THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

MANUFACTURING PROCESSES

UTA026

Department of Mechanical Engineering
Thapar Institute of Engineering and Technology, Patiala

MILLING OPERATIONS

MILLING

- In **MILLING**, a rotating tool with multiple cutting edges is fed slowly across the work material to generate a plane or straight surface.
- The axis of **rotation** of the cutting tool is **perpendicular** to the direction of **feed.**
- This **orientation** between the tool axis and the feed direction is one of the features that **distinguishes milling from drilling**.
- In drilling, the cutting tool is fed in a direction parallel to its axis of rotation.

MILLING

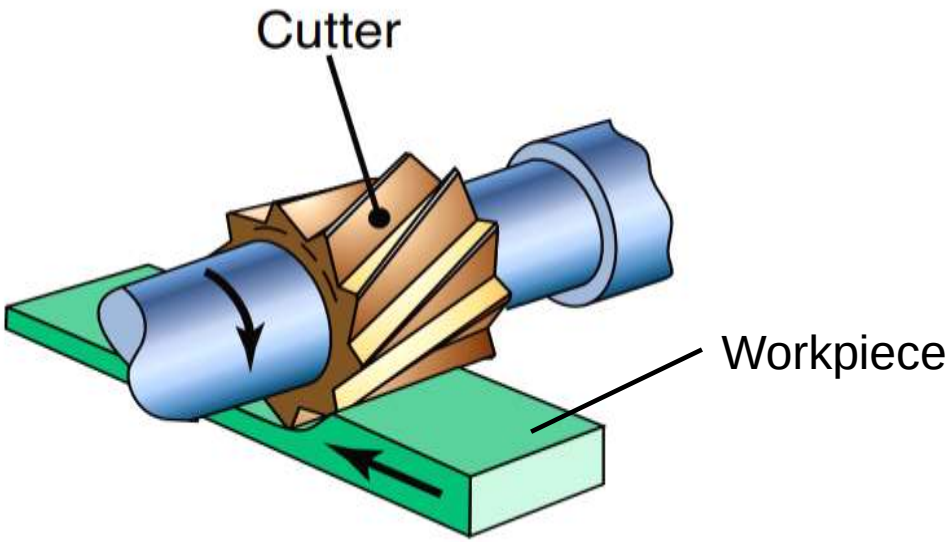
- The cutting tool in milling is called a **milling cutter** and the cutting edges are called **teeth**.
- The conventional machine tool that performs this operation is a **milling machine** .

TYPES OF MILLING OPERATIONS

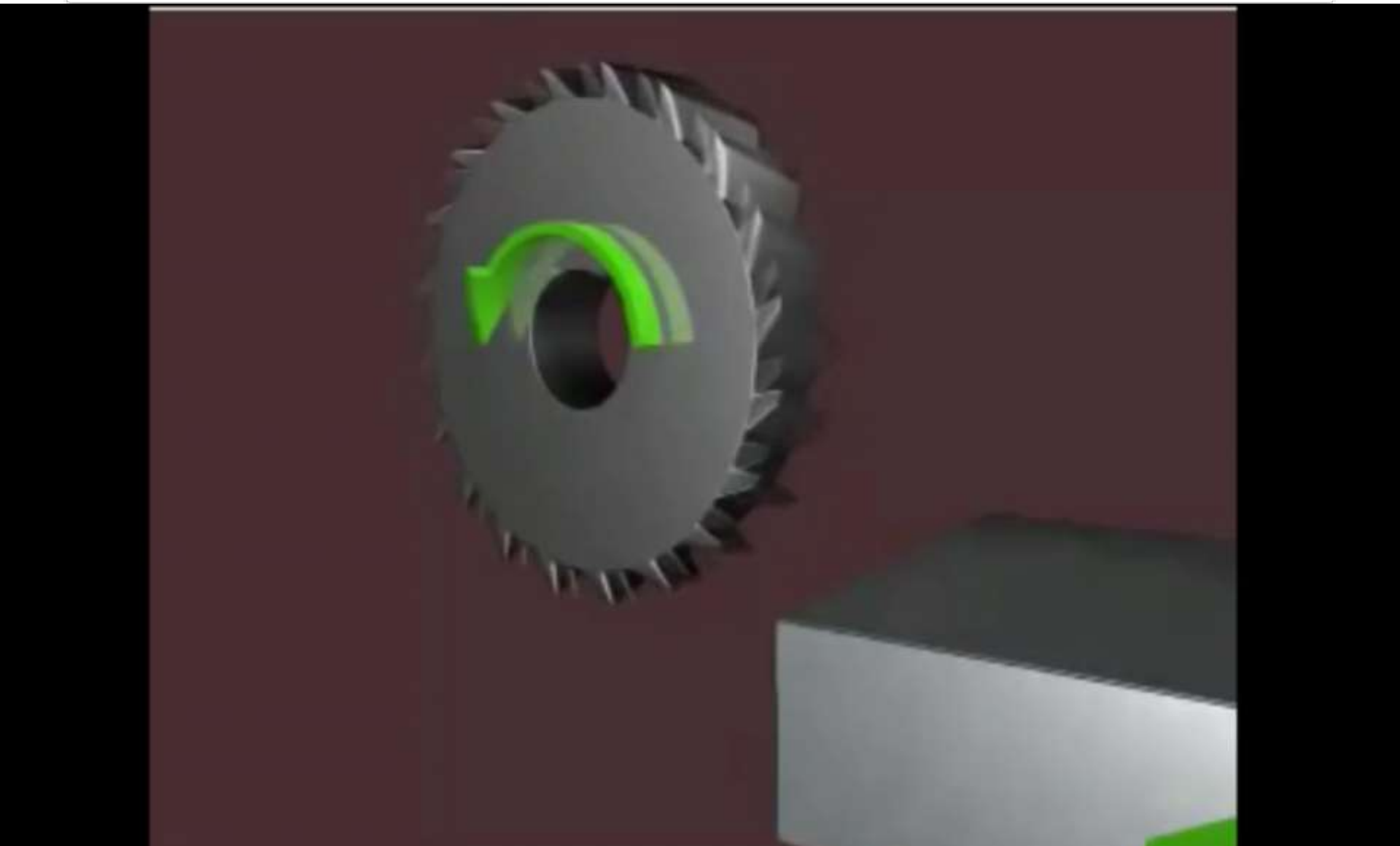
- There are three basic types of milling operations.
  - **(A) peripheral milling**
  - **(B) face milling**
  - **(C) end milling**

(A) PERIPHERAL MILLING

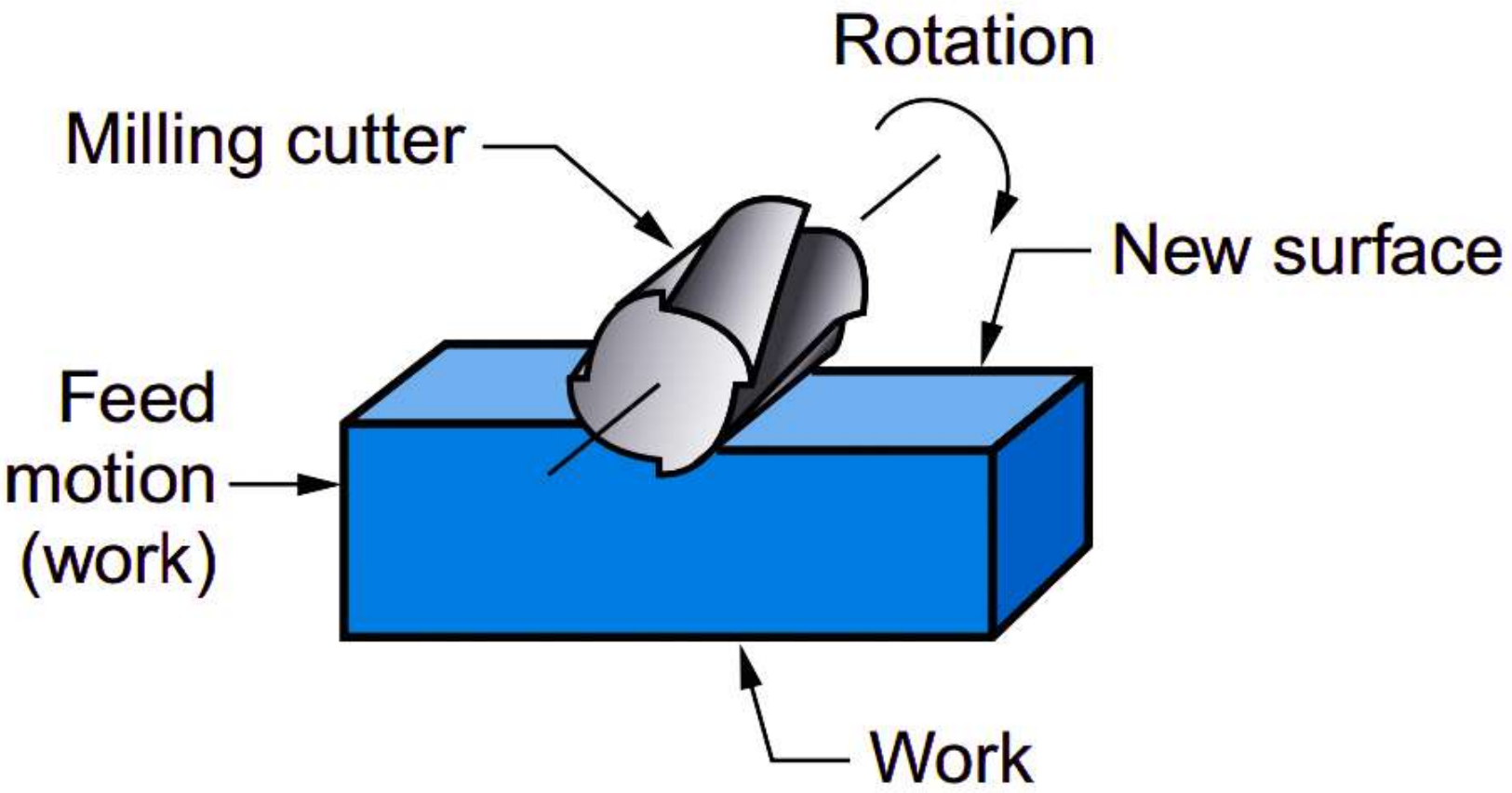
- In **PERIPHERAL MILLING**, also called **plain milling**, the **axis** of the tool is **parallel** to the surface being machined, and the operation is performed by cutting edges on the outside periphery of the cutter.



(A) PERIPHERAL MILLING



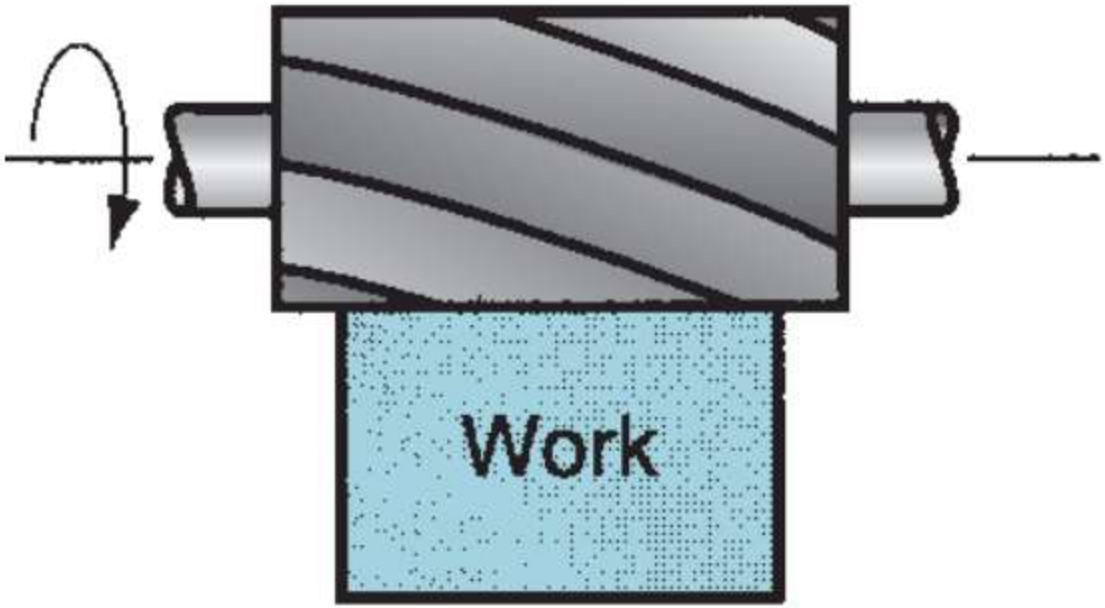
(A) PERIPHERAL MILLING



(A) PERIPHERAL MILLING

1. SLAB MILLING

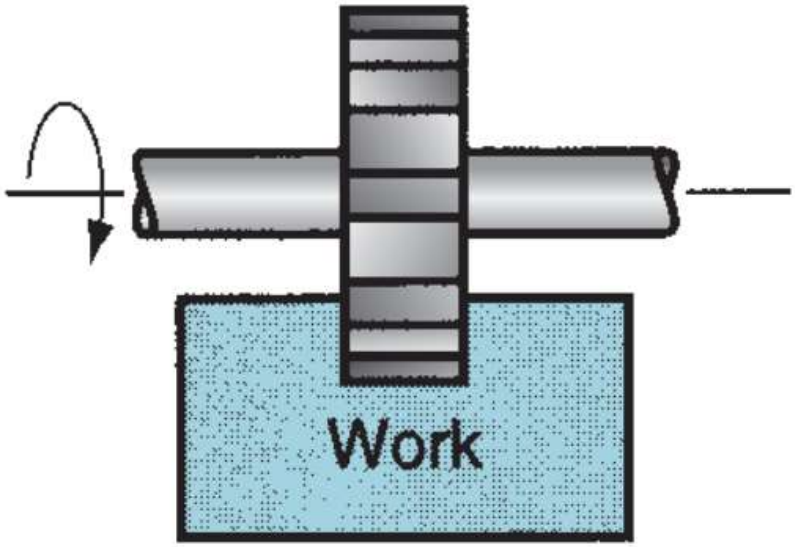
- **SLAB MILLING** , the basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides.



1. SLAB MILLING

2. SLOTTING/ SLOT MILLING

- **SLOTTING** , also called **SLOT MILLING** ,in which the **width of the cutter is less than the workpiece width,** creating a slot in the work—when the cutter is very thin, this operation can be used to mill narrow slots or cut a workpart in two, called **saw milling**.

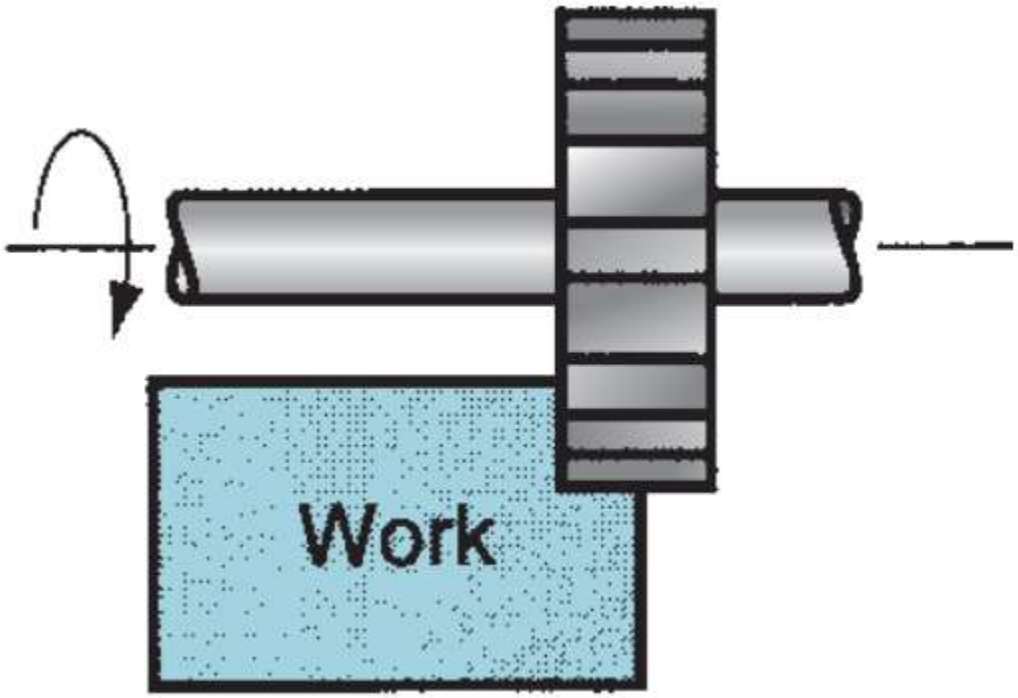


2. SLOTTING/ SLOT MILLING

2. SLOTTING/ SLOT MILLING

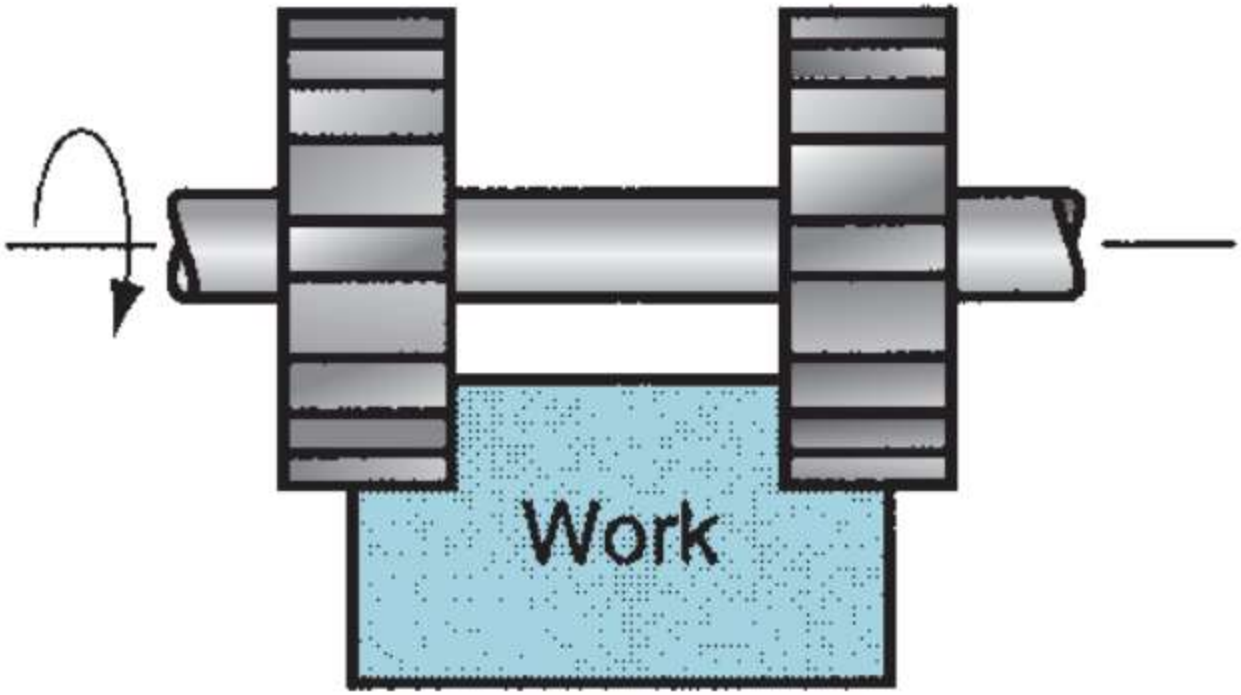
3. SIDE MILLING

- **SIDE MILLING** , in which the cutter machines the side of the workpiece



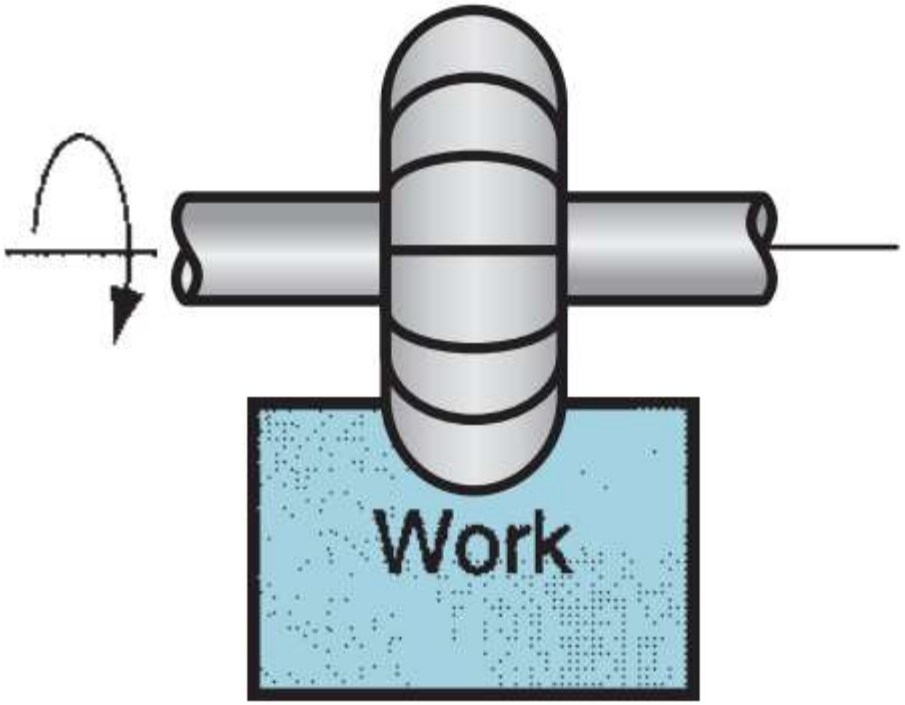
4. STRADDLE MILLING

- **STRADDLE MILLING** , the same as side milling, only cutting takes place on both sides of the work.

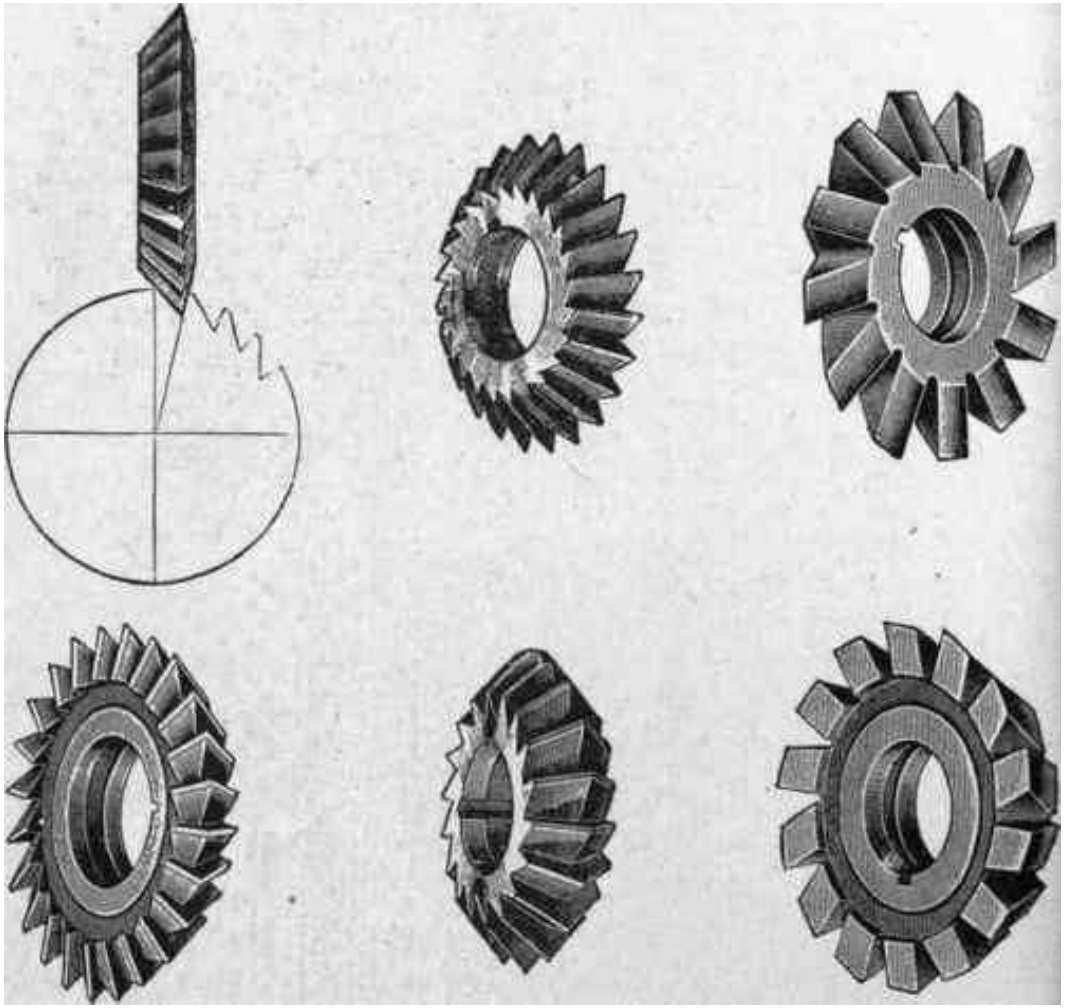


5. FORM MILLING

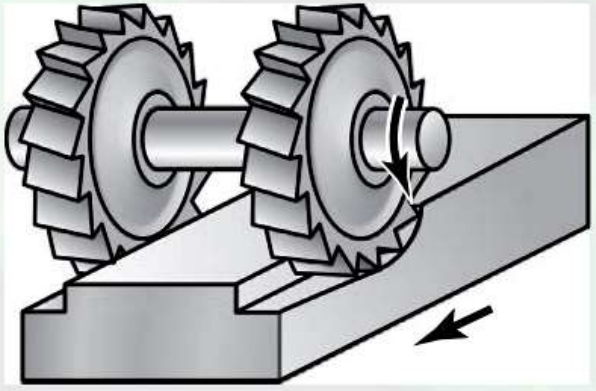
- **FORM MILLING** , in which the milling teeth have a special profile that determines the shape of the slot that is cut in the work.



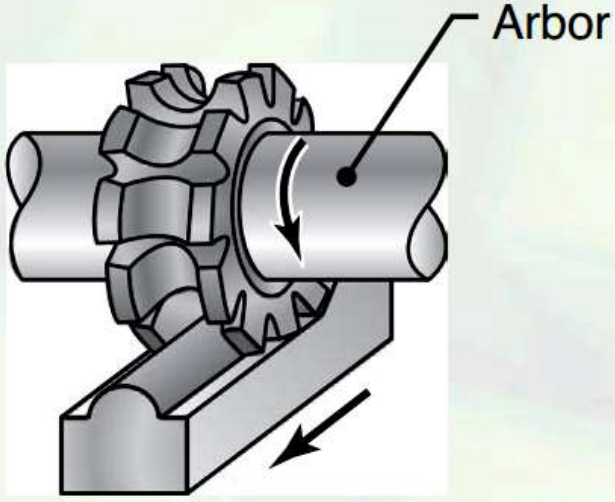
5. FORM MILLING



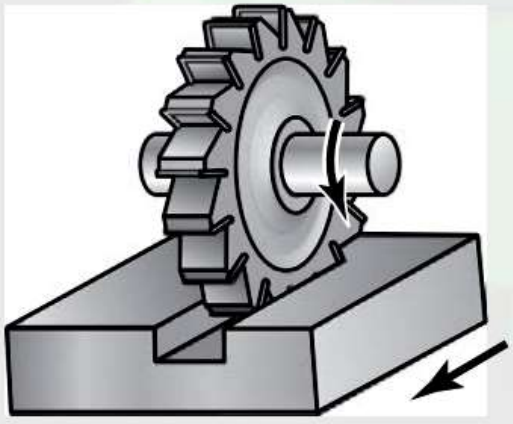
More Examples



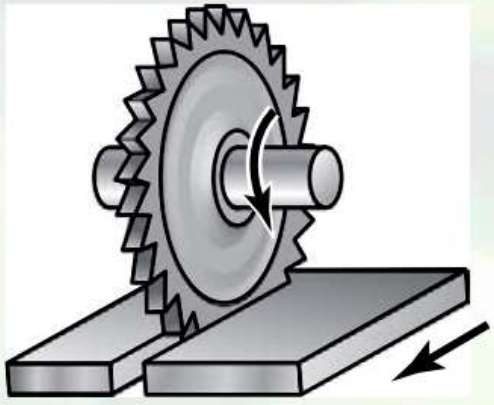
(a) Straddle milling



(b) Form milling



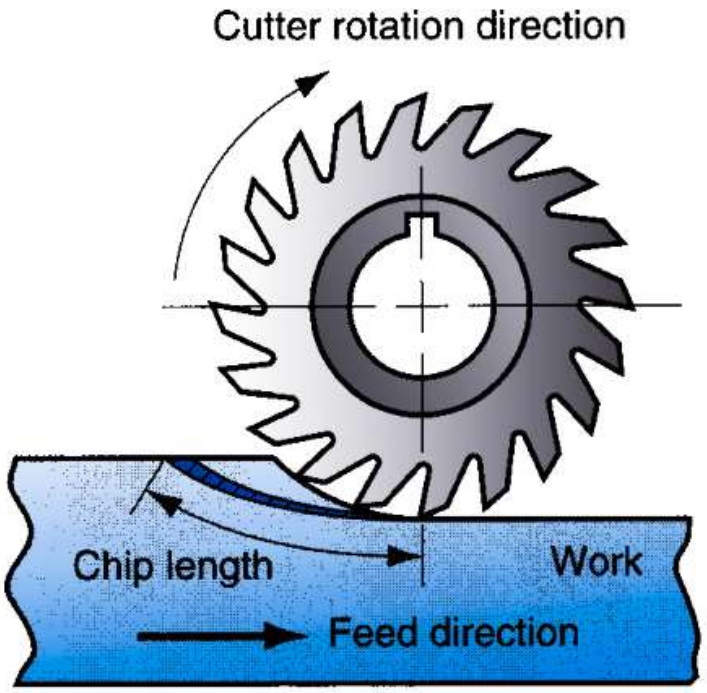
(c) Slotting



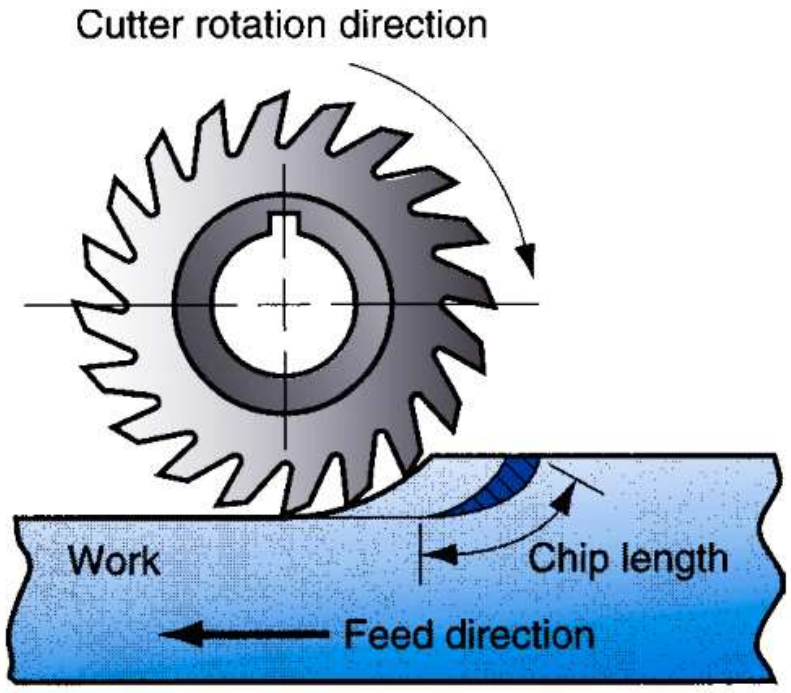
(d) Slitting

UP/DOWN MILLING

- In milling, the direction of cutter rotation distinguishes two forms of milling:



UP MILLING



DOWN MILLING

UP/DOWN MILLING

UP/Conventional MILLING

- In **UP MILLING** , also called **conventional milling** , the direction of motion of the cutter teeth is opposite the feed direction when the teeth cut into the work.
- It is milling ‘‘ **against the feed**.’’
- The **maximum** chip thickness is at the **end** of the cut as the tooth leaves the workpiece surface.
- The cutter tends to push the work along and **lift it upward** from the table.

UP/Conventional MILLING

- The action tends to **loosen the work** from the fixture.
- Therefore, **greater clamping forces** must be employed, with the danger of deflecting the part.
- **More power required** due to increased friction caused by the chip beginning at the minimum width.
- There may be a tendency for the **tool to chatter**.

UP/Conventional MILLING

- In up milling, **chips can be carried** into the newly machined surface, causing the **surface finish** to be **poorer** (rougher) than in down milling and causing damage to the insert.

DOWN/Climb MILLING

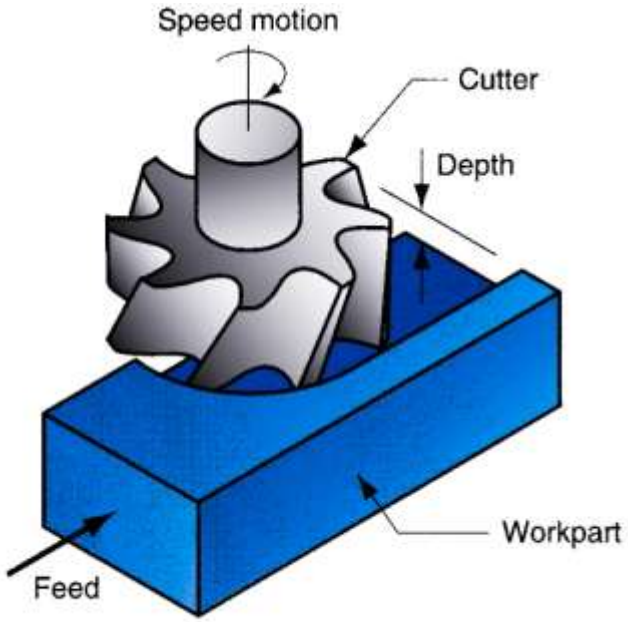
- In **DOWN MILLING** ,also called **climb milling** , the direction of cutter motion is the same as the feed direction when the teeth cut the work.
- It is milling ‘‘ **with the feed**.’’
- Chips are cut to **maximum thickness at initial** engagement of cutter teeth with the work, and decrease to zero at the end of its engagement.

DOWN/Climb MILLING

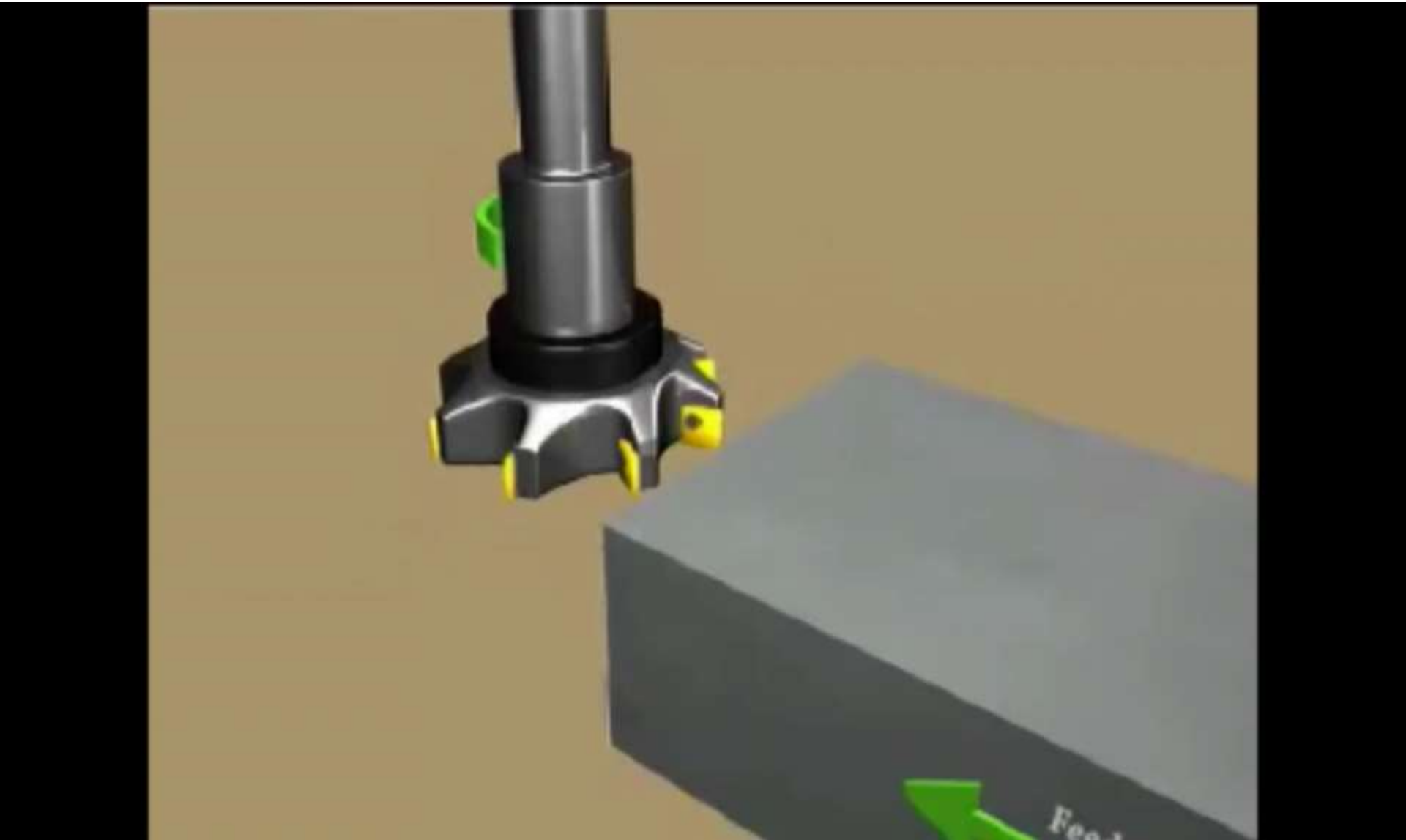
- The cutting force tends to **hold the work** against the machine table, permitting **lower clamping forces.**
- Slightly **lower power consumption** is obtainable by climb milling, since there is no need to drive the table against the cutter.
- Down-milling is characterized by **fewer tendencies of chattering and vibration**, which leads to **improved surface finish.**
- **Easier chip disposal** - chips removed behind cutter.

(B) FACE MILLING

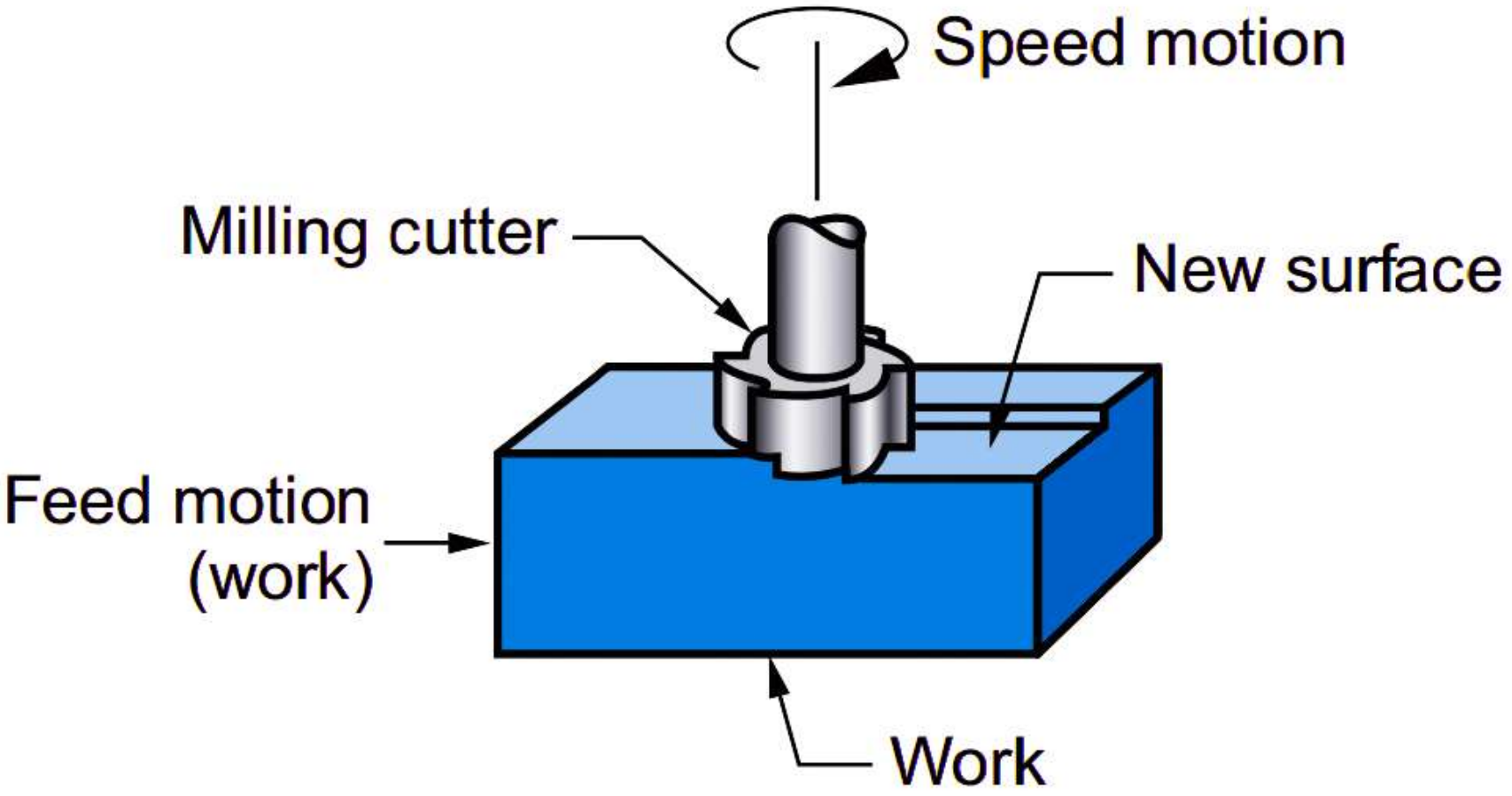
- In **FACE MILLING**, the axis of the cutter is **perpendicular** to the **surface** being milled, and machining is performed by cutting edges on both the end and outside periphery of the cutter.



(B) FACE MILLING



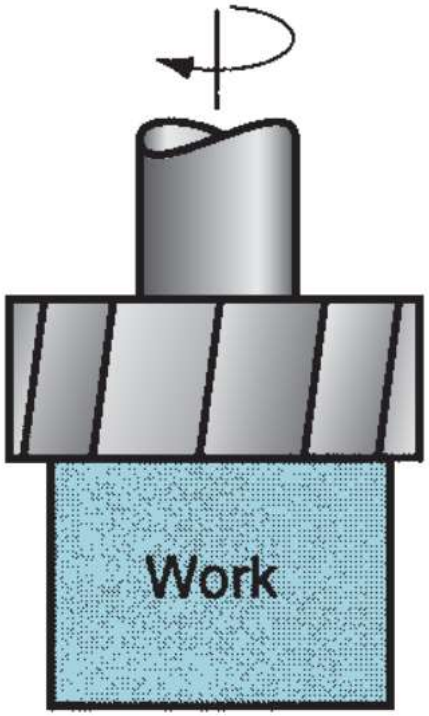
(B) FACE MILLING



(B) FACE MILLING

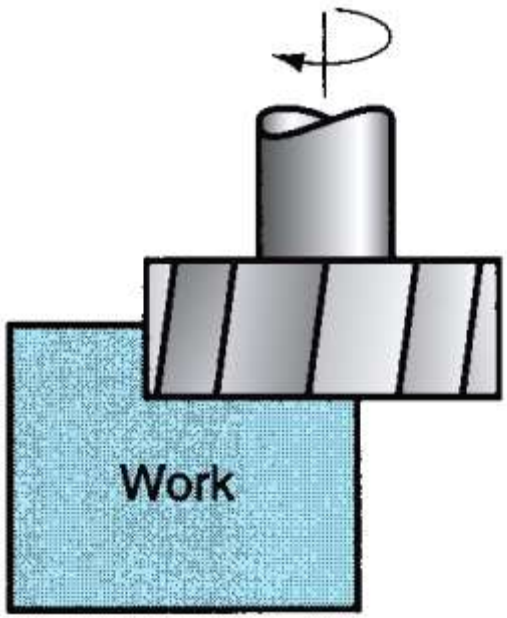
CONVENTIONAL FACE MILLING

- **CONVENTIONAL FACE MILLING** , in which the diameter of the cutter is greater than the workpart width, so the cutter overhangs the work on both sides.



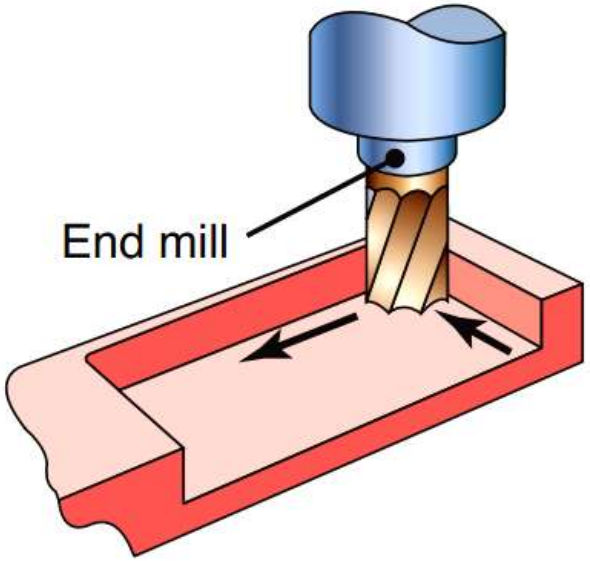
PARTIAL FACE MILLING

- **PARTIAL FACE MILLING** , where the cutter overhangs the work on only one side.

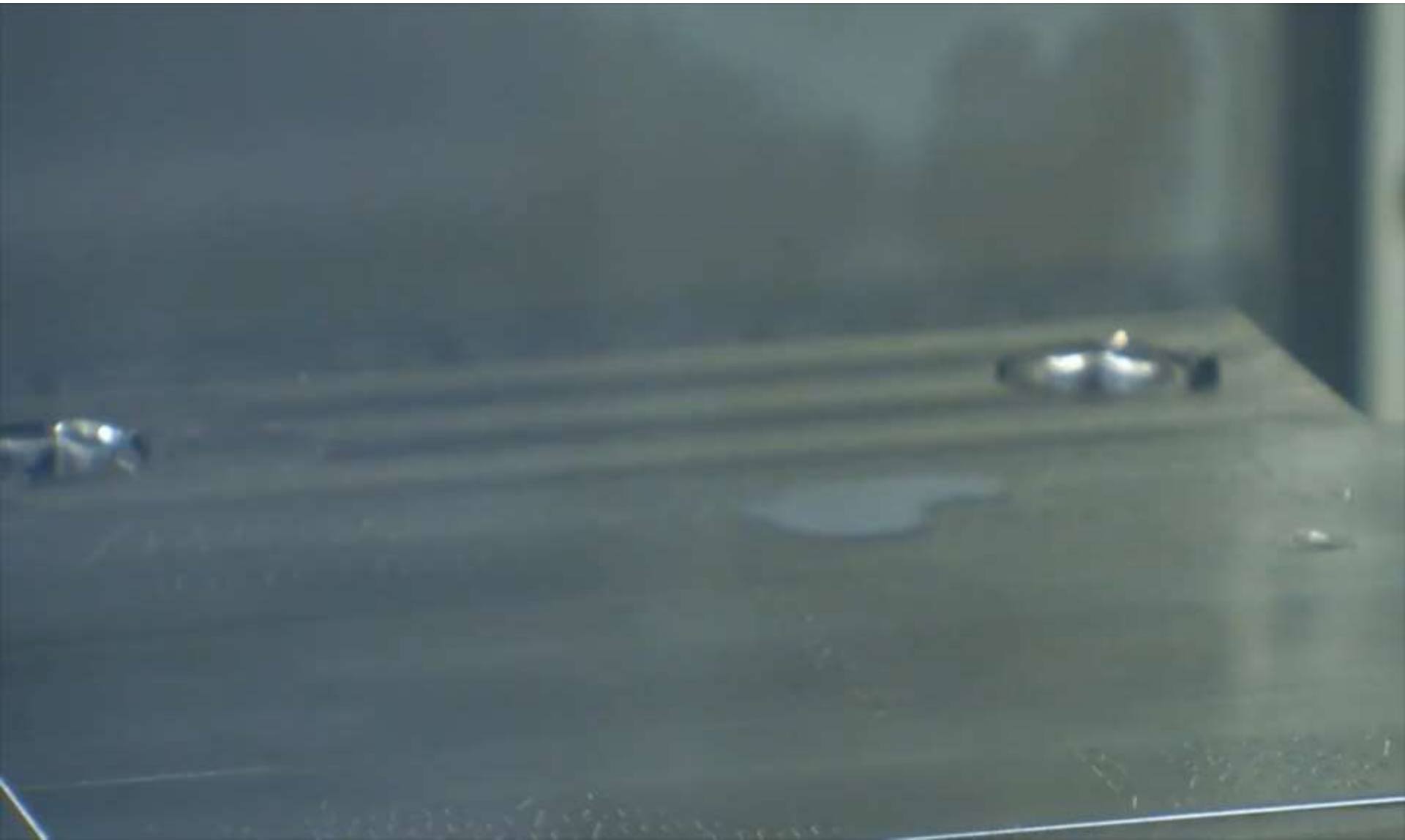


(C) END MILLING

- In case of **end milling** thin (low diameter) cutter are used as compared to workpiece width. It is used to make slot in the workpiece.
- **A milling cutter that performs a mix of peripheral and face milling.**



(C) END MILLING



(C) END MILLING

(C) END MILLING

- End milling, in which a rotating cutter travels along a certain depth in the workpiece and produces a cavity.
- End milling is an important and common machining operation because of its versatility and capability to produce various profiles and curved surfaces.
- The cutter, called an end mill.

(C) END MILLING

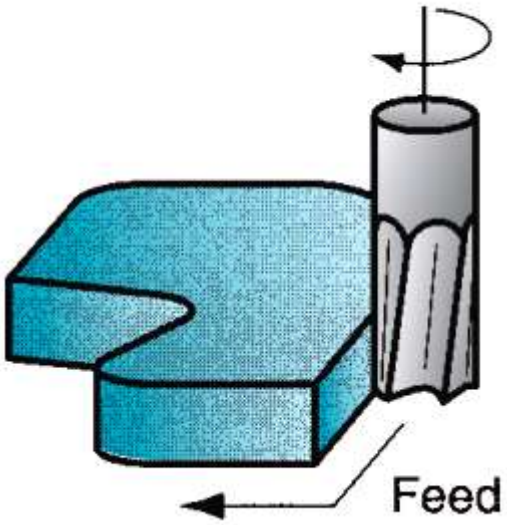
- The cutter usually rotates on an axis perpendicular to the workpiece surface, and it also can be tilted to conform to machine-tapered or curved surfaces.
- Machining can also be carried out in areas not accessible to other types of cutters.
- However, the length-to-diameter ratio of end mills is high and they can be supported only at one end, so they are less rigid than cutters for other milling methods.

(C) END MILLING

- Lighter feeds may be required to reduce cutter deflection.
- Material removal rates are less than with other milling methods and accuracy may not be as great.

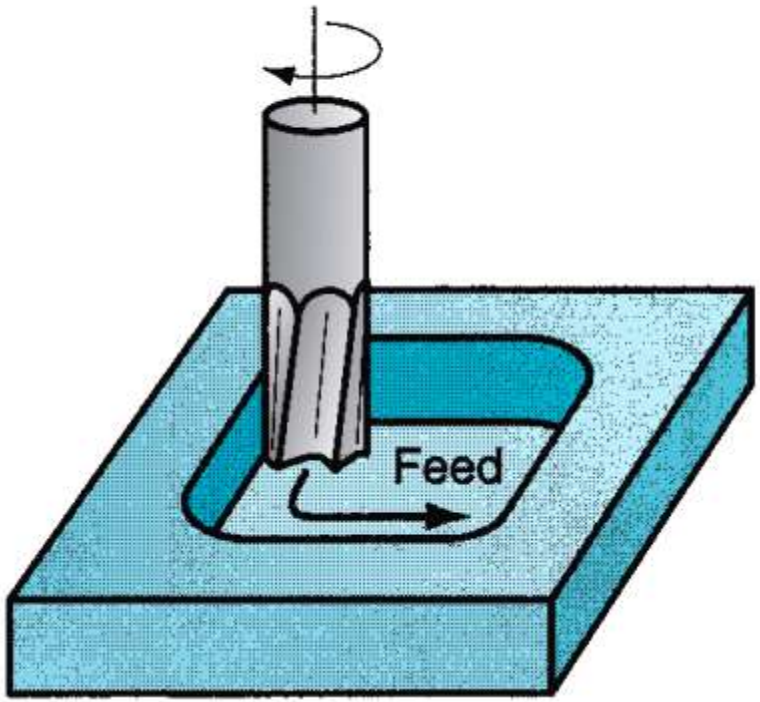
PROFILE MILLING

- **PROFILE MILLING** ,a form of end milling in which the outside periphery of a flat part is cut.



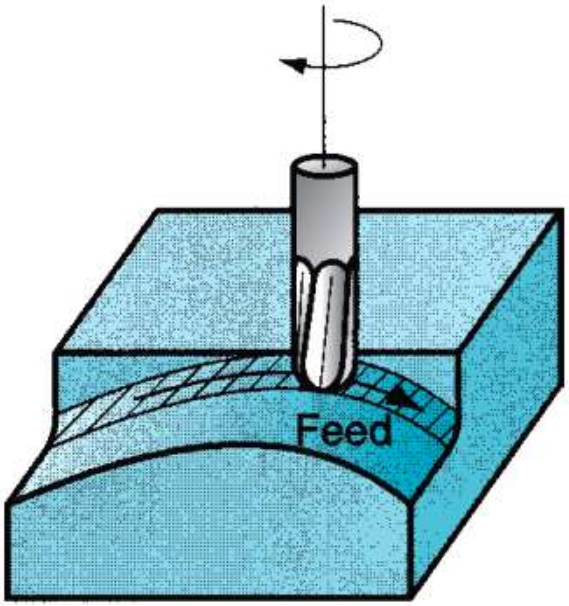
POCKET MILLING

- **POCKET MILLING** , another form of end milling used to mill shallow pockets into flat parts.



SURFACE CONTOURING

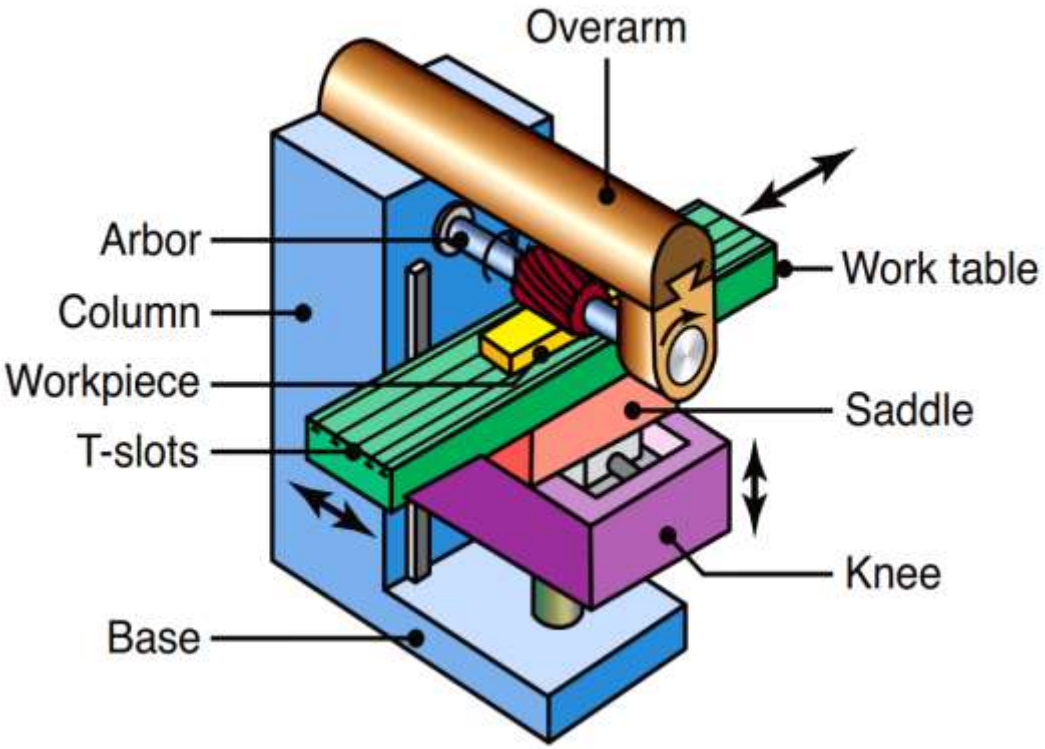
- **SURFACE CONTOURING** , in which a ball-nose cutter (rather than square-end cutter) is fed back and forth across the work along a curvilinear path at close intervals to create a three-dimensional surface form.



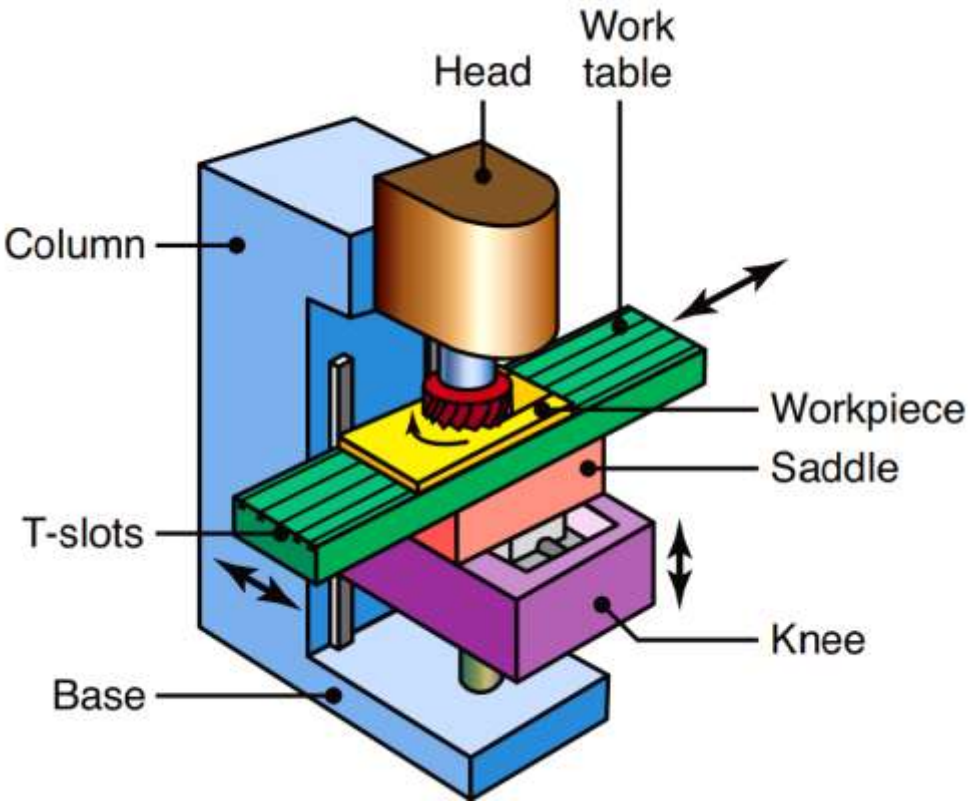
TYPES OF MILLING MACHINES

- **Horizontal milling machine**
- **Vertical milling machine**

HORIZONTAL MILLING MACHINE



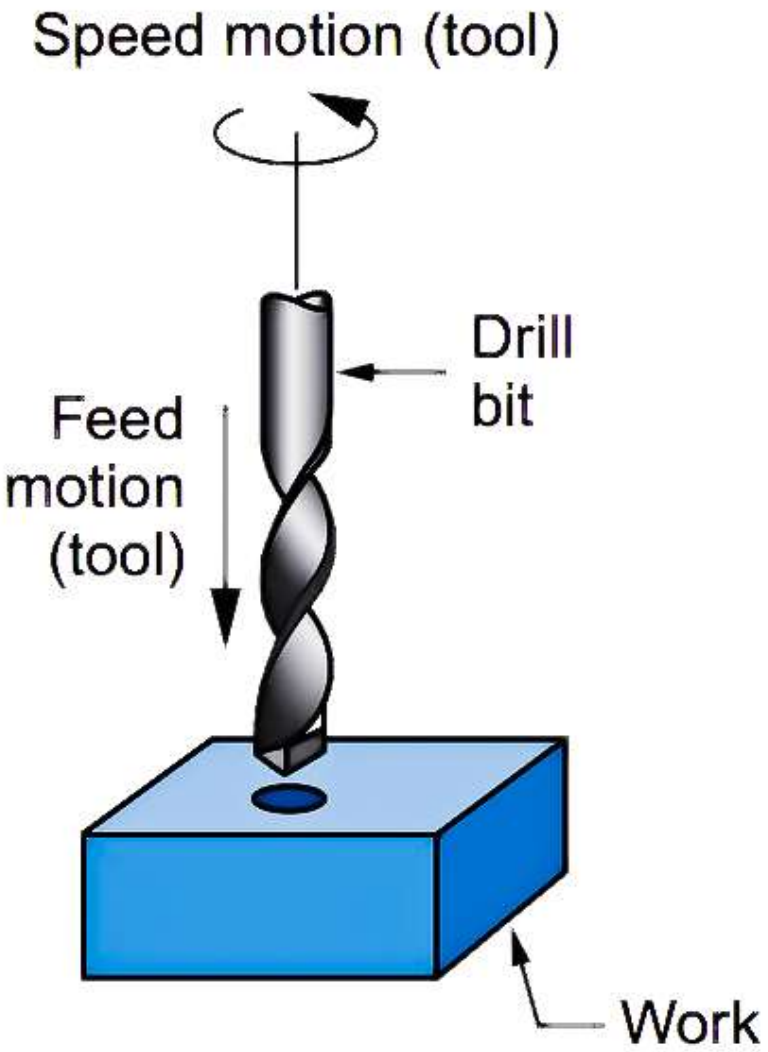
VERTICAL MILLING MACHINE



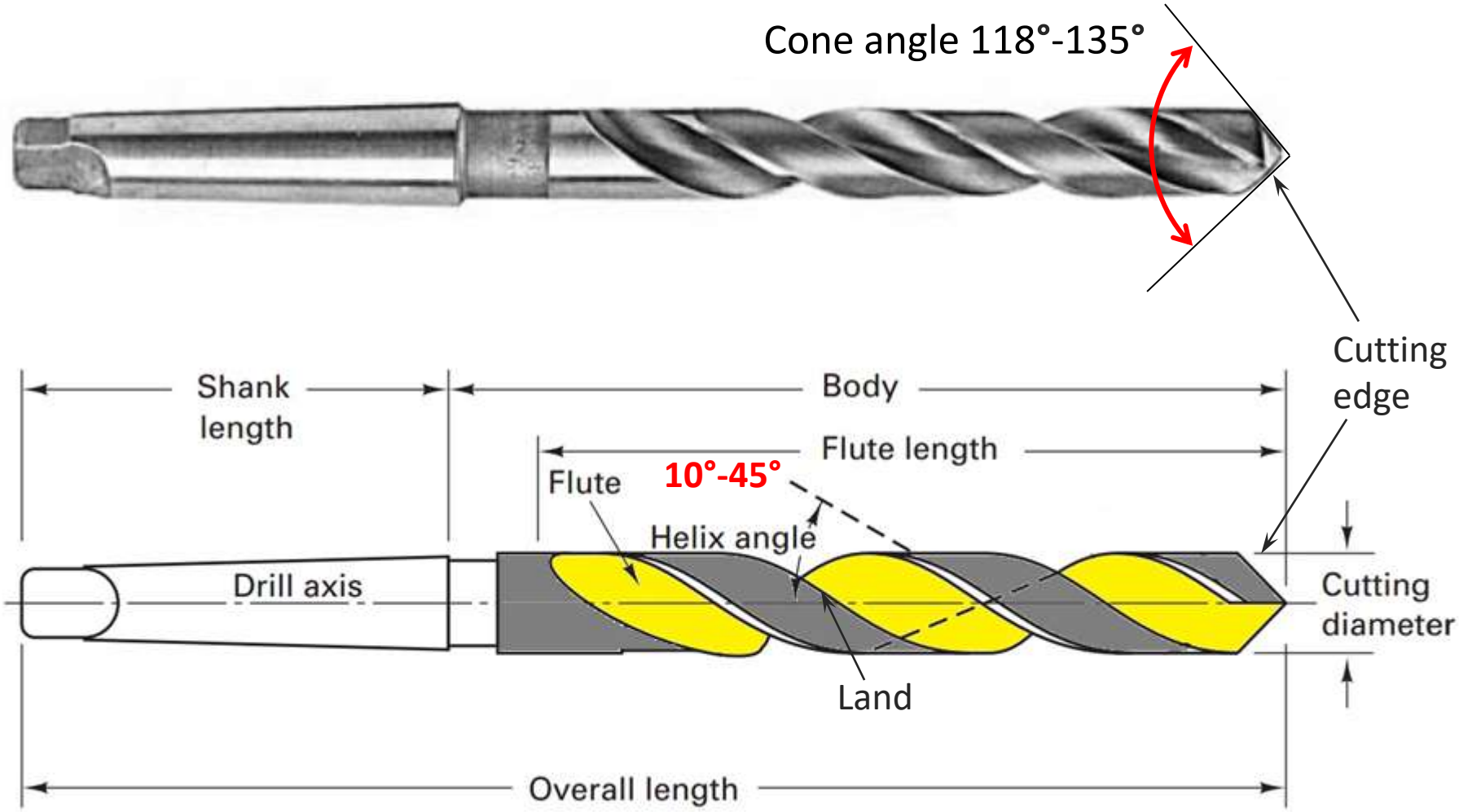
DRILLING

- **DRILLING** is a machining operation used to create a round hole in a workpart.
- Drilling is usually performed with a rotating cylindrical tool that has **two cutting edges** on its **working end**.
- The tool is called a **drill** or **drill bit**.
- The tool is **fed** in a direction **parallel to its axis of rotation** into the workpart to form the round hole.

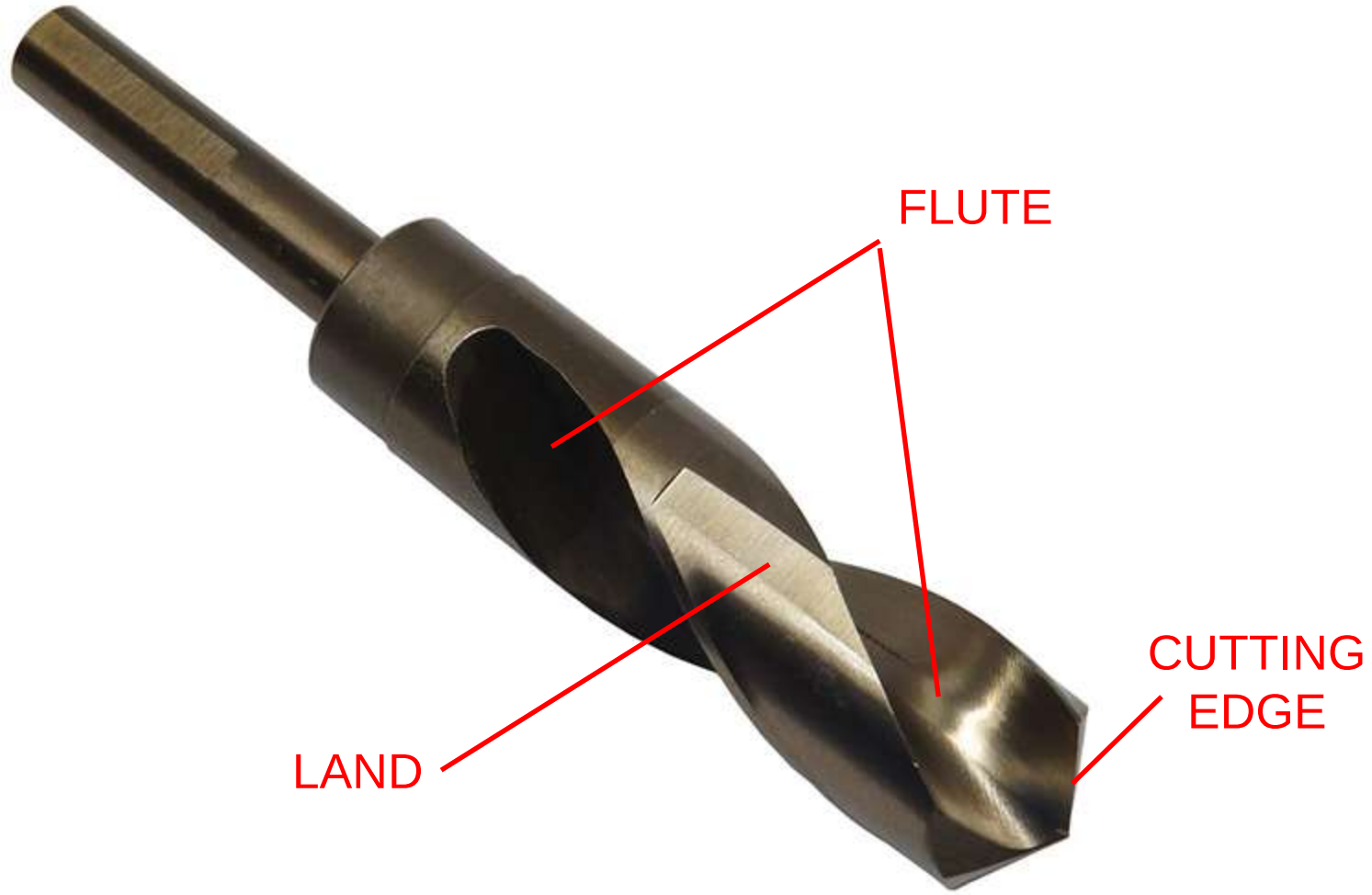
DRILLING



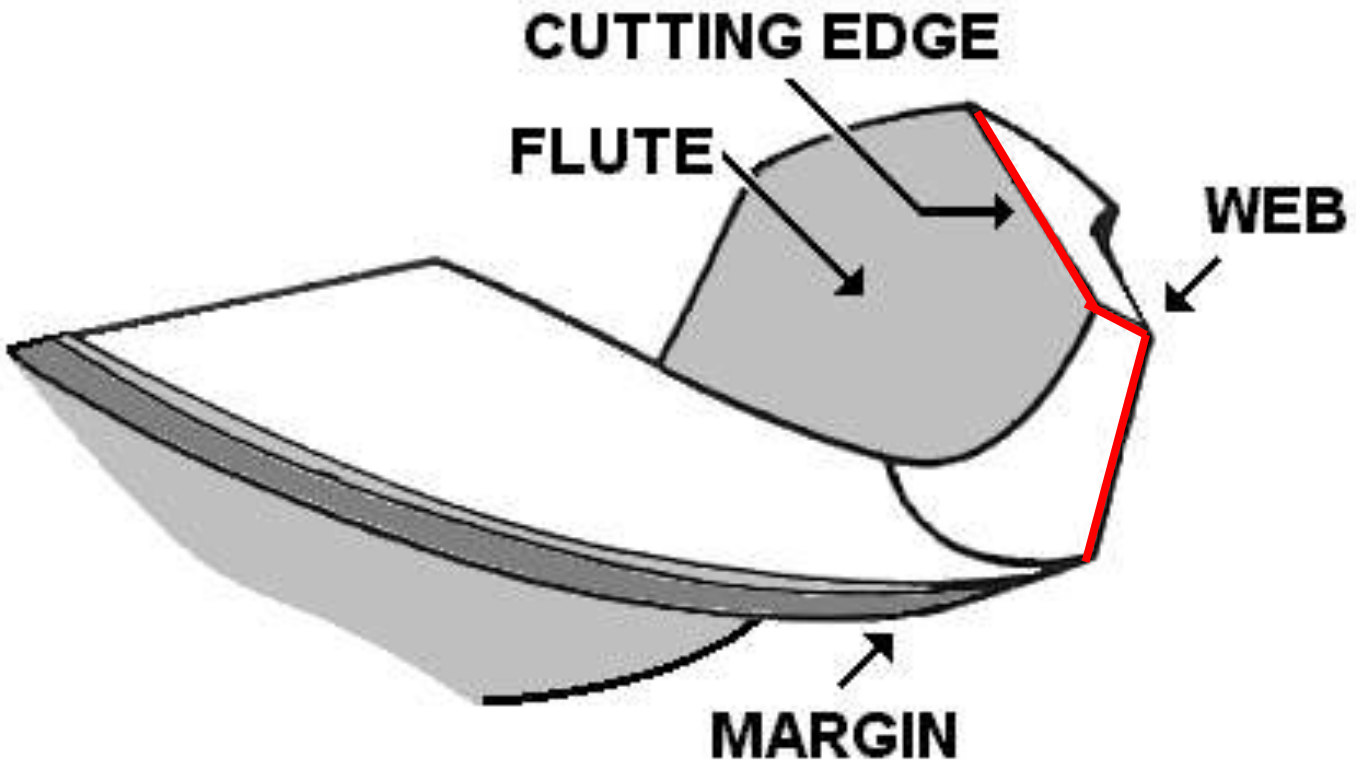
DRILL BIT


Cone angle 118°-135°
Cutting edge
Shank length
Body
Flute length
Flute
10°-45°
Helix angle
Drill axis
Cutting diameter
Land
Overall length

DRILL BIT



DRILL BIT



DRILLING

- The most common types of drills are **twist drills** .
- These have three basic parts: the **body**, the **point**, and the **shank**.
- The body contains two or more spiral or helical grooves, called **flutes**, separated by **lands** .
- The **lands terminate in the point**, with the leading edge of each land **forming a cutting edge**.

DRILLING

- The **flutes serve as channels** through which the chips are withdrawn from the hole and coolant gets to the cutting edges.
- The **cone-shaped point** on a drill contains the **cutting edges** and the various clearance angles.
- The rotating drill feeds into the stationary workpart to form a hole whose diameter is equal to the drill diameter.
- Drilling is customarily performed on a **drill press** , although other machine tools also perform this operation.

DRILLING

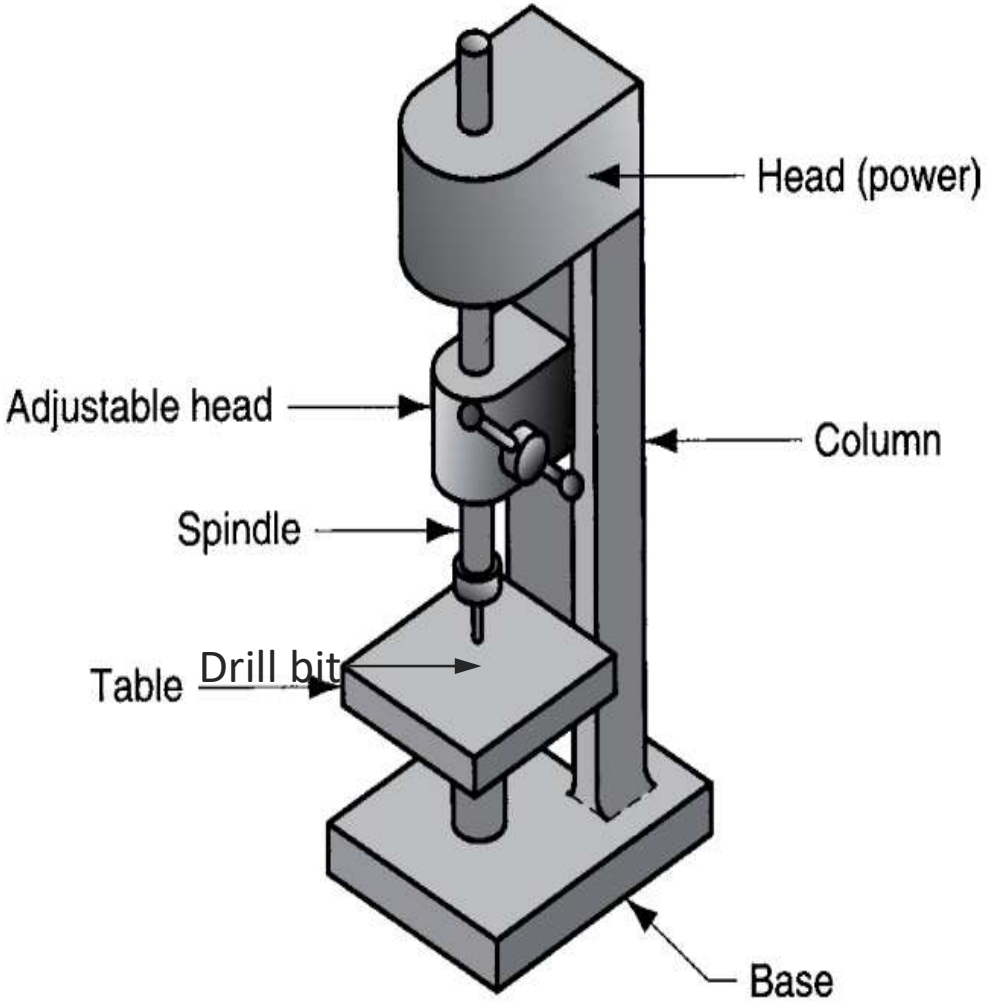
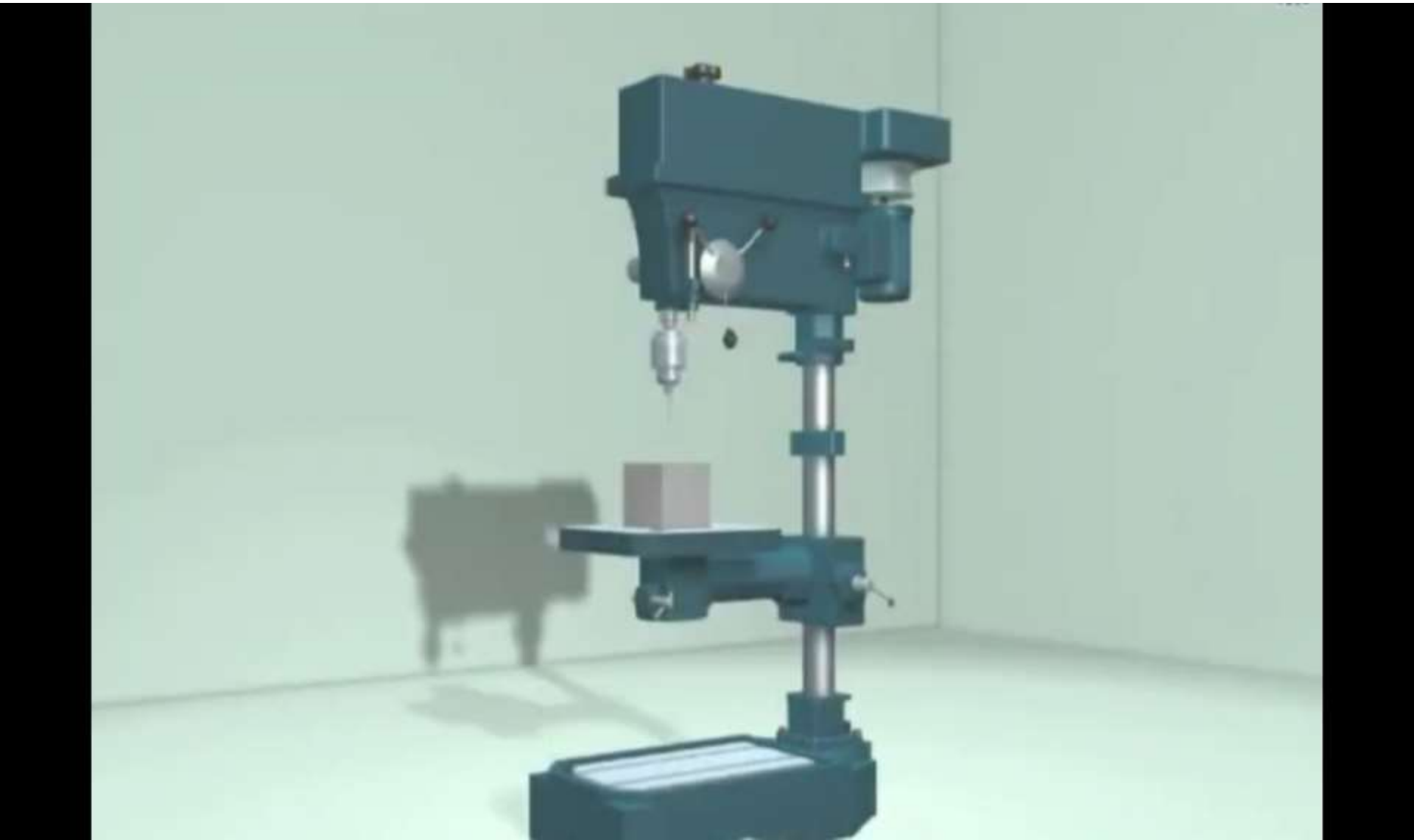


Image Source: https://www.indiamart.com/proddetail/bench-drilling-machine

DRILLING



DRILLING

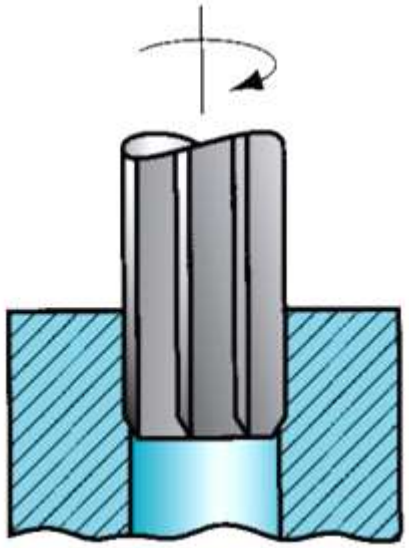
Image Source: https://www.bosch-pt.co.in/

OPERATIONS RELATED TO DRILLING

- Several operations are related to drilling.
- Most of the operations follow drilling; a hole must be made first by drilling, and then the hole is modified by one of the other operations.
- Centering and spot facing are exceptions to this rule.
- All of the operations use rotating tools.

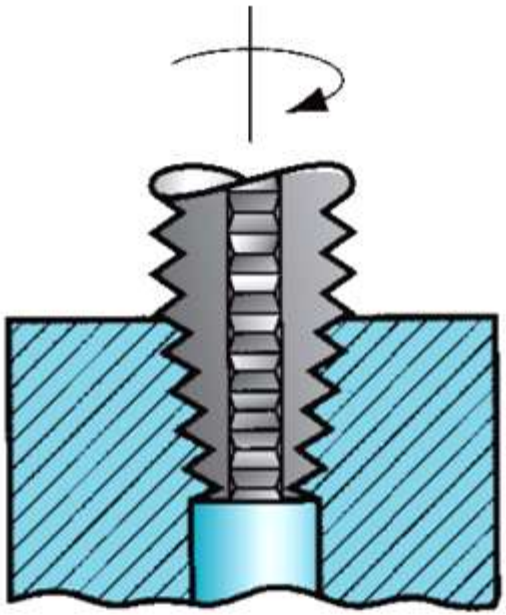
REAMING

- Reaming is used to ***slightly enlarge a hole***, to provide a ***better tolerance*** on its diameter, and to ***improve its surface finish***.
- The tool is called a reamer, and it usually has straight flutes.



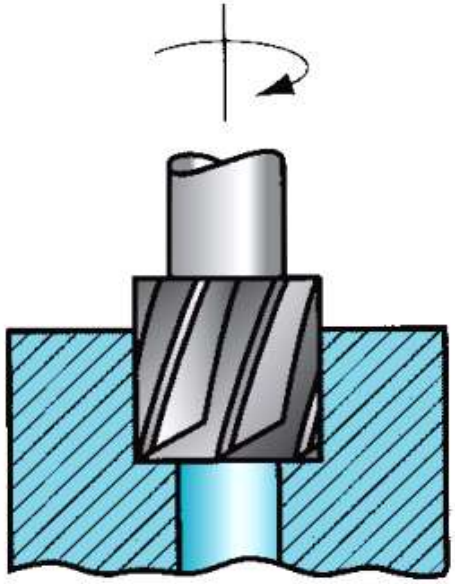
TAPPING

- This operation is performed by a tap and is used to provide ***internal screw threads*** on an existing hole.



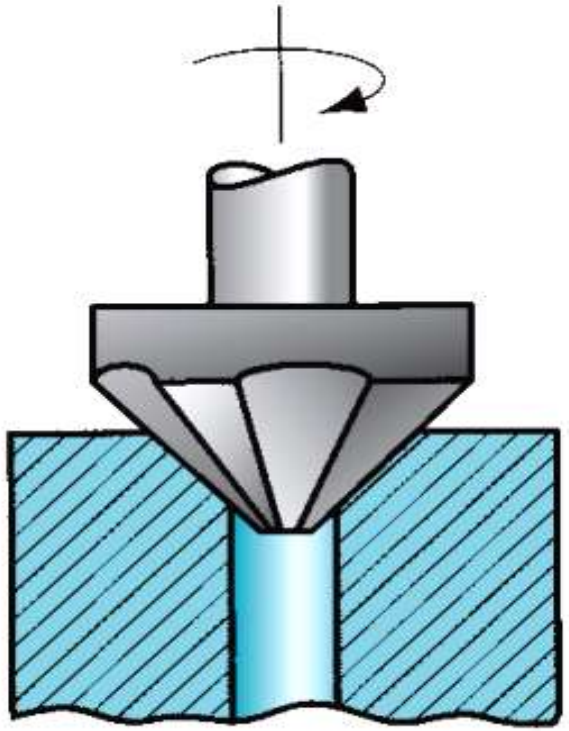
COUNTERBORING

- Counterboring provides ***a stepped hole***, in which a larger diameter follows a smaller diameter partially into the hole.
- A counterbored hole is ***used to seat bolt heads*** into a hole so the heads do not protrude above the surface.



COUNTER SINKING

- This is ***similar to counterboring***, except that the step in the hole is ***cone-shaped*** for flat head screws and bolts.



CENTERING

- Also called center drilling, this operation drills a ***starting hole*** to accurately establish its location for subsequent drilling.
- The tool is called a center drill.