Conventional Machining:

- Conventional machining is a manufacturing process in which a sharp cutting tool is used to cut away material to leave the desired part shape.
- The predominant cutting action in conventional machining involves shear deformation of w.p. to form chip; as chip is removed a new surface is produced as shown in figure (4-22).

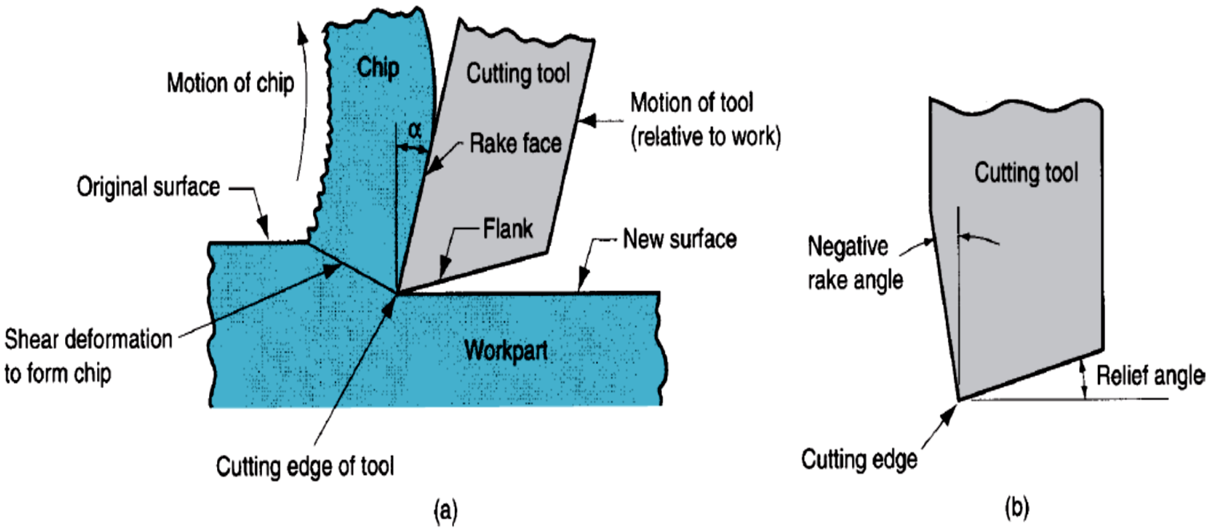


Figure (4-22) (a) a cross-sectional view of the machining process (b) tool with negative rake angle compare with positive rake angle in (a).

- Conventional machining is generally performed after other manufacturing processes such as casting or bulk deformation (e.g., forging, bar drawing).
- The other processes create the general shape of the starting w.p. and conventional machining provides the final geometry, dimensions and finish.

Advantages of Conventional Machining:

- Variety of work materials can be machined like all solid metals, plastics, plastic composites. Ceramics can be machined by abrasive machining.
- Variety of part shapes and geometric features can be produced by conventional machining. Regular geometries (flat planes, round holes, cylinders) and irregular geometries (screw threads, T-slots) can be manufactured by CM.

- Dimensional accuracy to very close tolerances. Some of machining operations can achieve tolerances of ±0.025mm.
- Good surface finish. Roughness values less than 0.4 microns can be achieved by CM processes.

Disadvantages of Conventional Machining:

- Wasteful of material. Although the generated chip can usually be recycled but still CM considered a wasteful processes.
- Time consuming. CM takes more time to shape part than alternative shaping processes such as casting or forging.

Overview of Conventional Machining Technology:

- To carry out CM and form the chip, a relative motion is required between cutting tool and w.p.
- This relative motion is achieved by means of a primary motion (cutting speed) and a secondary motion (feed).
- The shape of cutting tool and its penetration into w.p., combined with these motions, produces the desired geometry of w.p.

Common CM Operations:

Figure (4-2) illustrates these operations.

- **Turning:** in which a cutting tool with a single cutting edge is used to remove material from a rotating w.p. to generate a cylindrical shape.
- The primary motion is provided by rotating w.p. and the feed motion is achieved by the cutting tool moving slowly in a direction parallel to axis of rotation of w.p.

- **Drilling:** is used to create a round hole. It is accomplished by a rotating cutting tool that typically has two cutting edges.
- The cutting tool is fed in a direction parallel to its axis of rotation into the w.p.

- **Milling:** in which a rotating cutting tool with multiple cutting edges is fed slowly across the w.p. to generate a plane or straight surface.
- The direction of feed motion (by w.p.) is perpendicular to the cutting tool's axis of rotation.

- The primary motion is provided by the rotating milling cutter.

<u>The Cutting Tool:</u>

- A cutting tool has one or more sharp cutting edges and is made of a material that is harder than w.p.
- The cutting edge serves to separate a chip from the parent w.p. as shown in figure (4-22).
- Connected to the cutting edge are two surfaces of the tool: the rake face and flank.
- **The rake face:** it directs the flow of generated chip and is oriented at angle called "the rake angle".
- **The flank:** provides a clearance between the cutting tool and the new generated surface, thus protecting the surface from abrasion, which would degrade the finish. The flank is defined by angle called "the relief angle".
- There are two basic types of cutting tools: **(a) single-point tool (b) multiple-cutting-edge-tool**
- Figure (4-23) shows the cutting tool.

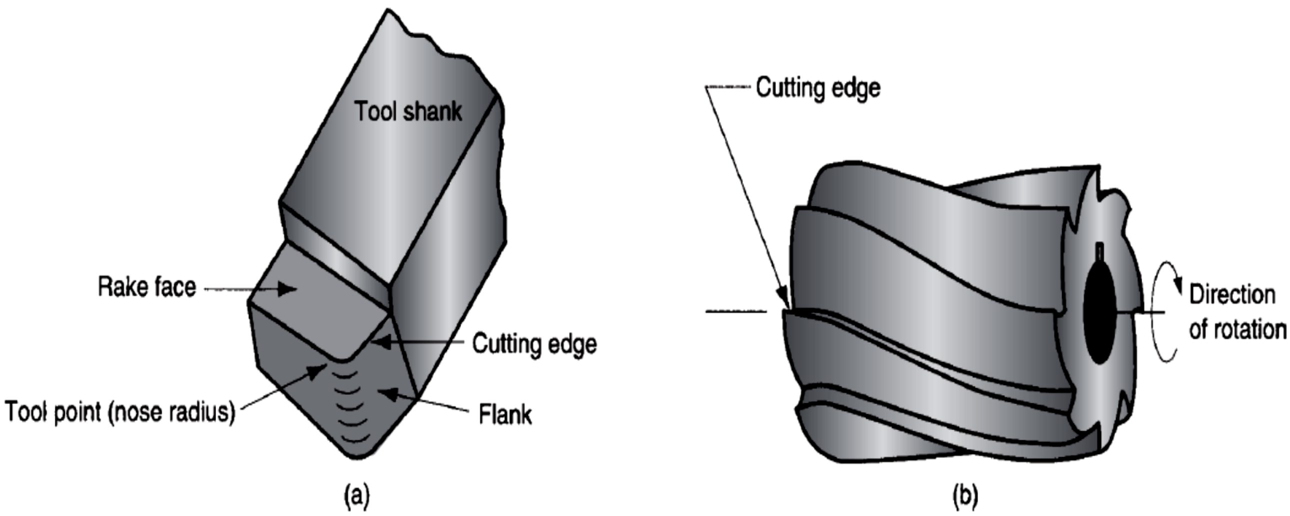


Figure (4-23) (a) a single-point tool, (b) a helical milling cutter (multiple cutting edge tool)

(a) Single-Point Tool

- It has one cutting edge and is used for operations such as turning.
- Also, there is one tool point, during machining, penetrates below the original w.p. surface.
- This point is usually rounded to a certain radius called "nose radius".

(b) Multiple-Cutting-Edge Tool

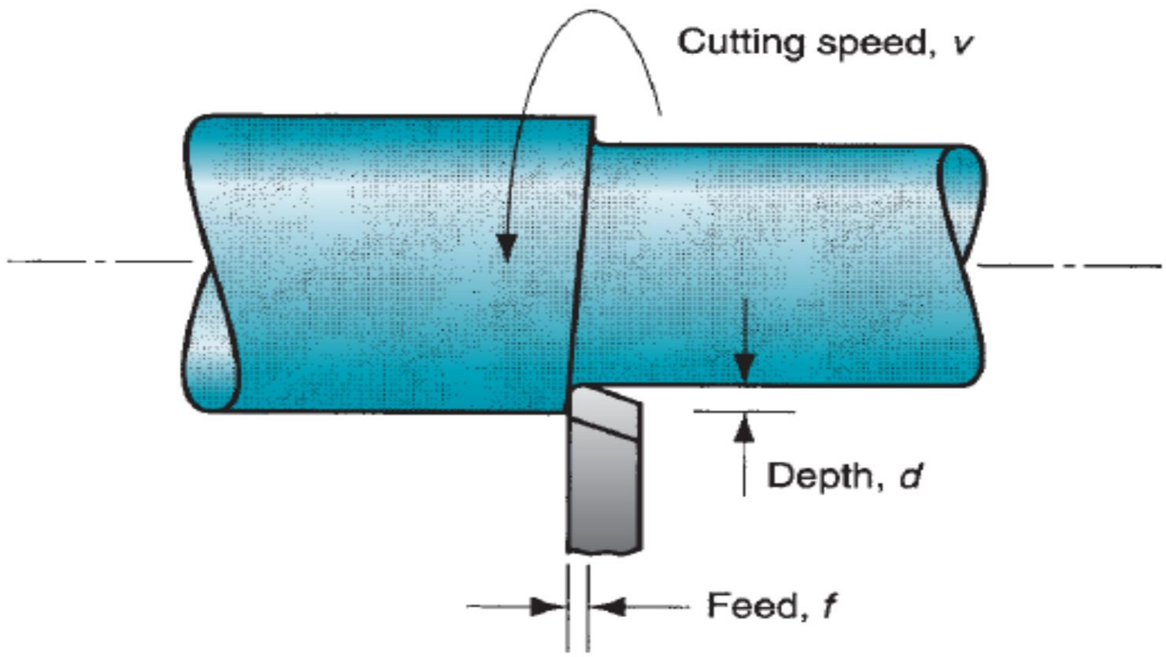
- It has more than one cutting edge and usually achieve its motion relative to w.p. by rotating.
- Drilling and milling use this type of tool.

Cutting Conditions:

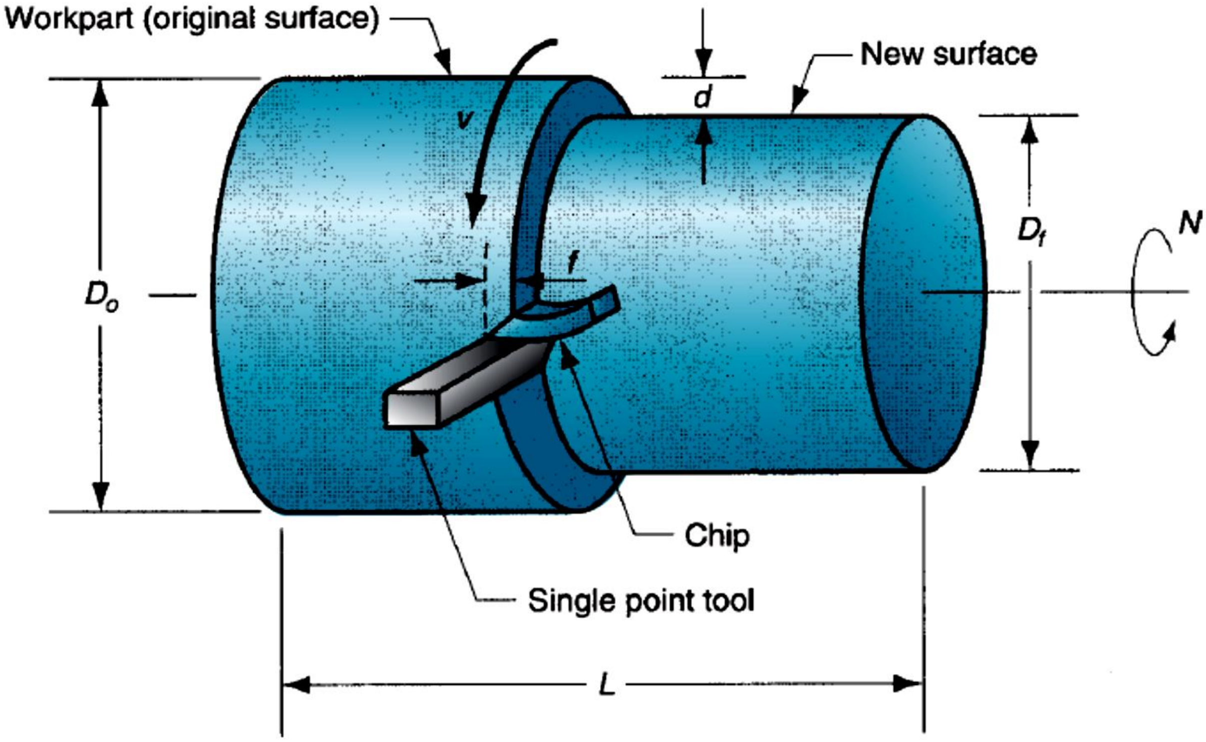
- Cutting speed (*v*): primary relative motion between cutting tool and w.p. (mm/s, in/min, ft/min).
- Feed (*f*): secondary motion of the cutting tool laterally across the w.p. This is much slower motion. (mm, in, ft).
- Depth of cut (*d*): it is penetration of cutting tool below the original w.p. surface. (mm, in, ft).
- The above three terms are called the cutting conditions.
- They can be used to calculate the material removal rate (R_{MR}) for certain operations (e.g., most single-point tool operations).
- Figure (4-24) shows the cutting conditions for a turning operation.

- **Turning Operations:**

$$R_{MR} = vfd \quad \left(\frac{mm^3}{s}, \frac{in^3}{min}, \frac{ft^3}{min}\right)$$



(a)



(b)

Figure (4-24) cutting speed, feed and depth of cut for a turning operation; (a) two dimensions, (b) three dimensions

- Feed Rate: $$f_r = Nf$$

  f_r: feed rate (mm/min), N: rotational speed (rpm), f: feed (mm/rev)

- Machining Time: $$T_m = \frac{L}{f_r} = \frac{\pi D_o L}{f v}, \qquad N = \frac{v}{\pi D_o}$$

  T_m: machining time (min), L: w.p. length (mm), D_o: w.p. diameter (mm), v: cutting speed (m/min).

- **Drilling Operations:**

- **Material Removal Rate:** $$R_{MR} = \frac{\pi D^2 f_r}{4} \qquad (mm^3/min)$$

  D: drill diameter (mm), f_r: feed rate (mm/min)

- **Feed Rate:** $$f_r = Nf \quad , \qquad N = \frac{v}{\pi D}$$

  N: drill rotational speed (rpm), v: cutting speed (mm/min), f: feed (mm/rev)

  Since there are (usually) two cutting edges at the drill point, the uncut chip thickness (chip load) taken by each cutting edge is half the feed.

- **Machining Time:**

1. **<u>Through Holes</u>:** $T_m = \frac{t+A}{f_r}$, $A = 0.5D \tan\left(90 - \frac{\theta}{2}\right)$

t: w.p. thickness (mm), f_r: feed rate (mm/min), *A*: approach allowance (mm), θ: drill point angle

A: an approach allowance that accounts for the drill point angle, representing the distance the drill must feed into the work before reaching full diameter.

2. **<u>Blind Holes</u>:** $T_m = \frac{d+A}{f_r}$,

T_m: machining time (min), *d*: hole depth (mm),

Figure (4-25) shows cutting conditions of drilling operations.

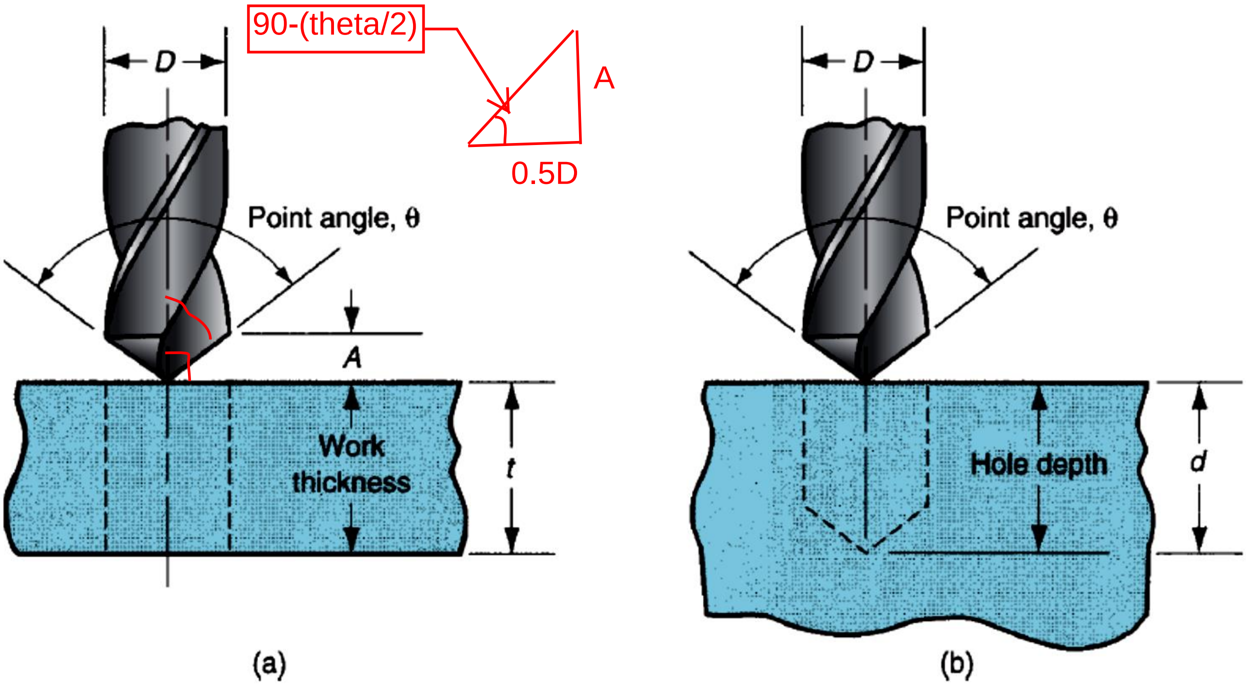


Figure (4-25) two hole types in drilling operation; (a) through hole, (b) blind hole

- **<u>Milling Operations:</u>**

- **Material Removal Rate:** $R_{MR} = wdf_r \quad (mm^3/min)$

w: w.p. width (mm), *d*: cut depth (mm), f_r: feed rate (mm/min)

MRR: it is determined using the product of the cross-sectional area of the cut and the feed rate.

- **Feed Rate:** $f_r = N n_t f,\qquad N = \frac{v}{\pi D}$

f_r: feed rate (mm/min), N: cutter rotational speed (rpm), n_t: number of teeth on the cutter, f: feed per cutter tooth (chip load) (mm/tooth), v: cutting speed (mm/min), D: cutter diameter (mm)

Chip Load: it represents the size of the chip formed by each cutting edge.

- **Machining Time:**

1. Slab Milling (Peripheral): $T_m = \frac{L+A}{f_r}\quad , \quad A = \sqrt{d(D-d)}$

T_m: machining time (min), L: w.p. length (mm), d: depth of cut (mm), D: cutter diameter (mm), A: approach distance

Approach Distance: the T_m required to mill a w.p. of length L must account for the approach distance (A) required to fully engage the cutter (to reach full cutter depth) as in Figure (4-26).

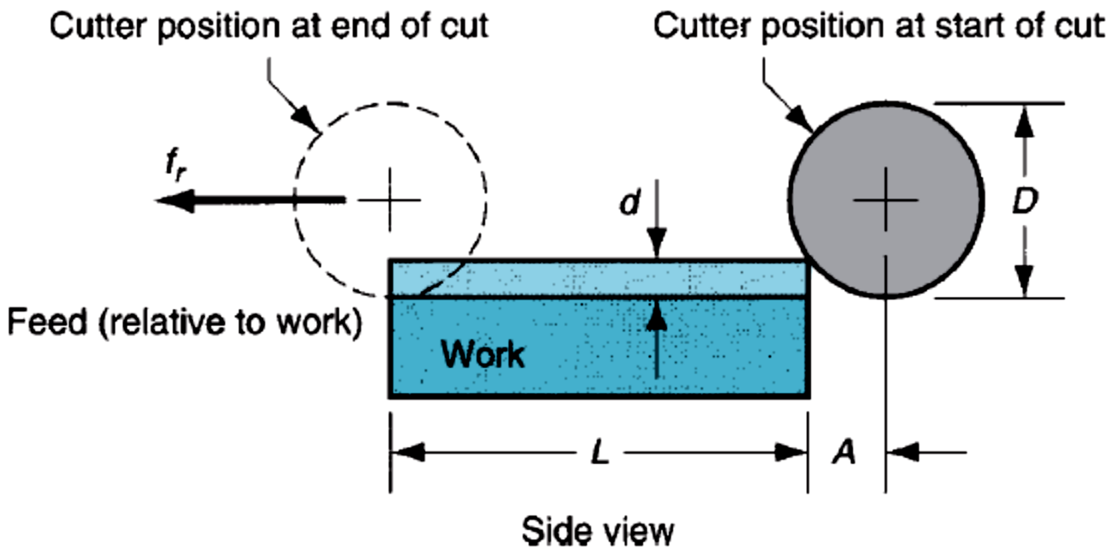


Figure (4-26) slab (peripheral) milling showing entry of cutter into w.p.

2. Face Milling: there are two cases as shown in figure (4-27).

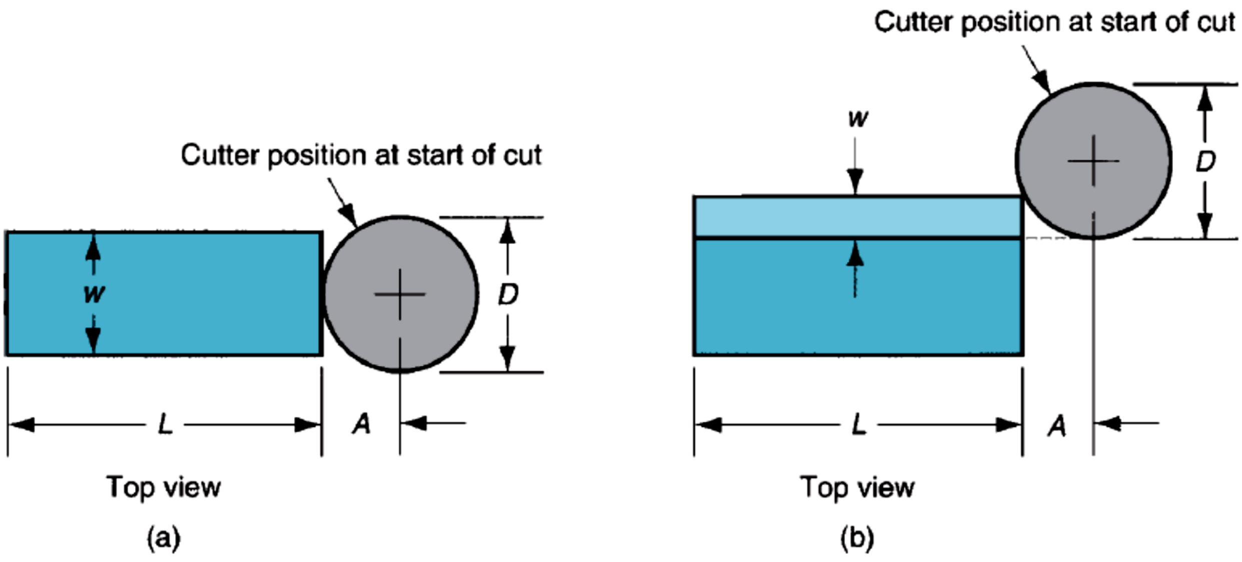


Figure (4-27) Face milling showing approach and overtravel distances for two cases.

(a) When cutter is centered over the w.p. The cutter feeds from right to left. In order for the cutter to reach the full width of w.p., it must travel an approach distance (*A*) which given by:

$$A = 0.5\left(D - \sqrt{D^2 - w^2}\right)$$

D: cutter diameter (mm), *w*: w.p. width (mm)

(b) When the cutter is offset to one side over the w.p. The approach distance is:

$$A = \sqrt{w(D - w)}$$

w: width of the cut (mm).

In both cases, the machining time is: $T_m = \frac{L+A}{f_r}$

Example (1):

A cylindrical w.p. 200 mm in diameter and 700 mm long is to be turned in an engine lathe. Cutting speed = 2.3 m/s, feed = 0.32 mm/rev, and depth of cut = 1.8 mm. Determine (a) feed rate, (b) cutting time (machining time), and (c) metal removal rate.

Solution:

(a) $f_r = Nf = \frac{v}{\pi D_o} f = \frac{2.3\,(10^3)}{\pi(200)}(0.32) = 1.17\,\frac{mm}{s} = 70.2\,\frac{mm}{min}$ *Answer*

(b) $T_m = \frac{L}{f_r} = \frac{700}{70.2} = 9.97\,min$ *Answer*

(c) $R_{MR} = vfd = 2.3(10^3)(60)(0.32)(1.8) = 79488\ mm^3/min$ *Answer*

Example (2):

A drilling operation is to be performed with a 12.7-mm diameter twist drill in a steel w.p. The hole is a blind hole at a depth of 60 mm and the point angle is 118º. The cutting speed is 25 m/min and the feed is 0.3 mm/rev. Determine (a) feed rate, (b) the cutting time to complete the drilling operation, and (c) metal removal rate during the operation, after the drill bit reaches full diameter.

Solution:

(a) $f_r = Nf = \frac{v}{\pi D} f = \frac{25\,(10^3)}{\pi(12.7)}(0.3) = 187.9\ \frac{mm}{min}$ *Answer*

(b) $T_m = \frac{d+A}{f_r}$

$$A = 0.5D\tan\left(90 - \frac{\theta}{2}\right) = 0.5(12.7)\tan\left(90 - \frac{118}{2}\right) = 3.815mm$$

$\therefore T_m = \frac{d+A}{f_r} = \frac{60+3.815}{187.9} = 0.339\,min = 20.34\,s$ *Answer*

(c) $R_{MR} = \frac{\pi D^2 f_r}{4} = \frac{\pi 12.7^2(187.9)}{4} = 23803\,\frac{mm^3}{min}$ *Answer*

Example (3):

A peripheral milling operation is performed on the top surface of a rectangular w.p. which is 400 mm long x 60 mm wide. The milling cutter, which is 80 mm in diameter and has five teeth, overhangs the width of the part on both sides.

Cutting speed = 70 m/min, chip load = 0.25 mm/tooth, and depth of cut = 5 mm. Determine (a) feed rate, (b) the actual machining time to make one pass across the surface and (c) the maximum material removal rate during the cut.

Solution:

Chip load = feed = 0.25 mm/tooth

(a) $\boldsymbol{f_r = Nn_t f = \frac{v}{\pi D} n_t f = \frac{70(10^3)}{\pi(80)}(5)(0.25) = 348.15\,\frac{mm}{min}}$ ***Answer***

(b) $\boldsymbol{T_m = \frac{L+A}{f_r}}$, $\boldsymbol{A = \sqrt{d(D-d)} = \sqrt{5(80-5)} = 19.4\,mm}$

$\boldsymbol{\therefore T_m = \frac{L+A}{f_r} = \frac{400+19.4}{348.15} = 1.2\,min}$ ***Answer***

(c) $\boldsymbol{R_{MR} = wdf_r = 60(5)(348.15) = 104445\,mm^3/min}$ ***Answer***

Example (4):

A face milling operation is used to machine 6 mm from the top surface of a rectangular piece of aluminum 300 mm long by 125 mm wide in a single pass. The cutter follows a path that is centered over the w.p. It has four teeth and is 150 mm in diameter. Cutting speed = 2.8 m/s, and chip load = 0.27 mm/tooth. Determine (a) feed rate, (b) the actual machining time to make the pass across the surface and (c) the maximum metal removal rate during cutting.

Solution:

Chip load = feed = 0.27 mm/tooth

(a) $f_r = N n_t f = \frac{v}{\pi D} n_t f = \frac{2.8(10^3)(60)}{\pi(150)}(4)(0.27) = 385 \frac{mm}{min}$ Answer

(b) $T_m = \frac{L+A}{f_r}$,

$$A = 0.5\left(D - \sqrt{D^2 - w^2}\right) = 0.5\left(150 - \sqrt{150^2 - 125^2}\right) = 33.5\ mm$$

$\therefore T_m = \frac{L+A}{f_r} = \frac{300+33.5}{385} = 0.866\ min = 52\ s$ Answer

(c) $R_{MR} = w d f_r = 125(6)(385) = 288750\ mm^3/min$ Answer