Unit 5

MACHINING TIME CALCULATION

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 :

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

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

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

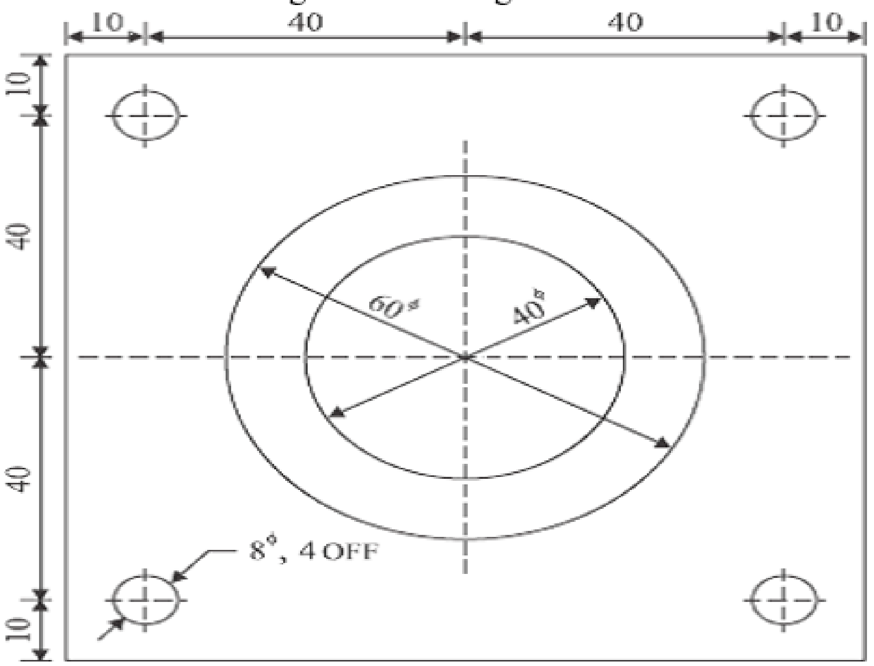
$$f = 0.35 \text{ mm/rev.}$$

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

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

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

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.



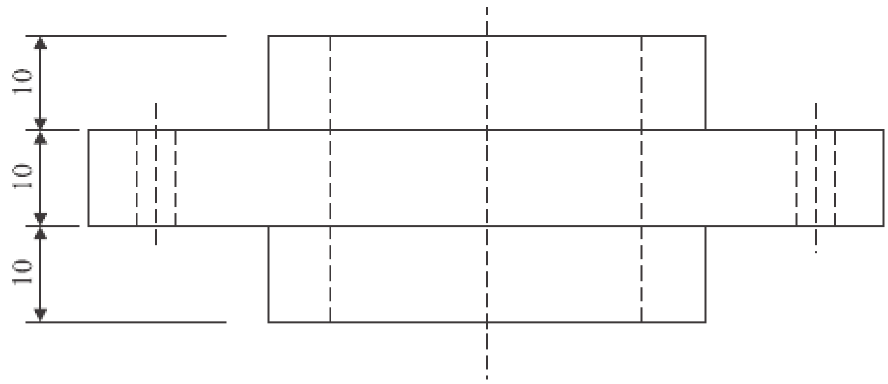


Fig. 5.26

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

$f = 0.4$ mm/rev.

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

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

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

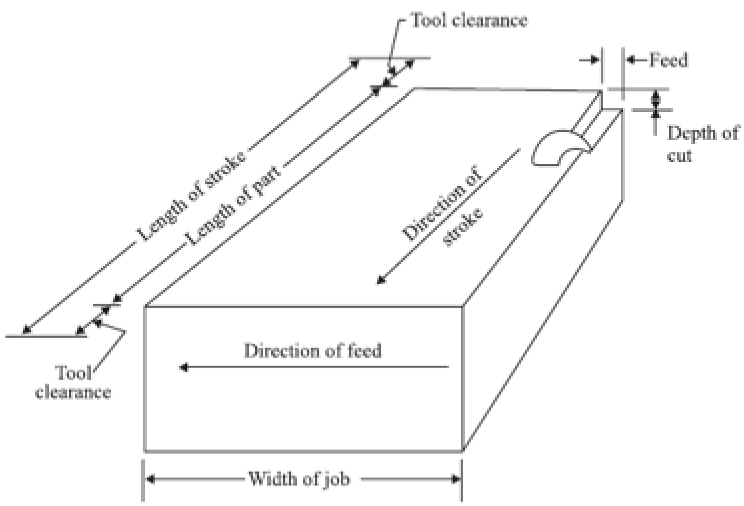


Fig. 5.18. Shaper operation terms.

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 = $\frac{W}{f}$

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.

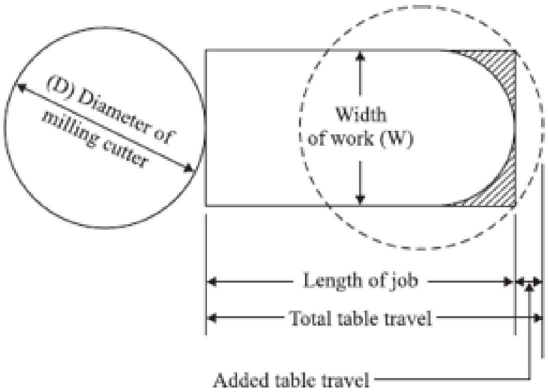


Fig. 5.19. Face milling

(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 :

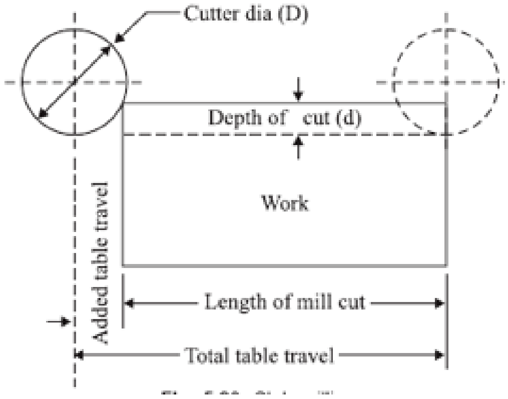
Added table travel $=\sqrt{Dd + d^2}$

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.

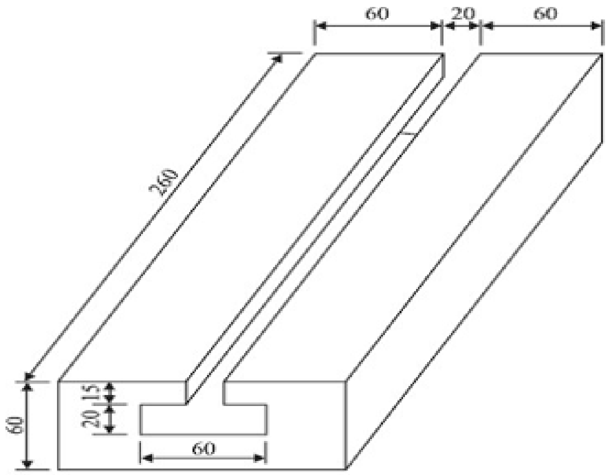
Solution:

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

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

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

since dia of cutter = 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

Cross feed for rough cut = 2 mm/stroke

Cross feed for finish cut = 1 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.

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

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

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

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

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

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

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

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

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

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

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