Milling is a basic machining process by which a surface is generated progressively by the removal of chips from a workpiece as it is fed to a rotating cutter in a direction perpendicular to the axis of the cutter.

In some cases the work is stationary, and the cutter is fed to the work.

Nearly in all cases, a multiple-teeth cutter is used. The tool used in milling is known as milling cutter. Milling is performed by using milling machines.
Types of Milling Operations

1. **Peripheral (Slab) Milling**
   A surface is generated by teeth located on the periphery of the cutter body. The surface produced is parallel to the axis of rotation of the cutter (slab milling).

2. **Face Milling**
   The surface is perpendicular to the cutter axis and the teeth located at the periphery and the face of the cutter removes the chip.

3. **End Milling**
Milling cutters can be classified according to the manner of mounting.

1. Arbor cutters (*malafalı frezeler*)
2. Shank cutters (*saplı frezeler*)
3. Facing cutters (*alın frezeler*)
Arbor cutters have a hole at their centers, so they can be mounted on an arbor.
Shank cutters have either a tapered or straight integral shank.

Cutters with straight shanks are held in collets.

Facing cutters are usually bolted to the end of a stub arbor.
1. **Plain Milling Cutters** (silindirik frezeler)

Used for milling flat surfaces (plain or slab milling).

They are cylindrical or disk-shaped, have straight or helical teeth on the periphery. Helical teeth are preferred over straight teeth due to reduced shock and chattering during cutting action.
2. **Side Milling Cutters (yan frezeler)**

Similar to plain milling cutters except that the teeth extend radially part away across one or both ends of the cylinder towards the center.

The teeth may be straight or helical.

They are relatively narrow and disklike in shape.

They can be used for **milling the sides of workpieces** and **milling of slots**.
3. **Staggered Tooth** (çapraz dişli) **Milling Cutters**

Narrow cylindrical cutters having staggered teeth with alternate teeth having **opposite** helix angles.

They are ground to cut only on the periphery, but each tool also has chip clearance ground on the protruding side.

They have free cutting action particularly effective in milling of **deep slots**.
4. **Slitting Saws (testere freze)**

Thin, plain milling cutters which are 0.5 to 5 mm thick. Their sides are slightly "dished" to provide clearance and prevent binding.

They usually have more teeth for unit of diameter than ordinary plain milling cutters and are used for milling of deep, narrow slots, and for cutting-off and slitting operations.
5. **Angle Milling Cutters** *( açılı freze )* 

Used for milling slots of various angles or for milling the edges of workpieces to a desired angle.

Single angle cutters have teeth on the conical surface, usually at an angle of 45° to 60° to the plane face.

The V-angle usually is 45°, 60°, 90°.
6. **Inserted-Tooth Milling Cutters** *(takma uçlu frezeler)*

Larger-sized milling cutters are of inserted-tooth type in order to reduce the tool cost.

This method can be used for any type of cutter but most often is used with face mills.
7. **Form Milling Cutters** *(biçim freze)*

Have the teeth ground to a special shape to produce a surface having a desired transverse contour.

Convex, concave, corner rounding and *gear-tooth cutters* are of this type.
Arbor Type Milling Cutters

8. Fly Cutters

Made by attaching a single point cutting tool to a special holder.

The cutting edge can be made in any desired shape and, because it is a single-point tool, is very easy to grind.
1. **End Mills (parmak frezeler)**

Have teeth on the circumferential surface and one end.

They can be used for facing, profiling and end milling.

They may have straight or helical teeth, helical teeth being more common.

Small ones have straight, larger ones have taper shanks.
Plain end mills have multiple teeth that extend only about halfway toward the center on the end. Used in milling of slots, profiling and facing narrow surfaces.

Two-lip end mills have two straight or helical teeth that extend to the center. Thus they may be sunk into material, like a drill, and then fed lengthwise to form a groove.
Shell end mills are solid type multiple-teeth cutters, similar to plain end mills but without a shank.

The center of the face is recessed to receive a screw head or nut for mounting the cutter on a separate shank or a stub arbor.

They are used to reduce the tool cost. One shank may hold many different cutters.

The back of the cutter contains driving slots that engage collar keys on the shank.
Hollow end mills are tubular in cross-section, with teeth only on the end but having internal clearance.

They are used primarily on automatic screw machines for sizing cylindrical stock, producing a short cylindrical surface of accurate diameter.
2. **T-Slot Cutters (T-kanal frezesi)**

Integral-shank cutters with teeth on the periphery and both sides.

Used for milling the wide groove of a T-slot.

The vertical groove should be machined before, with a slotting mill, or an end mill to provide clearance for the shank.

Cuts on five surfaces simultaneously.
3. **Woodruff Keyseat Cutters** *(kama yuva frezesi)*

Used for milling of semi cylindrical seats for woodruff keys. Small ones have integral shanks, larger ones are mounted on arbors.
Facing cutters are usually bolted to the end of a stub arbor.
1. **Column-and-Knee Type Milling Machines (yatay/dikey freze tezgahı)**

Most basic milling machines are of column-and-knee construction.

They may have **horizontal** or/and **vertical** spindles.

Column is the main supporting frame and contains the spindle with its drive mechanism.

Knee (**masa gövdesi**) moves vertically on ways on the front of the column.

Saddle (**enine kızak**) moves transversely on ways on the knee.

Table (**tabla**) moves longitudinally on ways on the saddle.
Column-and-Knee Type Milling Machines

Horizontal spindle

Vertical spindle
Column-and-Knee Type Milling Machines

Milling machines having the three perpendicular table motions are called **plain** column-and-knee type milling machines.

In **universal** column-and-knee type milling machines, the table is mounted on a housing that can be swiveled in a horizontal plane.

This permits milling of helices, as found in twist drills, milling cutters, and helical gear teeth.
2. **Bed-Type Milling Machines**

The table is mounted directly on the bed and has only longitudinal motion.

Capable of making **heavy cuts**, therefore suitable for **production manufacturing operations**, where **time** is important.

The spindle head can be moved vertically in order to set-up the machine for a given operation.
Simplex, duplex and triplex types, having one, two, and three spindles, respectively, are available.
3. **Planer-Type Milling Machines**

Since single-point cutting tools are used, and a large table and a heavy workpiece cannot be reciprocated rapidly, **planers are not productive** machines, and have largely been replaced by planer-type milling machines. Several milling heads can be used.
Planer-Type Milling Machines
Planer-Type Milling Machines
4. **Rotary Table Milling Machines**

Roughing and finishing cuts can be made in succession as the workpieces are moved past the several milling cutters while held in fixtures on the rotating table of the machine.

The operator can load and unload the work without stopping the machine.
5. **Profilers and Duplicators** (kopya freze tezgahları)

**Profilers** are milling machines that can reproduce external or internal profiles in **two dimensions**.

**Duplicators** reproduce forms in **three dimensions**.

They have been replaced by CNC (Computer Numerical Control) machine tools.
During their operation, a template is followed by means of tracing heads or probes, and the same motion is simultaneously transferred to the milling head.
Profilers and Duplicators
In general, during milling operations, workpieces are either directly clamped to the table of the milling machine by making use T-slots, or held in *vises* which are attached to the table.
*** MACHINING/milling (SME/Wiley’s video)***