MS101: Makerspace Laboratory

Topic: Manufacturing Techniques Part 2: Machining and Material removal

Instructor: **Parag Tandaiya**

Associate Professor

Department of Mechanical Engineering

Room S18 (2nd Floor, ME)

Email: parag.ut@iitb.ac.in

Ref.:
[1] Groover, Fundamentals of Manufacturing
[2] Kalpakijan and Schmidt, Manufacturing Technology

Slides adapted from Profs. Rakesh G Mote and K. P. Karunakaran

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

2

Typical Subtractive Manufacturing Process

Raw-material **+** Material Removal **=** Finished product

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

3

Common machine tools for subtractive manufacturing
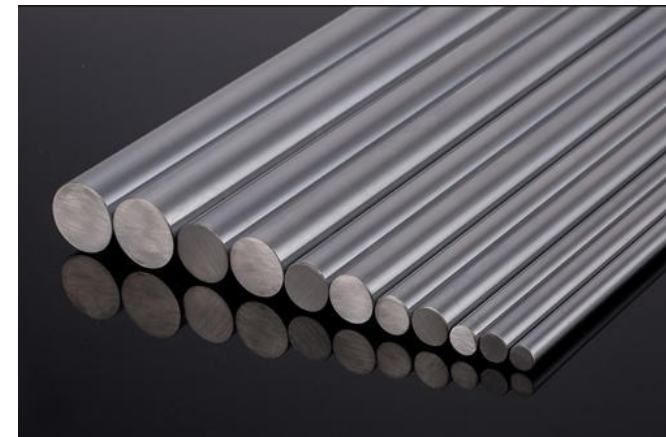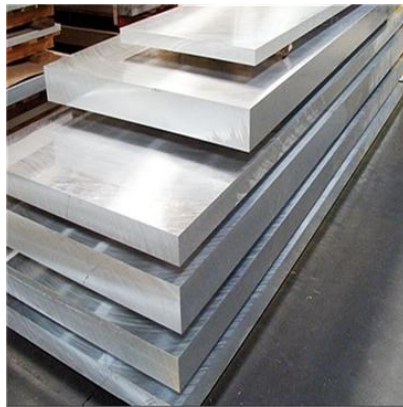
Traditional Machine Tools

- Lathe
- Milling
- Shaper
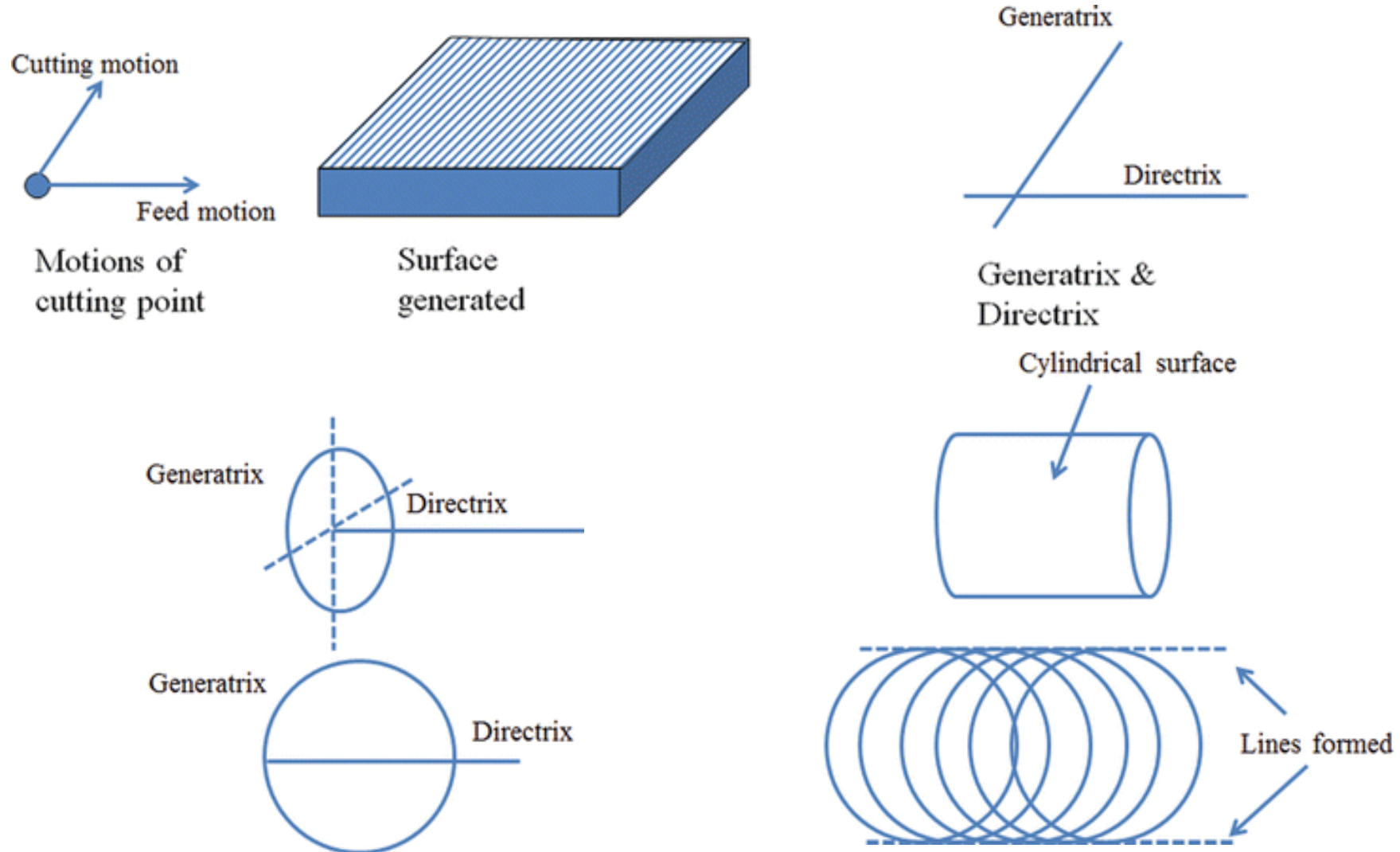- Slotting
- Drilling

Modern Machine Tools

- CNC Machining Center

Non-Traditional Machine Tools

- Electrical Discharge Machining (EDM)
- Laser Cutting

Geometry Formation/realization

1. Cutting Speed
2. Feed
3. Depth of cut

Cutting motion

Feed motion

Motions of cutting point

Surface generated

Generatrix

Directrix

Generatrix & Directrix

Cylindrical surface

Generatrix
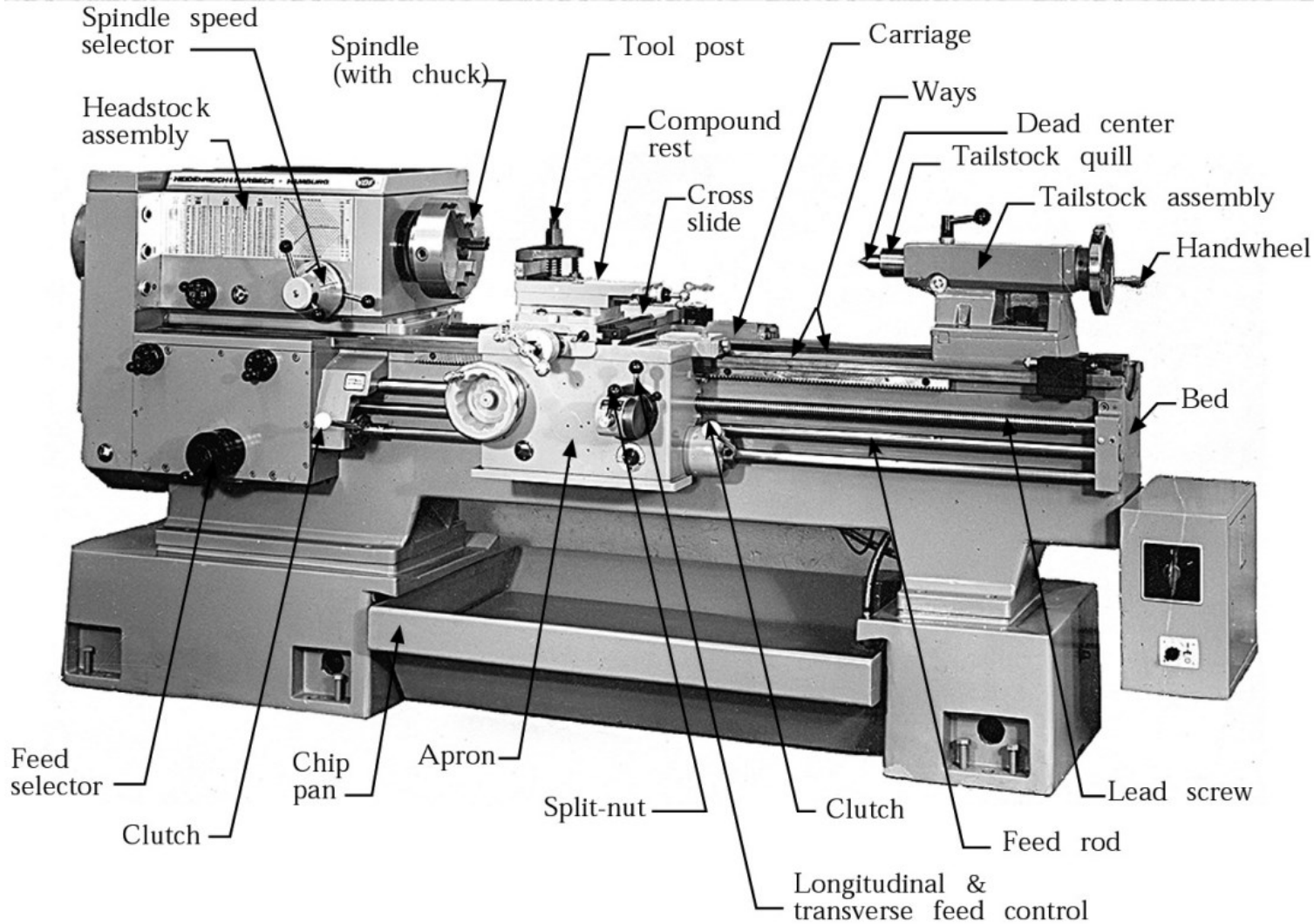
Directrix

Generatrix

Directrix

Lines formed

Traditional Machine Tools: Lathe

Center Lathe

For manufacturing primarily rotational components

Traditional Machine Tools: Lathe
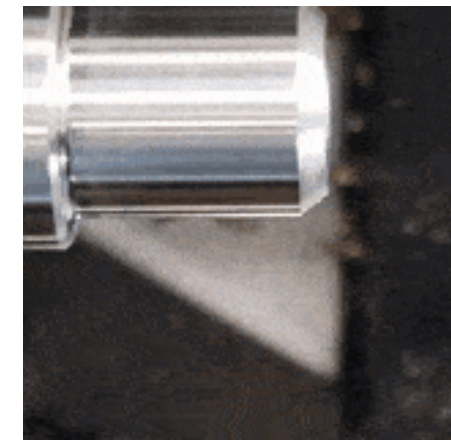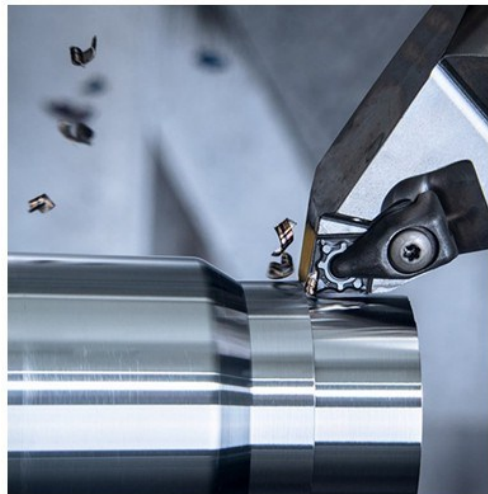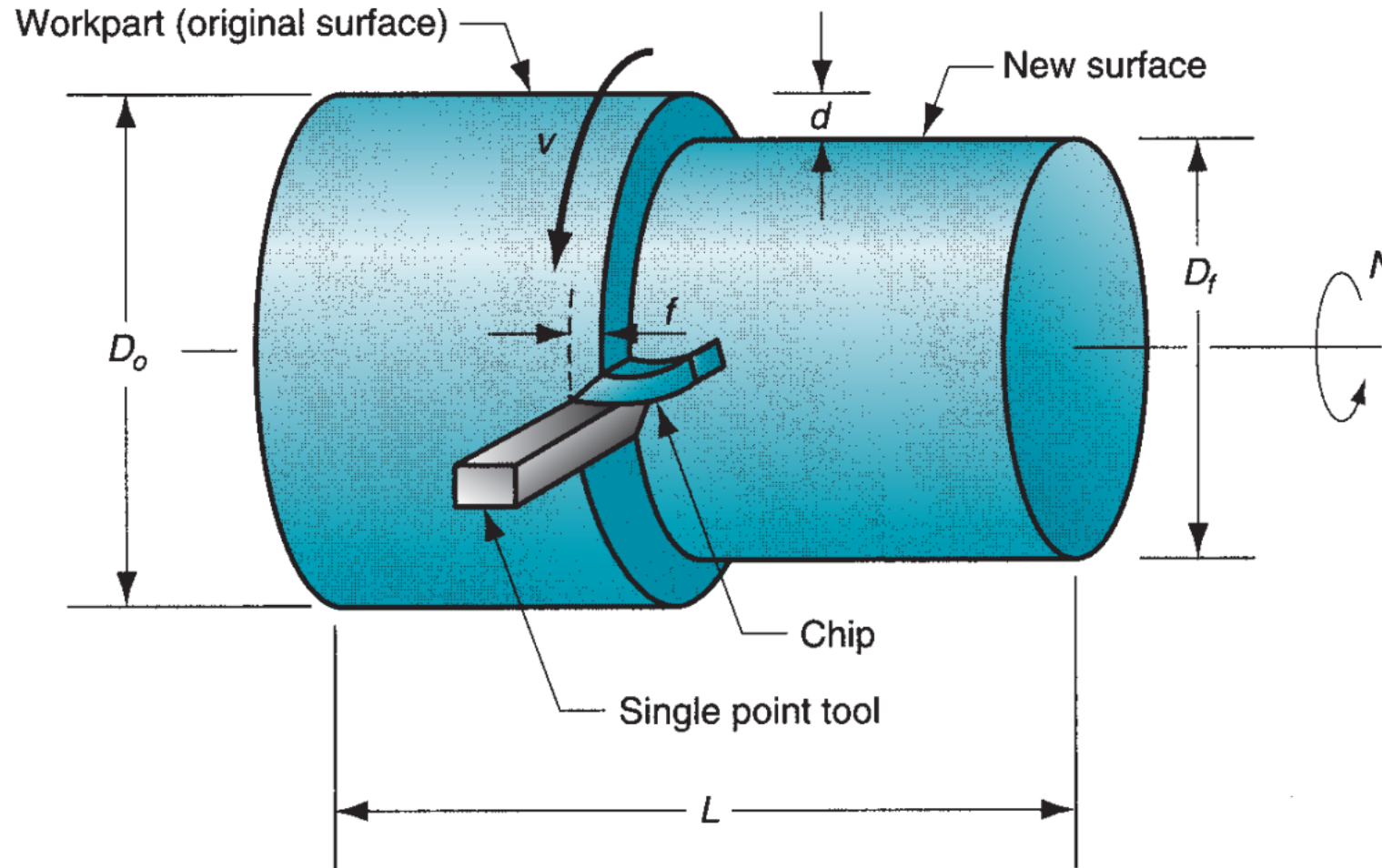
Single Point Cutting Tool

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

7

Spindle speed   : N (rpm)
Cutting velocity   : V (m/s)
Feed   : f (mm/rev)
Feed rate   : f_r (mm/s)
Depth of Cut   : d (mm)

$$V = \frac{\pi D N}{60} \text{ and } f_r = fN$$

Material Removal Rate (MRR, mm³/s)
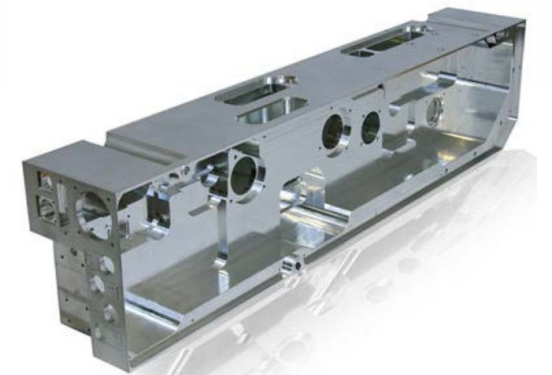
$$\text{MRR} = Vfd$$

Traditional Machine Tools: Milling
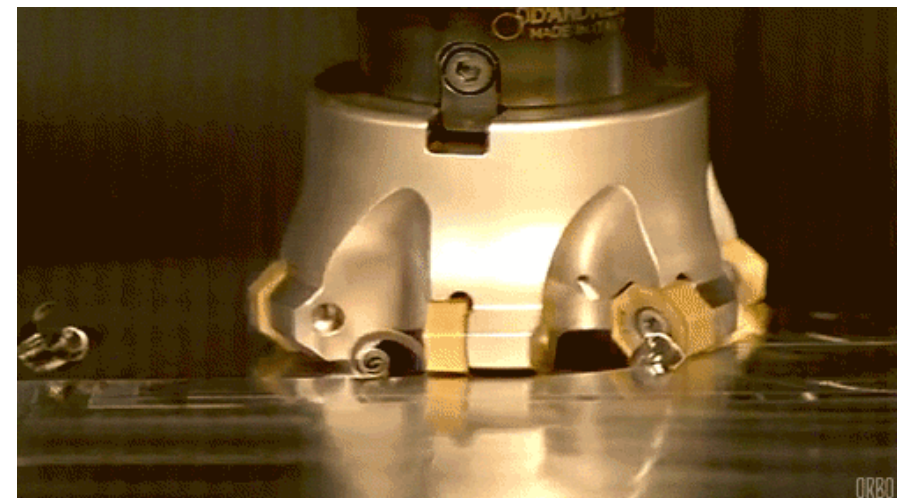
Horizontal Milling Machine

Vertical Milling Machine

Milling machined parts

Variety of geometries, complex shapes

Traditional Machine Tools: Milling

Milling cutters: Multi-point cutting tools

FACE MILLING CUTTER

SLITTING SAW
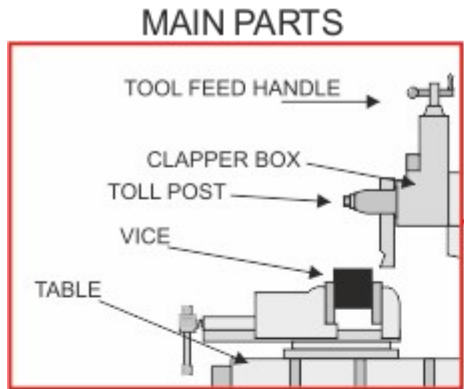
SINGLE ANGLE

EQUAL ANGLE

End Mill Cutter

Roughing End Mill

Thread Mill Cutter

Woodruff Cutter

Ball Cutter

CONCAVE CUTTERS

SINGLE CORNER ROUNDING CUTTER

CONVEX CUTTER

Concave Milling Cutter

Fly Cutter

Side Milling Cutter

Face Milling Cutter

CYLINDRICAL CUTTER

SLAB CUTTERS

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

10

Traditional Machine Tools: Milling

Machining on a Milling Machine

https://youtu.be/AxHexqN0Hr0?si=0-XNX6s4T4gixrDp

Traditional Machine Tools: Shaping Machine

MAIN PARTS

- TOOL FEED HANDLE
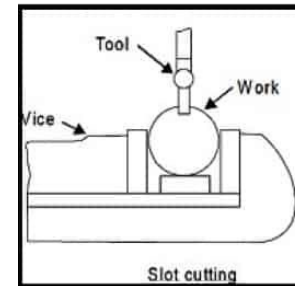- CLAPPER BOX
- TOLL POST
- VICE
- TABLE

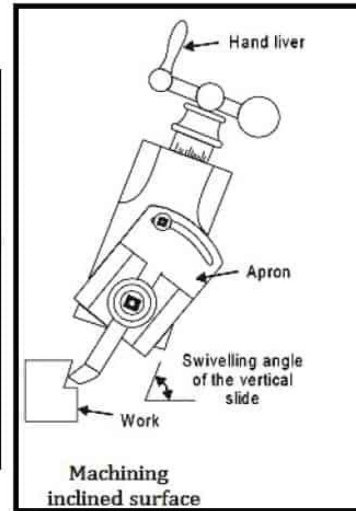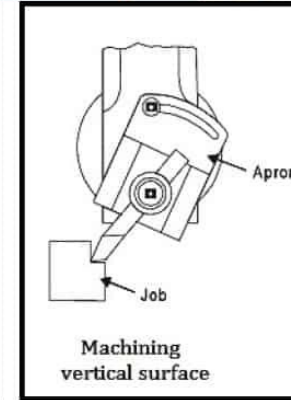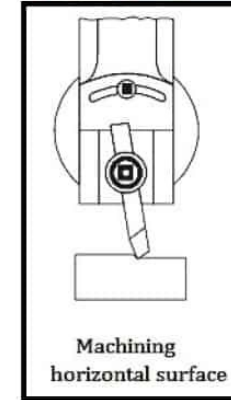**SELECTION OF SHAPING MACHINE CUTTING TOOLS**

HEAVY DUTY MACHINE VICE
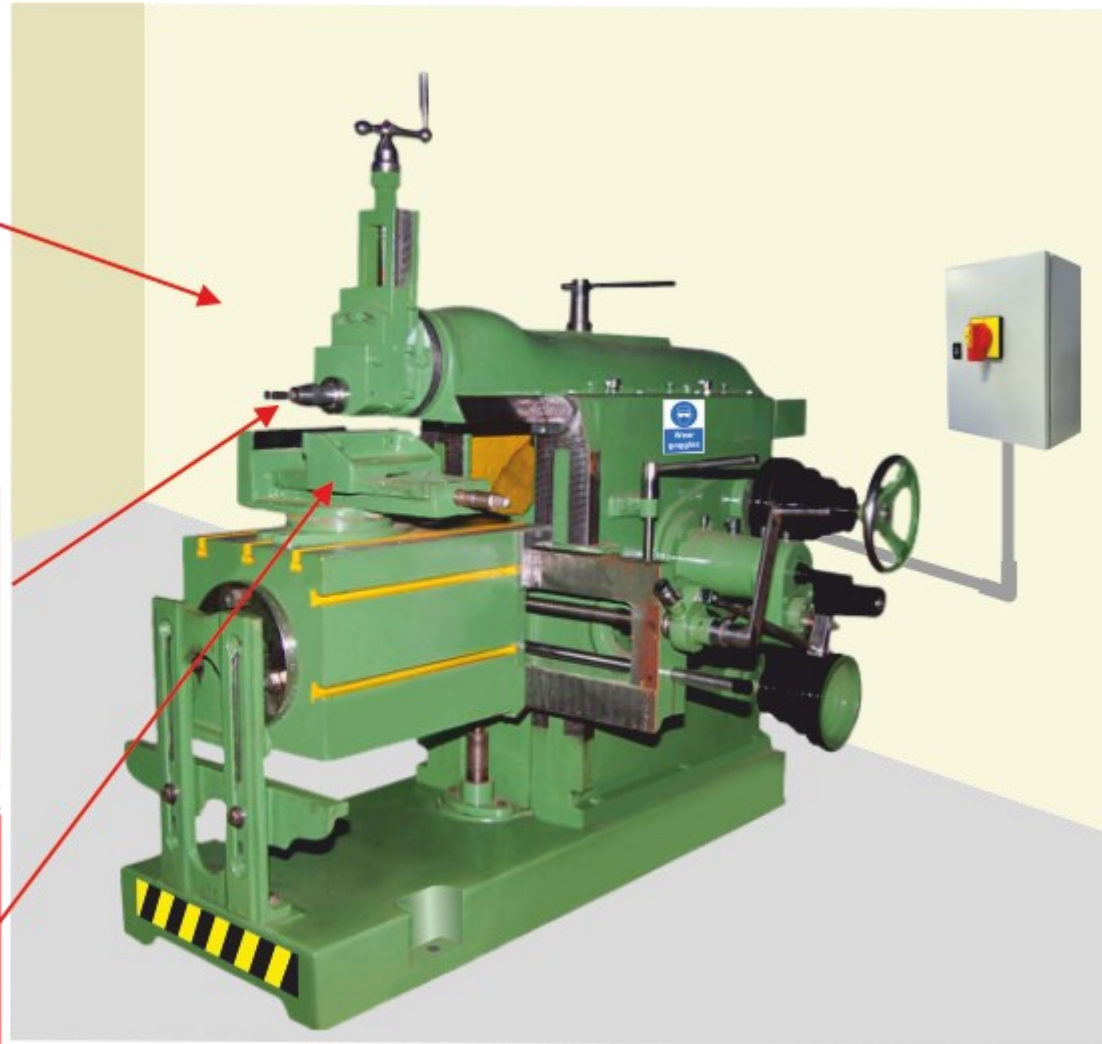
Products: Flat surfaces, grooves, slots,

Shaping Machine Operation

Machining horizontal surface

Hand liver — Apron

Machining vertical surface

Machining inclined surface — Apron, Swivelling angle of the vertical slide, Work

Slot cutting — Tool, Work, Vice

Keyway cutting — Job, Vice, Tool bit

Irregular machining

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB
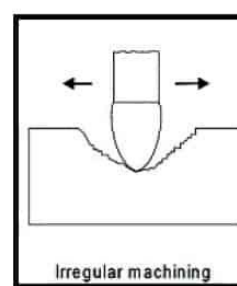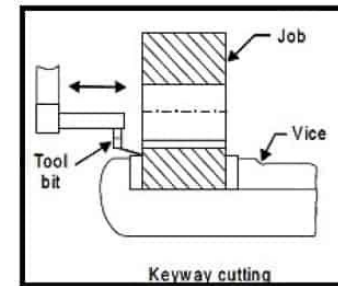
Traditional Machine Tools: Slotting Machine

Labels: Ram, Tool Head, Table, Carriage, Cross Slide, Saddle, Column, Base
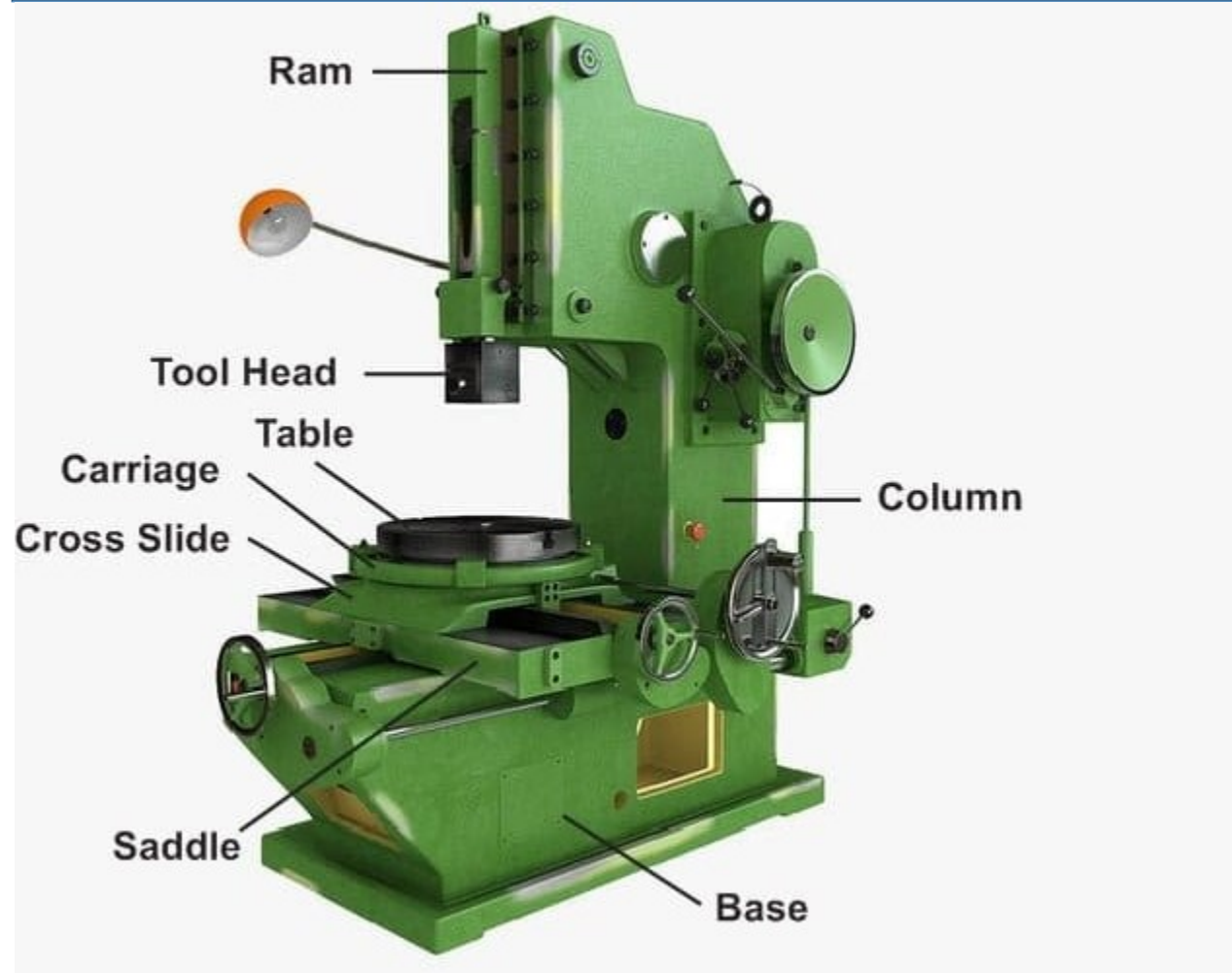
Slotting machine Tools

Products: Flat surfaces, grooves, keyways, Slots, internal splines

https://youtube.com/shorts/pv7aN2v0PWQ?si=dxyzYeVUXxpgxDIg   https://youtube.com/shorts/kJyG_vR0Nk8?si=MYfK2oCihn8rh8uS

Traditional Machine Tools: Drilling Machine

➤ **For machining holes, enlarging holes, and threading holes**

Radial Drilling Machine
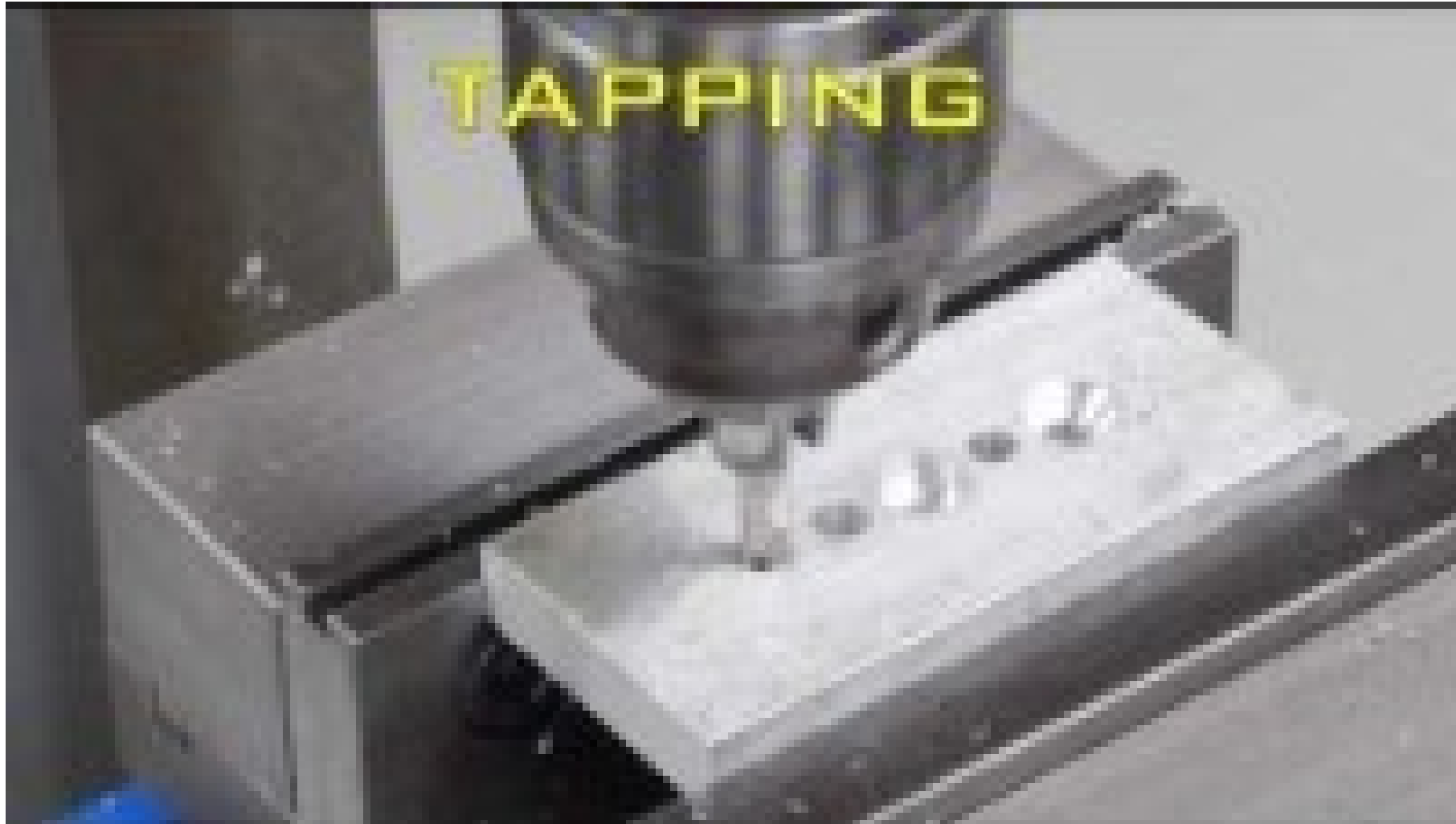
➤ Cutting tools: **drill bits**

TYPES OF DRILL BITS

FLAT DRILL	STRAIGHT-FLUTED DRILL	CENTRE DRILL	TWIST DRILL	AUGER BIT	COUNTER-SINK BIT
COUNTER-BORE BIT	INSTALLER BIT	FORSTNER BIT	MASONRY DRILL	STEP DRILL	TILE BIT

Drilling, Reaming and Tapping Processes on a Drilling machine

https://youtu.be/f5HfRpeT7Fg?si=sWg1Ji9RaLwQkkKP
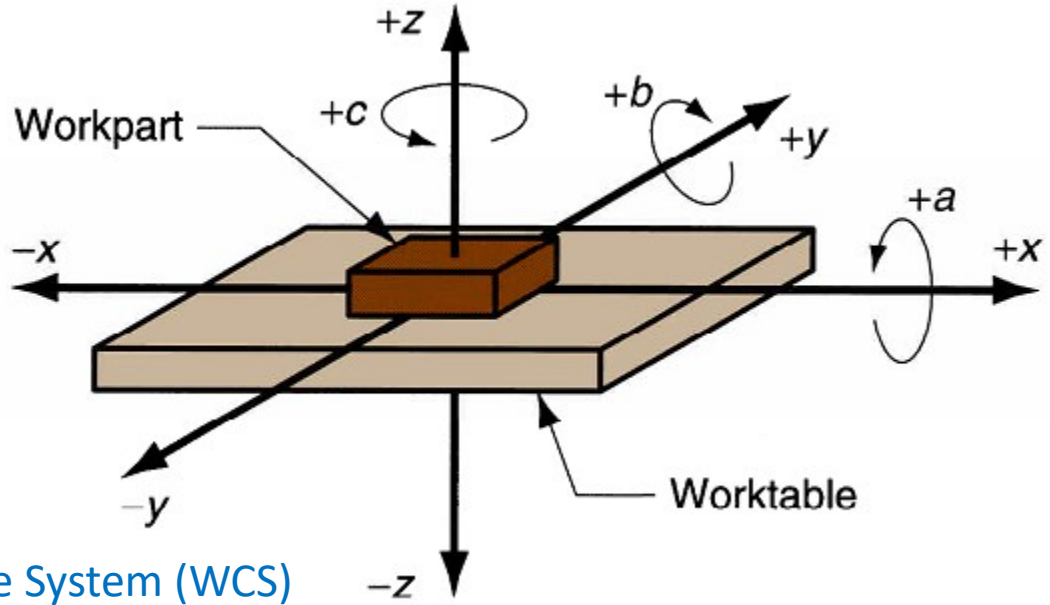
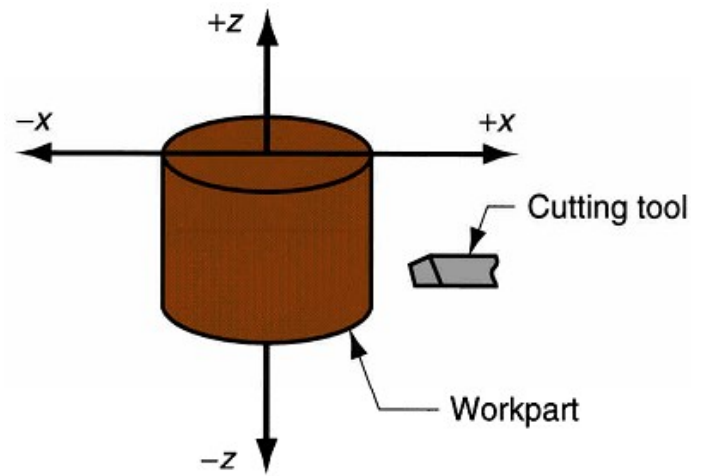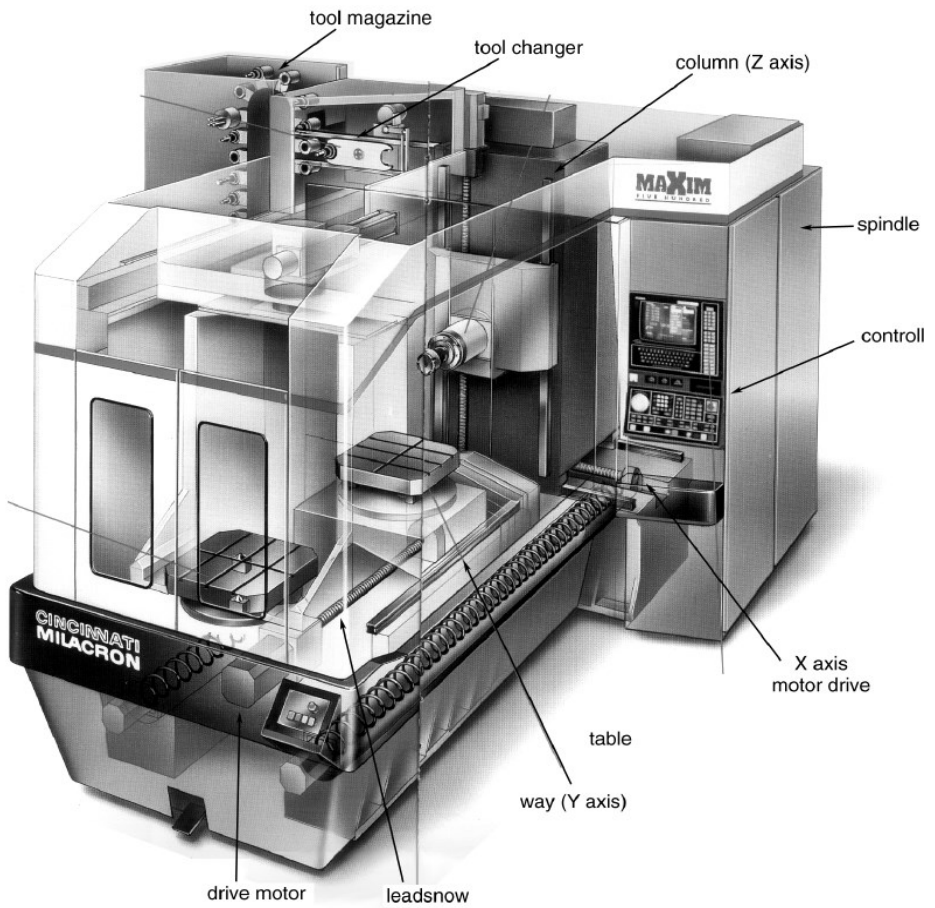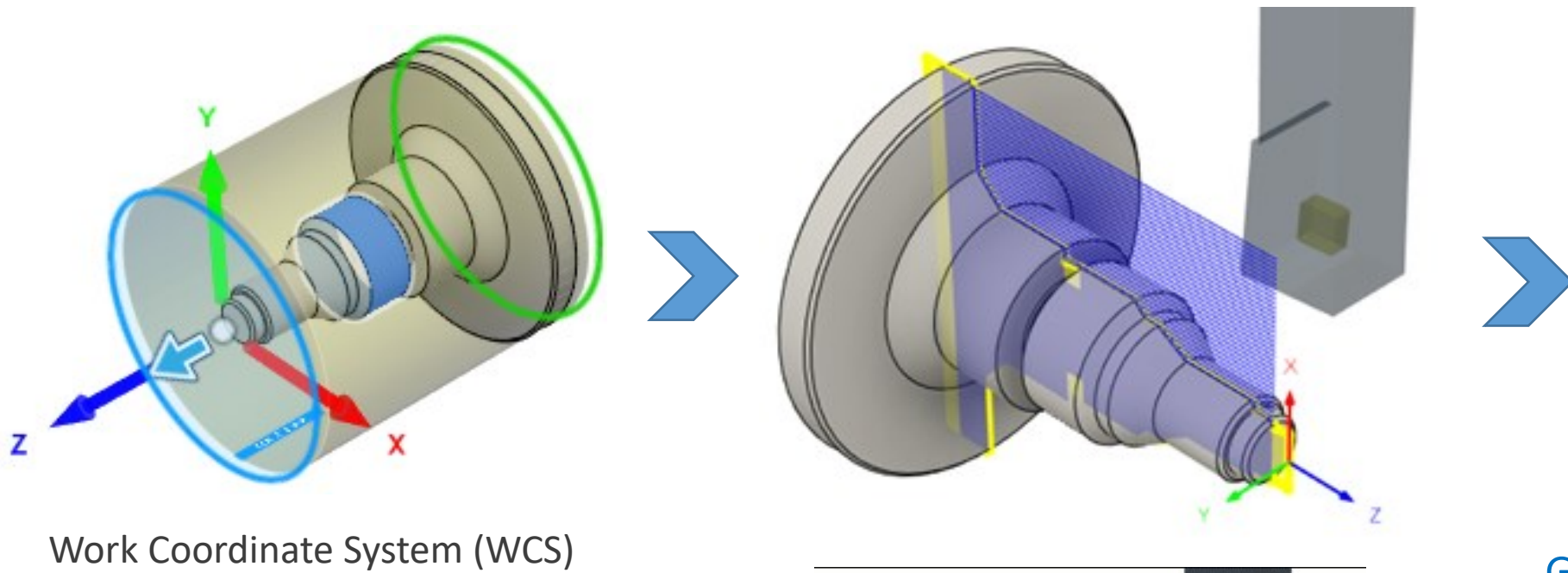Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

17

Modern Machine Tools: Manual Control to CNC Control (CAD/CAM): CNC Machining Center

Work Coordinate System (WCS)

Manual Control to CNC Control (CAD/CAM)

Work Coordinate System (WCS)
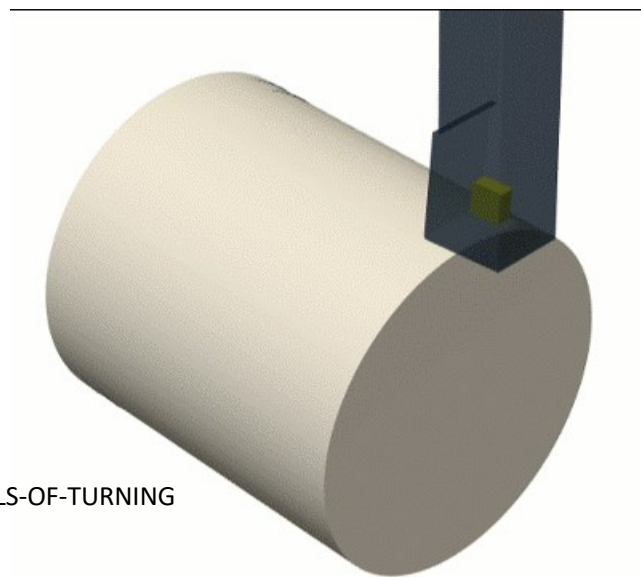
Part Program

```
1    %
2    O1001
3    N10 G98 G18
4    N11 G21
5    N12 G50 S6000
6    N13 M31
7    N14 G53 G0 X0.
8    N15 G53 G0 Z0.
9
10   (Face2)
11   N16 T101
```

G-Codes
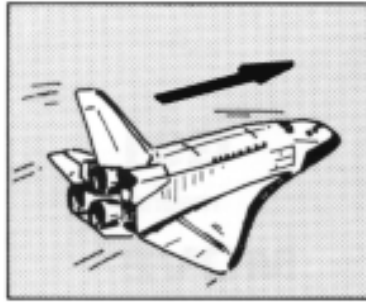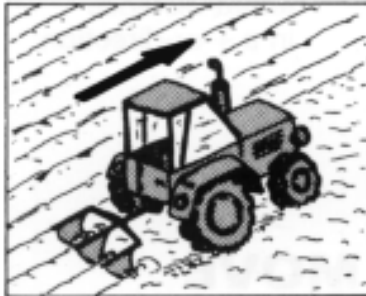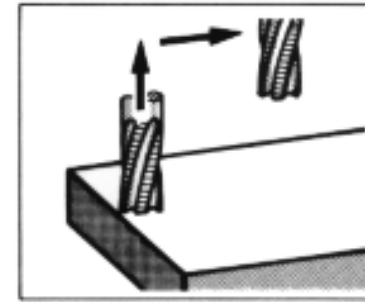Preparatory codes associated with axes motions etc.

M-Codes
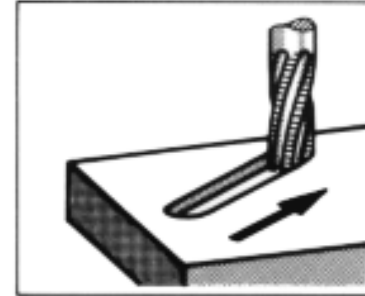Miscellaneous codes for auxiliary actions like spindle, coolant on/off, tool change, etc.

https://help.autodesk.com/view/fusion360/ENU/courses/AP-C-FUNDAMENTALS-OF-TURNING
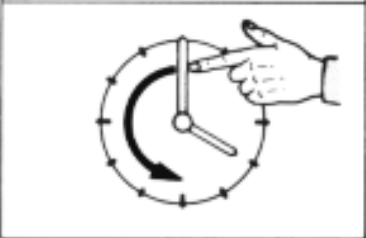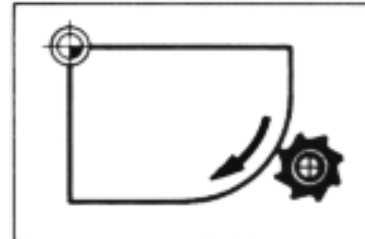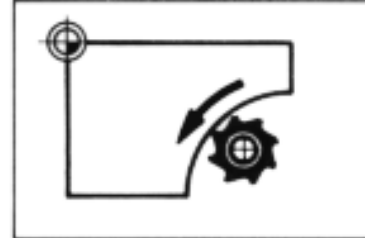
TB

G00
RAPID TRAVERSE

G01
LINEAR INTERPOLATION
(STRAIGHT LINE MOVEMENT)

G02
CIRCULAR INTERPOLATION
(CLOCKWISE)

G03
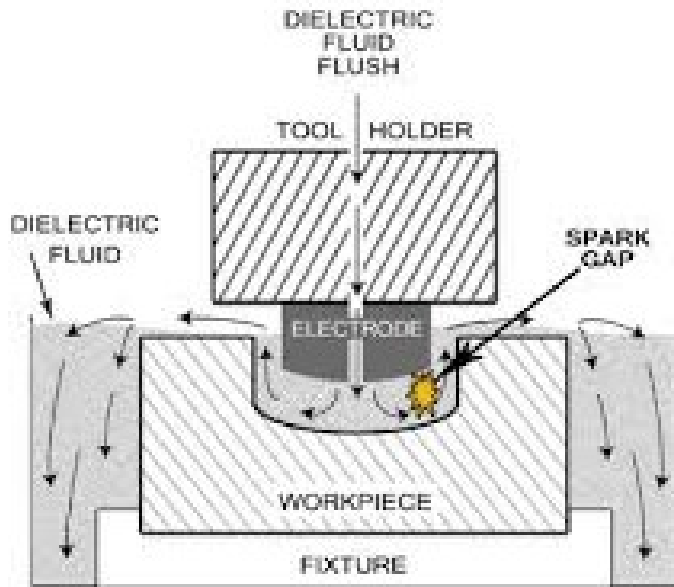CIRCULAR INTERPOLATION
(COUNTERCLOCKWISE)

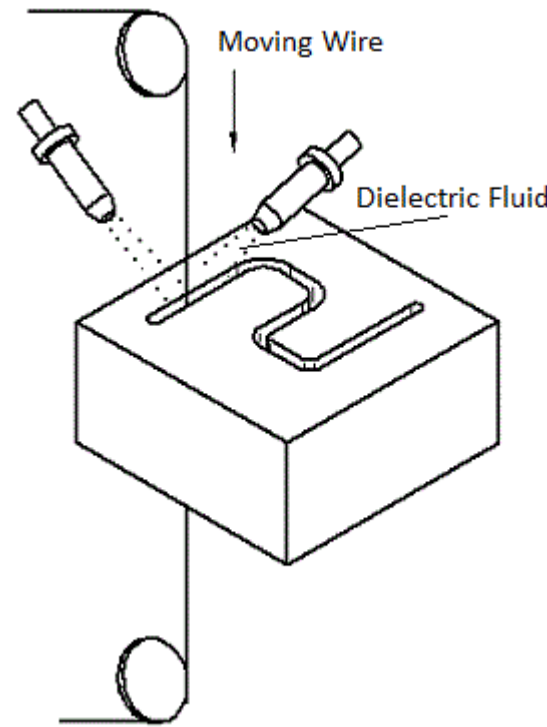# Non-Traditional Manufacturing Processes: EDM Process

Non-Traditional Machining Processes => Material removal by other forms of energy than heat and force such as kinetic energy of beams (laser, electron beam, plasma) and jets (water-jet, abrasive jet etc.), electro-thermal energy, chemical energy, electro-chemical energy, ultrasonic vibrations, etc.

https://youtube.com/shorts/LKVBNX1spZU?si=fkfKtJqkpwxN8Odw

Electro-Discharge Machining (EDM)

Wire EDM

Laser is a versatile tool. It can do cutting, sintering, curing or polymerization etc.

https://youtube.com/shorts/WxJJH84jJtw?si=eHGOBvdUQcPt-zJm   https://youtube.com/shorts/a-OOFqn5Rpo?si=dzT3aiKw0-SDA0lo

CO_2 glass tube Laser (λ=10.6 μm)

Parag Tandaiya and Rakesh Mote, Mech. Engg., IITB

22

Useful Resources...
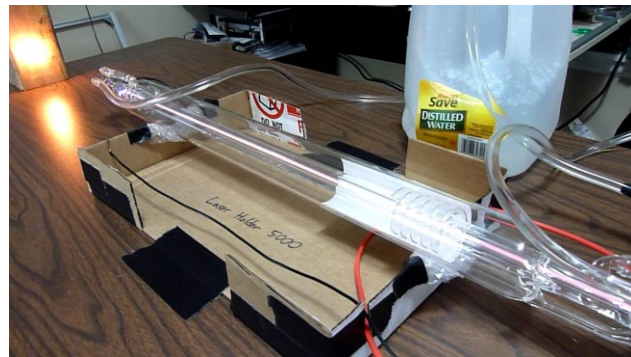
- Principles of Modern Manufacturing: Materials, Processes, and Systems, Mikell P. Groover, Wiley India Edition, 2018.

- Manufacturing Engineering and Technology (SI Edition), S. Kalpakjian and S. R. Schmid, Pearson Education; Seventh edition, 2018.

- Fusion 360 Tutorials on additive manufacturing
  - https://help.autodesk.com/view/fusion360/ENU/courses/AP-MFG-ADD-FFF

- How to 3D print using Fusion 360
  - https://www.youtube.com/watch?v=wPScDWi-X4s (practice upto time 3:05)