# LANDMARK UNIVERSITY, OMU-ARAN

**LECTURE NOTE: 2**
**COLLEGE: COLLEGE OF SCIENCE AND ENGINEERING**
**DEPARTMENT: MECHANICAL ENGINEERING**
**PROGRAMME: MECHANICAL ENGINEERING**
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*Course code: MCE 314*
*Course title:* WORKSHOP PRACTICE
Credit unit: *2 UNITS.*
Course status: *compulsory*
**Course Content:–**

*The topics in this course are: workshop safety; Workshop fitting and measurement; Sheet metal work; lathe work; Milling; Machine Shop and Metal Work Training; Plastic Technology Training; Injection moulding, rotational moulding, compression moulding; CAD and CNC machining; Hands-on-experience of students on all workshop equipment.*

ESTIMATION IN MACHINE SHOP.

For estimation purposes, machining cost is calculated after finding the material cost. Machining is done on castings, forgings, and bar stocks etc, for getting the exact size and shape of the product. In machine shop certain material is added as machining allowance, for this purpose we take slightly bigger dimensions than that shown on finished drawings on the sides which are to be machined.

MACHINE SHOP OPERATIONS.

Generally, the following operations are performed in the machine shop on different machines.

1 Turning, 2, Knurling, 3, Facing, 4, Drilling, 5, Boring, 6, Reaming, 7, Threading, 8, Tapping, 9, Milling, 10, Grinding, 11, shaping, 12, Planning.

In estimating, our aim is to find out the time which an operator takes for performing the machining operation and for calculating their wages. In addition to this machining time (also known as operation time) the following time considerations are taken:

I Setting up the job and tool or cutters

Ii Setting up the machine.

Iii Inspection of job

Iv Fatigue allowance.

V  Tool changing and sharpening time.

Vi  Machine cleaning and servicing time

Vii  Personal allowance.

In the study of machining time the following terms are generally used.

I  Cutting speed. This is the distance which the tool travels along the material in one minute. Its unit is metres/ min.

Let us consider an example, in which a job of D cm dia is revolving at a speed of N r.p.m. Then, distance travelled by the tool point in one minute = Distance moved in one revolution x Revolutions performed in one minute.

∴Cutting speed = $\frac{\pi DN}{100}\ {}^{m}/_{min}$

Cutting speed depends on the following factors:

a. Hard material requires a lower cutting speed than that of soft and ductile materials.
b. High speed tools, and tools of special cutting alloys can cut at higher cutting speeds than carbon steel tools.
c. If the depth of cut and feed is more, then less cutting speed is taken and vice versa.
d. By using good cutting fluids, cutting speeds may be increased.

An estimator should consider the above factors while selecting a suitable cutting speed.

The table below shows the cutting speeds of different materials on different operations. The cutting speeds are with high speed steel (H.S.S) tools.

| | Operations (cutting speeds are in m/min) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Materials | Turning and Boring | Drilling | Reaming | Threading | Tapping | Milling | Shaping, Sloting and Planing | Grinding |
| Aluminium | 300 | 120 | 120 | 30 | 45 | 200 | 25 | 20 |
| Brass/Gun metal | 50 | 50 | 25 | 30 | 20 | 40 | 12 | 22 |
| Mild Steel | 30 | 25 | 12 | 25 | 5 | 20 | 20 | 15 |
| Cast Iron | 20 | 15 | 10 | 20 | 7 | 50 | 10 | 12 |
| Copper | 30 | 50 | 15 | 30 | 20 | 40 | 10 | 22 |

NOTE.

1. Cutting speed for grinding in the table shown above shows the speed of the work at which it travels against the grinding wheel, while grinding wheel has its speed for

external grinding at 1800 m/min, for internal grinding as 1200 m/min and for surface grinding as 1500 m/min.

2. When the tungsten carbide tools are used, the cutting speeds are 2 to 3 times of these speeds.

2 Feed. It is the distance, through which the tool advances into the work-piece during one revolution of the work-piece or the tool or cutter. Its unit is mm/rev. As the feed depends on the depth of cut, cutting speed and power of the machine, hence no specific values for this can be mentioned.

3 Depth of cut. It is the amount by which a tool or a cutter is inserted into the metal during one cut. In other words, it is the thickness of the metal removed in one cut. It is generally measured in mm.

A. LATHE OPERATIONS.

Now we shall discuss about the estimation of time on different operations to be performed on lathe.

1 Turning: It is the operation of metal removal in which job is rotated against a tool.

Let S = Cutting speed in m/min.

D = Dia. Of job to be turned in cm.

N = Revolution of the job/min.

F = Feed/rev.

but $S = \frac{\pi DN}{100} {}^{m}/_{min}$

$\therefore$ $N = \frac{100S}{\pi D}\ r.p.m$

As we know that feed/min. = r.p.m x Feed/rev. and time taken to turn unit length

$$= \frac{1}{Feed/min}\ min$$

$\therefore$ Time taken to turn L metre length,

$$= \frac{L}{Feed/min} = \frac{L}{\frac{Feed}{rev}.\times r.p.m.}$$

Hence, $T = \frac{Length\ of\ the job\ to\ be\ turned}{\frac{Feed}{rev}.\times r.p.m} = \frac{L}{F \times N}\ min.$

Ex. 1. Estimate the machining time to turn a M.S bar of 3 cm dia down to 2.5 cm for a length of 10 cm in a single cut. Assume cutting speed = 30 m/min and feed =0.4 mm/rev.

Solution. To estimate the time required to turn the M.S bar, the first step is to find out the r.p.m at which this bar should be rotated to give the cutting speed as 30 m/min approximately.

Now using the formula,

$$N = \frac{100S}{\pi D}\ r.p.m$$

Where S = 30 m/min.

D = 3 cm

$\therefore$ $N = \frac{100x30}{\pi x3} = \frac{1000}{\pi} 318\ r.p.m$

Now, second step is to find the machining time. As we know that

$$\text{Time} = T = \frac{Length}{\frac{Feed}{rev} \times r.p.m.}$$

Where, L = 10 cm

Feed = 0.04 cm/rev.

N = 318 r.p.m.

$\therefore$ Time $T = \frac{10}{0.04 \times 318} = 0.79\ min. Ans.$

Ex. 2. Estimate the total time taken to turn a 10 cm long 2.5 dia M.S rod to a dia of 2.3 cm in a single cut. Assume cutting speed to be 25 m/min. , feed to 0.1 mm/rev. and the mounting time in a self- centering 3 jaw chuck to be 40 seconds. Neglect time taken for setting up tool etc.

Solution: Here L = 10 cm, S = 25 m/min, F = 0.01 cm/rev.

As $N = \frac{100S}{\pi D} = \frac{100 \times 25}{\pi \times 2.5} = 318\ r.p.m.$

$$T = \frac{10}{0.01 \times 318} = 3.14\ min.$$

Now, it is given that job mounting time is 40 second.

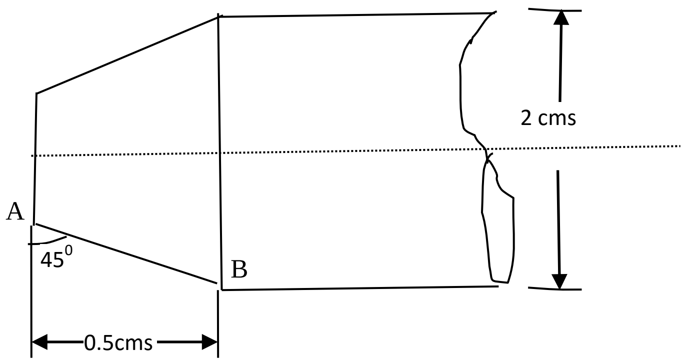
$\therefore$ Total machining time = 3.14 + 40/60 = 3.80 mins. Ans.

Ex. 3.Cw. A M.S bolt 2cm dia is rotating at 500 R.P.M. How much machining time is required to make $45^0$ chamfer by 0.5 cm. Assume feed as 0.2 mm/rev.

Solution: Let AB is the length of the cut required for chamfering.

Now 0.5/AB = $\sin 45^0 = \frac{1}{\sqrt{2}}\ or\ AB = 0.5 \times \sqrt{2} = 0.707\ cm.$

$\therefore$ Now, time for chamfering, $T = \frac{Length\ of\ cut}{\frac{feed}{rev} \times r.p.m.} = \frac{L}{F \times N} = \frac{0.707}{0.02 \times 500}\ min. = 0.07\ mins = 4.2\ secs.$ Ans.




EX. 4.cw. Find the time required to turn a 60 mm dia. rod to the dimensions shown below. Take cutting speed as 20 m/min, feed as 1.2 mm. All cuts are 3 mm deep.

Solution: Reducing the dia. from 60 to 54 mm for a length of 215 mm by turning. As deep of cut is 3 mm hence one cut is required.

∴ Time for turning, $T_1 = \frac{L_1}{F_1 \times N_1}, Hence, T_1 = \frac{215}{1.2 \times \frac{100 \times 20}{\pi \times 0.60}} = 1.7\ min.$

Second step: Reducing the dia from 54 to 42 mm by turning. As depth of cut is 3 mm.

∴ 54 – 42/6 = 2 will be the number of cuts.

$1^{st}$ cut.

$$N_2 = \frac{100S}{\pi D_2} = \frac{100 \times 20}{\pi \times 0.54} = 118\ r.p.m.$$

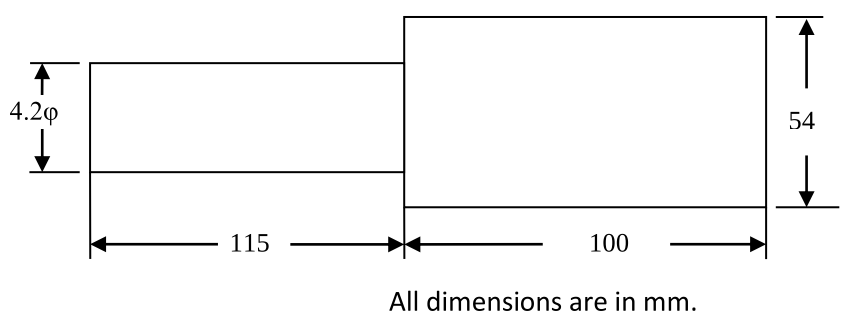
$$\therefore T_2 = \frac{115}{1.2 \times 118} = 0.8\ min.$$

$2^{nd}$ cut.

$$N_3 = \frac{100S}{\pi D_3} = \frac{100 \times 20}{\pi \times 0.42} = 152.\ r.p.m.$$

$$\therefore T_3 = \frac{115}{1.2 \times 152.} = 0.63 min.$$

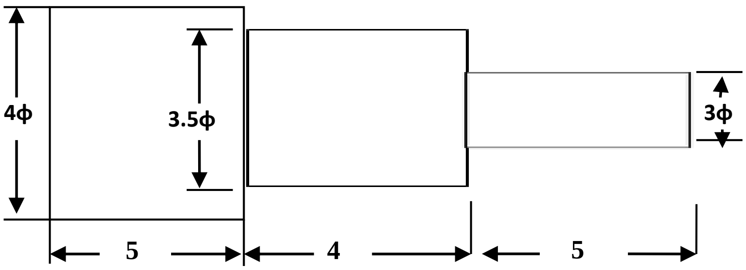
∴ Total turning time: = 1.7 + 0.8 + 0.63 = 3.13 mins. Ans.




All dimensions are in mm.

EX5.

Calculate the required to turn a stepped shaft to the dimensions shown below from M.S stock of 4cm dia. Neglect facing and setting up time. The depth of cut should not exceed 0.25 cm. assume the cutting speed to be 20 m/min and feed to be 0.3 mm/rev for each cut.




Solution. First step.

Reducing the dia from 4 to 3.5 cm for a length of 9 cm in single cut as depth of cut is 0.25 cm.

∴ N1 = $\frac{100s}{\pi D} = \frac{100 \times 20}{\pi \times 0.4} = 159.2\, r.p.m.$

∴ T1 = $\frac{L}{\frac{F}{rev} \times r.p.m} = \frac{9}{0.03 \times 159.2} = 1.9\, min.$

Second step.

Reducing the dia from 3.5 to 3 cm for a length of 5 cm in single cut as depth of cut is 0.25 cm.

∴ N2 = $\frac{100s}{\pi D} = \frac{100 \times 20}{\pi \times 0.35} = 182\, r.p.m$

∴ T2 = $\frac{5}{0.03 \times 182} = 0.9\, min.$

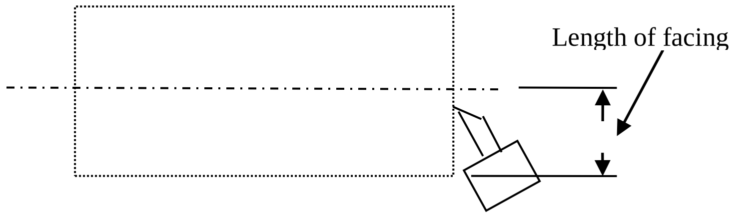
∴ Total turning time = T1 + T2 = 1.9 + 0.9 = 2.8 min. Ans

B .Knurling is the process used for making diamond shaped impressions on the surface of a component to produce a rough surface to facilitate easy grip. This is done with the help of a knurling tool also known as knurl. This process is performed on a lathe machine. Time required for knurling operation can be calculated the same formula as that of turning. i.e,

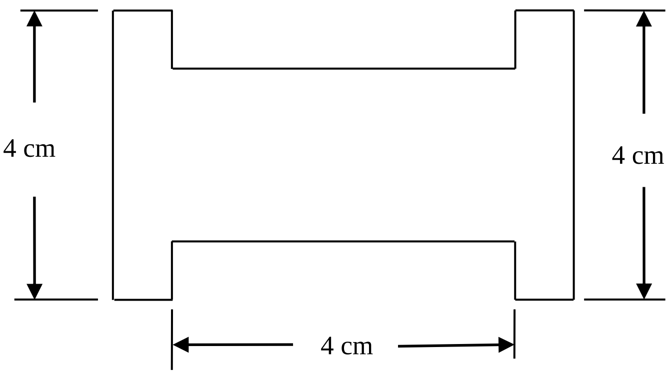
Time for knurling $= \frac{Length\ of\ cut}{\frac{feed}{rev} . \times r.p.m}\ min.$ Cutting speed for knurling should be little less than that of turning.

C. Facing: It is the process of material removal from the surface at right angles to the axis of rotation of the job. See fig below. In this process tool is feed crosswise, while in turning, tool is feed longitudinally. Time required per cut,

$= \frac{Length\ of\ cut}{F \times N}$ where, length of cut = ½ (dia of job).




EX. 10 Find the time required to face both ends of a component as shown below, in one cut. Assume speed of rotation of the job as 100 rpm. And cross-feed as 0.03 cm/rev.




Solution: As we know that,

Time for facing = $\frac{Length\ of\ cut}{F \times N}$ where, length of cut = $\frac{D}{2} = \frac{4}{2} = 2\ cm.$

But, feed/rev = 0.03 cm/rev and N = 100 rpm.

∴ Time for facing on one end = $\frac{2}{0.03\ x\ 100} = \frac{2}{3}\ min.$

∴ Total time for facing = 2 x $\frac{2}{3} = 1.33\ min.$ Ans.

D . Drilling: It is the process of producing hole in an object. Time required for drilling hole can be calculated by using the following formula:

$$\text{Time for drilling} = \frac{Depth\ of\ hole\ to\ be\ produced}{\frac{Feed}{rev}.\ x\ rpm.}$$

E. Boring: It is the process of enlarging a hole, which has already been drilled or casted or punched. Time required for boring can be calculated by using the following formula:

$$\text{Time required for boring} = \frac{Length\ to\ bored}{\frac{Feed}{rev}.\ x\ rpm.}$$

F. Reaming: It is the process of removing very small amount of material, to make the drilled holes in very accurate size. This process is carried out by a tool known as reamer.

$$\text{Time for reaming} = \frac{Depth\ of\ hole}{\frac{Feed}{rev}.\ x\ rpm.}$$

EX.11: Find the time required to drill six holes in a casted flange each 1 cm depth, if the holedia is 1.5 cm. Assume cutting speed as 20m/min and feed as 0.02 cm/rev.

Solution: As we know that,

Time for drilling = $\frac{depth\ of\ hole}{\frac{Feed}{rev}.\ x\ rpm.}$ Where depth of hole = 1 cm; Feed = 0.02 cm/rev,

and N = $\frac{100S}{\pi D} = \frac{100\ x\ 20}{\pi\ x\ 1.5} = 424\ rpm$

∴ Time for drilling one hole = $\frac{1}{0.02\ x\ 424} min.$

∴ Time for drilling 6- holes,

$$= \frac{6\ x\ 60}{0.02\ x\ 424} sec. = 42.7\ sec.\ \text{Ans.}$$

G. Threading (screw cutting): It is the removal of material to produce helix on external or internal circular surfaces for fastening purposes. Formula for calculating the time required in threading is nearly similar to that for turning, only the change is to replace the feed by pitch or lead.

Time for threading T = $\frac{L+0.7}{pitch\ or\ lead\ x\ r.p.m.}\ min/cut$ where L is the length of thread in cm and 0.7 is taken as additional distance for tool travel.

Pitch for single start thread = $\frac{I}{Thread/cm}$

Lead for multi-start thread = $\frac{No\ of\ start}{Thread/cm}$

Number of cuts. As threading up to full depth requires several cuts, therefore, total time for producing threads up to full depth can be found by multiplying the number of cuts to the time required in one cut. There is no hard and fast rule, for calculating the number of cuts but for general guidance, the following two systems are used.

First system: Number of cuts can be calculated by using the following relation:

No of cuts = 25 x pitch (for external threads).

= 32 x pitch (for internal threads).

System two: Number of cuts can be found by using the following table:

| S.No | Material | No. of cuts required for threading. |
|---|---|---|

| | | |
|---|---|---|
| 1 | Aluminium | 4 |
| 2 | Brass | 3 |
| 3 | Copper | 5 |
| 4 | Cast Iron | 6 |
| 5 | Mild Steel | 7 |

H. Tapping: It is the process of making internal thread with the help of a tool known as tap. Taps are generally used for internal small works.

Time required for tapping = $\frac{\text{Length travelled by tap}}{\text{Pitch x r.p.m.}}$

$= \frac{L+(\frac{D}{2})}{\text{Pitch x r.p.m.}}$ min/cut, where L = length of threaded portion.

D = dia of tap used.

The above formula gives the time required to push the tap inside the job. Time for returning the tap is taken as ½ of the time required for pushing it in the job. Therefore, total time for cutting threads:

$= \frac{\frac{3}{2}(L+\frac{D}{2})}{\text{Pitch x r.p.m.}}$ min.

TABLE-2:- Metric screw threads(L.S.I)

| Basic dia in mm | 10 | 12 | 14 | 16 | 18 - 22 | 24 | 25 | 27 | 30 | 35 | 42-45 | 46 - 55 | 56 - 60 | 64 - 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pitch in mm | 1.5 | 1.75 | | 2 | 2.5 | 3 | 3 | 3 | 3.5 | 1.5 | 4.5 | 5 | 5.5 | 6 |
| | 1.25 | 1.5 | 2 | | | | | | 3 | | 4 | 4 | 4 | |
| | | | | | | | | | | | | | | 4 |
| | | | 1.5 | 1.5 | 2 | 2 | | 2 | 2 | | 3 | 3 | 3 | 3 |
| | 1 | 1.25 | 1.25 | | 1.5 | 1.5 | | 1.5 | 1.5 | | 2 | 2 | 2 | 2 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.75 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 1.5 | 1.5 | 1.5 | 1.5 |

Pitches are generally used according to dias for coarse, medium and fine thread ranges.

EX.15 Estimate the time required for cutting 3 mm pitch threads on a mild steel bar of 2.8 cm dia and 8 cm long. Assume the cutting speed for threading as 15m/min.

Solution: As, pitch = 3 mm = 0.3 cm, bar dia. D = 2.8 cm, Length, L = 8 cm, Cutting speed, S = 15 m/min.

$$N = \frac{100S}{\pi D} = \frac{100 \text{ x } 15}{\pi \text{ x} 2.8} = 170 \text{ rpm. and threading time, } T = \frac{L \text{ x } 0.7}{\text{pitch x N}} = \frac{8.7}{0.3 \text{ x } 170} = 0.17 \text{ min.}$$

This is the time required for making one cut but in mild steel full depth of threads can be produced in 7- cuts. Hence, time for threading up to full depth = 0.17 x 7 = 1.19 min. Ans.

EX.16. Find out the time of threading on a 3 cm dia spindle for a length of 10 cm by single point tool, if three threads per cm are to be cut and speed of spindle is 66 rpm. Assume suitable approach and overtake for the tool.

Solution: Spindle dia = 3 cm, length of threads = 10 cm, No of threads to be cut = 3/cm.

∴pitch of threads = 1/3 cm, N = 66 rpm.

The movement of the tool will have to be started certain distance before the commencement of threads, which is known as approach length. Let it be 0.5 cm. In the same way tool will go ahead by a certain distance after completion of the threads, till tool stops. The distance is known as overtake for the tool, let it be 0.5 cm. Therefore,

Length of tool travel = 10 + 0.5 + 0.5 = 11 cm.

$$\therefore \text{ Time required for thread / cut } = \frac{\text{Length of tool travel}}{\text{pitch x N}} = \frac{11}{\frac{1}{2} \text{ x } 66} = 0.5 \text{ min.}$$

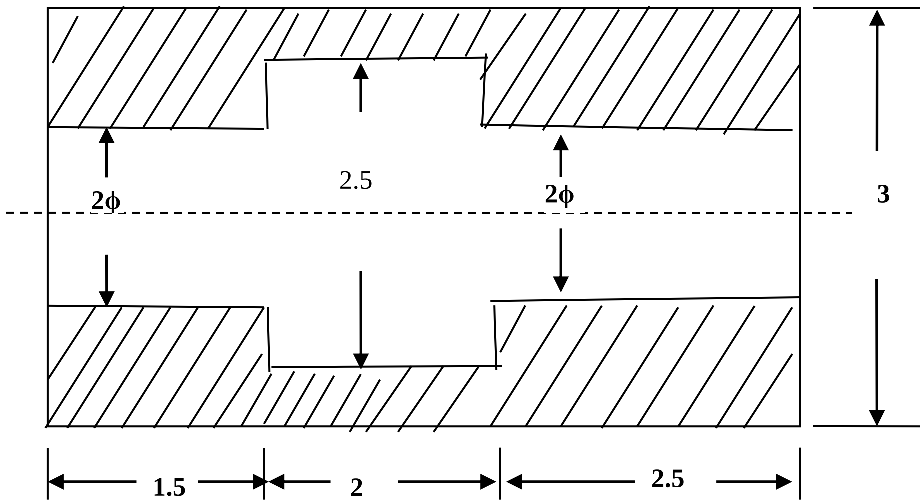
To get full depth of threads, 7-cuts are necessary.

∴ Total time required for threading = 7 x 0.5 = 3.5 min. Ans.

EX.24

Find the time taken to prepare a job according to the dimensions shown below from a bar 3.5 cm dia and 6 cm long. Assume the following data:

A. Cutting speed for turning and boring = 20 m/min.
B. Cutting speed for drilling = 30 m/min.
C. Feed for turning and boring = 0.2 mm/rev.
D. Depth of cut not to exceed = 3 mm.




All dimensions are in cm

Solution: Step 1. In this problem the dia of the bar stock is 3.5 cm. First it has to be reduced to 3 cm by turning in single cut as depth of cut is 2.5 mm.

Here, $D_1 = 3.5$ cm, $S_1 = 20$ m/min, $F_1 = 0.02$ cm/rev.

$$N_1 = \frac{100 \text{ x } S_1}{\pi D_1} = \frac{100 \text{ x } 20}{\pi \text{ x } 3.5} = 182 \text{ rpm}$$

$$T_1 = \frac{\text{Length of cut}}{\frac{\text{Feed}}{\text{rev}}. \text{ x rpm.}} = \frac{6}{0.02 \text{ x } 182} = 1.6 \text{ min}$$

Step 2.Drilling a hole of 2 cm dia to a length of 6 cm.

Time for drilling, $T_2 = \frac{\text{Length to be drilled}}{\frac{\text{Feed}}{\text{rev}}. \text{ x rpm.}} = \frac{L_1}{F_2 \text{x } N_2}$

Here, $N_2 = \frac{100 \text{ x } S_2}{\pi D_2} = \frac{100 \text{ x } 30}{\pi \text{ x } 2} = 477$ rpm.

$\therefore$ $T_2 = \frac{6 \text{ x } 10}{0.23 \text{ x } 477} = 0.547$ min.

Step 3. Enlarging a hole 2 to 2.5 cm dia for a length of 2 cm

$$N_3 = \frac{100 \text{ x } S_3}{\pi D_3} = \frac{100 \text{ x } 20}{\pi \text{ x } 2} = 318 \text{ rpm.}$$

$\therefore$ $T_3 = \frac{2.0}{0.02 \text{ x } 318} = 0.314$ min.

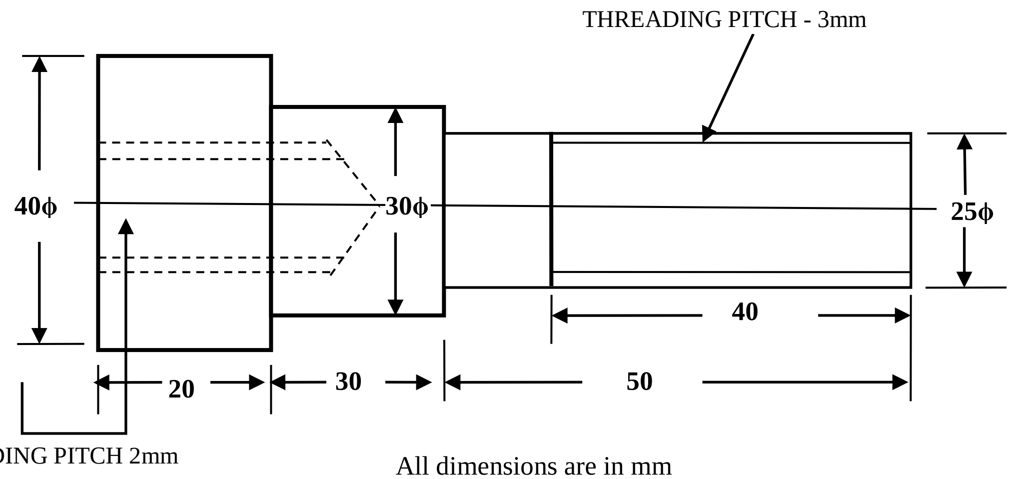
$\therefore$ Total machining time,

= 1.6 + 0,547 + 0.314 = 2.461 minutes. Ans.

Ex.25. Find the machining time to complete the job as shown below from the basic raw material of 50mm dia and 100 mm length.

Assume:

a. Cutting speed for turning = 30 m/min.
b. Feed = 1 mm/rev.
c. Depth of cut = 2.5 mm.
d. Cutting speed for thread cutting = 9 m/min.
e. Cutting speed for drilling = 30 mm/rev.
f. Feed for briclling = 0.2 mm/rev.




Solution: Step one. Reducing the dia from 50 to 40 mm for a length of 100 mm in two cuts as depth of cut is 2.5 mm.

As, No. of cuts = $\frac{50-40}{2.5 \text{ x } 4} = \frac{10}{5} = 2$ cuts.

∴ Dia will be reduced from 50 to 45 mm in first cut and then 45 to 40 mm in second cut.

∴ $T_1 = \frac{L}{F \text{ x } N_1} = \frac{100}{1 \text{ x} \frac{100\text{x } 300}{3.14 \text{ x } 5.0}} = 0.53$ min.

Similarly $T_2 = \frac{L}{F \text{ x } N_2} = \frac{100}{1 \text{ x} \frac{100\text{x } 30}{3.14 \text{ x } 4.5}} = 0.47$ min.

Step two: Reducing the dia from 40 to 30mm for a length of 80 mm in two cuts. As depth of cut is 2.5 mm, therefore, number of cuts

$$= \frac{40-30}{2.5 \text{ x } 2} = 2 \text{ cuts.}$$

∴ $T_3 = \frac{80}{1 \text{ x} \frac{100\text{x } 30}{3.14 \text{ x } 4}}$ for first cut. $= \frac{80 \text{ x } 3.14 \text{ x } 4}{100 \text{ x } 30} = 0.33$ min

∴ $T_4 = \frac{80}{1 \text{ x} \frac{100\text{x } 30}{3.14 \text{ x } 3.5}} = \frac{80 \text{ x } 3.14 \text{ x } 3.5}{100 \text{ x } 30} = 0.31$ min.

Step three: Reducing the dia from 30 to 25 mm for a length of 50 mm in single cut.

$$\therefore T_5 = \frac{L}{F \text{ x r.p.m}} = \frac{50}{1 \text{ x } \frac{100\text{x } 30}{3.14 \text{ x } 3.5}} = \frac{50 \text{ x } 3.14 \text{ x } 3.5}{100 \text{ x } 30} = 0.157 \text{ min.}$$

Step four: Drilling for a length of 30 mm and dia of 10 mm

$$\therefore \quad T_6 = \frac{L}{F \text{ x r.p.m}} = \frac{30}{0.2 \text{ x } \frac{100\text{x } 30}{3.14 \text{ x } 1.0}} = \frac{30 \text{ x } 3.14 \text{ x } 1}{100 \text{ x } 30} = 0.157 \text{ min}$$

Step five: Threading for length of 30 mm, dia 10 mm, pitch 2 mm. let number of cuts = 7.

$$\therefore \quad T_7 = \frac{30}{2 \text{ x } \frac{100\text{x } 9}{3.14 \text{ x } 1.0}} \text{ x } 7 = 0.36 \text{ min.}$$

Step six: Threading for length of 40 mm, dia 25mm, pitch 3 mm. Let number of cuts = 7.

$$\therefore \quad T_8 = \frac{40}{3 \text{ x } \frac{100\text{x } 9}{3.14 \text{ x } 2.5}} \text{ x } 7 = 0.81 \text{ min.}$$

$\therefore$ T $= T_1 + T_2 + T_3 \ldots\ldots\ldots + T_8$

= 0.53 + 0.47 + 0.33 + 0.31 + 0.157 + 0.157 + 0.36 + 0.81 = 8.124 min. Ans.

MILLING OPERATIONS.

In estimating the time for milling operations, it is essential to take into account:

i. The time taken to mill the surface. This depends on the length of job or the work-piece.
ii. The approach length. This is the distance by which cutter has to be engaged before the full depth of cut is reached. See figures below.(a)&(b)
iii. The over-run. This is the distance considered so that the cutter may clear the job or work- piece. See figures (a) & (b) which shows over – run or over travel.
iv. The total numbers of cuts to complete the operations.
v. The sum of approach length and over – run is called, Added Table Travel.

Operations performed on the milling machines are mainly cutting and facing. The time taken for performing these operations can be obtained by using the same formula, i.e.

$$\text{Time required / cut} = \frac{\text{Length of cut}}{\frac{\text{Feed}}{\text{rev}}. \text{ x rpm.}} \quad \text{Where length of cut,}$$

= Length of job + added table travel.

Feed/rev. = Feed/ tooth x No. of teeth on cutter.

$$\text{R.P.M} = \frac{100S}{\pi D}, \text{ Where, } D = \text{Dia of the cutter}$$

$$\text{Total time} = \frac{\text{Length of cut}}{\frac{\text{Feed}}{\text{min}}} \text{ x No. of cuts or index.}$$

a. Cutting operation.

Figure (a) shows how the cutter is adjusted to cut a depth d of the job and also shows the approach length and over travel or over – run.

Approach length AB = $\sqrt{OA^2 - OB^2}$

$$= \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - d\right)^2}$$

$$= \sqrt{Dd - d^2} \quad \ldots\ldots\ldots\ldots.(i)$$

In these operations over – travel is generally taken as 5 mm.

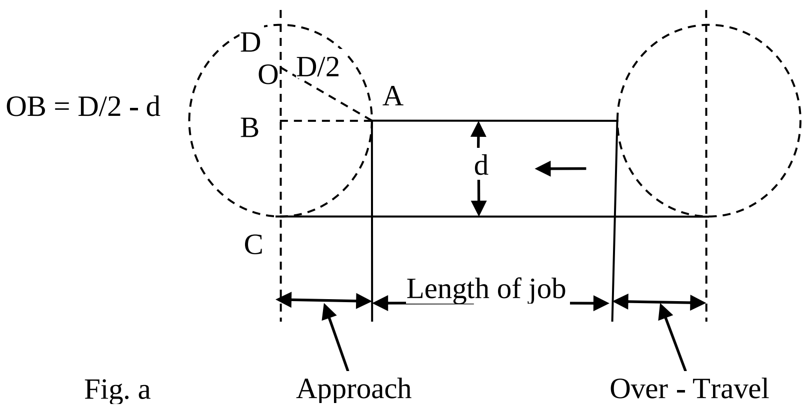



Fig. a

(b). Facing operation.

i. If the cutter dia D is less than the width of the job w then several cuts are required to face the width w. Fig (b) shows the first and last positions of the facing cutter. In this case, approach is generally taken as 0.5D and over – travel is 7 mm.

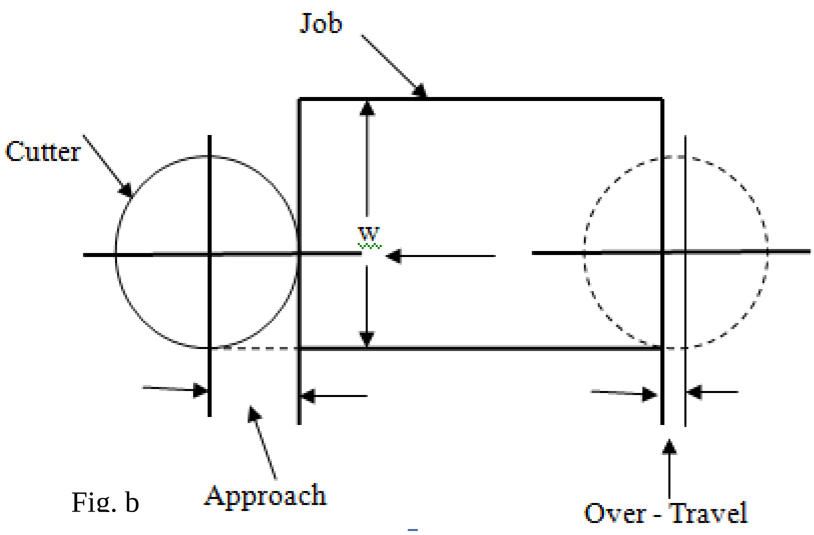



Fig. b

ii. If the cutter dia is bigger than the width of the job w, facing is done only in one cut. Fig.(c)shows how the facing is done when the cutter dia is greater than the width of the job. In this case over – travel is,

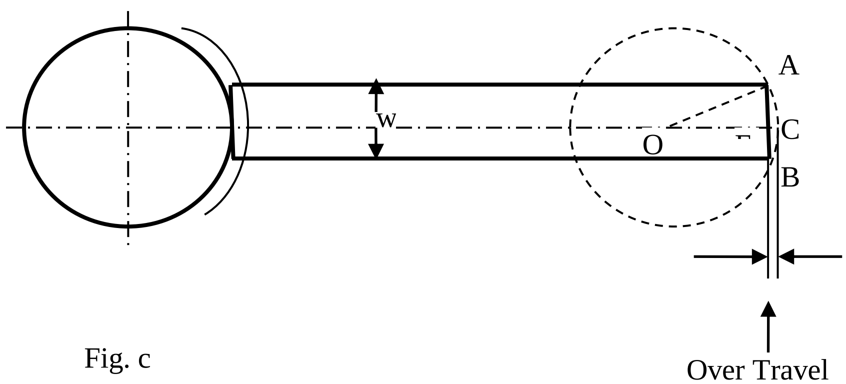



Fig. c

EC = OC – OE

$$= \frac{D}{2} - \sqrt{OA^2 - AE^2}$$

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

$\therefore$ Over – travel = $\frac{D}{2}\left(D - \sqrt{D^2 - w^2}\right)$

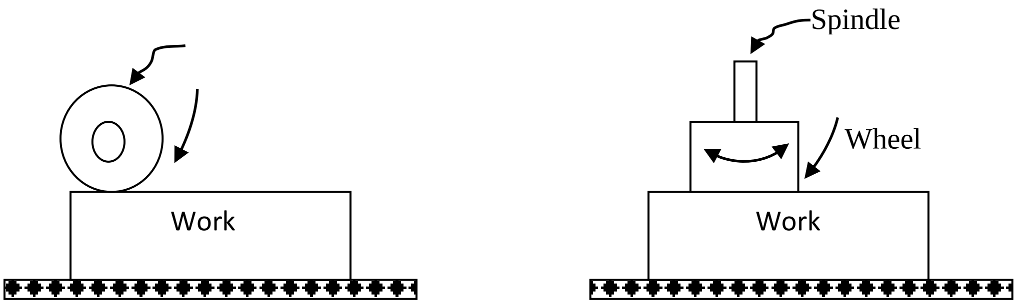
## GRINDING OPERATIONS.

It is a process of metal remover by abrasion. The following are the important methods of grinding :

(a). Surface grinding.

(b). Cylindrical grinding.

(a) Surface grinding : This is useful for removing small amount of material from flat surfaces. The time required for surface grinding is calculated by using the formula used in milling. When grinding is done as shown in fig.(a), time is calculated as for cutting operations on milling machine; and when grinding is done as shown in fig. (b), time is calculated as for facing operations on milling machine.




(a) (b)

(b). Cylindrical grinding: As the name suggests, the process is used for grinding the internal and external surfaces of the cylindrical jobs which have previously been turned on the lathe, to get accurate size and smooth finish.

Time required for cylindrical grinding /cut

$$=\frac{\text{Length of cut}}{\frac{\text{Feed}}{\text{rev}}.\ \text{x rpm.}},$$ Where, Length of cut, = Length of job + over – travel.

$$= L + 0.5 \text{ cm}$$

and, Feed/rev. $= \frac{w}{2}$ (for rough cut)

$$= \frac{w}{4} \text{ (for finishing cut)}$$

Where w = width of grinding wheel.

SHAPING AND PLANING OPERATIONS.

These operations are carried out on reciprocating machines. On these machines cutting is done in one stroke and the second is the idle stroke which is also known as return stroke.. To reduce the total time, the time required for idle stroke is reduced by increasing the speed of idle stroke.

(a). If a shaper has a length of stroke as S cm and it has N cutting stroke /min, then its effective speed,

$E = \frac{S}{100}$ x N m/min. , For example, a shaper makes 30 cutting strokes /min each 20 cm long. Then effective speed, E, will be,

$= \frac{S}{100}$ x N = $\frac{20}{100}$ x 30 = 6 m/min.

Speed of the ram during cutting stroke is known as cutting speed, this speed is maximum at the middle of the stroke and minimum at the beginning and at the end of the stroke. Therefore, for calculation purposes an average cutting speed C is considered. Mostly, cutting time is 3/5$^{th}$ of the total time. Therefore, the effective speed is 3/5 of the cutting speed C.

Hence, $E = \frac{3}{5}C$, but, $E = \frac{NS}{100}$

$\therefore \frac{NS}{100} = \frac{3}{5}C$

$\therefore$ $N = \frac{100}{\square} \times \frac{3}{5}C = \frac{60C}{S}$ strokes /min.

In the above formulae, S is generally taken as (L+5) cm, where L is the length of the job.

If F is the feed/ stroke in cm then, area swept by the tool/stroke

$$= F \times (L+5)$$

$\therefore$ Area swept/min = F x (L+5) x N

$$= F \times (L+5) \times \frac{60C}{S} = F \times (L+5) \times \frac{60C}{(L+5)} = 60\ CF \ldots (2)$$

If the width of the job is B cm then the width for calculation is taken as (B + 2.5) cm. Therefore, time required for shaping = $\frac{\text{Total area to be swept}}{\text{Area swept/min}}$

$\therefore \quad T = \frac{(L+5)(B+2.5)}{60\ CF}$ min.

(b) Planing operation.

The effective speed for the planning machine is generally 3/4$^{th}$ of the cutting speed. For time calculation, stroke length is taken as (L + 25) cm, while width is taken as (B + 5) cm. Similar to that in shaping,

Time required in planning $= \frac{(L+25)(B+5)}{K}$ min., where K is the area swept/min.

As in case of planing operations $E = \frac{3}{4}\square$,

$\frac{NS}{100} = \frac{3}{4}\square$

$\therefore \quad N = \frac{75\ C}{S}$ ………………… (1)

$\therefore$ Area swept/min = N x F x S or K = $\frac{75\text{ C}}{\text{S}}$ x F x S, or K = 75CF ………. (2)

$\therefore$ Time taken = $\frac{\text{L+25)(B+5)}}{75\text{ CF}}$ min.

POWER CONSUMPTION.

During any metal cutting operation power supplied to the machine tool is used for (a) cutting the material, and (b) to drive the machine itself. The power required for cutting is related to the magnitude of the forces at the tool point, of which cutting force is most significant. Other two forces namely ‘feed force’ and ‘reaction between tool and job’ are too small and hence are neglected in calculations.

Power consumption can be calculated using the following formulae:

Power = $\frac{\text{Work done (J)}}{\text{Time taken (S)}} = \frac{J}{S}\ watts.$, where work done = Force x Distance = Newton metres (N-m)

= joules (J)

Work done due to cutting force during one rev. = $F_c$ x $\frac{\pi D}{1000}$

$\therefore$ Power due to cutting force = $F_c$ x $\frac{\pi DN}{1000 \text{ x } 60}$ watts.

Where, D = Mean dia in mm

N = Spindle speed in rev/min.

$F_c$ = Cutting force.

METAL REMOVER RATE.

Manufacturing Engineers from economic point of view are interested in the rate at which metal can be removed from the work piece. Economy does not mean to use fast speeds and feeds, since this condition will consume more power, promote rapid tool wear leading to expensive re-grinding time and tool replacement. Therefore, engineers are interested in optimization, and consider a metal removal rate which will be both efficient and economic, taking into account speed, feed, depth of cut, surface finish, power consumption, tool wear rate and tool life.

In general, metal remover rate is the amount of metal removed in one minute, and is expressed $mm^3$/min.

$\therefore$ Metal removal rate = $\frac{\text{Volume (mm)}^3}{\text{Time (min).}}$

For a plain cylindrical turning, metal removal rate = cutting speed (mm/min) x Feed (mm/rev.) x Depth of cut (mm).

TOOL LIFE.

Life of a cutting tool is directly related to the amount of wear that takes place at the tool point. To understand tool life, we must first know as to how tool wears. During cutting, two forms of wear are produced, 'flank wear' at the tip of the tool and 'crater wear' behind the tip caused by the underside of the chip rubbing against the top of the tool. These wears result in deterioration in surface finish, and also in exact dimensions of the job. If a tool is allowed to cut continuously until it fails completely then it can be seen that the tool life can be divided into three distinct stages.

First stage: Tool wears rapidly and a small wear land is established

Second stage: Uniform wear takes place.

Third stage: Tool wear rate increases rapidly until it finally fails.

In practice tool is re-grinded before the end of the second stage. F.W. Tailor, has given the expression for expected tool life as :

$$VT^n$$

Where, V = Cutting speed in m/min.

T = Expected tool life between re-grinds in minutes.

N = A constant, dependent upon cutting tool material.

C = A constant, dependent upon cutting conditions; e.g depth of cut, feed and tool geometry.

High speed steel 01 to 0.5

Tungsten carbide 0.2 to o.4

Ceramics 0.1 to 0.6

**MILLING**

**INTRODUCTION**

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine. This is the reason that a milling machine finds wide application in production work. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections. Typical components produced by a milling are given in Fig. 1. In many applications, due to its higher production rate and accuracy, milling machine has even replaced shapers and slotters.

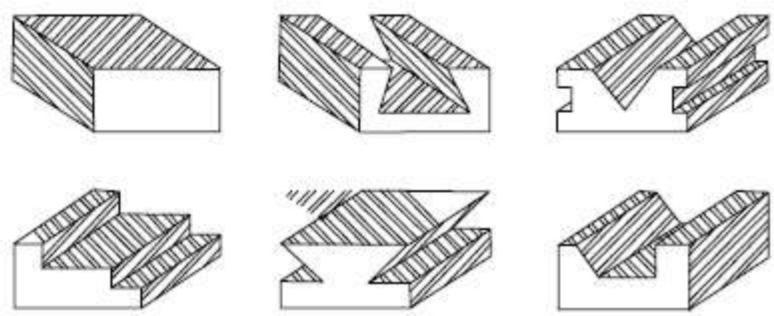


**Fig. 1** Job surfaces generated by milling machine

- **PRINCIPLE OF MILLING**

In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges. For cutting operation, the work-piece is fed against the rotary cutter. As the work-piece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape. Machined surface is formed in one or more passes of the work. The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table. The rotatory speed of the cutting tool and the feed rate of the work-piece depend upon the type of material being machined.

- **MILLING METHODS**

There are two distinct methods of milling classified as follows:

1. Up-milling or conventional milling, and
2. Down milling or climb milling.

  - **UP-Milling or Conventional Milling Procedure**

In the up-milling or conventional milling, as shown in Fig. 2, the metal is removed in form of small chips by a cutter rotating against the direction of travel of the work-piece. In this type of milling, the chip thickness is minimum at the start of the cut and maximum at the end of cut. As a result the cutting force also varies from zero to the maximum value per tooth movement of the milling cutter. The major disadvantages of up-milling process are the tendency of cutting force to lift the work from the fixtures and poor surface finish obtained. But being a safer process, it is commonly used method of milling.

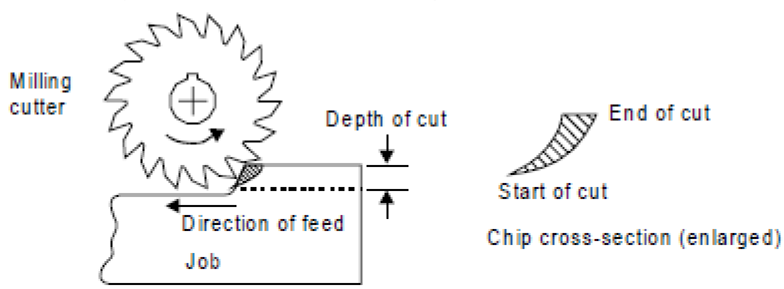



**Fig. 2** Principal of up-milling

  - **Down-Milling or Climb Milling**

Down milling is shown in Fig. 24.3. It is also known as climb milling. In this method, the metal is removed by a cutter rotating in the same direction of feed of the work-piece. The effect of this is that the teeth cut downward instead of upwards. Chip thickness is maximum at the start of the cut and minimum in the end. In this method, it is claimed that there is less friction involved and consequently less heat is generated on the contact surface of the cutter and work-piece. Climb milling can be used advantageously on many kinds of work to increase the number of pieces per sharpening and to produce a better finish. With climb milling, saws cut long thin slots more satisfactorily than with standard milling. Another advantage is that slightly lower power consumption is obtainable by climb milling, since there is no need to drive the table against the cutter.

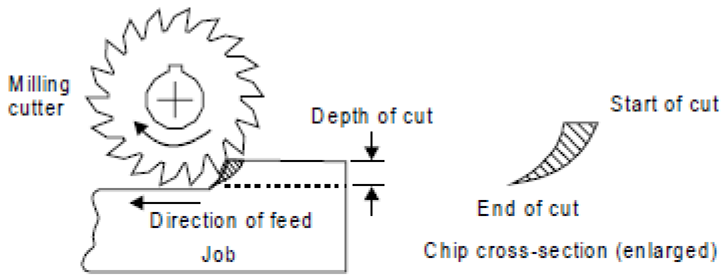



**Fig. 3** Principal of down-milling

- **TYPES OF MILLING CUTTERS**

Fig. 4 illustrates some types of milling cutters along with work-pieces. Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

(1) Plain milling cutters,
(2) Side milling cutters,
(3) Face milling cutter,
(4) Angle milling cutters,
(5) End milling cutter,
(6) Fly cutter,
(7) T-slot milling cutter,
(8) Formed cutters,
(9) Metal slitting saw,

Milling cutters may have teeth on the periphery or ends only, or on both the periphery and ends. Peripheral teeth may be straight or parallel to the cutter axis, or they may be helical, sometimes referred as spiral teeth.

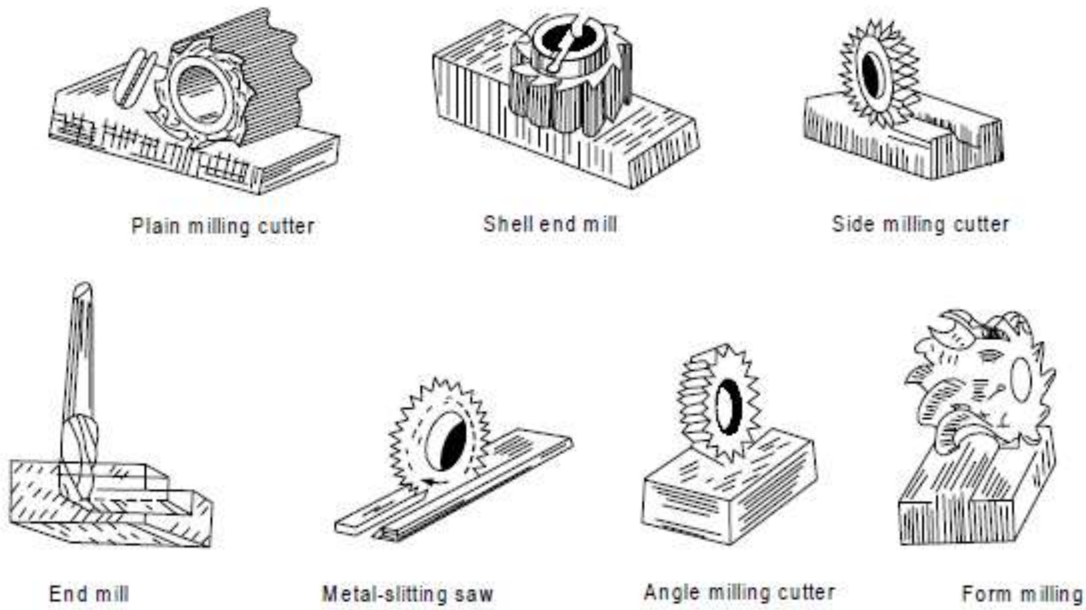



**Fig. 4** Types of milling cutters

- **TYPES OF MILLING MACHINES**

Milling machine rotates the cutter mounted on the arbor of the machine and at the same time automatically feed the work in the required direction. The milling machine may be classified in several forms, but the choice of any particular machine is determined primarily by the size of the work-piece to be undertaken and operations to be performed. With the above function or requirement in mind, milling machines are made in a variety of types and sizes. According to general design, the distinctive types of milling machines are:

1. Column and knee type milling machines

(*a*) Hand milling machine

(*b*) Horizontal milling machine (Fig. 5)

(*c*) Universal milling machine

(*d*) Vertical milling machine (Fig. 6)

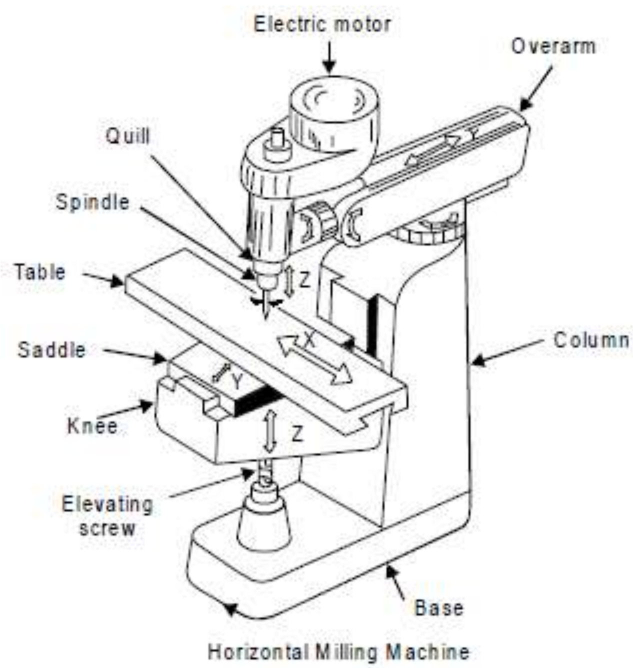



**Fig. 5** Horizontal column and knee type milling machine

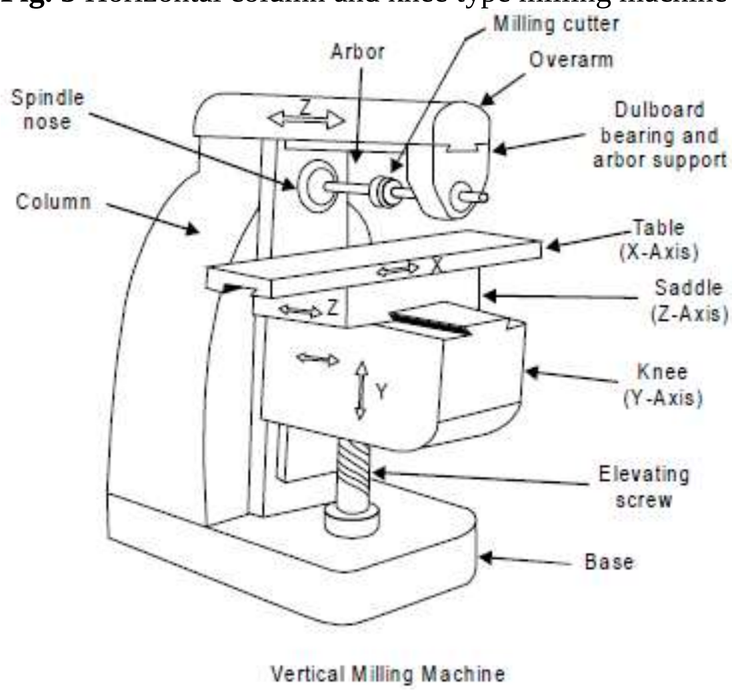



**Fig. 6** Vertical column and knee type milling machine

2. Planer milling machine
3. Fixed-bed type milling machine
(*a*) Simplex milling machine.
(*b*) Duplex milling machine.
(*c*) Triplex milling machine.
4. Machining center machines
5. Special types of milling machines
(*a*) Rotary table milling machine.

(*b*) Planetary milling machine.
(*c*) Profiling machine.
(*d*) Duplicating machine.
(*e*) Pantograph milling machine.
(*f*) Continuous milling machine.
(*g*) Drum milling machine
(*h*) Profiling and tracer controlled milling machine
Some important types of milling machines are discussed as under.

- **Column and Knee Type Milling Machine**

Fig. 7 shows a simple column and knee type milling machine. It is the most commonly used milling machine used for general shop work. In this type of milling machine the table is mounted on the knee casting which in turn is mounted on the vertical slides of the main column.

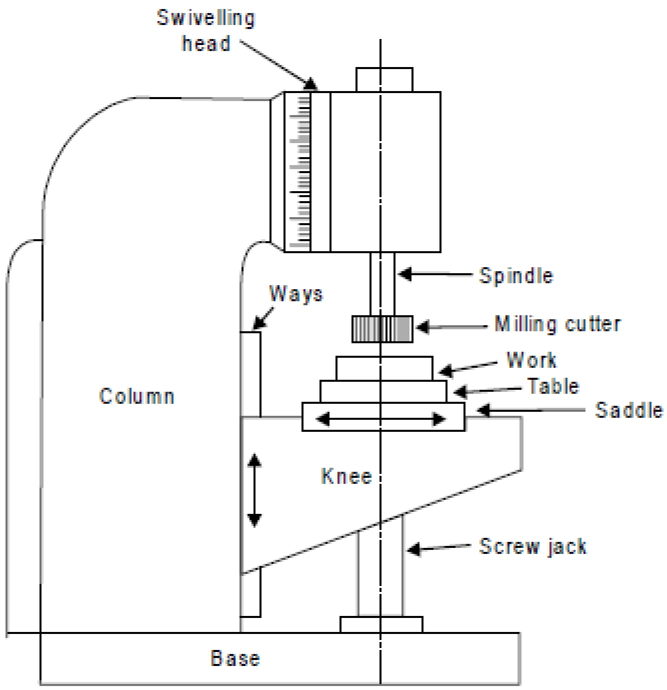



**Fig. 7** A column and knee type milling machine

The knee is vertically adjustable on the column so that the table can be moved up and down to accommodate work of various heights. The column and knee type milling machines are classified on the basis of various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle. Column and knee type milling machine comprises of the following important parts-

| | |
|---|---|
| 1. Base | 2. Column |
| 3. Saddle | 4. Table |
| 5. Elevating screw | 6. Knee |
| 7. Knee elevating handle | 8. Cross feed handle |
| 9. Front brace | 10. Arbor support |
| 11. Arbor | 12. Overhanging arm |
| 13. Cutter | 14. Cone pulley |
| 15. Telescopic feed shaft. | |

The principal parts of a column and knee type milling machine are described as under.

- **Base**

It is a foundation member for all the other parts, which rest upon it. It carries the column at its one end. In some machines, the base is hollow and serves as a reservoir for cutting fluid.

- **Column**

The column is the main supporting member mounted vertically on the base. It is box shaped, heavily ribbed inside and houses all the driving mechanism for the spindle and table feed. The front vertical face of the column is accurately machined and is provided with dovetail guide way for supporting the knee.

- **Knee**

The knee is a rigid grey iron casting which slides up and down on the vertical ways of the column face. An elevating screw mounted on the base is used to adjust the height of the knee and it also supports the knee. The knee houses the feed mechanism of the table, and different controls to operate it.

- **Saddle**

The saddle is placed on the top of the knee and it slides on guide ways set exactly at 90° to the column face. The top of the saddle provides guide-ways for the table.

- **Table**

The table rests on ways on the saddle and travels longitudinally. A lead screw under the table engages a nut on the saddle to move the table horizontally by hand or power. In universal machines, the table may also be swiveled horizontally. For this purpose the table is mounted on a circular base. The top of the table is accurately finished and T -slots are provided for clamping the work and other fixtures on it

- **Overhanging arm**

It is mounted on the top of the column, which extends beyond the column face and serves as a bearing support for the other end of the arbor.

- **Front brace**

It is an extra support, which is fitted between the knee and the over-arm to ensure further rigidity to the arbor and the knee.

- **Spindle**

It is situated in the upper part of the column and receives power from the motor through belts, gears. and clutches and transmit it to the arbor.

- **Arbor**

It is like an extension of the machine spindle on which milling cutters are securely mounted and rotated. The arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The draw bolt is used for managing for locking the arbor with the spindle and the whole assembly. The arbor assembly consists of the following components.

1. Arbor 2. Spindle
3. Spacing collars 4. Bearing bush
5. Cutter 6. Draw bolt
7. Lock nut 8. Key block
9. Set screw

- **Planer Type Milling Machine**

It is a heavy duty milling machine. It resembles a planer and like a planning machine it has a cross rail capable of being raised or lowered carrying the cutters, their heads, and the saddles, all supported by rigid uprights. There may be a number of independent spindles carrying cutters on the rail as two heads on the uprights. The use of the machine is limited to production work only and is considered ultimate in metal re-moving capacity.

- **Special Type Milling Machines**

Milling machines of non-conventional design have been developed to suit special purposes. The features that they have in common are the spindle for rotating the cutter and provision for moving the tool or the work in different directions.

- **SIZE OF MILLING MACHINE**

The size of the column and knee type milling machine is specified by

(1) The dimensions of the working surface of the table, and

(2) Its maximum length of longitudinal, cross and vertical travel of the table.

In addition to above, number of spindle speeds, number of feeds, spindle nose taper, power available, floor space required and net weight of machine will also be required for additional specification.

- **DEPTH OF CUT**

The depth of cut in milling is defined as the thickness of the material removed in one pass of the work under the cutter. Thus it is the perpendicular distance measured between the original and final surface of the work-piece, and is expressed in mm.

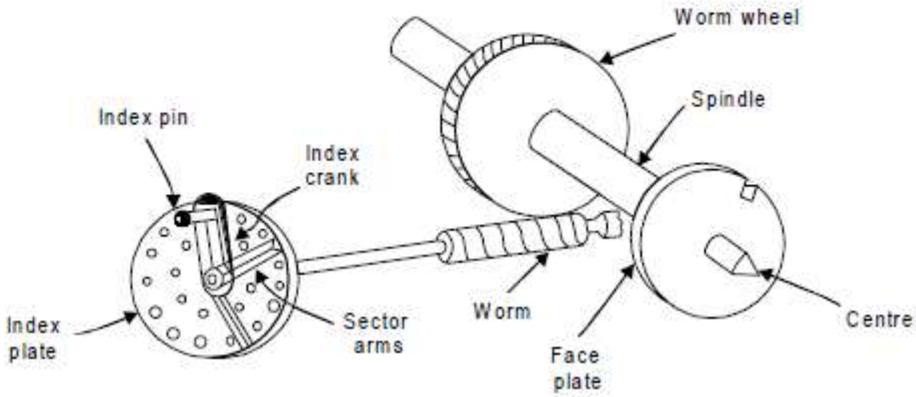
- **INDEXING AND DIVIDING HEADS**

Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. In cutting spur gear equal spacing of teeth on the gear blank is performed by indexing. Indexing is accomplished by using a special attachment known as dividing head or index head as shown in Fig. 8. The dividing heads are of three types:

(1) Plain or simple dividing head,

(2) Universal dividing head and

(3) Optical dividing head.




- **Plain or Simple Dividing Head**

The plain dividing head comprises a cylindrical spindle housed on a frame, and a base bolted to the machine table. The index crank is connected to the tail end of the spindle directly, and the crank and the spindle rotate as one unit. The index plate is mounted on the spindle and rotates with it. The spindle may be rotated through the desired angle and then clamped by inserting the clamping lever pin into anyone of the equally spaced holes or slots cut on the periphery of the index plate. This type of dividing head is used for handling large number of work-pieces, which require a very small number of divisions on the periphery.

1. Swiveling block 2. Live centre

3. Index crank 4. Index plate.

- **OPERATIONS PERFORMED ON MILLING MACHINE**

Unlike a lathe, a milling cutter does not give a continuous cut, but begins with a sliding motion between the cutter and the work. Then follows a crushing movement, and then a cutting operation by which the chip is removed. Many different kinds of operations can be performed on a milling machine but a few of the more common operations will now be explained. These are:

  - **Plain milling or slab milling**

Fig. 9(a) illustrates the plain and slab milling operation. It is a method of producing a plain, flat, horizontal surface parallel to the axis of rotation of the cutter.

  - **Face milling**

Fig. 9(b) illustrates the face milling operation. It is a method of producing a flat surface at right angles to the axis of the cutter.

  - **Side milling**

Fig. 9(c) illustrates the side milling operation. It is the operation of production of a flat vertical surface on the side of a work-piece by using a side milling cutter.

  - **Angular milling**

Fig. 9(d) illustrates angular milling operation. It is a method of producing a flat surface making an angle to the axis of the cutter.

  - **Gang-milling**

Fig. 9(e) illustrates the gang milling operation. It is a method of milling by means of two or more cutters simultaneously having same or different diameters mounted on the arbor of the milling machine.

  - **Form milling**

Fig. 9(f) illustrates the form milling operation. It is, a method of producing a surface having an irregular outline.

  - **End milling**

Fig. 9(g) illustrates end milling operation. It is a method of milling slots, flat surfaces, and profiles by end mills.

  - **Profile milling**

Fig. 9(h) illustrates profile milling operation. It is the operation of reproduction of an outline of a template or complex shape of a master die on a work-piece.

  - **Saw milling**

Fig. 9(i) illustrates saw milling operation. It is a method of producing deep slots and cutting materials into the required length by slitting saws.

  - **T-slot milling**

Fig. 9(j) illustrates T-slot milling operation.

  - **Keyway milling**

Fig. 9(k) illustrates keyway milling operation.

  - **Gear cutting milling**

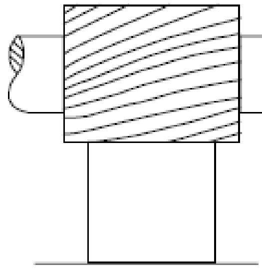
Fig. 9(l) illustrates gear cutting milling operation.

  - **Helical milling**

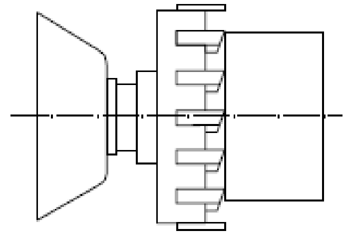
Fig. 9(m) illustrates helical milling operation.

- **Flute milling**

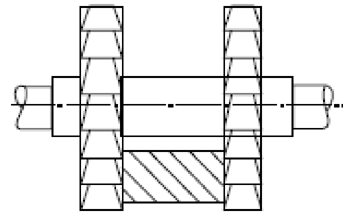
It is a method of grooving or cutting of flutes on drills, reamers, taps, etc,



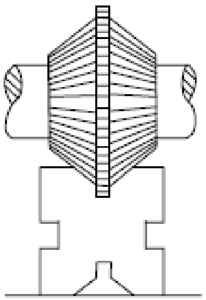
(a) Plane milling



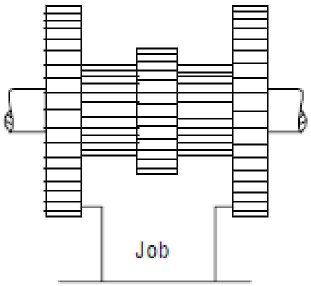
(b) Face milling



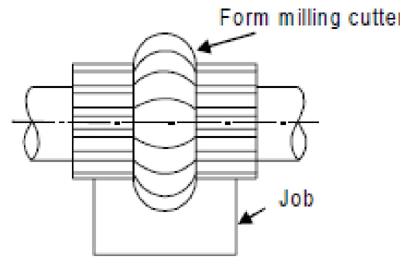
(c) Side milling



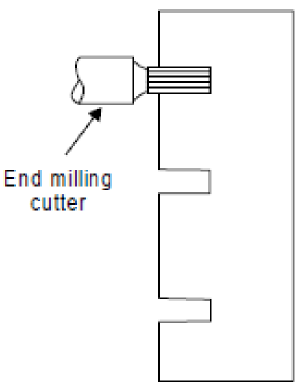
(d) Angular milling



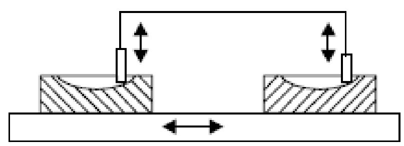

(e) Gang milling



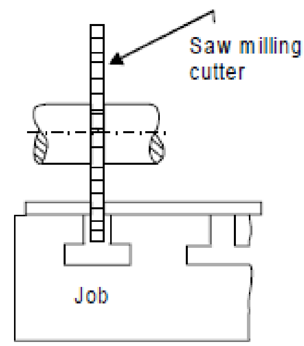

(f) Form Milling




(g) End milling

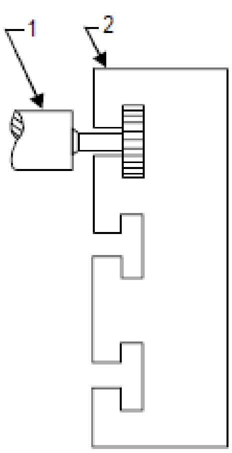


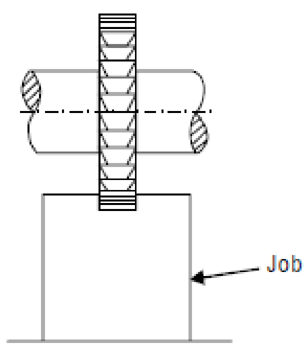
(h) Profile milling



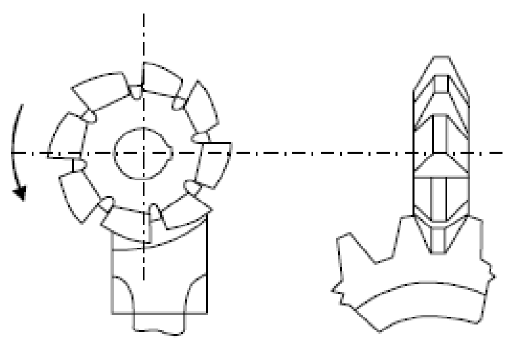

(i) Saw milling

(j)
T - Slot
Milling




(k) Key way milling



(l) Gear Cutting Milling

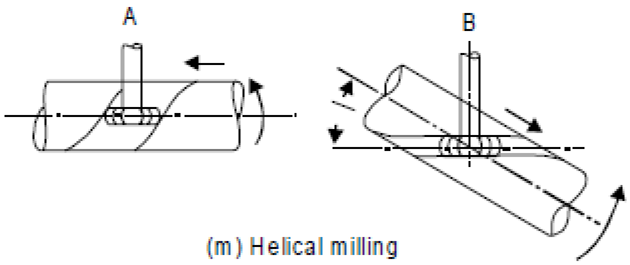



**Fig. 9** Various types of milling operations

**Straddle milling**

It is a method of milling two sides of a piece of work by employing two side-milling cutters at the same time.

**Thread milling**

It is a method of milling threads on dies, screws, worms, etc. both internally and externally. As an alternative to the screw cutting in a lathe, this method is being more extensively introduced now a day in modern machine shops.