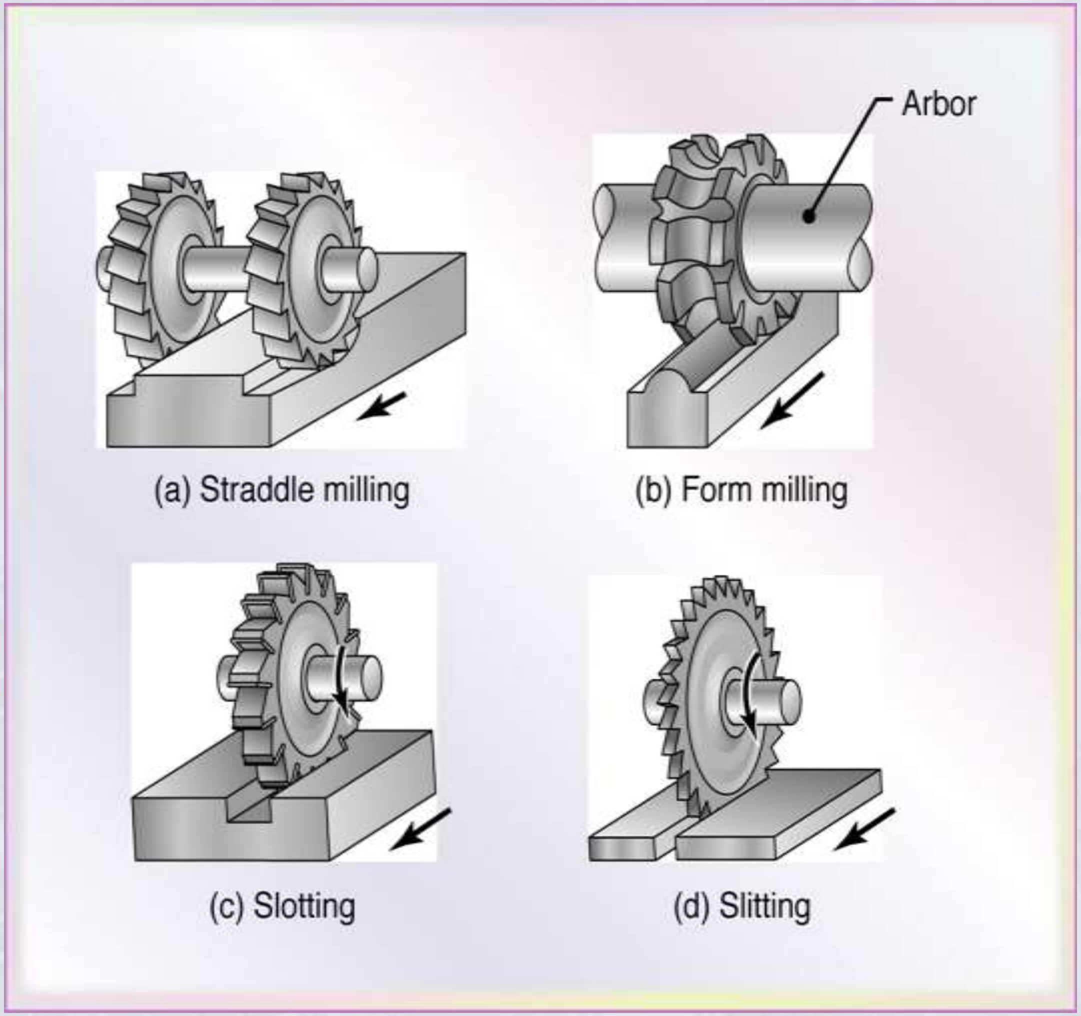
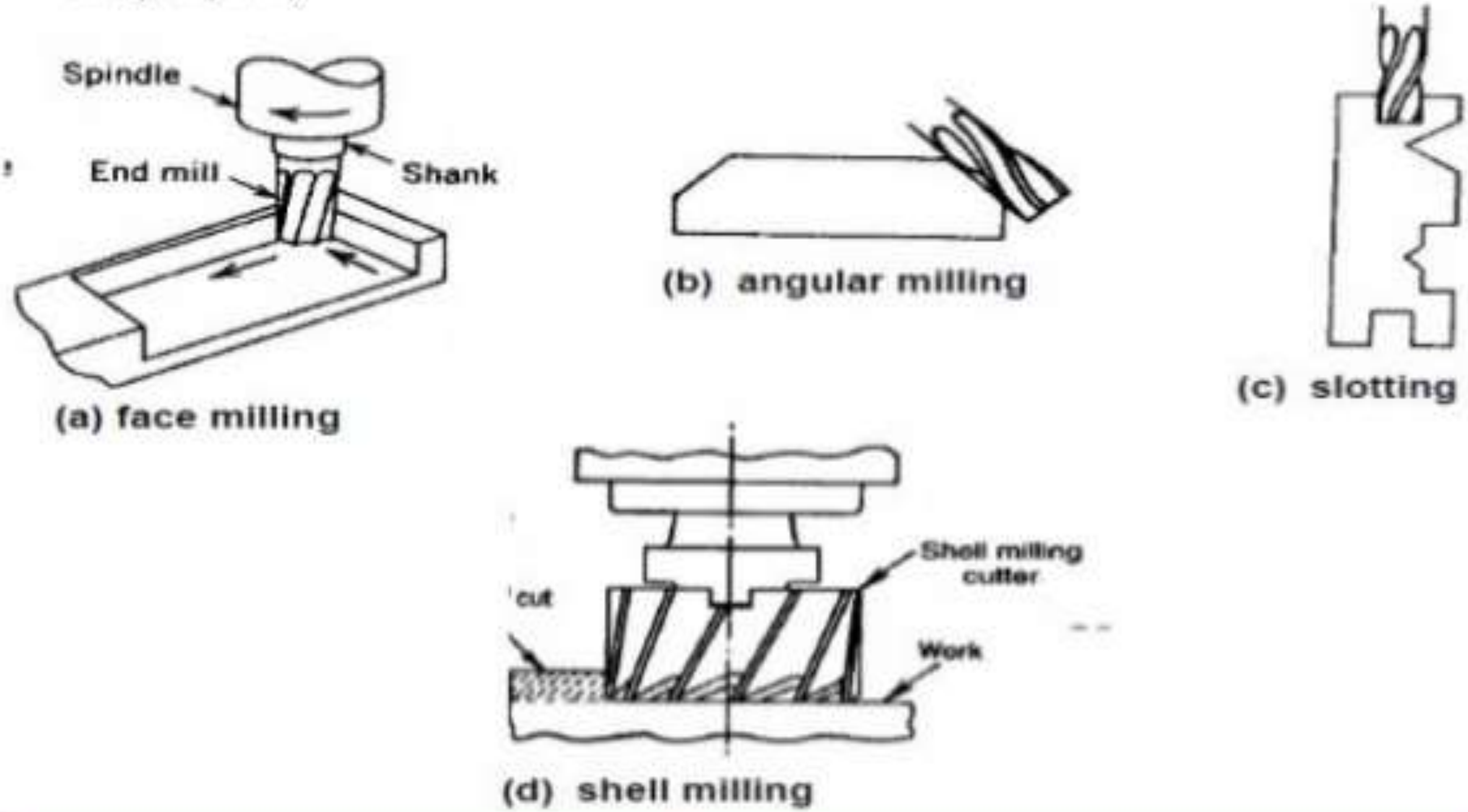


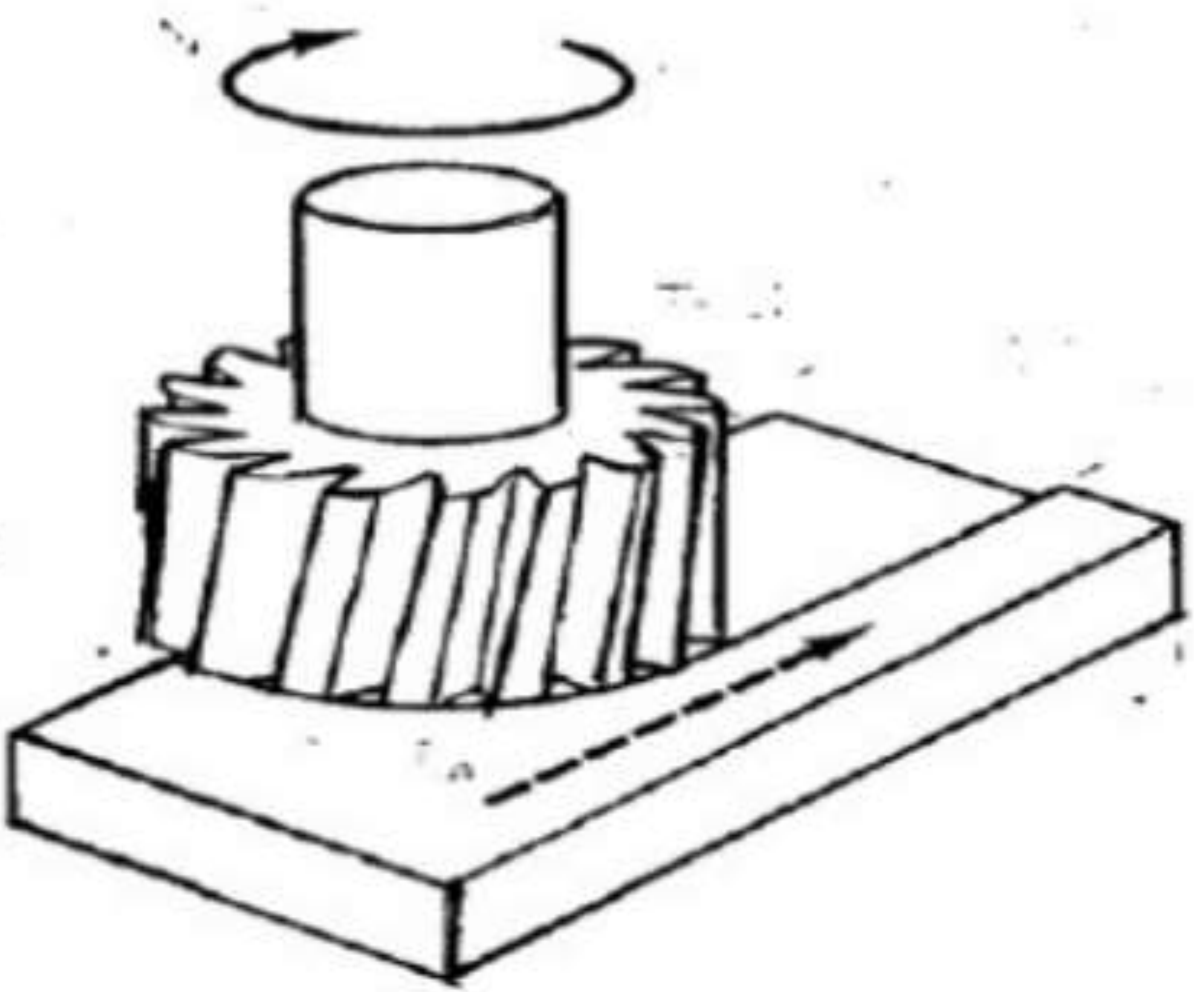
Figure 24.11 Cutters for (a) straddle milling, (b) form milling, (c) slotting, and (d) slitting with a milling cutter.

End milling cutters

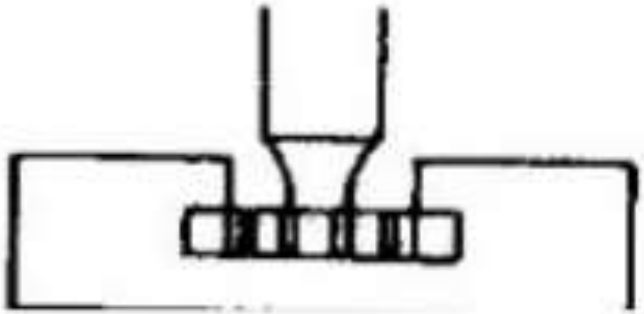
- The end milling cutter, also called an end mill, has teeth on the end as well as the periphery

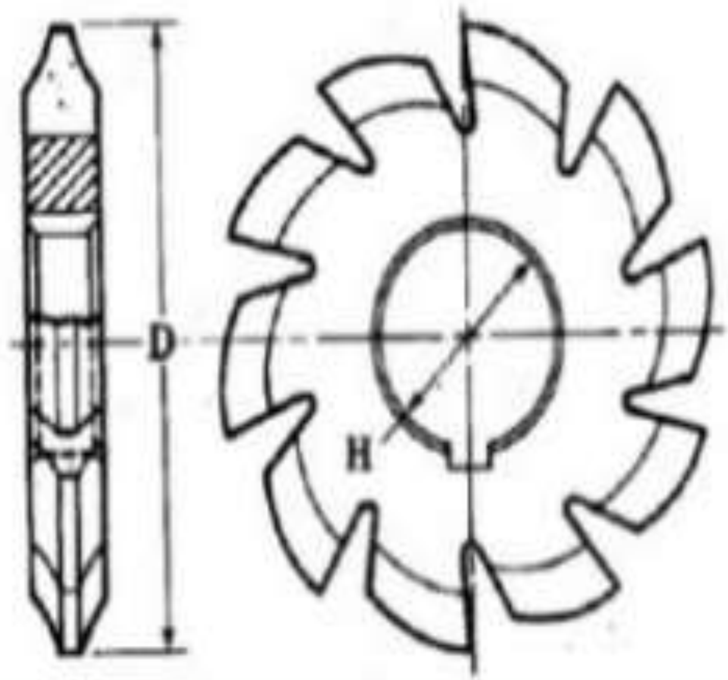


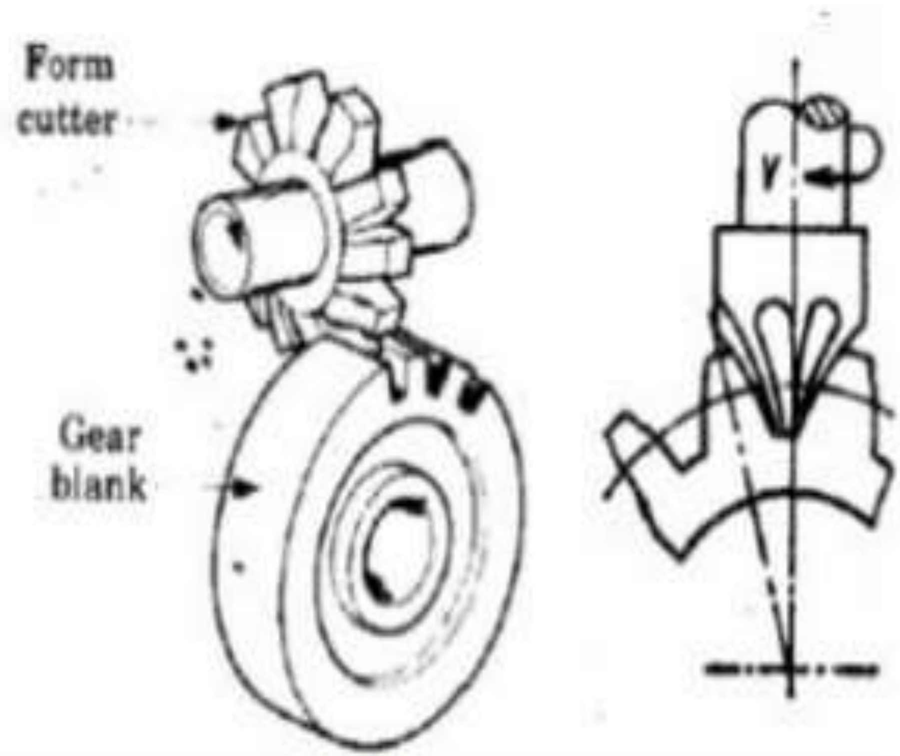
Face milling cutter



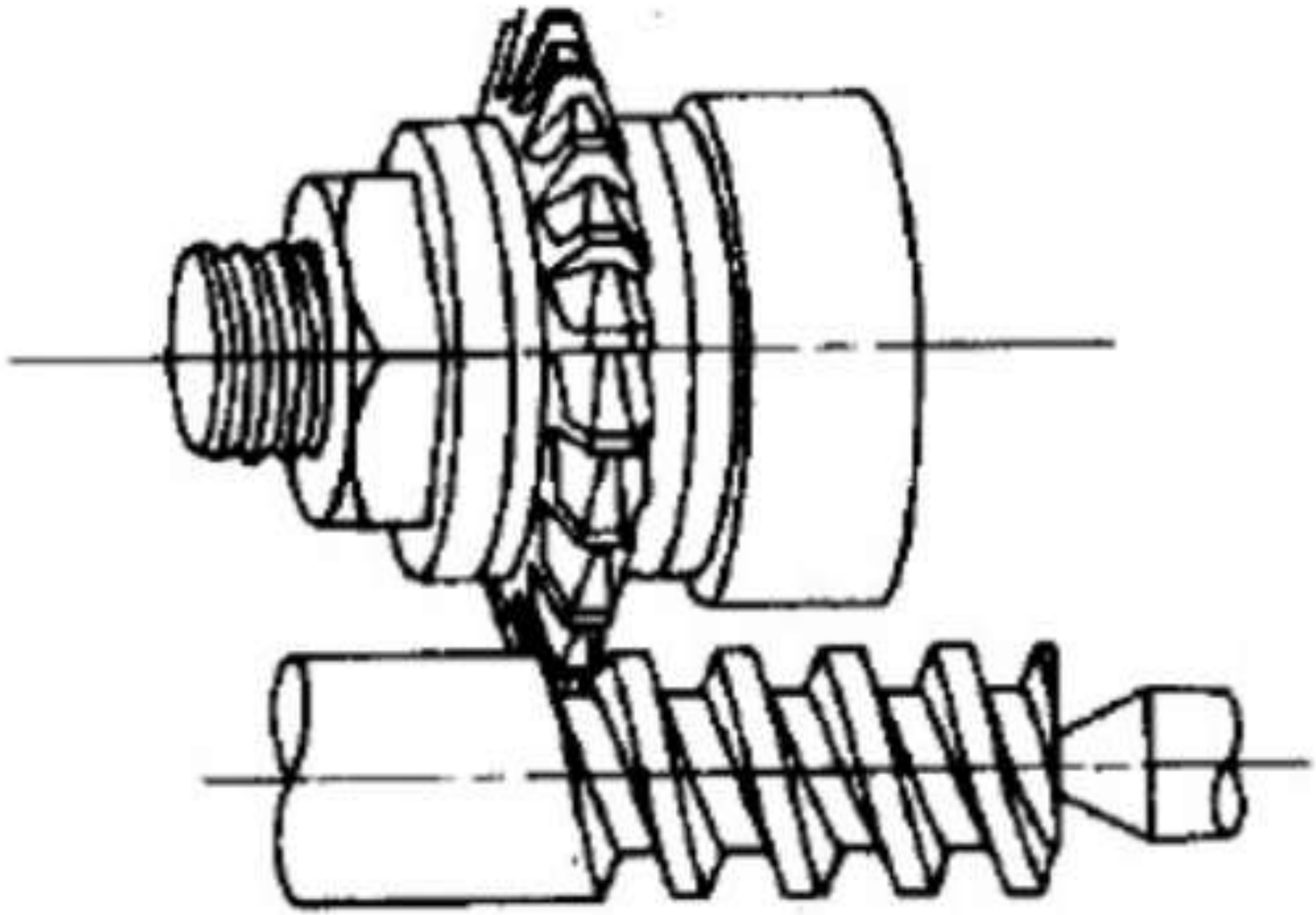
T-slot & Gear milling cutters



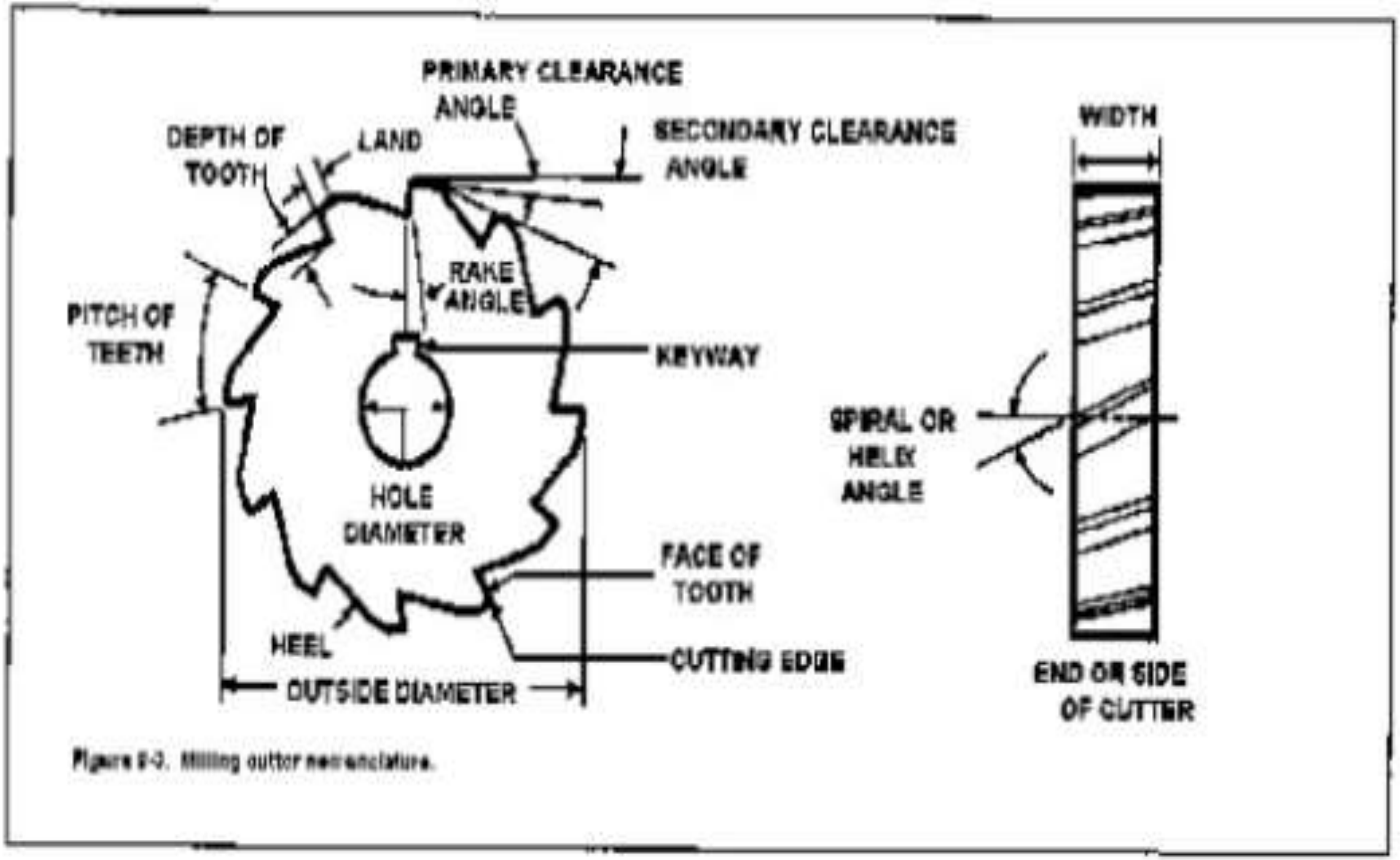




Thread milling cutter



Milling Cutter Nomenclature



Milling Cutter Nomenclature

- The pitch refers to the angular distance between like or adjacent teeth.
- The pitch is determined by the number of teeth. The tooth face is the forward facing surface of the tooth that forms the cutting edge.
- The cutting edge is the angle on each tooth that performs the cutting.
- The land is the narrow surface behind the cutting edge on each tooth.
- The rake angle is the angle formed between the face of the tooth and the centerline of the cutter. The rake angle defines the cutting edge and provides a path for chips that are cut from the workpiece.
- The primary clearance angle is the angle of the land of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents each tooth from rubbing against the workpiece after it makes its cut.

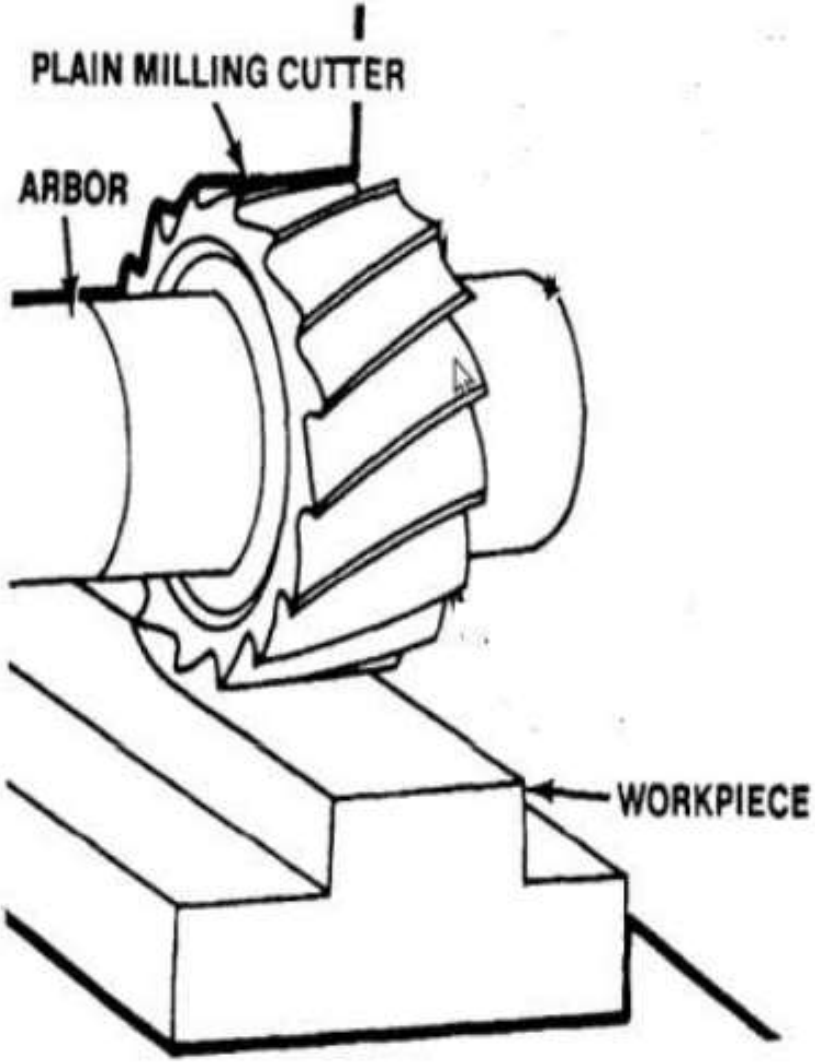
MILLING OPERATIONS

- Plain or slab milling
- Face milling
- End milling
- Side milling
- Slot milling
- Angular milling
- Form milling
- Straddle milling

MILLING OPERATIONS

- Slitting or saw milling
- Gear cutting
- Key way milling
- String milling
- Profile milling
- Thread milling
- Helical milling
- Cam milling

PLAIN/SURFACE/ SLAB MILLING



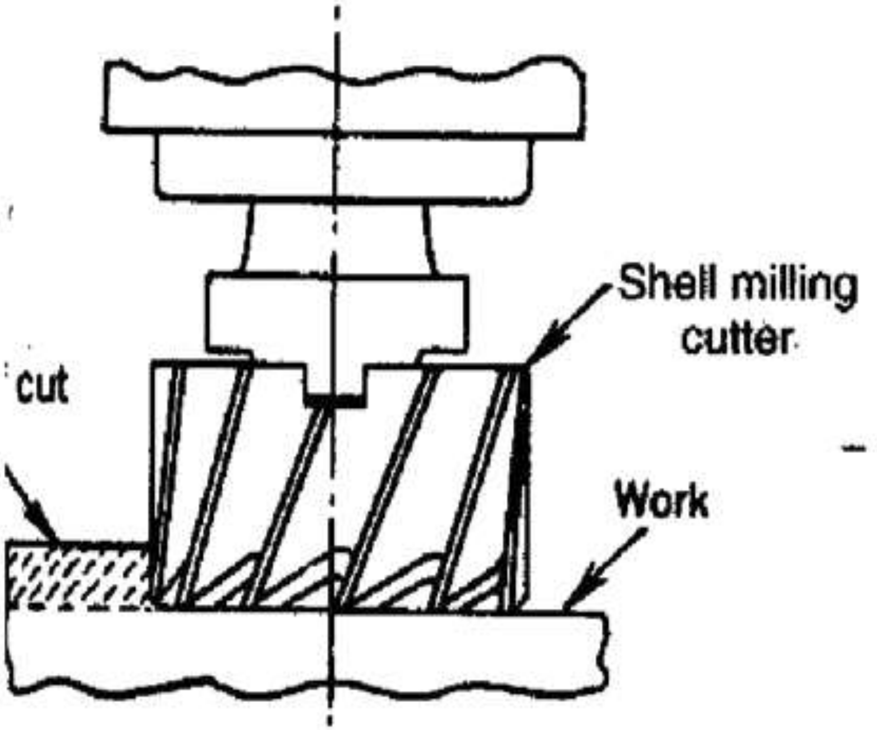
Plain Milling:

Process to get the flat surface on the work piece in which the cutter axis and work piece axis are parallel. The primary motion is the rotation of the cutter. The feed is imparted to the work piece.

Cutter: Plain milling cutter.

Machine: Horizontal Milling m/c.

FACE MILLING



Face Milling:

Operation carried out for producing a flat surface, which is perpendicular to the axis of rotating cutter.

Cutter: Face milling cutter.

Machine: Vertical Milling Machine

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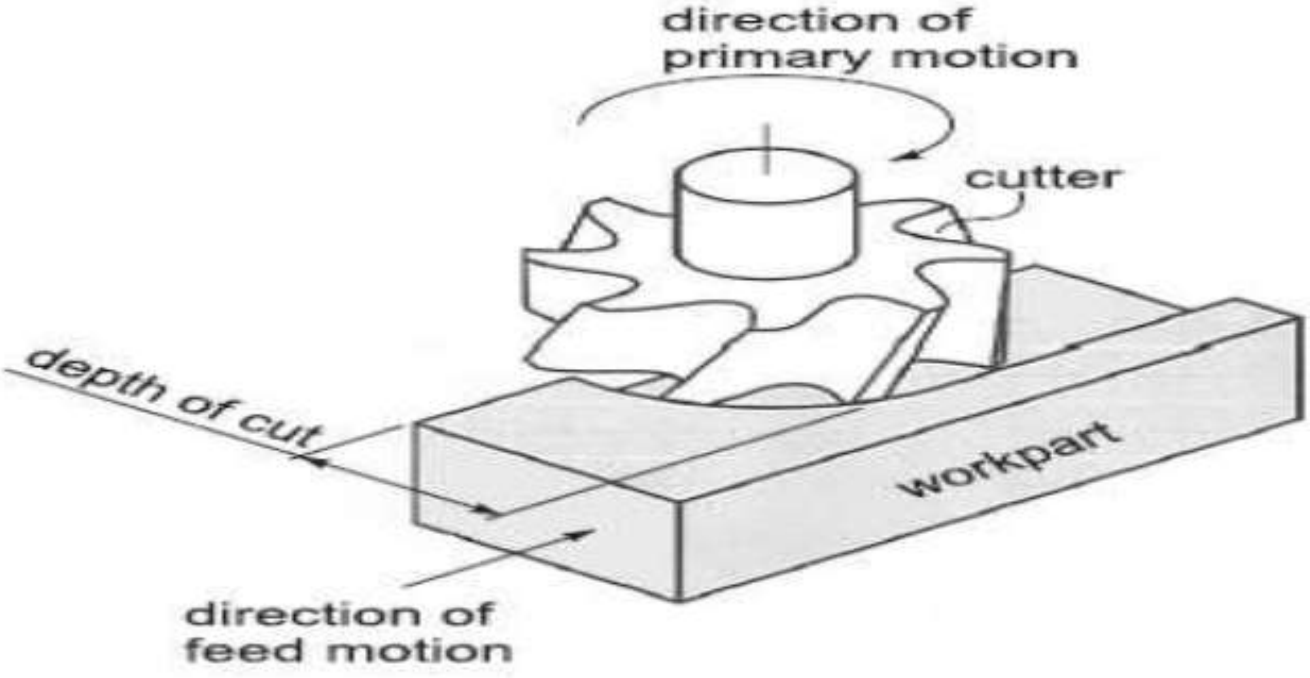
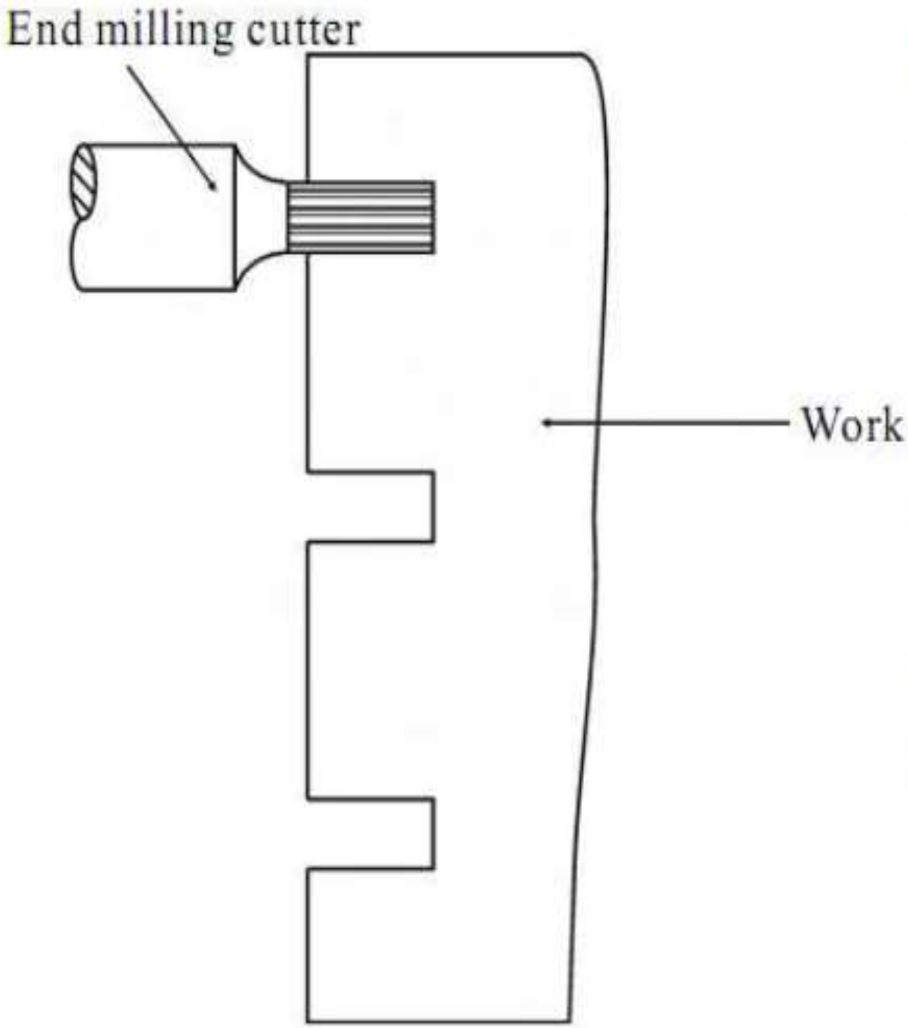
FACE MILLING



Partial face milling operation. The face-milling cutter machines only one side of the workpiece.

END MILLING



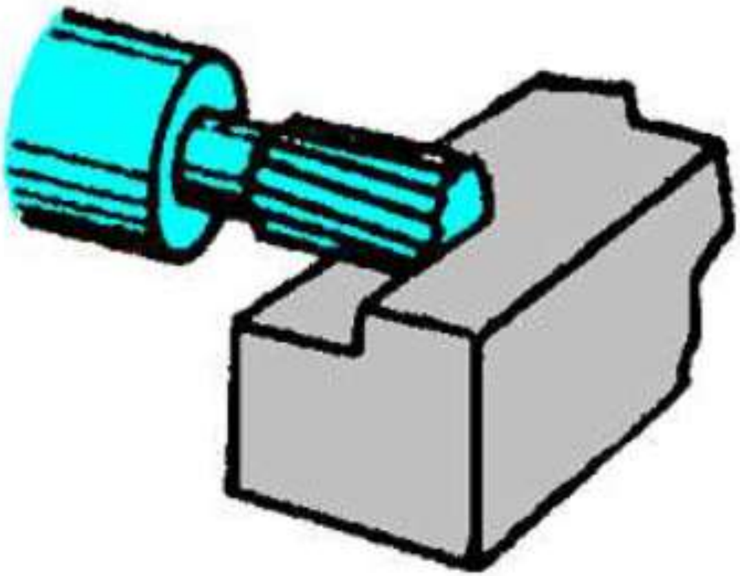
End Milling:

Operation performed for producing flat surfaces, key slots, grooves or finishing the edges of the work piece.

Cutter: End milling cutter.

Machine: Vertical Milling Machine

SIDE MILLING



SIDE MILLING : Operation performed for producing flat surfaces, slots, grooves or finishing the edges of the work piece.

Cutter: End milling cutter.

Machine: Horizontal Milling Machine

SLOT MILLING

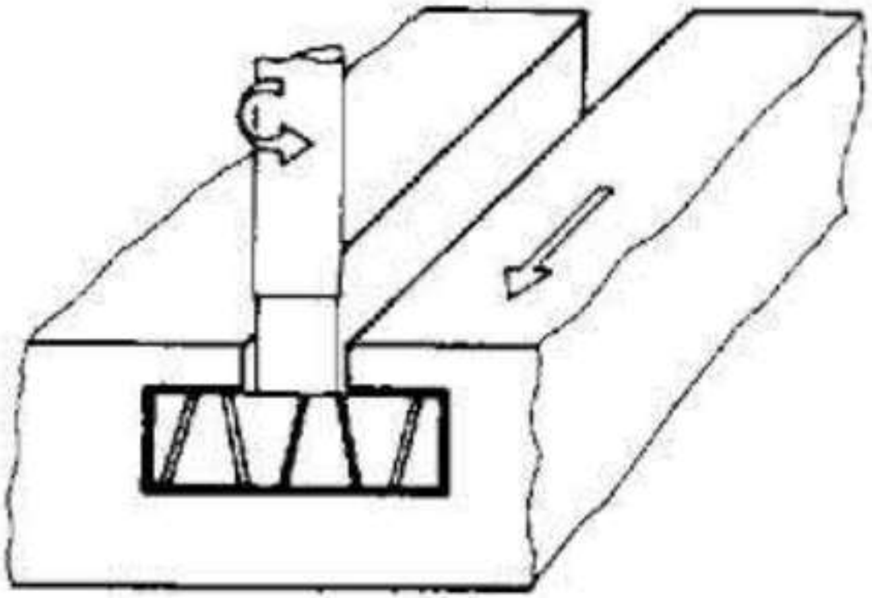


FIG. T-SLOT MILLING

Slot Milling:
Operation of producing slots like T-slots, plain slots etc.,

Cutter: End milling cutter, T-slot cutter, side milling cutter

Machine: Vertical Milling Machine

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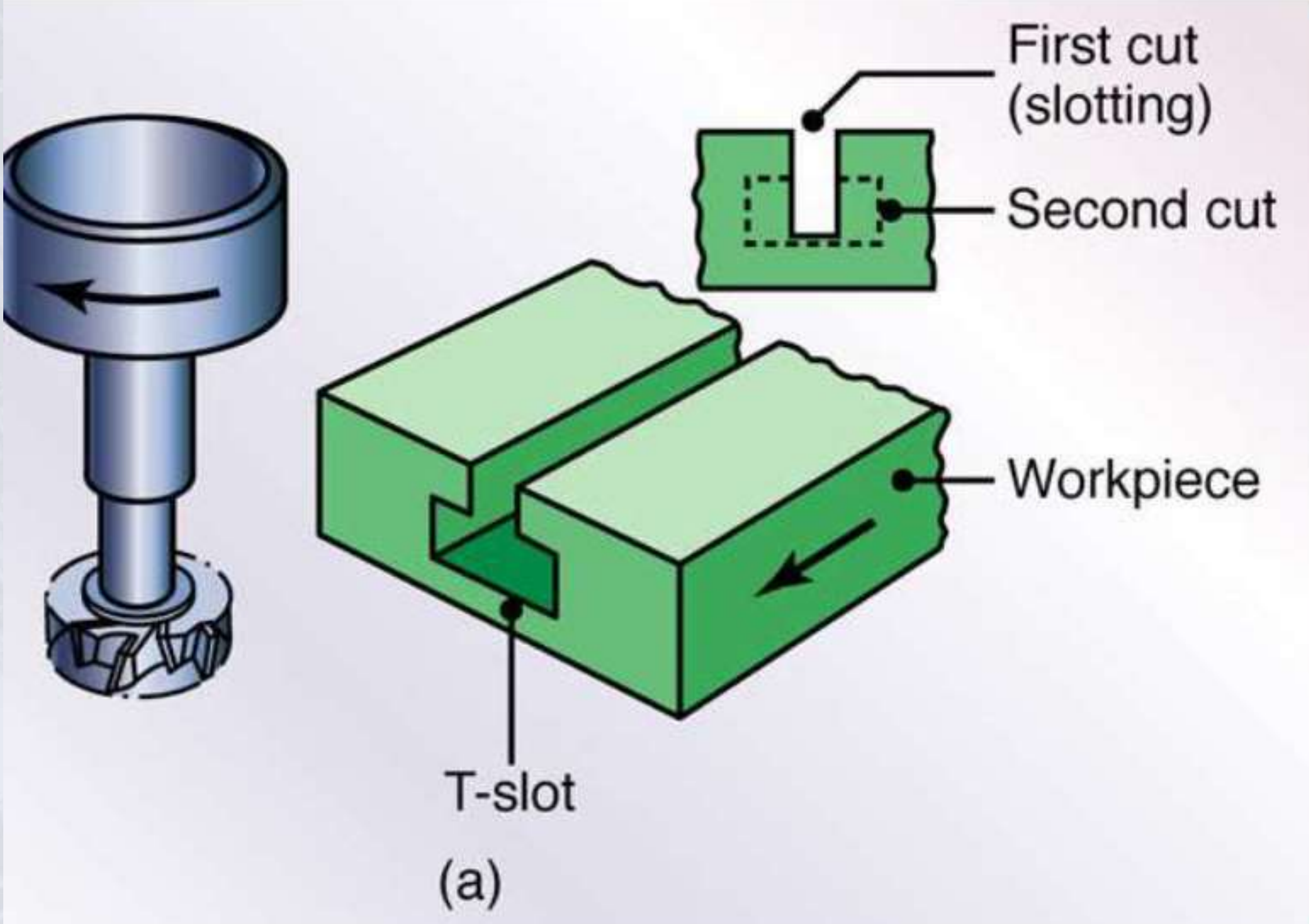

First cut
(slotting)
Second cut
Workpiece
T-slot
(a)

ANGULAR MILLING

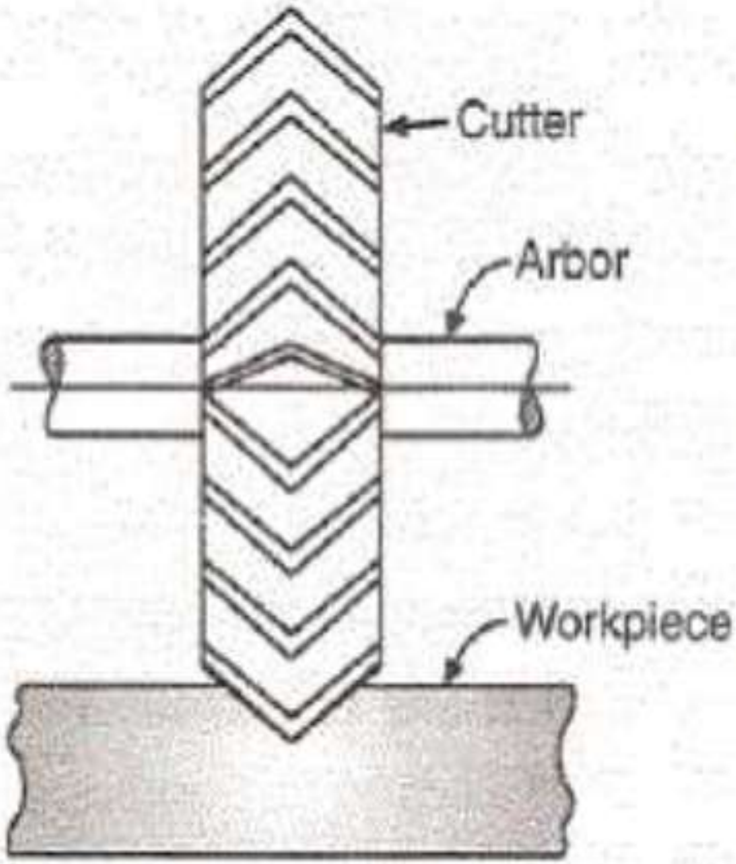


FIG. ANGULAR MILLING

Angular Milling:

Operation of producing all types of angular cuts like V-notches and grooves, serrations and angular surfaces.

Cutter: Double angle cutter.

Machine: Horizontal Milling Machine

FORM MILLING

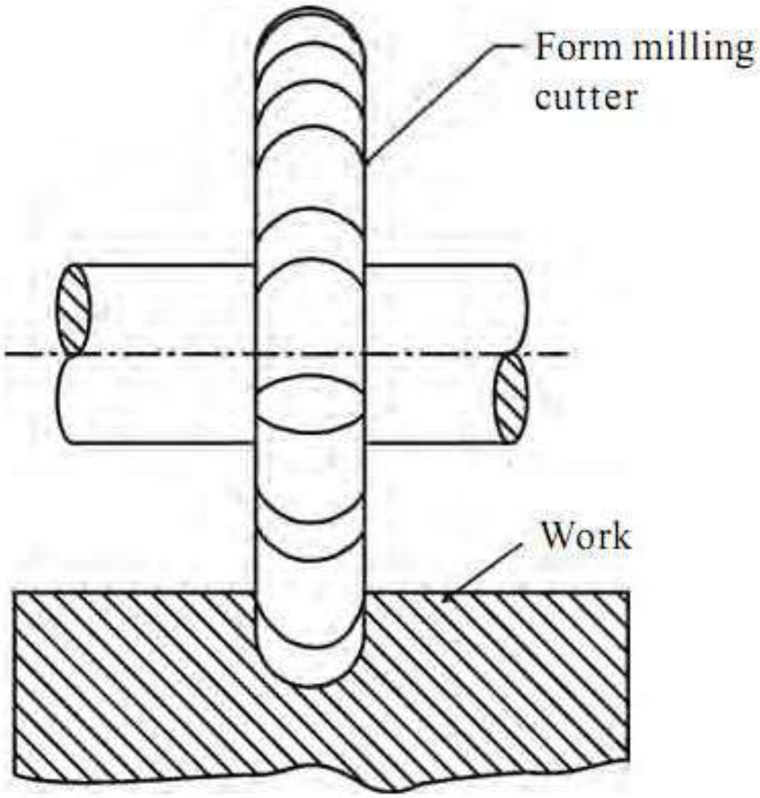


FIG. FORM MILLING

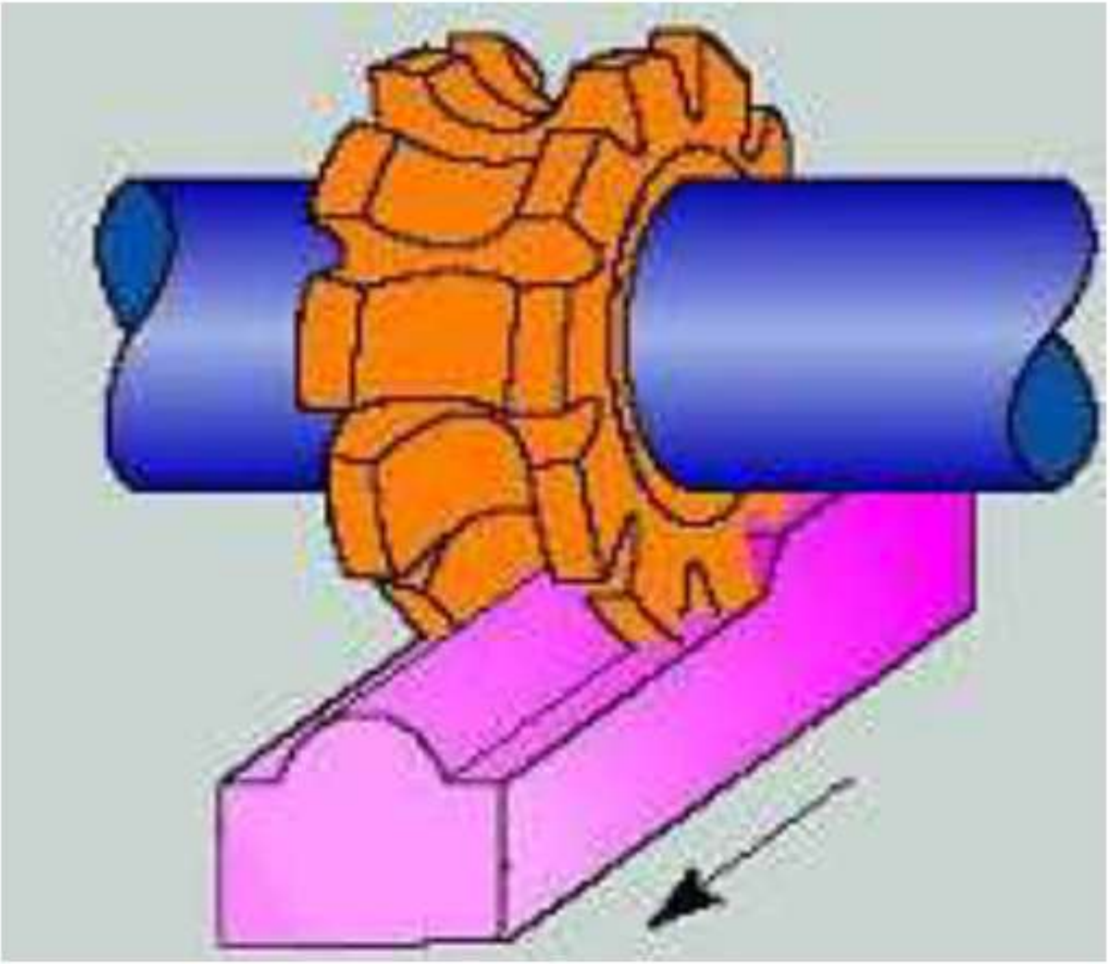
Form Milling:

Operation of producing all types of angular cuts like V-notches and grooves, serrations and angular surfaces.

Cutter: Double angle cutter.

Machine: Horizontal Milling Machine

FORM MILLING



STRADDLE MILLING

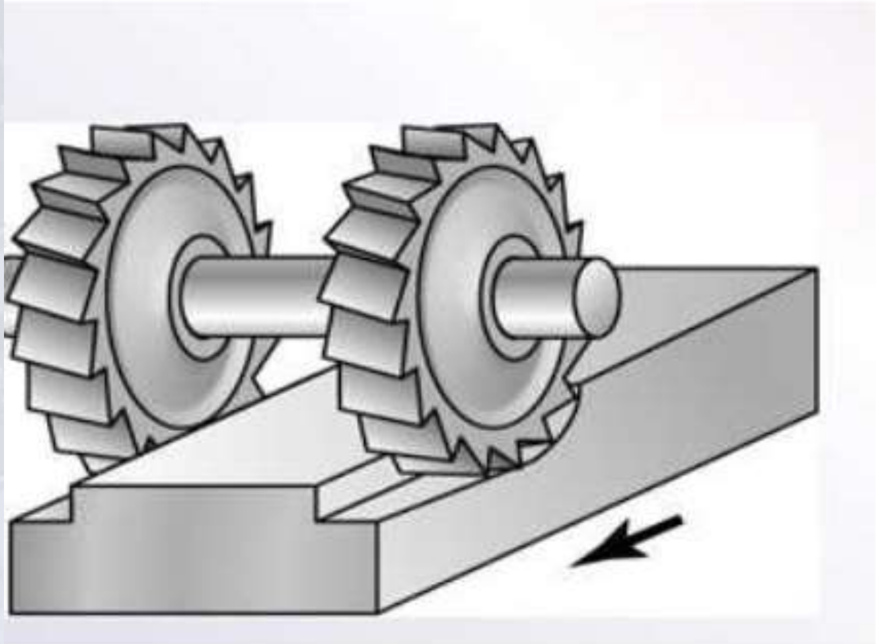


FIG. STRADDLE MILLING

Straddle Milling:
Operation of machining two parallel surfaces simultaneously on a work piece.

Cutter: 2 or more side & face milling cutters

Machine: Horizontal Milling Machine

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GANG MILLING

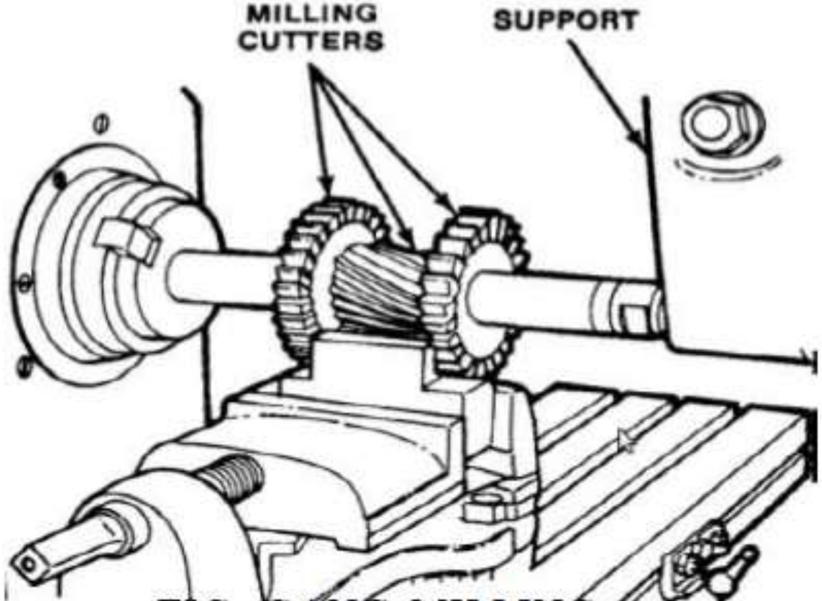


FIG. GANG MILLING

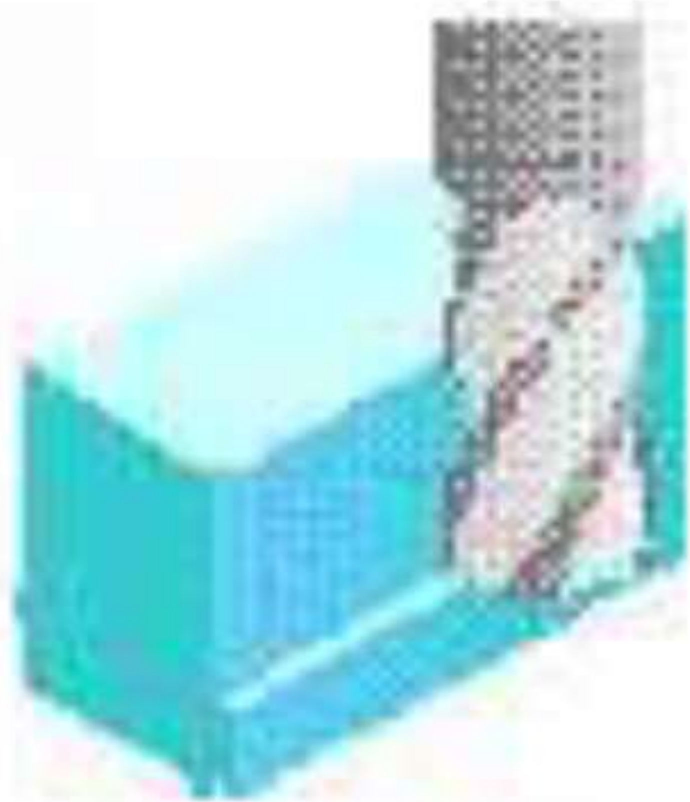
Gang Milling:
Process to get different profiles on the work piece simultaneously with two or more cutters at one stretch.

Cutter: Different cutters as required.

Machine: Horizontal Milling Machine

Profile milling

- Outside periphery of flat part is cut.
- Conventional end mill is used to cut the outside or inside periphery of a flat part.



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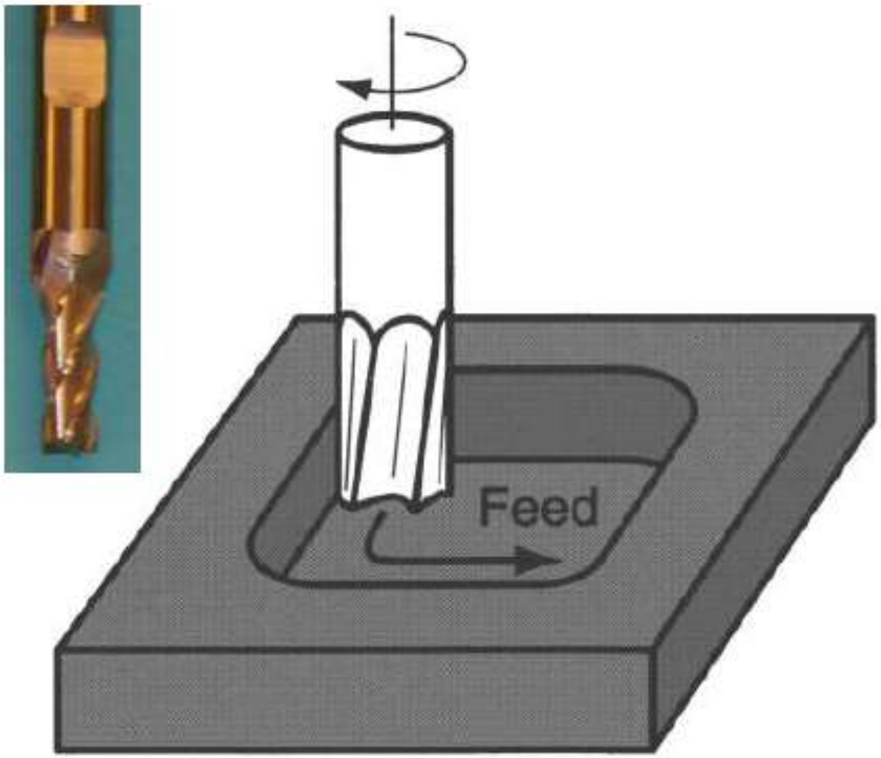
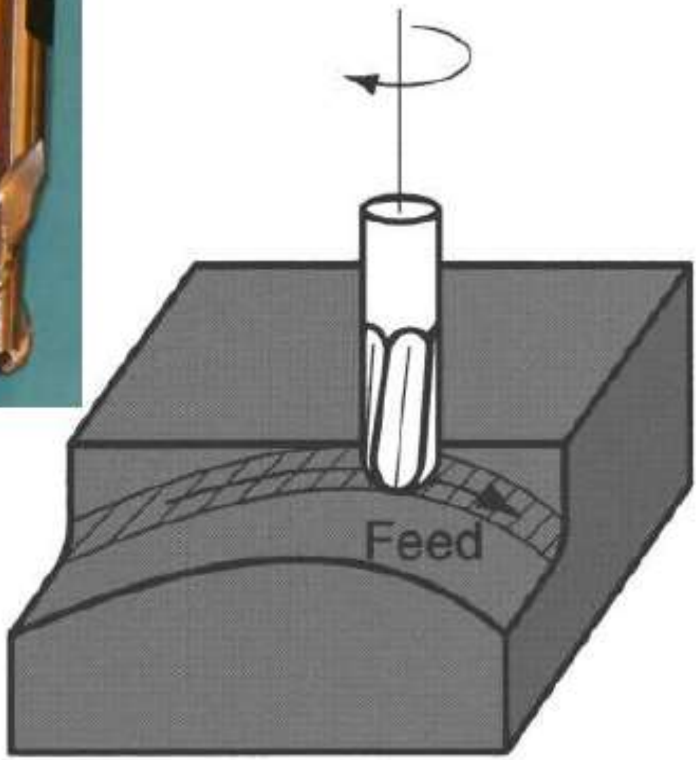
Pocket Milling



(e)

Another form of end milling used to mill shallow pockets into flat parts

SURFACE CONTOURING



(f)

Ball - nose cutter is fed back and forth across the work along a curvilinear path at close intervals to create a three dimensional surface.