IPE-431

MACHINE TOOLS

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Contents

1 Lecture 01: Engine Lathe

Date: 05/06/2023

Booklist

Machine Tools by N. Chernov

Engine Lathe

An engine lathe, also known as a center lathe or a turning lathe, is a type of machine tool used in metalworking processes to shape and cut metal workpieces. A machine tool used for machining of mainly cylindrical workpieces. It is one of the most commonly used lathes in manufacturing and repair shops. Engine lathes are versatile machines capable of performing a wide range of operations, including **facing, centering, turning, threading, parting, drilling, boring, chamfering, knurling.** Both external and internal operations can be performed.

Components of Engine Lathe

The basic components of an engine lathe include a bed, headstock, tailstock, carriage, tool post, and various controls. Let's explore each component in more detail:

- **Bed**: The bed is the main base of the lathe and provides a rigid and stable platform for supporting other components. It is usually made of cast iron and has a flat, horizontal surface on which the workpiece rests. The bed contains guideways or V-ways that guide the movement of the carriage along the length of the lathe.
- **Headstock**: The headstock is located on one end of the bed and houses the main spindle. The spindle is driven by a motor and provides the rotational motion to the workpiece. It also contains a variety of speed and feed controls to adjust the cutting speed and direction.
- **Tailstock**: The tailstock is located on the other end of the bed and is movable along the bed's guideways. It consists of a spindle, which can be extended or retracted, and is used to support the other end of the workpiece. The tailstock often includes a center or a chuck for gripping the workpiece securely.
- **Carriage**: The carriage is mounted on the bed and can move along the length of the lathe using the guideways. It consists of several components, including the saddle, cross-slide, and apron. The carriage carries the cutting tool and controls its movement across the workpiece.
- **Tool Post**: The tool post is located on top of the carriage and holds the cutting tool securely. It allows for quick and easy tool changes, enabling the operator to use different tools for various operations.
- **Controls**: The engine lathe has a variety of controls to regulate the speed, feed, and direction of the cutting tool. These controls can be manual or automated, depending on the lathe's design and features. They enable the operator to adjust the cutting parameters according to the workpiece material and desired machining outcome.

Bed

- Main body of the machine
- All the main components are bolted on it including the headstock, tailstock, carriage etc.
- Usually made of cast iron due to its high compressive strength
- Contains guide ways that guides the carriage and tailstock

Headstock

- Provides the rotational power for the lathe's operations
- Holds the speed gear box, spindle, chuck, gear speed control levers, and feed controllers
- Made up of cast iron
- Usually positioned on the left side of the bed

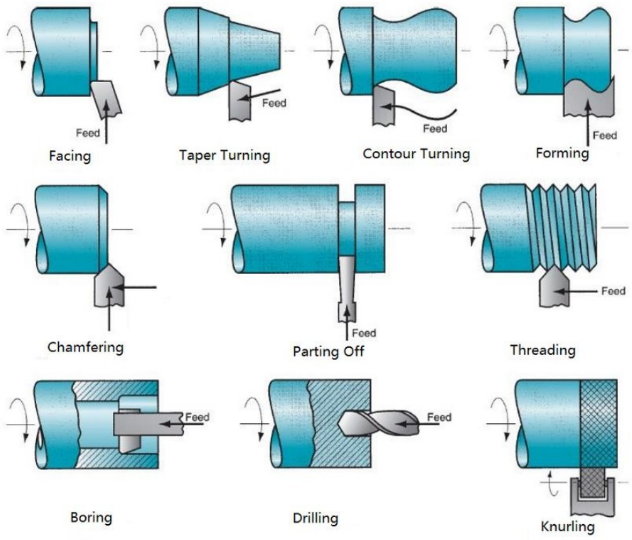


Figure 1: Operations of Engine Lathe

Figure 2: Engine Lathe Machine

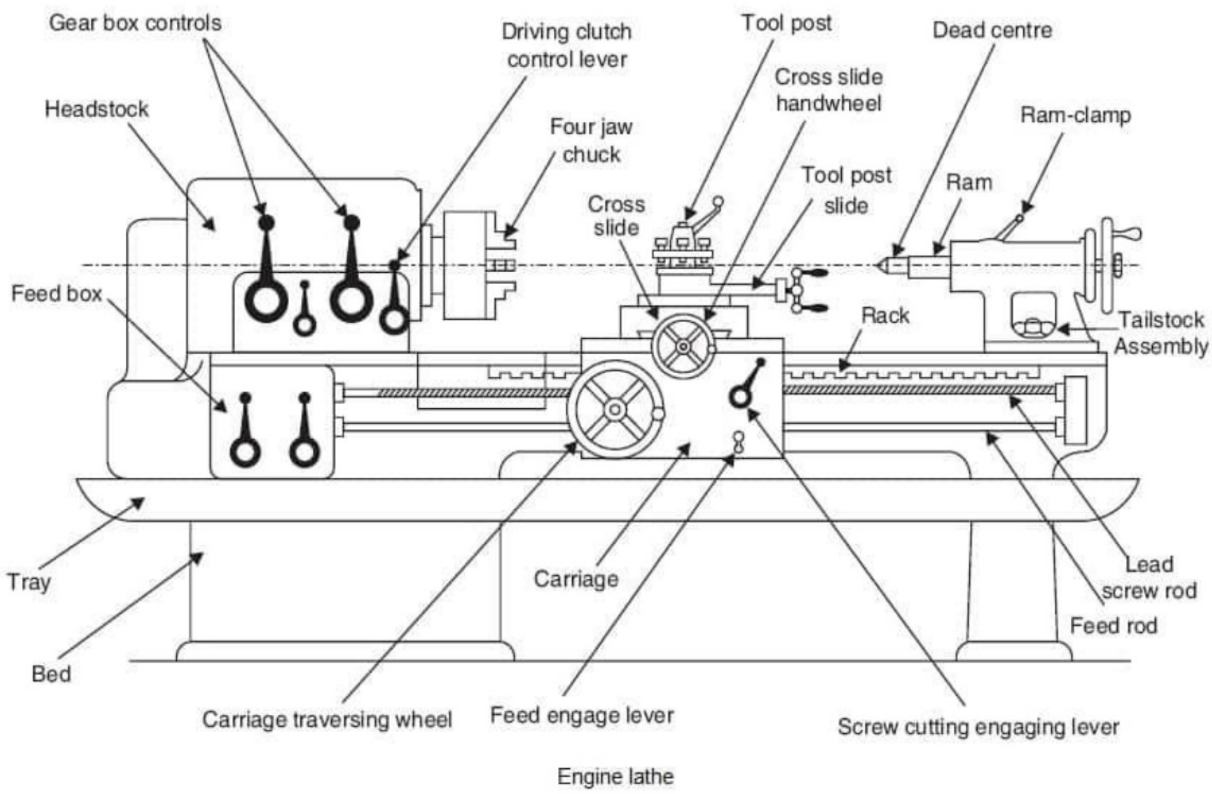


Figure 3: A Schematic Diagram Engine Lathe

Spindle

- A hollow shaft on which the chuck is mounted and rotated
- Made from good quality alloy steel and is heat treated
- Threads, tapers, etc. are made at one end of the spindle to which holding devices can be attached

Chuck

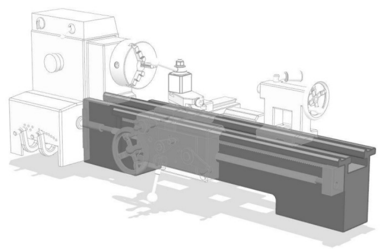
- Used to hold workpiece
- Usually of 2 types – 3 Jaw Self centering Chuck and 4 Jaw Independent Chuck
- Collet chuck is used for some special purpose cases

Tailstock

- Support the loose end of the workpiece or a job while machining
- Hold the cutting tools such as drill chucks, drills, reamers etc.
- Can slide on the bed guideways and can be clamped in any position
- Center can be live or dead; live center rotates with workpiece while dead center does not

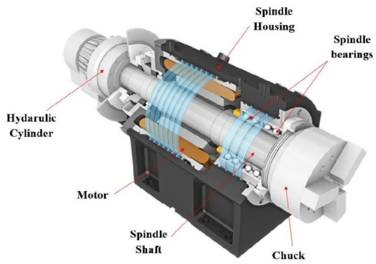
Carriage

- Located between headstock and tailstock
- Move the tool post along the bed
- Impart the feed movement along z axis of lathe machine from lead screw and feed rod
- Consists of 7 main parts – (i) Apron (ii) Saddle (iii) Cross slide (iv) Swivel plate (v) Compound Rest (vi) Top slide (vii) Tool post



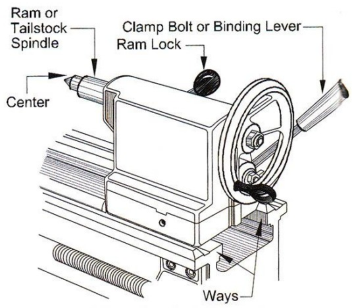
(a) Bed

(b) Headstock

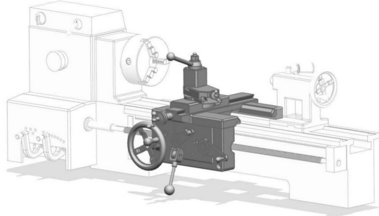


(c) Spindle

(d) Chuck



(e) Tailstock



(f) Carriage

Figure 4: Components of Engine Lathe

Apron

- Located on the front face of the carriage
- Responsible for receiving power from the lead screw or the feed rod
- Transfer the power to move either the carriage itself or the cross slide

Saddle

- A ‘H’ shaped part of the carriage that rides on the bed
- Responsible for supporting cross slide movements

Cross Slide

- Mounted on top surface of saddle
- Allow the movement of a tool post at a right angle to the bed guideways during machining (along x axis of lathe machine)

Swivel Plate

- Mounted on cross slide
- Allow the compound rest thus the tool post to rotate as per requirement
- Graduations of degrees are marked on the swivel plate to facilitate rotation

Compound Rest

- Mounted on swivel plate
- It is a stationary part on which the top slide moves
- Direction of the compound rest is set by the direction of swivel plate

Top Slide

- Mounted on compound rest
- Movement of this part provides the depth of cut of the corresponding lathe operation
- Tool post is mounted on top of it

Tool Post

- Mounted on top slide
- Used to hold the tools at the correct position with rigidity
- Main tool holder is known as square turret which is used for typical lathe cutting tool
- Back tool holder is used for grooving operations

Speed Gear Box

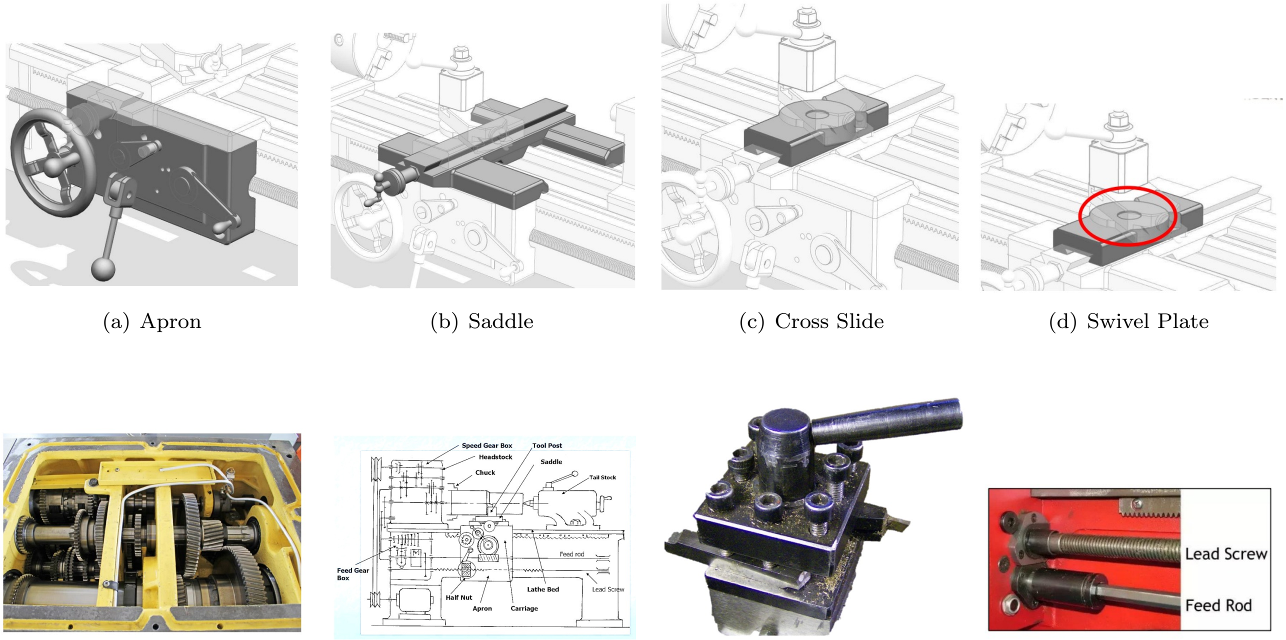
- Gear train positioned inside headstock
- Responsible for precise rotational speed of spindle
- Has a number of available standard rotational speeds
- Takes the power from main motor via belt pulley mechanism

Feed Gear Box

- Gear train positioned below the speed gear box
- Responsible for feed movements of carriage and cross slide
- Receives the power from spindle via change gear box
- Provides motion to lead screw and feed rod

Lead Screw & Feed Rod

- Responsible for transferring feed motion from feed gear box to carriage
- Engage with carriage via apron
- Lead screw is used for high feed rate operations like threading while feed rod is used for low feed rate operations like turning



(a) Apron (b) Saddle (c) Cross Slide (d) Swivel Plate

(e) Speed Gear Box (f) Feed Gear Box (g) Tool Post (h) Lead Screw

Figure 5: Components of Engine Lathe

Axis of Rotation

- Along the spindle → z axis
- up to down → y axis
- front to back → x axis

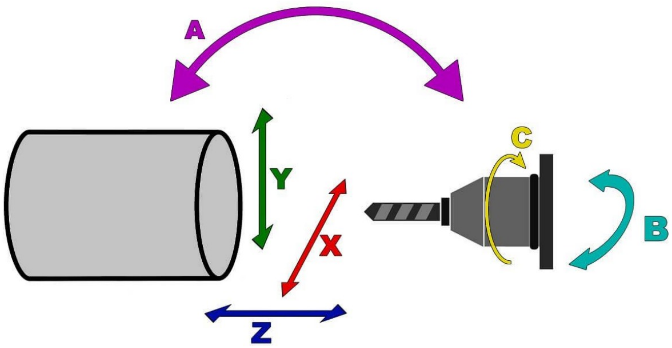


Figure 6: Axis of Rotation in engine lathe

2 Lecture 2: Apron Mechanism & Short Gear Train

Date: 12/06/2023

Apron Mechanism

- Apron mechanism is the mechanism of power transmission from feed rod to apron
- Carriage moves using rack and pinion mechanism
- Feed rod is engaged with the worm gear using key slot mechanism
- Automatic motion can be provided to longitudinal and cross direction using power clutch system

Half Nut Mechanism

- Lead screw is engaged with apron using half nut mechanism unlike key slot mechanism of feed rod
- The half nut is mounted on the back side of the apron
- Half nut can be engaged/disengaged using a lever

Main Dimension of Engine Lathe

1. Height of centers over bed
2. Maximum diameter of workpiece accommodated over the bed (most important)
3. Maximum diameter of workpiece accommodated over the carriage
4. Maximum diameter of workpiece accommodated over the gap
5. Maximum distance between centers
6. Length of the bed
7. No. of speeds and feeds

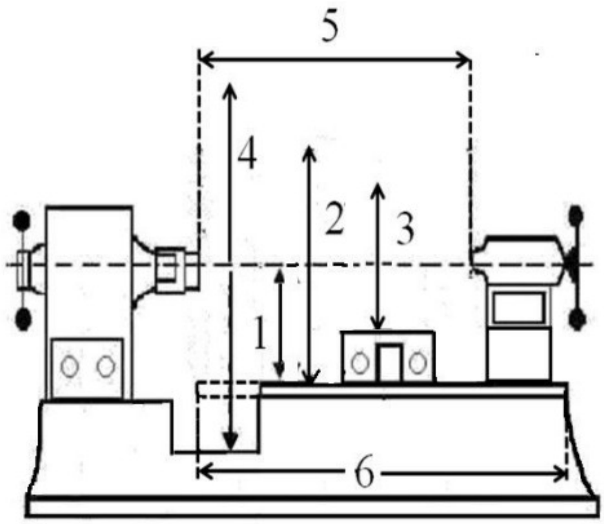
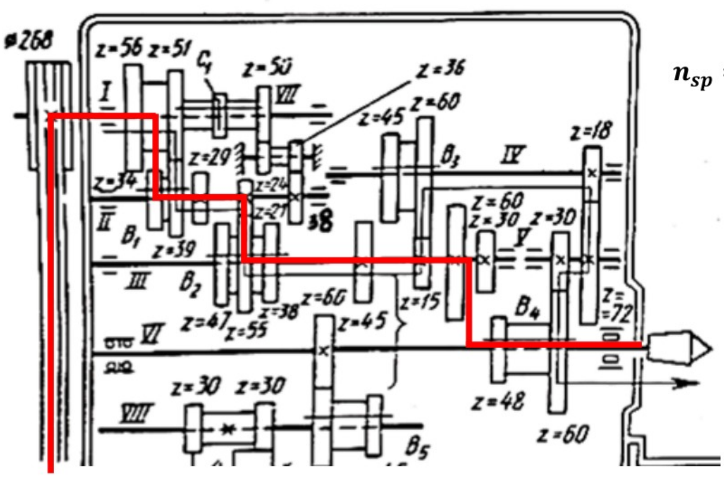


Figure 7: Main Dimension of engine lathe

Short Gear Train



$$n_{sp} = 1460 \times \frac{148}{268} \times \overset{\text{Belt Slippage Factor}}{0.985} \times \boxed{\begin{array}{c} \frac{51}{39} \\ \frac{56}{34} \end{array}} \times \boxed{\begin{array}{c} \frac{21}{55} \\ \frac{38}{38} \\ \frac{29}{47} \end{array}} \times \boxed{\begin{array}{c} \frac{30}{60} \\ \frac{60}{48} \end{array}}$$

12 High Speeds (Forward)

Figure 8: Forward Rotation (without back gear) → C_1 Disengaged

What is Back gear? why it is used?

In an engine lathe, the back gear is a mechanism located in the headstock. The back gear is used in an engine lathe to provide lower spindle speeds with increased torque. This allows the lathe to handle heavy-duty cutting tasks, work with large workpieces, and improve control and precision during machining operations.

long gear train or short gear train, where back gear is used?

The back gear is typically associated with a long gear train in an engine lathe. A long gear train refers to a gear arrangement where multiple gears are used to transmit power from the motor to the spindle, resulting in a larger gear reduction. This allows for slower spindle speeds and increased torque.

In the case of the back gear mechanism, it often involves an intermediate gear and a larger gear that work together to create the gear reduction. By engaging the back gear, power is transmitted through this longer gear train, resulting in lower rotational speeds.

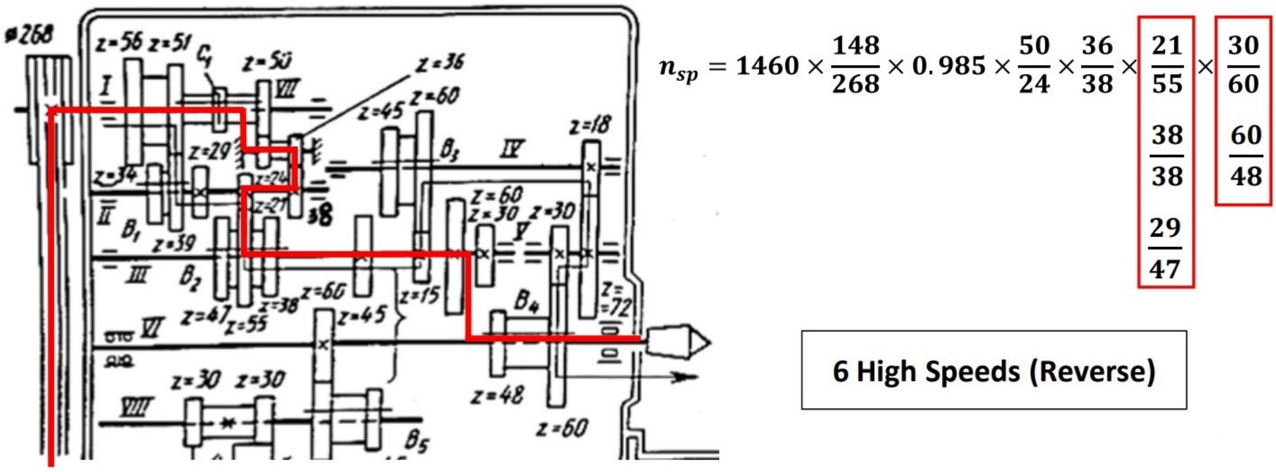


Figure 9: Forward Rotation (with back gear) → C_1 Engaged

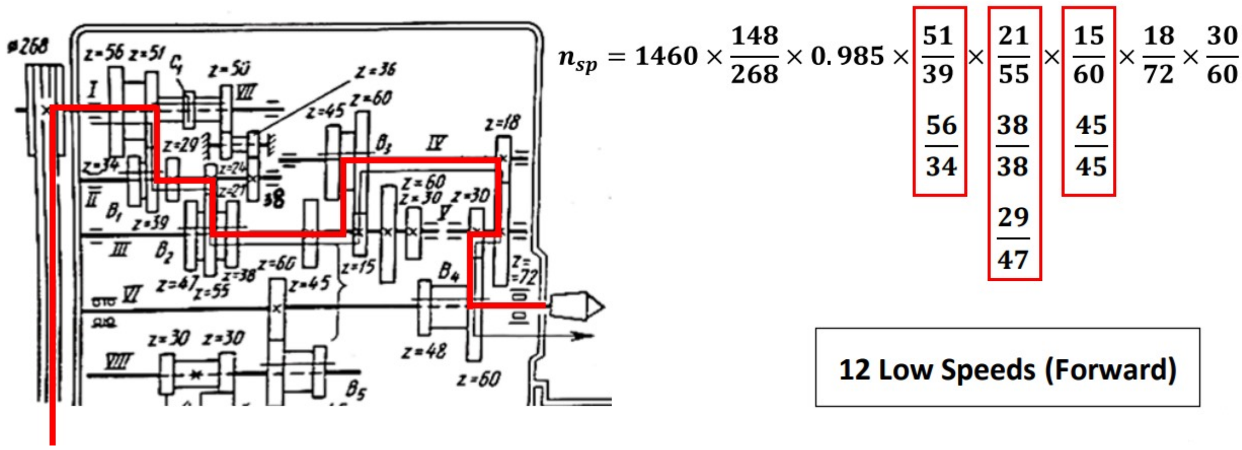


Figure 10: Forward Rotation (without back gear) → C_1 disengaged

It's worth noting that the terminology "long gear train" does not refer to the physical length of the gears, but rather the number of gears involved in the gear reduction mechanism.

Difference between Forward Rotation and Reverse Rotation:

- Forward rotation: In the forward rotation mode, the spindle of the lathe rotates in the same direction as the workpiece is being machined. This is the most common mode used for most turning operations. When the lathe is set to forward rotation, the cutting tool moves from the outer diameter of the workpiece towards the center.

- Reverse rotation: In the reverse rotation mode, the spindle rotates in the opposite direction to the workpiece rotation. Reverse rotation is typically used for specific operations such as thread cutting or left-hand cutting. When the lathe is set to reverse rotation, the cutting tool moves from the center of the workpiece towards the outer diameter.

Summery

- Total Count of Forward Speeds: 24 (12 High and 12 Low)
- Total Distinct Count of Forward Speeds: 22 (500 rpm and 630 rpm repeats)
- Maximum Forward Speed:1635 rpm
- Minimum Forward Speed: 12.5 rpm

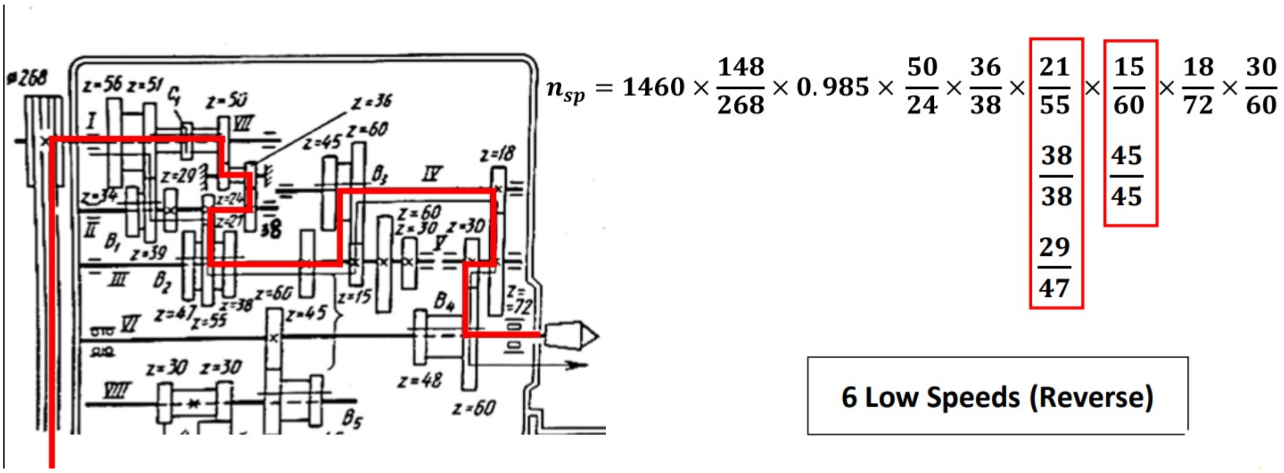


Figure 11: Reverse Rotation (with back gear) $\rightarrow C_1$ Engaged

Feed Mechanism

Steps

- Either a constant transmission or pitch increasing gearing/coarse feed unit
- A reversing mechanism
- A change gear train
- A feed gear box
- An apron transmission

Difference between Constant Transmission & Pitch increasing Gearing

Constant transmission: In this feed mechanism, the ratio between the spindle speed and the feed rate stays the same no matter how you adjust the feed lever. It provides precise and consistent feed rates during turning operations. It's commonly used in modern lathes with variable speed control.

Pitch increasing gearing (coarse feed unit): With this feed mechanism, you can select different feed rates by adjusting the feed lever or engaging different gears. The feed rates increase in steps, getting faster with each step. It's useful for quickly removing material during roughing or rapid traverse operations when you don't need fine control.

Reversing Mechanism

A reversing mechanism in an engine lathe allows the operator to change the direction of spindle rotation. It's useful for operations like thread cutting and enables the creation of both right-hand and left-hand threads.

Change Gear Train

A change gear train in an engine lathe is a set of interchangeable gears that control the spindle's rotational speed. It allows the operator to adjust the gear ratios for different cutting operations and achieve various spindle speeds.

Feed Gear Box

A feed gear box in an engine lathe controls the feed rates of the cutting tool. It consists of gears and mechanisms that adjust the tool's advancement along the workpiece, allowing for different cutting speeds and depths. It provides control over feed rates and threading capabilities during machining operations.

Points

- C_3 clutch has special significance here. If it is disengaged, shaft won't get motion from the gear. They well get detached.
- C_5 Engaged $\rightarrow$ motion to the Lead screw
- C_5 Disengaged $\rightarrow$ motion to the feed rod
- By 1 rotation of spindle, feed = pitch

Apron Mechanism

refers to the component on the carriage that controls the feed rates and movements of the cutting tool. It includes levers, dials, and controls for selecting feed rates and directions, allowing precise control over tool movements during machining operations.

Kinematic Equation of Feed

The kinematic equation of feed is given by:

$$1\,\text{rev.sp} \times i_{\text{const}} \times i_{\text{rev,m}} \times i_{\text{cng}} \times i_{\text{f.g.b.}} \times i_{\text{i.p.}} \times \pi m z_p = S\,\text{mm/rev}$$

Here, $1rev.sp$ = 1 revolution of spindle
m = module of the pinion gear
$\pi m z_p$ = Circumference of the pinion gear along pitch circle
z_p = no. of teeth of the pinion gear
S = feed rate
i_{const} = motion by constant transmission
$i_{rev,m}$ = motion by reverse mechanism
i_{cng} = motion by change gear box
$i_{f.g.b}$ = motion by feed gear box
i_{ap} = motion by apron mechanism

✓**Follow Slide for better understanding**

3 Lecture 03: Gear Train

Date: 03/07/2023

Setup of Change Gears for Non-standard Pitch Thread

$$\frac{K}{L} \times \frac{M}{N} = \frac{5}{8} \times \frac{P_{\text{to be cut}}}{P_{\text{on plate (standard)}}}$$

- $P_{\text{to be cut}}$ is the non-standard pitch which is to be imparted in the workpiece
- Find the nearest pitch on the chart provided with the lathe machine and set that as the $P_{\text{on plate (standard)}}$
- Try to use the default gears as much as possible (K = 40, 60; L = 86; M = 86; N = 64)

Example

Select change gears K, L, M and N for cutting a metric thread with pitch P = 18 mm.

Solution

Here, $P_{\text{to be cut}} = 18$ mm
$P_{\text{on plate (standard)}}$ = nearest pitch on the chart provided with lathe machine = 16 mm or 20 mm
Now, Have to adjust K, L, M, N to maintain the ratio mentioned above.

Cutting Multiple Start Threads

Lead (L) = Distance between 2 consecutive similar points of a particular thread
And Pitch,

$$P = \frac{\text{Lead (L)}}{\text{No. of Start (Z)}}$$

There are 3 methods for multiple start threads.

Method - I

1. Cut the first thread as if the pitch is equal to lead.
2. After cutting the first thread, move back the carriage to the initial position (exactly the point of start of the already cut thread)
3. Rotate $\frac{1}{Z}$ portion of the circumference of the workpiece if the no. of start is Z. For example rotate $\frac{1}{2}$ of the circumference of the workpiece if the no. of start is 2.
4. In the studied lathe machine, a ring is fixed on the headstock housing marking revolutions in respect to workpiece circumference i.e.,
$$\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}, \frac{1}{10}, \frac{1}{12}, \frac{1}{15}, \frac{1}{20}, \frac{1}{30}, \frac{1}{60}$$
to simplify the rotation process

Method - II

After cutting the first thread, move $\frac{L}{Z} = P$ mm in the longitudinal direction from the start point of the first thread

Method - III

Threads are cut using multiple tool holder where the tools are positioned at P mm spacing

Points

- For better precision, follow method - I
- For minimum time, follow method - III
- If multiple tool holders are not available or cutting down a portion of workpiece is not an issue, then choose method - II

Setup for Taper Turning

There are 5 ways to setup lathe machine for taper turning operation.
1. Form tools for taper turning
2. Setting over the tailstock
3. Swiveling the compound rest
4. Providing simultaneous longitudinal and cross feed
5. Using taper turning attachment

Form tools for taper turning

- Easy method
- Hard to maintain precision. As maintaining 90° angle is so challenging
- Taller workpiece can not tapered by this process
- Here, the shape of cutting tool is tapered, that's why the workpiece also becomes tapered.

Setting over the tailstock

- Suitable for long lengthed workpiece
- Suitable for a lower taper angle
- $$a = \frac{d_1 - d_2}{2} = l \tan \alpha$$
  $$\tan \alpha = \frac{d_1 - d_2}{2l}$$
- $$h = L \sin \alpha$$
  as α is very small, then,
  $$h \approx L \tan \alpha = \frac{L(d_1 - d_2)}{2l}$$

Swiveling the Compound Rest

- Feed is provided using the top slides
- Used in short internal and outer tapers
- Swivel plate angle = half of taper angle

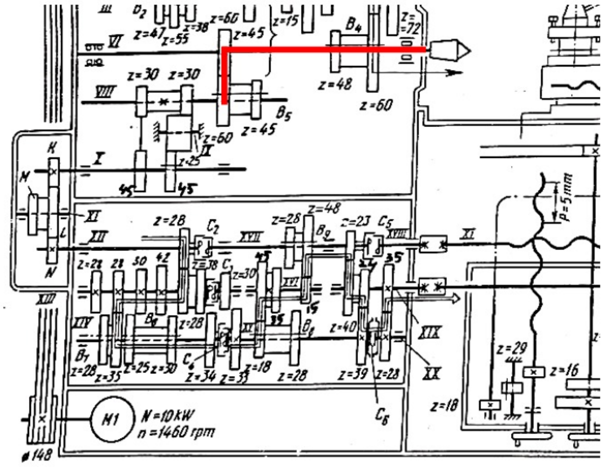
Providing simultaneous Longitudinal and cross feed

- Longitudinal and cross, both feed are given at the same time.
- Vector resultant, $\overline{S} = \overline{S_l} + \overline{S_c}$, where S_l = longitudinal feed and S_c = cross feed.
- Setting angle of swivel plate,
$$\beta = \alpha + \sin^{-1}\left(\frac{S_l}{S_c}\sin\alpha\right)$$
where, α is taper angle
- $$S_l = \frac{sin\,(\beta - \alpha)}{\sin\beta} \times S$$

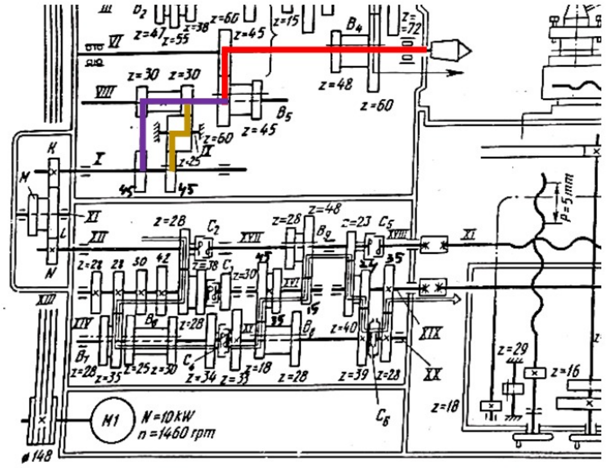
Using Taper Turning Attachment

- The most universal and convenient way of generating taper surface.

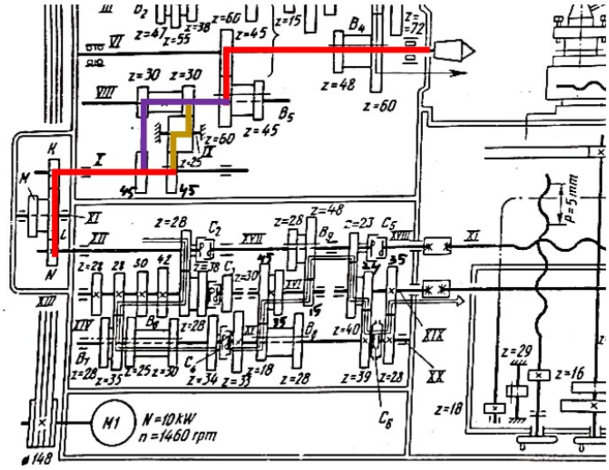
✓ Follow slide no. #1 : Case study of Engine Lathe



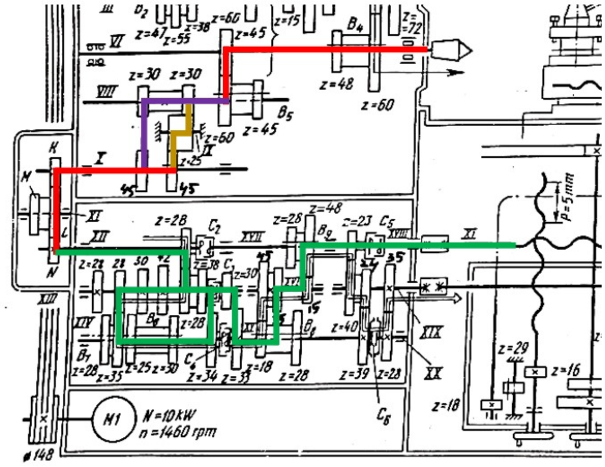
(a) Constant Transmission



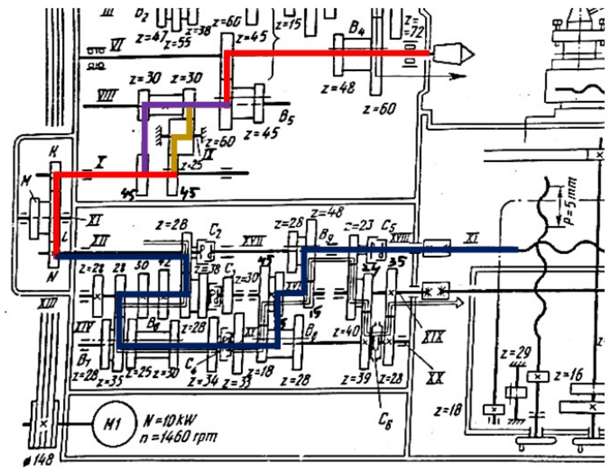
(b) Reversing Mechanism



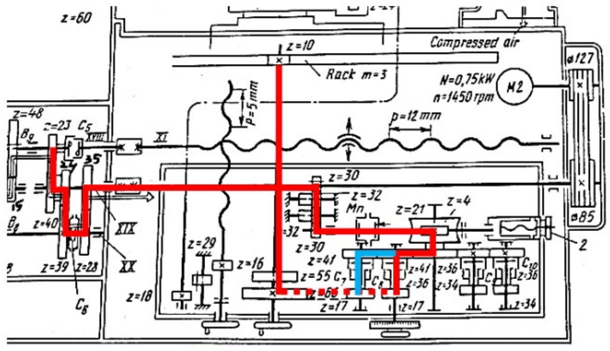
(c) Change Gear Box



(d) Feed Gear box (Clutches C2, C3 and C4 disengaged, C5 engaged)



(e) Feed Gear Box (Clutches C2 disengaged, C3, C4 and C5 engaged



(f) Apron Mechanism (Clutches C6 engaged

Figure 12: Steps for Feed Mechanism