

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.

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

Where,

L = Length of forward stroke in mm (including clearance on both sides)

N = No. of forward strokes/minute

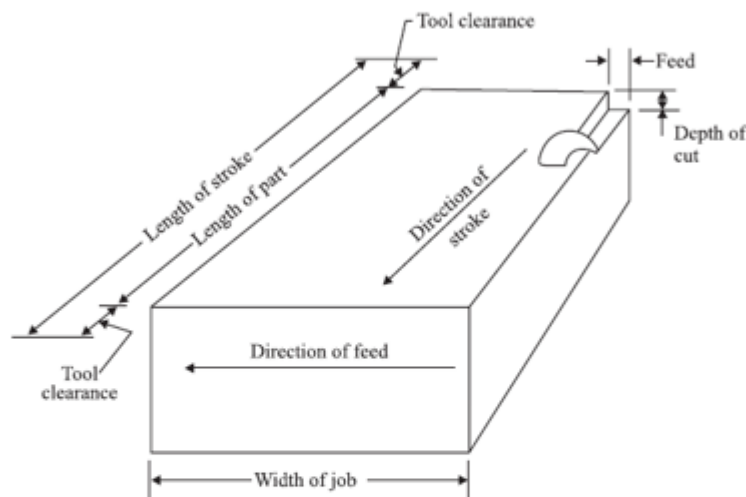


Fig. 5.18. Shaper operation terms.

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

Then cutting speed is given by

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

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

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

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 on a 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 \times 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 mm per Tooth)

Work material	S in meters per minute							
	Braze d cutters				Indexable inserts			
	I.S.O. Carbide grade				I.S.O. Carbide grade			
	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	Aluminium
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.

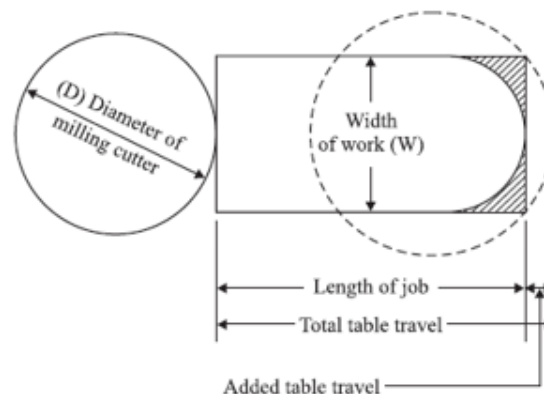


Fig. 5.19. Face milling

(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:

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

Where,

D = cutter dia

W = Width of work piece

If

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

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

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 :

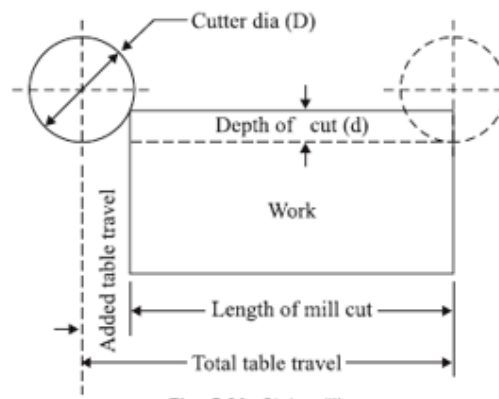
$$\text{Added table travel} = \sqrt{Dd + d^2}$$

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:

$$L = 30 \text{ mm}$$

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

$$S = 10 \text{ m/min}$$

$$\text{No. of threads per cm} = 3$$

$$\text{Pitch of thread} = \text{Feed/rev.}$$

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

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

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

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

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

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

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

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

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:

$$\text{Dimensions of slab} = 300 \text{ mm} \times 50 \text{ mm.}$$

$$\text{Cutting speed } S = 50 \text{ meters/min.}$$

$$\text{Feed } F = 50 \text{ mm/min.}$$

$$\text{No. of teeth on cutter} = 12$$

$$\text{Cutter dia} = 80 \text{ mm}$$

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

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

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

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

(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.

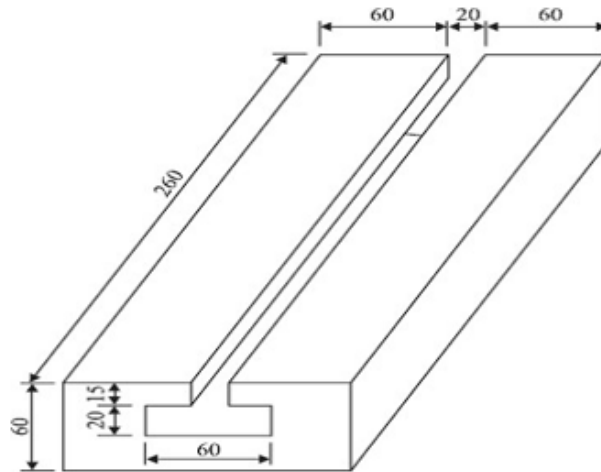
Solution:

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



Length of job = 260 mm

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

$$\begin{aligned} \text{Over travel} &= \sqrt{Dd - d^2} \\ &= \sqrt{80 \times 35 - 35^2} = 40 \text{ mm} \end{aligned}$$

Total tool travel = 260 + 40 = 300 mm

$$\begin{aligned} \text{Time for cutting slot} &= \frac{\text{Length of cut}}{\text{Feed/min.}} \\ &= \frac{300}{0.25 \times 100} = 12 \text{ min.} \end{aligned}$$

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

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

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

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

$$\begin{aligned} \text{Total time to cut T-slot} &= 12 + 8.7 \\ &= 20.7 \text{ minutes.} \end{aligned}$$

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 cutting time 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.

$$S = 15 \text{ m/minute}$$

$$\begin{aligned} \text{Length of stroke} = L &= \text{Length of plate} + \text{clearance on both sides} \\ &= 1200 + 2 \times 25 = 1,250 \text{ mm.} \end{aligned}$$

$$\begin{aligned} \text{Cross travel of table} = W &= \text{Width of job} + \text{clearance} \\ &= 600 + 2 \times 15 = 630 \text{ mm.} \end{aligned}$$

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

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

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

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

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

$$\begin{aligned} \text{Time for one complete stroke} &= \frac{L(1+K)}{1000 \times S} \\ &= \frac{1,250(1+0.67)}{1,000 \times 15} \\ &= 0.14 \text{ min} \end{aligned}$$

$$\begin{aligned} \text{No. of strokes for roughing cut} &= \frac{\text{Cross travel of table}}{\text{Feed/stroke (Roughing)}} \\ &= \frac{630}{2} = 315 \end{aligned}$$

$$\begin{aligned}\text{No. of strokes for finishing cut} &= \frac{\text{Cutting travel of table}}{\text{Feed/stroke (Finishing)}} \\ &= \frac{630}{1} = 630\end{aligned}$$

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

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

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:

$$L = 300 \text{ mm}$$

$$W = 40 \text{ mm}$$

$$D = 43.3 \text{ mm}$$

$$\text{Work surface speed} = S = 12 \text{ m/min.}$$

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

$$\begin{aligned}\text{Depth of material to be removed } d &= 43.3 - 43.0 \\ &= 0.3 \text{ mm.}\end{aligned}$$

$$\text{Depth of cut 'r' } = 0.02 \text{ mm per pass}$$

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

$$\begin{aligned}\text{Now longitudinal feed for roughing} &= \frac{W}{2} \\ &= \frac{40}{2} = 20 \text{ mm per rev.}\end{aligned}$$

$$\begin{aligned}\text{Time taken for one cut} &= \frac{L - W + 5}{\text{feed/ rev.} \times \text{r.p.m.}} \\ &= \frac{300 - 40 + 5}{20 \times 89} = 0.15 \text{ min.}\end{aligned}$$

$$\begin{aligned}\text{Time taken for 8 cuts} &= 8 \times 0.15 \\ &= 1.20 \text{ minutes.}\end{aligned}$$