WORKSHOP TECHNOLOGY

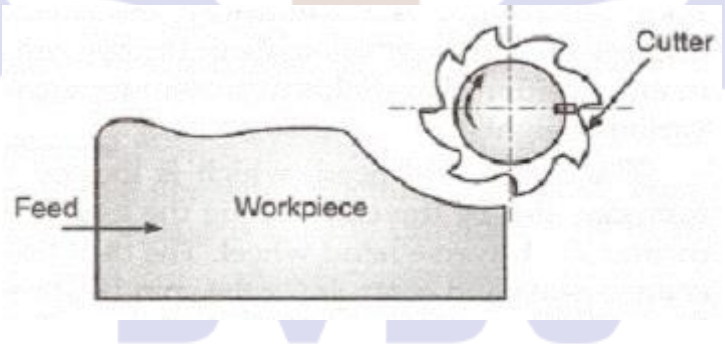
Unit-5 **Milling machines and Introduction to Jigs & Fixtures**	Introduction, working principle, principal parts, Size and specification, up milling and down milling, **Milling machine types:** Column and Knee type-hand, plain or horizontal, vertical, universal, Universal milling machine, Planer type milling machine or plan mill. **Milling cutters:** Plain, Side, End, Face, Metal slitting, Angle milling, Form milling, Woodruff-Key and T-slot milling cutters, Materials for milling cutters, cutting speed and feed. **Milling operations;** Plain or Slab, Face, Angle, Form, Straddle and Gang, Slot and Groove, Keyway, Side, End, Profile, Gear milling operations Importance and use of jigs and fixtures, types of jigs, principle of location, locating and clamping devices, advantages of jigs and fixtures

Introduction:

Milling is the cutting operation that removes metal by feeding the work against a rotating, cutter having single or multiple cutting edges. Flat or curved surfaces of many shapes can be machined by milling with good finish and accuracy. A milling machine may also be used for drilling, slotting, making a circular profile and gear cutting by having suitable attachments.

Working Principle:

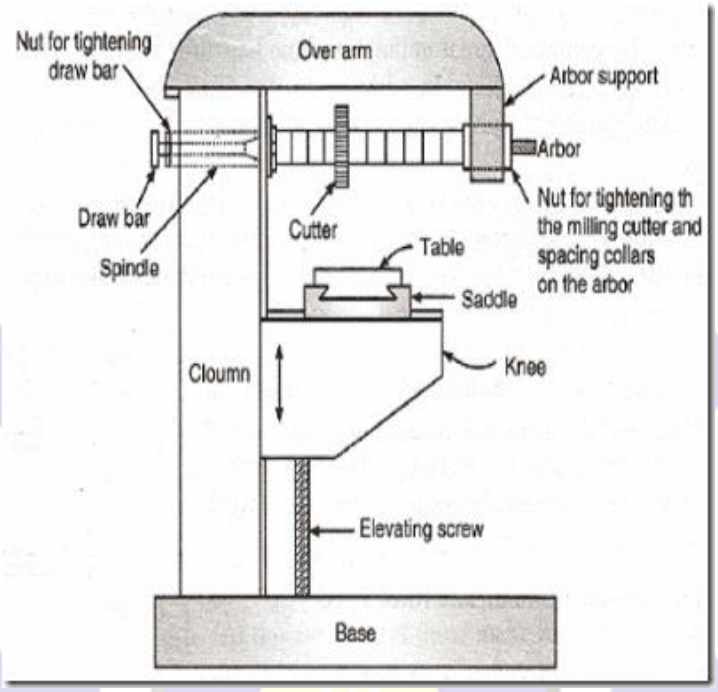
The workpiece is holding on the worktable of the machine. The table movement controls the feed of workpiece against the rotating cutter. The cutter is mounted on a spindle and revolves at high speed. Except for rotation the cutter has no other motion. As the workpiece advances, the cutter teeth remove the metal from the surface of workpiece and the desired shape is produced.



Horizontal Milling Machine Construction: The main part of machine is base, Column, Knee, Saddle, Table, Overarm, Arbor Support and Elevating Screw.

1. **Base**: It gives support and rigidity to the machine and also acts as a reservoir for the cutting fluids

2. **Column**: The column is the main supporting frame mounted vertically on the base. The column is box shaped, heavily ribbed inside and houses all the driving mechanisms for the spindle and table feed.



3. **Knee**: The knee is a rigid casting mounted on the front face of the column. The knee moves vertically along the guide ways and this movement enables to adjust the distance between the cutter and the job mounted on the table. The adjustment is obtained manually or automatically by operating the elevating screw provided below the knee.

4. **Saddle**: The saddle rests on the knee and constitutes the intermediate part between the knee and the table. The saddle moves transversely, i.e., crosswise (in or out) on guide ways provided on the knee.

5. **Table**: The table rests on guide ways in the saddle and provides support to the work. The table is made of cast iron, its top surface is accurately machined and carriers T-slots which accommodate the clamping bolt for fixing the work. The worktable and hence the job fitted on it is given motions in three directions:

a). Vertical (up and down) movement provided by raising or lowering the knee.

b). Cross (in or out) or transverse motion provided by moving the saddle in relation to knee.

c). Longitudinal (back and forth) motion provided by hand wheel fitted on the side of feed screw.

In addition to the above motions, the table of a universal milling machine can be swiveled 45° to either side of the centre line and thus fed at an angle to the spindle.

6. **Overarm:** The Overarm is mounted at the top of the column and is guided in perfect alignment by the machined surfaces. The Overarm is the support for the arbor.

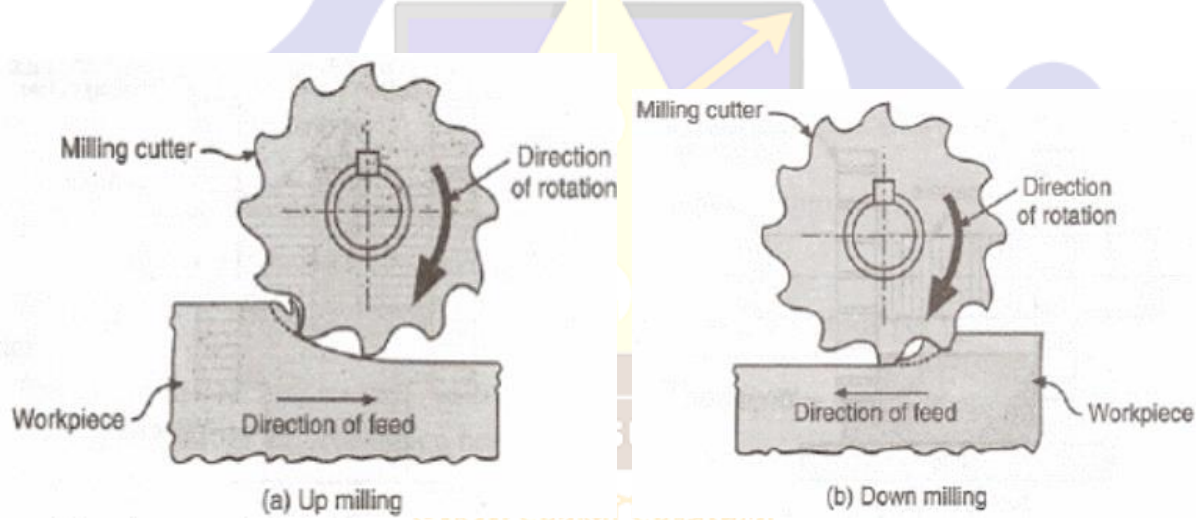
7. **Arbor support**: The arbor support is fitted to the Overarm and can be clamped at any location on the Overarm. Its function is to align and support various arbors. The arbor is a machined shaft that holds and drives the cutters.

8. **Elevating screw**: The upward and downward movement to the knee and the table is given by the elevating screw that is operated by hand or an automatic feed.

Up milling

In up milling (conventional milling), the feed direction of the cutting tool is opposite to its rotation.

The chip thickness starts at zero and increases toward the end of the cut. The cutting edge has to be forced into the cut, creating a rubbing or burnishing effect due to friction, high temperatures and, often times, contact with a work-hardened surface caused by the preceding edge. All this reduces the tool life.



Down milling

In down milling (climb milling), the cutting tool is fed with the direction of rotation. Down milling is always the preferred method wherever the machine tool, fixture and workpiece will allow.

In peripheral down milling, the chip thickness will decrease from the start of cut, gradually reaching zero at the end of cut. This prevents the edge from rubbing and burnishing against the surface before engaging in the cut.

Milling machine types

Column and Knee Type

For general shop work, the most used type of milling machine is the column and knee type machine. where the table is mounted on the knee-casting which in turn is mounted on the vertical slides of the main column.

The knee vertical adjustable on the column so that the table can be moved up and down to accommodate work of various heights.

The column and knee type milling machines are classified.

- According to the various methods of supplying power to the table.
- Different movements of the table. and
- The different axis of rotation of the main spindle.

1. Hand Milling Machine

It simplest of all types of milling machine in which table feeding is controlled by hand. The cutter is mounted on a horizontal arbour and is rotated by power.

This type of milling machine is of small in size and suitable for light and simple milling operations. For Example, machining slots, grooves, and keyway.

2. Plain Milling Machine

These are much stronger than hand millers. The table feeding is done either by hand or power. the plain milling machine having a horizontal spindle is also called as a horizontal spindle milling machine. The table may be fed in a longitudinal, cross or vertical directions.

The feed is:

- Longitudinal – when the table is moved at right angles to the spindle.
- Cross – when the table is moved parallel to the spindle.
- Vertical – when the table is adjusted in the vertical plane.

3. Universal Milling Machine

It can be adapted to a wide range of milling operations. Here the table can be swivelled to any angle up to 45-degrees on either side of the normal position.

In addition to 3 movements as mentioned earlier in a plain milling machine, the table may have the fourth movement when it is fed at an angle to the milling cutter. Helical milling operation can also be performed. The capacity of this type of machine is increased by using special attachments such as

- Dividing head or index head.
- Vertical milling attachment.
- Rotary attachment.
- Slotting attachment.

This machine can produce spur, bevel, spiral, twist drill, reamer, milling cutter. All operations that are performed on a shaper can be done using a universal milling machine.

Planer Type Milling Machine

This type of milling machine are also called as "Plano-Miller". It is a massive machine used for heavy-duty work having spindle heads adjustable in the vertical and transverse direction.

It relates a planer and like a planing machine. This machine has a cross rail capable of being raised or lowered carrying the cutters. It has their heads, and the saddles, all supported by rigid uprights.

This arrangement of driving multiple cutter spindles enables a number of work surfaces to be machined. Thereby it obtains the great reduction in production time.

The essential difference between a planer and a Plano-miller lies in the table movement. In a planer, the table moves to give the cutting speed. But in a Plano-milling machine, the table movement gives the feed.

Milling cutters:

1. Plain Milling Cutter:

It has straight or helical teeth cut on the periphery of a disc or a cylindrical surface. It may be of solid inserted blade or tipped type, and is usually profile sharpened but may be form relieved also. Generally helical teeth are used if the width of the cutter exceeds 15 mm.

The plain milling cutter is generally used for milling flat surfaces parallel to cutter axis. Helical teeth cutter is used where large stock removal is required. Helical angle permits several teeth to cut simultaneously which results in smoother cutting action.

Heavy duty plain cutters have fewer teeth and helix angle of 35-45°. These are sometimes nicked on their periphery on a helical pattern for chip breaking and smooth operation.

2. Side Milling Cutter:

This cutter is similar to plain cutter except that it has teeth on the side. However, the side milling cutter may have teeth on the periphery and on one or both sides of the tool. These cutters may have straight, spiral or staggered teeth. Further these may be solid, inserted blade or tipped construction, and may be profile sharpened or form relieved.

Half side milling cutters have teeth only on one side in addition to circumferential teeth. These cutters are usually used in pair for milling both ends of work to a given dimension.

3. End Mill Cutters:

These cutters have an integral shaft for driving and have teeth on both periphery and ends. These are the cutters with teeth on the periphery and end integral with a shank for holding and driving (Refer Fig. 16.41). These are used to mill flat, horizontal, vertical, bevel, chamfer and slant surfaces, grooves and keyways, and to cut slot and in recess work such as die making etc.

The flutes on the cutter may be either straight or helical. End mills with high helix are used for milling aluminum and light metals. The end mill cutter may have either taper shank (tanged or tapped) or straight shank.

Large cutters (shell end mill cutters) have the cutter part separate and are held to a stub arbor owing to the high cost of the high speed steel. This construction results in a considerable saving in material cost.

4. Metal Slitting Saw Cutters:

These cutters resemble a plain to side cutter except that these are made very thin. These are usually profile sharpened and may be either solid or tipped. These are used for cutting off and slotting operations and are somewhat similar to the circular saw blades. Plain cutters of this type are relieved by grinding the sides to afford clearance for the cutter.

5. Angle Milling Cutters:

Any cutter, angle shaped, comes under this classification. These may have cutters either on only one conical surface (single-angle cutter) or on two conical surfaces (double angle cutter).

Angle cutters are used for cutting ratchet wheel, dovetails, flutes on milling cutters and reamers, machining angles and V_s of 30°, 45°, 60° and 90°.

Angle milling cutters have circumferential teeth and its cutting edges lie on a conical surface

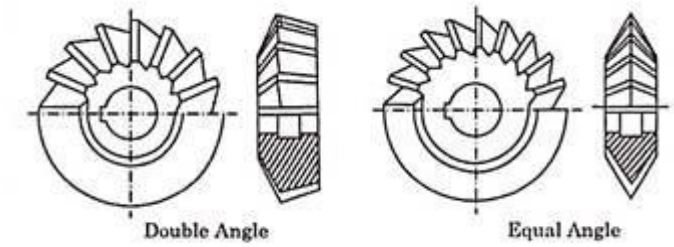


Fig. 16.43

6. T-Slot Cutters:

These are used for milling T-slots in one operation and are available in special sizes for standard T-slots. These resemble plain or side milling cutters which have an integral straight or tapered shaft for driving.

Straight or staggered teeth are cut on the periphery and both sides. For making T-slot, first a side milling cutter makes the groove and then the T-slot cutter enlarges the width of the bottom of the groove of form the desired T-slot.

7. Form Milling Cutters:

These have a special curved tooth outline and are used for milling contours of the various shapes. According to the method of grinding employed, these could be classified as profile-ground or face-ground.

8. **Woodruff cutters:**

Woodruff cutters are used to cut the keyway for a woodruff key. Woodruff cutters are slightly hollow ground on the sides for relief and the teeth are not side cutting. The teeth come in both straight and staggered varieties.

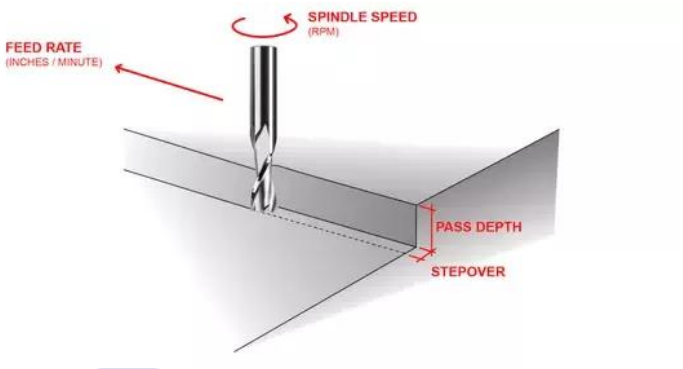
Cutting Speed and Feed in Milling Operation

Cutting speed in milling process is the ability of the milling cutter cutting workpiece with a speed that is calculated by multiplying the circumference of the milling cutter diameter with the number of length in a minute.

Factors affecting Cutting Speed:
1 Hardness (hardness)
2. ductility (ductility)
3. tensile stress (tensile strength)

Based cutting speed shown, equation for calculating spindle speed of milling machine

$$n = \frac{1000 \, . \, CS}{\pi . D}$$

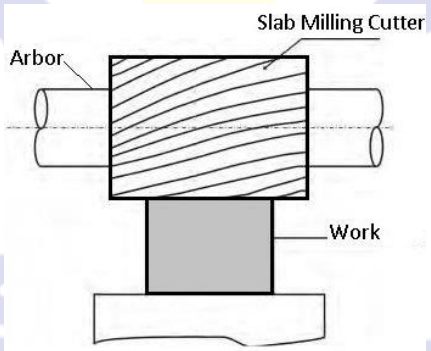


Note:
n = spindle revolution (rev / min)
D = Diameter of the milling cutter (mm)
CS = Cutting Speed (m / min)

The **"feed"** is the rate at which the bit passes through the material. The "speed" is the RPMs of the bit. The faster the feed, the higher the speed to get the same amount of chipload.

Milling operations

1. **Plain Milling**

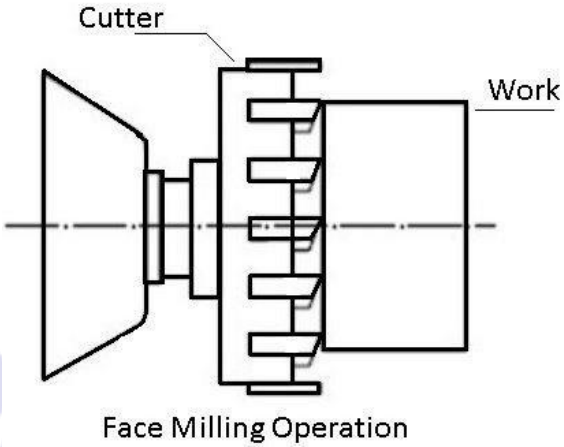


Plain Milling Operation

- The plain milling is the most common types of milling machine operations.
- Plain milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.
- To perform the operation, the work and the cutter are secured properly on the machine.

- The depth of cut is set by rotating the vertical feed screw of the table. And the machine is started after selecting the right speed and feed.

2. Face Milling



Face milling operation

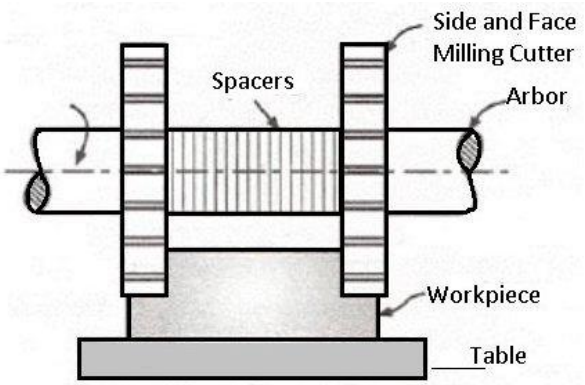
- The face milling is the simplest milling machine operations.
- This operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface.
- The operation is carried in plain milling, and the cutter is mounted on a stub arbor to design a flat surface.
- The depth of cut is adjusted by rotating the crossfeed screw of the table.

3. Side Milling

- The side milling is the operation of producing a flat vertical surface on the side of a workpiece by using a side milling cutter.
- The depth of cut is set by rotating the vertical feed screw of the table.

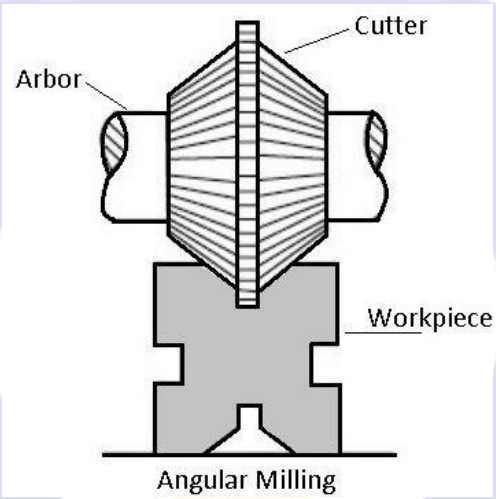
4. Straddle Milling

- The straddle milling is the operation of producing a flat vertical surface on both sides of a workpiece by using two side milling cutters mounted on the same arbor.
- Distance between the two cutters is adjusted by using suitable spacing collars.
- The straddle milling is commonly used to design a square or hexagonal surfaces



Straddle Milling Operation

5. Angular Milling



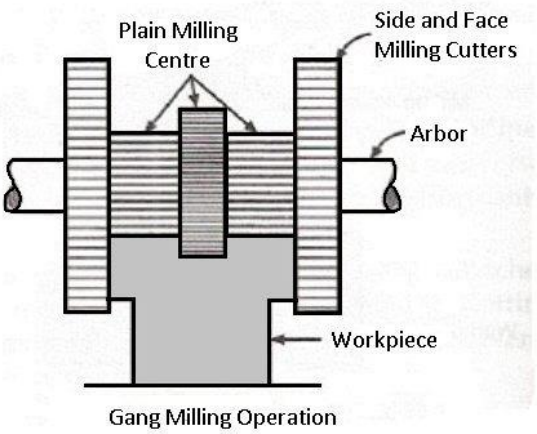
Angular Milling

The angular milling is the operation of producing an angular surface on a workpiece other than at right angles of the axis of the milling machine spindle.

- The angular groove may be single or double angle and may be of varying included angle according to the type and contour of the angular cutter used.
- One simple example of angular milling is the production of V-blocks.

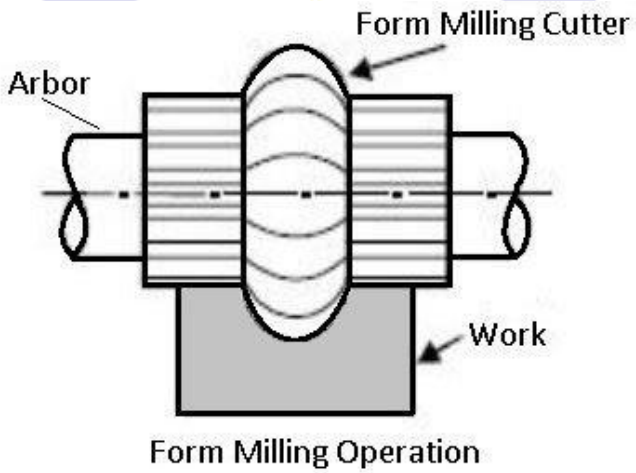
6. Gang Milling

- The gang milling is the operation of machining several surfaces of a workpiece simultaneously by feeding the table against a number of cutters having the same or different diameters mounted on the arbor of the machine.
- The method saves much of machining time and is widely used in repetitive work.



- Cutting speed of a gang of cutters is calculated from the cutter of the largest diameter.

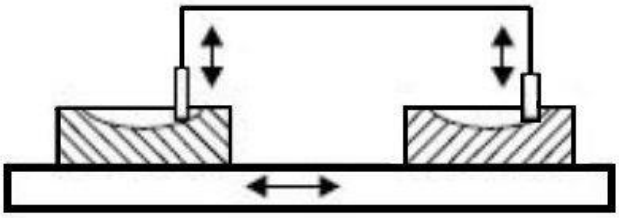
7. Form Milling



- The form milling is the operation of producing the irregular contour by using form cutters.
- The irregular shape may be convex, concave, or of any other shape. After machining, the formed surface is inspected by a template gauge.
- Cutting rate for form milling is 20% to 30% less than that of the plain milling.

8. Profile Milling

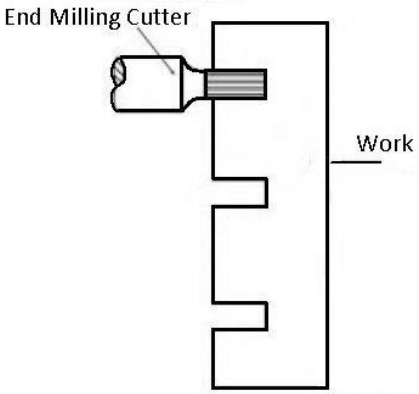
- The profile milling is the operation of reproduction an outline of a template or complex shape of a master dies on a workpiece.



Profile Milling Operation

- Different cutters are used for profile milling. An end mill is one of the widely used milling cutters in profile milling work.

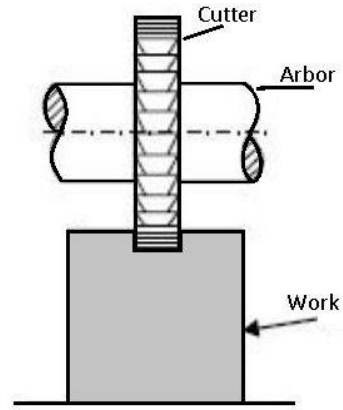
9. End Milling



End Milling Operation

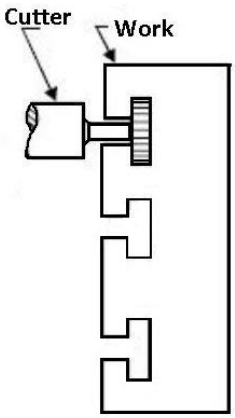
- The end milling is the operation of producing a flat surface which may be vertical, horizontal or at an angle in reference to the table surface.
- The cutter used is an end mill. The end milling cutters are also used for the production of slots, grooves or keyways.
- A vertical milling machine is more suitable for end milling operation.

10. Milling Keyways, Grooves and Slots



Keyway Milling Operation

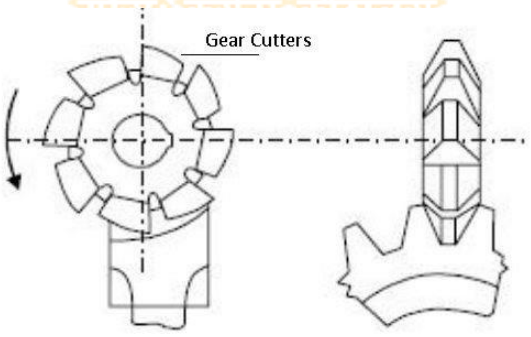
- The operation of producing of keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.
- It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.
- The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using endmills.



T-Slot Milling Operation

- A dovetail slot or T-slot is manufactured by using special types of cutters designed to give the required shape on the workpiece.
- The second slot is cut at right angles to the first slot by feeding the work past the cutter.
- A woodruff key is designed by using a woodruff key slot cutter.
- Standard keyways are cut on the shaft by using side milling cutters or end mills.
- The cutter is set exactly at the centre line of the workpiece and then the cut is taken.

11. Gear Cutting



Gear Cutting Milling Operation

- The gear cutting operation is performed in a milling machine by using a form-relieved cutter. The cutter may be a cylindrical type or end mill type.
- The cutter profile fits exactly with the tooth space of the gear.

- Equally spaced gear teeth are cut on a gear blank by holding the work on a universal diving head and then indexing it.

Importance And Use Of Jigs And Fixtures

As the efficient running of a manufacturing company which demands a prompt and simple work positioning strategy for correct operations depends largely on the interchangeability of machine components and work-pieces, to ensure un-complication of assembly, and unit cost reduction, as well as to become competitive, reduce the enormous manufacturing cost, and also increase their profitability, the industry has resorted to streamlining its supply chain in a bid to maintaining a very low amount of inventory. This has also led to the demand for a better and cost-effective work-holding devices which will ensure better quality products, reduce lead time, and also increase throughput.

Also, although some machining operations are so straight-forward, like in turning where the job is secured tightly on the chuck while the turning operations are easily performed, some jobsin other operations may not be easily held on either the three or four jaw chucks, and may also require the tools to be guided by the means of a different device. This explains the need for production standard work-holding devices to increase the rate of manufacturing.

Jig is the device which guides the tool, while fixture is a device that securely holds the job in position during machining operations.

Principle of location

A fundamental concern in metalworking is locating the part to be machined, punched, bent, or stamped relative to the work platform (fixture). For example, a CNC machine tool starts its process at a specific point relative to the fixture and proceeds from there. Hence, the accuracy with which a part is machined is quite dependent on the accuracy with which it is positioned in the fixture.

Accurate locating of not just one part, but each and every part that is loaded into the fixture is crucial. Any variation in part location on the fixture adds to the dimensional tolerance that must be assigned to the finished parts.

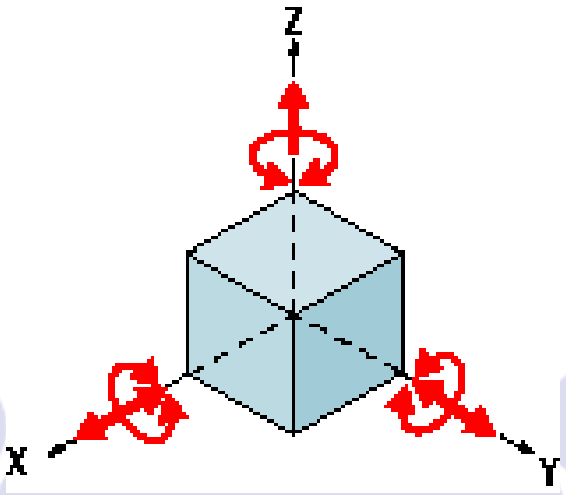
Additionally, the method of supporting and securing the part in the fixture affects not only dimensional tolerances, but surface finishes as well. This is true because improper supporting or clamping can temporarily or permanently deform the part. Hence, techniques for supporting and clamping must be considered together with the method of locating in order to assure repeatability from part-to-part.

Locating of a part to be machined is a three-step process:

1. Supporting

2. Locating (positioning)

3. Holding (clamping)



The Locating Process: Degrees of Freedom

In order to completely specify the position in space of a three-dimensional object (such as the cube that's shown), we refer to six coordinates:

- Translational position along the X-axis
- Translational position along the Y-axis
- Translational position along the Z-axis
- Rotational position about the X-axis
- Rotational position about the Y-axis
- Rotational position about the Z-axis

These six coordinates are known as the six degrees of freedom of a three-dimensional object. As the double-headed arrows indicate, the translational and rotational positions can vary in either direction with respect to each of the three axes.

To completely prevent movement, all six degrees of freedom must be restricted.

The Locating Process: 3-2-1 Method

We have two objectives when mounting a part in a fixture for machining:
1. Accurately position the part at the desired coordinates.
2. Restrict all six degrees of freedom so that the part cannot move.
A widely used method of accomplishing these two objectives uses the 3-2-1 principle, so-called because it entails three steps that employ three, then two, then one fixed points of known location. Since that adds up to six fixed points, it's also known as the six point method.

In the three steps of the 3-2-1 method, three mutually perpendicular planes, called datum planes, are introduced, one at each step. These three planes define the workpiece position, and

together with opposing clamping forces fully constrain the part. Let's take a look at the details of the 3-2-1 method.

Locating And Clamping Devices

Jigs and fixtures are the economical ways to produce a component in mass. These are special work holding and tool guiding device. Quality of the performance of a process largely influenced by the quality of jigs and fixtures used for this purpose. The main purpose of a fixture is to locate and, in the cases, hold a workpiece during an operation A jig differs from a fixture - it guides the tool to its correct position or towards its correct movement during an operation in addition to locating and supporting the workpiece. An example of jig is when a key is duplicated, the original key is used as base for the path reader which guides the movement of tool to make its duplicate key

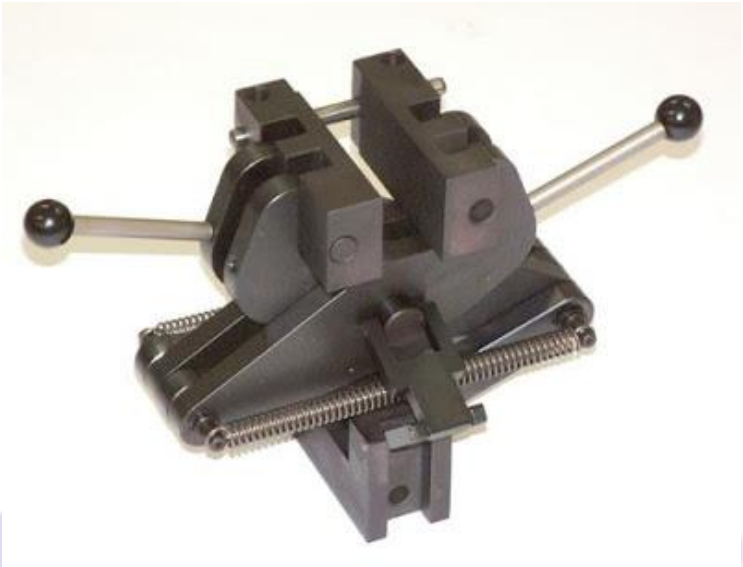
Jigs and Fixtures:

What is Jig?

A jig is a device in which a component is held and located for a specific operation in such a way that it will guide one or more cutting tools to the same zone of machining. The usual machining operation for jigs are drilling and reaming. Jigs are usually fitted with hardened steel bushings for guiding drills or cutting tools. The most common jigs are drilling jigs, reaming jigs, assembly jigs etc. when these are used, they are usually not fastened to machine tools or table but are free to be moved so as to permit the proper registering of the work and the tool.

What is Fixture?

A fixture is a production tool that locates, holds and supports the work securely in a fixed orientation with respect to the tool so that the required machining operations can be performed. Fixtures vary in design from relatively simple tools to expensive complicated devices. There are most frequently attached to some machine tool or table. The most common fixture are milling fixtures, broaching fixtures, assembly fixture etc.



Advantages of Jigs and Fixtures:

Jigs and fixtures are used in mass production of identical parts. They gives following advantages.

- They improve productivity.
- It gives rapid production work.
- It reduced manufacturing costs.
- Complex and heavy components can be easily machined.
- Owing to high clamping rigidity, higher speed, feeds and depth of cut can be used.
- Jigs and fixtures are increased machining accuracy.
- It reduces in the expenditure due to inspection and quality control of finished components.