Unit 5

MACHINING TIME CALCULATION

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.

$$\text{Total time per component} = \frac{\text{Handling time} + \text{Machining time} + \text{Set-up time} + \text{Tear-down time} + \text{Down time} + \text{Allowances}}{N}$$

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:

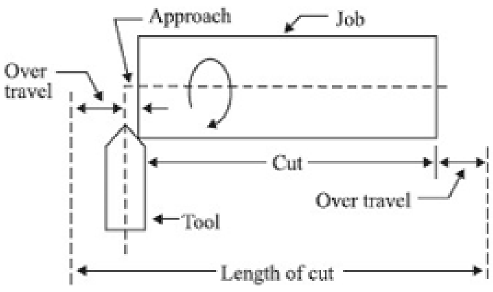
Length of cut: It is the distance travelled by the tool to machine the work piece and is calculated as follows:

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.

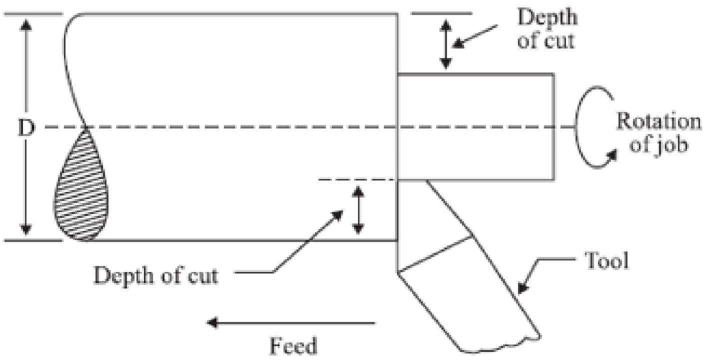


Fig. 5.11

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.

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.

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

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.

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

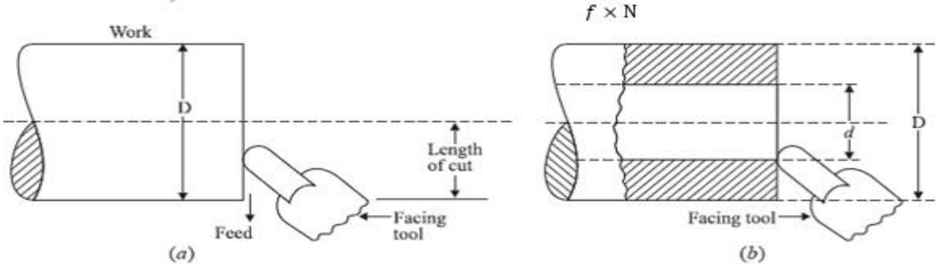


Table . Cutting Speeds and Feeds for Drilling Operation (Tool Material : HSS)

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.

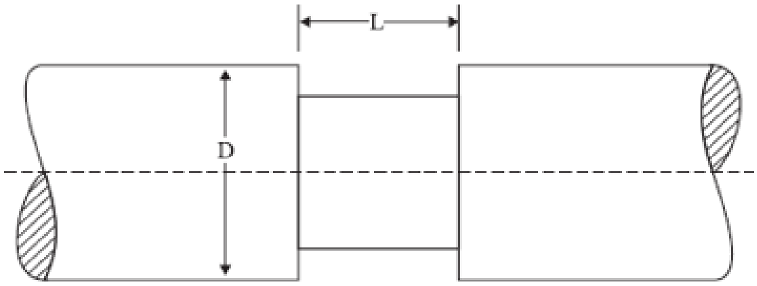


Fig. 5.13. External relief.

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

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.

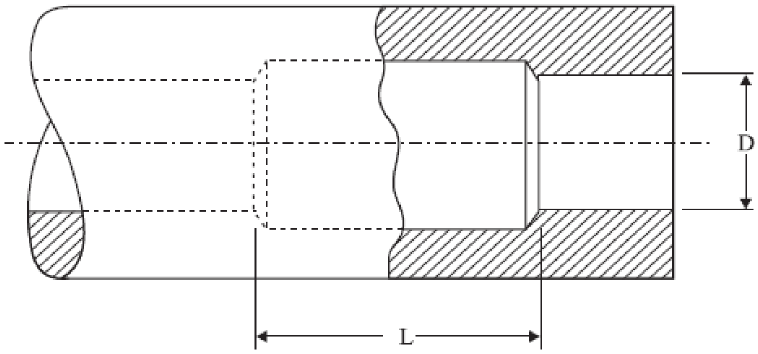


Fig. 5.14. Internal relief.

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.

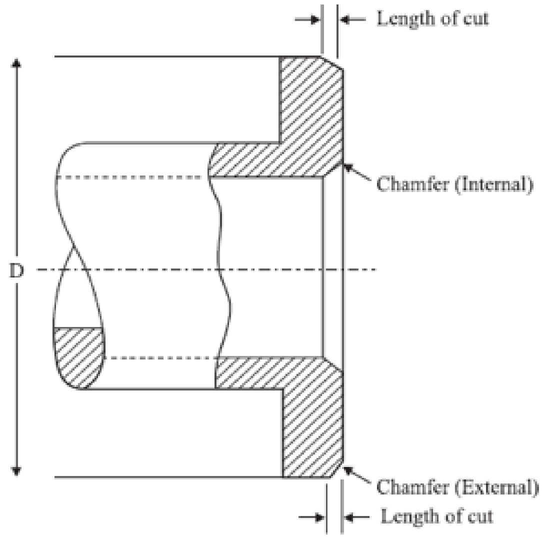


Fig. 5.15. Chamfer (External and Internal)

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.

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

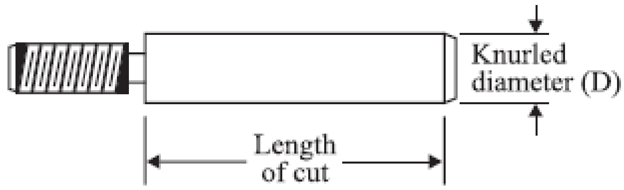
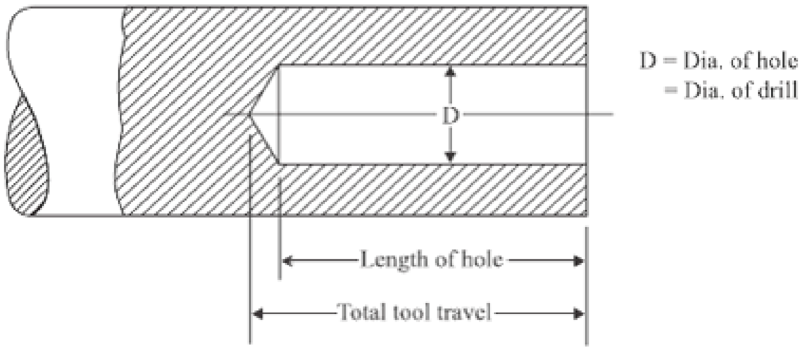


Fig. 5.16. Knurling

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

Length of cut = 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.

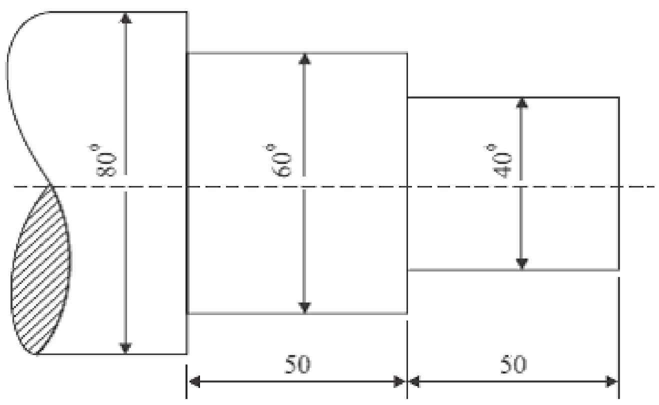


Fig. 5.22

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.

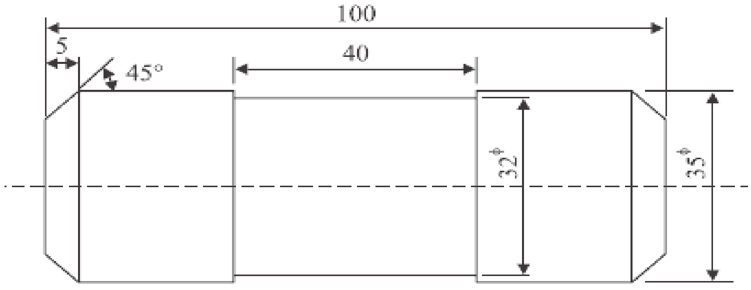


Fig. 5.23

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

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

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

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

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

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

$$= 0.88 \text{ min}$$