CHAPTER 6: MILLING

6.1 INTRODUCTION

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections. Typical components produced by a milling are given in Fig. 6.1.

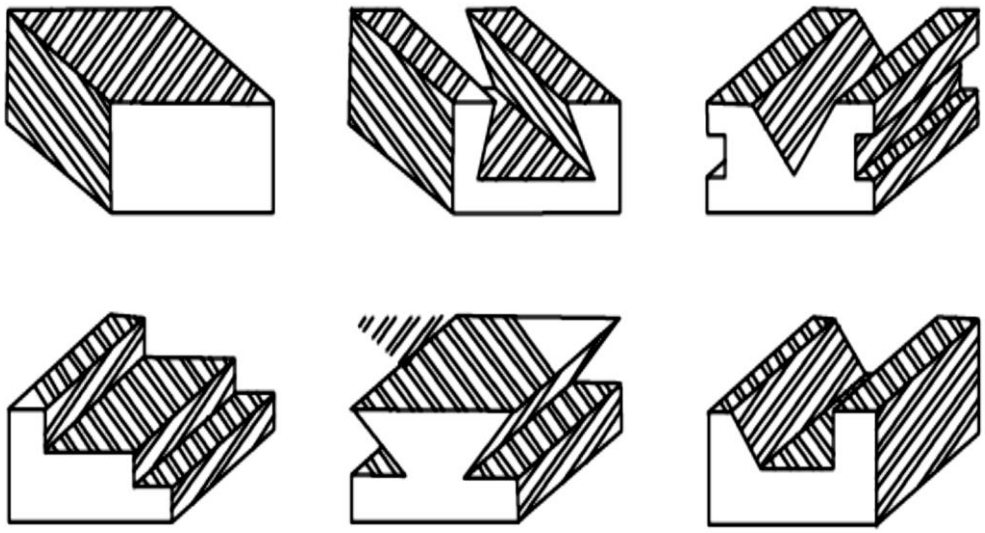


Fig. 6.1: Job surfaces generated by milling machine.

6.2 PRINCIPLE OF MILLING

In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges. For cutting operation, the workpiece is fed against the rotary cutter. Machined surface is formed in one or more passes of the work. The rotatory speed of the cutting tool and the feed rate of the workpiece depend upon the type of material being machined.

6.3 MILLING METHODS

There are two distinct methods of milling classified as follows:

1. **Up-milling or conventional milling, and**
2. **Down milling or climb milling.**

6.3.1 UP-Milling or Conventional Milling Procedure

In the up-milling or conventional milling, as shown in Fig. 6.2, the metal is removed in form of small chips by a cutter rotating against the direction of travel of the workpiece.

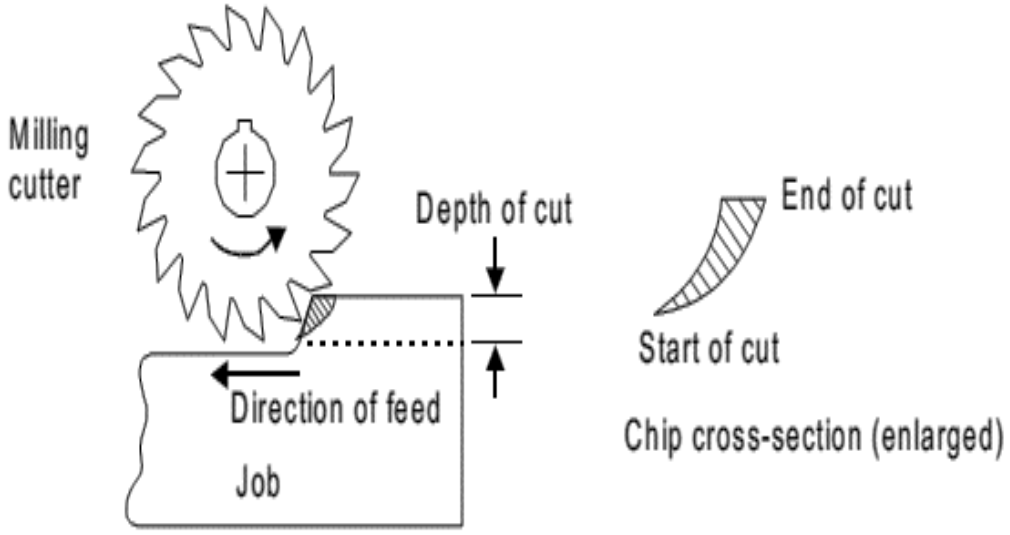


Fig. 6.2: Principal of up-milling.

6.3.2 Down-Milling or Climb Milling

Down milling is shown in Fig. 6.3. It is also known as climb milling. In this method, the metal is removed by a cutter rotating in the same direction of feed of the workpiece.

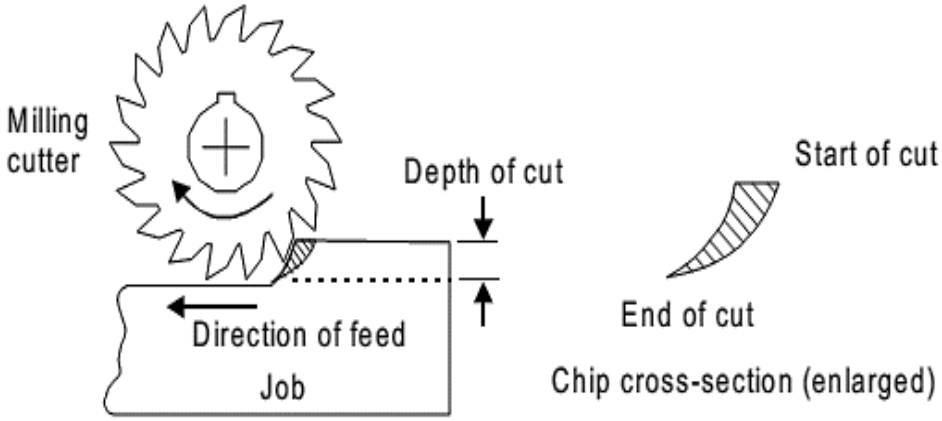
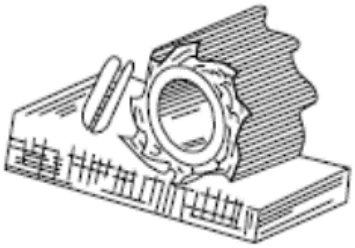


Fig. 6.3: Principal of down-milling.

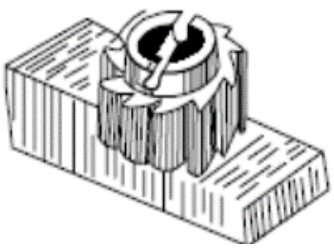
6.4 TYPES OF MILLING CUTTERS

Fig. 6.4 illustrates some types of milling cutters along with workpieces. Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

(1) Plain milling cutters,
(2) Side milling cutters,
(3) Face milling cutter,
(4) Angle milling cutters,
(5) End milling cutter,
(6) Fly cutter,
(7) T-slot milling cutter,
(8) Formed cutters,
(9) Metal slitting saw,



Plain milling cutter



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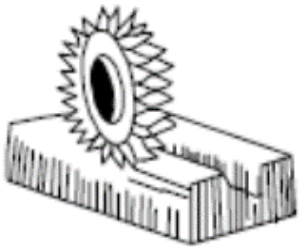
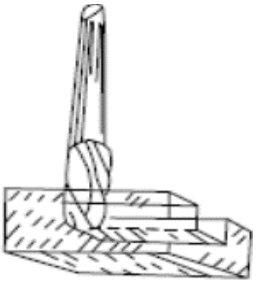
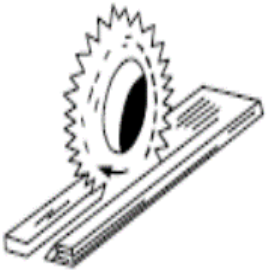


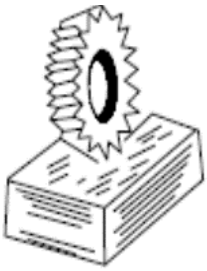
Side milling cutter



End mill



Metal-slitting saw



Angle milling cutter

Form milling

Fig. 6.4: Types of milling cutters.

6.5 TYPES OF MILLING MACHINES

Milling machine rotates the cutter mounted on the arbor of the machine and at the same time automatically feed the work in the required direction. The milling machine may be classified in several forms, but the choice of any particular machine is determined primarily by the size of the workpiece to be undertaken and operations to be performed. With the above function or requirement in mind, milling machines are made in a variety of types and sizes. According to general design, the distinctive types of milling machines are Fig. 6.5, Fig. 6.6):

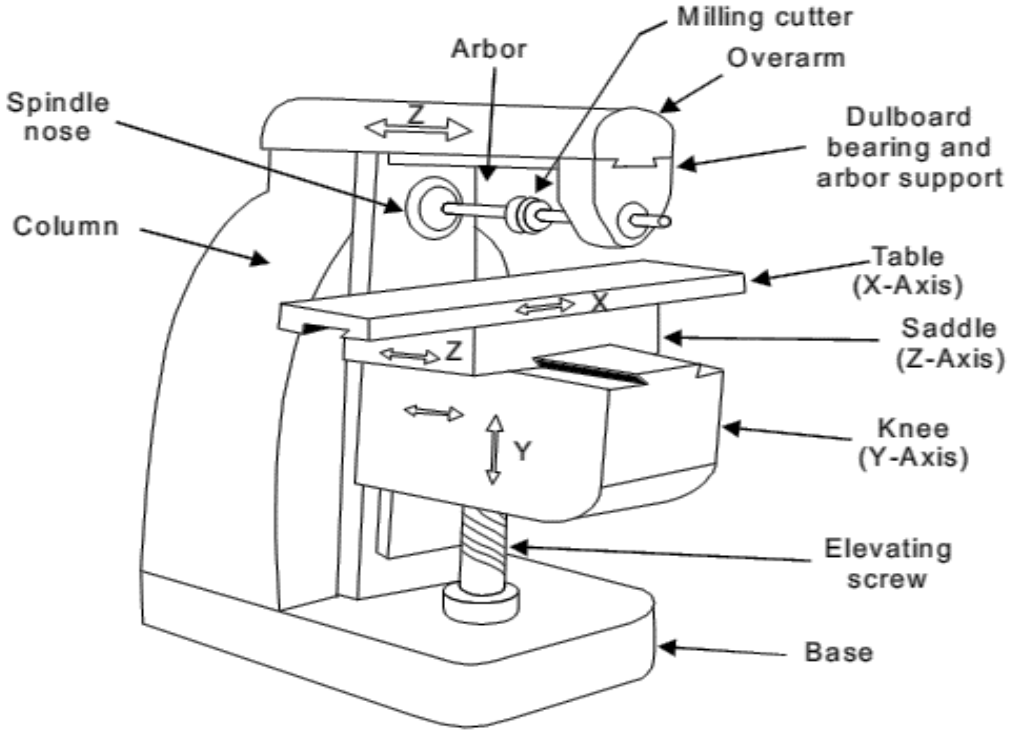


Fig. 6.5: Horizontal column and knee type milling machine.

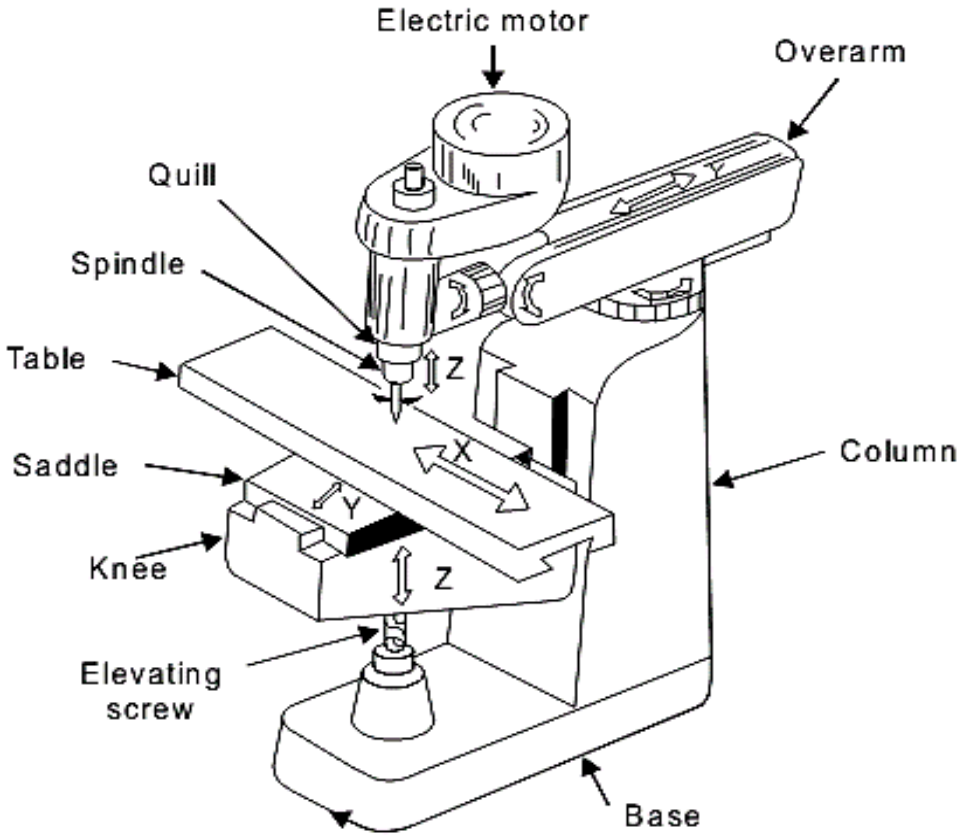


Fig. 6.6: Vertical column and knee type milling machine.

6.5.1 Column and Knee Type Milling Machine

Fig. 6.7 shows a simple column and knee type milling machine.

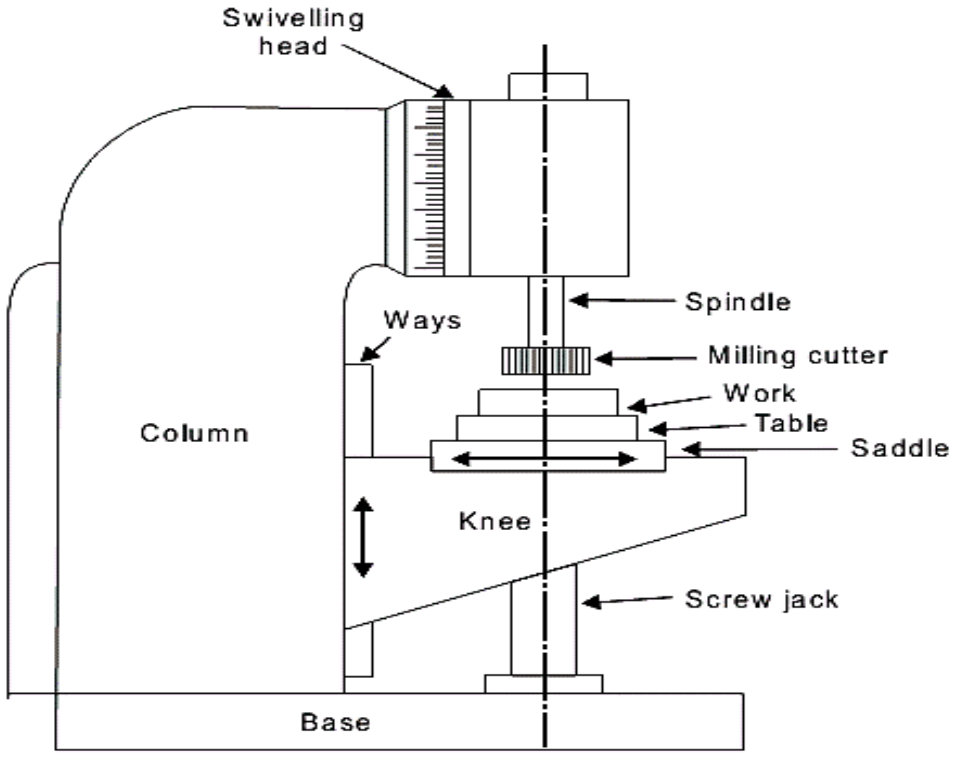


Fig. 6.7: A column and knee type milling machine

6.6 INDEXING AND DIVIDING HEADS

Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. In cutting spur gear equal spacing of teeth on the gear blank is performed by indexing. Indexing is accomplished by using a special attachment known as dividing head or index head as shown in Fig. 6.8. The dividing heads are of three types:

(1) Plain or simple dividing head,
(2) Universal dividing head and
(3) Optical dividing head.

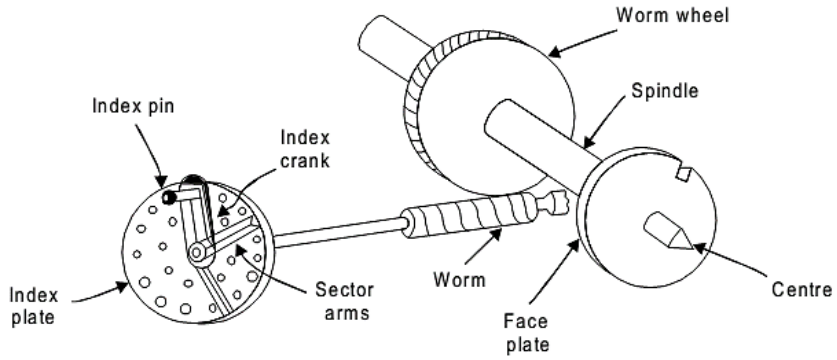


Fig. 6.8: Dividing head.

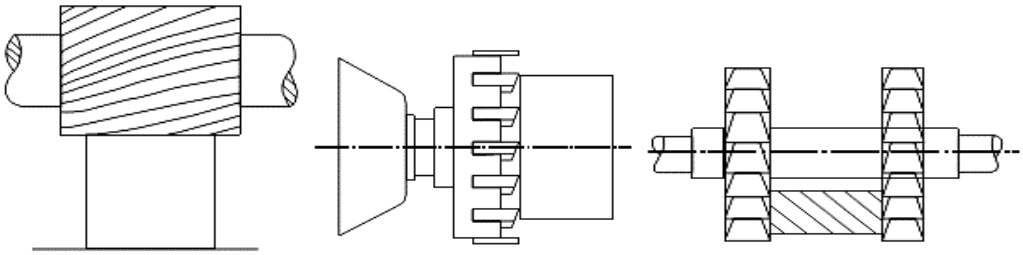
6.7 OPERATIONS PERFORMED ON MILLING MACHINE

Many different kinds of operations can be performed on a milling machine but a few of the more common operations will now be explained. These are:

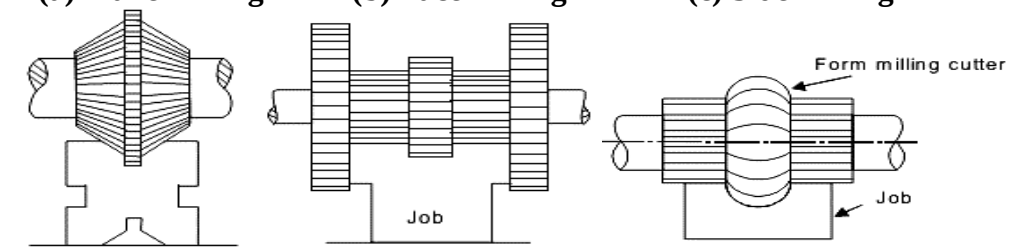
- **Plain milling or slab milling**
  Fig. 6.9(a) illustrates the plain and slab milling operation. It is a method of producing a plain, flat, horizontal surface parallel to the axis of rotation of the cutter.
- **Face milling**
  Fig. 6.9(b) illustrates the face milling operation. It is a method of producing a flat surface at right angles to the axis of the cutter.
- **Side milling**
  Fig. 6.9(c) illustrates the side milling operation. It is the operation of production of a flat vertical surface on the side of a work-piece by using a side milling cutter.
- **Angular milling**
  Fig. 6.9(d) illustrates angular milling operation. It is a method of producing a flat surface making an angle to the axis of the cutter.
- **Gang-milling**
  Fig. 6.9(e) illustrates the gang milling operation. It is a method of milling by means of two or more cutters simultaneously having same or different diameters mounted on the arbor of the milling machine.
- **Form milling**
  Fig. 6.9(f) illustrates the form milling operation. It is, a method of producing a surface having an irregular outline.
- **End milling**
  Fig. 6.9(g) illustrates end milling operation. It is a method of milling slots, flat surfaces, and profiles by end mills.
- **Profile milling**

Fig. 6.9(h) illustrates profile milling operation. It is the operation of reproduction of an outline of a template or complex shape of a master die on a workpiece.

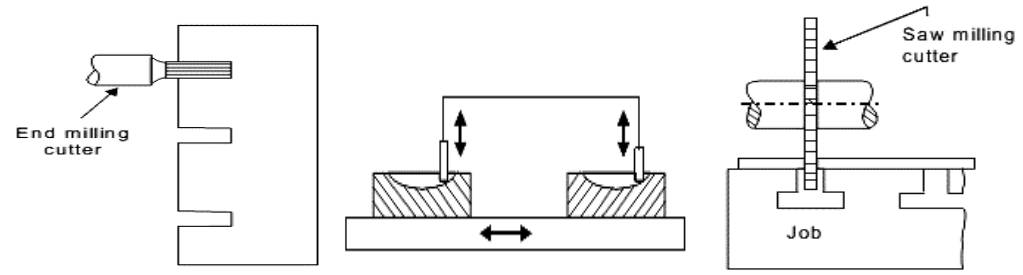
- **Saw milling**
  Fig. 6.9(i) illustrates saw milling operation. It is a method of producing deep slots and cutting materials into the required length by slitting saws.
- **T-slot milling**
  Fig. 6.9(j) illustrates T-slot milling operation.
- **Keyway milling**
  Fig. 6.9(k) illustrates keyway milling operation.
- **Gear cutting milling**
  Fig. 6.9(l) illustrates gear cutting milling operation.
- **Helical milling**
  Fig. 6.9(m) illustrates helical milling operation.
- **Flute milling**
  It is a method of grooving or cutting of flutes on drills, reamers, taps, etc.
- **Straddle milling**
  It is a method of milling two sides of a piece of work by employing two side-milling cutters at the same time.
- **Thread milling**
  It is a method of milling threads on dies, screws, worms, etc. both internally and externally. As an alternative to the screw cutting in a lathe, this method is being more extensively introduced now a day in modern machine shops.



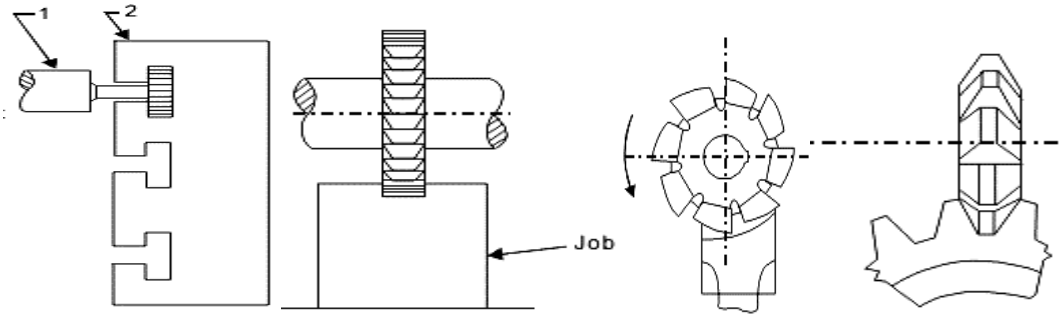
(a) Plane milling **(b) Face milling** **(c) Side milling**



(d) Angular milling **(e) Gang milling** **(f) Form Milling**



(g) End milling **(h) Profile milling** **(i) Saw milling**



(j) T-slot milling **(k) Key way milling** **(l) Gear Cutting Milling**

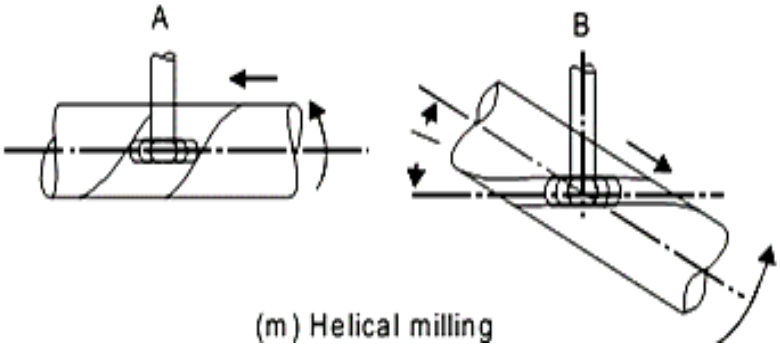


Fig. 6.9: Various types of milling operations

6.8 QUESTIONS

1. **State the working principle of milling machine.**
2. **How will you classify milling machines?**
3. **Using neat sketch, describe the principal parts of the milling machine by neat sketches.**
4. **Differentiate between up milling and down milling.**
5. **With the help of a neat sketch explain the column and knee type milling machine and name its main parts.**
6. **Explain various types of milling operations using neat sketches.**
7. **Describe thread milling.**
8. **Sketch and describe the indexing head used for gear cutting.**
9. **Explain the principle of differential indexing.**
10. **What is indexing? Describe direct indexing, with example.**
11. **Single angle milling cutter (*b*) Slot milling cutter (*d*) convex milling cutter.**
12. **How will you index the gear teeth? Sketch the indexing set-up showing necessary calculations.**
13. **Sketch the machining set-up indicating tool work motions.**
14. **Sketch and specify the milling cutter indicating important tool geometry.**
15. **Define the following terms used in milling operation.**
    - ***(a)*** **Cutting speed**
    - ***(b)*** **Feed**
    - ***(c)*** **Depth of cut**
    - ***(d)*** **Machining time.**