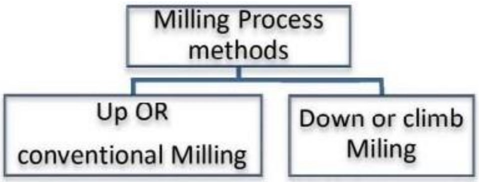
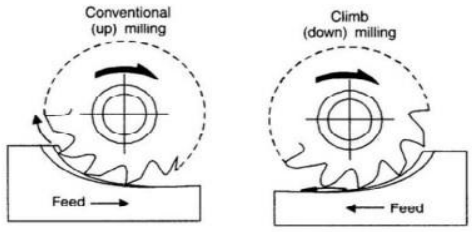
Milling & Milling Machine Tool

Milling is a process of metal removal/ cutting by means of a multi-teeth (point) rotating tool called milling cutter. The form of each tooth of cutter is same as that of the single point cutting tool, used in the lathe machine. Milling process is of two types:



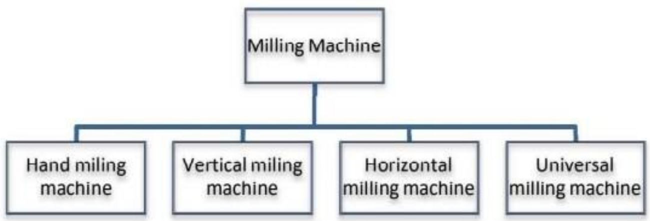
Up Milling: In up milling also known as conventional milling, the cutter rotates against the direction in which the work is being fed.

Down Milling: In down milling also known as climb milling; the cutter rotates in the same direction in which the work is being fed.



Up Milling and Down Milling.

Working principle of milling process is that the work is rigidly held by the clamps (Vice) on the table and a revolving milling cutter mounted on the arbor OR spindle removes the metal. The cutter revolves at high speed and each tooth of the milling cutter removes the metal in the form of chips. The work may be fed to the cutter, longitudinally, transversely or vertically, the cutter is set to a certain depth of cut by raising the table.

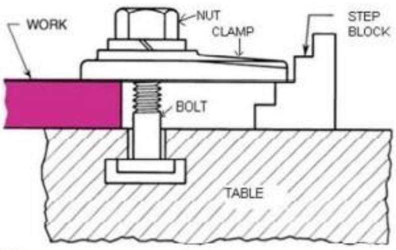


Milling machine is a machine tool in which metal is removed by means of a revolving cutter with many teeth (multipoint cutting tool known as **milling cutter**). Milling machines are of many types and the **universal milling machine** has a swivel-able housing on which the table is mounted.

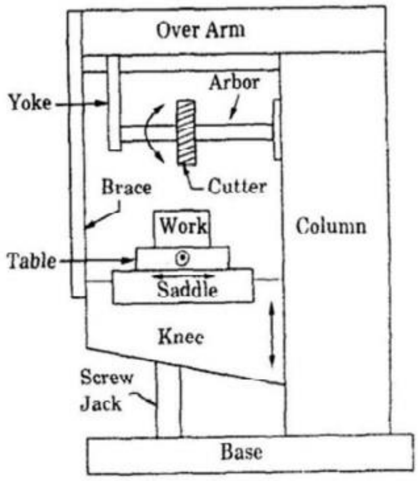
Differentiation / Comparison between up milling and down milling

UP MILLING	DOWN MILLING
The cutter rotates against the direction in which the work is being fed.	The cutter rotates in the same direction as that in which the work is being fed
It is also known as conventional milling.	It is also known as climb milling.
Job-tool motion is in the opposite direction.	Job-tool motion is in the same direction.
Chip thickness varies from minimum to maximum.	Chip thickness varies from maximum to minimum.
Cutting forces vary from zero to maximum.	Cutting forces vary from maximum to zero.
Surface finish is poorer compared to down milling.	Surface finish is better, if it is free from backlash error.
Use of cutting fluid is difficult.	Use of cutting fluid is easy.
There is tendency to lift the job so more clamping forces are needed to fix the job on the table.	Forces are sufficient on the job to press downward. So clamping problem is not so much.
Advantage: It is practicable.	**Disadvantage**: It is impracticable

Work holding Devices: These are the devices used for holding and fixing the workpiece on the table of milling machine for performing the milling operations.



In case of simple shape, size and weight many work-pieces can be directly held conveniently with help of ***vices*** but in case of complex shapes the work-pieces are secured to the machine table with help of the Vice (used to hold round and square work-pieces) ***Clamps, strapclamps (are cheap,easy to use, flexible force can be applied by tightening a nut by hand or wrench), jacks, step blocks (to provide support to outer end of the strap clamps) and clamping bolts*, etc.** All these clamps, straps contain a hole which is used align and clamping bolt is passed through it to fix the work-piece. *Toggle clamps can accommodate small variation in thickness and provide excellent and consistent clamping force*. Toggle clamps are fast, adjustable, inexpensive, provide high ratio of leverage and can be automated.



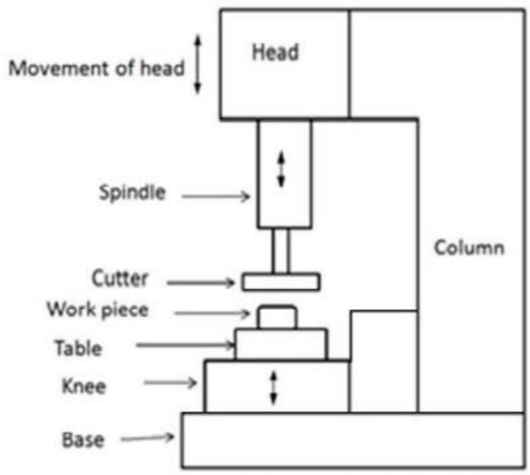
Horizontal knee type milling machine

In general a milling machine has the following **Principal parts**:

a) Base b) Column c) Knee d) Saddle e) Table f) Over Arm g) Spindle h) Arbor

Base: It is the foundation of the machine upon which all other parts are mounted. It is generally made of grey cast iron to absorb shock and vibration. Sometime it also serves as a reservoir for cutting fluid.

Column: It is the main supporting frame mounted vertically on one side of the base. The motor and other driving mechanisms are contained in it. It supports and guides the knee in its vertical travel. It carries the jack for elevating the knee.



Vertical Knee type Milling Machine

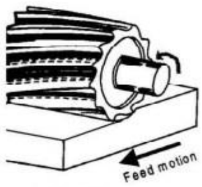
Knee: The knee projects from the column and slides up and down on its face. It supports the saddle and table. It is partially supported by the elevating screw which adjusts its height. It carries the table feed mechanism and controls to feed in longitudinal, cross, vertical and rotation etc. by hand power or machine power.

Saddle: The saddle supports and carries the table and is adjustable transversely on ways on top of the knee. It is provided with graduation for exact movement and can be operated by hand or power.

Table: The table rests on ways on the saddle and travels longitudinally in a horizontal plane. It supports the workpiece, fixtures etc.

Over-arm: The over arm is mounted on and guided by the top of the column. It is adjusted in and out by hand to the position of maximum support for the arbor and then clamped. (Not in the vertical type of milling machines)

Spindle: The spindle is mounted on the upper part of the column. It receives power from the motor through belts, gears, clutches etc. and can be rotated at different speeds by the step cone pulley drive or by gearing arrangement and transmits it to arbor or sub-arbor. (In the vertical type of milling machines)



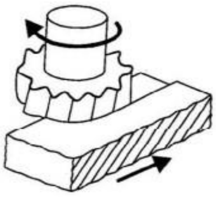
Slab milling

Arbor: The arbor is the extension of the spindle on which all the various cutters are mounted. It is tapered at one end to fit the spindle nose and has two slots to fit the nose keys for locating and driving it.

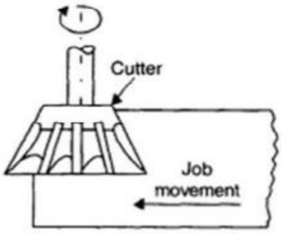
Operations carried out on the milling machine are:

Plain or Slab Milling: The plain milling operation is the production of flat or horizontal surface parallel to the axis of the cutter.

Face Milling: The face milling operation is also the production of flat surface which is at right angle to the axis of rotation of the face milling cutter.



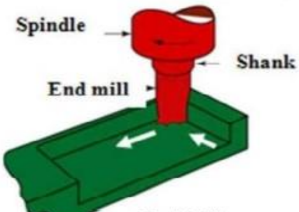
Face milling



Angular or Bevel Milling

Angular or Bevel Milling: The angular milling operation is production of flat surface, which is at an angle to the axis of the cutter.

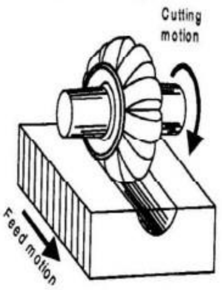
Side Milling: The side milling operation is the production of a vertical flat surface on the side face of a job by using a side milling cutter.



End Milling

End Milling: The End milling operation is the production of **both peripheral and face milling** operations simultaneously, generates vertical, horizontal or angular surfaces by using an end milling cutter.

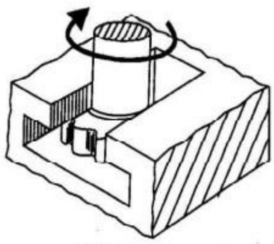
Gang Milling: Gang milling is operation production of producing many surfaces of a job simultaneously by feeding the table against a number of required cutters, (more than two). The surfaces produced may be flat horizontal or vertical surfaces and are produced simultaneously.



Form milling

Form Milling: The form milling operation is the production of irregular contours by using the cutters having the same profile corresponding to the surface to be generated.

T-Slot milling refers to the formation of T-Slots.



T- Slot milling

Indexing Mechanism

Indexing Mechanism is a mechanism that is used for dividing the periphery of a workpiece into any number of equal parts. The machine used for the indexing mechanism is called indexing head. Indexing head is also known as a dividing head or spiral head.

Indexing Mechanism is mainly used to cut gear teeth accurately. This mechanism is used for equal spacing of the teeth of the gear.

This mechanism is also used for machining flutes of a milling cutter, milling curved slots and drilling a bolt hole circle around the circumference of a part.

This indexing mechanism can be achieved using a special attachment known as **dividing head or indexing head**.

Parts Used in Indexing Mechanism:-

Indexing Plate – Indexing plate is a circular plate and it has equally spaced holes. There are minimum 6 holes in an indexing plate. This indexing plate is connected to a crank which is connected to a handle. This indexing plate is stationary in Simple Indexing Mechanism and can move in Differential Indexing Mechanism.

Crank – This crank has a handle which is rotated manually and give the initial rotation to the worm shaft and worm which transferred to the worm wheel.

Crank Pin – Crank Pin is used to lock the rotation of the crank. Crank pin is inserted into the whole of indexing plate which is fixed and does not rotate and hence the rotation of crank is locked.

Worm Shaft – This shaft is connected with the crank and rotates with it. It connects the crank to the worm.

Worm – Worm is connected to the crank by worm shaft. This worm is like a threaded screw. It is a single-threaded worm. When the crank is rotated using handle this worm also rotates due to rotation of worm shaft and a single tooth in worm wheel which is connected to the worm passes through the worm.

Worm Wheel (W.W) – The worm wheel contains teeth like gears. When all the teeth of worm wheel passes through the worm. The worm wheel completes one rotation.

Spindle: - Spindle is connected with the worm wheel and rotates as the worm wheel rotates. When all the teeth of worm wheel passes through the worm, this worm wheel completes one rotation and the spindle connected to the worm wheel also completes one rotation. This spindle is connected to a plate known as face plate.

Face Plate – This face plate is connected to the spindle and rotates as the spindle rotates. This face plate is connected to the workpiece and this workpiece also rotates with this face plate.

Change Gears – These gears are used in differential indexing mechanism for rotating the indexing plate in forward or backward direction as required. These gears are connected to the worm wheels and takes worm wheel rotation as input and output its rotation to indexing plate.

The machine formed by combination of all these parts is called **indexing head.**

In this article we will study about two main types of indexing mechanism that are :-

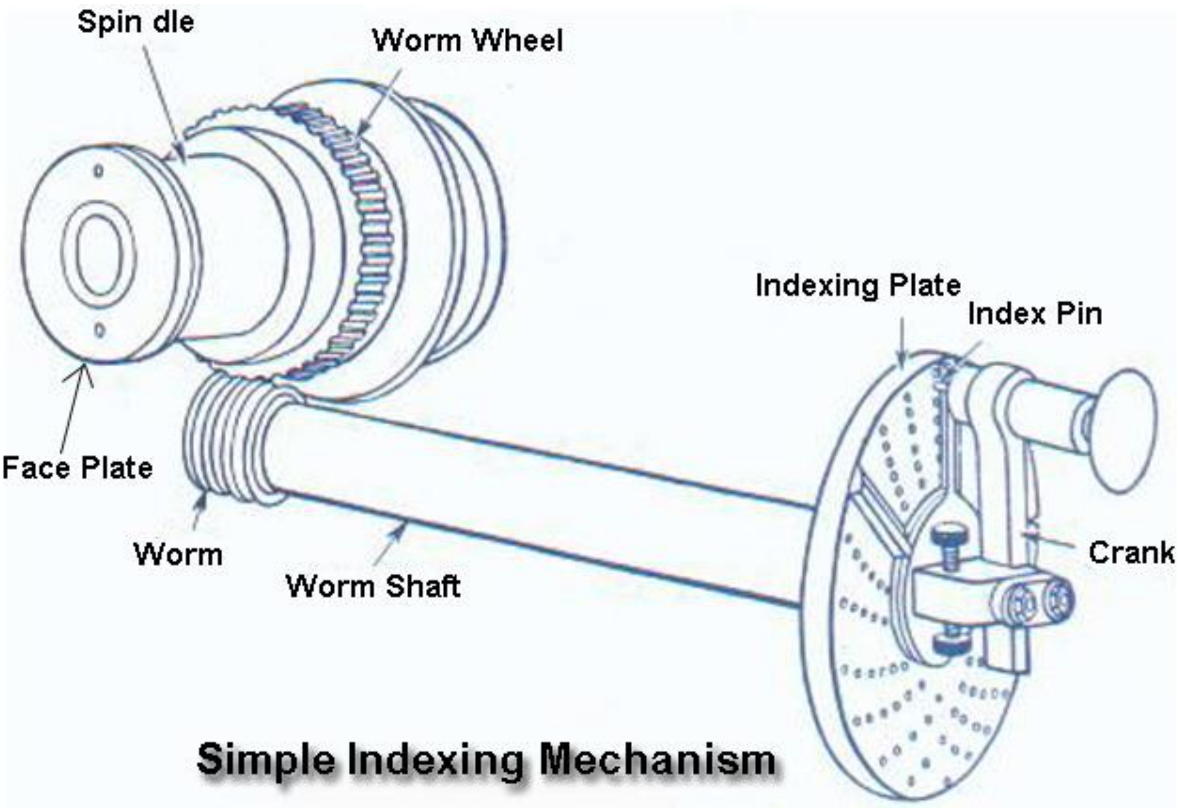
1) Simple Indexing Mechanism

2) Differential Indexing Mechanism

1. Simple Indexing Mechanism:-

At first, the handle of the indexing plate is rotated manually. With the handle the crank also rotates. As the crank rotates, the worm shaft rotates attached to it rotates and hence the worm also rotates.

When the worm rotates, the teeth of the worm wheel pass through the worm and produce a partial rotation in the worm wheel. When the worm completes one complete rotation, one tooth of the worm wheel passes through the worm.



The spindle and the face plate connected to the worm wheel also rotates with the worm wheel. The workpiece is connected to the face plate and also rotates with the worm wheel.

Indexing mechanism is mainly used to cut teeth of the spur gear. It is also used for cutting splines, milling grooves in reamers and taps, and spacing holes on a circle

Case 1:-

Let's say there are 40 teeth in the worm wheel and we have to machine 8 teeth in the workpiece. So the number of rotation of crank handle that will be required to cut one tooth in the workpiece will be = 1/8 x 40 = 5. i.e 5 rotation of crank will be required to cut one tooth in the workpiece.

After every five rotation the crank pin will be inserted in the indexing plate and the rotation of the crank will be locked and the workpiece rotation will also be locked and the workpiece can be machined at this time.

In one rotation of crank one tooth or worm wheel passes by worm and in five rotation five worm teeth will pass by the worm.

When 5 teeth of worm wheel will pass by worm one tooth will be cut in the workpiece. One tooth will be cut in the workpiece for each 5th teeth of worm wheel that crosses worm.
Hence 5 rotation of crank handle is required to cut one teeth in workpiece when there are 40 teeth in worm wheel and 8 teeth has to be cut in the workpiece.

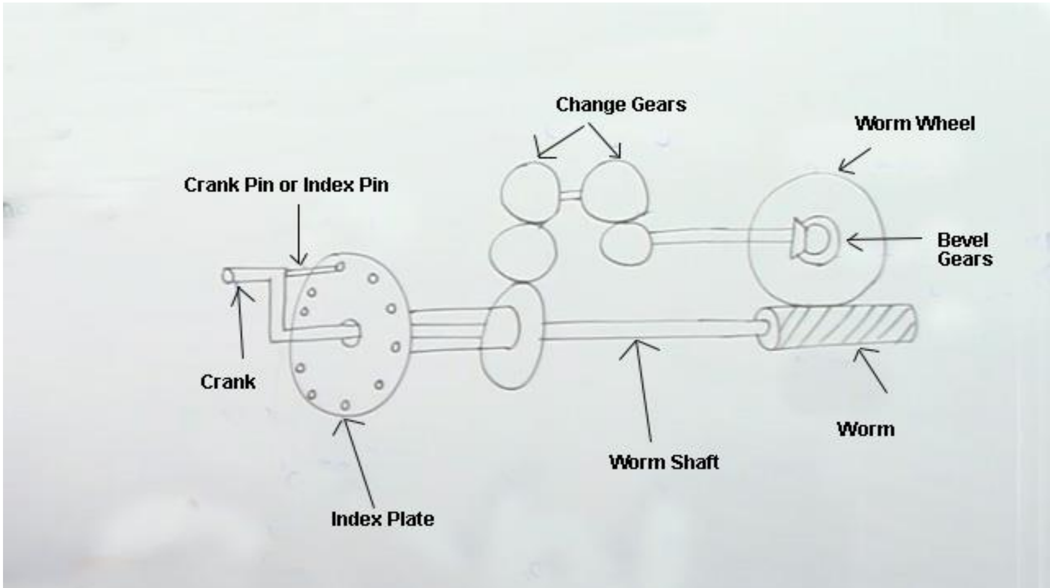
Case 2 :-

In this case, we have to machine 7 teeth in the workpiece which is not a factor of 40. Now the number of rotation of crank handle rotation that will be required to cut one tooth in workpiece will be = 1/7 x 40 = 5 whole 5/7 rotations i.e 5 complete rotations and 5/7 of rotation of the crank handle.

Since a fraction of rotation of crank handle is required. Hence, the holes of indexing plates will be used to obtain this fractional rotation of crank.
5/7 can also be written as 15/21. So a 21 hole indexing plate will be used to obtain this result. i.e 5 whole rotation of the crank handle and after that crank handle should rotate till the 15th hole of the 21 hole indexing plate is reached.
This is the main function of indexing plate with holes, its main use is seen when we need a mixed fraction of rotation of the crank handle.

2. Differential Indexing Mechanism:-

Differential indexing is used when the fraction of rotation of crank handle cannot be achieved using holes of indexing plates.
This situation occurs when the workpiece has to be divided into a number of divisions which is greater than the maximum number of holes an indexing plates can have.
Maximum holes that can be in indexing plate is 66. For more than 66 divisions **Differential Indexing Mechanism** is used.



Differential Indexing Mechanism

In differential indexing mechanism along with parts of simple indexing mechanism some change gears are used. These change gears are used to rotate the indexing plate in forward or backward direction as required so that the required division of workpiece is obtained.

Let's say we have to cut 67 holes in the job or the workpiece. For that, the job should rotate 1/67 of the total rotation after each cut.
So the number of rotation required to cut one tooth in workpiece = 1/67 x 40
= 40/67.
Since we do not have an indexing plate with 67 holes, so we cannot do this with simple indexing mechanism.
So now we will see how we can achieve this using a differential indexing mechanism.
In differential indexing mechanism, the change gears are connected to the change gears through bevel gears and transmit rotation in 90 degrees angle.
These change gears are connected to the indexing plate and rotate the indexing plate to some extent so that we can cut certain numbers of cuts in the job.
We can rotate the job to 1/66 of total rotation using simple indexing but we need to rotate it to 1/67 of total rotation.

If there are two points A and B int the job covering which the job rotates 1/66 of total rotation then a point C lies in between these two points such AC covers 1/67 of total rotation.
If we reach AB or 1/66 by rotating crank then to reach 1/67 we have to come back some distance so that it becomes 1/67 or we reduce rotation to some amount so that we reach 1/67 instead of 1/66.
We can reduce the amount of rotation by some amount by rotating the indexing plate by some amount in opposite direction of rotation of crank.
The amount that the indexing plate needs to rotate so that 1/67 of rotation is obtained instead of 1/66 = 1/66 – 1/67.
i.e **Index Plate Rotation** = 1/66 – 1/67 …… (i)
Now we will have to find the gear ratio of change gears that is required to rotate index plate so that we can rotate job to 1/67 of total rotation.

We know that **Gear Ratio (G)** = Output Rotation (No) / Input Rotation (Ni)

We also know that Input rotation for change gear is the rotation of worm wheel.
Since we have to divide the job into 67 parts. So let's take crank rotation = 1/67.

Now rotation of worm wheel = 1/67 x 1/40 (Since gear ratio of worm wheel is 1/40)

Now Input rotation for change gear (Ni) = 1/67 x 1/40
Now the output rotation i.e **rotation of index plate** = G x Ni
= 1/67 x 1/40 x G …. (ii)
Now equating eq (i) and eq (ii),we get
G x 1/67x 1/40 = 1/66 – 1/67
G = 40/66 (67 – 66) = 40 / N (available) (N (required) – N (available))
This is the generalized formula calculating the **gear ratio** of change gears in **differential indexing mechanism**.

Using this formula if the gear ratio has a negative sign then the indexing plate needs to be rotated in the opposite direction of the crank handle and if it has a positive sign then it needs to be rotated in the same direction of the crank handle.

In this way, we can divide the job into a number of divisions more than the maximum number of holes available indexing plate using differential indexing mechanism.

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