Chapter 5

Lathe
Turning Operations

- Machine Tool – LATHE
- Job (workpiece) – rotary motion
- Tool – linear motions
  - "Mother of Machine Tools"
  - Cylindrical and flat surfaces
Some Typical Lathe Jobs

Turning/Drilling/Grooving/Threading/Knurling/Facing...
The Lathe

- Head Stock
- Tail Stock
- Bed
- Feed/Lead Screw
- Carriage
Types of Lathes

- Engine Lathe
- Speed Lathe
- Bench Lathe
- Tool Room Lathe
- Special Purpose Lathe
- Gap Bed Lathe

...
Size of Lathe

Workpiece Length

Swing
Size of Lathe...

Example: 300 - 1500 Lathe

- Maximum Diameter of Workpiece that can be machined
  = SWING (= 300 mm)

- Maximum Length of Workpiece that can be held between Centers (=1500 mm)
Workholding Devices

- Equipment used to hold
  - Workpiece – **fixtures**
  - Tool - **jigs**

*Securely HOLD or Support while machining*
Chucks

Workholding Devices

Three jaw

Four Jaw
Centers

Headstock center (Live Centre)

Tailstock center (Dead Centre)

Workpiece
Faceplates

Workholding Devices

Workpiece
Dogs

Workholding Devices...
**Mandrels**

Workpiece (job) with a hole
Rests

Steady Rest  
Follower Rest

- Workholding Devices
- Jaws
- Hinge
- Lathe bed guideways
- Carriage
Operating/Cutting Conditions

1. Cutting Speed $v$
2. Feed $f$
3. Depth of Cut $d$
relative tool travel in 1 rotation = $\pi D$

peripheral speed = $S = \pi D N$
Cutting Speed

$D$ – Diameter (mm)
$N$ – Revolutions per Minute (rpm)

The **Peripheral Speed** of Workpiece past the Cutting Tool

$\nu = \frac{\pi DN}{1000}$ \text{ m/min}$

= Cutting Speed
**Feed**

\( f \) – the distance the tool advances for every rotation of workpiece (mm/rev)
**Depth of Cut**

perpendicular distance between machined surface and uncut surface of the Workpiece

\[ d = \frac{(D_1 - D_2)}{2} \text{ (mm)} \]
3 Operating Conditions

- Chip
- Machined surface
- Workpiece
- Cutting speed
- Depth of cut ($d$)
- Chuck
- Feed ($f$)
- Tool
- Depth of cut
Selection of ..

- Workpiece Material
- Tool Material
- Tool signature
- Surface Finish
- Accuracy
- Capability of Machine Tool
MRR

Volume of material removed in one revolution $\text{MRR} = \pi D d f \text{ mm}^3$

- Job makes $N$ revolutions/min

\[ \text{MRR} = \pi D d f N \text{ (mm}^3/\text{min)} \]

- In terms of $v$, MRR is given by

\[ \text{MRR} = 1000 \; v \; d \; f \text{ (mm}^3/\text{min)} \]
MRR

dimensional consistency by substituting the units

MRR: \( D \cdot d \cdot f \cdot N \Rightarrow \) (mm)(mm)(mm/rev)(rev/min) = \( \text{mm}^3/\text{min} \)
Operations on Lathe

- Turning
- Facing
- Knurling
- Grooving
- Parting

- Chamfering
- Taper turning
- Drilling
- Threading
Turning

Cylindrical job
Turning ..

Cylindrical job

Operations on Lathe ..
Turning ..

- Excess Material is removed to reduce Diameter
- Cutting Tool: *Turning Tool*

✓ a *depth of cut* of 1 mm will reduce diameter by 2 mm
Facing
Flat Surface/Reduce length

- Chuck
- Workpiece
- Cutting speed
- Tool
- Machined Face
- Depth of cut
- Feed
- Feed
- Chuck

Operations on Lathe
Facing ..

- machine end of job \( \Rightarrow \) Flat surface or to Reduce Length of Job
- Turning Tool
- Feed: in direction perpendicular to workpiece axis
  - Length of Tool Travel = radius of workpiece
- Depth of Cut: in direction parallel to workpiece axis
Operations on Lathe

Facing..
Eccentric Turning

4-jaw chuck

Axis of job

Cutting speed

Eccentric peg (to be turned)
Knurling

- Produce rough textured surface
  - For Decorative and/or Functional Purpose
- Knurling Tool

- A Forming Process
- MRR~0
Knurling

Operations on Lathe

Knurled surface

Cutting speed

Feed

Knurling tool

Tool post

Movement for depth
Knurling

It is used to produce regular patterned rough surface. Knurling tool containing a set of hardened steel rollers with teeth cut on them is used. The metal is squeezed against the multiple edges. The speed should be low and plenty of lubricant should be used.
Grooving

- Produces a **Groove** on workpiece
- Shape of tool ⇔ shape of groove
- Carried out using **Grooving Tool** ⇔ **A form tool**
- Also called **Form Turning**
Grooving

Shape produced by form tool

Groove

Form tool

Feed or depth of cut

Grooving tool
Parting

- Cutting workpiece into Two
- Similar to grooving

Parting Tool

- Hogging – tool rides over – at slow feed
- Coolant use
Parting

Parting tool

Feed
Chamfering Operations on Lathe

Chamfering tool

Chamfer

Feed

Chamfering tool
Chamfering

- Beveling sharp machined edges
- Similar to form turning
- Chamfering tool – 45°
- To
  - Avoid Sharp Edges
  - Make Assembly Easier
  - Improve Aesthetics
Taper Turning

Taper:

\[ \tan \alpha = \frac{D_1 - D_2}{2L} \]

Operations on Lathe
**Taper Turning**

Conicity

\[ K = \frac{D_1 - D_2}{L} \]

**Methods**

- Form Tool
- Swiveling Compound Rest
- Taper Turning Attachment
- Simultaneous Longitudinal and Cross Feeds
Taper Turning ..
By Form Tool

- Workpiece
- Taper
- Form tool
- Direction of feed
- Straight cutting edge

\( \alpha \)
Taper Turning
By Compound Rest

Operations on Lathe

- Face plate
- Dog
- Tail stock quill
- Tail stock
- Mandrel
- Tool post & Tool holder
- Cross slide
- Direction of feed
- Compound rest Slide
- Compound rest
- Hand crank
- α
Drilling

**Drill** – cutting tool – held in TS – feed from TS
Process Sequence

How to make job from raw material 45 long x 30 dia.?

Steps:
- Operations
- Sequence
- Tools
- Process
**Process Sequence ..**

**Possible Sequences**

- TURNING - FACING - KNURLING
- TURNING - KNURLING - FACING
- FACING - TURNING - KNURLING
- FACING - KNURLING - TURNING
- KNURLING - FACING - TURNING
- KNURLING - TURNING – FACING

What is an Optimal Sequence?
Machining Time

Turning Time

- Job length $L_j$ mm
- Feed $f$ mm/rev
- Job speed $N$ rpm
- $fN$ mm/min

$$t = \frac{L_j}{fN} \text{ min}$$
Manufacturing Time

Manufacturing Time = Machining Time + Setup Time + Moving Time + Waiting Time
Example

A mild steel rod having 50 mm diameter and 500 mm length is to be turned on a lathe. Determine the machining time to reduce the rod to 45 mm in one pass when cutting speed is 30 m/min and a feed of 0.7 mm/rev is used.
Example

Given data: \( D = 50 \text{ mm}, \ L_j = 500 \text{ mm} \)
\( v = 30 \text{ m/min}, \ f = 0.7 \text{ mm/rev} \)

Substituting the values of \( v \) and \( D \) in

\[
\nu = \frac{\pi D N}{1000} \quad \text{m/min}
\]

calculate the required spindle speed as: \( N = 191 \text{ rpm} \)
Example

Can a machine have a speed of 191 rpm?

Machining time:

\[
t = \frac{L_j}{fN} \text{ min}
\]

\[
t = \frac{500}{0.7 \times 191}
\]

= 3.74 minutes
Example

Determine the angle at which the compound rest would be swiveled for cutting a taper on a workpiece having a length of 150 mm and outside diameter 80 mm. The smallest diameter on the tapered end of the rod should be 50 mm and the required length of the tapered portion is 80 mm.
Example

Given data: $D_1 = 80$ mm, $D_2 = 50$ mm, $L_j = 80$ mm (with usual notations)

$$\tan \alpha = \frac{(80-50)}{2 \times 80}$$

or $\alpha = 10.620$

The compound rest should be swiveled at $10.62^\circ$
Example

A 150 mm long 12 mm diameter stainless steel rod is to be reduced in diameter to 10 mm by turning on a lathe in one pass. The spindle rotates at 500 rpm, and the tool is traveling at an axial speed of 200 mm/min. Calculate the cutting speed, material removal rate and the time required for machining the steel rod.
Example

- Given data: \( L_j = 150 \text{ mm}, \; D_1 = 12 \text{ mm}, \; D_2 = 10 \text{ mm}, \; N = 500 \text{ rpm} \)
- Using Equation (1)
  \[ v = \pi \times 12 \times 500 / 1000 \]
  \[ = 18.85 \text{ m/min.} \]
- depth of cut = \( d = (12 - 10)/2 = 1 \text{ mm} \)
Example

- feed rate = 200 mm/min, we get the feed $f$ in mm/rev by dividing feed rate by spindle rpm. That is
  
  \[ f = \frac{200}{500} = 0.4 \text{ mm/rev} \]

- From Equation (4),
  
  \[ \text{MRR} = 3.142 \times 12 \times 0.4 \times 1 \times 500 = 7538.4 \text{ mm}^3/\text{min} \]

- from Equation (8),
  
  \[ t = \frac{150}{(0.4 \times 500)} = 0.75 \text{ min.} \]
Example

Calculate the time required to machine a workpiece 170 mm long, 60 mm diameter to 165 mm long 50 mm diameter. The workpiece rotates at 440 rpm, feed is 0.3 mm/rev and maximum depth of cut is 2 mm. Assume total approach and overtravel distance as 5 mm for turning operation.
Example

Given data: $L_j = 170\, \text{mm}$, $D_1 = 60\, \text{mm}$, $D_2 = 50\, \text{mm}$, $N = 440\, \text{rpm}$, $f = 0.3\, \text{mm/rev}$, $d = 2\, \text{mm}$,

How to calculate the machining time when there is more than one operation?
Example

**Time for Turning:**

Total length of tool travel = job length + length of approach and overtravel

\[ L = 170 + 5 = 175 \text{ mm} \]

Required depth to be cut = \((60 - 50)/2 = 5 \text{ mm}\)

Since maximum depth of cut is 2 mm, 5 mm cannot be cut in one pass. Therefore, we calculate number of cuts or passes required.

Number of cuts required = \(5/2 = 2.5 \text{ or } 3\) (since cuts cannot be a fraction)

Machining time for one cut = \(L / (f \times N)\)

Total turning time = \( [L / (f \times N)] \times \text{ Number of cuts} \)
Example

- **Time for facing:**
- Now, the diameter of the job is reduced to 50 mm. Recall that in case of facing operations, length of tool travel is equal to half the diameter of the job. That is, \( l = 25 \text{ mm} \). Substituting in equation 8, we get

\[
 t = \frac{25}{0.3 \times 440} \\
 = 0.18 \text{ min.}
\]
Example

- **Total time:**
  - Total time for machining = Time for Turning + Time for Facing
  - $= 3.97 + 0.18$
  - $= 4.15$ min.

- The reader should find out the total machining time if first facing is done.
Example

From a raw material of 100 mm length and 10 mm diameter, a component having length 100 mm and diameter 8 mm is to be produced using a cutting speed of 31.41 m/min and a feed rate of 0.7 mm/revolution. How many times we have to resharpen or regrind, if 1000 work-pieces are to be produced. In the taylor’s expression use constants as $n = 1.2$ and $C = 180$. 

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Example

- Given $D = 10$ mm, $N = 1000$ rpm, $\nu = 31.41$ m/minute
- From Taylor’s tool life expression, we have $\nu T n = C$
- Substituting the values we get,
  - $(31.40)(7)1.2 = 180$
- or $T = 4.28$ min
Example

- Machining time/piece = \( \frac{L}{f \times N} \)
  
  = \( \frac{100}{0.7 \times 1000} \)
  
  = 0.142 minute.

- Machining time for 1000 work-pieces
  
  = \( 1000 \times 0.142 \) = 142.86 min

- Number of resharpenings = \( \frac{142.86}{4.28} \)
  
  = 33.37 or 33 resharpenings
Example

6: While turning a carbon steel cylinder bar of length 3 m and diameter 0.2 m at a feed rate of 0.5 mm/revolution with an HSS tool, one of the two available cutting speeds is to be selected. These two cutting speeds are 100 m/min and 57 m/min. The tool life corresponding to the speed of 100 m/min is known to be 16 minutes with \( n = 0.5 \). The cost of machining time, setup time and unproductive time together is Rs.1/sec. The cost of one tool re-sharpening is Rs.20.
Example

- Given $T_1 = 16$ minute, $v_1 = 100$ m/minute, $v_2 = 57$ m/minute, $D = 200mm$, $l = 300$ mm, $f = 0.5$ mm/rev

- Consider Speed of 100 m/minute

- $N_1 = \frac{(1000 \times v_1)}{\pi \times D} = \frac{(1000 \times 100)}{\pi \times 200} = 159.2$ rpm

- $t_1 = \frac{l}{f \times N_1} = \frac{3000}{0.5 \times 159.2} = 37.7$ minute

- Tool life corresponding to speed of 100 m/minute is 16 minute.

- Number of resharpening required = $37.7 / 16 = 2.35$

Example

- Total cost =
- Machining cost + Cost of resharpening × Number of resharpening
  - = 37.7×60×1 + 20×2
  - = Rs.2302
Example

- Consider Speed of 57 m/minute
- Using Taylor\’s expression $T_2 = T_1 \times (\frac{v_1}{v_2})^2$ with usual notations
  
  $= 16 \times (\frac{100}{57})^2 = 49$ minute
- Repeating the same procedure we get $T_2 = 66$ minute, number of resharpener=1 and total cost = Rs. 3980.
Write the process sequence to be used for manufacturing the component from raw material of 175 mm length and 60 mm diameter.
Example

Threading

20 Dia

20

40 Dia

50

50

50

40
Example

To write the process sequence, first list the operations to be performed. The raw material is having size of 175 mm length and 60 mm diameter. The component shown in Figure 5.23 is having major diameter of 50 mm, step diameter of 40 mm, groove of 20 mm and threading for a length of 50 mm. The total length of job is 160 mm. Hence, the list of operations to be carried out on the job are turning,
Example

A possible sequence for producing the component would be:

- Turning (reducing completely to 50 mm)
- Facing (to reduce the length to 160 mm)
- Step turning (reducing from 50 mm to 40 mm)
- Thread cutting.
- Grooving