MACHINING PROCESSES

1.8 Milling Processes

Milling is one of the most versatile machining processes, and can be used to produce a very large variety of shapes. In fact, you may have noticed that many manufacturing processes use some form of mold or die. A large percentage of these molds and dies are produced by milling. **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 multiple-teeth cutter in a direction perpendicular to the axis of the cutter. The tool used in milling is known as **milling cutter**. Milling is performed by using **milling machines**.

The workpiece is clamped to the machine table, and the table moves along X-, Y- and Z-directions.

1.8.1 Types of Milling Operations

1. Peripheral Milling

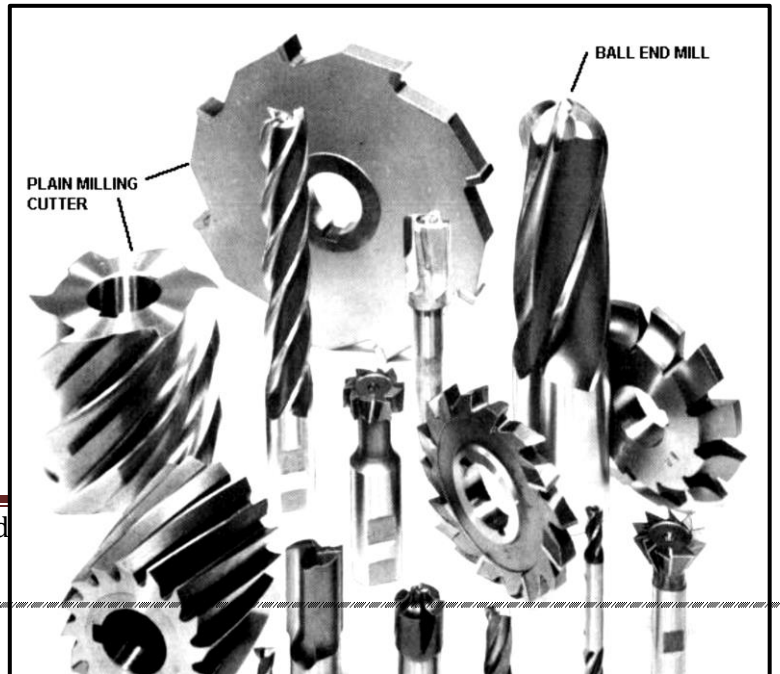
2. Face Milling

3. End Milling

1.8.2 Types of Milling Cutters

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

1. Arbor cutters
2. Shank cutters
3. Facing cutters



Arbor Type Milling Cutters

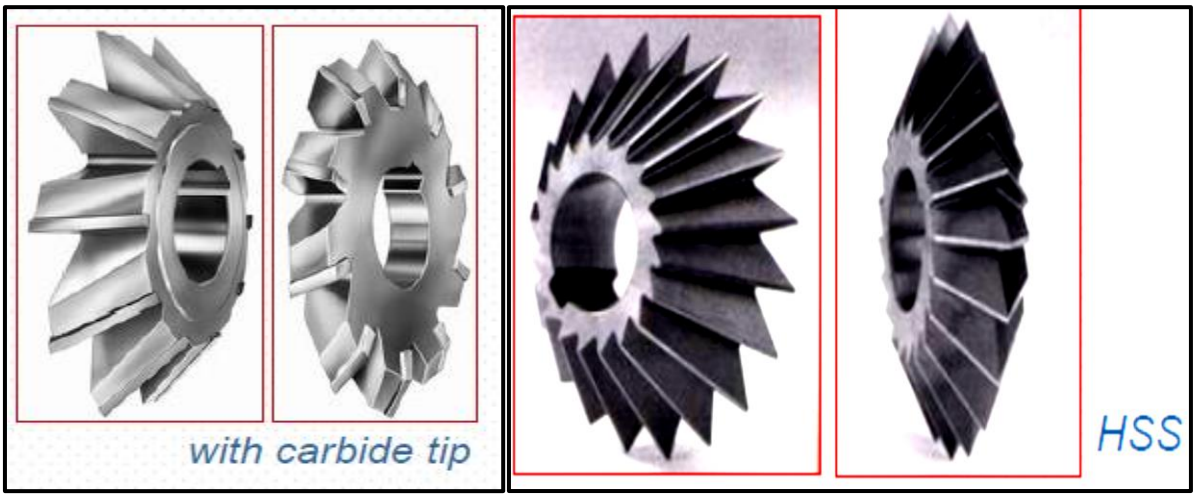
1. Plain Milling Cutters

2. Side Milling Cutters

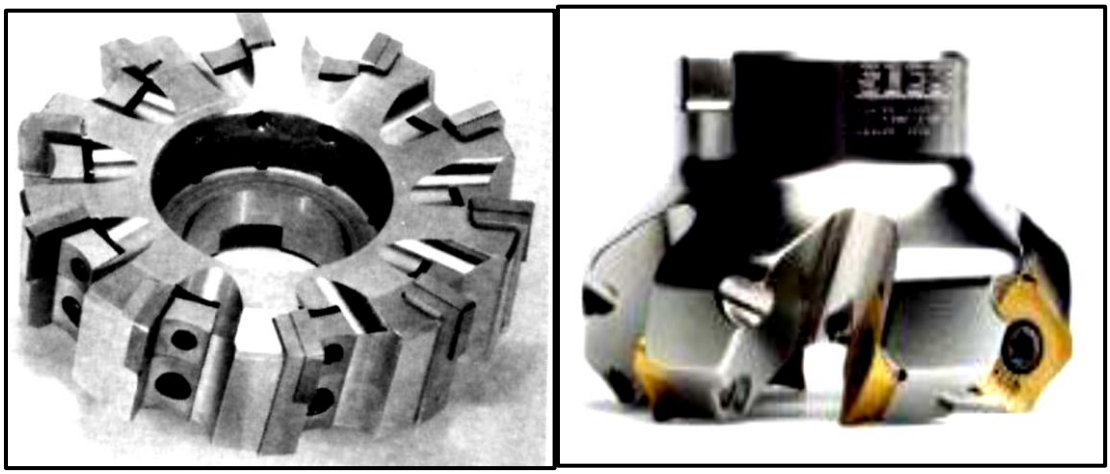
3. Staggered Tooth Milling Cutters

4. Slitting Saws

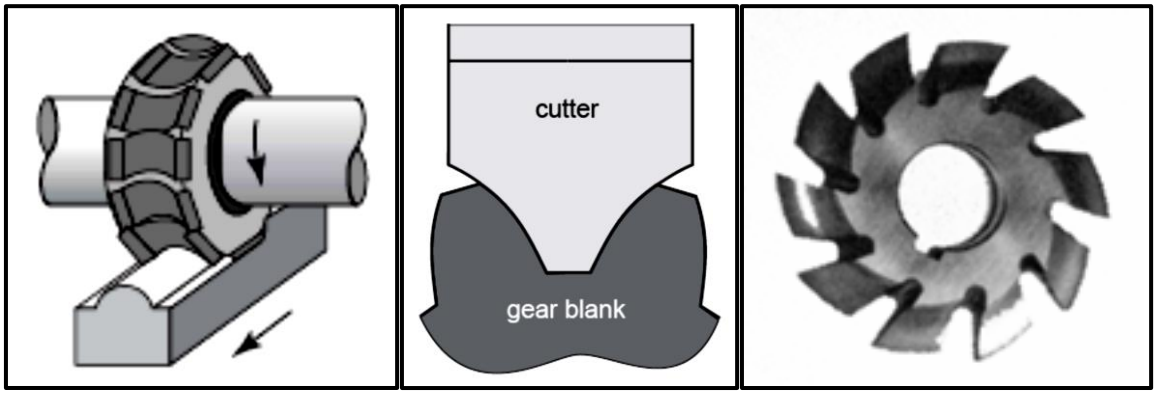
5. Angle Milling Cutters The V-angle usually is 45°, 60°, 90°.



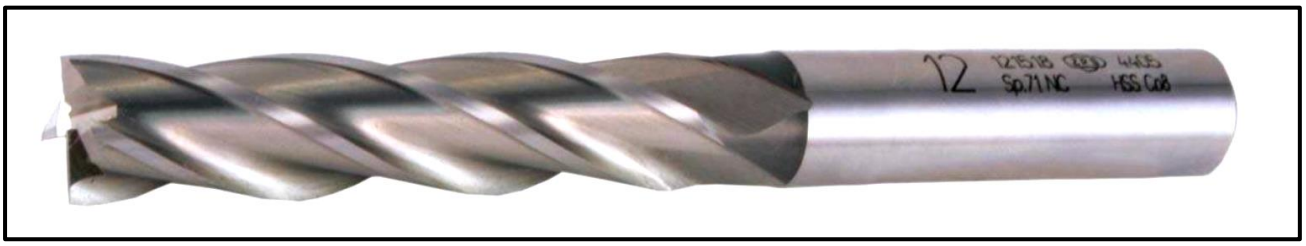
6. Inserted-Tooth Milling Cutters



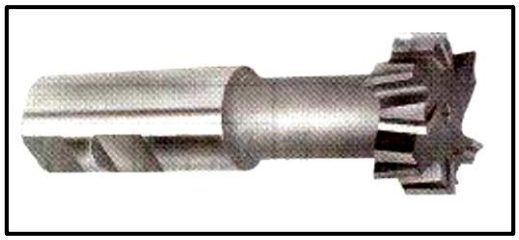
7. Form Milling Cutters

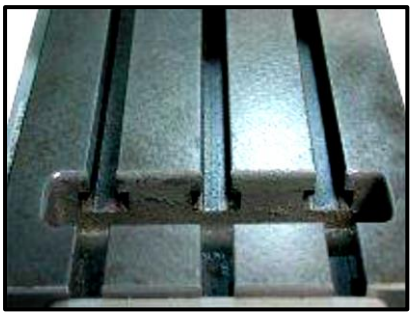


8. End Mills

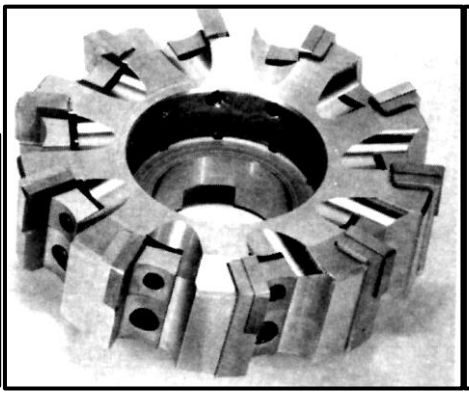


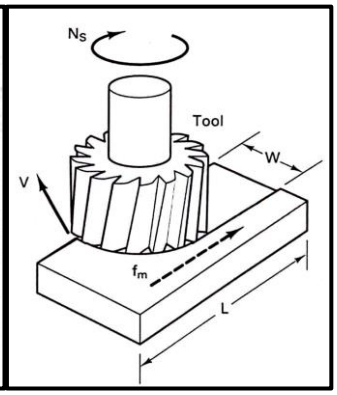
9. T-Slot





10. Facing Cutters

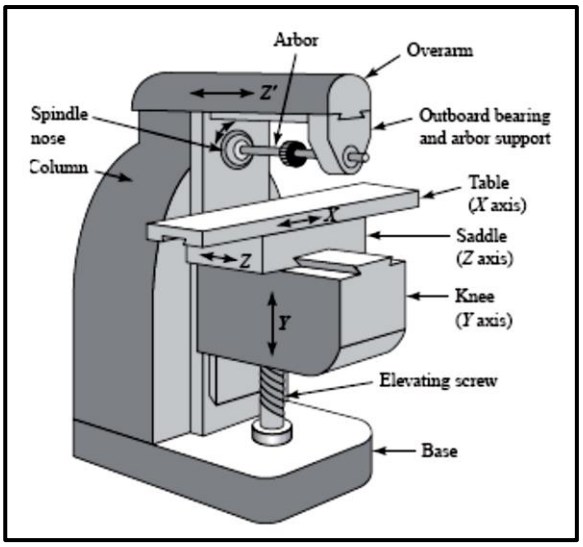




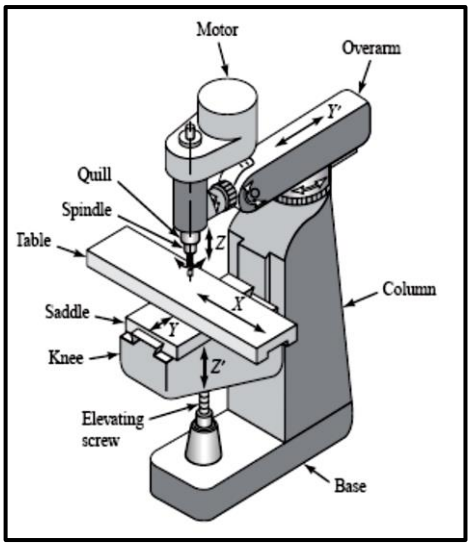
1.8.3 Milling Machines

1. Column-and-Knee Type Milling Machines 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.

Milling machines having the three perpendicular table motions. 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



Horizontal milling machine



Vertical milling machine

2. Bed-Type Milling Machines

3. Planer-Type Milling Machines

4. Rotary Table Milling Machines

5. Profilers and Duplicators 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.

1.8.4 Work-holding for milling operations

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. Several types of fixtures are commonly used to hold parts while milling them.

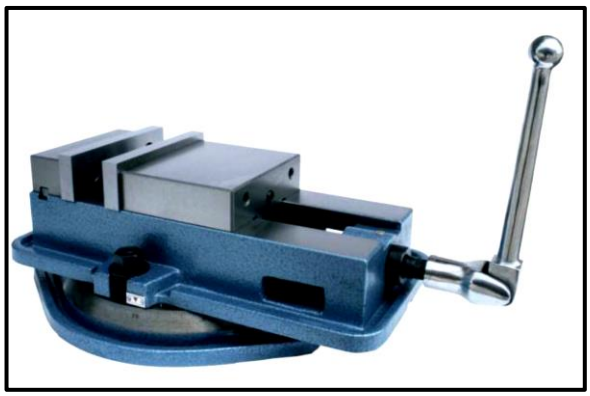


Figure. A vise is the most common fixture

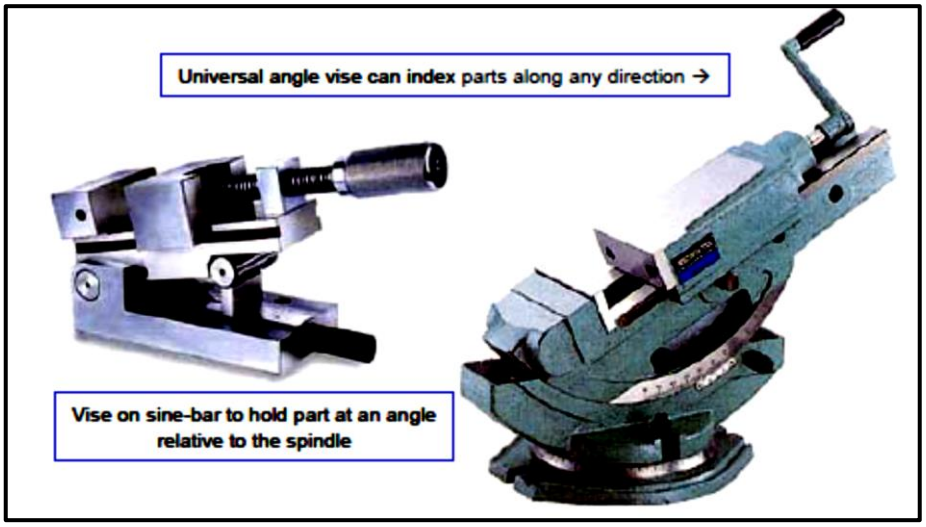


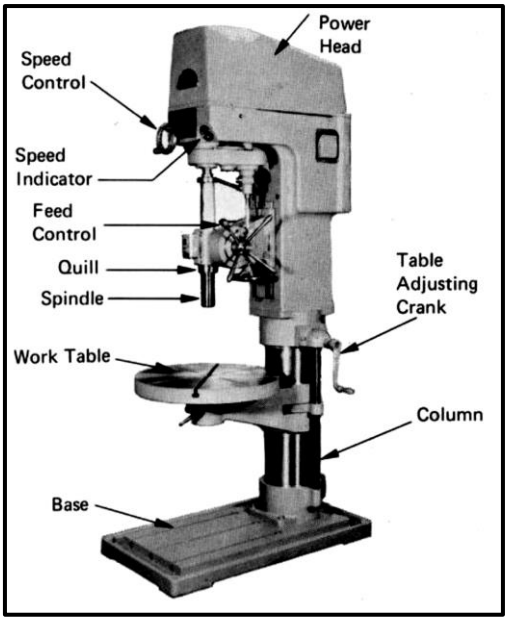
Figure. Indexing vises can hold parts at a given orientation to the spindle

1.9 Drilling Processes

Drilling is a widely used manufacturing process for hole making. Although it seems to be a relatively simple process, substantial difficulties are encountered due to poor heat and chip removal. There are also difficulties in feeding the coolant to the cutting zone. Drilling can also be made by using a **lathe**, or **boring machine**.

1.9.1 Drilling, Reaming, Boring, Tapping

These four methods all produce holes of different types. Drilling produces round holes of different types; reaming is used to improve the dimensional tolerance on a drilled hole; boring uses a special machine operating like a lathe, to cut high precision holes; and tapping creates screw-threads in drilled holes.

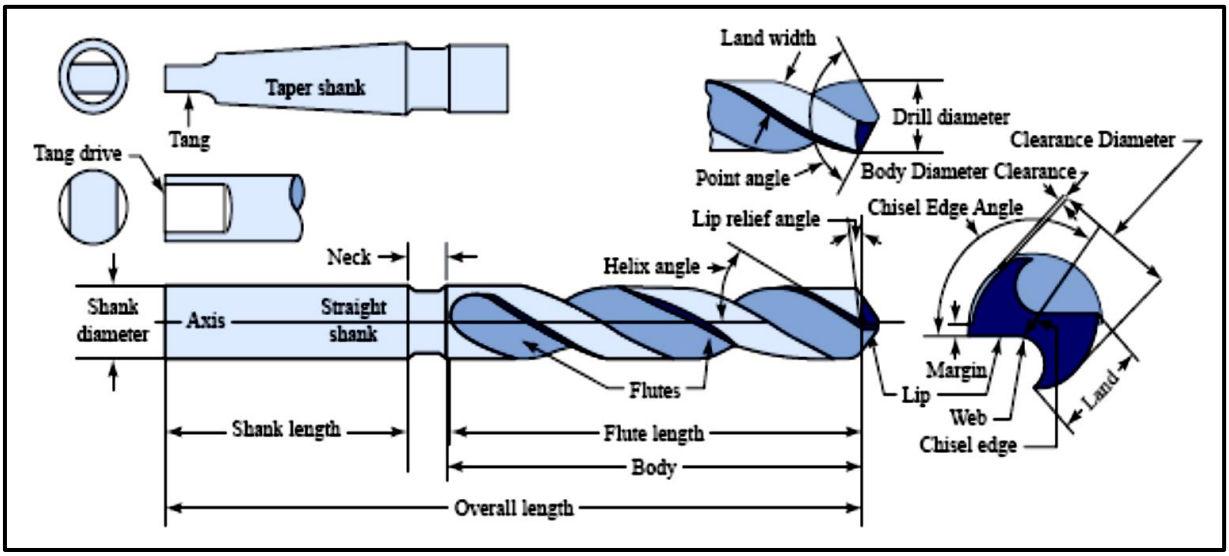


Drilling machine

Drilling process

Twist Drill

The most common types of drills are twist drills. They are made from HSS. They have three basic parts, namely the **body**, **point** and **shank**. The body contains two or more spiral grooves, called **flutes**, and solid sections called **lands**, in the form of a helix. The **lands** terminate in the **point**, with the leading edge of each land forming a **cutting edge**.



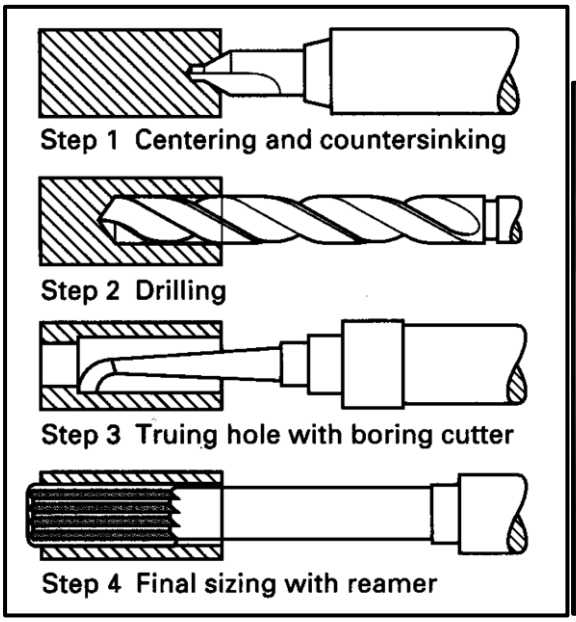
Geometry of a drill

Accurate Hole Making

If accuracy in these respects is desired, it is necessary to follow **center drilling** and **drilling** by **boring** and **reaming**. Boring trues the hole alignment, whereas reaming brings the hole to accurate size and improves the surface finish.

Boring

Boring is enlargement of an existing hole. Therefore, before boring, the hole must be made by using one of the hole making methods (e.g. drilling). Boring trues (corrects) the hole alignment. Makes hole concentric with the axis of rotation of the workpiece. Surface quality of the hole is improved.



Boring cutters

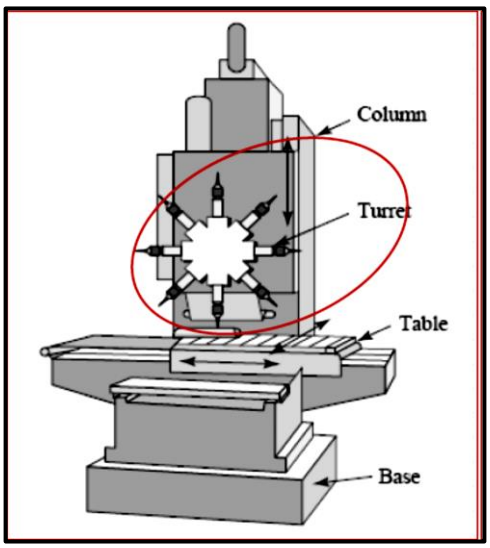
1.9.2 Drilling Machines

Basic components of a typical drilling machine are, base, column, power head, spindle, and worktable.

1. Bench-Type Drilling Machines

2. Turret-Type Drilling Machines

They have a turret which is capable of holding and indexing a number of tools. Used where a series of holes of different size, or series of operations (such as center drilling, drilling, reaming, and spot facing) must be done repeatedly in succession.

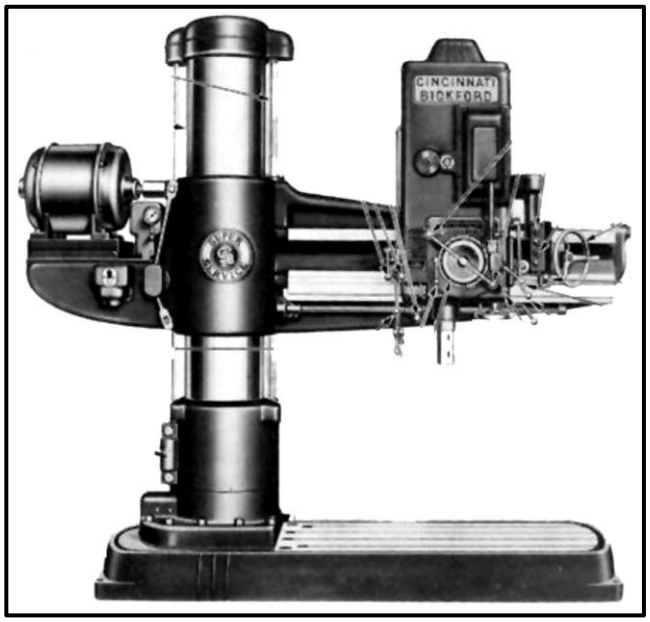


Turret-Type Drilling Machines

3. Radial Drilling Machines

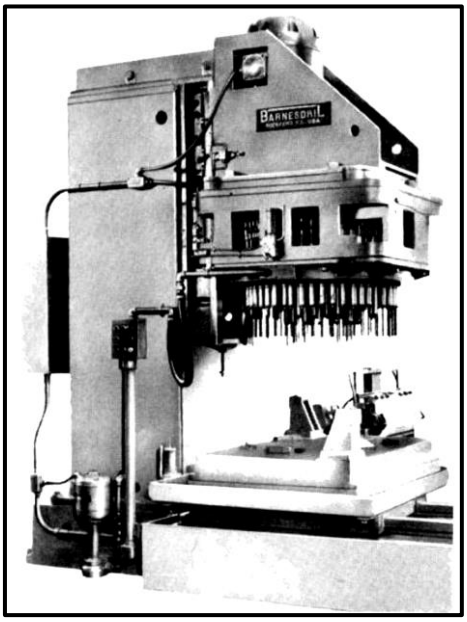
Used when holes are to be drilled at different locations on large workpieces which cannot be easily moved and clamped on upright drilling machines. Have a large,

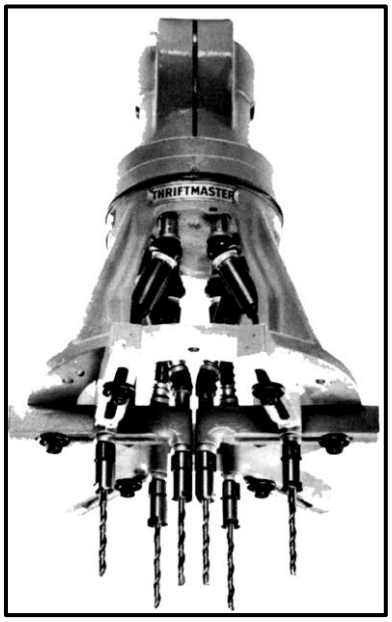
heavy, round, vertical column supported on a large base.



4. Multiple Spindle Drilling Machines

Used if a number of parallel holes must be drilled in a part. These are mass production machines with many spindles driven by a single powerhead and fed simultaneously into the work.





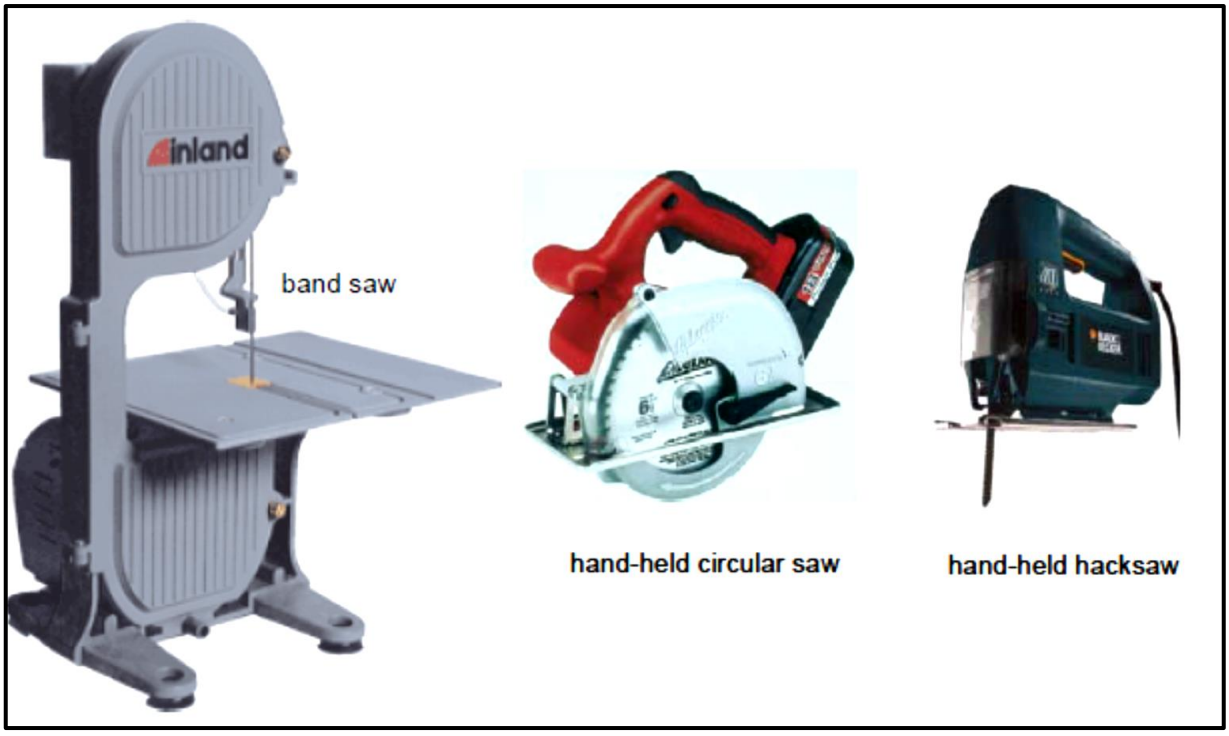
1.10 Sawing processes

Sawing is used to cut the correct sized workpiece from a large raw material stock. There are several types of saws.

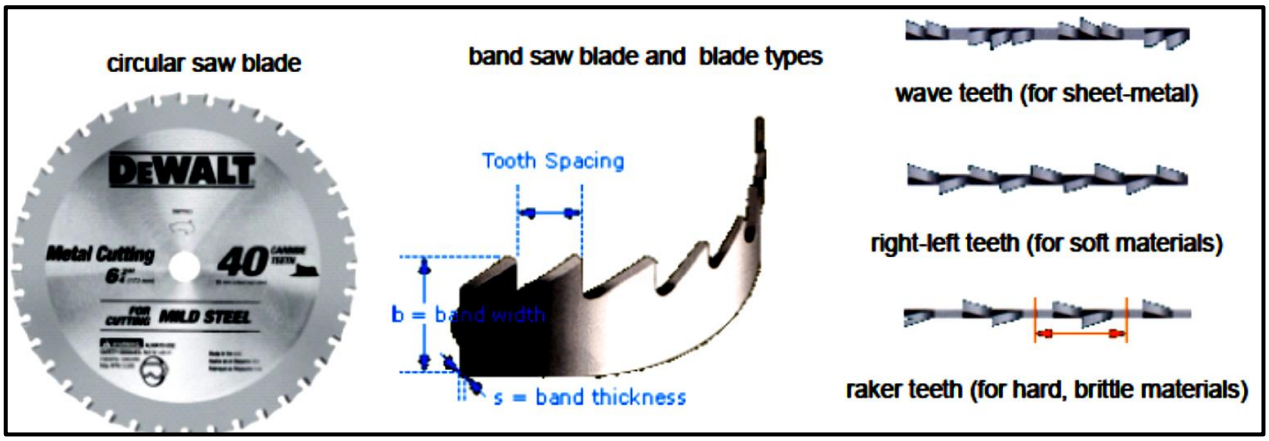
***Hacksaws*:** straight blade, moving in a reciprocating motion;

***Bandsaws*:** straight blade, ends welded together to make a loop, moving continuously in one direction;

***Circular saws*:** blade in the shape of a circular disk, rotating continuously.



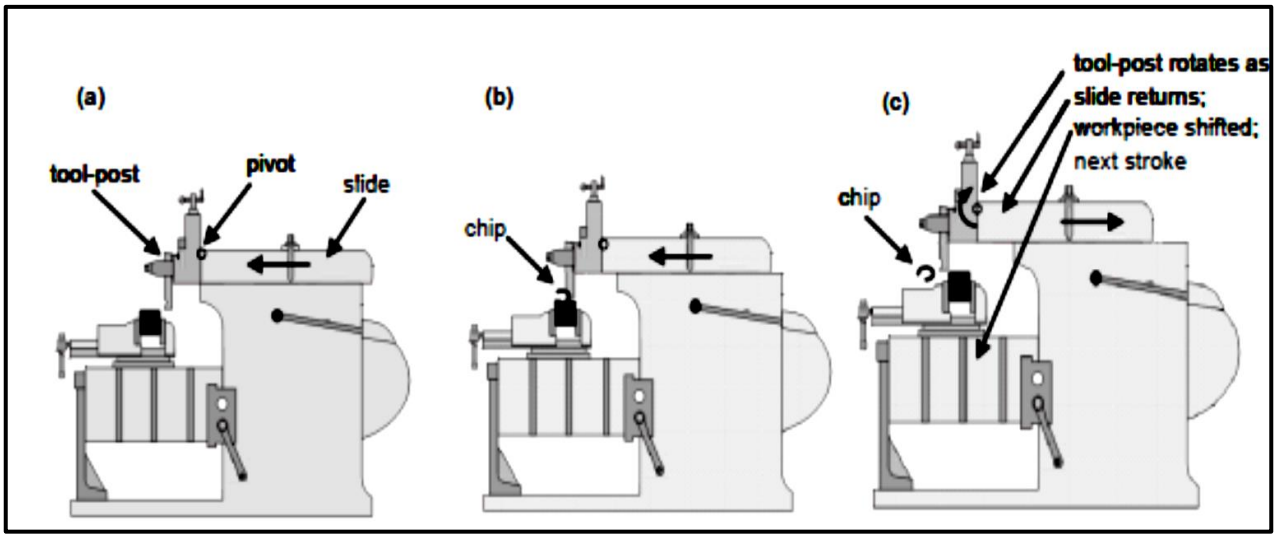
Types of saws



Types of saw blades

1.11 Shaping processes

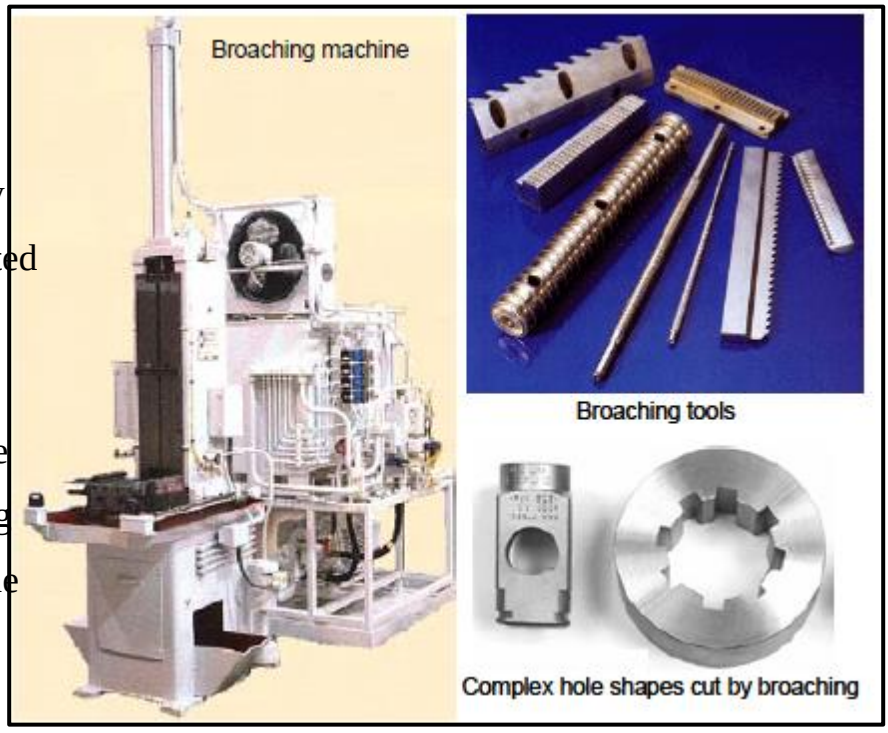
Shaping uses a single-point tool that is moved horizontally in a reciprocating motion along a slide. It is used to create a planar surface, usually to prepare rectangular blocks that can later be used as workpieces for machining on a milling machine etc.



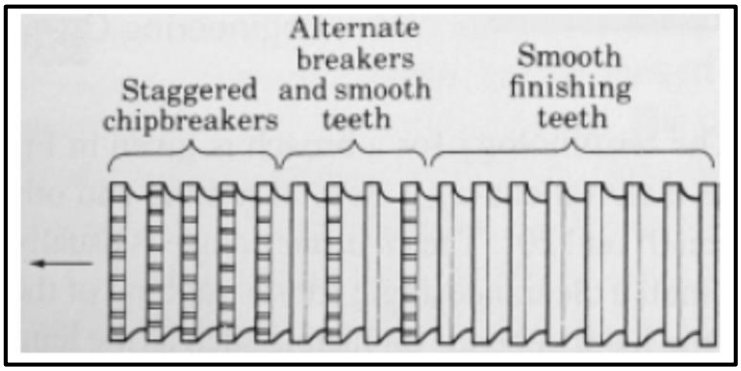
Shaping machine and shaping operation

1.12 Broaching processes

Broaching is capable of mass-production of complex geometry parts, especially when complicated hole-shapes are required to be machined. The broach tool has a series of cutting teeth along the axis of the tool. As the broaching tool is pulled with force along the part to be cut, each tooth cuts a tiny chip. Thus the first few sets



of teeth to engage the part remove most of the material, which the last few provide a finishing cut with very small amount of material removal.



Broaching cutter details

1.13 Grinding and other Abrasive machining processes

Abrasive machining uses tools that are made of tiny, hard particles of crystalline materials – abrasive particles have irregular shape. The effect is resulting in ***very good surface finish*** and ***excellent dimension control***, even for hard, brittle workpieces. The main uses of grinding and abrasive machining:

1. To improve the surface finish of a part manufactured by other processes
2. To improve the dimensional tolerance of a part manufactured by other processes
3. To cut hard brittle materials
4. To remove unwanted materials of a cutting process

1.13.1 Grinding Abrasive materials

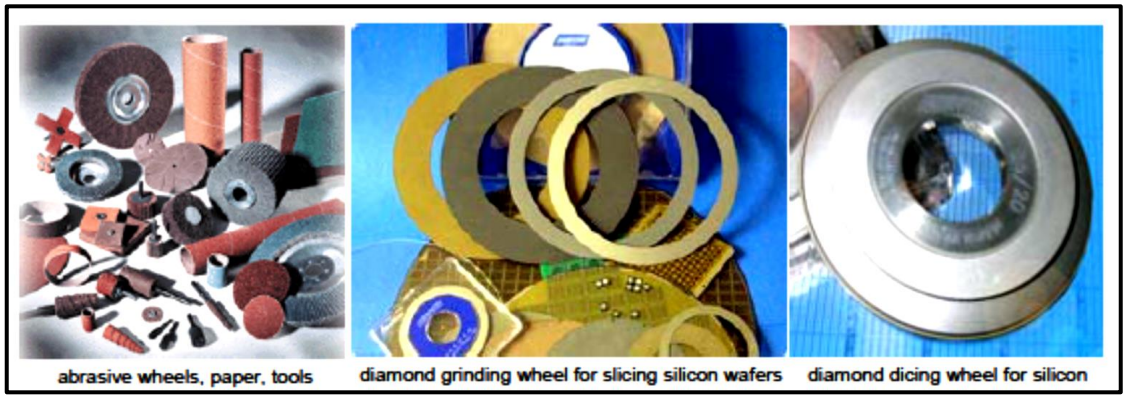
Common abrasive materials are Aluminum Oxide and Silicon Carbide. For harder materials and high precision applications, super abrasives (Cubic Boron Nitride, or CBN, and diamond powder), which are extremely hard materials, are used.

Abrasive materials have two properties: high hardness, and high friability. Friability means that the abrasive particles are brittle, and fracture after some amount of use, creating new sharp edges that will again perform more abrasion.

Abrasive material	Work material
Aluminum oxide	
97-99% Al_2O_3 hardened steels, 87-96% Al_2O_3	hardened steels, HSS steels, cast iron
Silicon carbide	
96-99% SiC	HSS, cemented carbides
<96% SiC	aluminum, brass, brittle materials
Cubic boron nitride (CBN)	tool steels, aerospace alloys
Synthetic diamond	ceramics, cemented carbides

1.13.2 Abrasive tools

Figure in the following shows several types of abrasive tools. They all contain abrasive grains that are glued together using resin or hardened rubber. Sometimes, the abrasive particles may be embedded in metal or ceramic. It is important for the bonding material to be softer than the abrasive.

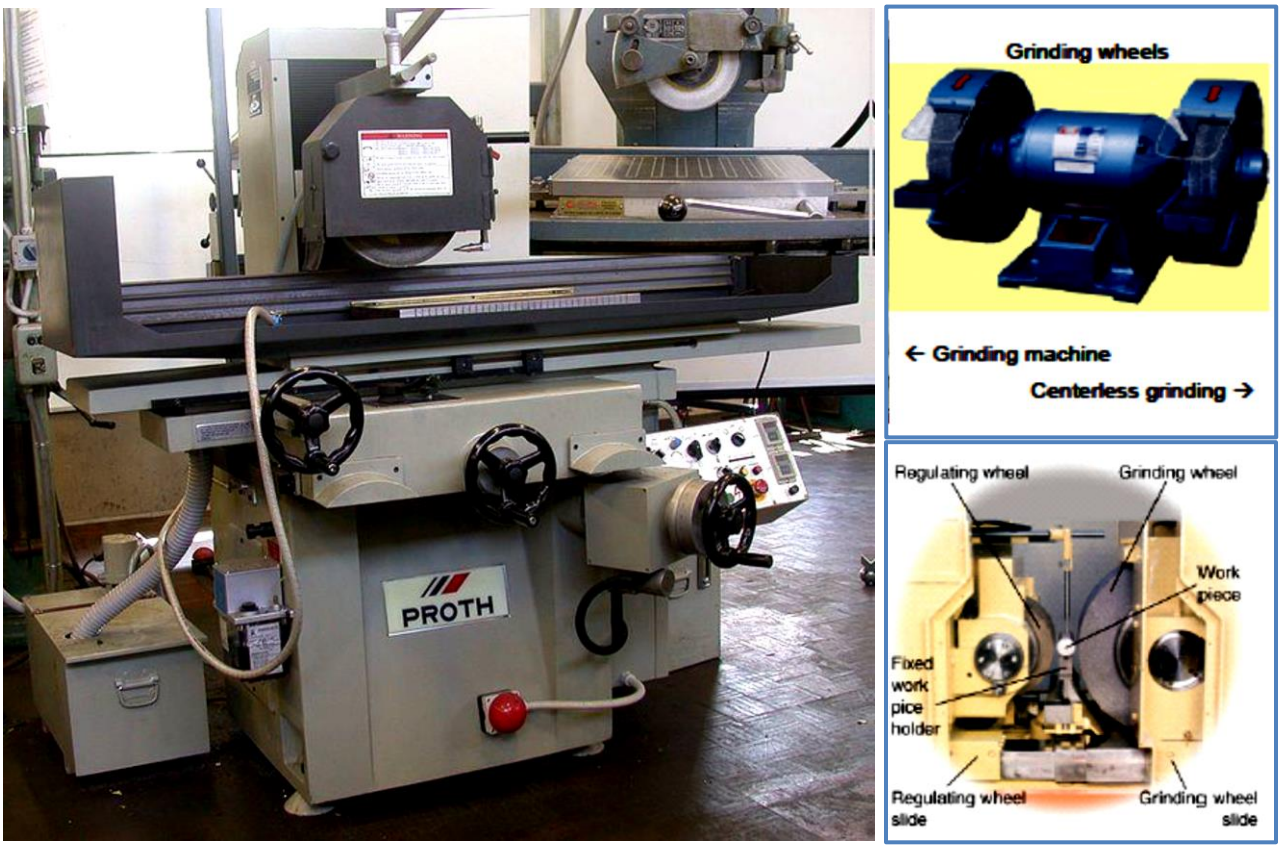


Different types of abrasive tools

1.13.3 Grinding machines

There are several types of grinding machines. The main ones are surface grinders, grinding wheels, cylindrical grinders and centerless grinders. Surface grinders produce flat surfaces. The part is held on the flat table (steel parts can be

held by a magnetic force – this is called ***magnetic chucking***). The table moves in a reciprocating motion (±X-axis), and the rotating wheel is lowered (Z-axis).



Some grinding machines

1.14 Honing Processes

Honing is a finishing operation used to improve the form tolerance of a cylindrical surface – in particular, it is used to improve the cylindricity. The honing tool is a metal bar holding a set of grinding stones arranged in a circular pattern. The tool brushes along the cylindrical part surface by rotating, and moving up-and-down along its axis. You can identify a honed surface by looking for the helical cross-hatched scratch marks on the part surface.

Honing tools

1.15 Lapping Processes

Lapping is a finishing operation. The lapping tool is made of metal, leather, or cloth, impregnated with very fine abrasive particles. Lapping operations use a flat metal disc that rotates a small distance above the part. The gap is filled with slurry containing fine abrasive grains. The rotation of the disc causes the slurry to flow relative to the part surface, resulting in very fine surface finish. This process gives dimensional tolerances of $\geq 0.5\mu m$, and surface finish of up to 0.1 μm.

Small lapping machine

Lapping machine and retention jig