required thread angle and mounting the cutter, which must be on the centre line of the lathe and at right angles to the work.

2. Set up the work. It must be chamfered to produce a clean start to the thread.
3. Take a light trial cut to check whether the desired pitch is being cut.
4. Take the first cut to the required length. Use the chasing dial when engaging the half nut. Engage on 1 or 3 if the thread has a pitch of odd number and 2 or 4 for a pitch of even number.
5. At the end of the cut, withdraw the tool from the work with the cross-slide handwheel.
6. Traverse the carriage back so that the tool is just past the end of the work in readiness for the cut. If the lathe is not fitted with a thread-chasing dial or when cutting metric thread on an English lathe, once the half nuts have been engaged for taking the first cut, they must remain engaged during the entire operation. In this case, the carriage is returned for each new cut by reversing the whole machine. This means reversing the rotation of the work. This will ensure correct pick-up at each pass.
7. When the thread has been cut to the required depth, use a thread chaser of the corresponding pitch to trim up the thread form while the lathe speed is increased.
8. Take off the work and clean up the machine.

The milling machine

The milling machine is one of the classes of machine tools that remove metals by feeding the work against a revolving cutting tool.

Types of milling machine

There are two types of milling machine: horizontal and vertical.

The **horizontal milling machine** is the most popular machine, commonly found in schools and colleges (Figure 13.47). It has an overhang, called a **knee**, which slides up and down the front of the machine and to which the cross-slide and the adjustable worktable are attached. It has a horizontal arbor onto which the cutter is fixed.

The horizontal machine is manufactured in two types. The worktable of the **universal machine** may be swung round in the same way as a machine vice. This enables the machine to be used for cutting helices, such as the flutes of a twist drill. It is normally supplied with a dividing head and a vertical head as well, which enables vertical milling operations to be carried out. The **plain pattern** is often made on more robust lines, and is used mostly in industry for production work, where heavy cuts are required, rather than a wide range of movements.

Figure 13.48 shows the horizontal milling machine in use.

The **vertical milling machine** has a vertical head, and the cutter is fixed into a spindle that is normally in a vertical position (Figure 13.49). The worktable traverses perpendicular to the vertical axis of the machine.

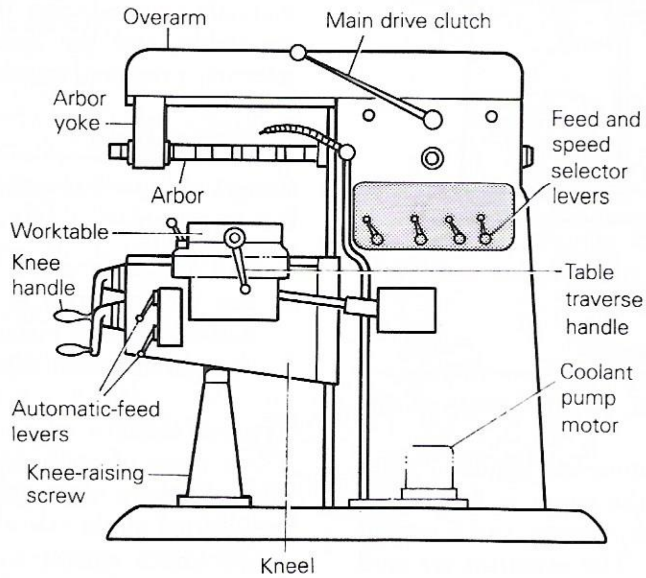

Figure 13.47 Horizontal milling machine.

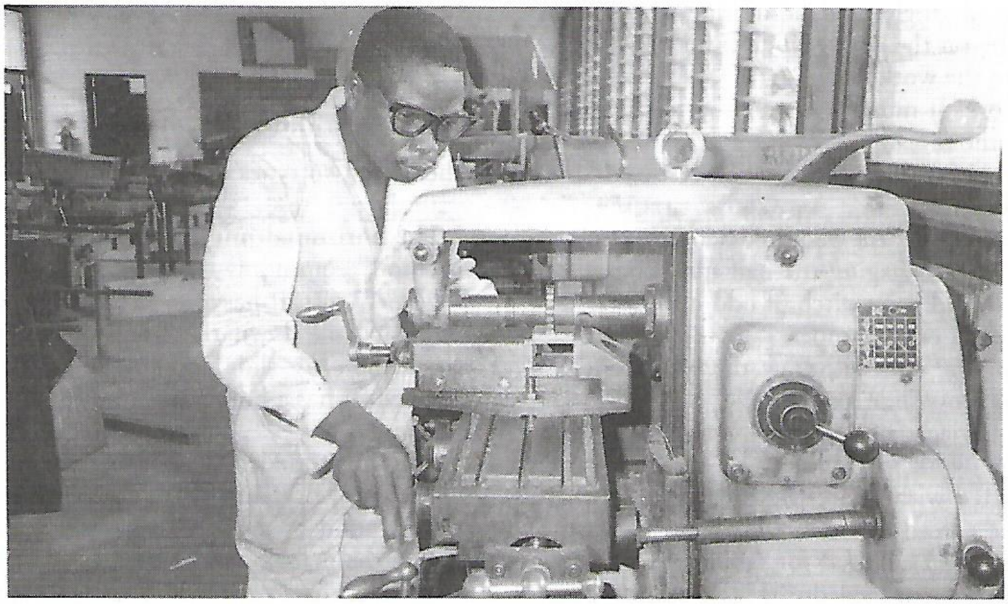

Figure 13.48 Horizontal milling machine in use.

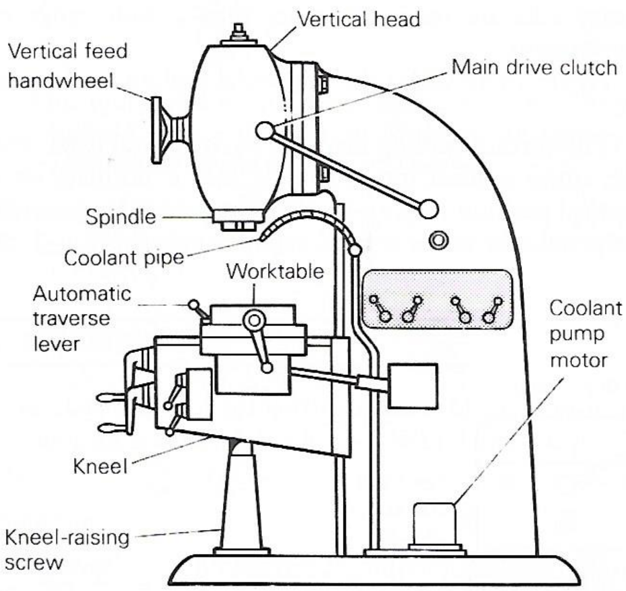

Figure 13.49 Vertical milling machine.

Parts of the milling machine

The following are some of the essential parts of the miller.

The **arbor** is between the column and the outer arbor yoke. It is on the arbor that the cutter is fitted. The **outer arbor yoke** is at end of the overarm, and is used as an outer support for the arbor. The **overarms** are used for positioning the outer arbor yoke. The **worktable** is used for holding the work. It traverses perpendicular to the arbor. The **knee** is the overhang in front, that carries the worktable; it slides up and down.

The **knee adjustment handle** (lever) is used to move the vertical feed of the table, but is automatically disengaged whenever the power feed is engaged. The **table traverse lever** (or handle) is used to control the direction of movement of the table. It also controls longitudinal feed. The **automatic-feed lever** is used to engage and disengage the automatic mechanism of the worktable. The **main drive clutch** is used for starting and stopping the arbor of the horizontal miller or the spindle arm of the vertical miller. The **feed selector lever** is used for increasing or reducing the automatic-feed rate of the worktable, and the **speed selector lever** is used for selecting a required speed of the arbor or spindle.

Milling cutters

Ranges of cutters in various forms are made of the following metals:

1. tool steel, carbon tool steel and high-speed steel;
2. cast tool materials – cast high-speed steel and cast non-ferrous tool materials;
3. sintered or cemented carbide tool materials.

Types of teeth

Three types of teeth are used in the manufacture of milling cutters: the saw tooth, the formed tooth, and the inserted tooth.

Saw tooth cutters are the cheapest type. They are produced in either straight or spiral form. Saw teeth are used for making metal-slitting cutters and smaller sizes

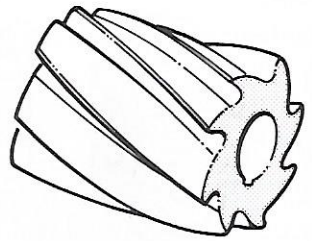

Figure 13.50 Plain helical milling cutter.

of plain milling cutter. The cutting edge is backed off for about 5° to give clearance. The teeth may be either form-relieved or profile-ground.

For **form-relieved** milling cutters, the clearance angle is produced during manufacture in a relieve machine. When sharpening a form-relieved cutter, it is necessary to sharpen on the face of the tooth to preserve the clearance angle and the contour of the profile. For **profile-ground** cutters, the profile of the tooth is ground to the exact shape desired.

Form tooth cutters are used for finishing irregular shapes to an exact outline. A formed cutter is made by leaving a land or relieving a land of a considerable width between the grooves and then backing off or relieving the land eccentrically. The formed cutter may be used with other cutters, to make up a **gang**. The main advantage of the formed cutter is that it can be sharpened many times without changing the shape of the cutting edge.

In the **inserted tooth cutter**, the teeth forming the cutting blades, made of high-speed steel, are inserted and rigidly held in a mild steel or cast iron blank. These cutters are economical in cost; worn-out or broken blades can be easily replaced by new blades. This is an economical way of making large cutters.

Categories of milling cutter

Milling cutters may conveniently be divided into three main classes: plain cutters, face mills and form cutters.

Plain cutters include cylindrical slab cutters, with parallel teeth on the periphery, and **helical** or **spiral mill cutters**, with spiral teeth around the periphery (Figure 13.50).

Face mills (Figure 13.51) include:

1. **face mills**, particularly thin plain cutters in the family of both the slitting cutter and the side cutter;
2. **shell end mills**, with diameters over 25 mm and detachable from the shank;
3. **slotting cutters**, with cutting edges on both of the sides and on the face, like the slab cutter but thinner;
4. **slitting saws**, similar to the slotting cutter but thinner and with no cutting edges on the sides; mostly used for slitting (cutting) metal pieces;

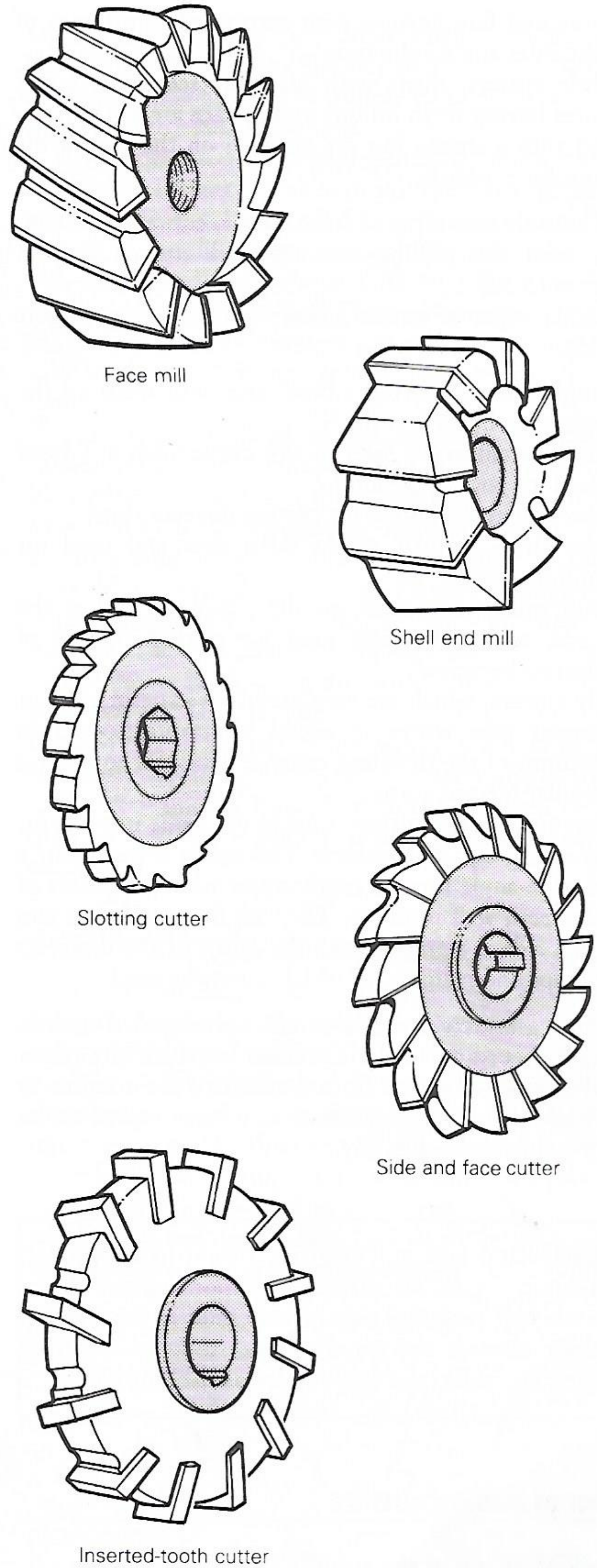

Figure 13.51 Face mills.

5. **side and face cutters**, with cutting edges on both of the sides and on the face;
6. **face cutters**, made with inserted teeth. The larger sizes having teeth on one end or face are not provided with a shank, but are fastened on the end of the machine spindle.

There are two types of **form cutter**, concave and convex, used for milling concave and convex grooves (Figure 13.52).

Other types of cutter include the following (Figure 13.53):

1. **angle cutters**, having a bevel face with teeth on the side as well;
2. **tee-slot cutters**, a kind of slot cutter with a T-head used for cutting T-slots;
3. **dovetail cutters**, used for cutting dovetail slots;
4. **slot drills**, similar to the twist drill and used for milling slots;
5. **end mills**, with teeth on the periphery and at the ends, and particularly used for vertical milling of slots or keyways;
6. **fly cutters**, which are very useful for experimental or urgent jobs where it would be impracticable on account of the time and expense necessary to make a regular formed cutter;
7. **tap and reamer cutters**, used as the name implies; for grooving taps and reamers. This cutter is essentially a double-angle formed tooth cutter with the points of the teeth well rounded. They are in several sizes and each side is stamped with the range of the diameter of taps and reamers for which it may be used.

Milling cutters are said to cut right-handed or left-handed according to the direction in which the cutter revolves when observed from the back of the machine or the back of the cutter. Cutters may be mounted on an arbor to be used either way.

> A left-hand end mill is given a right-hand spiral and vice versa, so that the reaction against the tooth as it peels the chip off will tend to force the cutter towards the spindle rather than loosen it. The same principles apply to spiral slabbing mills.

Holding milling cutters

Standardisation of the spindle end

The main drive of the spindle of the milling machine takes the cutter with it. The spindle is designed to hold and drive the cutter, whether it is arranged on an arbor,

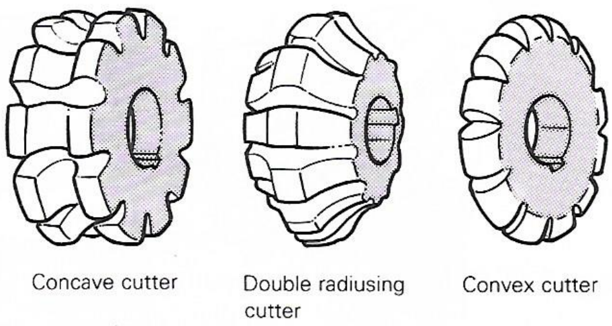

Figure 13.52 Form cutters.

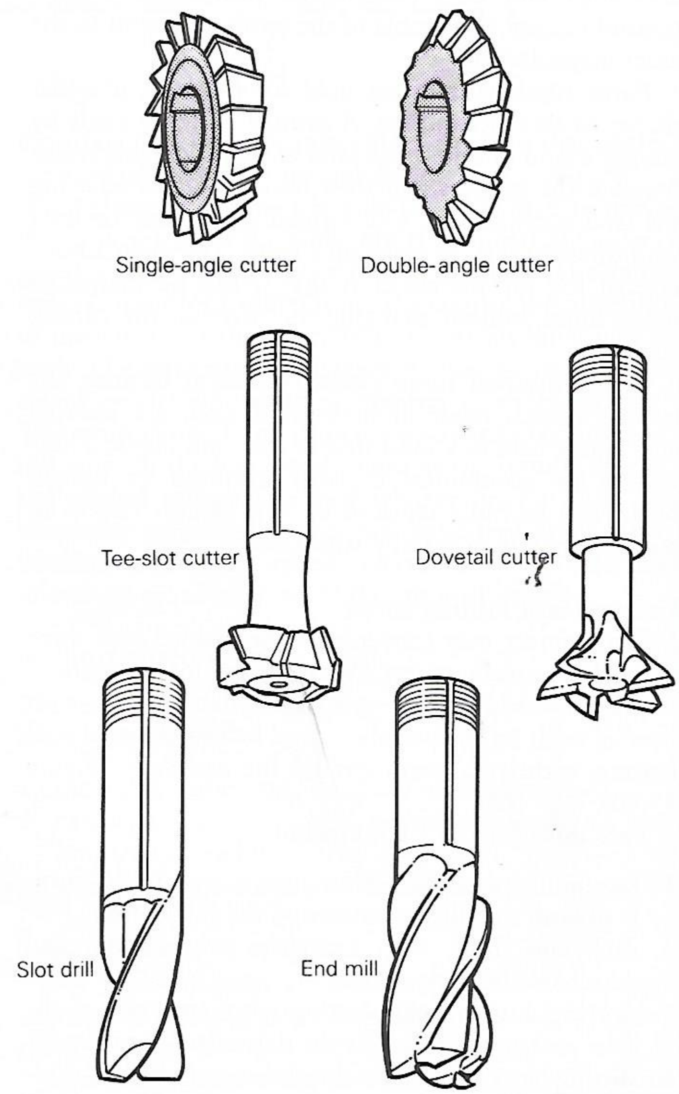

Figure 13.53 Various types of milling cutter.

in an adapter, in a collet, or screwed on the nose of the spindle.

Apart from ensuring that all arbors and face-milling cutters are interchangeable in all makes of milling machines, and eliminating the great variety of different sizes and types, standardisation has retained and improved the best features of the older design.

The arbors are driven by two lugs instead of depending upon the hold of the taper plus the tang. A draw-in bolt is used to pull the arbor tightly in place, irrespective of any chance of spoiling the arbor. To remove the arbor, just loosen the draw-in bolt, hold the bolt head lightly and then completely unscrew the bolt. Unscrew and remove the arbor yoke, then pull out the arbor. The entering end of the arbor is straight and fits the straight part of the spindle nose in order to have the threaded hole in line when fixing in the drawbolt.

Adaptors are manufactured to allow the use of older types of arbor, etc. in new machines. An extension threaded end is provided on the drawbolt for holding certain kinds of adapter. Face-milling cutters are held centrally on the spindle end, held by four bolts and driven by the two lugs.

When fixing cutters to the arbor, you need to take certain precautions:

1. Cutters should be as near the column as possible, as it is firmer there than at the far end of the arbor.
2. Fit a suitable set of spacing collars to cover the first two or three threads of the arbor so that the nut can hold them tightly in position.
3. Make sure that both the bores and the faces of the cutter and collars are clean. Dirt trapped between them will reduce the holding power by which the cutter is driven, and could cause the cutter to get out of line or, in the case of a slotting cutter, to produce a groove greater than its normal width.
4. The arbor nut must not be tightened when the arbor yoke is not in position, as this can cause the arbor to pull out of alignment, resulting in the cutter's running eccentrically and seriously reducing the efficiency of the machine.

Factors influencing efficient and economical operations

The following factors must be considered when deciding to perform milling operations.

The **milling machine** must be of strong construction, so that it can absorb both the forces and the shock from the cutting action. It should be always in good condition.

A valuable **milling cutter** is the type that can be used for several operations and yet remain in good form. A cutter may be said to be accurate when it can duplicate the required part. The efficiency of a cutter is measured in terms of the number of completed items of work that it can produce per sharpening.

A milling cutter must be dependable, and it must be long-lived. It must be made to suit the job at hand. Use coarse-toothed cutters for heavy operations. For soft and ductile materials choose cutters with large rake angles (10–20°). Smaller rake angles (0–10°) are suitable for hard and brittle materials. The best average rake angle for milling cutters is between 10° and 15°. A cutter with rake angle of 12.5° has proved suitable for all-round work.

The **size and shape of the work** to be machined influence the type of cutter used as well as the permissible feeds and speeds. For thin work use a light cut and a slow feed to avoid vibration or breakage of work. When a cutter with a large spiral or helix angle is used, a smooth cut is produced, which eliminates **hogging in.** This allows the feed to be greater than with cutters that have small spiral angles or straight **gashes.**

The **device for holding the work** must be able to support both itself and the work so that vibration is reduced to a minimum. If the work is not held properly the result will be a poor finish, inaccuracy and chatter.

If a very smooth **finish** is required, the feed must be quite slow so that tooth marks or rotation marks will be eliminated.

Classification of milling methods

There are two distinct methods of milling: conventional or up-milling and climb milling or down-milling

In **conventional milling** (Figure 13.54), the work is fed against the rotation of the cutter, creating a force that lifts the work into the cutter, which is forced down into the work. The thickness of the milled chip increases uniformly at the top (end) of the cut. This process is sometimes called **up-milling** or **up-cut.**

In **climb milling** (Figure 13.55), the work is fed in the same direction as the movement of the cutter. Here

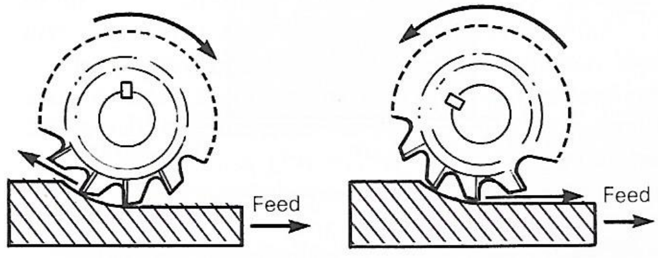

Figure 13.54. Left Conventional milling.
Figure 13.55. Right Climb milling.

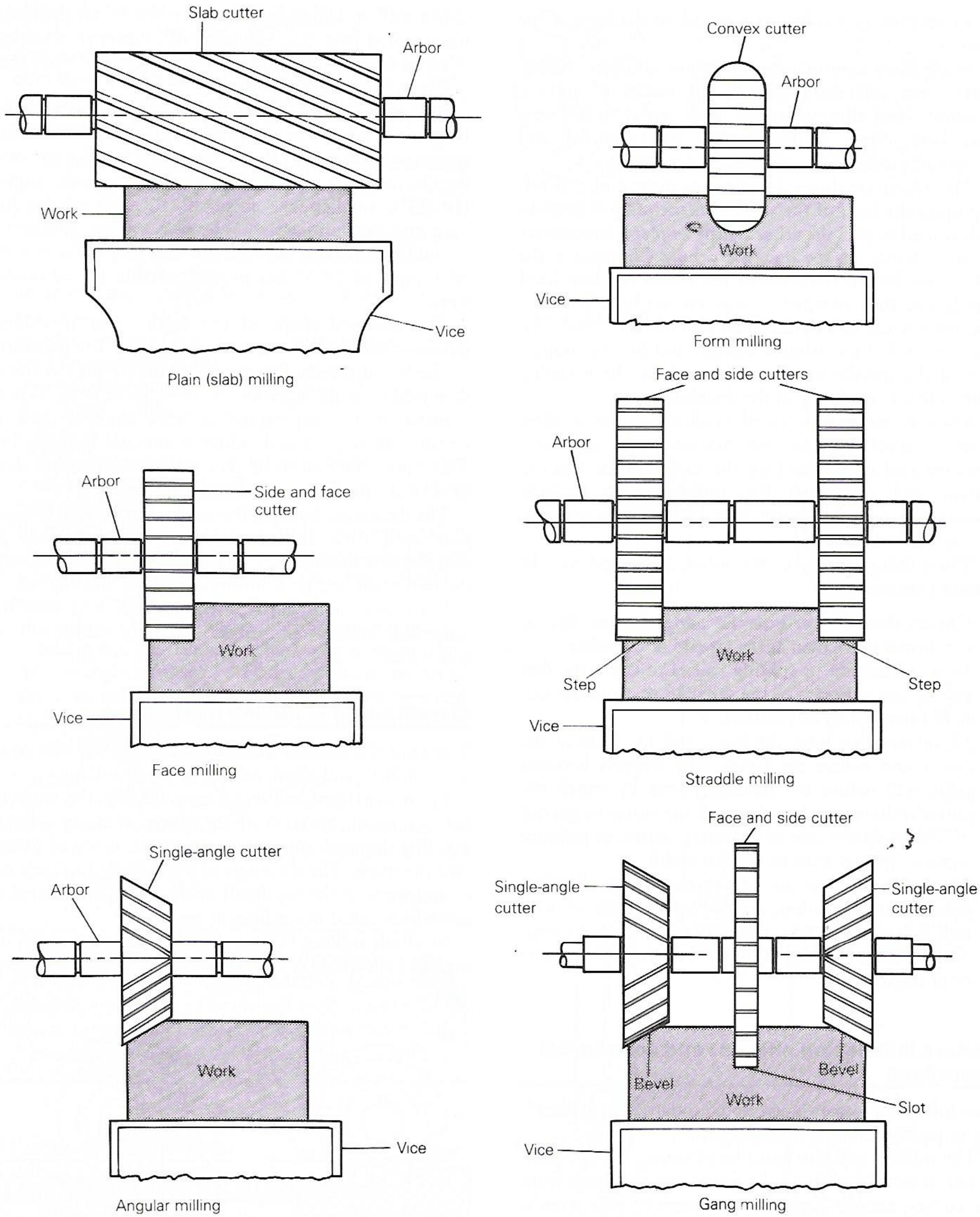

Figure 13.56 Common milling operations.

the cutter has a tendency to get away from the work, pushing the work down against its supporting surface. The thickness of the chip decreases uniformly from a minimum at the top (beginning) of the cut to zero at the bottom (end) of the cut. Climb milling has the following advantages:

1. You can use it on many kinds of work, to increase the number of pieces per sharpening and produce a better finish.
2. It increases production, as you can perform milling operations at both ends of the machine table. It allows you to load and unload one holding device while the cutter has engaged the work in another device.
3. Climb milling permits a saw cutter to produce thin slots more satisfactorily than with conventional milling.
4. Work can be held more securely, as the cutter itself tends to force the work into the holding device and against the table.

Common milling operations

The milling machine is a very versatile machine, and you can perform many different kinds of operation on it. Figure 13.56 shows some of the more common milling operations:

1. **plain milling** or **slab milling**: the production of a flat surface parallel to the axis of the cutter;
2. **face milling**: the production of a flat surface at right angles to the axis of the cutter;
3. **angular milling**: the production of a flat surface at an inclination to the axis of the cutter;
4. **form milling**: the production of a surface having an irregular outline, e.g. concave and convex grooves;
5. **milling flutes**: a term applied to the grooving or cutting of flutes on drills, reamers, taps, etc.;
6. **straddle milling**: term applied when two side-milling cutters are used and two sides of the work are milled at the same time;
7. **gang milling**: two or more cutters used together on one arbor;
8. **profiling**: milling to a predetermined outline by means of a guide bar and template;
9. **routing**: milling to a more or less irregular outline while guiding by hand.

There are other more specialised operations, such as sawing, grooving, slotting and gear cutting.

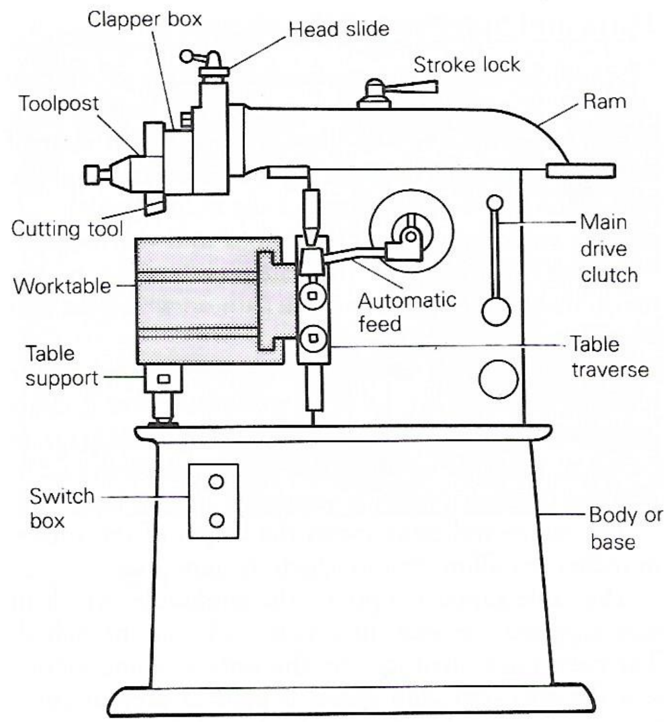

Figure 13.57 The shaping machine.

The shaping machine

As well as the centre lathe, which is used to produce parallel shafts or tapers, the mechanical engineer needs machines to produce flat surfaces. One such is the shaping machine, which is mainly used for the production of flat surfaces, vee grooves, vee slides and keyways (Figure 13.57).

Principles of operation

In the construction of the shaping machine, circular motion is changed to reciprocating motion through a cam, through an eccentric, or through a crank pin.

The crank pin is used in the standard shaper. With this method, the reciprocating motion (forward and backward) is transferred to the ram by the circular motion of the large gear, called the **crank gear** or **bull wheel**, acting through a crank pin and an oscillating arm or rocker arm.

Shapers are classified by size according to the maximum length of the cut that may be taken. Thus a shaper of a given size will hold and machine a cube of that size.