Unit 5

MACHINING TIME CALCULATION

Content 1:

Estimation of Machining Time:

To estimate the cost of any product involving machining operations, the machining time is required to be estimated before the total cost of the product/component can be computed. In addition to actual time taken for operation to be carried out, time is spent on certain other elements of work.

The total time required to perform a machining operation consists of following elements :

(i) Set-up time,
(ii) Handling time,
(iii) Machining time,
(iv) Tear down time,
(v) Down time, and
(vi) Allowances.

1 Set-up Time

This is the time taken to prepare the machine for operation. The set-up time includes the time taken to :

(i) Study the component drawing.
(ii) Draw tools from tool crib, and
(iii) Install and adjust the tools, jigs and fixtures on the machine.

The time over and above the unit standard time to produce first few pieces is also considered in set-up time. We can say that set-up time is the overall preparationtime less the standard time for the units produced during the process of preparation.

The set-up time occurs only once for a batch or lot being taken up for production. Standard data are available for set-up time for various machine tools.

2. Handling Time

It is the time taken by the operator in preparing a part for machining and for disposing the part after operation has been completed. The handling time includes the time for loading and unloading the component on the machine, making measurements on parts during machining, etc.

3. Machining Time

It is the time for which the machine works on the component, *i.e.* from the time when the tool touches the work piece to when the tool leaves the component after completion of operation. The machining time depends on the type and extent of machining required, material being machined, speed, feed, depth of cut and numberof cuts required.

4. Unit Operation Time

The sum of handling time and machining time for a job is called operation time. It is the duration of time that elapses between output of two consecutive units of production. It is also called cycle time.

5. Tear down Time

It is the time taken to remove the tools, jigs and fixtures from the machine and to clean the machine and tools after the operation has been done on the last component of batch. The tear down time is usually small. The tear down time occurs only once for a complete lot or batch taken for machining. Standard data are available for tear down time for various machines.

6. Down Time

It is the time wasted by the operator due to breakdowns, non-availability or delay in supply of tools and materials etc.

7. Allowances

In additions to the elements of time described above, the total time to perform an operation includes a number of allowances like time for personal needs of the operator, time for checking, time for tool sharpening etc. The various allowances are follows:

(a) Personal allowance: This is the time taken by the operator in attending tohis personal needs and includes the time spent in going to toilet and cafeteria. It is usually taken as 5 percent of total time.

(***b*****) Fatigue :** The long working hours and working conditions such as poor lighting, poor ventilation etc., cause fatigue and affects the efficiency of worker *i.e.*, fatigue decreases the workers capacity to work. The allowance for fatigue is taken depending upon the type of work.

Tool sharpening/Tool change allowance: This allowance is provided for the time taken by the operator to get the tool changed or to resharpen the tool when it becomes dull. This time varies from machine to machine and depends upon the type of tool being used.

Inspection or checking allowance: Inspection is a vital part of the total process of production. Inspection is necessary to ensure that parts are manufactured according to laid down standards. The time taken in checking the part for its dimension, process and fitness is reckoned as inspection time. The inspection time depends on the dimensional tolerances and the instrument being used for checking.

Other allowances: Some allowance is provided to compensate for the activities, in which the operator is engaged, but are not included in normal operation cycle. The activities include periodic cleaning of machines, getting stocks, filling coolant reservoirs and disposal of scrap etc. These miscellaneous activities vary from shop to shop and in a well organized shop, these may be reduced to a minimum by proper planning.

The total time required to make a component is the sum of unit operation time and proportion of set-up time, tear-down time, down time and allowances for one work piece.

Handling time + Machining time + Set −up time
Total time per component = + Tear −down time + Down time + Allowances
N
Where,
N = Number of components produced in one lot.

Estimation of machining time means calculating the time required to complete the operations to make the components as per drawing.

Machining time is the time for which the machine works on the component. The basic formula used for determining the machining time is :

$$T = \frac{L}{F}$$

Where,
T = Machining time, minutes
L = Length of cut or total tool travel, mm

F = Feed rate of tool, mm/minute
= Feed per revolution × r.p.m.

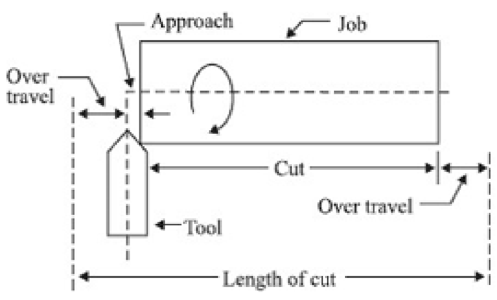
Before we take up the estimation of machining time for various operations, the terms used in cutting time formula are defined, in general, as follows:

Length of cut: It is the distance travelled by the tool to machine the work piece and is calculated as follows:

Length of cut = L
= Approach length + Length of work piece to be machined + over travel

Approach is the distance a tool travels, from the time it touches the work piece until it is cutting to full depth. Over travel is the distance the tool is fed while it is not cutting. It is the distance over which the tool idles before it enters and after it leaves the cut. These terms are explained in the Fig. 5.10 for a cutting operation on lathe.

Total tool travel = length of job + approach + over travel



Total tool travel = length of job + approach + over travel

Feed : Feed is the distance that a tool travels along the work or the work travels w.r.t. the tool for each revolution of the work-piece or cutter.

Depth of cut: it is the difference between unfinished dimension and finished dimension of the job. For example, in case of turning, depth of cut is the difference between radius of the bar before and after taking the cut. The feed and depth of cut for a particular operation depend on the material to be machined, surface finish required and tool used.

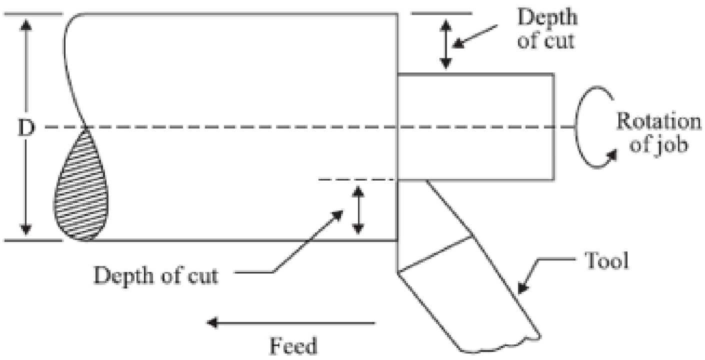


Fig. 5.11

Cutting speed : Cutting speed is the speed at which the cutting edge of tool passes over the job and it is usually expressed in meters per minute. The cutting speed depends on the cutting tool material, the work piece material and the operation. Once the cutting speed has been selected, the revolution per minute of job/machine are calculated as follows : DN

$$S = \frac{\pi DN}{1000}$$

Where,

S = Surface cutting speed in meters per minute
D = Diameter of the job in mm
N = r.p.m. of machine/job.

Unit 5

MACHINING TIME CALCULATION

Content 2:

Calculation of Machining Time for Different Lathe Operations:

The calculation of machining time for various lathe operations is discussed here.

Turning : Turning, on a lathe, is the removal of excess material form the workpiece by means of a pointed tool, to produce a cylindrical or cone shaped surface. From cutting speed, r.p.m. of job are calculated by using the formula.

1000 S

$$N = \frac{1000S}{\pi D}$$

Where,

N = r.p.m. of job
S = Surface cutting speed in meters/minute
D = Diameter of the stock to be turned (in mm)

If f = Feed per revolution (in mm)
L = Length of stock to be turned (in mm)

T = Time required for turning (in minutes)

Then

$$T = \frac{L}{f \times N}$$

In case it is not possible to obtain the required dimensions in single cut, more than one cut may be required. In such cases the r.p.m. is determined by using the mean diameter of the job.

$$N = \frac{1000S}{\pi \times D\ (average\ )}$$

where D (average) = Average Diameter of job

$$= \frac{D+d}{2}$$

where

D = Diameter of stock before turning
d = Diameter of job after turning

and

$$T = \frac{L}{f \times N} \times p$$

Table . Cutting Speeds and Feed Rates for Lathe Operations.

Work material	Cutting speed metres/min								Feed rate f in mm/rev	
	HSS Tool				Carbide Tool		Stellite Tool			
	Turning		Reaming and Threading	Drilling	Turning		Turning			
	Rough	Finish			Rough	Finish	Rough	Finish	Rough	Finish
Mild Steel	40	60	7.5 to 15	30	90	180	50	75	0.65 to 2.0	0.12 to 0.75
Cast Steel	15	24	3.5	12	45	100	24	33	0.5 to 1.25	0.12 to 0.5
Stainless Steel	15	18	3	12	27	45	22	25	0.5 to 1.0	0.07 to 0.17
Grey C.I.	18	27	3.5	13	60	100	33	45	0.4 to 2.5	0.2 to 1.0
Aluminium	90	150	15	72	240	360	120	180	0.1 to 0.5	0.07 to 0.25
Brass	75	100	18	60	180	270	90	150	0.37 to 2.0	0.2 to 1.25
Phosphor Bronze	18	36	4.5	13	120	180	30	50	0.37 to 0.75	0.12 to 0.5

where,

P = Number of cuts (passes) required.

If over travel and approach are also to be taken into account

$$T = \frac{A + L + O}{f \times N} \times P$$

Where,

A = Approach length

O = Over travel

The cutting speeds and feeds for various tool and work material combinations for lathe operations are given in Table. The depth of cut should not exceed 3 mm in roughing operation and 0.75 mm in finishing operation.

\

Facing : Facing is the process of removing material from the ends of the job by moving the tool perpendicular to the axis of the job Fig. 5.12 (*a*) and (*b*). Time taken for facing is calculated in the same way as for turning but here

Length of job $= \frac{1}{2} \times$ dia. of job (in case of solid job)

$= \frac{1}{2}(D - d)$ in case of hollow jobs

D = Outer diameter of job

d = Inner diameter of job

f = Feed/revolution, is the movement of tool per revolution perpendicular to the axis of the job.

Time taken, $T = \frac{\text{Length of cut}}{f \times N}$

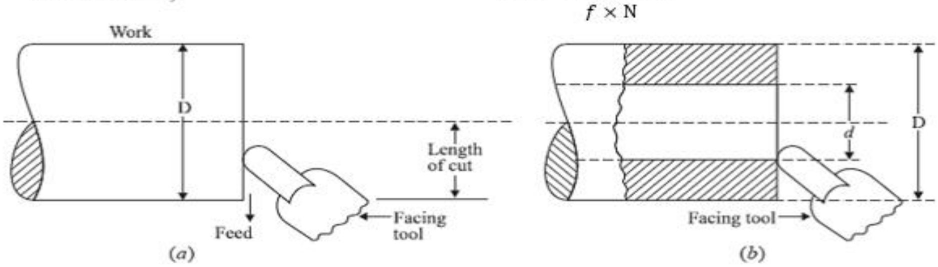


Table . Cutting Speeds and Feeds for Drilling Operation (Tool Material : HSS)

Work material	S mpm	Drill size, mm	*f* mm per revolution
Stainless steels	9 – 12	0 – 3.2	0.02 – 0.05
C-steels (0.4 – 0.5% C)	21 – 24	3.2 – 6.35	0.05 – 0.10
C-steels (0.2 – 0.3 % C)	24 – 33	6.35 – 12.7	0.10 – 0.17
Soft grey C.I.	30 – 45	12.7 – 25.4	0.17 – 0.37
Brass and Bronze	60 – 90	> 25.4	0.37 – 0.62
Aluminium alloys	60 – 90		
Magnesium alloys	75 – 120		

External relief: The external relief is the removal of material from a previously turned surface along the same axis and within the limits of turned area. The method of calculating the time for external relief is same as for turning.

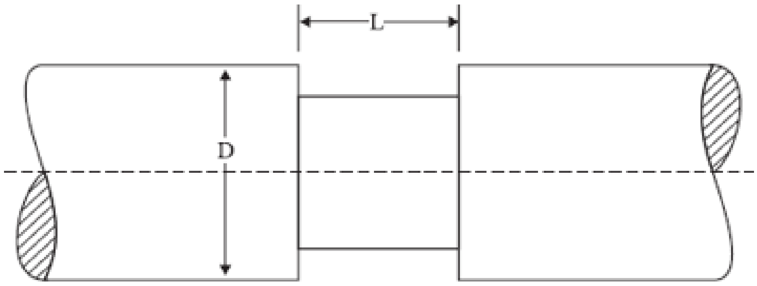


Fig. 5.13. External relief.

$$T = \quad T = \frac{l}{f \times N} \times p$$

P = Number of cuts (passes)

In external relief process, there is no approach length and over travel. The term, L is the length to be machined.

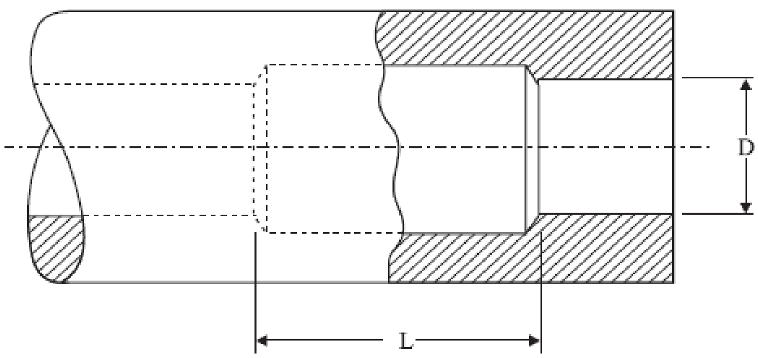


Fig. 5.14. Internal relief.

Undercutting : In undercutting, also called internal relief, a previously bored hole is made larger along the same axis and is within the longitudinal limits of the main bore. Internal relieving time is calculated by the same formula as for turning, *i.e.*,

$$\text{Time required} = \frac{\text{Length of cut}}{\text{Feed pre rev.} \times \text{r.p.m.}} \times \text{No. of cuts}$$

Chamfering: Chamfering is the process of removal of material from the edges of external or internal diameters to facilitate the entering of mating parts or to form a seat.

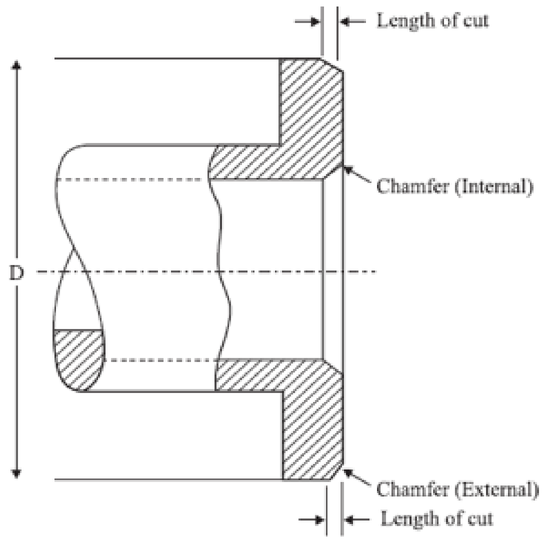


Fig. 5.15. Chamfer (External and Internal)

Formula for calculating the time for chamfering is the same as for turning operation

$$T = \frac{L}{f \times N}$$

Knurling : The purpose of knurling operation is to provide a rough surface on a part so that it will not easily slip when grasped by the fingers or hand. The material on surface is upset (deformed) in such a way that straight lined or diamond shaped patterns are formed on the surface. The formula for calculation of time is the same as for turning.

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

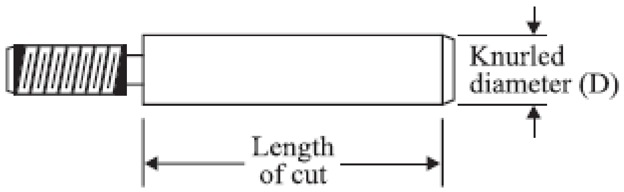
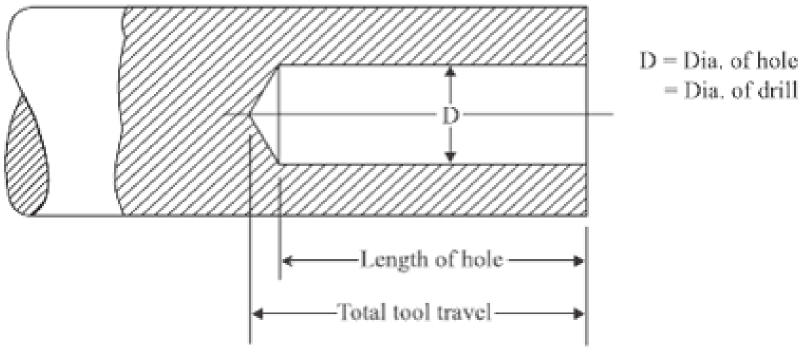


Fig. 5.16. Knurling

Boring: It is the operation of enlarging or finishing an hole which has been previously drilled or bored. The cutting time formula is similar to that used for simple turning.

Drilling : Drilling is the removal of material to produce holes in the material. Sometimes the drilling operation is done on the lathe by holding the drill in tailstock and forcing it into the rotating work piece. As in case of turning the time taken to drill a hole is affected by material of job, size of drill, material of drill, the feed and depth of the drilled hole. Generally the drilling speeds are lower than the turning speeds for the same type of tool material. The speeds and feeds for drilling in various materials are given in Table 5.5.



If length of cut = L

f = feed/revolution

N = r.p.m.

$$\text{Time T} = \frac{L}{f \times N}$$

Threading: Threads can be cut on lathe with the help of a single point cutting tool or on a turret lathe with the help of a die head. The time for cutting threads is calculated as follows:

$$\text{Time T} = \frac{\text{Length of cut}}{\text{Feed per revolution} \times \text{r.p.m.}}$$

Where,

Feed/rev. = lead of thread

Full depth of the thread cannot be obtained in a single cut when cutting threads by single point cutting tool on a lathe. A number of cuts have to be taken to get the full depth.

The number of cuts may be calculated with the help of following relations :

$$\text{Number of cuts} = \frac{25}{\text{Thread per cm}} \quad \text{for external threads}$$

$$= \frac{32}{\text{Thread per cm}} \quad \text{for internal threads}$$

If threads are cut with the help of die nuts, then full depth of the threads is obtained in single cut up to 3 mm pitch threads, otherwise two cuts may have to be taken.

$$\therefore \text{Time for threading} = \frac{\text{Length of cut}}{\text{Feed /rev} \times \text{r.p.m.}} \times \text{No. of cuts}$$

Tapping: Tapping is the operation of cutting internal threads with the help of a tool called tap.

The time required is calculated as follows:

∴

$$\text{Time taken } T = \frac{\text{Length of cut}}{\text{Feed per revolution} \times N}$$

Where,

$$N = \frac{1{,}000\, S}{\pi \times D}$$

And feed/rev. = pitch of thread

D

$$\text{Length of cut} = \text{Length to be threaded} + \frac{D}{2}$$

Where,

D = Major dia of thread.

Example 1: Calculate the machining time to turn the dimensions shown in Fig. 5.22.Starting from a M.S. bar of dia 80 mm. The cutting speed with HSS tool is 60 meters per minute and feed is 0.70 mm/rev., depth of cut is 2.5 mm per pass.

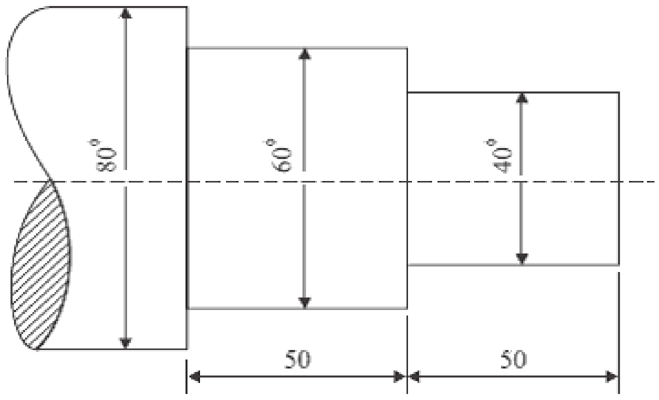


Fig. 5.22

Solution :

S = 60 m/min

f = 0.70 mm/rev.

The turning will be done in 2 steps. In first step a length of (50 + 50) = 100 mm willbe reduced from 80 f to 60 f and in second step a length of 50 mm will be reduced from dia 60 to dia 40 .

***Step I*:** For turning from dia 80mm to dia 60mm and 100 mm long.

$$N = \frac{1,000\ S}{\pi D} = \frac{1,000 \times 60}{\pi \times 80}$$

$$= 238.8 \simeq 240 \text{ r.p.m.}$$

$$\text{No. of passes} = \frac{\text{Depth of material to be removed}}{\text{Depth of cut}}$$

$$= \frac{(80-60)}{2 \times 2.5} = 4$$

$$\text{Time required : } \frac{100}{0.7 \times 240} \times 4 = 2.38 \text{ min.}$$

Step II : To turn f 40 from f 60 and 50 mm long.

$$N = \frac{1,000\ S}{\pi D} = \frac{1,000 \times 60}{\pi \times 60}$$

$$= 318 \text{ r.p.m.}$$

$$\text{No. of passes} = \frac{(60-40)}{2 \times 2.5} = 4$$

$$\text{Time} = \frac{50}{0.7 \times 318} \times 4 = 0.9 \text{ min.}$$

$$\text{Total time} = 2.38 + 0.90 = 3.28 \text{ min.}$$

Example 2: A mild steel bar 100 mm long and 38 mm in diameter is turned to 35 mm dia. and was again turned to a diameter of 32 mm over a length of 40 mm as shown in the Fig. 5.23. The bar was machined at both the ends to give a chamfer of45° × 5 mm after facing. Calculate the machining time. Assume cutting speed of 60m/min and feed 0.4 mm/rev. The depth of cut is not to exceed 3 mm in any operation.

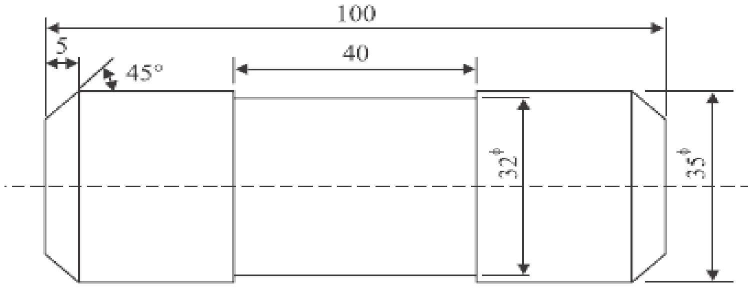


Fig. 5.23

Solution:

Ist operation : Turning from f 38 mm to f 35 mm

$$S = 60 \text{ meters/min.}$$

$$D = 38 \text{ mm}$$

$$N = \frac{1{,}000\ S}{\pi D} = \frac{1{,}000 \times 60}{\pi \times 38}$$

$$= 503 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{\text{Length of cut}}{\text{r.p.m.} \times \text{Feed/rev.}}$$

$$= \frac{100}{503 \times 0.4} = 0.5 \text{ min.}$$

2nd operation: External relief

L = 40 mm.

D = 35 mm.

S = 60 m/min.

$$N = \frac{60 \times 1{,}000}{\pi \times 35} = 545 \text{ r.p.m.}$$

$$\text{Time taken for second operation} = \frac{\text{Length}}{\text{r.p.m.} \times \text{Feed/rev.}}$$

$$= \frac{40}{545 \times 0.4} = 0.18 \text{ min.}$$

3rd operation :

$$L = \text{Length of cut}$$

$$= \frac{35}{2} = 17.5 \text{ mm}$$

$$D = 35 \text{ mm}$$

$$S = 60 \text{ m/min}$$

$$N = \frac{60 \times 1{,}000}{\pi \times 35} = 545 \text{ r.p.m.}$$

$$\text{Time for facing one end} = \frac{17.5}{0.4 \times 545} = 0.08 \text{ min}$$

$$\text{Time for facing both ends} = 2 \times 0.08 = 0.16 \text{ min}$$

4th operation : Chamfering 45° × 5 mm

$$\text{Length of cut} = 5 \text{ mm}$$

$$N = 545 \text{ r.p.m.}$$

$$\text{Time taken for chamfering on one side} = \frac{5}{545 \times 0.4} = 0.02 \text{ min}$$

$$\text{Time taken for chamfering on both sides} = 0.02 \times 2 = 0.04 \text{ min}$$

$$\text{Total machining time} = 0.50 + 0.18 + 0.16 + 0.04$$

$$= 0.88 \text{ min}$$

Example 3: A mild steel shaft, shown in Fig. is to be turned from a 24 mm dia bar.

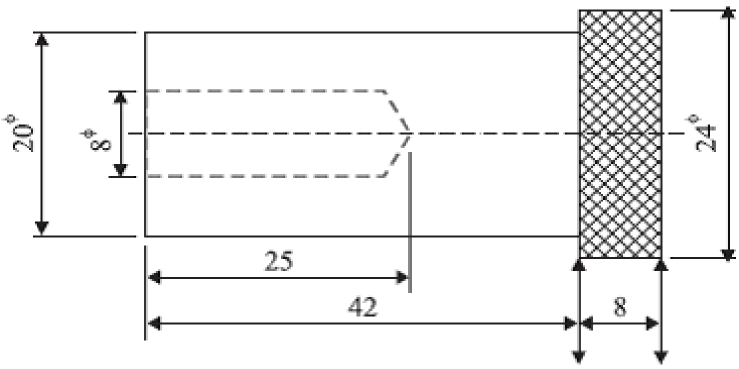


Fig. 5.24

The complete machining consists of the following steps:

(i) Facing 24 mm f on both sides

(ii) Turning to f 20 mm.

(iii) Drilling f 8 mm hole

(iv) Knurling.

With H.S.S tool the cutting speed is 60 m/min. The feed for longitudinal machiningis 0.3 mm/rev. The feed for facing, 0.2 mm/rev., feed for knurling 0.3 mm/rev., andfeed for drilling is 0.08 mm/rev. Depth of cut should not exceed 2.5 mm in any operation. Find the machining time to finish the job.

Solution:

Solution : ***Step I*** : Facing 24 £ bar on both ends

$$\text{Cutting speed} = 60 \text{ m/min}$$

$$\text{Diameter} = 24 \text{ mm}$$

$$\text{Length of cut (for facing)} = \frac{24}{2} = 12 \text{ mm}$$

$$f = 0.2 \text{ mm/rev.}$$

$$N = \frac{60 \times 1{,}000}{24 \times \pi} = 796 \text{ r.p.m.}$$

$$\text{Time taken to face on one side} = \frac{L}{f \times N} = \frac{12}{0.2 \times 796}$$

$$= 0.07 \text{ min.}$$

$$\text{Time to face on both ends} = 2 \times 0.07 = 0.14 \text{ min.}$$

Step 2 : Turn £ 20 mm from £ 24 mm

$$\text{Length of cut} = 42 \text{ mm}$$

$$f = 0.3 \text{ mm/rev.}$$

$$N = \frac{60 \times 1{,}000}{\pi \times 24} = 796 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{42}{0.3 \times 796} = 0.17 \text{ min.}$$

Step 3 : Drilling 8 mm dia hole

$$D = 8 \text{ mm}$$

$$L = 25 \text{ mm}$$

$$f = 0.08 \text{ mm/rev.}$$

$$N = \frac{60 \times 1{,}000}{8 \times \pi} = 2{,}388 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{25}{0.08 \times 2{,}388} = 0.13 \text{ min.}$$

Step 4 : Knurling

$$D = 24 \text{ mm}$$

$$L = 8 \text{ mm}$$

$$f = 0.3 \text{ mm/rev.}$$

$$N = \frac{60 \times 1000}{\pi \times 24} = 796 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{8}{0.3 \times 796} = 0.03 \text{ min.}$$

$$\text{Total machining time} = 0.14 + 0.17 + 0.13 + 0.03$$

$$= 0.47 \text{ min.}$$

Unit 5

MACHINING TIME CALCULATION

Content 3: Calculation of Machining Time for Drilling and Boring

Drilling is the process of making holes in work piece by means of a revolving tool called drill. The drilling machine can also be used for some other operations like counter-sinking, counter-boring and threading. The machining time for drilling operation is calculated as follows :

Time, $$T = \frac{L}{f \times N}$$

L = Length of drill travel
= Length of hole + Allowance
f = Feed per revolution
N = r.p.m. of drill
Allowance = 0.3 d for 118° drill point angle

Where,
d = Dia of drill in mm.

If
S = Surface cutting speed of drill in meters/min
N = r.p.m. of the drill
d = dia of the drill

$$S = \frac{\pi d N}{1000}$$

Example 1: Estimate the time taken to drill a 25 mm dia × 10 cm deep hole in a casting. First a 10 mm dia drill is used and then the hole is enlarged by a 25 mm diadrill. Assume:

Cutting speed = 15 m/min.
Feed for f 10 mm drill= 0.22 mm/rev. Feed for f 25 mm drill= 0.35 mm/rev.

Solution :

(*i*) To calculate the time to drill £ 10 mm hole — 10 cm deep

$$S = 15 \text{ m/min.}$$

$$f = 0.22 \text{ mm/rev.}$$

$$\text{Dia of drill } D = 10 \text{ mm}$$

$$\text{Length of cut} = 10 \text{ cm} = 100 \text{ mm}$$

$$\text{r.p.m. of drill } N = \frac{15 \times 1{,}000}{\pi \times 10} = 478$$

$$\text{Time taken} = \frac{\text{Length of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$= \frac{100}{0.22 \times 478} = 0.95 \text{ min.}$$

(*ii*) To calculate time for enlarging 10 mm dia hole to 25 mm dia hole

$$\text{Dia of drill} = 25 \text{ mm}$$

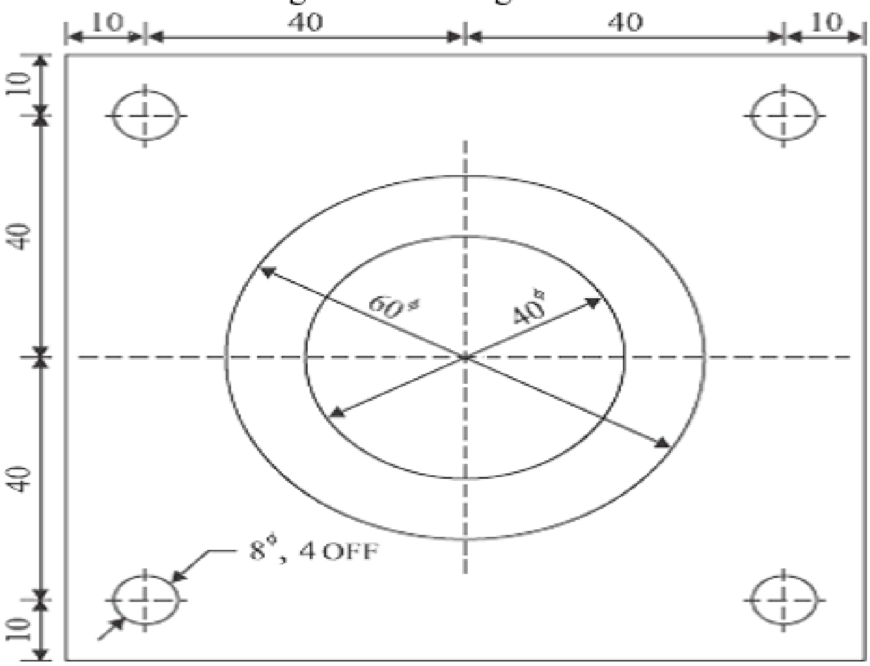
$$f = 0.35 \text{ mm/rev.}$$

$$N = \frac{15 \times 1{,}000}{\pi \times 25} = 190 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{100}{0.35 \times 190} = 1.5 \text{ min.}$$

$$\text{Total time to drill the hole} = 0.95 + 1.5 = 2.45 \text{ min.}$$

Example 2: Calculate the machining time to drill four 8 mm dia holes and one 40 mm dia central hole in the flange shown in Fig. 5.26.



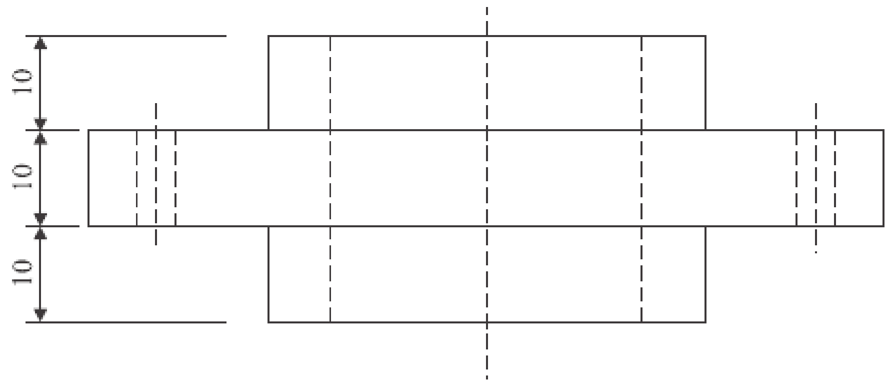


Fig. 5.26

20 mm dia hole is drilled first and then enlarged to 40 mm f hole. Take cutting speed 10 m/min, feed for 8 mm drill 0.1 mm/rev, for 20 mm drill feed is 0.2 mm/rev.and for 40 mm f drill feed is 0.4 mm/rev.

Solution:

(*i*) Time to drill four 8 mm dia holes

S = 10 m/min.

Dia of drill D = 8 mm.

$$L = 10 \text{ mm}$$

$$f = 0.1 \text{ mm/rev.}$$

$$N = \frac{S \times 1{,}000}{\pi D} = \frac{10 \times 1{,}000}{\pi 8}$$

$$= 398 \text{ r.p.m.}$$

$$\text{Time taken to drill one hole} = \frac{L}{f \times N} = \frac{10}{0.1 \times 398}$$

$$= 0.25 \text{ min.}$$

$$\text{Time to drill 4 holes} = 0.25 \times 4 = 1 \text{ minute.}$$

(*ii*) Time to drill one hole of 40 mm diameter :

This hole is made in two steps :

(*a*) Drill 20 mm f hole — 30 mm long

$$N = \frac{10 \times 1{,}000}{\pi \times 20} = 159 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{30}{0.2 \times 159} = 0.95 \text{ min.}$$

(*ii*) Enlarge 20 mm f hole with 40 mm f drill

Here $$N = \frac{10 \times 1,000}{\pi \times 40} = 80 \text{ r.p.m.}$$

$$f = 0.4 \text{ mm/rev.}$$

$$\text{Time taken} = \frac{30}{0.4 \times 80} = 0.94 \text{ min.}$$

$$\text{Total time taken to drill all the holes} = 1.0 + 0.95 + 0.94 = 2.9 \text{ min.}$$

Unit 5

MACHINING TIME CALCULATION

Content 4: Machining Time Calculation for Milling, Shaping Planning and Grinding

In all the above operations the relative motion between the tool and the work-piece is reciprocating. The cutting action takes place only in the forward stroke and the return stroke is idle.

So the return stroke should be completed in minimum time.

Effective cutting speed = $\frac{L}{1,000} \times N$ meters/minute

Where,
L = Length of forward stroke in mm (including clearance on both sides)
N = No. of forward strokes/minute

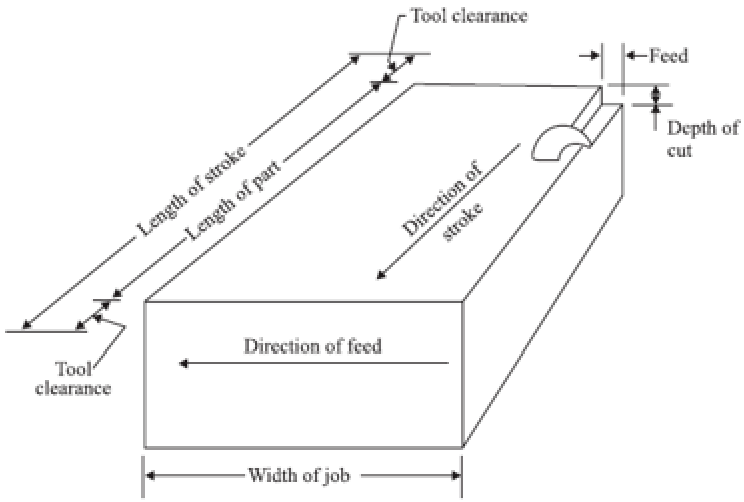


Fig. 5.18. Shaper operation terms.

If $K = \frac{\text{Time for return stroke}}{\text{Time forward stroke}}$

Then cutting speed is given by

$$S = \frac{L\ (1 + K)}{1,000} \times N \text{ m/min}$$

Now time taken by cutting stroke = $\frac{L}{S \times 1000}$

Now time taken by return stroke = $\frac{L}{S \times 1000} \times K$

The total time for one cut (one cutting stroke and one return stroke) L

$$T = \frac{L}{S \times 1000} + \frac{LK}{S \times 1000} = \frac{L(1+K)}{S \times 1000}$$

Now if W = Width of job in mm

f = feed per stroke

W

Then number of strokes required to complete one pass on full width = $\frac{W}{f}$

$$\text{Total time for completing one cut} = \frac{L(1+K)}{S \times 1000} \times \frac{W}{f}$$

Table. Cutting Speed and Feeds for Shaping, Planing and Slotting

Work material	*Type of tool*					
	HSS		*Cast alloys*		*Carbides*	
	S mpm	*f* mm/rev.	S mpm	*f* mm/rev.	S mpm	*f* mm/rev.
Steel (hard)	6 – 10.5	0.75 – 1.25	—	—	30 – 54	0.9
Steel (medium)	18 – 21	0.75	—	—	54 – 75	1.25
Steel (soft)	21 – 30	0.75 – 3.0	—	—	54 – 90	1.25
Cast steel	7.5 – 18	1.25	18 – 24	1.0	30 – 54	1.00
C.I. (hard)	9 – 15	1.50	15 – 24	1.25	30 – 60	1.25
C.I. (soft)	15 – 24	3.0	27 – 36	1.25	33 – 67.5	1.25
Malleable iron	15 – 27	2.25	14 – 36	1.25	45 – 75	1.0
Brass	45 – 75	1.25 – 1.50	—	—	—	—
Bronze	9 – 18	2.0	—	—	45 – 90	1.25
Aluminium	60 – 90	0.75 – 1.25	—	—	—	—

If it is not possible to cut the material in one pass, more than one pass may be required If

P = No. of passes required

Time. $$T = \frac{L(1+K)}{S \times 1000} \times \frac{W \times P}{f}$$

The cutting speeds and feeds for shaping, planing and slotting are given in Table.

ESTIMATION OF MILLING TIME

Milling machine is a very versatile machine. The milling machine employs a multipoint tool, called milling cutter, for machining. The various operations done ona milling machine are facing, forming or profile machining, slotting, key way cutting, etc.

In milling machine, the formula to calculate machining time is:

$$\text{Time} = \frac{\text{Length of cut}}{(\text{Feed per rev.}) \times (\text{r.p.m.})}$$

Where, $\text{r.p.m. } (N) = \frac{1000 \times S}{\pi \times D}$ (D is cutter dia)

In case of milling cutters:

Feed per revolution = Feed per tooth × number of teeth on cutter

Average cutting speeds and feeds per tooth for various materials are given in Table

$$\text{Time taken per cut} = \frac{\text{Length of cut (Total table travel)}}{\text{Feed per rev.} \times \text{r.p.m. of cutter}}$$

Total table travel = Length of job + added table travel

The added table travel = Cutter approach + over travel

Cutting Speeds (For Carbide Cutter for a Feed Rate of 0.2 mmper Tooth)

	S in meters per minute							
	Brazed cutters				*Indexable inserts*			
	I.S.O. Carbide grade				*I.S.O. Carbide grade*			
Work material	*P.10*	*P.30*	*P.40*	*K.20*	*P.10*	*P.30*	*P.40*	*K.20*
Aluminium	150	130	100	—	200	170	130	—
C-Steel, 0.7% C	120	90	75	—	150	90	75	—
Steel Castings	60	45	50	—	80	75	50	—
Stainless steel	100	100	100	—	125	125	115	—
Grey C.I.	150	130	110	—	150	130	110	—
Aluminium Alloy	—	—	—	600	—	—	—	600

Feed per Tooth (HSS Cutter)

Type of cutter	*Slab Mill (Helix angle up to 30°)*	*Slab Mill (Helix angle 30° to 60°)*	*Face Mill*	*End Mill*	*Slot Mill*	*Form relieved cutter*
Feed per tooth (mm)	0.10 to 0.25	0.07 to 0.20	0.12 – 0.50	0.02 – 0.25	0.07 – 0.12	0.07 – 0.20

Cutting Speed (HSS Cutter)

Material being cut	*Brass*	*C.I.*	*Bronze*	*Mild Steel*	*Hard C Steel*	*Hard alloy Steel*	*Alluminium*
S, mpm	45 – 60	21 – 30	24 – 45	21 – 30	15 – 18	9 – 18	15 – 30

$$\text{Time taken/cut} = \frac{\text{Length of job} + \text{added table travel}}{\text{Feed per rev.} \times \text{r.p.m.}}$$

The added table travel will depend upon the type of milling operation.

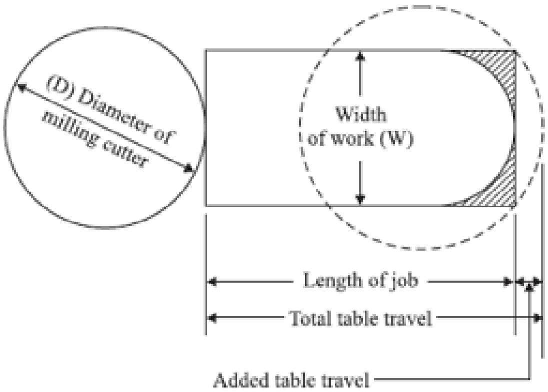


Fig. 5.19. Face milling

(*i*) For face milling : In a face milling operation, refer Fig. 5.19, when the milling cutter has traversed the length of face, some portion of the face is yet to be milled as shown by shaded area.

In order to complete milling an additional distance must be travelled by the table, which is given by:

$$\text{Added table travel} = \frac{1}{2}\left(D - \sqrt{D^2 + W^2}\right)$$

Where,

D = cutter dia

W = Width of work piece

If

D = W, then approach $= \frac{W}{2}$

D > W, then approach $= \frac{D}{2}$

but we will have to take more than one transverse cut to complete one cut on the face width.

(*ii*) For slab or spot milling :

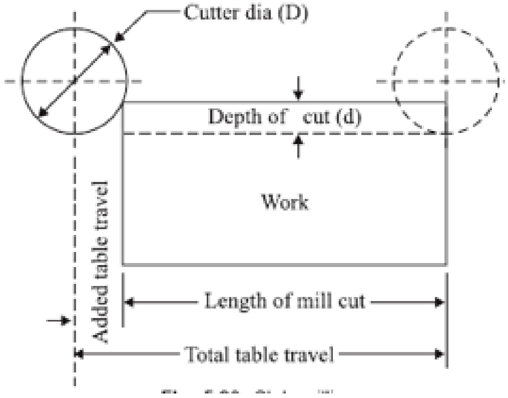
Added table travel $=\sqrt{Dd + d^2}$

Where,

D = Dia of cutter

d = Depth of cut.

This formula is valid when depth of cut is less than radius of cutter *i.e* $d<\frac{D}{2}$. *if* $d=\frac{D}{2}$ the added table travel is equal to radius of cutter.



Example 1 : Calculate the time required to tap a hole with 25 mm dia tap to a length of 30 mm having 3 threads per cm. The cutting speed is 10 m/min. For return stroke the speed is 2 times the cutting speed.

Solution:

L = 30 mm

D = 25 mm

S = 10 m/min

No. of threads per cm = 3

Pitch of thread = Feed/rev.

$$= \frac{1}{3} \text{ cm} = \frac{10}{3} \text{ mm}$$

$$N = \frac{10 \times 1{,}000}{\pi \times 25} = 127 \text{ r.p.m.}$$

$$\text{Time taken for tapping} = \frac{L + \frac{D}{2}}{N \times \text{Feed/rev.}}$$

$$= \frac{30 + 12.5}{127 \times \frac{10}{3}} = \frac{42.5 \times 3}{127 \times 10}$$

$$= 0.1 \text{ min.}$$

$$\text{Return time} = \frac{1}{2} \times 0.1 = 0.05 \text{ min.}$$

$$\text{Time for one pass} = 0.1 + 0.05 = 0.15 \text{ min.}$$

$$\text{Total time for tapping (3 passes)} = 0.15 \times 3 = 0.45 \text{ min.}$$

Example 2: A 300 mm × 50 mm rectangular cast iron piece is to be face milled with a carbide cutter. The cutting speed and feed are 50 m/min and 50 mm/min. If the cutter dia is 80 mm and it has 12 cutting teeth, determine:

(i) Cutter r.p.m.
(ii) Feed per tooth
(iii) Milling time

Solution:

Dimensions of slab = 300 mm × 50 mm.
Cutting speed S = 50 meters/min.
Feed F = 50 mm/min.
No. of teeth on cutter = 12
Cutter dia = 80 mm

(*i*)
$$\text{Cutter r.p.m.} = \frac{\text{Cutting speed}}{\pi \times \text{Dia of cutter}}$$

$$= \frac{50 \times 1000}{\pi \times 80} = 200 \text{ r.p.m.}$$

(*ii*)
$$\text{Feed per tooth} = \frac{\text{Feed per min}}{\text{r.p.m.} \times \text{No. of teeth}}$$

$$= \frac{50}{200 \times 12} = 0.02 \text{ mm/tooth}$$

(*iii*) For face milling – since dia of cutter (D) is greater than width of work piece (W)

$$\text{Over travel} = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

$$= \frac{1}{2}\left(80 - \sqrt{80^2 - 50^2}\right) = 8.8 \text{ mm}$$

$$\text{Total cutter travel} = 300 + 8.8 = 309 \text{ mm (approx.)}$$

$$\text{Time taken for milling} = \frac{\text{Total cutter travel}}{\text{Feed per min.}}$$

$$= \frac{309}{50} = 6.18 \text{ min.}$$

Example 3: A T-slot is to be cut in a C.I. slab as shown in Fig. Estimate the machining time. Take cutting speed 25 m/min, feed is 0.25 mm/rev. Dia of cutter for channel milling is 80 mm.

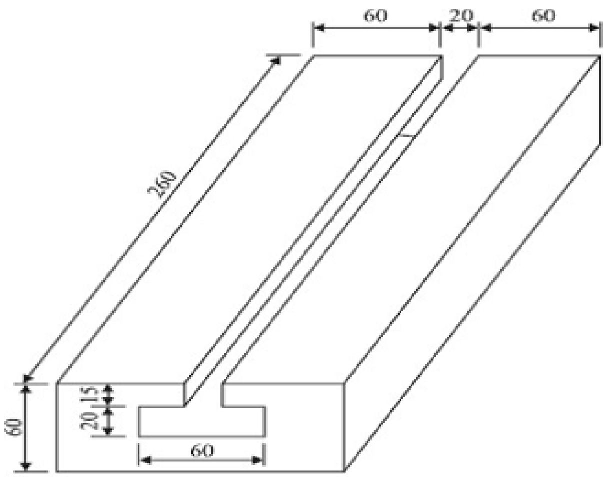
Solution:

The T-slot will be cut in two steps:

Step I: Cut a 20 mm wide and 35 mm deep channel along the length

Dia of cutter = 80 mm

Cutting speed = 25 m/min



$$\text{Length of job} = 260 \text{ mm}$$

$$\text{r.p.m. of cutter} = \frac{25 \times 1000}{\pi \times 80} = 100$$

$$\text{Over travel} = \sqrt{Dd - d^2}$$

$$= \sqrt{80 \times 35 - 35^2} = 40 \text{ mm}$$

$$\text{Total tool travel} = 260 + 40 = 300 \text{ mm}$$

$$\text{Time for cutting slot} = \frac{\text{Length of cut}}{\text{Feed/min.}}$$

$$= \frac{300}{0.25 \times 100} = 12 \text{ min.}$$

Step II : Cut T-slot of dimensions 60 × 20 with a T-slot cutter

Here dia of cutter = 60 mm

$$\text{r.p.m. of cutter} = \frac{25 \times 1{,}000}{\pi \times 60} = 133$$

$$\text{In this case the over travel of tool} = \frac{1}{2} \text{ Dia of cutter,}$$

since

$$\text{dia of cutter} = \text{width of slot}$$

$$\text{Over travel} = \frac{60}{2} = 30 \text{ mm}$$

$$\text{Total tool/Table travel} = 260 + 30 = 290 \text{ mm}$$

$$\text{Time taken} = \frac{290}{0.25 \times 133} = 8.7 \text{ min}$$

$$\text{Total time to cut T-slot} = 12 + 8.7$$

$$= 20.7 \text{ minutes.}$$

Example 4 : Find the time required on a shaper to machine a plate 600 mm × 1,200mm, if the cutting speed is 15 meters/min. The ratio of return stroke time to cuttingtime is 2 : 3. The clearance at each end is 25 mm along the length and 15 mm on width. Two cuts are required, one roughing cut with cross feed of 2 mm per stroke and one finishing cut with feed of 1 mm per stroke.

S = 15 m/minute

Length of stroke = L = Length of plate + clearance on both sides

= 1200 + 2 × 25 = 1,250 mm.

Cross travel of table = W = Width of job + clearance

= 600 + 2 × 15 = 630 mm.

$$K = \frac{2}{3} = 0.67$$

Cross feed for rough cut = 2 mm/stroke

Cross feed for finish cut = 1 mm/stroke

$$\text{Cross feed for rough cut} = 2 \text{ mm/stroke}$$

$$\text{Cross feed for finish cut} = 1 \text{ mm/stroke}$$

$$\text{Time for one complete stroke} = \frac{L(1 + K)}{1000 \times S}$$

$$= \frac{1,250 (1 + 0.67)}{1,000 \times 15}$$

$$= 0.14 \text{ min}$$

$$\text{No. of strokes for roughing cut} = \frac{\text{Cross travel of table}}{\text{Feed/stroke (Roughing)}}$$

$$= \frac{630}{2} = 315$$

$$\text{No. of strokes for finishing cut} = \frac{\text{Cutting travel of table}}{\text{Feed/stroke (Finishing)}}$$

$$= \frac{630}{1} = 630$$

$$\text{Total no. complete strokes required} = 630 + 315 = 945$$

$$\text{Total machining time} = 945 \times 0.14 = 132 \text{ min.}$$

Example 5 : Mild steel shaft 30 cm long is to be rough ground from 43.3 mm dia to 43 mm dia using a grinding wheel of 40 mm face width. Calculate the time required to grind the job assuming work speed of 12 m/min and depth of cut 0.02 mm per pass.

Solution:

L = 300 mm
W = 40 mm
D = 43.3 mm |

Work surface speed = S = 12 m/min.

$$N = \frac{12 \times 1000}{\pi \times 43.3} = 89 \text{ r.p.m.}$$

$$\text{Depth of material to be removed } d = 43.3 - 43.0$$

$$= 0.3 \text{ mm.}$$

$$\text{Depth of cut '}t\text{'} = 0.02 \text{ mm per pass}$$

$$\text{No. of passes required} = \frac{0.3}{0.02 \times 2} = 8$$

$$\text{Now longitudinal feed for roughing} = \frac{W}{2}$$

$$= \frac{40}{2} = 20 \text{ mm per rev.}$$

$$\text{Time taken for one cut} = \frac{L - W + 5}{\text{feed/ rev.} \times \text{r.p.m.}}$$

$$= \frac{300 - 40 + 5}{20 \times 89} = 0.15 \text{ min .}$$

$$\text{Time taken for 8 cuts} = 8 \times 0.15$$

$$= 1.20 \text{ minutes.}$$