Notes: Milling
Basic Mechanical Engineering
(Part – B, Unit - I)

1 Introduction:

Milling is a machining process which is performed with a rotary cutter with several cutting edges arranged on the periphery of the cutter. It is a multiple point cutting tool which is used in conjunction with a milling machine. This process is used to generate flat surfaces or curved profile and many other intricate shapes with great accuracy and having very good surface finish. Milling machines are one of the essential machines in any modern machine shop.

2 BASIC MILLING PROCESS

Generally, there are two types of milling processes. These are called (*a*) Up milling or conventional milling process, and (*b*) Down milling or climb milling process. Both these processes are illustrated in Fig. 1.

In **up milling**, the direction of rotation of milling cutter and the direction of work piece feed are opposite to each other; whereas in **down milling**, they move in the same direction at the point of contact of the cutter and the work piece. In up milling, the thickness of chip at the start is nil and is maximum when the cutting teeth leave the surface of the work piece. In down milling, it is vice-versa. In up milling, the cutting teeth try to up root and lift the work piece from the machine table, in down milling, reverse happens. Technically, **down milling is a superior process**, but up milling is commonly used. Down milling is not used unless the milling machine is fitted with a backlash eliminator. From Fig.1, basic milling operation can also be understood. The milling cutter is circular and a large number of cutting edges (or teeth) are arranged along its circumference. The cutter is rotated at a speed of *N* r.p.m. If the cutter diameter is *D*, then **cutting speed** at the tip of teeth can be calculated as πDN metres/minute and it should conform to the recommended values. The depth of cut is clearly shown in the figure and the thickness of the work piece will reduce by this amount in one pass. Usually, the width of the milling cutter is more than the width of the work piece, hence one pass is all that is required. Feed of the work piece is measured in terms of mm/minute. Actually, the correct measure of feed is movement of work piece per revolution of cutter per teeth. If a milling cutter has *z* number teeth and if the table feed is '*f*' mm/minute, **feed per rev per teeth** will be f/NZ mm. It should therefore
be clear that metal removal rate in milling operation is much higher than in shaping or planning operations.

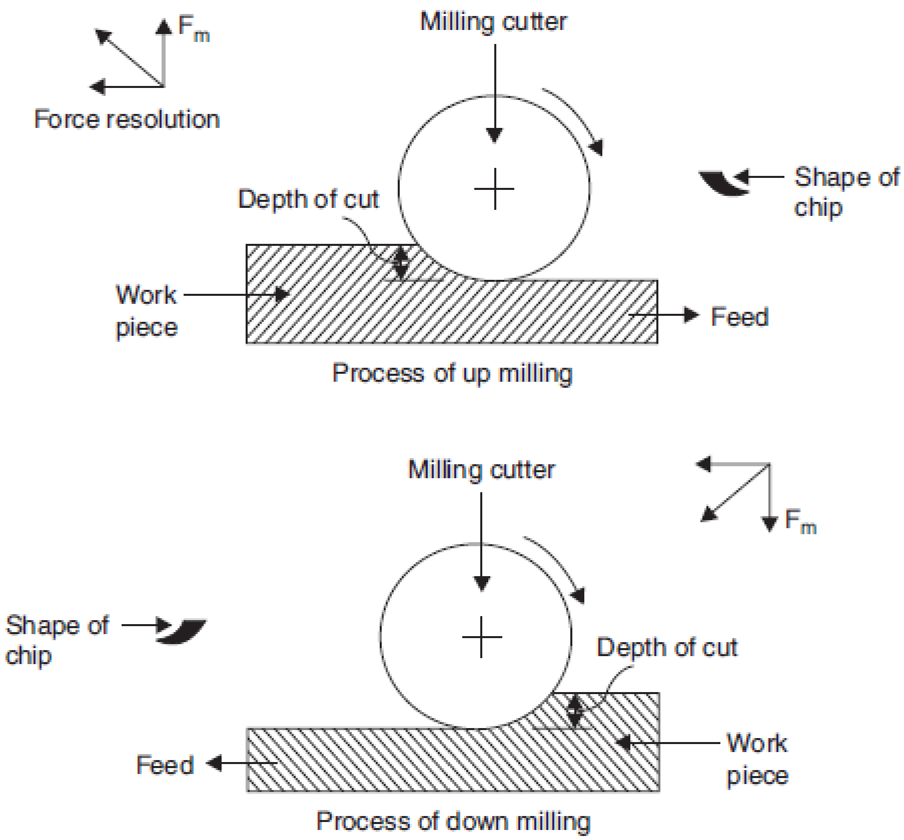


Fig. 1 Up and down milling processes

However, as in shaping or planning operation, the stroke length is always a little more than the length of the job, in milling operation also, the minimum table traverse required is *L* + *D*, where *L* is the length of job and *D* is the milling cutter diameter. *D*/2 is the minimum overlap required on either side of job, so that the cutter becomes clear of the job. Unlike turning, the milling process involves intermittent cutting and the chip cross-section is not uniform. The high impact loads at entry as well as fluctuating cutting force make milling process subject to vibration and chatter. This aspect has great influence on design of milling cutters.

TYPES OF MILLING PROCESSES

The milling process is broadly classified into peripheral milling and face milling. In peripheral milling, the cutting edges are primarily on the circumference or periphery of the milling cutter (in Fig. 4, cutters shown are peripheral cutters) and the milled surface is generally parallel to cutter axis. In face milling, although the cutting edges are provided on the face as well as the periphery of the cutter, the surface generated is parallel to the face of the cutter and is perpendicular to the cutter axis. Refer to Fig. 2; in which both these process have been illustrated.

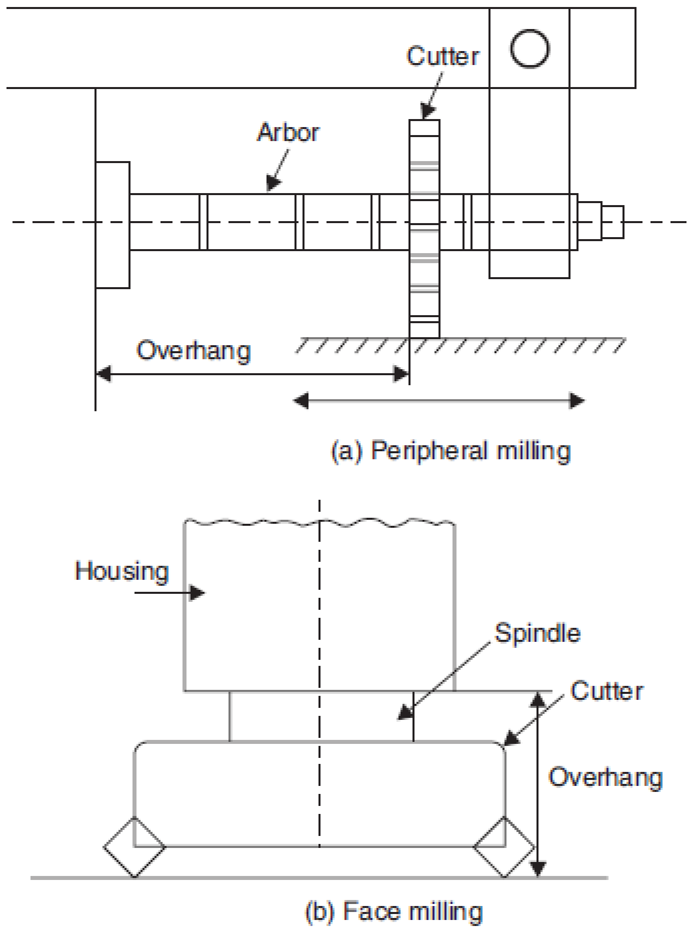


Fig. 2 Peripheral and face milling

The peripheral milling cutters are supported on a long arbor. The deflection of arbor restricts the dimensional and form accuracy of this process. In face milling, the overhang of the cutter is limited resulting in better dimensional control and flatness. Peripheral milling cutters are normally used with a horizontal milling machine whereas the face cutters are used in conjunction with a vertical milling machine. Milling cutters are made of solid high speed steel, or have high speed steel inserts. The cutters are also made, with tungsten carbide blades (either brazed or with throw away inserts).

PERIPHERAL MILLING

Peripheral milling is adopted for the following machining operations:

1. Slab milling to produce flat surfaces.
2. Slot milling to produce precision slots.
3. Side and face milling to machine adjacent horizontal and vertical surfaces simultaneously.
4. Form milling to produce prismatic shape of any form, *e.g.*, involute form in gear cutting.

5. Straddle milling to machine two parallel vertical faces.
6. J Gang milling to machine a number of surfaces simultaneously with a set of cutters.

The various peripheral milling operations are illustrated in Fig. 3.

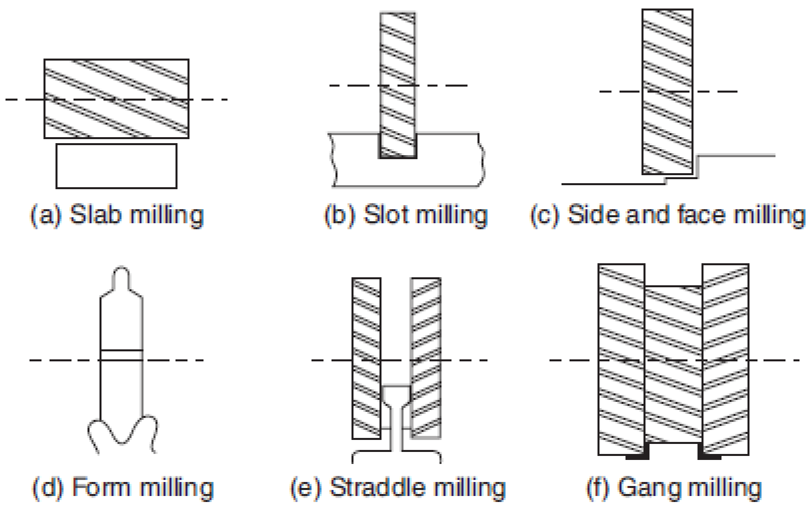
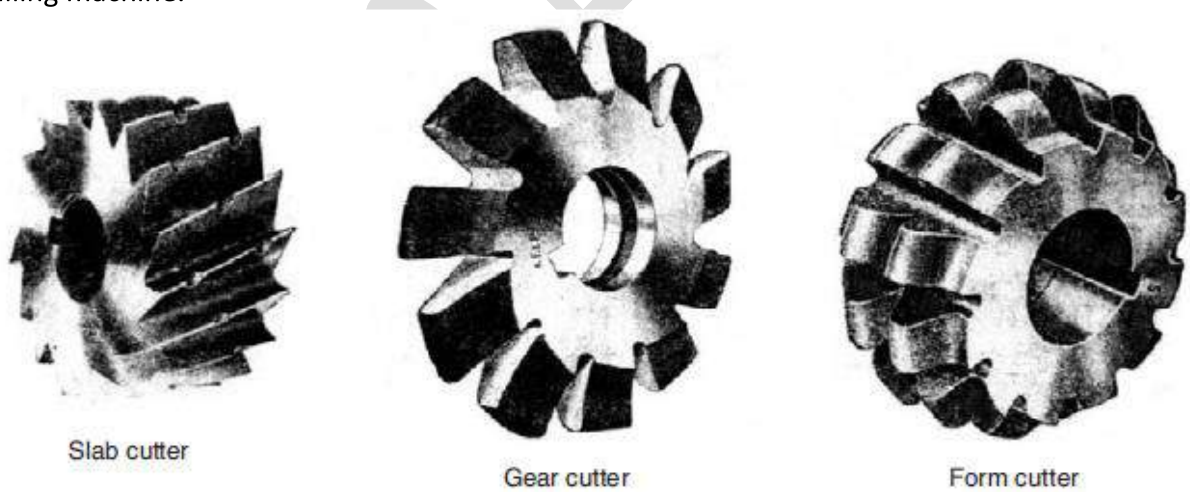
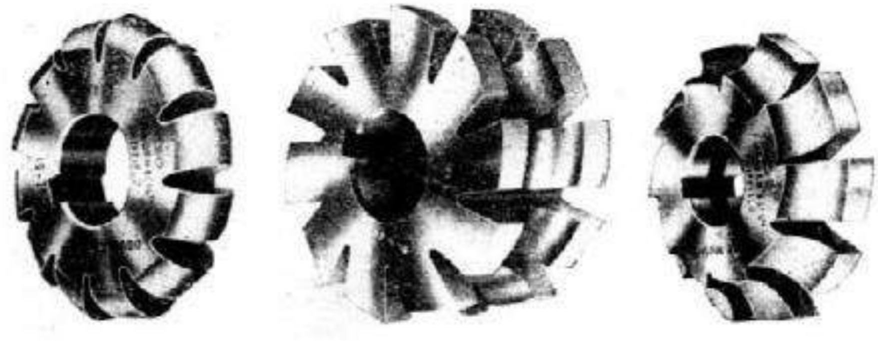


Fig. 3 Various peripheral milling operations

A number of milling cutters of peripheral milling type are shown in Fig. 4. The hole and the keyway provided in the centre of all peripheral cutters is for mounting them on the arbor of a horizontal milling machine.





Form cutter

Fig.4 Peripheral milling cutters

FACE MILLING

Face milling is widely used for milling operations involving high metal removal rate. The operation of face milling with a face milling cutter having coated tungsten carbide inserts is shown in Fig. 5.

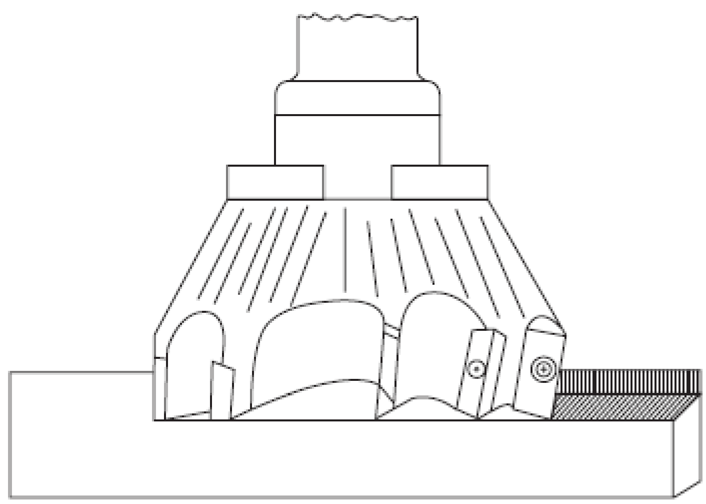


Fig. 5 Face milling

Face milling is a combination of up cut and down cut milling operation. The points discussed earlier about up and down milling operations in peripheral milling, apply equally well to the face milling operation (refer to Fig. 6)

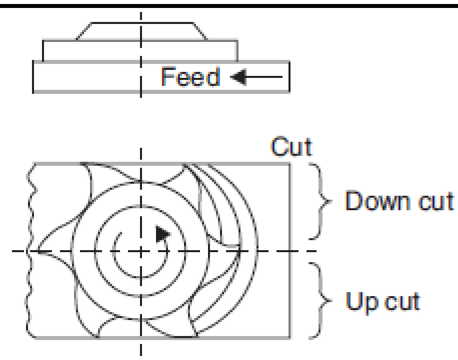


Fig. 6: Down and up cut in face milling

In face milling, the position of the cutter with respect to the work piece is of considerable significance. Three possibilities are there. Either the cutter may be symmetrically placed on the work piece or it may be asymmetrically placed, offset slightly towards the entry side or it may be asymmetric, offset slightly towards the exit side.

END MILLING

End mills perform a combination of peripheral as well as face milling operations simultaneously. It has got cutting edges on the bottom face as well as on its periphery. End mills are extremely useful and are used for machining edges, shoulders, grooves, slots and keyway pockets. They are also widely used for Jdie-sinking and generation of sculpted surfaces. Today, end mills are available in many tool materials:

1. Cobalt high speed steel (super H.S.S.)
2. Coated H.S.S.
3. Solid carbide
4. Micro grain solid carbide
5. Indexable inserts of cemented carbide or coated carbide.

A solid carbide end mill and its applications in shoulder and pocket machining are shown in Fig. 7. End mills have a taper shank which fits into a taper sleeve provided in the spindle of a vertical milling machine.

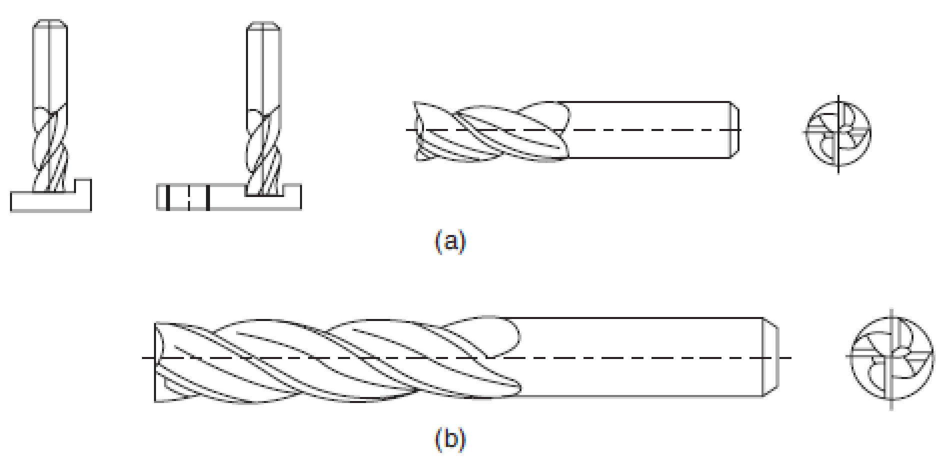


Fig. 7: Solid carbide end mills (a) short series (b) long series

MILLING MACHINES

All the milling cutters described above are used in conjunction with milling machines, which provide rotary movement to the cutters, and feed to the work piece and arrangement for clamping, automatic feed etc. Milling machines come in three basic models:

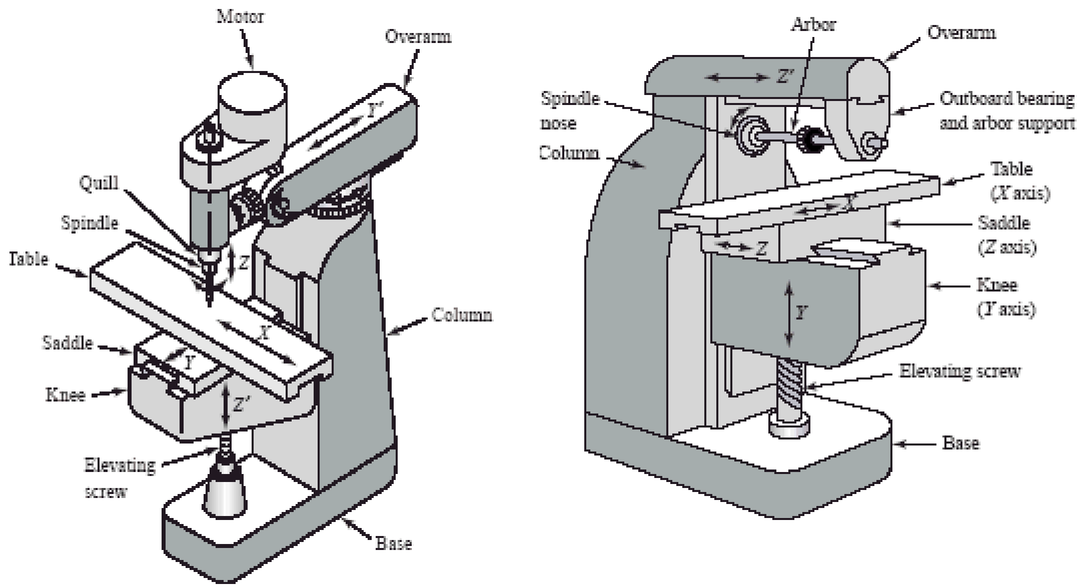
1. Horizontal milling machines,
2. Vertical milling machines, and
3. Universal milling machines (This is also of horizontal type with a few special features).

Other configurations of the milling machine have been developed for special applications, but above three are most common.

HORIZONTAL MILLING MACHINE

The most common type of milling machine is the horizontal knee type; so called, because of the overhanging ‘‘knee’’ which can slide up and down the front of the machine and which carries the cross slide and the table. A diagram of the horizontal milling machine is given in Fig. 4.9. Horizontal milling machines may be either plain or universal type. The main difference between the two is that the table of the universal type is mounted on a turn table and may be swiveled in a horizontal plane. This feature permits the cutting of helix. In addition, the standard accessories provided on the universal machine include a ‘dividing head’ for indexing. There are some other minor refinements, which make the universal horizontal machine very useful for tool room work. The plain version of the horizontal machine is much more robust and more suitable for production work. In the diagram, the arbor on which peripheral cutters are mounted is not shown. It is fitted in the spindle nose ‘*C*’ and extends a little beyond arbor supporting bracket ‘*B*’. Even end mills, face milling cutters and drills etc. can be used with this machine. In such a situation, arbor is removed and the taper shank of these cutters is fitted into the hollow spindle ‘*C*’. With such an arrangement the vertical faces of the work piece may be milled without any difficulty. The table of the horizontal milling machine can be given either hand feed or auto feed. It is also capable of being traversed at high speed. With these features, the machine proves really useful.

Knee Type Milling Machine



Vertical-Spindle Ccolumn | **Horizontal Spindle Column**

Fig. 4.9: Milling Machines