

Module

8

Jigs and Fixtures for Machine shops

Lesson

33

Purposes of jigs and fixtures and their Design principles

Instructional objectives

This lesson will enable the students

- (i) Define Fixture and Jig that aid machining
- (ii) Conceive the purposes of use of jigs and fixtures
- (iii) State the design considerations for jigs and fixtures
- (iv) Illustrate the methods of
 - (a) locating
 - (b) supporting and
 - (c) clamping of blanks
 - (d) guidance of cutting toolsin fixtures and jigs to facilitate machining

(i) Definition Of Fixture And Jig

Fixtures, being used in machine shop, are strong and rigid mechanical devices which enable easy, quick and consistently accurate locating, supporting and clamping, blanks against cutting tool(s) and result faster and accurate machining with consistent quality, functional ability and interchangeability.

Jig is a fixture with an additional feature of tool guidance.

(ii) Purpose Of Using Fixtures And Jigs

For a machining work, like drilling a through hole of given diameter eccentrically in a premachined mild steel disk as shown in Fig. 8.1.1 in a

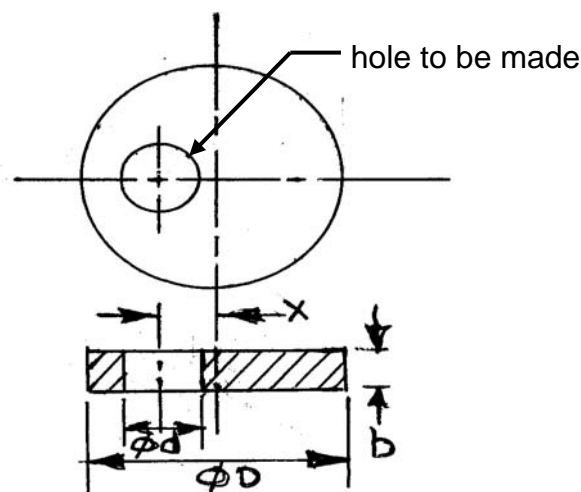


Fig. 8.1.1 A through hole has to be drilled in a pre-machined mild steel disc.

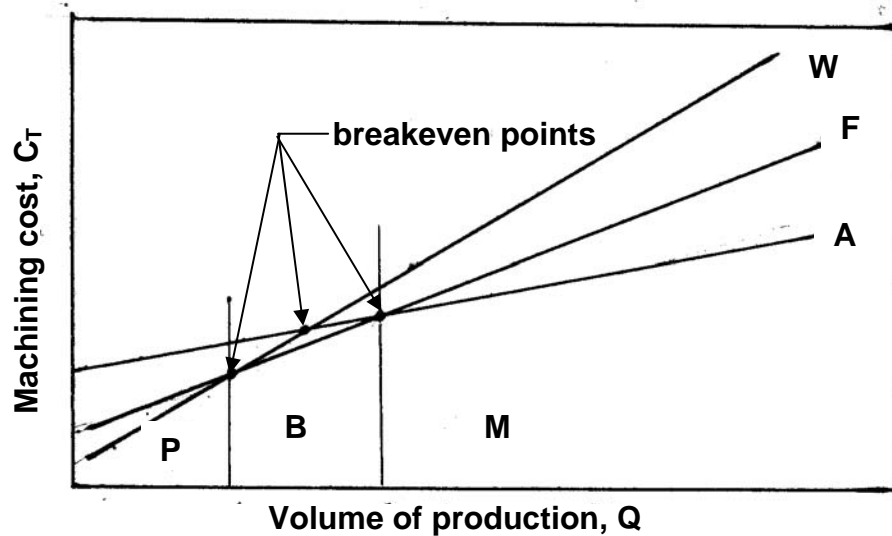
conventional drilling machine without using any fixture or jig, the following elementary steps are to be sequentially followed

- cleaning and deburring the blank (disc)
- marking on the blank showing the location of the hole and its axis on the blank
- punch the centre at the desired location and prick punch the periphery of the hole to be made in the disc
- mount the blank in a drilling vice using parallel block, a small Vee block etc. to provide support and clamp the blank firmly
- position the vice along with the marked blank to bring the hole axis in alignment with the drill axis by
 - △ either adjusting the vise position w.r.t. the fixed drill axis
 - △ or moving the drilling machine table and then locking the table position
 - △ or moving the radial arm and the drilling head, if it is a radial drilling machine
- after fixing the blank, vise and the table, alignment is checked again
- if error, like eccentricity, is found to occur then readjustment of location of the hole – axis is to be done before and even after starting drilling
- drilling is accomplished.

Therefore it appears that so many operations are needed to be carried out carefully and skilfully by the machinist or operator for such a simple job. Even after that there may be inaccuracies in machining. Such tedious and time consuming manual work are eliminated or drastically reduced in mass production by automatic or special purpose machine tools. But such machine tools are quite expensive and hence are economically justified for only huge or mass production and not viable for small lot or batch production. For batch production proper design and use of simple but effective jigs and fixtures are appropriate and economically justified. This is schematically illustrated in Fig. 8.1.2.

The basic purposes of developing and using suitable jigs and fixtures for batch production in machine shops are :

- to eliminate marking, punching, positioning, alignments etc.
- easy, quick and consistently accurate locating, supporting and clamping the blank in alignment of the cutting tool
- guidance to the cutting tool like drill, reamer etc.
- increase in productivity and maintain product quality consistently
- to reduce operator's labour and skill – requirement
- to reduce measurement and its cost
- enhancing technological capacity of the machine tools
- reduction of overall machining cost and also increase in interchangeability.



W – without using jig & fixture
 F – using jig and fixture
 A – automatic (special purpose) machine
 P – piece production
 B – batch production
 M – mass production

Fig. 8.1.2 Role of Jigs and Fixtures on machining cost

(iii) Design Considerations For Jigs And Fixtures

Jigs and fixtures are manually or partially power operated devices. To fulfil their basic purposes, jigs and fixtures are comprised of several elements (as indicated in Fig. 8.1.3) :

- base and body or frame with clamping features
- locating elements for proper positioning and orientation of the blank
- supporting surfaces and base
- clamping elements
- tool guiding frame and bushes (for jig)
- indexing plates or systems, if necessary
- auxiliary elements
- fastening parts

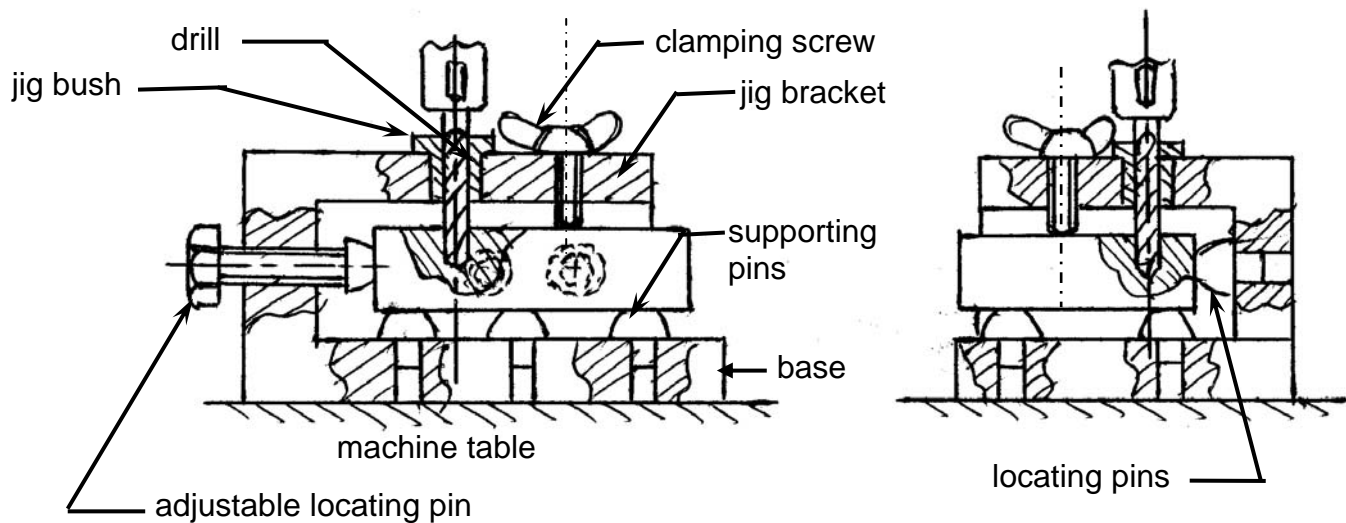


Fig. 8.1.3 Major elements of jig and fixtures.

Therefore keeping in view increase in productivity, product quality, repeatability i.e. interchangeability and overall economy in batch production by machining, the following factors are essentially considered during design, fabrication and assembly of jigs and fixtures :

- easy, quick and consistently accurate locating of the blank in the jig or fixture in reference to the cutting tool
- providing strong, rigid and stable support to the blank
- quick, strong and rigid clamping of the blank in the jig or fixture without interrupting any other operations
- tool guidance for slender cutting tools like drills and reamers
- easy and quick loading and unloading the job to and from the jig or fixture
- use of minimum number of parts for making the jig or fixture
- use of standard parts as much as possible
- reasonable amount of flexibility or adjustability, if feasible, to accommodate slight variation in the job - dimensions.
- prevention of jamming of chips, i.e. wide chips-space and easy chip disposal
- easy, quick and accurate indexing system if required.
- easy and safe handling and moving the jig or fixture on the machine table, i.e., their shape, size, weight and sharp edges and corners
- easy and quick removal and replacement of small parts
- manufacturability i.e. ease of manufacture
- durability and maintainability
- service life and overall expenses

(iv) Principles And Methods Of Locating, Supporting And Clamping Blanks And Tool Guidance In Jigs And Fixtures

It is already emphasized that the main functions of the jigs and fixtures are :

(a) easily, quickly, firmly and consistently accurately

- locating
- supporting and
- clamping

the blank (in the jig or fixture) in respect to the cutting tool(s)

(b) providing guidance to the slender cutting tools using proper bushes

There are and can be several methods of locating, supporting and clamping depending upon the size, shape and material of the job, cutting tool and the machining work required. But some basic principles or rules are usually followed while designing for locating, supporting and clamping of blank in fixtures.

(a) Locating, Supporting and Clamping of jobs in jigs and fixtures

□ Locating – principles and methods

- **Principles or rules of locating in jigs and fixtures**

For accurate machining, the workpiece 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 and the machine tool. It has to be assured that the blank, once fixed or clamped, does not move at all.

Any solid body may have maximum twelve degrees of freedom as indicated in Fig. 8.1.4. By properly locating, supporting and clamping the blank its all degrees of freedom are to be arrested as typically shown in Fig. 8.1.5.

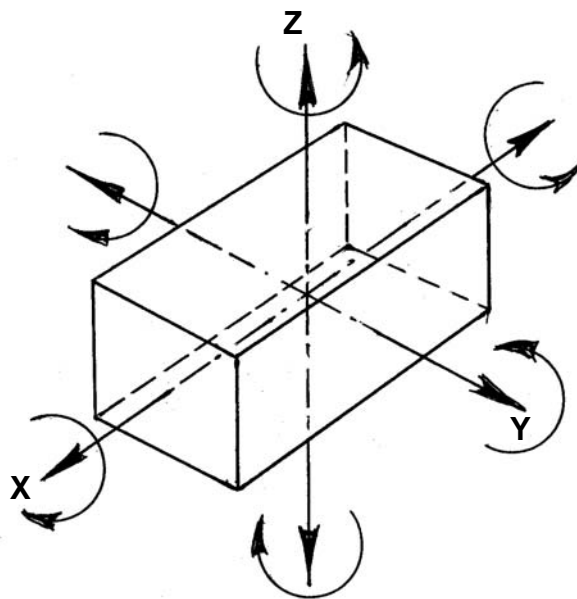


Fig. 8.1.4 Possible degrees of freedom of a solid body.

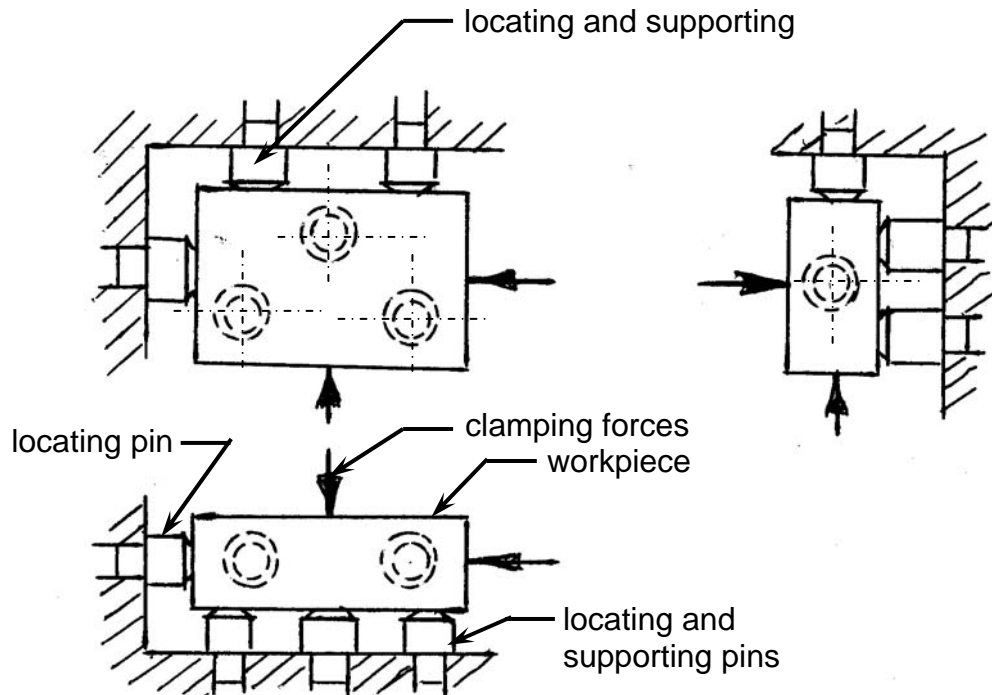


Fig. 8.1.5 Arresting all degrees of freedom of a blank in a fixture.

The three adjacent locating surfaces of the blank (workpiece) are resting against 3, 2 and 1 pins respectively, which prevent 9 degrees of freedom. The rest three degrees of freedom are arrested by three external forces usually provided directly by clamping. Some of such forces may be attained by friction.

Some basic principles or rules need to be followed while planning for locating blanks in fixtures, such as;

- One or more surfaces (preferably machined) and / or drilled / bored hole(s) are to be taken for reference
- The reference surfaces should be significant and important feature(s) based on which most of the dimensions are laid down
- Locating should be easy, quick and accurate
- In case of locating by pin, the pins and their mounting and contact points should be strong, rigid and hard
- A minimum of three point must be used to locate a horizontal flat surface
- The locating pins should be as far apart as feasible
- Vee block and cones should be used for self-locating solid and hollow cylindrical jobs as typically shown in **Fig. 8.1.6**
- Sight location is applicable to first – operation location of blank with irregular surfaces produced by casting, forging etc. as indicated in **Fig. 8.1.7** when the bracket is first located on two edges to machine the bottom surface which will be used for subsequent locating.

- o Adjustable locating pin(s) as indicated in Fig. 8.1.3 is to be used to accommodate limited part size variation

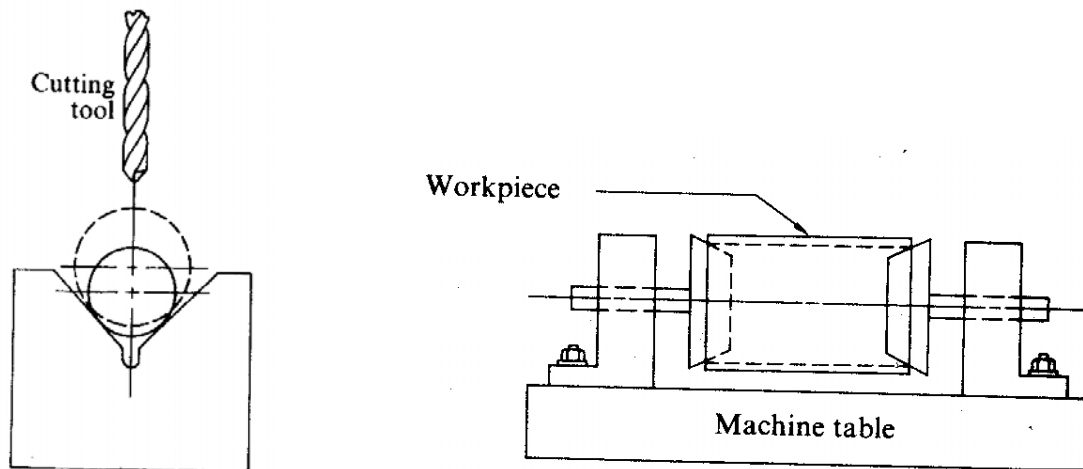


Fig. 8.1.6 Locating by Vee block and cone.

- o For locating large jobs by rough bottom surface one of the three pins may be replaced by a pivoted arm as indicated in Fig. 8.1.7. The pivoted arm provides two contact points.

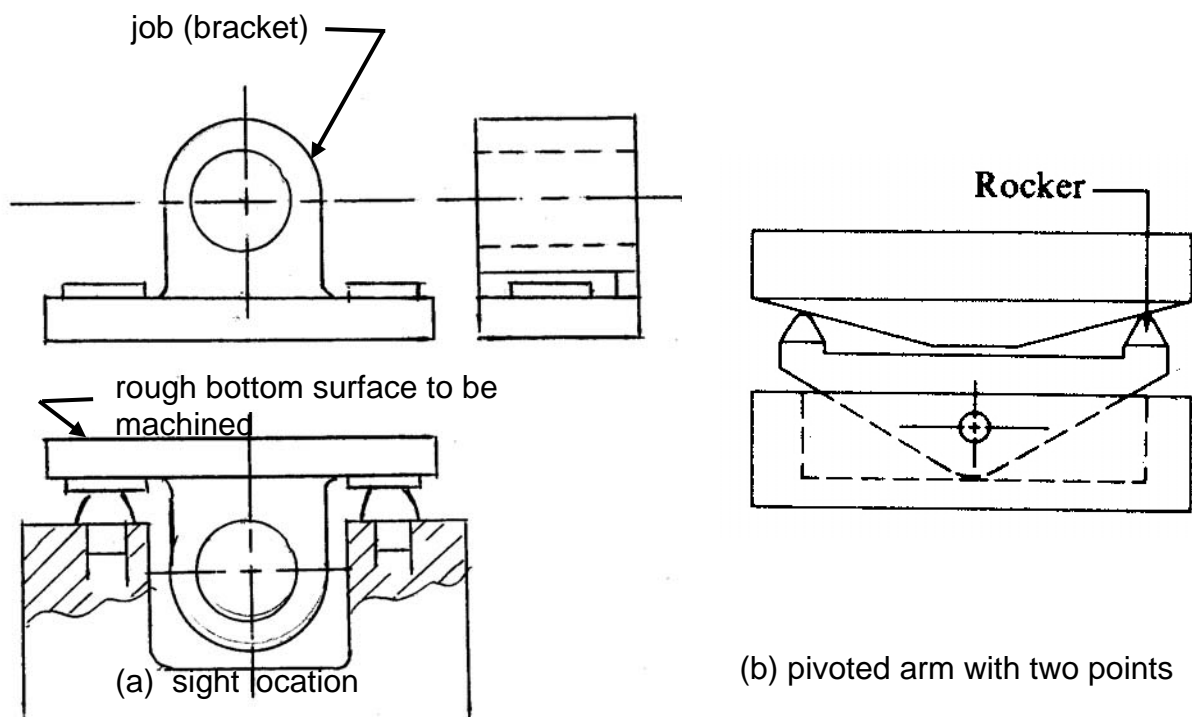


Fig. 8.1.7 (a) Sight location and (b) location by pivoted points (equalizer)

- **General methods of locating**

- △ **Locating blanks for machining in lathes**

In lathes, where the job rotates, the blanks are located by

- fitting into self centering chuck
- fitting into 4 – independent jaw chuck and dead centre
- in self – centering collets
- in between live and dead centres
- by using mandrel fitted into the head stock – spindle
- fitting in a separate fixture which is properly clamped on a driving plate which is coaxially fitted into the lathe spindle.

- △ **Locating for machining in 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 the 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 :

- **Locating by flat surfaces**

Fig. 8.1.8 typically shows locating jobs by their flat surfaces using various types of flat ended pins and buttons.

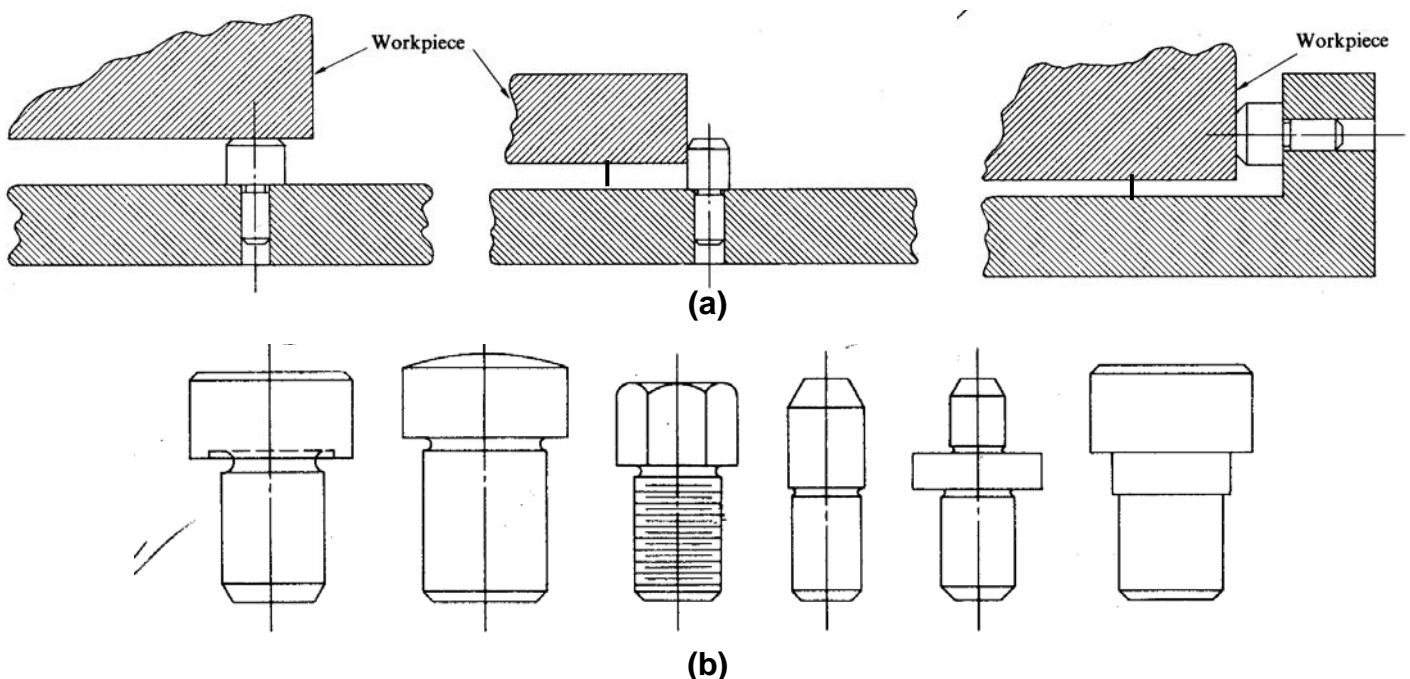


Fig. 8.1.8 Locating by (a) flat surfaces and (b) types of pins used for that.

o Locating by holes

In several cases, workpieces are located by premachined (drilled, bored or pierced) holes, such as;

- * Locating by two holes as shown in Fig. 8.1.9 (a) where one of the pins has to be diamond shaped to accommodate tolerance on the distance between the holes and their diameters
- * Locating by one hole and an external pin which presents rotation of the blank around the inner pin as indicated in Fig. 8.1.9 (b)
- * Locating by one hole and one Vee-block as shown in Fig. 8.1.10

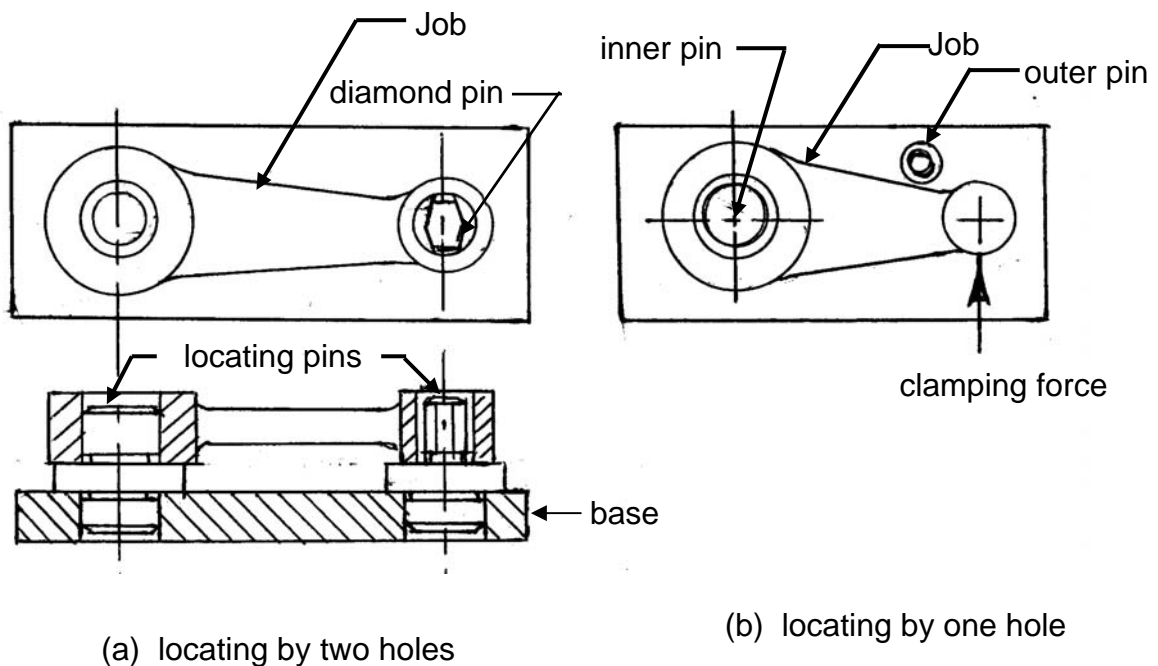


Fig. 8.1.9 Locating by holes.

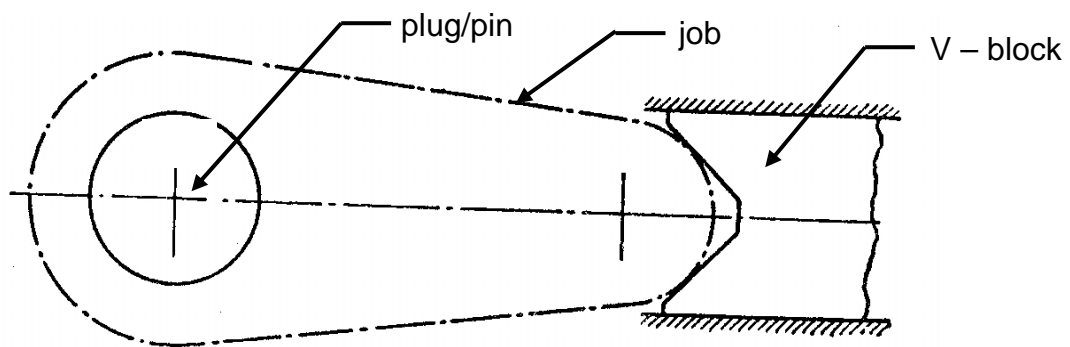


Fig. 8.1.10 Locating by a pin and Vee block.

o Locating on mandrel or plug

Ring or disc type workpieces are conveniently located on mandrel or single plug as shown in Fig. 8.1.11.

However, there may be several other ways of locating depending upon the machining conditions and requirements.

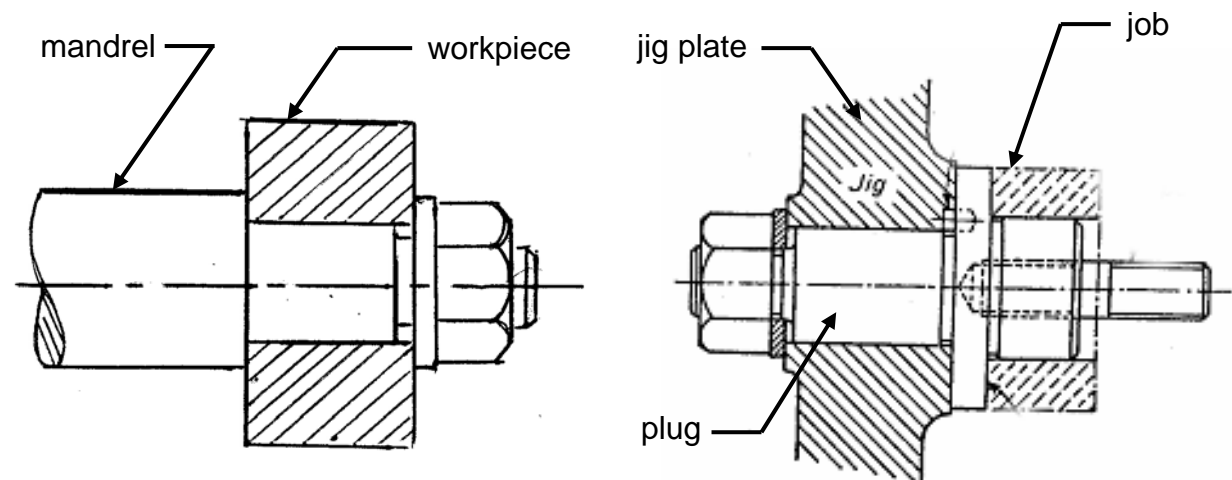


Fig. 8.1.11 Locating by mandrel or plug.

□ **Supporting – principles and methods**

A workpiece has to be properly placed in the jig or fixture not only for desired positioning and orientation but also on strong and rigid support such that the blank does not elastically deflect or deform under the actions of the clamping forces, cutting forces and even its own weight.

- **Basic principles or rules to be followed while designing or planning for supporting**
 - supporting should be provided at least at three points
 - supporting elements and system have to be enough strong and rigid to prevent deformation due to clamping and cutting forces
 - unsupported span should not be large to cause sagging as indicated in fig. 8.1.12
 - supporting should keep the blank in stable condition under the forces as indicated in fig. 8.1.13
 - for supporting large flat area proper recess is to be provided, as indicated in fig. 8.1.14, for better and stable support.
 - round or cylindrical workpieces should be supported (along with locating) on strong vee block of suitable size
 - heavy workpieces with pre-machined bottom surface should be supported on wide flat areas, otherwise on flat ended strong pins or plugs.
 - if more than three pins are required for supporting large workpieces then the additional supporting pins are to be spring loaded or adjustable

- o additional adjustable supporting pins need to be provided
 - * to compensate part size variation
 - * when the supporting surface is large and irregular
 - * when clamping and cutting forces are large
- o ring or disc type jobs, specially requiring indexing should be supported (and located) in mandrel

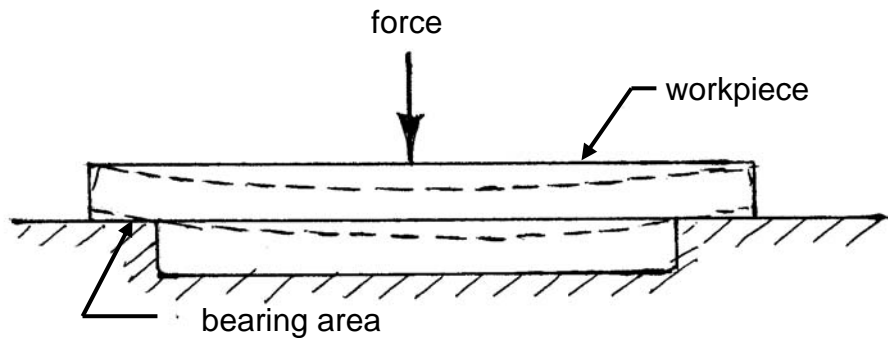


Fig. 8.1.12 Deflection due to force(s) for wide gap in between supports.

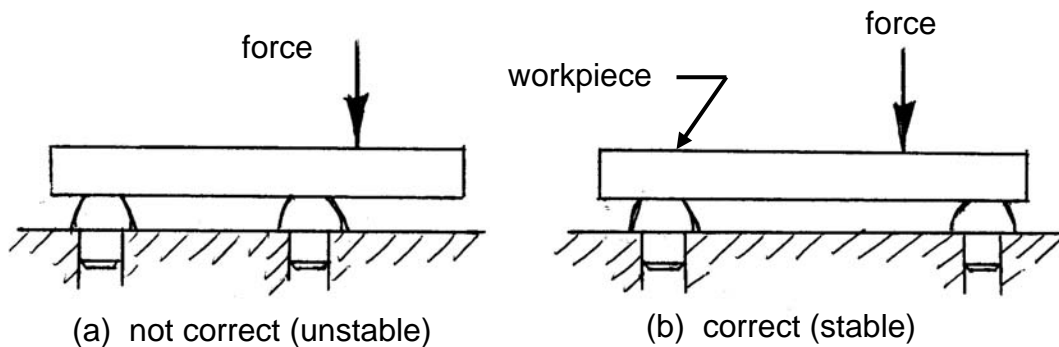


Fig. 8.1.13 Stability in supporting.

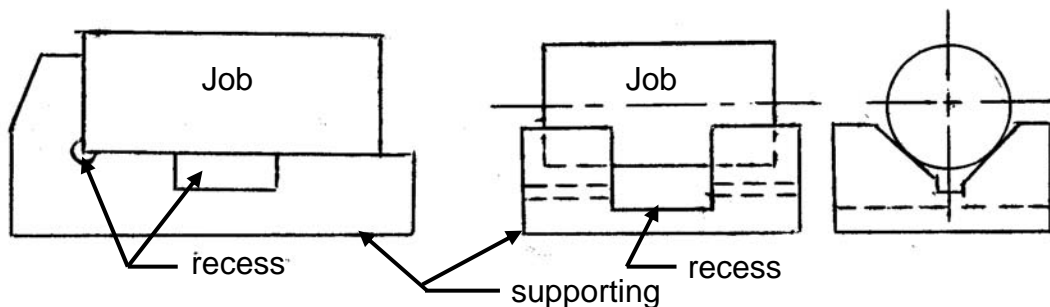


Fig. 8.1.14 Recess in long span supporting.

- Common methods of supporting job in fixtures
 - o supporting on vices
 - o supporting on flat surfaces / blocks (fig. 8.1.15 (a))
 - o supporting by fixed pins (fig. 8.1.15 (b))
 - o additional supporting by adjustable pins and plugs or jack screws as shown in fig. 8.1.16
 - o supporting (and locating) on vee blocks and mandrels (fig. 8.1.11)

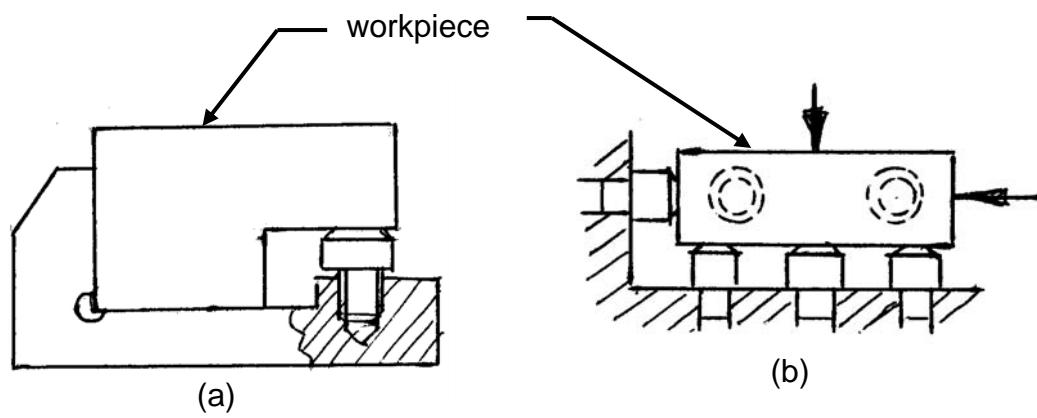


Fig. 8.1.15 Supporting (a) by flat surface and (b) by pins

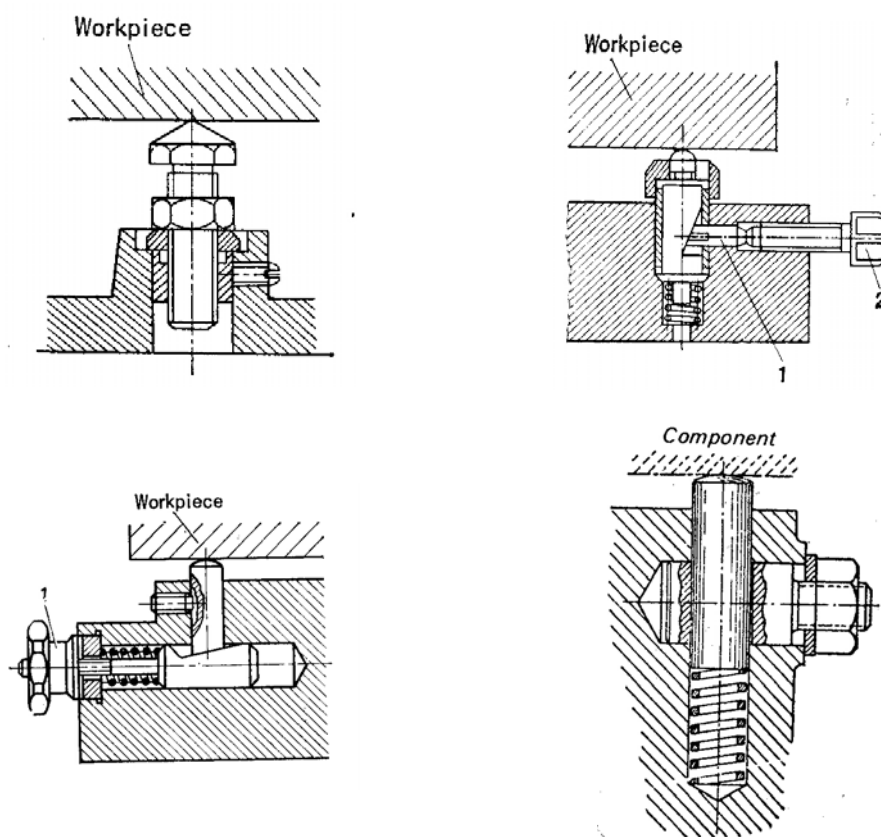


Fig. 8.1.16 Adjustable supporting pins.

□ **Clamping of workpiece in fixtures**

In jigs and fixtures the workpiece 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.

- **While designing for clamping the following factors essentially need to be considered :**

- clamping need to be strong and rigid enough to hold the blank firmly during machining
- clamping should be easy, quick and consistently adequate
- clamping should be such that it is not affected by vibration, chatter or heavy pressure
- the way of clamping and unclamping should not hinder loading and unloading the blank in the jig or fixture
- the clamp and clamping force must not damage or deform the workpiece
- 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, which move by slide or slip or tend to do so during applying clamping forces, should be avoided
- clamping system should comprise of less number of parts for ease of design, operation and maintenance
- the wearing parts should be hard or hardened and also be easily replaceable
- clamping force should act on heavy part(s) and against supporting and locating surfaces
- clamping force should be away from the machining thrust forces
- clamping method should be fool proof and safe
- clamping must be reliable but also inexpensive

- **Various methods of clamping**

Clamping method and system are basically of two categories :

- (a) general type without much consideration on speed of clamping operations
- (b) quick acting types

(a) General clamping methods of common use :

- Screw operated strap clamps as typically shown in Fig. 8.1.17. The clamping end of the strap is pressed against a spring which enables quick unclamping

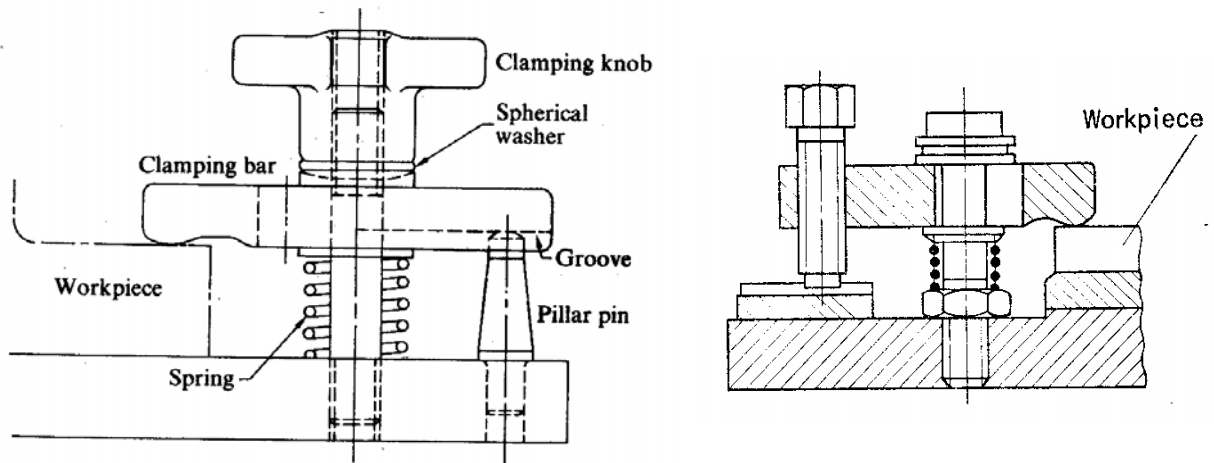


Fig. 8.1.17 Common strap type clamping.

- Clamping from side for unobstructed through machining (like milling, planing and broaching) of the top surface. Some commonly used such clamping are shown in Fig. 8.1.18

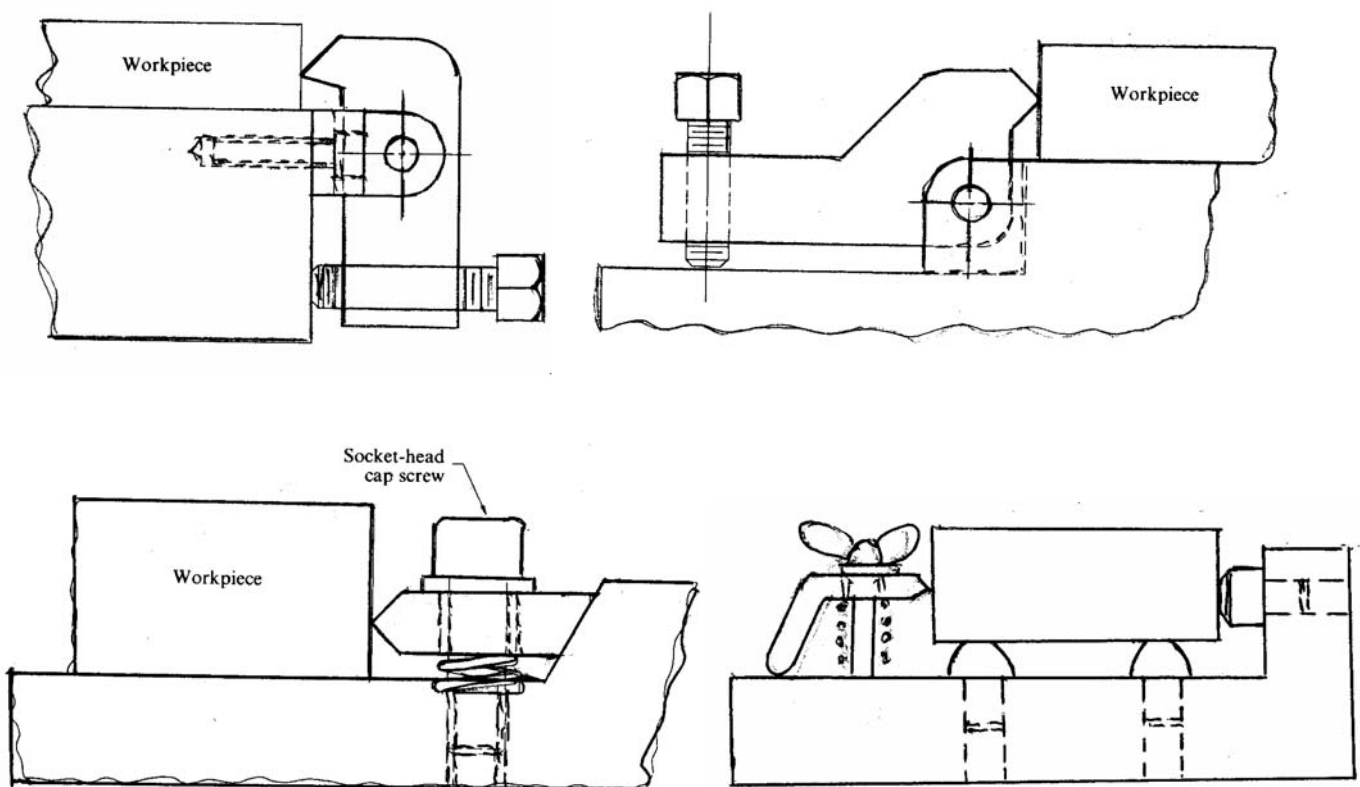


Fig. 8.1.18 Clamping from side for free machining of the top surface.

- **Clamping by swing plates**

Such clamping, typically shown in Fig. 8.1.19, are simple and relatively quick in operation but is suitable for jobs of relatively smaller size, simpler shape and requiring lesser clamping forces.

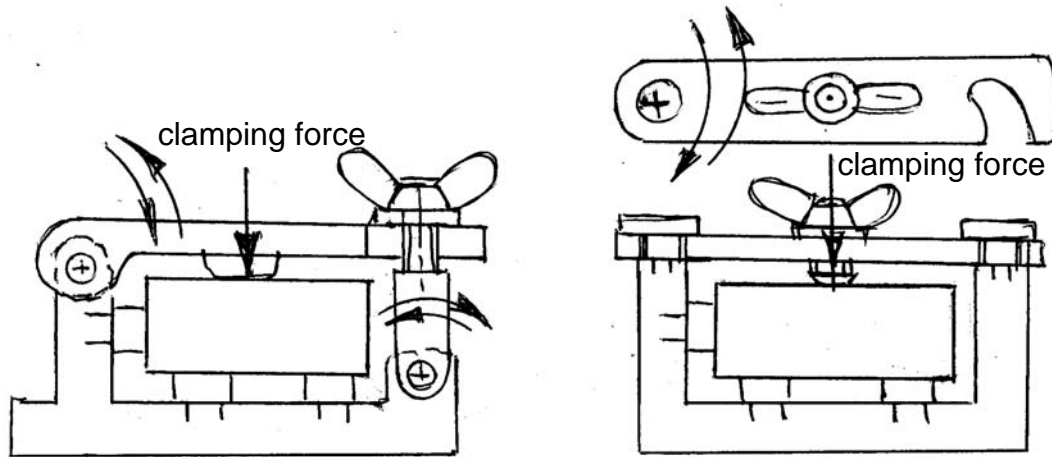


Fig. 8.1.19 Clamping by swing plates.

- Other conventional clamping methods include :
 - * Vices like drilling and milling vices
 - * Magnetic chucks
 - * Chucks and collets for lathe work
- **Quick clamping methods and systems**
 - **Use of quick acting nut** – a typical of such nut and its application is visualised schematically in Fig. 8.1.20

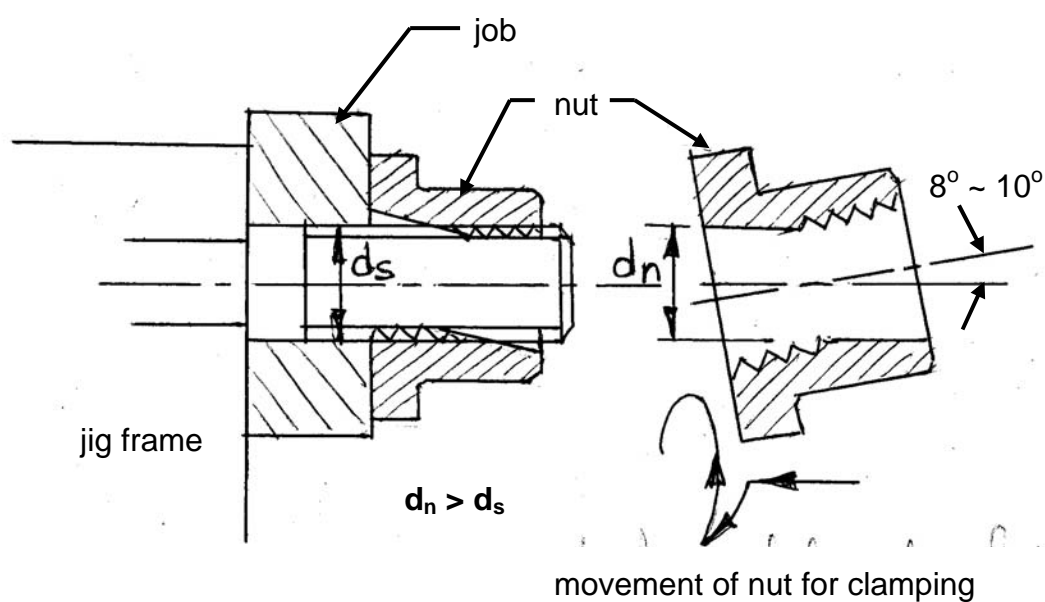
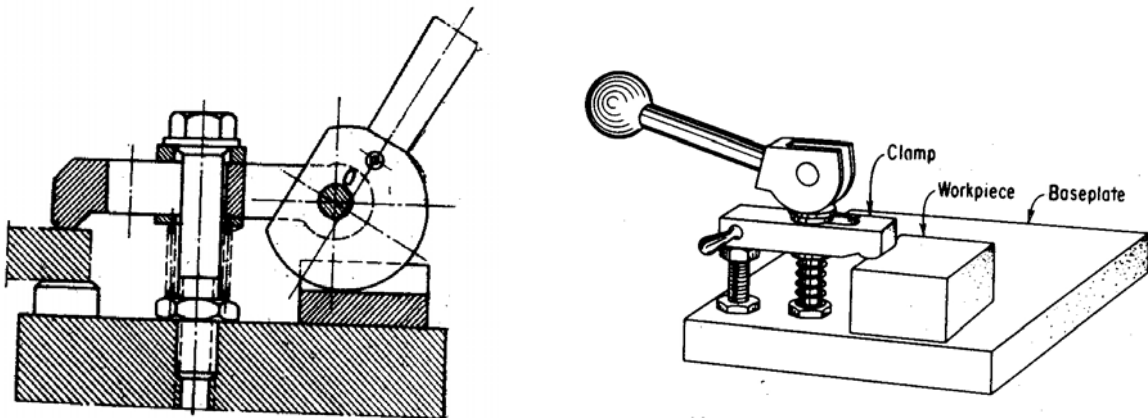


Fig. 8.1.20 Quick acting nut for rapid clamping.

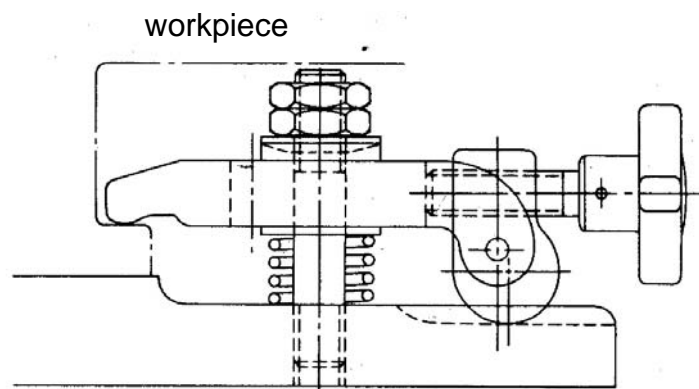
o **Cam clamping**

Quick clamping by cam is very effective and very simple in operation. Some popular methods and systems of clamping by cam are shown in Fig. 8.1.21

The cam and screw type clamping system is used for clamping through some interior parts where other simple system will not have access.



(a) clamping by cam



(b) screw and cam clamping from distance

Fig. 8.1.21 Quick clamping by cams.

- Quick multiple clamping by pivoted clamps in series and parallel. This method shown in Fig. 8.1.22 is capable to simultaneously clamp number of rods even with slight diameter variation
- Quick clamping by hydraulic and pneumatic force for strong and light clamping respectively
- Light but quick clamping by bayonet type clamp as indicated in Fig. 8.1.23

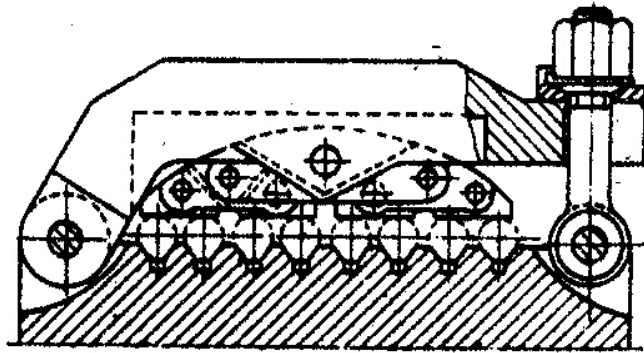


Fig. 8.1.22 Quick multiple locating and clamping of cylindrical jobs.

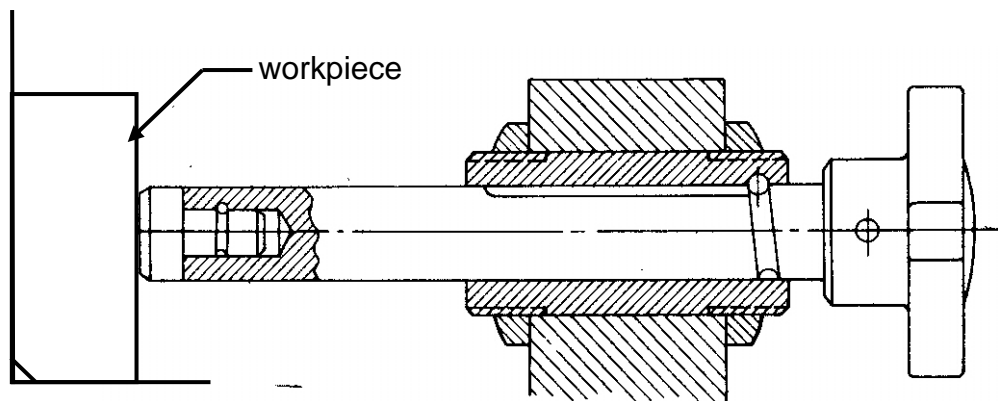


Fig. 8.1.23 Quick acting screw (bayonet type) clamping.

(b) Drill – jig bushing

Slender and cantilever type cutting tools, mainly drills, usually suffer from run – out due to possible errors in the drill, sockets and drilling machine spindle and finally in the overall alignment. Such run out causes over sizing, out of roundness and surface roughening of the drilled holes. Such run out aggravates further with the increase in drill speed (rpm) and the thrust force, specially if the drill is not geometrically symmetrical. This often leads to, in addition to poor product quality, breakage of the drill by bending and / or buckling. To reduce such problems, bushes are used in the jigs to guide the drill bits as indicated in Fig. 8.1.3.

- △ **The factors to be considered while designing for jig – bushing, are :**
- The bushes, used to guide and properly locate drills, reamers etc. are generally made of carbon or alloy steel and made wear resistive by hardening to R_C 60 and above. Often bushes are also made from grey cast iron for antifriction and protection of the tools.

- The hardened jig bushes are finished outside by grinding and inside by grinding and lapping if high precision is insisted.
- The bush's length should be sufficient (\geq twice drill diameter) and its diameter should be slightly larger than the drill diameter
- Design and construction should enable easy and quick proper fitting and removal or replacement of the bushes
- Bushes should not come out from its seat along with the drill during its return.

△ Types of jig bushes

Depending upon nature of fitting, quick mounting and replacement, job requirement etc. jig bushes are classified into several types.

- Bushes may be
 - Press fitted type
 - Slip type
 - Screwed type

Press fitted thin sleeve type bushes are generally used for shorter runs and are not renewable. Renewable type slip bushes are used with liner. But screw bushes, though renewable may be used without or with liner.

- Bushes may be
 - Without head
 - With head
 - With a flange being screwed on the bracket

Fig. 8.1.24 shows such various bushes

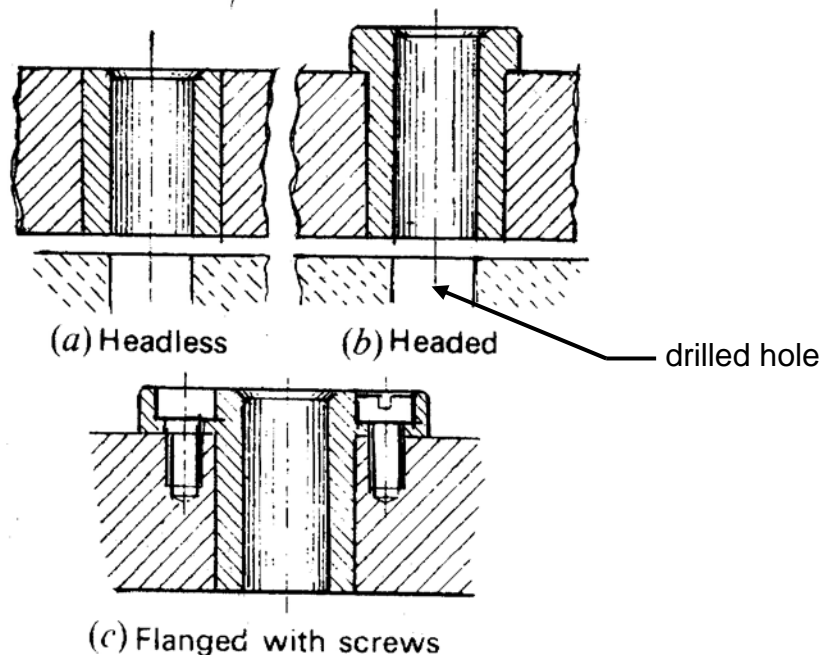


Fig. 8.1.24 Bushes (a) without head, (b) with head and (c) flange.

- Frequently replaceable bushes are provided with some locking system as shown in Fig. 8.1.25

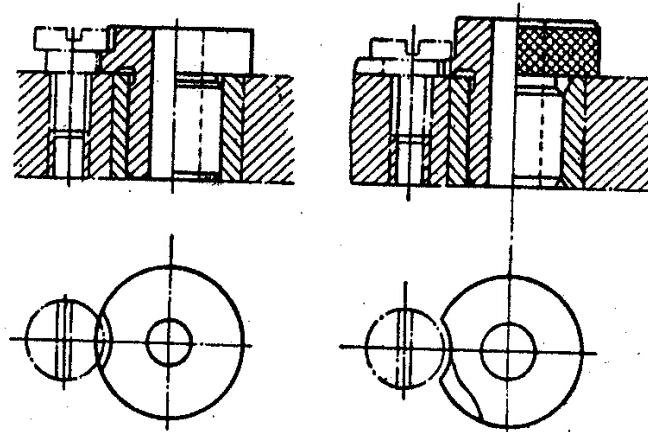


Fig. 8.1.25 Locking of frequently replaceable bushes.

- Some special jig bushings are often designed and used as and when required as indicated in Fig. 8.1.26

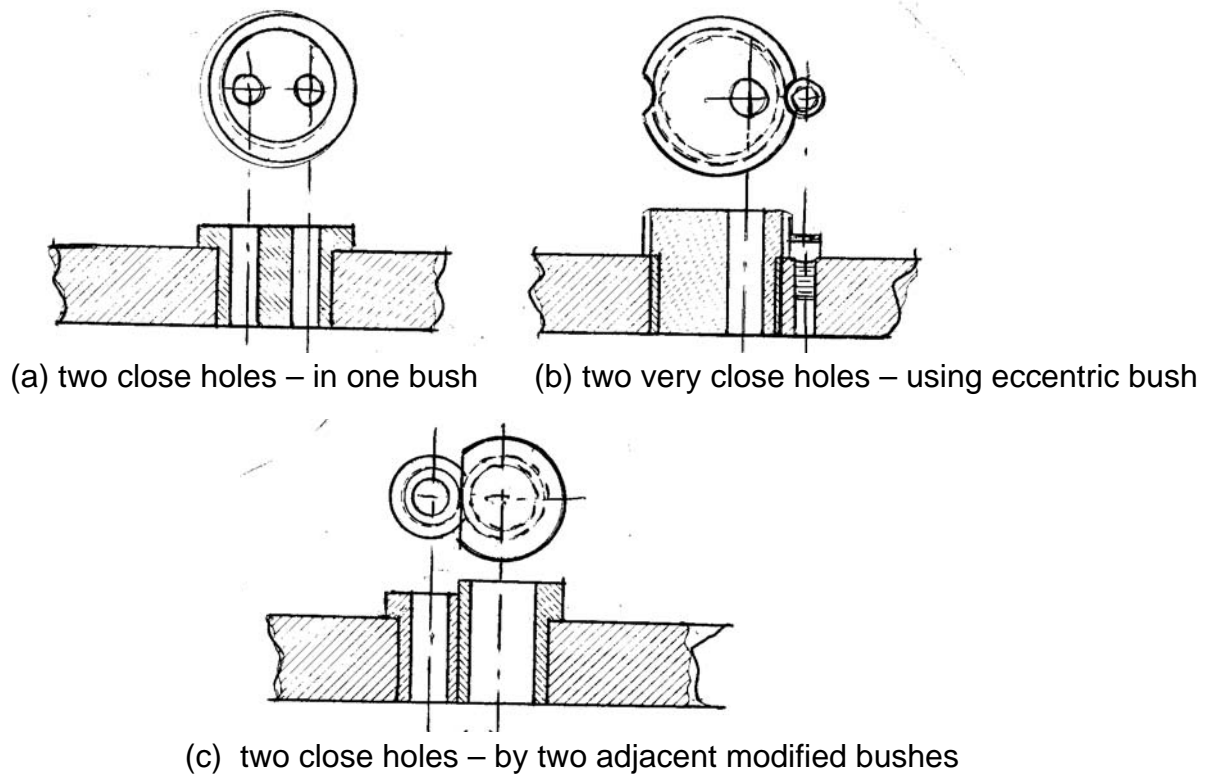


Fig. 8.1.26 Special jig – bushes for critical requirements.

Many other types are possible and made depending upon the working situation and critical requirements.