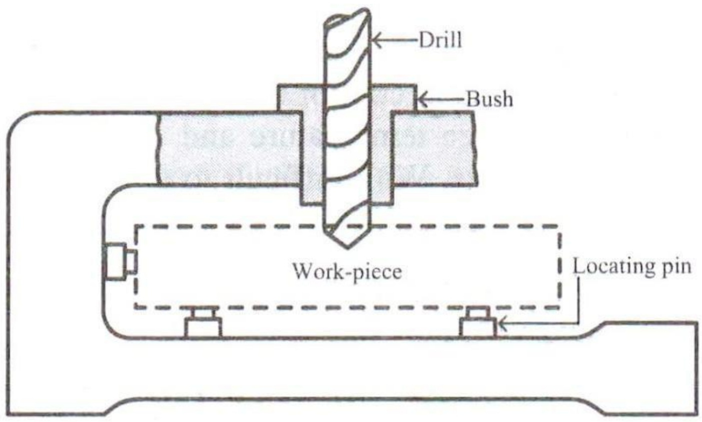
JIGS AND FIXTURES

Jigs and fixtures are special purpose tools which are used to facilitate production (machining, assembling and inspection operations) when machined products are to be produced on a mass scale. The mass production of work-pieces is based on the concept of inter- changeability according to which every part will be produced within an established tolerance. Jigs and fixtures provide a means of manufacturing interchangeable parts since they establish a relation, with predetermined tolerances, between the work and the cutting tool. They are specially designed so that a large number of components can be machined or assembled identically, and to ensure inter-changeability of components. They eliminate the necessity of a special set up for each individual part. Once a jig or fixture is properly set up, any number of duplicate parts may be readily produced without additional set up.

Jig

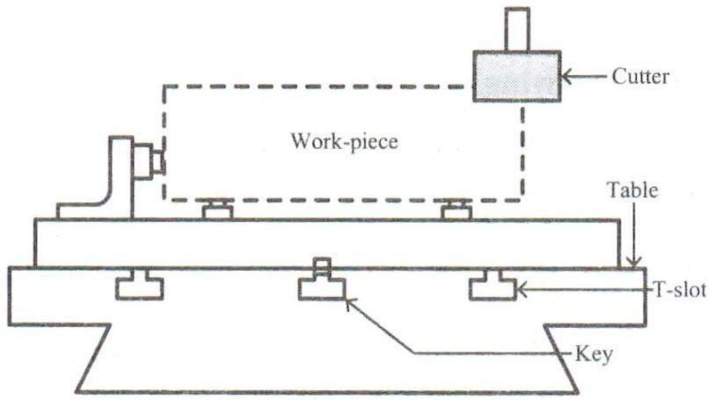
A jig is a device in which a component is held and located for a specific operation in such a way that it will guide one or more cutting tools to the same zone of machining. The usual machining operations for jigs are drilling and reaming. Jigs are usually fitted with hardened steel bushings for guiding 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. A simple drilling jig is shown in the figure. In the figure shown, the work-piece to be drilled is held and positioned in the drilling jig. Bushes guide the drills to the desired location(s) in the work-piece.



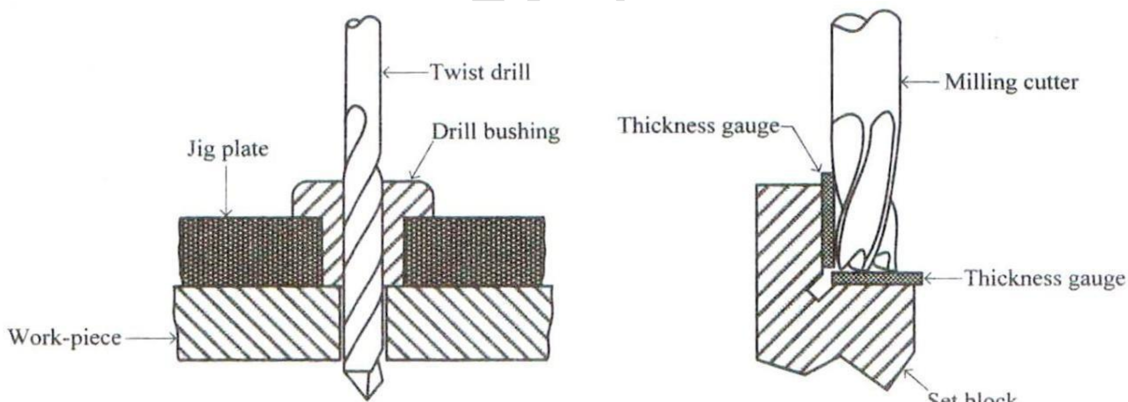
Fixture

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. The setting of the tool is done by machine adjustment and a setting block or by using slip gauges. A fixture is bolted or clamped to the machine table. It is usually heavy in construction. A simple fixture is shown in the figure. Fixtures vary in design from relatively simple tools to expensive complicated devices. These are most frequently attached to some machine tool or table. Consequently they are associated in name with the particular machine tool with which they are used, e.g., milling fixtures, broaching fixtures, assembly fixtures, etc. A fixture can be used in almost any operation that requires a precise relationship in the position of a tool to a work-piece.

Locating pins are stops or pins which are inserted in the body of jig or fixture, against which the work-piece is pushed to establish the desired relationship between the work-piece and the jig or fixture. To assure inter-changeability, the locating elements are made from hardened steel. The purpose of clamping elements is to exert a force to press a work-piece against the locating elements and hold it there in opposition to the action of the cutting forces. In the case of a jig, a hardened bushing is fastened on one or more sides of the jig, to guide the tool to its proper location in the work. However, in the case of a fixture, a target or set block is used to set the location of the tool with respect to the work-piece within the fixture. Most jigs use standard parts such as drill bushings, screws, jig bodies and many other parts. Fixtures are made from grey cast iron or steel by welding or bolting. Fixtures are usually massive bodies because they have to withstand large dynamic forces. Because the fixtures are in between the machine and the work-piece their rigidity and the rigidity of their fastening to the machine table are most important. Jigs are positioned or supported on the machine table with the help of feet which slide or rest on the machine table. If the drill size is quite large, either stops are provided or the jig is clamped to the machine table to withstand the high drilling torque. Fixtures are clamped or bolted to the machine table.



DIFFERENCES BETWEEN JIGS AND FIXTURES



(a) *Jig*

(b) *Fixture*

Often the terms 'jig' and 'fixture' are confused or used interchangeably; however, there are clear distinctions between these two tools. Both jigs and fixtures hold, support, and locate the work-piece. A jig, however, guides the cutting tool. A fixture references the cutting tool. The differentiation between these types of work-holders is in their relation to the cutting tool. As shown in the figure (a), jigs use drill bushings to support and guide the tool. Fixtures, figure (b) use set blocks and thickness, or feeler, gages to locate the tool relative to the work-piece.

Following are the differences between jigs and fixtures.

1) Essential difference between a jig and fixture is that the jig incorporates bushes that guide the tools whereas, the fixture holds the component being machined with the cutters working independently, of it.

2) Jigs are used on drilling, reaming, tapping and counter boring operations, while fixtures are used in connection with turning, milling, grinding, shaping, planing and boring operations.
3) Whereas jigs are connected with operations, fixtures most commonly are related to specific machine tools.
4) Jigs are lighter than fixtures, for quick handling; fixtures are heavier in construction and bolted rigidly on the machine table.

Advantages of using jigs and fixtures

1) Jigs and fixtures provide easy means for manufacture of interchangeable parts and, thus, facilitate easy and quick assembly.
2) Reduced manufacturing costs (since large number of identical and interchangeable parts are produced) using jigs and fixtures.
3) Large reduction in fatigue to the operator (since there is considerable reduction in manual handling operations).
4) Complex and heavy components can be easily machined (since such parts can be rigidly held in proper location for machining in jigs and fixtures).
5) Owing to high clamping rigidity (offered by jigs and fixtures), higher speeds, feeds and depth of cut can be used and increased machining accuracy owing to the automatic location of the work and guidance of the tool.

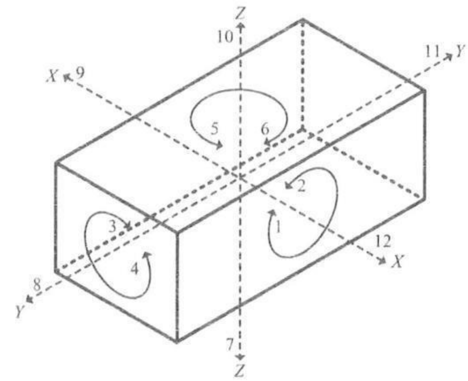
Main components of jigs and fixtures

In order to fulfill their basic functions, both jigs and fixtures should process the following components or elements.

1) Sturdy and rigid body.
2) Locating elements.
3) Clamping elements.
4) Tool guiding elements (for jigs) or tool setting elements (for fixtures).
5) Positioning elements (these elements include different types of fastening devices).
6) Indexing elements (not always provided).

Degrees of freedom

A work-piece free in space can move in an infinite number of directions. For analysis, this motion can be broken down into twelve directional movements, or 'degrees of freedom'. Notice the 12 degrees of freedom consisting of 6 axial degrees of freedom and 6 radial degrees of freedom as shown in the figure. The axial degrees of freedom permit straight-line movement in both directions along the three principal axes, shown as X, Y, and Z. The radial degrees of freedom permit rotational movement, in both clockwise and counter clockwise radial directions, around the same three axes.

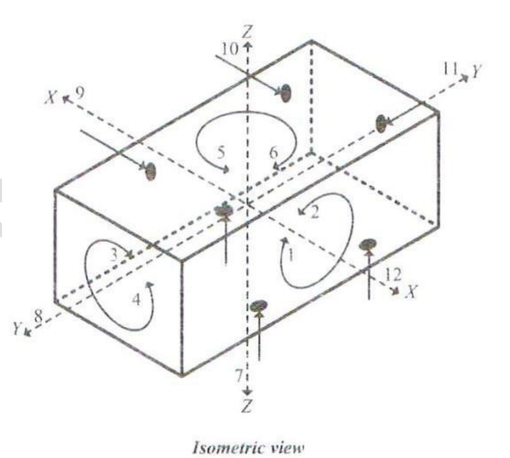


For accurate machining, the work-piece is to be placed and held in correct position and orientation in the fixture (or jig) which is again appropriately located and fixed with respect to the cutting tool (part of machine tool) and the machine tool (machine tool represent machine its self such as lathe, milling machine, etc., used to cut a metal in the desires shape). It has to be assured that the work-piece, once fixed or clamped, does not move at all. Any solid body may have maximum twelve degrees of freedom as indicated in the figure. By properly locating, supporting and clamping the blank it's all degrees of freedom are to be arrested as typically shown in the figure.

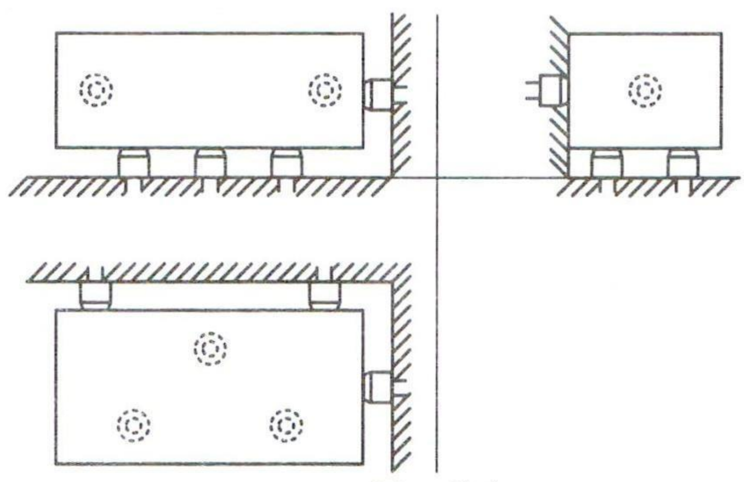
PRINCIPLES OF LOCATION

The term, ***'location'*** refers to the method of establishing correct relative position of the work-piece with respect to the cutting tool. In order to decide upon the location method, one has to consider the work-piece shape, surfaces and features that are likely to obstruct the tool movement or access direction. The correct positioning of the work-piece essentially requires restricting all the degrees of freedom of the work-piece. This is done with the help of locators, which must be strong enough to resist the cutting forces while maintaining the position of the work-piece. The basic principles of location are explained below.

1) ***3-2-1 Principle-*** A widely used method of restricting the 12 degrees of freedom is to uses the 3- 2-1 principle, so-called because it consists of three steps that employ three pins, then two pins, then one fixed pins of known location. Since that adds up to six fixed points, it's also known as the ***six point location principle***. Application of 3-2- 1 principle generally gives rise to proper arresting of all the motions.



Isometric view



Orthographic view

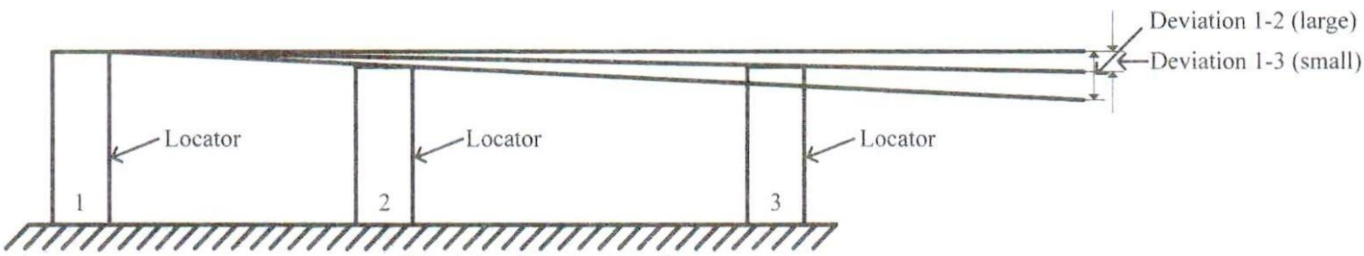
In 3-2-1 method, three pins are inserted in the base of the body restrict five motions viz., ***1*** and ***2*** rotation about the axis XX", ***3*** and ***4*** rotation about axis YY and downward motion ***7*** along Z axis. Inserting two more pins in a plane perpendicular to the plane containing the first three pins will

restrict the rotation about Z axis (***5*** and ***6***) and also restrict the axial movement along X axis (degree of freedom ***9***). Another pin is inserted in the vertical face of the body to restrict degree of freedom ***11***. Three degrees of freedom viz., ***8***, ***10*** and ***12*** are still free. To restrict these three more pins are needed. But this will completely enclose the work-piece making its loading and unloading into jigs and fixture impossible. The rest three degrees of freedom are arrested by three external forces usually provided directly by clamping. This is the most common locating method employed for ***square*** or ***rectangular parts***. The use of pin type locators offers more accuracy as the area of contact is less.

2) ***The principle of mutually perpendicular planes -*** An ideal location of a component is achieved when it is located on six locating points ('3- 2- 1 principle') in three mutually perpendicular planes. Other arrangements are possible but not desirable.

3) ***Principle of least point -*** In order to secure location in any one plane, points more than necessary should not be used. However, if more points are used such as for finished surface, the extra ones should only be inserted because they serve a useful purpose and care must be taken that they do not damage the location.

4) ***Principle of extreme position -*** On any one work-piece surface, locating points should be chosen as far apart as possible.

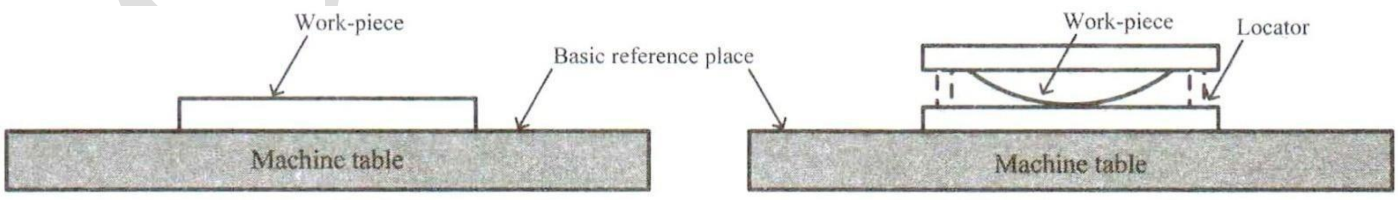


From the figure, it can be seen that, for a given displacement of any locating point from another, the resulting deviation decreases as the distance between the points increases.

Locating methods

Depending upon the nature of surfaces to be located, most commonly methods of locating surfaces are explained below.

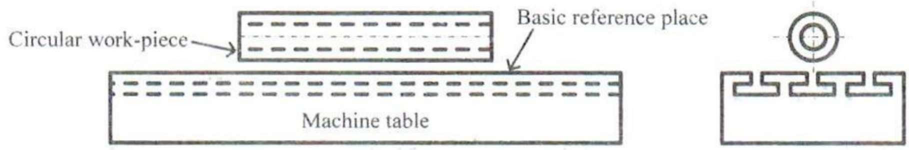
Locating from plane surfaces - The basic reference for locating is a flat plane, generally a machine table. The machine table is usually at right angles or parallel with the machines' feed movements. All locating devices are made with regard to the basic reference plane (machine table). If the work-piece has a flat side to mate with the machine table, the machine table becomes the locating surface.



a) Work-piece with flat side   b) Work-piece without flat side

If the work-piece does not have a flat side to mate with the machine table, the flat plane of the machine table cannot be used as a locating surface. A minimum of three points (or locators) must be used to locate the work-piece shown in the figure (b), although four or more may be used to provide adequate support. It should be noted that a minimum of three locators will always theoretically establish the same location of the work-piece. The number of adjustable supports would depend upon the shape, strength and size of the work-piece.

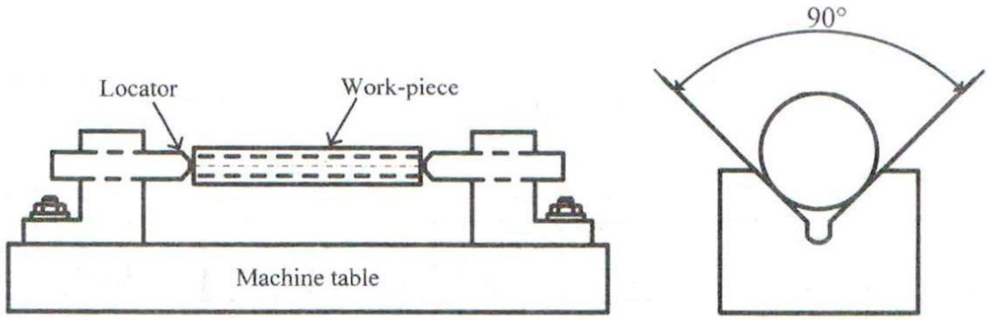
Locating from circular surfaces - The basic reference for locating from circular surfaces is the flat plane of the machine-tool table surface. However, instead of locating the flat plane of the work-piece parallel to the reference plane, it is necessary to locate the axis of the circular work-piece as shown in the figure.



Circular work-piece must be located with its axis parallel with the basic reference plane.

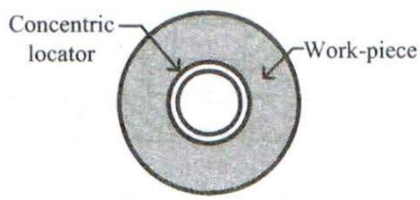
One of the common methods of locating from a circular surface is by using cones, a method commonly referred to as conical location and usually employed when locating is done from a hole. Conical locators are used mainly to locate rough unmachined cylinders in castings and forgings.

Closely related to conical location is the V method, used primarily to locate round work-pieces or work-pieces with convex circular surfaces. It has been found that the best general Vangie is 90°. Smaller included angles hold a round work-piece more securely but are more susceptible to location errors.



Conical locator ***V locator***

Concentric locating - Concentric locators locate a work-piece from its axis. This axis may or may not be in the center of the work-piece. The most-common type of concentric location is a locating pin placed in a hole.



LOCATING DEVICES

There are several methods of locating; few of them are discussed below.

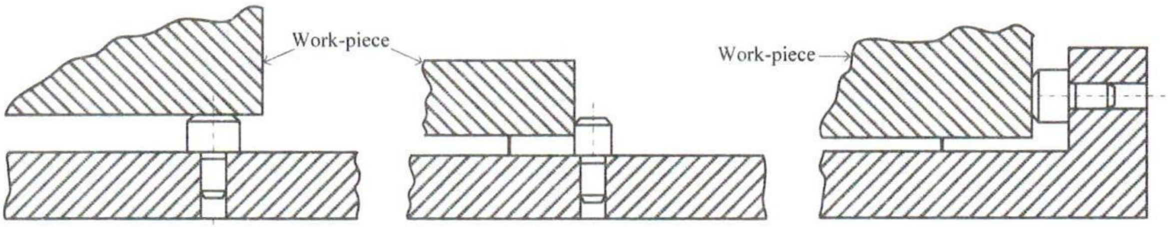
Locating blanks for machining in lathes - In lathes, where the job rotates, the blanks are located by the following methods.

a) Fitting into self centering chuck.
b) Fitting into 4- independent jaw chuck and dead centre.
c) In self- centering collets.
d) In between live and dead centres.
e) By using mandrel fitted into the head stock - spindle.
f) Fitting in a separate fixture which is properly clamped on a driving plate which is coaxially fitted into the lathe spindle.

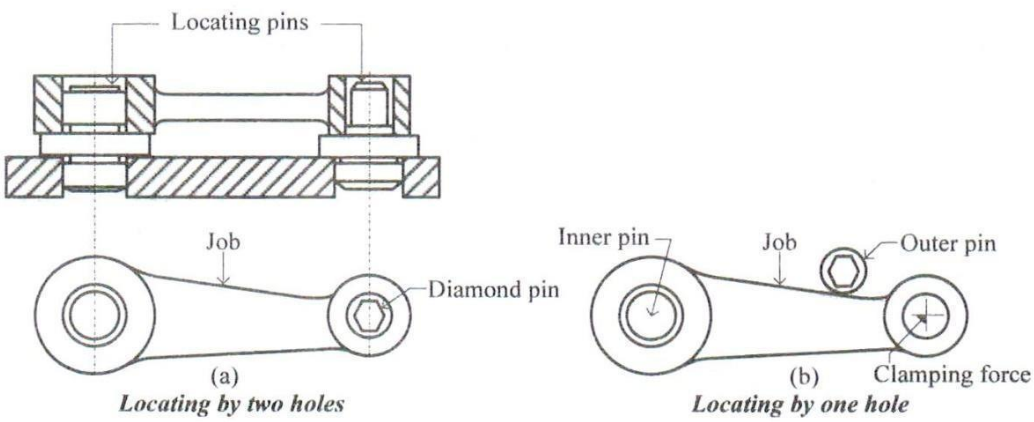
Locating for machining other than lathes - In machine tools like drilling machine, boring machine, milling machine, planing machine, broaching machine and surface grinding machine the job remains fixed on the bed or work table of those machine tools. Fixtures are mostly used in tpe aforesaid machine tools and jig specially for drilling, reaming, etc. for batch production. For machining in those jigs and fixtures, the blank is located in several ways which include the followings.

1) Locating by flat surfaces

The figure typically shows locating jobs by their flat surfaces using various types of flat ended pins and buttons.



2) Locating by holes

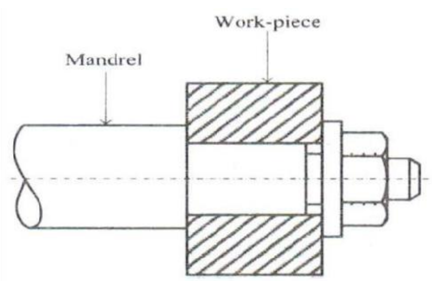


In several cases, work-pieces are located by pre-machined (drilled, bored or pierced) holes, such as below.

i. Locating by two holes as shown in the figure (a) where one of the pins has to be diamond shaped to accommodate tolerance on the distance between the holes and their diameters.
ii. Locating by one hole and an external pin which presents rotation of the blank around the inner pin as indicated in figure (b).

3) Locating on mandrel or plug

Ring or disc type work-pieces are conveniently located on mandrel or single plug as shown in the figure.



CLAMPING DEVICES

In jigs and fixtures, the work-piece or blank has to be strongly and rigidly clamped against the supporting surfaces and also the locating features so that the blank does not get displaced at all under the cutting forces during machining. A clamp is a device that holds the work-piece firmly against the locators provided and also resists all the forces generated by the cutting action of the tool on the work-piece. The most common example of a clamp is the bench vice, where the movable jaw of the vice exerts force on the work-piece thereby holding it in the correct location in the fixed jaw of the vice. A clamping device ensures proper location and centering of the work-piece.

Basic requirements of clamping devices

1. To force the work-piece to remain in firm contact with locating pins or surfaces.
2. To rigidly hold the work-piece in a jig or fixture against all forces.
3. To exert just sufficient pressure on the work-piece.
4. To not to damage the work-piece it holds.

PRINCIPLES OF CLAMPING

While designing for clamping the following factors essentially need to be considered.

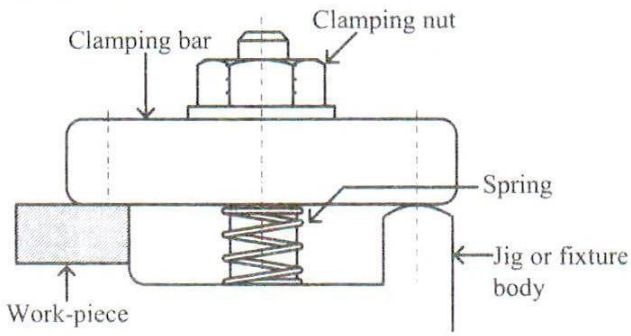
1) Clamping need to be strong and rigid enough to hold the blank firmly during machining.
2) Clamping should be easy, quick and consistently adequate.
3) Clamping should be such that it is not affected by vibration, chatter or heavy pressure.
4) The way of clamping and unclamping should not hinder loading and unloading the blank in the jig or fixture.
5) The clamp and clamping force must not damage or deform the work-piece.
6) Clamping operation should be very simple and quick acting when the jig or fixture is to be used more frequently and for large volume of work clamps.
7) Clamping system should comprise of less number of parts for ease of design, operation and maintenance.
8) The wearing parts should be hard or hardened and also be easily replaceable.
9) Clamping force should act on heavy part(s) and against supporting and locating surfaces.
10) Clamping force should be away from the machining thrust forces.
11) Clamping method should be fool proof and safe.

Types of clamps

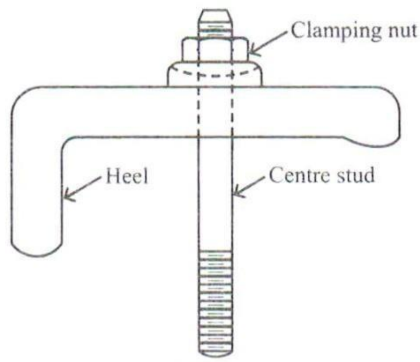
The type of clamp to be used depends on the shape and size of the work-piece, the type of jig or fixture being used and the work to be done. There a number of clamps used by tool designers for clamping the work-piece properly. Different variety of clamps used with jigs and fixtures are classified into different categories are discussed below.

Strap clamp - Strap clamp are made of rectangular plates and act like levers. This type clamping is done with the help of the lever pressure acting as a strap on the workpiece. Different types of strap clamps are discussed below.

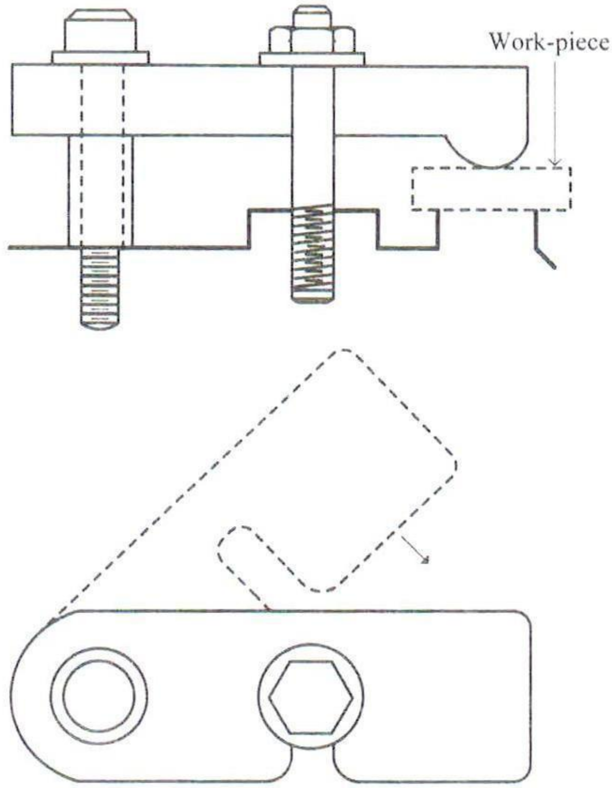
a) ***Bridge clamp -*** It is very simple and reliable clamping device. The clamping force is applied by the spring loaded clamping nut. The relative positions of the nut, the point of contact of the clamp with the work and with outer support should be carefully considered, since the compressive force of the nut is shared between the work-piece and the clamp support. To release the work-piece, the nut named as clamping nut is unscrewed. The spring lifts the lever to release the work-piece.



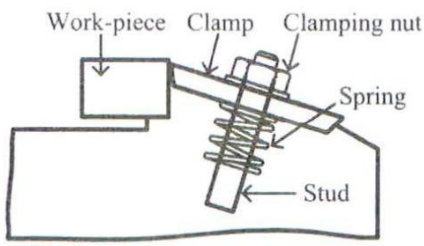
b) ***Heel clamp -*** Heel clamp consist of strap, centre stud and a heel. The design differs from the simple bridge clamp in that a heel is provided in the outer end of the clamp to guide its sliding motion for loading and unloading the work-piece. By tightening the stud, the clamping force is transferred to the work-piece. Heel pin is the fulcrum about which the lever acts, while clamping force is applied at the stud by tightening the screw. The work-piece is loaded into the jig or fixture or removed from these, by unscrewing the clamping nut.



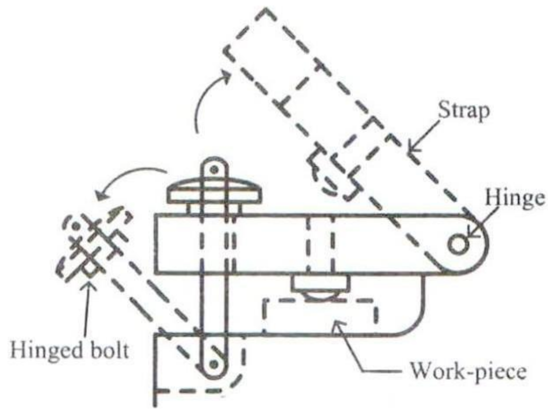
c) ***Swinging strap clamp-*** Swinging strap clamp is a special type of clamp which provides a means of entry for loading and unloading the work-piece. For this, the strap can be swung out or in. A swing strap clamp is shown in the figure.



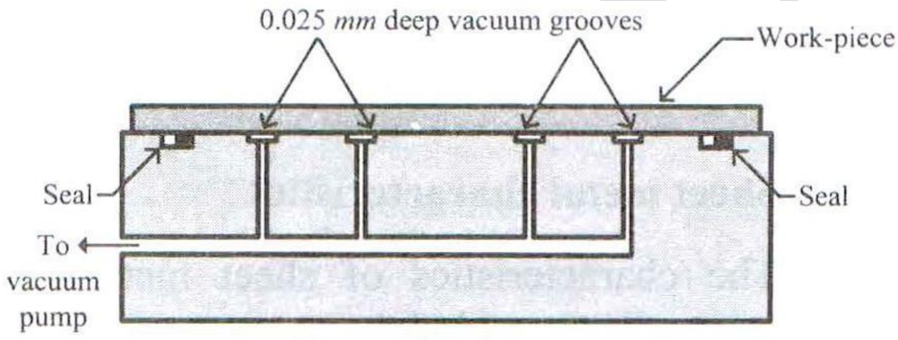
Side clamp - A side clamp is also known as edge clamp. In this case the surface to be machined is always clamped above the clamping device. This clamping device is recommended for fixed length work-piece. The clamping device is illustrated in the figure. Releasing and clamping of the work-piece can be accomplished by unscrewing and screwing of the clamping nut respectively.



Hinged clamp - Several times, the requirement in a jig is that the strap (latch) should be completely lifted up for loading and unloading the work-piece. Hinged clamp has a hinged bolt and hinged strap/plate which when swung apart gives space to mount the workpiece. An example of hinged clamp is shown in the figure. The upper strap is locked on one side by means of the hinged bolt. This clamp provides rapid clearance for loading and unloading the work-piece.



Vacuum clamping - Vacuum clamping is convenient for securing thin flat sheets which are vulnerable to distortion under heavy clamping force. Vacuum clamping provides light clamping. The holding face is provided with 0.025 mm deep grooves which serve as vacuum ducts. The clamping face is circumscribed by a rubber seal groove all around. The seal in the groove segregates the clamping vacuum area from the space outside the seal. The vacuum pressure is usually limited to 1 kg/cm^2. The figure shows a vacuum holding fixture, distribution grooves and rubber seal.



Magnetic clamping- Magnetic clamping uses electromagnetism for holding and is often used to hold ferrous metals or work-pieces made from other magnetic materials. It is independent of the component geometry to a certain degree. Magnetic clamping force can be developed by permanent magnets or electromagnets. In permanent magnet type, the work-piece to be clamped is placed on the work surface of the clamp. Below the working surface, there are a number of permanent magnets. When the lever is in 'ON' position, the magnetic flux passes through the work-piece to complete the magnetic circuit. When the lever is in OFF' position, the magnetic flux passes through the working surfaces of the clamp only and not through the work-piece, thus unclamping the work-piece. This is done by aligning the magnets with a number of non-magnetic separators. In electromagnetic clamp, direct current is used for clamping the work-piece on electromagnetic devices. These magnets are more powerful than permanent magnet type clamps. Compared to other clamping methods, magnetic clamping is relatively weak. Magnetic clamping is widely used for grinding, and can be used for light milling and turning. It is fast and convenient.