



Introduction

Mass production aims at high productivity to reduce unit cost and interchangeability to facilitate easy assembly. This necessitates production devices to increase the rate of manufacturing and inspection devices to speed-up inspection procedure.



Production Devices

Production devices are generally workholders with/without tool guiding/setting arrangement. These are called jigs and fixtures.

Jigs are provided with tool guiding elements such as drill bushes. These direct the tool to the correct position on the workpiece. Jigs are rarely clamped on the machine table because it is necessary to move the jig on the table to align the various bushes in the jig with the machine spindle.

Fixtures hold the workpiece securely in the correct position with respect to the machine/cutter during operation. There is sometimes a provision in the fixture for setting the tool with respect to the workpiece/fixture, but the tool is not guided as in a jig. Fixtures are often clamped to the machine table.

Elements of Jigs and Fixtures

Generally, all the jigs and fixtures consist of:

1. **Locating Elements** These position the workpiece accurately with respect to the tool guiding or setting elements in the fixture.
2. **Clamping Elements** These hold the workpiece securely in the located position during operation.

3. **Tool Guiding and Setting Elements** These aid guiding or setting of the tools in correct position with respect to the workpiece. Drill bushes guide the drills accurately to the workpiece. Milling fixtures use setting pieces for correct positioning of milling cutters with respect to the workpiece.

Advantages of Jigs and Fixtures

1. **Productivity** Jigs and fixtures eliminate individual marking, positioning and frequent checking. This reduces operation time and increases productivity.
2. **Interchangeability** Jigs and fixtures facilitate uniform quality in manufacture. There is no need for selective assembly. Any part of the machine would fit properly in assembly, and all similar components are interchangeable.
3. **Skill Reduction** Jigs and fixtures simplify locating and clamping of the workpieces. Tool guiding elements ensure correct positioning of the tools with respect to the workpieces. There is no need for skillful setting of the work piece or tool. Any average person can be trained to use jigs and fixtures. The replacement of a skilled workman with unskilled labour can effect substantial saving in labour cost.
4. **Cost Reduction** Higher production, reduction in scrap, easy assembly and savings in labour costs result in substantial reduction in the cost of workpieces produced with jigs and fixtures.

Inspection Devices

Inspection devices facilitate interchangeability. It calls for uniformity which must be limited, taking into account the machine's capability. Certain variations in the size of shaft (or hole) should be allowed for economic reasons.

Limits and Fits

The largest and the smallest dimensions of the shaft (or hole) are called the high and low limit, respectively. The difference between these limits, i.e. the permissible variation, is called tolerance. If tolerance is allowed only on one side of the nominal dimension, it is called unilateral. For example, $20.00^{+0.02}_{-0.00}$ has got unilateral tolerance. If tolerance is allowed on both sides of the nominal dimension ($20.00^{+0.01}_{-0.01}$), it is called bilateral.

Classification of Fits Tolerance and its direction depend upon the functional requirements of the assembled parts. The following four classes of fits cover most of the functional requisites of engineering assemblies.

1. **Running Fit (Fig. 1.1a)** This provides for easy rotation as well as axial movement of shaft (male part) in the hole (female part). It is used for bearing diameters of rotating shafts. Locators in production devices are made running fit with respect to the workpiece to facilitate quick loading and unloading.
2. **Push Fit** This fit requires light hand pressure or tapping for assembly of the mating parts. It is used mainly for precise assembly of replaceable locators in jigs and fixtures.
3. **Press Fit (Fig. 1.1a)** The mating parts are assembled by hammering or with a press. There is a positive interference between the hole and the shaft. This prevents rotary as well as axial movement between the assembled parts. Hence, press fit is used widely for assembly of drill bushes (outside diameter) and locators, which are rarely replaced.
4. **Force Fit** This is used for permanent assemblies, such as wheels and hubs, on shaft. Force fit parts require heavy pressure for assembly.

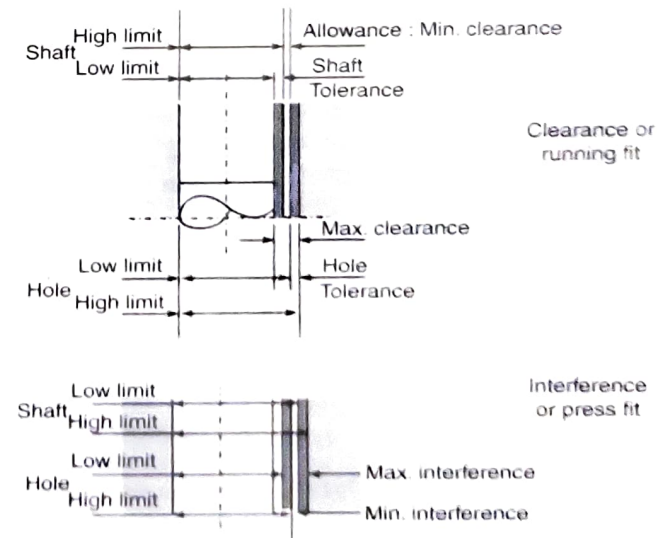


Fig. 1.1a Limits and fits

The clearance or interference provided for obtaining the various fits is called allowance. In shaft basis of fits, the diameter of the shaft is kept constant while that of the hole is varied. In hole basis, the hole size is kept constant and the shaft size is varied to obtain the various fits. As most of the holes are made by fixed diameter tools (drills, reamers, etc.), the hole basis is used widely in modern industry to keep the investment in cutting tools low.

The International Standards Organisation has standardised 27 types of fits and 18 grades of tolerances, which have been adopted by many countries. The tolerance depends upon the mating diameter sizes. The distribution of the tolerance is specified by alphabets. Holes are specified by capital letters *A, B, C, D*, etc. whereas shafts are specified by small letters *a, b, c, d*, etc. The alphabets are suffixed by digits 1, 2, 3, 4, 5...16 showing the grade of accuracy. Digit 1 signifies the highest accuracy and digit 16 the least (Fig. 1.1 b).

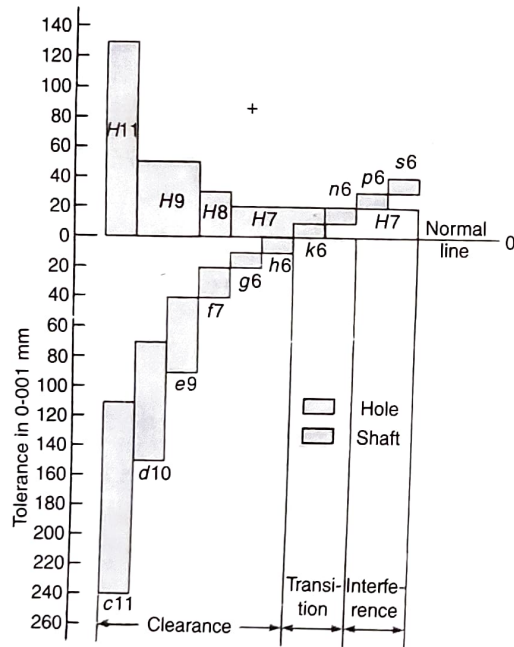


Fig. 1.1b Limits and fits

In toolmaking, accuracy grades 7–11 have been found to be the most convenient. Generally, unilateral *H* type tolerance distribution is preferred. Most of the accurate holes are made to *H7* limits, which can be obtained by careful reaming. For mass production, the less accurate *H8* holes are used. Simple drilling produces a hole within *H11* tolerance. Figure 15.1 shows the limits

for the grades of holes used widely. A 200 hole falling in range 18–30 mm has got the following tolerances for the various grades:

$$20\phi H7 _ 20_{+0}^{+0.21}$$

$$20\phi H8 _ 20_{+0}^{+0.033}$$

$$20\phi H11 _ 20_{+0}^{+0.13}$$

Shaft sizes are varied to obtain the required fits with the desired degree of precision. The following combinations are widely used in toolmaking:

	High Precision Hole/Shaft	Accurate Hole/Shaft
1. Running Fit	<i>H7/f6</i>	<i>H8/j7</i>
2. Push Fit	<i>H7/h6</i>	<i>H8/h7</i>
3. Press Fit	<i>H7/p6</i>	<i>H8/p7</i>
4. Force Fit	<i>H7/s6</i>	<i>H8/s7</i>

For example, for a 200 *H7* hole, the shaft should be:

$$20\phi f6, \text{ i.e. } 20.00_{-0.034}^{-0.016} \text{ for precision running}$$

$$20\phi h6, \text{ i.e. } 20.00_{-0.017}^0 \text{ for Push fit}$$

$$20\phi p6, \text{ i.e. } 20.00_{+0.035}^{+0.022} \text{ for press fit}$$

$$20\phi s6, \text{ i.e. } 20.00_{+0.048}^{+0.035} \text{ for force fit}$$

Thus, by controlling the hole and shaft sizes within certain tolerances, we can obtain the desired fit with interchangeability in various assemblies.

The workpieces are inspected at every stage to ensure that the dimensions are within the tolerance. The checking is speeded up by using inspection devices such as gauges and fixtures. These simplify inspection so that unskilled/semiskilled labour can be used to keep down the inspection costs.



Materials Used in Jigs and Fixtures

Jigs and fixtures are made from a variety of materials, some of which can be hardened to resist wear. It is sometimes necessary to use nonferrous metals like phosphor bronze to reduce wear of the mating parts or nylons or fibre to prevent damage to the workpiece. Given below are the materials often used in jigs, fixtures, press tools, collets, etc.

1. **High Speed Steels (HSS)** These contain 18% (or 22%) tungsten for toughness and cutting strength, 4.3% chromium for better

- hardenability and wear resistance and 1% vanadium for retention of hardness at high temperature (red hardness) and impact resistance. HSS can be air- or oil-hardened to RC 64–65 and are suitable for cutting tools such as drills, reamers and cutters.
2. **Die Steels** These are also called high carbon (1.5–2.3%) high chromium (12%) (HCHC) cold working steels and are used for cutting press tools and thread forming rolls. Hot die steels with lesser carbon (0.35%) and chromium (5%) but alloyed with molybdenum (1%) and vanadium (0.3–1%) for retention of hardness at high temperature are used for high-temperature work like forging, casting and extrusion.
 3. **Carbon Steels** These contain 0.85–1.18% carbon and can be oil hardened to RC62–63. These can be used for tools for cutting softer materials like woodwork, agriculture, etc. and also for hand tools such as files, chisels and razors. The parts of jigs and fixtures like bushes and locators, which are subjected to heavy wear can also be made from carbon steels and hardened.
 4. **Collet Steels (Spring Steels)** These contain about 1% carbon and 0.5% Manganese. Spring steels are usually tempered to RC 47 hardness.
 5. **Oil Hardening Non-Shrinking Tool Steels (OHNS)** These contain 0.9–1.1% carbon, 0.5–2% tungsten and 0.45–1% carbon. These are used for fine parts such as taps, hand reamers, milling cutters, engraving tools and intricate press tools, which cannot be ground after hardening (RC 62).
 6. **Case Hardening Steels** These can be carburised and case hardened to provide 0.6–1.5 thick, hard (RC 59–63) exterior. 17 Mn1Cr95 steel with 1% manganese and 0.95% chromium is widely used. 15 Ni2Cr1Mo25 steel with additional nickel (2%) reduces thermal expansion up to 100°C. Case hardening steels are suitable for parts which require only local hardness on small wearing surfaces where costlier, difficult to machine, full hardening tool steels are not warranted.
 7. **High Tensile Steels** These can be classified into medium carbon steels with 0.45%–0.65% carbon (En8-9) and alloy steels like 40 Ni2Cr1Mo28 (En24). The tensile strength can be increased up to 125 kg/mm² (RC 40) by tempering.
Medium carbon steels are used widely for fasteners and structural work while alloy steels are used for high stress applications like press rams.
 8. **Mild Steel** It is the cheapest and most widely used material in jigs and fixtures. It contains less than 0.3% carbon. It is economical

to make parts that are not subjected to much wear and are not highly stressed from mild steel.

9. **Cast Iron** It contains 2–2.5% carbon. As it can withstand vibrations well, it is used widely in milling fixtures. Self-lubricating properties make cast iron suitable for machine slides and guideways. The ingenious shaping of a casting and the pattern can save a lot of machining time. Although the strength of cast iron is only half the strength of mild steel, a wide variety of grades have been developed. Nodular cast iron is as strong as mild steel, while mechanite castings have heat, wear and corrosion resistant grades.
10. **Steel Castings** These combine the strength of steel and shapability of a casting.
11. **Nylon and Fibre** These are usually used as soft lining for clamps to prevent denting or damage to the workpiece under high clamping force. Nylon or fibre pads are screwed or stuck to mild steel clamps.
Fibre is also used to reduce weight of Jig/Fixture. I have seen a 1.1 m × 0.7 m German jig made of fibre reinforced by a steel angle iron frame. Fibre weighs only 1/6th of steel. So two person can load/unload the jig manually onto a larger workpiece (Also see topic titled: *Jigs for Large Workpieces* in Chapter 5 on Drill Jigs).
12. **Phosphor Bronze** It is widely used for replaceable nuts in screw operated feeding and clamping systems. Generally, screw making process is time consuming and costly. So, their wear is minimised by using softer, shorter phosphor bronze mating nuts. These can be replaced periodically.

Phosphor bronze is also used in applications calling for corrosion resistance, like boiler valves.



Presentation of Workpiece

A jig or fixture drawing shows the workpiece in position with the jig/fixture. However, the workpiece should be easily discernible from the jig/fixture. To accomplish this, the workpiece is drawn in a chaindotted line, preferably in colour (red, green or blue), which can be easily distinguished from the black linework of the fixture/jig drawing.

The workpiece drawn in a fixture jig drawing is considered transparent. As a result, locators, studs or other parts of the fixture passing through the workpiece are drawn in full lines instead of dotted (Fig. 1.2). Similarly, the parts of the fixture placed behind the workpiece are drawn full instead of dotted. As the workpiece is transparent, it would not obstruct or block the view of any part of the jig or fixture.

The workpiece is drawn mainly to facilitate drawing of the jig/fixture. In fact, the designer first draws the workpiece in coloured chaindotted line and then draws the jig/fixture around it. He can thus position the locators, clamps and bushes quickly and correctly with respect to the workpiece. Tool room, methods and manufacturing engineers studying a jig/fixture drawing can distinguish the workpiece from the chaindotted linework and see how it is placed in the jig/fixture. Thus, delineation of workpiece facilitates drawing of jig/fixture. It also helps the manufacturer and user of the jig/fixture to understand disposition of the workpiece with respect to jig/fixture.

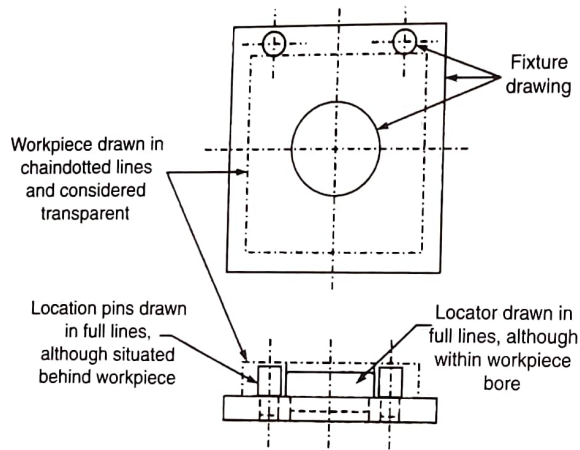


Fig. 1.2 Presentation of workpiece



Location

✂ Principles

Workpiece Requisites

The location has to meet dimensional requirements of the workpiece stated on the component drawing. For example, in the workpiece illustrated in Fig. 2.1, the drawing clearly states that hole C should be at distance D from face A. Consequently, we must use face A as a datum for locating the workpiece while drilling hole C. This would ensure that hole C is at distance D from face A. If we use face B as a stopper, the variation in length L would cause inaccuracies in the position of hole C. If length L is oversized by 1 mm, hole C will be at $(D + 1)$ mm from face A. If length L is undersize the hole would shift towards face A and would be nearer than distance D from face A.

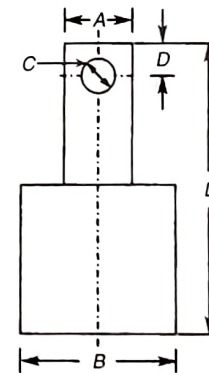


Fig. 2.1 Location and workpiece dimensions

If we locate on face A the hole would always be at distance D from face A irrespective of the variation in length L .

Accuracy

Location should be done on the most accurate surface of the workpiece. A machined surface is preferable to an unmachined one. When more than one machined surfaces are available, locate from the most accurate surface. For example, the centre of the turned part in Fig. 2.2 can be located from outside diameters 110 or 80 or from central 40ϕ bore. 80ϕ has the minimum tolerance of 0.05, so the workpiece can be located most accurately from outside diameter 80. Location from 40ϕ bore would be less accurate than location from 80ϕ but more precise than location from outside diameter 110ϕ , which has a much wider tolerance of 1 mm (± 0.5 mm).

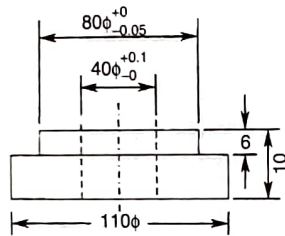


Fig. 2.2 Accuracy of location surfaces

Constraints

Location should prevent linear and rotary motion of the workpiece along and around the three major axes X, Y and Z.

The plate shown in Fig. 2.3 can move along the three axes X, Y and Z and can also rotate around these axes. The location system should prevent all these motions positively.

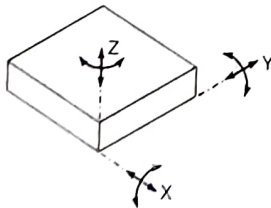


Fig. 2.3 Six degrees of freedom

Motion Economy

Location system should facilitate easy and quick loading of the workpiece in the fixture. It should effect motion economy. For example, there are two ways of drilling holes B and C in the turned component illustrated in Fig. 2.4a. We can drill either of the holes B and C first by locating on the machined bore A and then, locate on the drilled hole to drill the other hole.

If we drill hole C first and use it for location we would have to use two locators at right angles to each other and the workpiece needs to be loaded on the locator for bore A first.

It would be necessary to use another *removable* locator for hole C (Fig. 2.4b). Otherwise it would not be possible to load or unload the workpiece on the locator in bore A. Also, location on hole C would involve two motions—first, loading on locator A then inserting a removable pin in hole C which must be removed before the workpiece can be slid off axially from locator in bore A for unloading.

On the other hand, if we drill hole B first and use it for location while drilling hole C, it is possible to load the workpiece on both the locators in hole A and B in one motion as both the locators would be parallel (Fig. 2.4c). Thus, parallel locators are preferable to those placed at right angles.

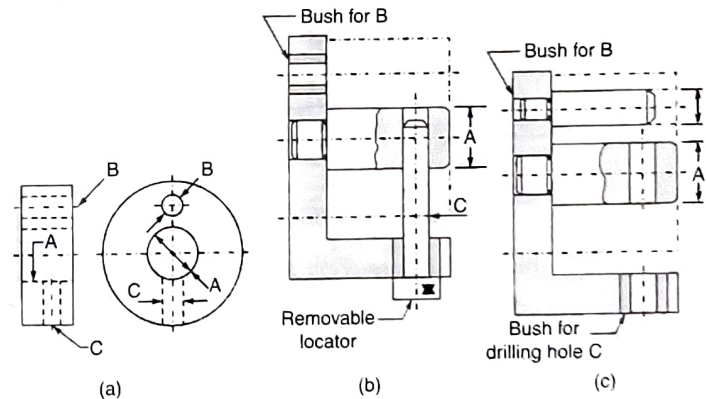


Fig 2.4 Motion economy in location

Redundant Locators

Redundant locators should be avoided. In case of the workpiece depicted in Fig. 2.5, we can only locate effectively on surface A or B. For, although both

the surfaces had been machined during previous operations, the distance between them would vary according to the process capability. If a fixed surface similar to A is provided to locate the surface at B as well, it would act as a redundant location since the job can be located from either A or B only. If the distance between surfaces A and B of the workpiece is more, there would be clearance between the locator and surface B. When clamped, the workpiece would bend as shown in Fig. 2.5b. When the clamp is released, the distorted part would spring back to its original position causing dimensional as well as form (flatness) errors. If the step in the component is less than the height of the locator, the component would not seat properly either on surface A or B (Fig. 2.6). The clamping force would distort the workpiece. This would cause errors, as the distorted part would spring back to its original position when the workpiece is unclamped.

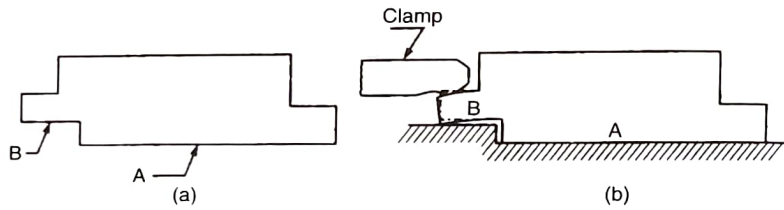


Fig. 2.5 Redundant location

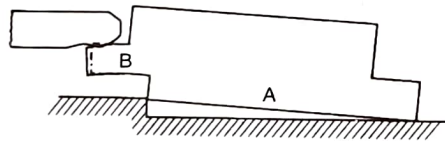


Fig. 2.6 Workpiece distortion due to redundant location

Under such circumstances, the redundant location at surface B should be replaced by an adjustable support illustrated in Fig. 2.7.

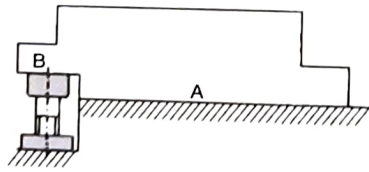


Fig. 2.7 Adjustable support

Foolproofing

The location system should positively prevent wrong loading of the workpiece in a fixture by foolproofing. The workpiece shown in Fig. 2.8 is to be located from holes A and C. As holes B and C are equidistant from A and their size is also the same, there is a risk of the workpiece being loaded wrongly as shown by the chain-dotted line. This wrong loading can be prevented by providing a foolproofing pin which would obstruct the path of the workpiece if it is loaded wrongly. It would be impossible to load the workpiece wrongly due to the foolproofing pin.

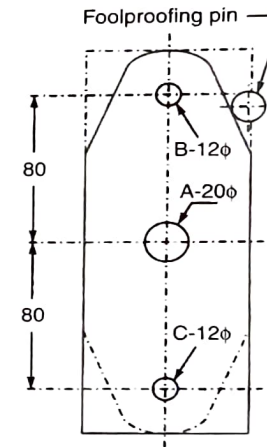


Fig. 2.8 Foolproofing



Locating Methods

A workpiece can be located from:

1. Plane surface
2. Profile
3. Cylindrical surface

Location from Plane Surface

A plane surface can be located with three points on the surface. A rough unmachined surface can be located with three location pads having point contact. This can be done by providing three location pins having spherical

surfaces at the locating points as shown in Fig. 2.9. The pins should be spaced as widely as possible for more accurate location. The height of the collar of the pins should be equal so that the located surface is parallel to the baseplate resting on the machine table. Although the three pins can define a plane, they cannot provide adequate support to the workpiece during machining operation such as milling. Additional adjustable supports are necessary to prevent distortion and vibrations in the workpiece during clamping and machining. The number of adjustable supports would depend upon the shape, strength and size of the workpiece.

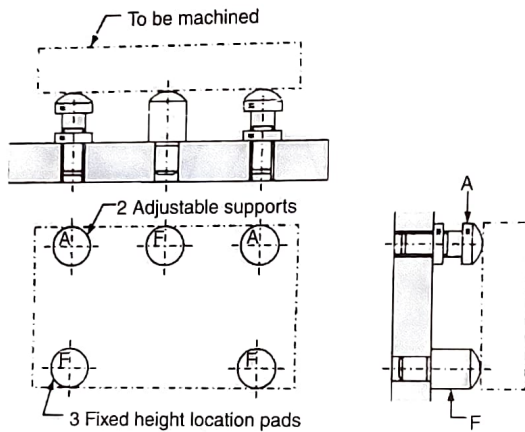


Fig. 2.9 Adjustable support for rectangular workpieces

Figure 2.10 illustrates a threaded adjustable support with the locking nut. Care should be taken that the adjustable supports do not dislocate the workpiece from the locating (resting) pins. This can be done by limiting the force used for adjusting the support. The screw illustrated in Fig. 2.10 is adjusted by rotating the knurled collar by using one's fingers so that the adjusting force would not dislocate (lift) the workpiece from the fixed locating pads (Fig. 2.9).

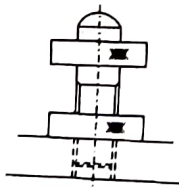


Fig. 2.10 Adjustable support

Surfaces that are reasonably plane (flat), such as hot or cold rolled plates, can be located by fixed locating pads and adjustable supports.

For locating very rough, uneven surfaces, it is necessary to use adjustable locating pads. Casting and forging can be located by adjustable screw pads as illustrated in Fig. 2.11.

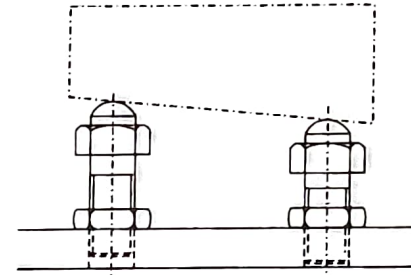


Fig. 2.11 Adjustable locators

During the first operation, it is often necessary to level the surface to be machined with a marking block by adjusting the locating pads. Even in the case shown in Fig. 2.11, there should only be three locators, and the workpiece should be supported at other points by adjustable supports having knurled collar. A hexagonal head screw rotated by a spanner can easily act as a screw jack and dislocate the workpiece from the locating pads. Sometimes, it is difficult to reach a support which is in recess or is distant from the operator. Under such circumstances, it is necessary to provide an elaborate adjustable support as shown in Fig. 2.12a.

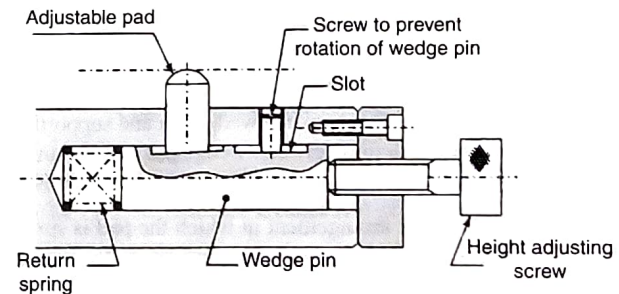


Fig. 2.12a Adjustable support at inaccessible place

The inclined surface on the wedge pin raises the pad when the wedge pin is pushed forward by the height adjusting screw. When the adjusting screw

is withdrawn, the return spring pushes the wedge pin towards the right and the pad slides down by gravity.

Wedge angle is usually 10° . Figure 2.12b shows the forces configuration. The wedge is usually moved by a screw. Page 43 (Chapter 4) gives the formula for calculating the force (F_w) generated by a screw. The force transmitted at the top face of the vertical supporting pin is proportional to the applied force F_s , the wedge angle (A) and coefficient s of friction between wedge pin and its housing bore, between the wedge pin and the supporting pin at the angular face, and between the supporting pin and its housing bore. Generally, the coefficient of friction between two dry machined faces ranges from 0.1 to 0.15. For the wedge angle (A) of 10° and the coefficient of friction 0.15, $F_w = 1.96 F_s$. For lesser coefficient of friction (0.10), $F_w = 2.55 F_s$. For other wedge angles (A) and coefficients of friction.

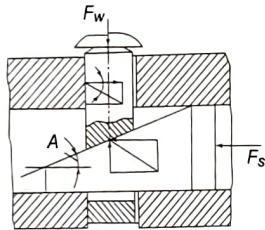


Fig. 2.12b Forces in wedge action

$$F_w = \frac{F_s [1 - \tan(A + f_1) \tan(f_3)]}{\tan(A + f_1) + \tan(f_2)}$$

F_s = Force developed by screw (page 47)

A = Wedge angle

$f_1 = \tan^{-1}$ [Coefficient of friction between wedge pin and supporting pin]

$f_2 = \tan^{-1}$ [Coefficient of friction between wedge pin and its housing]

$f_3 = \tan^{-1}$ [Coefficient of friction between supporting pin and its housing]

Figure 2.13 shows another arrangement in which the pad is spring-loaded so that it adjusts itself against the workpiece surface with limited spring force. The pad is locked in position by the clamping screw. The retaining screw prevents the pad from being pushed out of the housing by the spring.

Square or rectangular workpieces can be located better by replacing one of the locating pads by an equalising rocker as shown in Fig. 2.14a.

The rocker provides support at two points R . It pivots itself to suit the surface to be located. It provides contact at four points without contradict-

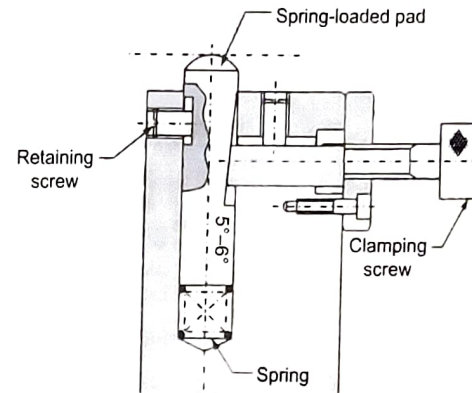


Fig. 2.13 Spring-loaded pad

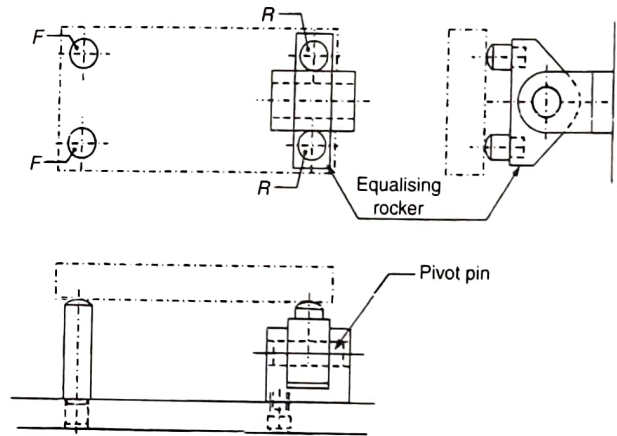


Fig. 2.14a Equalising rocker location

ing the three-point location of the plane. The pivot pin of the rocker acts as a single point complementing the other two points F in defining the plane.

Linear Self-adjusting Support Pins

Figure 2.14b shows three linear, self-adjusting, supporting pins. The pins are pushed upwards by light springs through the conical pins placed right below the supporting pins. The springs should push the conical pins and the support pins upwards to ensure contact between the workpiece and the

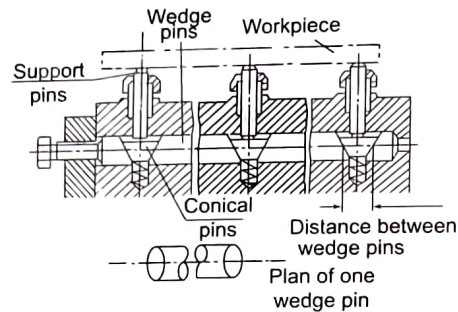


Fig. 2.14b Three linear self-adjusting, supporting pins

support pins; but they should not lift it off the locators (rest pads). The cones angles of the pins match with angular surface machined on wedge pins. These can be moved axially by a screw with a hexagonal head. Turning the adjustment screw clockwise reduces the distance between the angular faces of the wedge pins. The wedge pins move axially, assume suitable positions, till all the three conical pins touch the angular faces of the wedge pins to provide a positive support instead of spring support. Light tightening of the hexagonal headed bolt secures the pins in the position by clamping the conical pins against the angular faces of the wedge pins. The Hex. Head bolt can be replaced by a tommy bar screw to limit the clamping force, lest the workpiece is lifted off the locators (rest pads).

A machined surface can be located better by pads having a flat surface. For large components, the pads can be screwed to the body of the fixture as shown in Fig. 2.15. This saves machining time as only seats for the pads need to be machined instead of the entire body of the large fixture. Moreover, the locating pads can be levelled easily by grinding them individually after removing them from the fixture body. Errors in the machine of pad seats can be easily corrected by providing compensation in the pads.

For small workpieces, no location pads are necessary. The fixture body itself can be machined suitably to provide the locating surfaces. Ample recess should be provided in the corners so that burr on the workpiece corners, or dirt or swarf do not obstruct proper location through positive contact of the workpiece with the locating surface (Fig. 2.16).

Location pads in large fixtures automatically provide similar recess.

Six-point Location Figure 2.17 illustrates six-point location of a cubical workpiece. The workpiece is clamped against pads 1, 2 and 3. This prevents its linear movement along Y axis and rotation about axes X and Z. Pads 4 and 5 prevent linear motion along Z axis and rotation about Y axis. Pad 6 prevents linear motion along X axis. Thus, linear motion along the three axes as well as rotation around them is prevented.

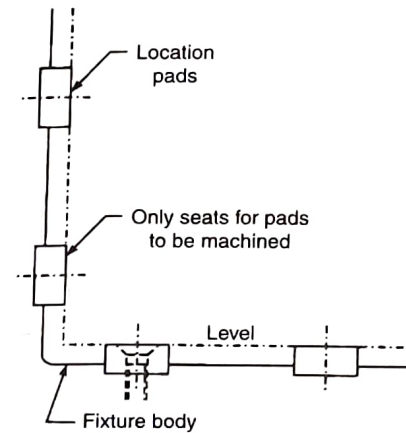


Fig. 2.15 Location pads for large fixtures

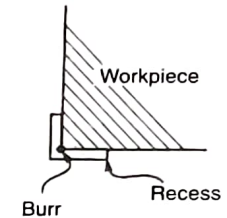


Fig. 2.16 Recess for burr and dirt

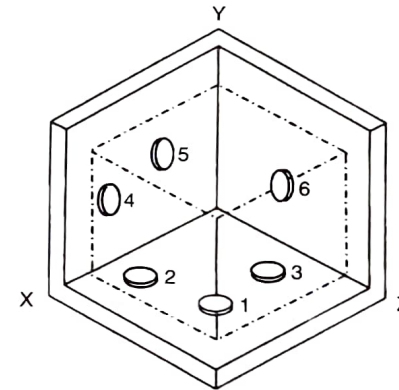


Fig. 2.17 Six-point location

Location from Profile

For simple components where appearance is important, a sighting plate can be provided. It is slightly bigger than the workpiece. The workpiece can be positioned on the sighting plate in such a way that there is equal margin on all the sides, as shown in Fig. 2.18.

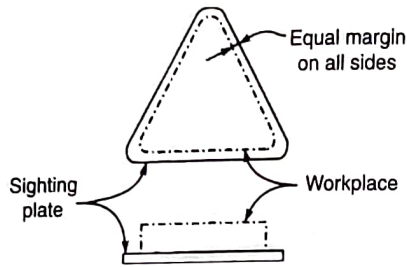


Fig. 2.18 Sighting location

The profile of a workpiece can also be located by confining the profile with cylindrical locating pins (Fig. 2.19).

When there is considerable variation in workpiece dimensions from batch to batch, an eccentric locator can be used (Fig. 2.20). The eccentricity of the locator can be varied by rotating it to suit the workpieces in the batch. The workpiece shown in Fig. 2.21 has got a milled flat on the collar. Dim F of the flat would be almost be the same for all the workpieces milled in a single batch. So, the eccentricity of the locator can be set to suit one of the workpieces from the milled batch and the eccentric locator would locate accurately all the workpieces in the batch.

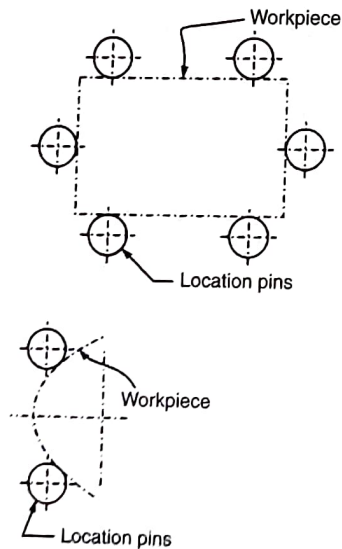


Fig. 2.19 Profile location by pins

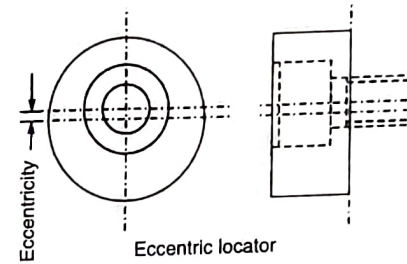


Fig. 2.20 Eccentric locator

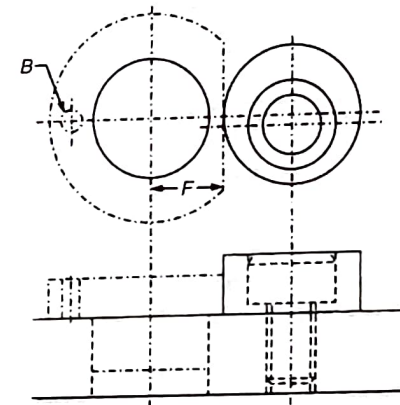


Fig. 2.21 Application of eccentric locator

The profile of a workpiece can be located by providing a pocket or nest around the profile of the workpiece (Fig. 2.22). The inside profile of the nest matches with the outside of the workpiece. The height of the nest should be lesser than the workpiece to permit grip over the workpiece for unloading. For thin sheet metal workpieces, finger slots or ejection arrangement should be provided for unloading the workpiece. Alternatively, a partial nest can be used.

Sheet metal blanks from the same die or die cast components from the same mould are almost identical. Such workpieces with little variation can be located precisely by a close fitting nest.

Location from Cylinder

Location from a cylinder is the most common and convenient form of location. For, when a cylinder is located on its axis and base, it can only

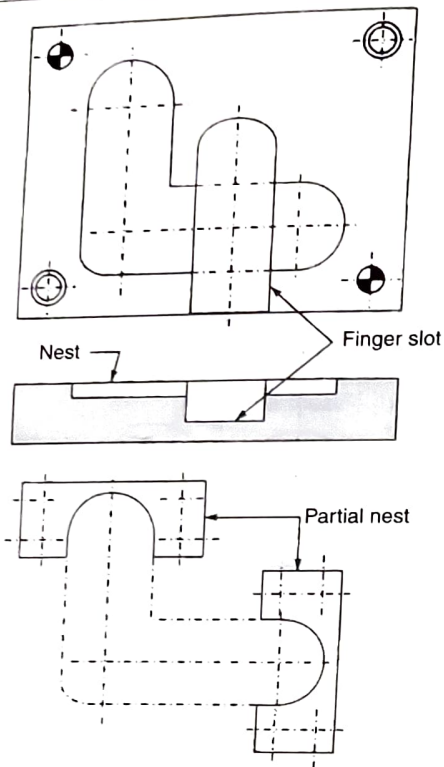


Fig. 2.22 Location nests

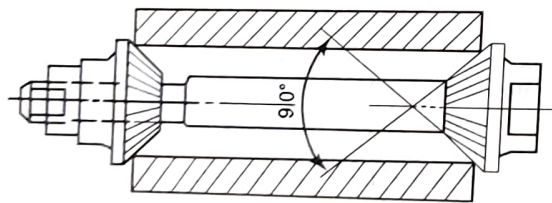


Fig. 2.23a Conical locators for rough bores

rotate about its axis. All other motions are constrained. Un-machined bores of castings or forgings can be located by two knurled conical locators (Fig. 2.23a) with 90° included angle. Un-machined external cylindrical surfaces like bosses in castings and forgings can be located by conical bores (Fig. 2.31). If the cylinder shown in Fig. 2.23a is located on a spigot having axis $Y-Y$, it can neither move linearly nor rotate around axes $X-X$ or $Z-Z$.

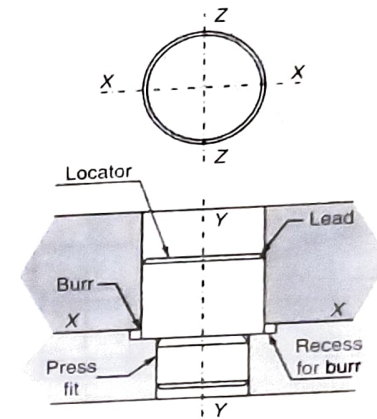


Fig. 2.23b Cylindrical locators

Clamping from top prevents linear motion along axis $Y-Y$. The seating surface for the locator should be recessed to provide space for dirt or workpiece burr. This ensures proper seating of the workpiece on the locating face. There should be ample chamfer or radius at the entry point so that the components can be loaded quickly. The chamfer is called lead. It centralises the workpiece quickly with the locator. The locator itself is located in the fixture by a concentric diameter generally made press fit in the fixture body.

Locating posts are often used for anchoring clamping studs (Fig. 2.24). The posts used for clamping should be secured by a retainer nut or a grub screw to prevent it from coming out of the fixture body when the clamp is tightened.

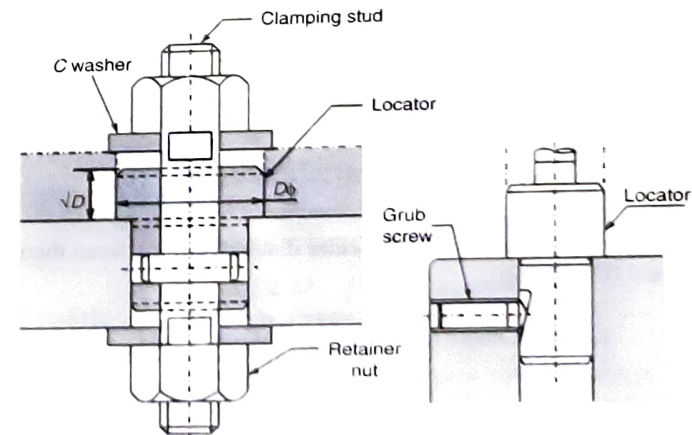


Fig. 2.24 Locators subjected to axial pull

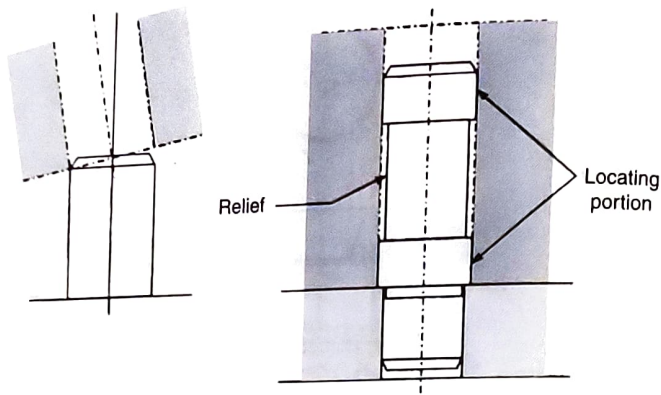


Fig. 2.25 Prevention of jamming

The length (L) of the locator should be short to minimise the loading/unloading time. Short length also reduces the possibility of workpiece jamming on the locator during loading/unloading. The optimum length (L) depends upon the minimum locator diameter (D), the distance (L_1) of the nearest edge from the hole centre and the minimum clearance (c) between the locator and the hole (Fig. 2.26a).

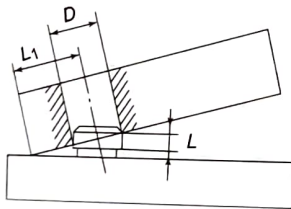


Fig. 2.26a Removal of work-piece from a single pin

$$\text{Locator Length } (L) = \frac{L_1 + 0.5D}{D} (\sqrt{2Dc})$$

While locating on two holes the centre distance (L_2) between them must be reckoned (Fig. 2.26b).

$$\text{Locator Length } (L) = \frac{L_1 + L_2 + 0.5D}{L_2 + D} \sqrt{2c\{L_2 + D\}}$$

We have also to reckon that the locator is also subjected to various forces developed during operation. The locator provides support to the workpiece during operation. Hence, it is necessary to use long location posts when the

workpiece is fragile. Under such circumstances, there should be ample lead at the entry point and the locator should be relieved, i.e. made undersize in the central portion.

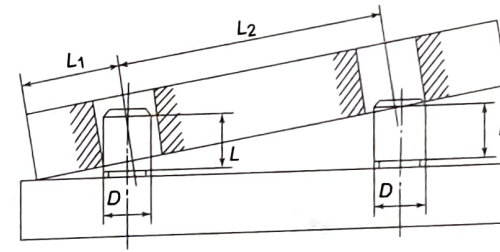


Fig. 2.26b Removal of workpiece from two pins

For locating a cylinder on the outside diameter, it is necessary to use a bush, which is called location pot. They should have generous lead at the entry point, and the central portion should be relieved in case of long pots (Fig. 2.27).

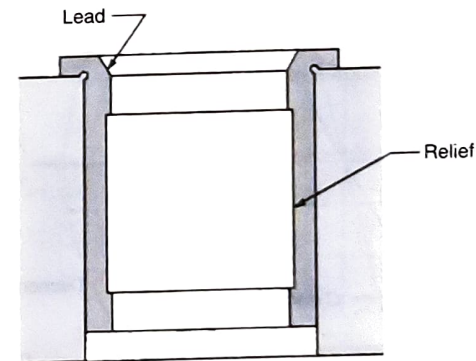


Fig. 2.27 Female locators

A single cylindrical locator cannot prevent rotation of the workpiece around the axis of the locator. For this, it is necessary to provide a second locator. For example, it is necessary to use two dowel pins to ensure that the piece is completely constrained.

If we want to fix plate B on base A we must use at least two dowel pins P and Q as shown in Fig. 2.28. If we use only one dowel pin P, plate B can pivot around P. The provision for dowel Q would prevent plate B from pivoting around P. The dowels P and Q should be placed as far as possible.

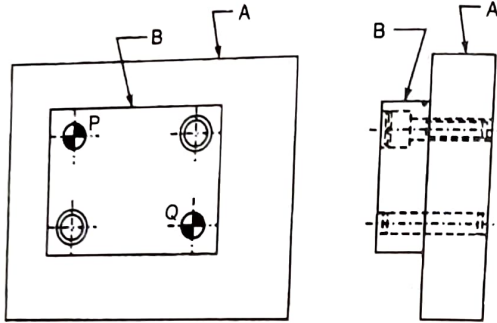


Fig. 2.28 Use of dowels

The dowels are used for permanent assembly of two parts. The holes in base A should be located from plate B so that there is no question of variation of centre distance between dowel holes P and Q.

When we have to use two holes in a workpiece for location, we must take into account the variation in the centre distance of the two holes due to the wear of the guide bushes for cutting tools.

This variation can be taken care of by making one of the two location pins diamond shaped as shown in Fig. 2.29.

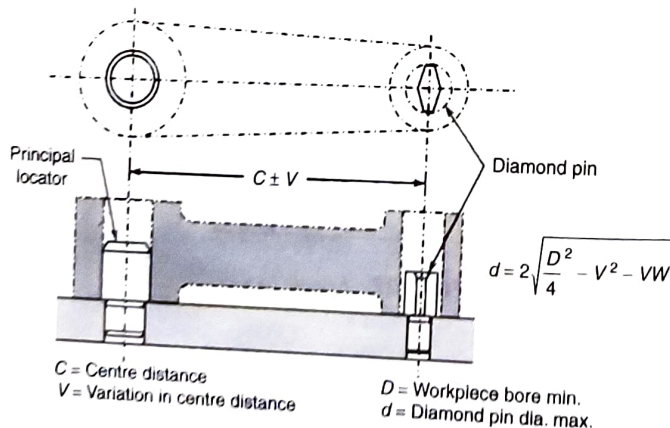


Fig. 2.29a Diamond pin application

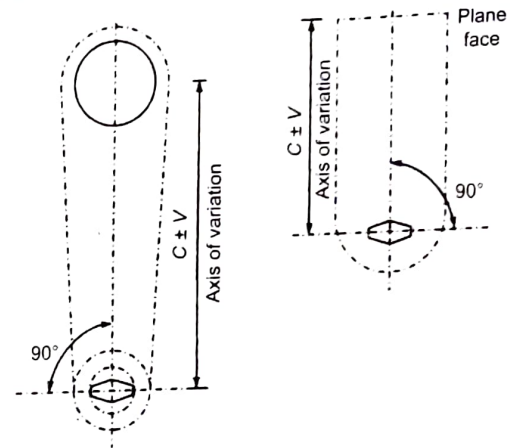


Fig. 2.29b Positioning diamond pin correctly

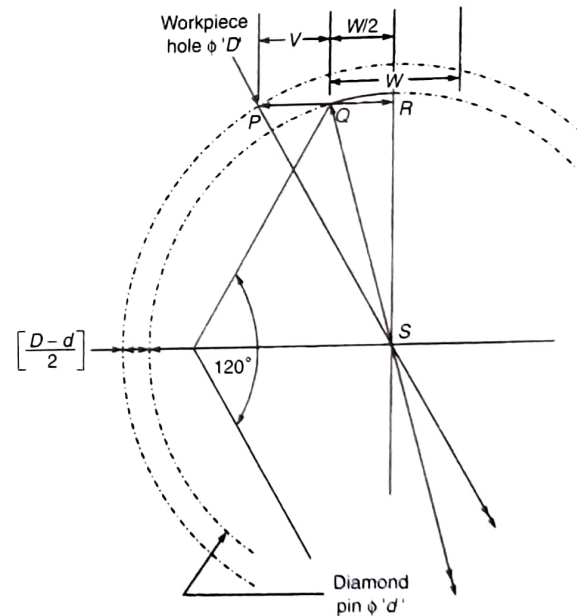


Fig. 2.29c Principle of diamond pin

Out of the two holes, the important and accurate one should be used for principal cylindrical location with a full pin. The diamond shaped pin should be used to constrain pivoting of the workpiece around the principal locator.

The principal locator should be longer than the diamond pin so that the workpiece can be located and pivoted around it before engaging with the diamond pin (Fig. 2.29a). This simplifies and speeds up loading of the workpiece.

Diamond pin can also be used for accommodating the variation in the distance of a hole from a plane surface (Fig. 2.29b).

Figure 2.29c illustrates the principle of a diamond pin. The locating surface of a diamond pin is usually less than 12% of a full cylindrical pin. This provides more clearance at location points. Clearance V at corner Q is much more than radial clearance $(D - D/2)$ between the workpiece hole and the diamond pin. Referring to Fig. 2.29c, in triangle PRS :

$$\begin{aligned} \therefore PS^2 &= PS^2 + RS^2 \\ &= (PQ + QR)^2 + (QS^2 - QR^2) \\ \left(\frac{D}{2}\right)^2 &= \left(V + \frac{W}{2}\right)^2 + \left(\frac{d}{2}\right)^2 - \left(\frac{W}{2}\right)^2 \\ \frac{D^2}{4} &= V^2 + VW + \frac{W^2}{4} + \frac{d^2}{4} - \frac{W^2}{4} \\ \therefore d &= 2\sqrt{\frac{D^2}{4} - VW - V^2} \end{aligned} \quad (2.1)$$

Example 2.1 Calculate the diameter of a diamond pin placed at 45 ± 0.15 distance from a plane surface if the locating hole in the workpiece D is $55.55/55.596$ and engagement width W of the pin is 2 (Fig. 2.29b).

Solution: Minimum ϕ of workpiece hole = D

$$D = 55.55$$

$$\text{Variation, } V = 0.15$$

$$W = 2$$

$$\therefore \text{Diamond } p \text{ in } \phi = d$$

$$\begin{aligned} d &= 2\sqrt{\frac{55.55^2}{4} - 0.15 \times 2 - 0.15^2} \\ &= 2\sqrt{771.45 - 0.3 - 0.0225} \\ &= 2\sqrt{771.1275} \\ &= 55.538 \end{aligned}$$

Radial clearance $(D - d)/2$ is only 0.006. But the clearance at location corner Q is 0.15, i.e. 25 times the radial clearance. The pin should be made further undersize to provide precision running fit ($H7/f6$) with the workpiece.

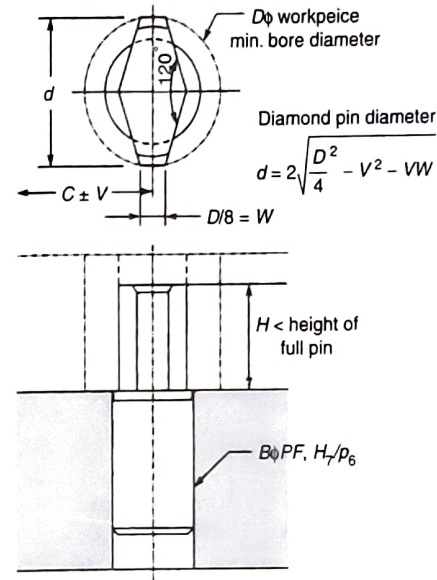


Fig. 2.30 Diamond pin design

$$\text{Diamond pin } \phi = d = 55.538f6$$

$$= 55.538_{-0.049}^{+0.03}$$

Width W of the diamond pin is usually kept one-eighth of the workpiece hole ϕD (Fig. 2.30). It can, however, be varied suitably to accommodate variation V in centre distance C in the workpiece and the desired fit between the diamond pin and the hole.

Example 2.2 Determine permissible variation V in centre distance 45 in example 2.1, if width W is increased to 7. While pin d remains same, i.e. $55.538f6$.

$$\begin{aligned} d &= 2\sqrt{\frac{D^2}{4} - VW - V^2} \\ 55.538 &= 2\sqrt{771.45 - 7V - V^2} \end{aligned}$$

$$\text{or } V^2 + 7V - 0.33264 = 0$$

$$V = \pm 0.0472$$

Angular accuracy required in location is the ultimate criterion for the radial clearance permissible between the diamond pin and the workpiece hole.

Example 2.3 Determine the angular accuracy of location if a diamond pin with 4 mm land is used for locating axis of 2 - $\phi 32$ H7 holes and centre distances between the holes (Fig. 2.29a) is 200 ± 0.2 .

Solution: $D = 32$; $W = 4$; $V = 0.2$

$$\begin{aligned} \therefore d &= 2\sqrt{\frac{D^2}{4} - VW - V^2} \\ &= 2\sqrt{\frac{32^2}{4} - 0.2 \times 4 - 0.2^2} \\ &= 31.947 \end{aligned}$$

$$\therefore \text{Pin } \phi = 31.947 \text{ f6} = 31.947 \begin{smallmatrix} -0.03 \\ -0.049 \end{smallmatrix}$$

$$\begin{aligned} \text{Angular accuracy} &= \tan^{-1} \left[\frac{D-d}{2C} \right] \\ &= \tan^{-1} \left[\frac{32-31.897}{2 \times 200} \right] \\ &= 0.01475^\circ = 0^\circ 0' 53.11'' \end{aligned}$$

Location land W of diamond pin should be square to the axis along which variation V occurs. When a diamond pin is used to locate the axis of two cylindrical holes (Fig. 2.29a), the land should be square to the axis joining the centres of the holes. While locating a plane surface and a hole (Fig. 2.29b), the centre line of land W should be parallel to the plane surface.

Conical Location Conical locators are used mainly to locate rough unmachined cylinders in castings and forgings. Cored holes and bosses are centralised by conical locators (Fig. 2.31). Conical locators generally have axial adjustment with a screw, which is also used to clamp the located work-

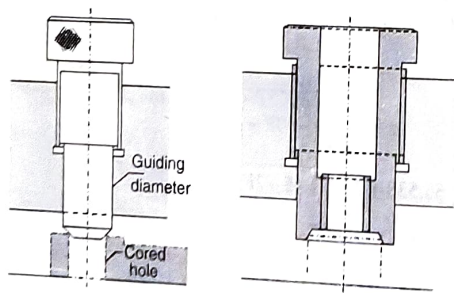


Fig. 2.31 Conical locators

piece in position. When a casting has a single boss which is to be drilled, a bush is made integral with the locator to facilitate drilling of the workpiece in the located position.

Vee Location Vee locators are used extensively to locate cylindrical surfaces from outside. Fixed V blocks are used for approximate location. These are generally fixed by screws to the fixture body and dowelled to prevent shifting during operation (Fig. 2.32).

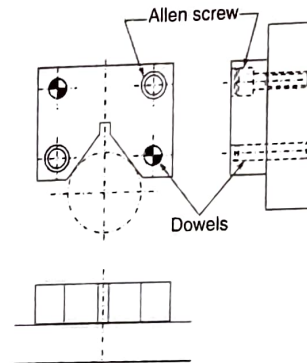


Fig. 2.32 Fixed V locator

For more accurate location, it is necessary to make V locator adjustable along the axis of V. The position of V block is adjusted by a screw to take care of the variation in the size of the workpiece (Fig. 2.34).

An adjustable V locator should be guided by a guide plate to constrain its movement along the axis of V. The guides must be dowelled to prevent shifting during operation. The side of the V face is sometimes inclined slightly to provide downward clamping force (Fig. 2.33).

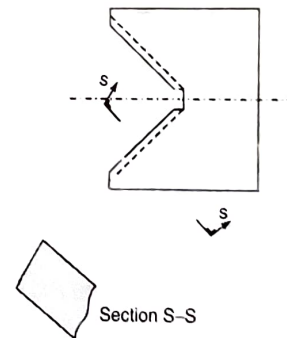


Fig. 2.33 Inclined V

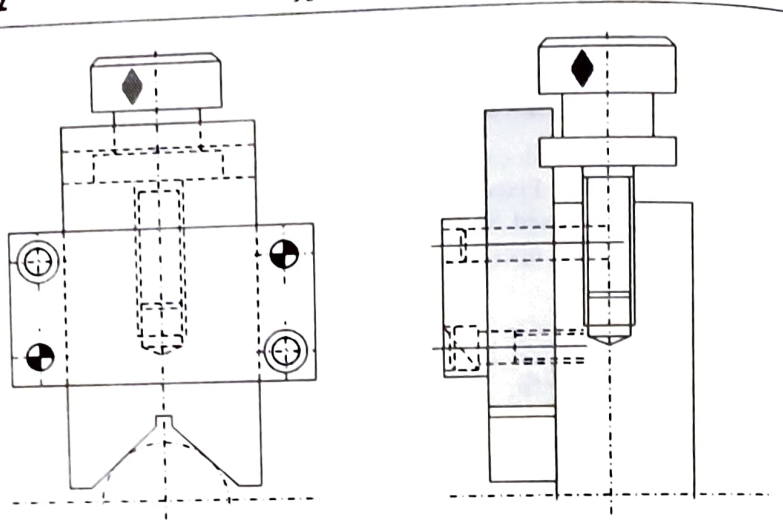


Fig. 2.34 *Screw adjusted V locator*

A Vee locator can be adjusted quickly by using a cam for adjustment (Fig. 2.35).

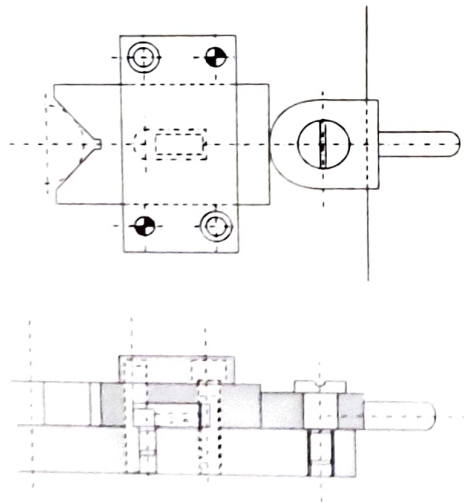


Fig. 2.35 *Cam-operated V locator*

It is necessary to provide a return spring for bringing back the V locator to its original position when a cam is used.

When the V plate has to be withdrawn quickly for a considerable distances, a swinging eyebolt is used. A slotted thrust plate must be provided as a seating face for the V adjusting nut. (Fig. 2.36).

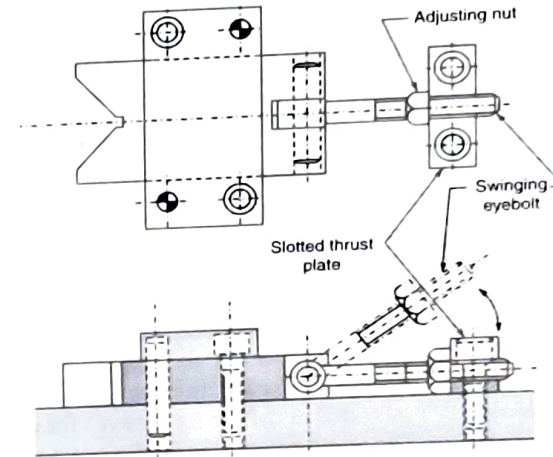


Fig. 2.36 *Quick action V locator*

When a cylindrical workpiece is located by the V block, the position of its centre would depend on its diameter. However, the centre would always lie on the centre line of V. So, for drilling central holes in round bars, the V block should be placed in such a way that its centre line is vertical. Even if the size of the workpiece varies, the drilled hole would always be at its centre (Fig. 2.37).

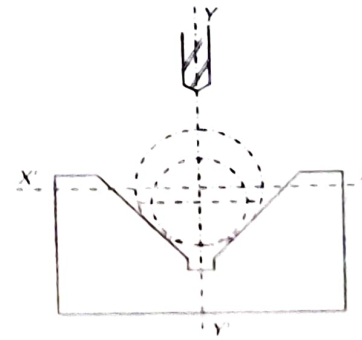


Fig. 2.37 *Correct position of V*

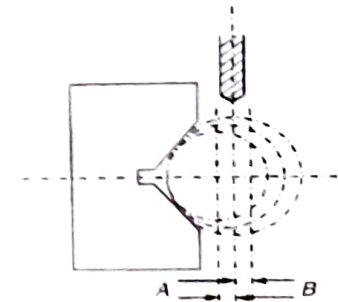


Fig. 2.38 *Correct position of V*

On the other hand, if the V block axis is horizontal, the variation in the diameter of the workpiece would lead to errors. As shown in Fig. 2.38, the hole in undersize bar would be eccentric by length A, whereas in case of an oversized bar, the hole would be offset by length B.

Locating Castings, Forgings and Mouldings

Most dies and moulds have two halves to facilitate removal of the formed workpiece. Excess raw material overflows (spills) at the interface between the die halves (Fig. 2.39). This projection at the joint is called flash. The flash is rarely uniform around the die cavity. Location on flash will give very erratic results. It should be avoided. This can be done by providing a clear groove in the flash area encountered by the locator. Fig. 2.40 shows a groove in a vee locator used for locating a cast boss. The groove accommodates the uneven flash ensuring that the workpiece is located on a better surface. Fig. 2.41 shows a locator for a flat surface. It locates above the flash. It has got a downward angle in the location area. The angle matches the draft angle (usually 5°) provided in the die (or pattern) for easy removal of workpiece after casting. The angle presses the workpiece downward onto the locating (resting) surface.

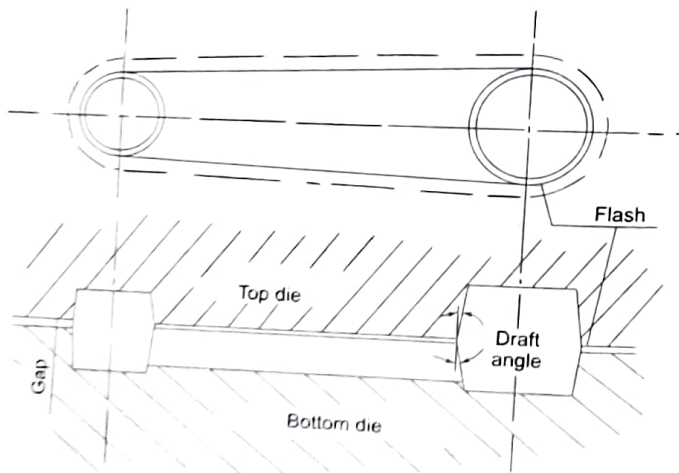


Fig. 2.39a Flash projection in forgings and mouldings

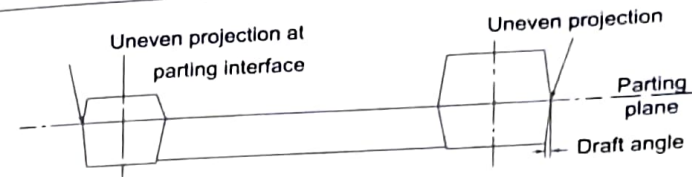


Fig. 2.39b Uneven projection at parting plane

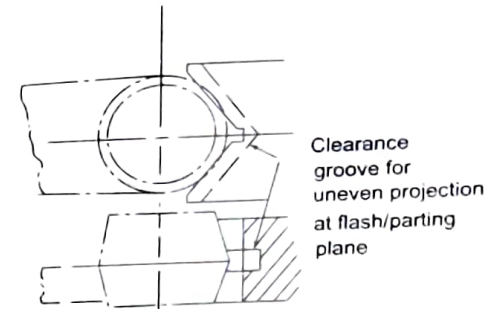


Fig. 2.40 'V' locator grooved at Flash/parting plane

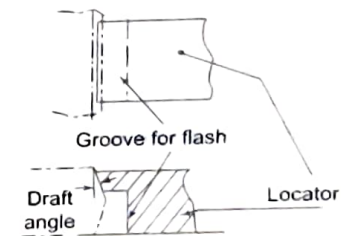


Fig. 2.41 Flash clearance grooves for flat locators



Summary

Principles of Location

1. Location must be related to the dimensional requirements stated on the component/workpiece drawing.
2. It is preferable to use a more accurately machined surface than a less accurate surface for location.

3. The workpiece should be prevented from moving along and rotating around the X, Y and Z axes.
4. Location system should facilitate easy and quick loading and unloading of the workpiece and aim at motion economy.
5. Redundant locators must be avoided.
6. Location system should positively prevent wrong loading of the workpiece by foolproofing.

Locating Methods

Plane Surfaces

1. A reasonably flat surface can be located by three pins of equal height having spherical surfaces at the location points.
2. A rough, uneven or tapered plane surface should be located by three adjustable location pins having spherical ends.
3. Additional adjustable supports are necessary to prevent vibrations or distortion of the workpiece during machining operation. The force for adjusting the supports should be kept minimum so that the workpiece does not get dislocated or lifted from the location pins.
4. A machined surface can be located by pads having flat surface.
5. There should be ample clearance for burr or dirt to ensure proper seating of the workpiece surfaces.
6. A cube can be prevented from linear movement and rotation around axes X, Y and Z by six location pads.

Profile

1. A profile can be located approximately by aligning it with a slightly bigger sighting plate.
2. Locating pins can also be used to locate a profile or cylindrical workpieces.
3. Variations in workpiece sizes from batch to batch can be taken care of by using eccentric locators whose eccentricity can be set to suit the batch.
4. Workpieces with little variation can be located precisely with nesting plates with suitable provision for unloading or ejection.

Cylinder

1. Spigots used for locating bores should have ample lead for easy entry, and their length should be short to prevent jamming of the workpiece.
2. Long locators for fragile workpieces should be relieved at the centre.
3. Location posts, which are also used for clamping, should be retained by a nut or a grub screw.
4. When two location pins are used, the less important one should be made diamond-shaped. The important full pin should be longer than the diamond pin in order to facilitate easy loading of the workpiece.
5. Rough cored holes and bosses are located by conical locators, which often have integral clamping arrangement and drill bush.
6. Fixed V blocks are used to locate approximately the outside surface of a cylinder.
7. For precise location, an adjustable guided V block is necessary. The V block can be adjusted by a screw or a cam. It can be withdrawn quickly by using a swinging eyebolt.
8. V blocks should be positioned in such a way that the variation in the workpiece would not affect the location for the operation. For drilling central holes, the centre line of V should be vertical.
9. Clearance grooves should be provided at flash line of cast, forged and moulded workpieces.



Clamping

Clamping elements hold the workpiece firmly engaged with the locating elements during operation. The clamping system should be strong enough to withstand forces developed during operation. At the same time, the clamping force should not dent or damage the workpiece. Speed of operation, operator fatigue and strategic positioning are other important considerations for contriving a clamping system.



Principles of Clamping

Position

Clamping should be positioned to direct the clamping force on a strong, supported part of the workpiece. Clamping on unsupported part bends slender workpieces, as shown in Fig. 3.1. This affects the accuracy of the operation. A vertical hole drilled in the bent workpiece would become angular when the unclamped workpiece springs back to its original shape, as shown by the chairdotted lines in Fig. 3.1.

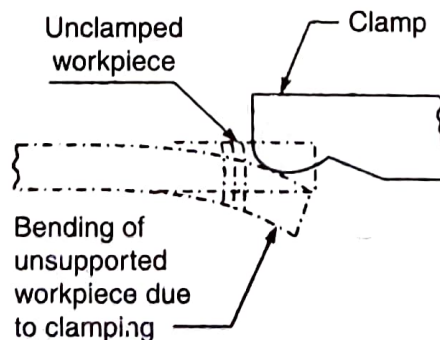


Fig. 3.1 *Distortion of unsupported workpiece*

The clamping system should not obstruct the path of loading and unloading of the workpiece. The clamps in the path of loading should be retractable (Fig. 3.9) or swinging type (Fig. 3.10a), so that the clamps can be withdrawn or swung clear of the path of loading and unloading of the workpiece.

Clamps should not obstruct the path of the cutting tool. They should not get drilled, milled or welded during operation.

Strength

The clamping system should be capable of holding the workpiece securely against the forces developed during operation. The clamping force should not dent or damage the workpiece with excessive pressure. For clamping weak or fragile workpieces, the clamping force should be distributed over a wider area of the workpiece. While clamping soft workpieces, clamps should be fitted with pads of softer materials, such as nylon or fibre to prevent damage and denting of the workpiece.

Productivity

Clamping time should be minimised by using hand knobs, tommy bars, knurled screws, handwheels and handles (Fig. 3.2), so that the clamp can be tightened or loosened manually without using spanners, as a spanner further adds motions of picking, aligning and laying it down.

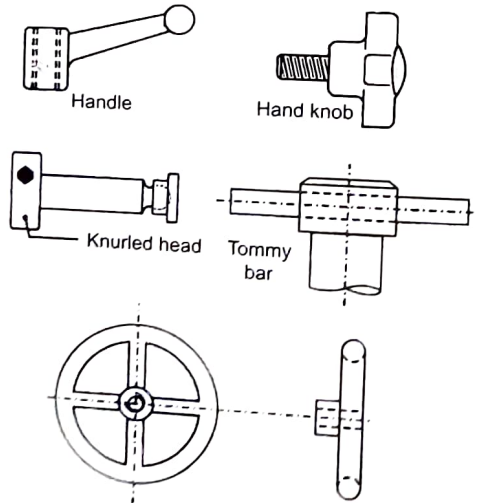


Fig. 3.2 Hand operated clamping devices

Operator Fatigue

Operator fatigue should be taken into account. If a considerable number of clamps are to be tightened and loosened repeatedly, it is better to use pneumatic or hydraulic clamping which, in addition to reducing operator fatigue, saves clamping time. Power clamping facilitates tightening or loosening of many clamps simultaneously.

Workpiece Variation

The clamping points should be provided with ample radius to make the clamp operable even if there is variation in the workpiece. Heel pin pressure surface should also be made spherical to permit some tilting of the clamp (Fig. 3.3a).

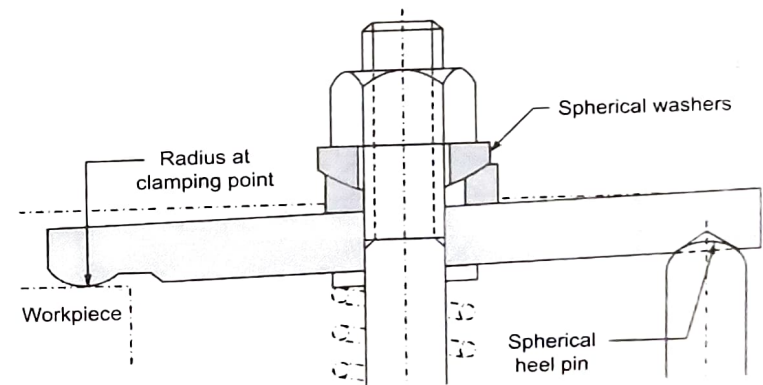


Fig. 3.3a Clamping variable workpieces

Misalignment between the clamp surface and the clamping nut due to tilting of the clamp can be countered by use of spherical washers between the clamp and the nut. As washers are used in pairs, the two washers have matching male and female spherical seats. The spherical bearing allows the washers to tilt with respect to each other. The lower female washer tilts with the clamp while the upper male washer below the nut remains square to the nut. The spherical seat transmits the clamping pressure from the nut to the clamp. Figure 3.3b shows a clamp with a cylindrical washer.

In multiple clamping, a pivoted equaliser is used for clamping two unequal workpieces simultaneously. The equaliser clamp pivots around the

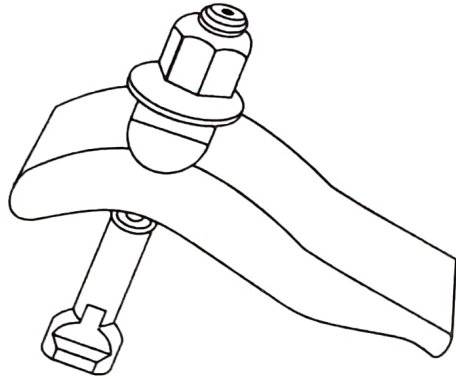


Fig. 3.3b Universal clamp with cylindrical washer

pin to suit the workpieces (Fig. 3.4). The equaliser principle can be extended to facilitate clamping of many even number of workpieces simultaneously by a single clamp (Fig. 3.5).

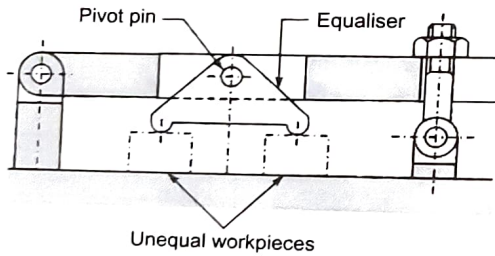


Fig. 3.4 Equaliser for two workpieces

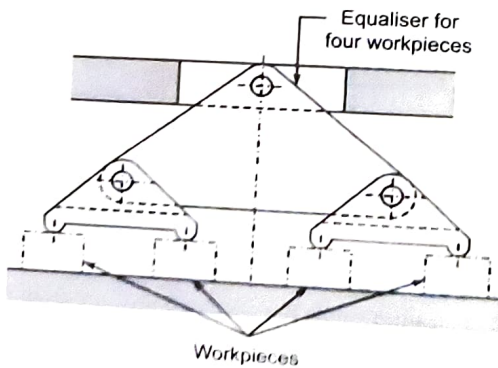


Fig. 3.5 Equaliser for four workpieces



Types of Clamps

Clamps can be broadly classified into screw clamps, strap clamps, pivoted clamps, hinged clamps, swinging clamps, quick action clamps, multiple clamps, power clamps and non-conventional clamps.

Screw Clamps

Screw clamps are threaded devices with knurled collar, hand knob, tommy bar or spanner flats for rotating and tightening the screw (Fig. 3.6).

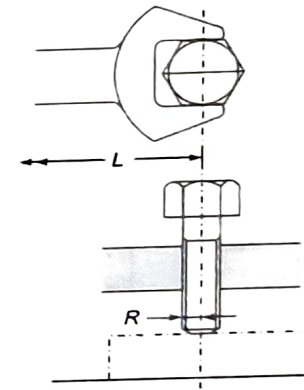


Fig. 3.6 Screw clamp

The Clamping area of a screw clamp can be increased by a provision for a pad (Fig. 3.7a). The clamping pad is free to rotate on the pivot. This eliminates friction between the workpiece and the pad. The clamping pad remains stationary on the workpiece while the screw rotates and rubs on the conical seat of the pad.

A swivel-type clamping pad provides a spherical joint between the clamping pad and the clamping screw (Fig. 3.7a). This allows the clamping pad to swivel around the clamping screw. The swivelling pad adjusts itself to suit the inaccuracies in the clamping face of the workpiece. The cross pin pulls the pad backwards when the screw is retracted. Figure 3.7b shows another type of floating pad.

The force developed by the screw can be calculated with the following formula:

$$F_c = \frac{F_n L}{R \tan(\alpha + \phi)}$$

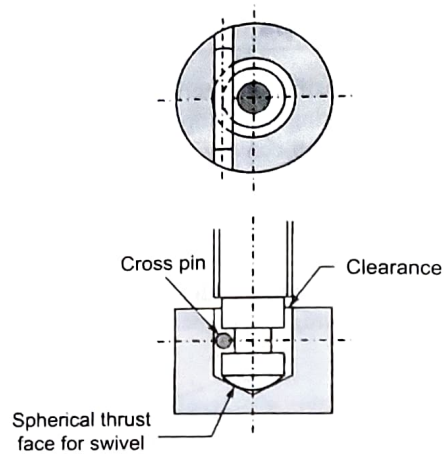


Fig. 3.7a Floating pad

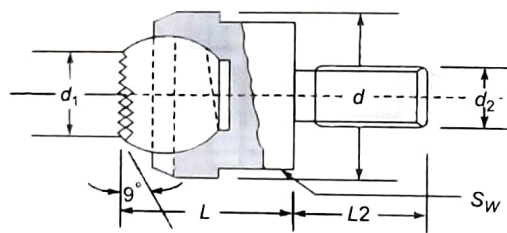


Fig. 3.7b Another type of floating pad

- F_s = Force developed by screw
- F_h = Pull or push applied to spanner
- R = Pitch radius of screw thread
- α = Helix angle of thread
- ϕ = Friction angle of thread
- L = Length of spanner or lever

A 12 mm hexagonal headed bolt with 100-mm-long wrench and a 10 kg manual pull can develop 700 kg clamping force along the axis of the screw.

Strap or Plate Clamps

These are made of rectangular plates and act like levers. In its simplest form, the clamp is tightened by rotating a hexagonal nut on a clamping screw (Fig. 3.8). One end of the clamp presses against the workpiece and the other on the heel pin, thus, loading the clamp like a simply supported

beam. The clamping face of the clamp is curved and the pressure face of the heel pin is made spherical to take care of any variations in the workpiece.

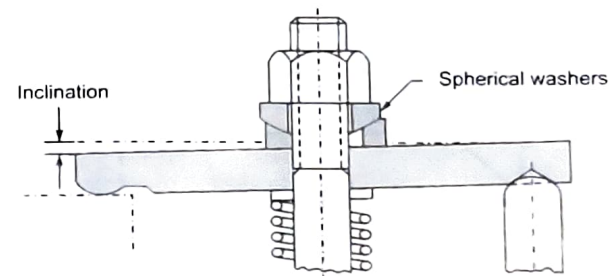


Fig. 3.8 Simple plate clamp

The provision for spherical washers between the clamp and the hexagonal nut provides a spherical joint which permits the clamp to tilt with respect to the screw and the nut. Thus, the clamp operates satisfactorily even if there is considerable variation in the workpiece height.

Generally, strap clamps are provided with a washer and a spring below the clamp. The spring lifts the clamp as the nut is loosened. The workpiece becomes free of even the gravitational load due to clamp weight. The spring holds the clamp in a raised position during loading and unloading of the workpiece.

Retractable Strap Clamps When clamps fall in the path of loading and unloading, they are made slotted to permit linear withdrawal (Fig. 3.9a). The clamp is retracted to the position shown by the chain-dotted line during loading and unloading of the workpiece. Figure 3.9b shows a U clamp that can be removed altogether.

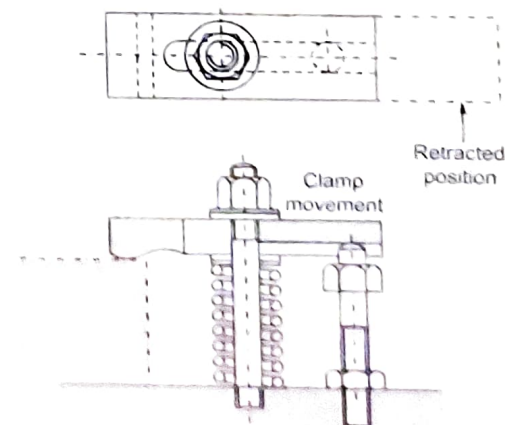


Fig. 3.9a Slotted strap clamp

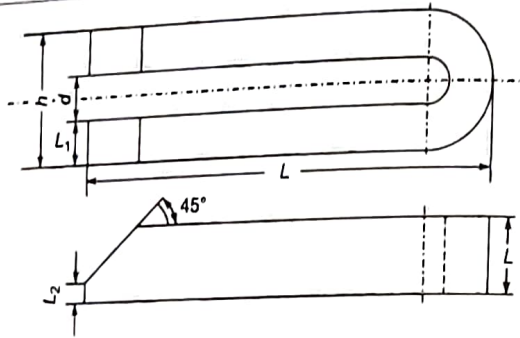


Fig. 3.9b U clamp with open slot

Swinging Strap Clamps In another design, the clamp is rotated by 90° to clear the passage for loading/unloading the workpiece (Fig. 3.10a). The clamp is swung to the position shown by the chaindotted line during loading and unloading of the workpiece.

Figure 3.10b shows a 45° swinging diagonal clamp developed by the author for clamping a jig for terminal box holes in the workpiece. As it is shaped to suit the square opening in the terminal box, the ends of the clamp are chamfered to enable loading and unloading of the clamp. The auxiliary view of the diagonal loading/unloading position of the clamp is in chaindotted lines.

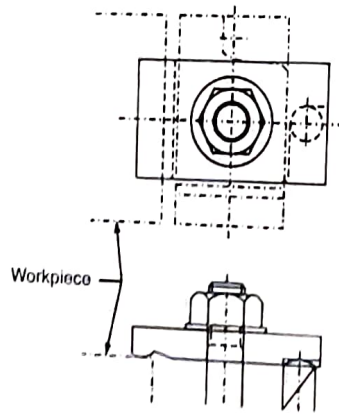


Fig. 3.10a Swinging strap clamp

The clamp is swung by 45° to bring the chamfered ends below the terminal box in the clamping position. The stop pins fitted in the jig plate facilitate bringing the clamp blindly in the clamping and loading/unloading

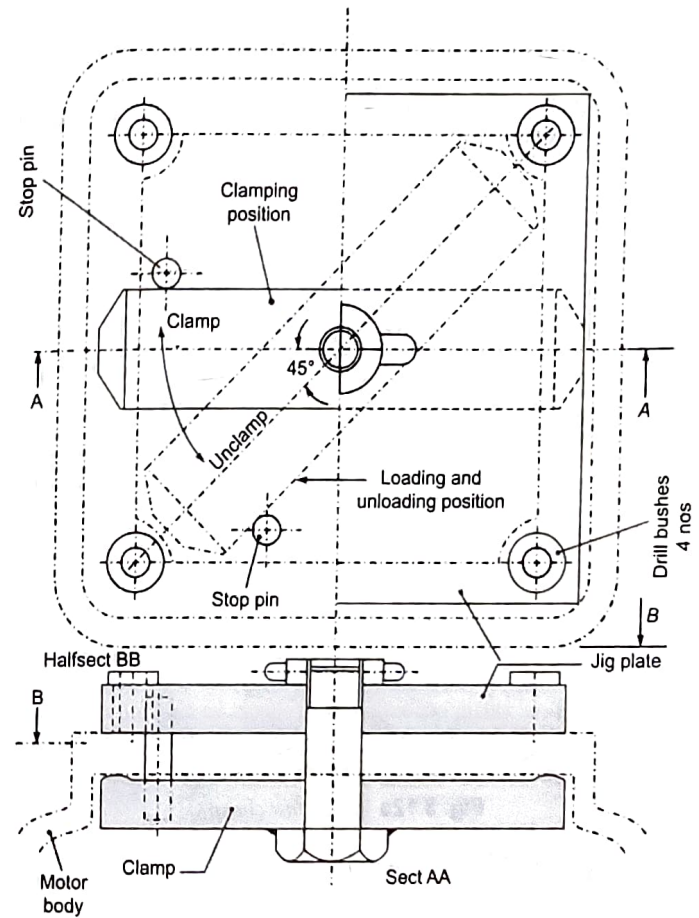


Fig. 3.10b Special swing clamp for drill jig for terminal box holes in electrical motor body

positions. The clamping bolt is welded to the clamp to simplify swinging of the clamp along with the bolt. The clamp is kept in the diagonal position while loading/unloading the jig. The clamp is lowered or raised through the opening in the terminal box. Clamping is effected by sandwiching the terminal box rim between the jig plate and the clamp.

After drilling is finished, the clamp is swung to the chaindotted diagonal position to permit withdrawal through the terminal box opening.

Edge Clamps Strap clamps are used extensively for clamping workpieces on the edges during facing operations. Figure 3.11 shows a simple

edge clamp. The tightening of the hexagonal nut wedges the clamp between the workpiece and the angular heel surface. This clamps the workpiece. Figure 3.12a shows another edge clamp. It slides down the inclined heel as the hexagonal nut is tightened. This pushes the jaw against the workpiece to clamp its edge. Figure 3.12b shows a pivoted edge clamp.

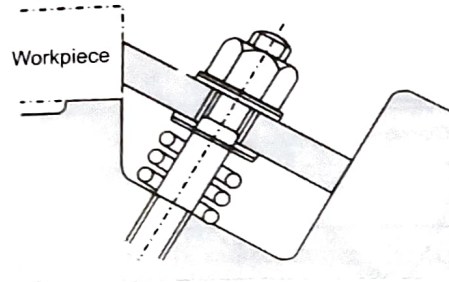


Fig. 3.11 Edge strap clamp

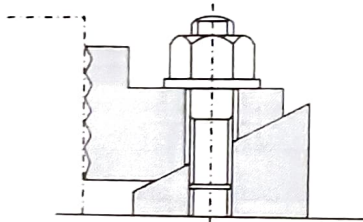


Fig. 3.12a Edge jaw clamp

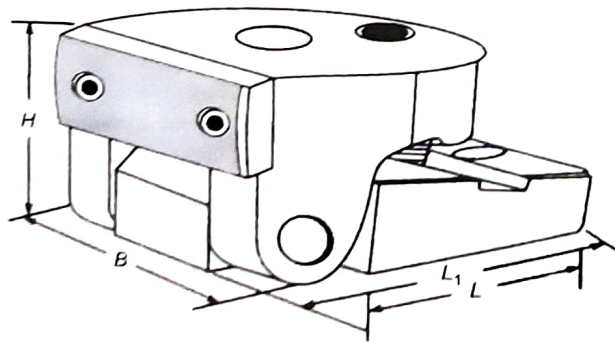


Fig. 3.12b Hinged edge clamp

Special Strap Clamps The clamp shape can be changed to suit the workpiece and the operation. In milling fixtures, clamps are often slotted

at the centre to permit passage of the cutter (Fig. 3.13a). Circular and symmetrical workpieces can be clamped well with a spider clamp having three clamping points (Fig. 3.13b). As the clamp acts as a sort of rigid washer, no heel pin is necessary.

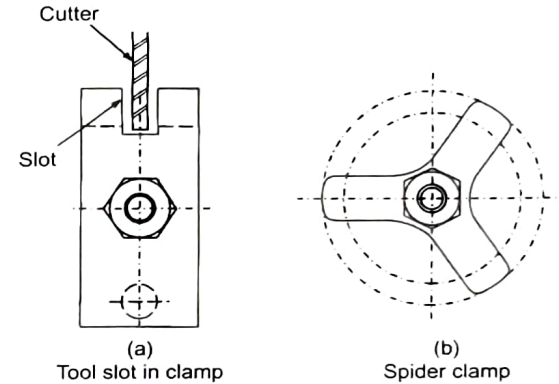


Fig. 3.13 Special clamps

Pivoted Clamps Clamps are often pivoted at the centre to simplify their operation. Figure 3.14 shows a pivoted strap clamp. It is tightened and loosened by the knurled head screw. The clamp pivots around the central pin during operation.

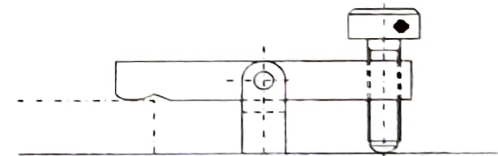


Fig. 3.14 Pivoted strap clamp

Figure 3.15 shows a couple of pivoted edge clamps. The point of operation should be noted, i.e. the screw has been shifted from the centre to the end opposite the clamping point. This places the clamp screw well below the path of cutter for facing workpiece top.

Pivot action can be used for two-way clamping of the workpiece (Fig. 3.16). The tightening of the knurled screw first pushes the workpiece till it touches the locator. Further tightening of the screw pivots the clamp anti-clockwise till the curved face of the clamp touches downward on the workpiece. Still further tightening of the screw clamps the workpiece vertically

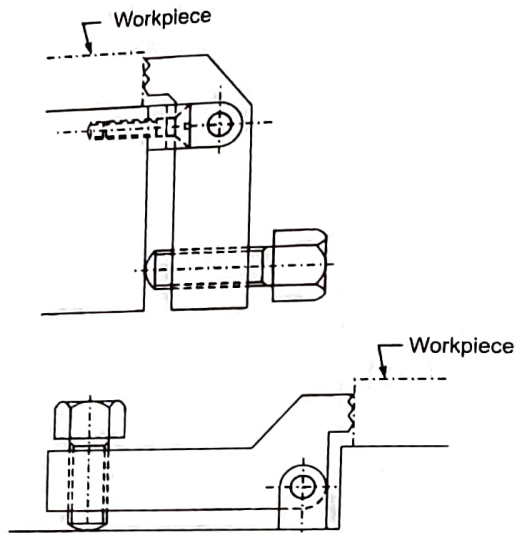


Fig. 3.15 Edge clamps

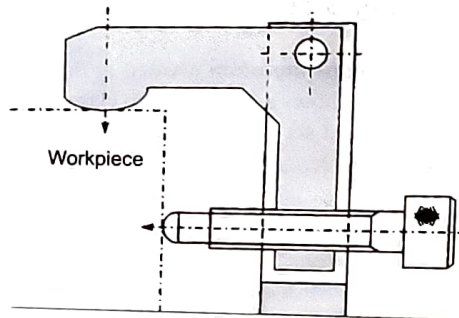


Fig. 3.16 Pivoted two-way clamp

and horizontally with the curved surface and the end of the knurled head screw. Thus, a two way-pivoted clamp pushes the workpiece against two locators before it clamps the workpiece simultaneously in two directions.

Hinged Clamps Hinged clamps provide rapid clearance of the loading and unloading passage. It is generally clamped with a swinging eyebolt. The clamp has an open slot through which the eyebolt can be swung into position as shown in Fig. 3.17(b). The tightening of the hexagonal nut clamps the workpiece. For loading and unloading the workpiece the hexagonal nut is loosened half-a-turn and the eyebolt is swung out of the open slot to free the hinged plate as shown in Fig. 3.17a. The hinged plate is swung aside during loading and unloading.

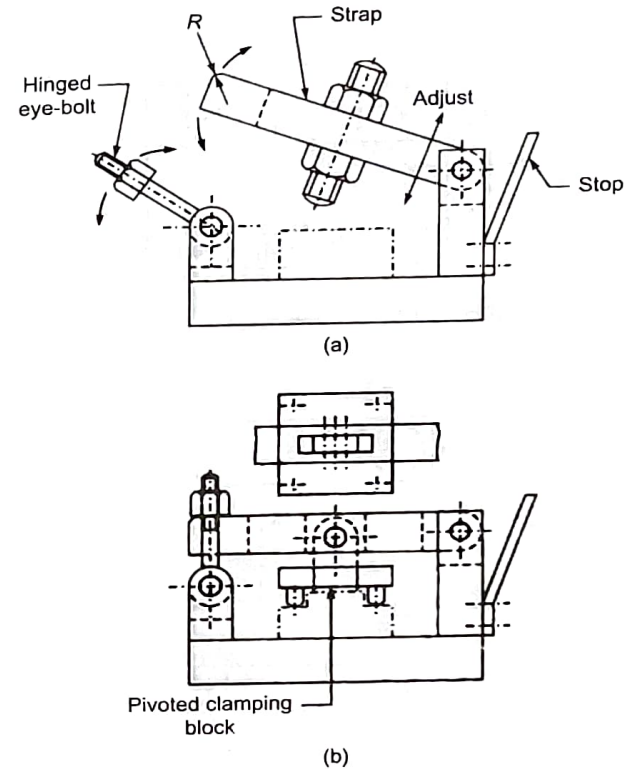


Fig. 3.17 Hinged clamp

A hinged clamp can also be used for two-way clamping (Fig. 3.18). The workpiece is pushed against the location pins by the pivoted edge clamp, which also houses the swinging eyebolt. The tightening of the knurled nut against the hinge clamp first pushes the workpiece against the location pins. After that, further tightening of the knurled nut pushes the clamping pad towards the workpiece, which is clamped simultaneously in two directions by the edge clamp and the pad in the hinge. The knurled nut is loosened only by half-a-turn before swinging the eyebolt and the hinge plate aside for loading and unloading the workpiece.

Swinging Clamps Like hinged clamps, swing clamps must be swung to the working position. However, in swinging clamps, the axis of rotation is square to the clamping plate face. Consequently, the swing clamps rotate in the planes of their plates. Figure 3.19 depicts a simple swinging clamp which is pivoted about the shoulder screw. The workpiece

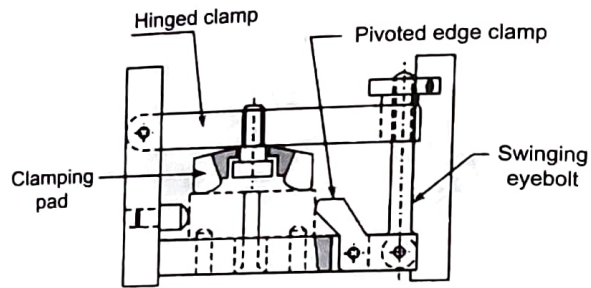


Fig. 3.18 Hinged two-way clamp

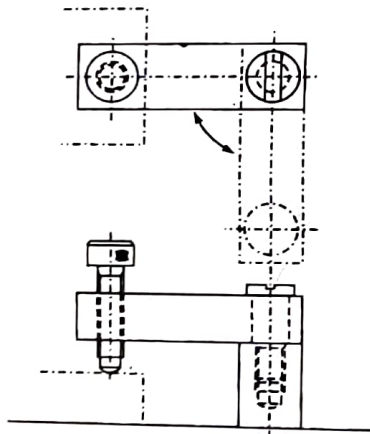


Fig. 3.19 Swinging strap clamp

is clamped by the knurled head screw as shown in full lines. For loading and unloading the workpiece, the clamp is swung aside as shown by the chain-dotted line.

Turning fixtures use compact and sturdy swinging hook bolt clamps (Figs 3.20 and 14.6). The clamp is shaped like a short cantilever with a turned outside diameter which slides in a housing.

The housing is milled with two steps which are at right angles to each other. These act as stoppers for the working and unloading position of the clamp. A spring raises the clamp clear above the workpiece as the clamp is loosened. For securing the workpiece, the clamp is turned through right angle to touch the stopper face in the housing. It holds the clamp in position as it is tightened by the hexagonal nut. The length of the clamping lever (G) should not be more than three fourth of the mating length (J) with the housing.

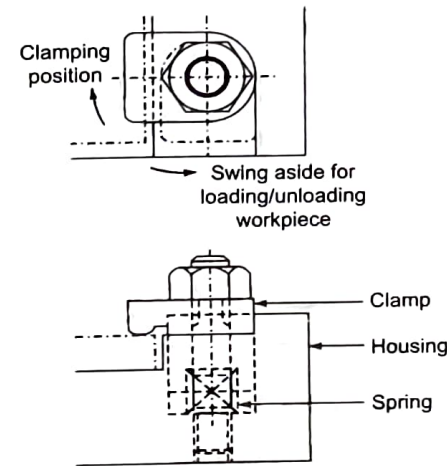


Fig. 3.20 Swinging hook clamp

Figure 15.6a gives the dimensions of the standard hook bolt clamps while Fig. 15.6b gives the relationship between the screw and clamping forces (F_w/F_s) for various G/J ratios.

Figure 3.21a shows a swinging latch with an open slot at one end. The latch is swung around pivot P at the other end. Shoulder screw S enters the open slot during operation. The workpiece is clamped by a knurled head screw. Collars of shoulder screws P and S provide reaction backing during clamping. For unloading and replenishment of the workpiece, the clamping screw is loosened slightly and the latch is swung aside to the position shown by the chain-dotted line.

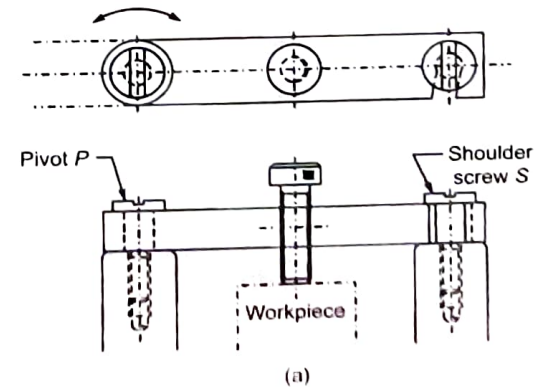


Fig. 3.21a Swinging latch

Figure 3.21b shows three other types of latches and their methods of operation. The chaindotted lines show the latches in clear loading and unloading position, whereas the full lines show the latches in the clamping position.

Shoulder screws are often used as pivots for thrust pads in jigs and fixtures. The shoulder diameter must be bigger than the thread diameter so that the shoulder face acts as a stop when the screw is tightened. The thickness of the pivoted part should be less than the shoulder length to provide clearance for trouble-free operation of the pivoted joint.

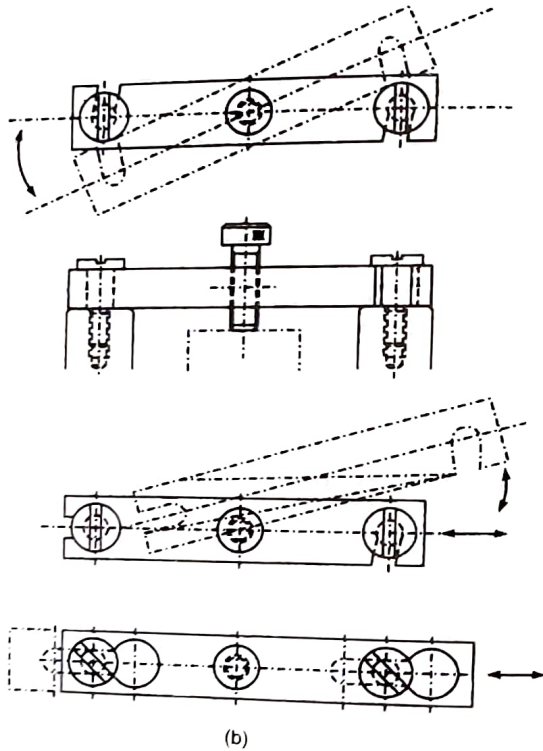


Fig. 3.21b Various types of latches

C Washer The C washer is a strap clamp with an open slot (Fig. 3.22) and is simple and quick in operation. The slot permits removal of C washer after a slight loosening of the hexagonal nut. The distance across corners of the hexagonal nut should be less than the bore of the workpiece to permit passage of the nut through the bore during loading and unloading. The loss of washer can be prevented by chaining it to the fixture or pivoting it around a shoulder screw. The pivot shoulder screw makes the C washer captive.

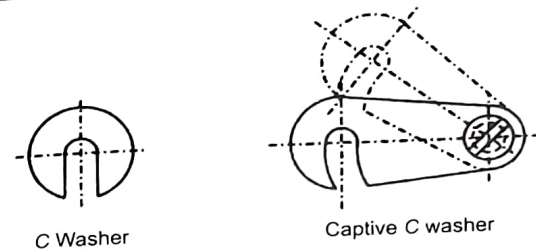


Fig. 3.22 C washers

Quick Action Clamps

The advent of mass production has resulted in the development of several ingenious quick action clamping gadgets. Some of these are described below.

Cams They are popular as quick action clamps. Cams tend to shift their mating faces. There is a risk of the cam clamp getting loose due to vibrations. The coefficient of friction between the cam and the mating surface must be taken into account while determining the eccentricity of the cam.

Eccentric cams are the easiest to manufacture. Eccentric pivoting of a cylinder converts it to a cam (Fig. 3.23). The eccentricity of the cam should be more than 1.5 times the variation in the workpiece. The outside diameter of the eccentric depend upon the co-efficient of friction between the eccentric and the mating surface. If the co-efficient of friction is more than 0.1, the outside diameter should be more than 20 times the eccentricity to

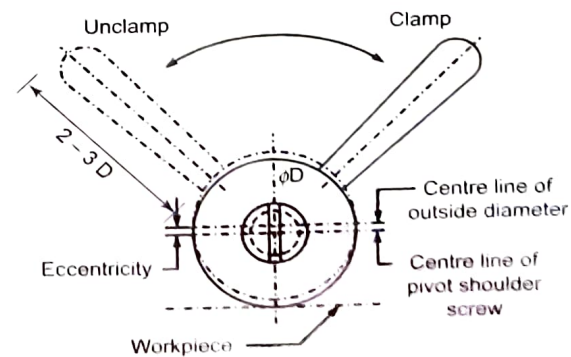


Fig. 3.23 Eccentric cam clamp

prevent loosening due to vibrations: The handle length should be 2–3 times the cam diameter 'D'.

The eccentric cam can replace the hexagonal nut in a strap clamp (Fig. 3.24) or a heel pin in a strap clamp (Fig. 3.25a). A female cylindrical surface can be used as a hook clamp (Fig. 3.26). Figure 3.25b shows a cam operated edge clamp.

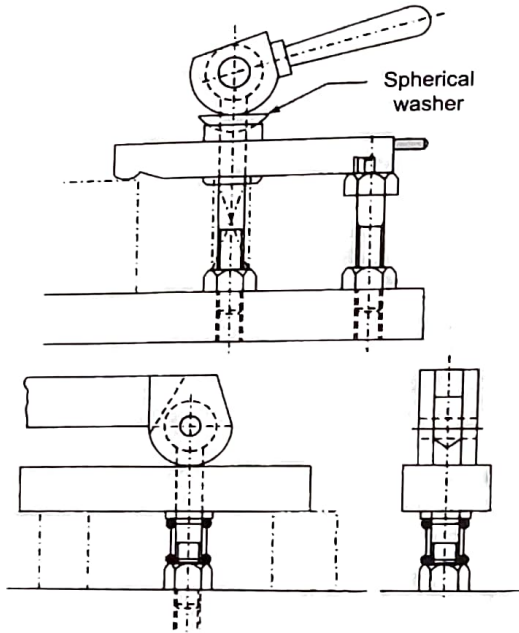


Fig. 3.24 Replacing nut by cam

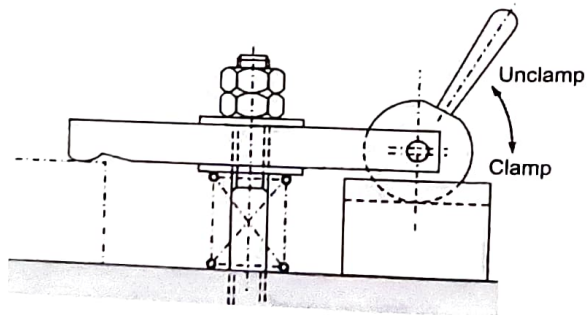


Fig. 3.25a Replacing heel by cam

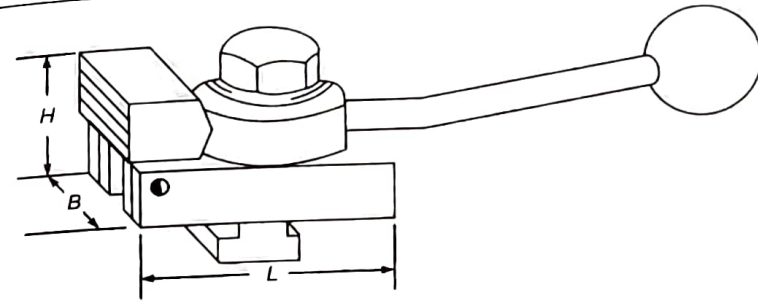


Fig. 3.25b Cam operated edge clamp

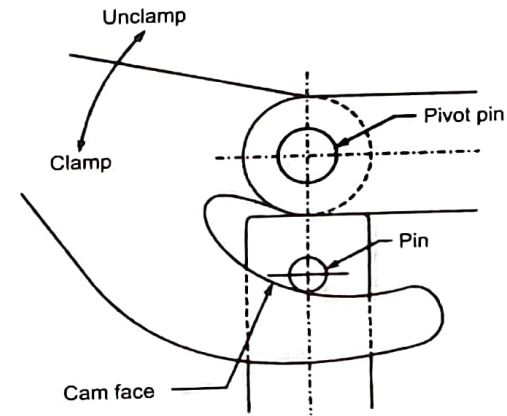


Fig. 3.26 Hook cam clamp

An eccentric shaft has been used for sandwich-type clamping in Fig. 3.27. The rotation of the eccentric shaft with a pinned handle raises and lowers the jig plate fixed to the two connecting rods. The jig plate is clamped against the workpiece face during drilling. For loading and unloading the workpiece, the jig plate is raised by rotating the handle in the opposite direction.

Bayonet Clamp This is a cylindrical cam with a part thread serving as a cam (Fig. 3.28). The motion of the bayonet is guided by the spherical-ended screw mating in the groove in the bayonet. A part of the bayonet groove is straight. The bayonet can be pulled back straight axially through the straight slot to provide ample clearance during loading and unloading of the workpiece. For clamping the workpiece, the bayonet is first pushed forward through the straight groove to close the distance between the workpiece and the bayonet face. At the end of its straight portion, the bayonet is turned

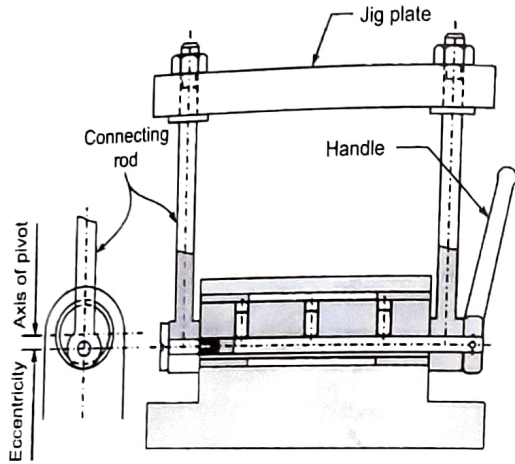


Fig. 3.27 Eccentric shaft clamping

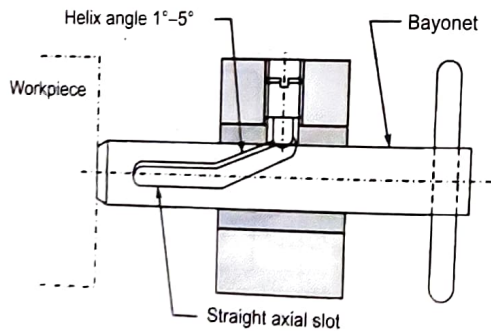


Fig. 3.28 Bayonet clamp

clockwise. The inclined groove in the bayonet acts like a part of a thread. The spherical-end screw pushes the rotating bayonet towards the workpiece to clamp it. To prevent the clamp from loosening due to vibrations the thread or helix angle of the inclined groove should be between 1° and 7° .

Toggle Clamps These are quick action clamps which can be withdrawn by a considerable distance for loading and unloading of the workpiece. Figure 3.29 shows two types of toggle clamps. The C frame clamp can be swung to the chandotted position during loading and unloading. The pusher-type toggle clamp withdraws backwards during unclamping. Toggle clamps are vulnerable to workpiece variations. Most of the toggle clamps are, therefore, provided with adjustable clamping screws.

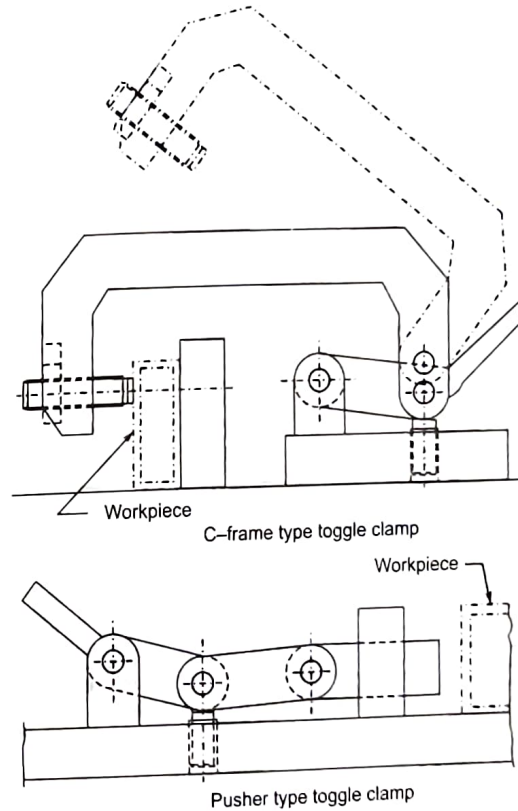


Fig. 3.29 Toggle clamps

Quarter-Turn Screw (Fig. 3.30) It is also called thumb screw and is used to clamp and unclamp hinged jig plates and latches within a quarter turn. In the unclamped position, the head of the thumb screw can pass through the slot provided in the jig/latch plate. The plate can be swung clear of the thumb screw head to the required position. For clamping the jig/latch plate, the thumb screw is turned through 90° , so that its head is at right angles to the slot in the plate. In this position, the thumb screw clamps the plate in the working position. For proper clamping, the mating faces of the thumb screw head must be filed to suit the thickness of the plate.

Quarter-turn screws are suitable for light loads only. For heavy loads, it is better to use a swinging eyebolt and nut knob-combination (Figs 3.17 and 5.17b)

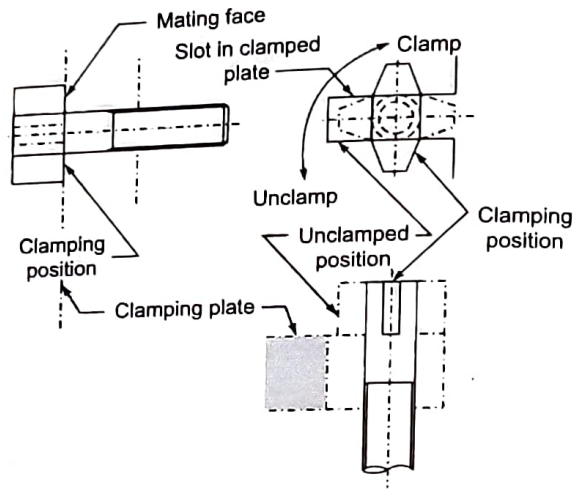


Fig. 3.30 Quarter-turn screw

Multiple Clamping

Double Clamping Two workpieces with limited variation can be clamped by a single strap clamp (Fig. 3.31a). Swivelable spherical washers between the nut and the clamp allow the clamp to tilt slightly to suit the variation in the two workpieces.

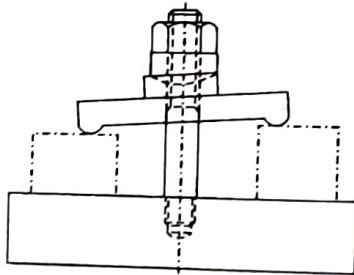


Fig. 3.31a Double clamping

Figure 3.31b shows a method for actuating two clamps by rotating a single handle. Furthermore horizontal cam-pin can assume suitable position to take care of the variation in thickness of flanges in the casting. Rotating the handle clockwise pushes the heel pin downwards. The angular face of the heel pin pushes the horizontal cam-pin towards the opposite clamp, raising its heel pin to clamp the workpiece at two places simultaneously.

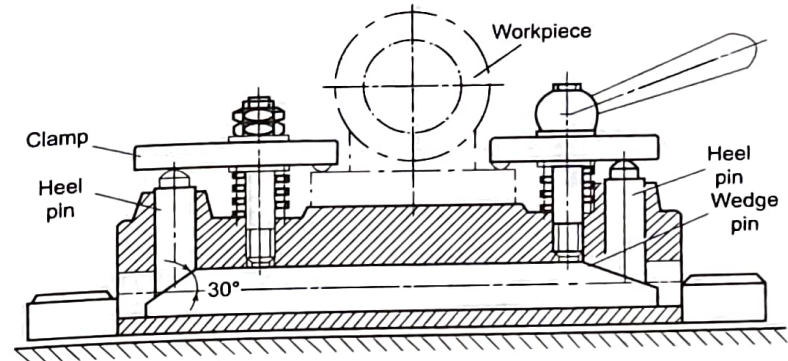


Fig. 3.31b Tightening two clamps by a single handle

Equaliser This method of compensating variation in two workpiece pivots the clamp around a pin (Fig. 3.4). The equaliser clamp pivots to suit the variation in the workpieces. The equaliser principle can be extended to clamp more than two workpieces. Figure 3.5 shows an equaliser arrangement for clamping four workpieces simultaneously with a single clamp.

Naturally only an even number of workpieces can be clamped by an equaliser.

Stacking Often, workpieces can be stacked together and the entire stack can be secured by a single clamp (Fig. 3.32). Alternatively, workpiece can be sandwiched between locators, and the multilayered sandwich can be secured by a single clamp. In the string milling fixtures shown in Fig. 6.12, round workpieces are sandwiched between V locators. All the workpieces are clamped simultaneously by the hexagonal head bolt at one end of the fixture.

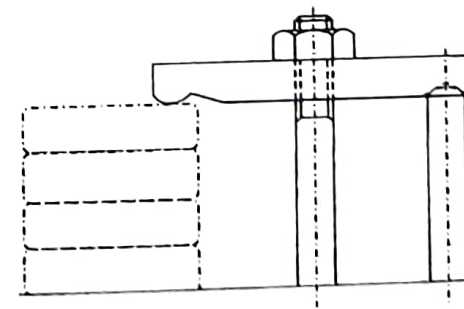


Fig. 3.32a Stack clamping

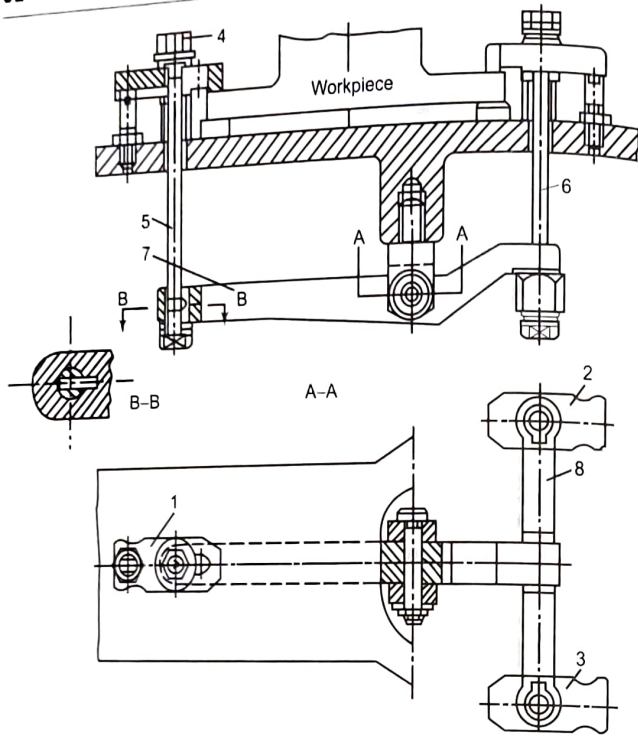


Fig. 3.32b Actuating three clamps by tightening a single handle

Power Clamping A number of clamps can be operated simultaneously by power clamping. Power clamping can be broadly divided into the following categories:

1. Fluid power clamping
 - (a) Pneumatic clamping
 - (b) Hydraulic clamping
2. Vacuum clamping
3. Magnetic clamping
4. Electrostatic clamping

1. Fluid Power Clamping Fluid power clamps are generally actuated by cylinders. Figure 3.33 shows a clamping fixture with the clamping nut attached to the cylinder ram. The feeding of pressurised fluid through the port pulls the ram downwards and presses the clamp against the workpiece. For unclamping, the port is connected to an unpressurised discharge line. The force of the spring under the clamp pushes the clamp and ram upwards. In

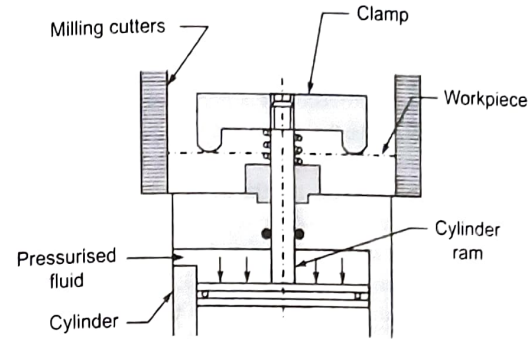


Fig. 3.33 Fluid power clamping

addition to unclamping the workpiece, the rising piston also drives the fluid out of the cylinder through the port.

For connecting the port alternately to pressure and discharge lines for clamping and unclamping, it is necessary to use a three-way direction control valve. Lever, pedal or electrical operation of the direction-control valve clamps or unclamps the workpiece.

The operation of a single-direction control valve can actuate a number of clamps through a number of cylinders. The valve simultaneously connects all the cylinders to pressure or discharge line. Figure 3.34 shows a fixture with four clamps and cylinders, which can be actuated by a single valve.

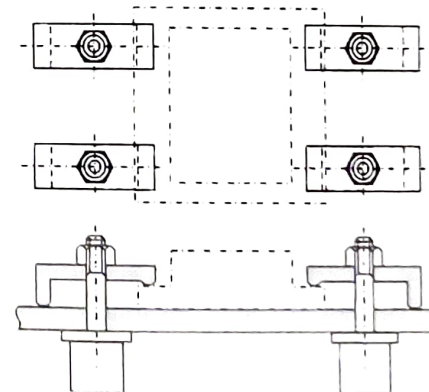


Fig. 3.34 Multiple clamping by fluid power

Moreover, the clamping pressures of all the clamps would be equal. The clamping pressure can be varied by regulating the pressure of the fluid.

Higher pressure can be used for heavy roughing cut. The pressure can be reduced considerably during light finishing cut.

There is a risk of sudden pressure drop in the event of a power failure. This can be countered by provision of a non-return valve in the pressure supply line. If the power fails, the non-return valve automatically closes the passage between the pressure line and the cylinder. This entraps pressurised fluid between the cylinder piston and the non-return valve. It prevents unclamping due to depressurisation of the supply source.

Some designers prefer to use positive rack and pinion nonreturn mechanism between the clamp and the cylinder (Fig. 3.35). The fluid power cylinder is used only to move the clamp into the position. The clamp would stay in position even if the cylinder is depressurised due to a power failure.

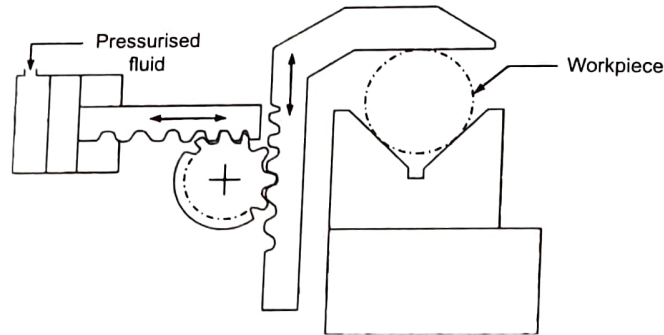


Fig. 3.35 Rack and pinion actuated fluid power clamping

Figure 3.36 shows a variety of cylinder mounting styles.

- a. **Pneumatic clamping** In pneumatic clamping compressed air is used as the fluid for power transmission and application. The air is pressurised to 5–6 atmospheres (5–6 kg/cm²) to energise it. Depressurised exhaust is discharged directly into the atmosphere through direction-control valve. Generally, a large centralised compressor supplies pressurised air to the entire shop—all the pneumatic drives and fixtures in the work place.

Although very rapid in operation, air-operated devices are vulnerable to variations in the load they move. If the load resistance increases, the speed of the pneumatic device drops and vice versa. Consequently, pneumatic devices are unsuitable for applications in which speed variations are unacceptable. Moreover, due to ageing, joints of old distribution pipes start leaking. This causes a drop in the pressure and wastage of energy. In humid climates, moisture in

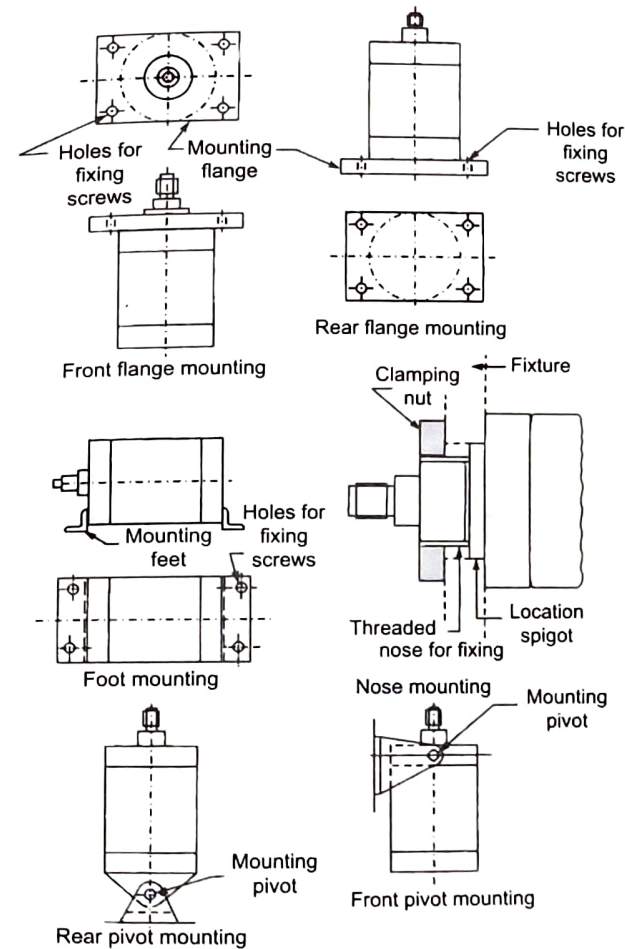


Fig. 3.36a Cylinder mounting styles

the air causes rusting of pneumatic cylinders and valves. This can be minimised by filtering out the moisture in the air before it enters the pneumatic fixture. It is necessary to use a lubricator also because it impregnates the air with oil mist, which is carried into the cylinders and valves to lubricate them. If it is necessary to vary the system pressure, a pressure regulator is also used.

- b. **Hydraulic clamping** Unlike air, hydraulic oils are almost incompressible. Consequently, variation in load does not cause much

speed variation in hydraulic systems. Speed variation can be minimised further to almost negligible by using pressure compensated flow control valve. The operating pressure of a hydraulic system ranges from 7 to 250 atmospheres. High pressure permits use of small compact cylinders to develop high force. However, hydraulic cylinders are slow in operation in comparison with pneumatic actuators. Oil is re-circulated in the system through a reservoir. Generally, every machine or fixture would have its own individual hydraulic reservoir and power unit. Large centralised power units are rarely used. The hydraulic operation of a mechanism generally requires substantial investment for hydraulic power pack and cylinders.

Hydraulic Power Multiplier Figure 3.36b shows a hydraulic power multiplier. The force (F_s) exerted by the screw '1' is enhanced manifold by using the device. The small ram with diameter ' d ' is pushed by the screw to develop hydraulic pressure in the oil in the big ' D ' diameter cylinder. This pushes the bigger ram to clamp workpiece, through a pin, with much more force ' F_w '.

$$F_w = F_s \times (D/d)$$

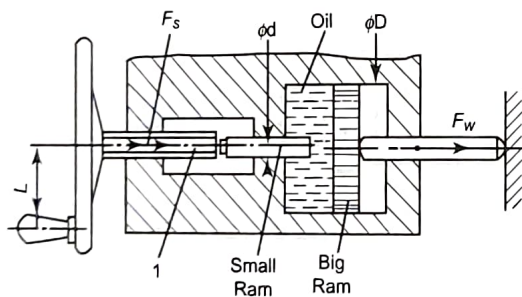


Fig. 3.36b Hydraulic force multiplier (intensifier)

This device does not require a costly power pack, but the small as well as the big ram must be provided with rubber seals to prevent oil leakage. The seals are not shown in the figure. Furthermore the multiplier body must be split into 2 or 3 parts to facilitate the manufacture as well as the assembly.

2. Vacuum clamping This is particularly 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 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/cm². Figure 3.37 shows a vacuum-holding fixture, distribution grooves and rubber seal.

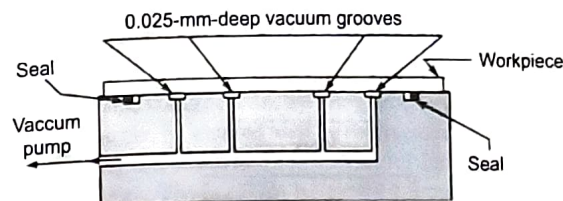


Fig. 3.37 Vacuum clamping

3. Magnetic Clamping Magnetic clamping force can be developed by permanent magnets or electromagnets.

- a. **Permanent magnets** They are mounted on a sliding member, which can be moved under a non-magnetic material on a table to block magnetic flux. This releases the workpiece. For clamping the workpiece, permanent magnets are moved under the magnetic part of the table. This allows the magnetic flux to pass through the workpiece and hold it magnetically. The permanent magnets are slid in the clamping and unclamping positions by a lever.

Generally, the magnetic table area is divided into alternative strips of magnetic and non-magnetic material. The non-magnetic strips block the path of a part of the magnetic flux and force the flux to pass through the workpiece to clamp it magnetically (Fig. 3.38). Thus, the non-magnetic strips act as flux dams or barriers. In permanent magnet tables, the magnets are slid below the non-magnetic strips to completely block the magnetic flux during unclamping.

- b. **Electromagnetic clamping** Electromagnetic tables use solenoid coils as temporary magnets. When DC current is passed through the solenoid coil, it acts like a magnet. The coils and the table is demagnetised on switching off the current and the workpiece is released. The magnetic clamping force can be varied by varying the current passing through the solenoid coil.

Magnetic clamping leaves some residual magnetism in the workpieces. This can be removed by demagnetising the workpiece.

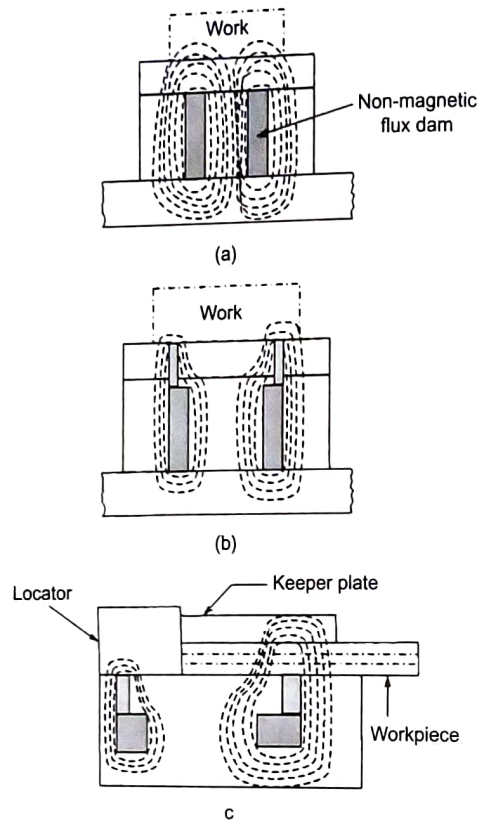


Fig. 3.38 Magnetic clamping

4. **Electrostatic clamping** In this method, the workpiece is charged with static electricity with polarity opposite to the polarity on the chuck face. The opposite attracting polarities of the workpiece and the chuck face develop the clamping force. The workpiece and the chuck are separated by insulating dielectric fluid. The clamping force can be varied by varying the static electrical charge. Even non-conducting materials can be coated with a thin metallic layer and secured by electrostatic clamping. The workpieces must be clean and dry for good electrostatic clamping.

Non-conventional Clamping

Adhesive Clamping Flat-surfaced workpieces subjected to light loads can be stuck to workholders by a thin film of compatible adhesive.

However, adhesives require some curing time for hardening. Furthermore, after completion of the operation, the workpiece has to be cleaned and the adhesive removed, which is a time-consuming operation. Consequently, adhesive clamping is used only when no other alternatives are available. Even then it can be used only for light loads.

Fusion clamping In this, the workpieces are jacketed by a cast of low melting point bismuth alloy, which is melted and poured around the workpiece. On cooling and solidification, the alloy secures the workpiece firmly. Complicated shape can be secured well by this method.

The alloy casting can be cut into two valves and machined to attach them to chuck or vice jaws. The jaws can be used for repeated clamping of the workpieces. Fusion clamping is, sometimes, the only method of clamping possible in odd-shaped difficult workpieces.



Compensating Differential Clamps

Differential clamps adjust their position themselves to suit the workpiece (Fig. 3.39). As a result, the clamps do not subject the workpiece to bending or any other distortion. They clamp the workpiece without shifting its position. The lever jaws are closed or opened by turning a screw which engages in *T* slot in the operating cam. The slot in the cam is much wider than the collar of the operating screw. This wide clearance allows the cam to slide towards any of the lever jaws. If jaw *A* touches the workpiece first the cam slides in the opposite direction towards jaw *B* till *B* also touches the workpiece. With both the jaws touching the workpiece, further tightening of the operating screw forces the jaws against the workpiece and clamps it firmly. Differential clamps are very convenient for securing a workpiece without shifting or distorting it.

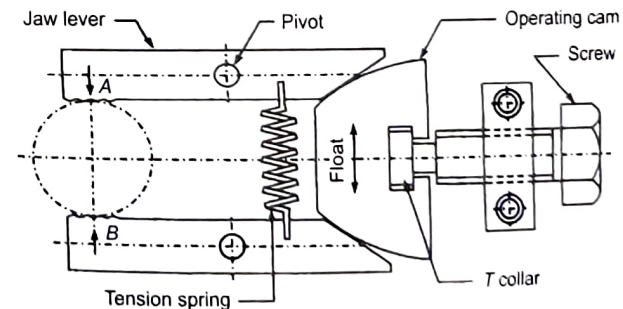


Fig. 3.39 Differential clamp

Figure 3.40 shows a gripper used for clamping parallel plates. The swivelling clamping pads position automatically to suit the object to be gripped as the clamping screw is turned.

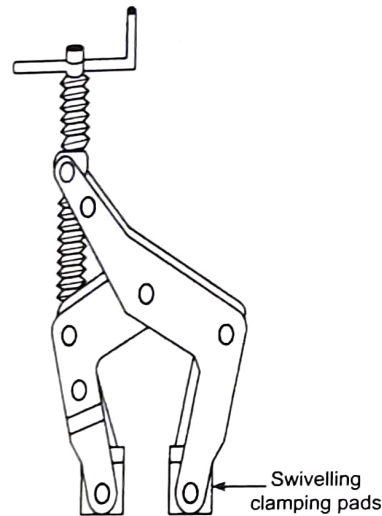


Fig. 3.40 Differential clamp



Summary

Principles of Clamping

1. Position clamp on a strong supported part of the workpiece, clear of the workpiece loading/unloading and cutting tool paths.
2. Clamp strength should be adequate to withstand operational forces without damaging the workpiece.
3. Quick operation without spanner (knobs, levers). Pneumatic/hydraulic operation for simultaneous actuation of numerous clamps.
4. Compensation for variation in the workpiece through radii at clamping point and on the heel pin, use of spherical washers and equalisers (in multiple clamping).

Clamps Types

1. Screw clamps with/without floating pad.
2. Plate clamps: slotted, swinging, edge clamps, pivoted two-way clamps, hinged clamps, hook clamps, latches, C washers.
3. Quick action clamps: Cam clamps, bayonet clamps, quarter-turn screw, toggle clamps.
4. Multiple clamping: double clamping, stacking workpieces, power clamping with pneumatic/hydraulic actuation, magnetic clamping.
5. Non-conventional clamping using adhesives, fusion.



Indexing Devices

Indexing is a process of quick, accurate location of a workpiece or fixture in a number of specific positions. Indexing involves periodic linear or rotary movement of the indexed part to the next position. An indexing plunger locates the indexed part precisely in each position.



Linear Indexing

When a number of holes with the same size and pitch are to be drilled in a workpiece (Fig. 4.1), the cost of the jig can be reduced greatly by resorting to linear indexing. Figure 4.2 depicts an indexing jig for a workpiece. The indexing pin is first inserted into hole *A* and used as a stopper for drilling the first hole through the drill bush. After drilling, the pin is removed from hole *A* and the workpiece is moved towards the right till the centre line of the drilled hole coincides with the centre line of bush *B*. The indexing pin is inserted into the drilled hole in the workpiece through bush *B*. The workpiece is, thus, indexed linearly to drill the next hole at 100 mm distance (pitch) from the hole drilled earlier. After drilling the second hole, the indexing pin is removed from the workpiece and the workpiece is moved further to the right till the hole drilled later coincides with the axis of the indexing pin

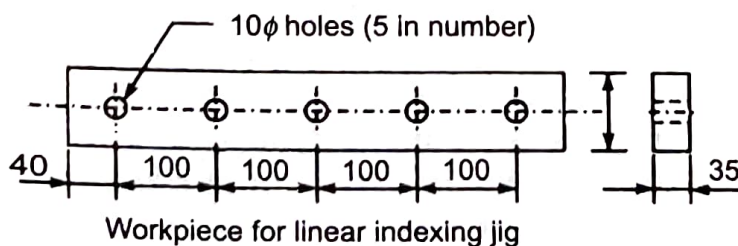


Fig. 4.1 Workpiece for linear indexing drill jig

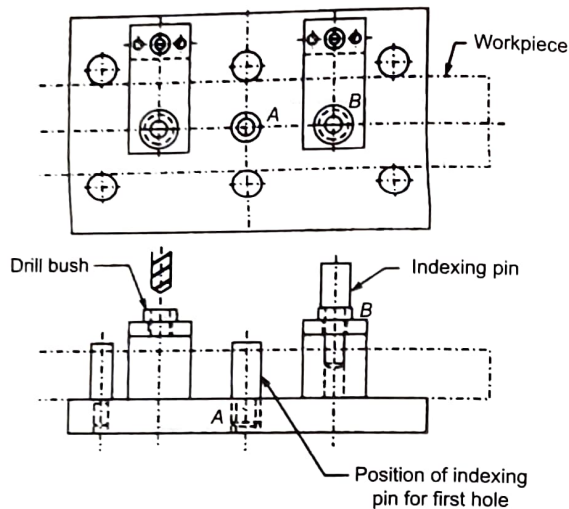


Fig. 4.2a Linear indexing drill jig

in bush *B*. The indexing pin is inserted through the workpiece drilled hole later to hold it in position for drilling the next hole. The procedure can be repeated to drill any number of holes at the given 100 mm pitch in similar workpieces. Thus, if there are 20 holes in the workpiece, we can eliminate 18 drill bushes by using linear indexing arrangement.



Precision Linear Indexing

A drilled hole usually measures within H11 tolerance range, more than H9 tolerance of a milled slot. For a 12 dia. hole the size will be $-0/+0.11$ mm. One can not locate precisely from such a widely varying hole. Even if we make the indexing pin a very close fit ($g6: -0.006/-0.02$), there can still be variation of 0.13 in the centre distance of the drilled holes. Generally, clear $(+0.5)$ holes for fixing screws can easily accommodate this variation till the wear of the drill guiding bush reaches 0.22 ($0.5 - 0.13 - 0.15$). After that the bush must be replaced. Otherwise the excessive wandering of the drill in the worn bore will create misalignment problems in assembly.

For precise linear pitch, say $+0$ or -0.025 mm, it is necessary to provide an indexing surface which is more precise than H11—say H7. Accurate location hole facilitates precise linear motion thru accurate indexing. A 12 dia. H7/g6 combination will confine the indexing error to 0.04 ($0.02 + 0.02$) only 1/3 of the error in H11/g6 fit.

For accurate linear indexing, we have to provide an indexing plate which is firmly attached to the workpiece to be drilled, and moves along with the workpiece during indexing. Figure 4.2b shows a workpiece, and Fig. 4.2c shows the indexing plate clamped to it by two swinging clamps. There are location pins for locating the channel at the ends. Note the uni-directional dimension system (Fig. 4.2b). The maximum centre distance 920 has the same tolerance (± 0.15) as the minimum C. D. 40. There should not be any cumulative error.

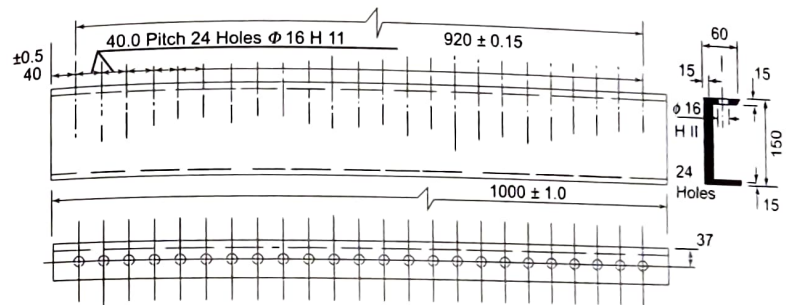


Fig. 4.2b Spindle frame (workpiece) for indexing plate (Fig. 4.2c) and drill jig in Fig. 4.2d

More number of holes (24) causes more wear. The bore of the drill guide bush must be checked more often, say every alternate day, by providing a plug gauge if necessary. The renewable type design allows quick replacement of worn bush—without removing the drill jig from the drilling m/c table.

Figure 4.2d shows the complete drill jig. Two pads locate the workpiece channel: one for resting, and another for centre distance (37) from the channel base. The indexing pin is housed in the angle plate of the jig body. The tapered pin engages with the tapered holes in the bushes in the indexing plate (Sect. A–A in Fig. 4.2d) to ensure precise linear indexing of the workpiece even after wear of the tapered locating surfaces. A spring ensures positive engagement of the indexing pin.

After drilling a hole the workpiece is unclamped slightly to permit moving (indexing) it for drilling the next hole. The indexing handle is pulled to compress the spring to allow withdrawal of the indexing pin from the tapered mating hole. The workpiece is moved forward for indexing. After the indexing pin crosses the tapered hole the indexing handle can be released. When the pin reaches the next tapered hole, the spring force will automatically push the pin into the mating hole.

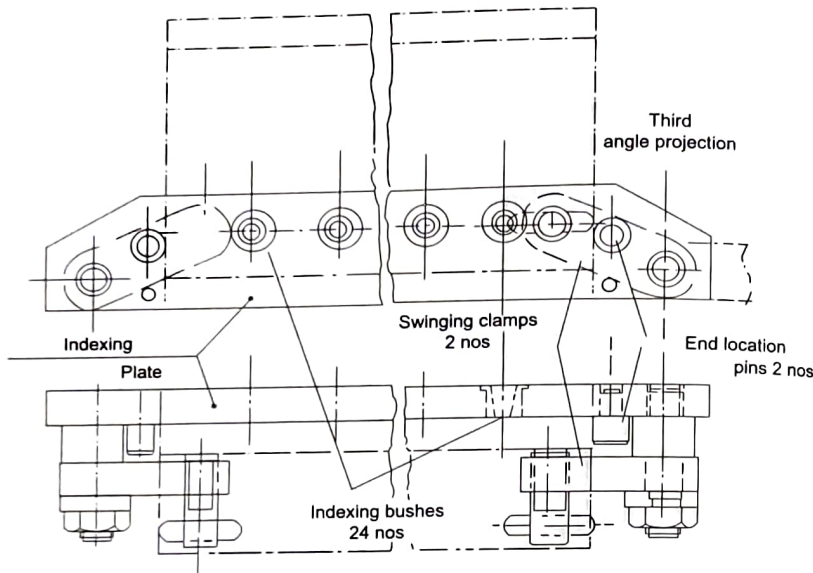


Fig. 4.2c Indexing plate for workpiece in Fig. 4.2b

The workpiece weighs more than 25 kg. The left and right side of the jig are fitted with angle iron fabricated frames mounted with ball bearings which serve as wheels (Fig. 4.2d plan). These reduce the fatigue resulting from moving the heavy workpiece. The left hand supporting structure must be a little longer than a metre, so that it can be used as a rest while clamping the indexing plate to the workpiece. The right hand support need not be longer than 550 mm.

A similar arrangement can be used for milling slots with equal size and pitch in a workpiece as shown in Fig. 4.3. In both instances, the indexing plunger is located on the previously machined part of the workpiece. The part must be unclamped for indexing and reclamped before the operation commences.



Rotary Indexing

Rotary indexing facilitates accurate positioning of a part around its axis. It can be used conveniently for drilling equi-spaced holes in round workpieces (Fig. 4.4a).

After drilling the first hole through bush A, the workpiece is unclamped and rotated clockwise to align the drilled hole with the axis of the indexing pin. The indexing pin is inserted in the drilled hole to index the workpiece

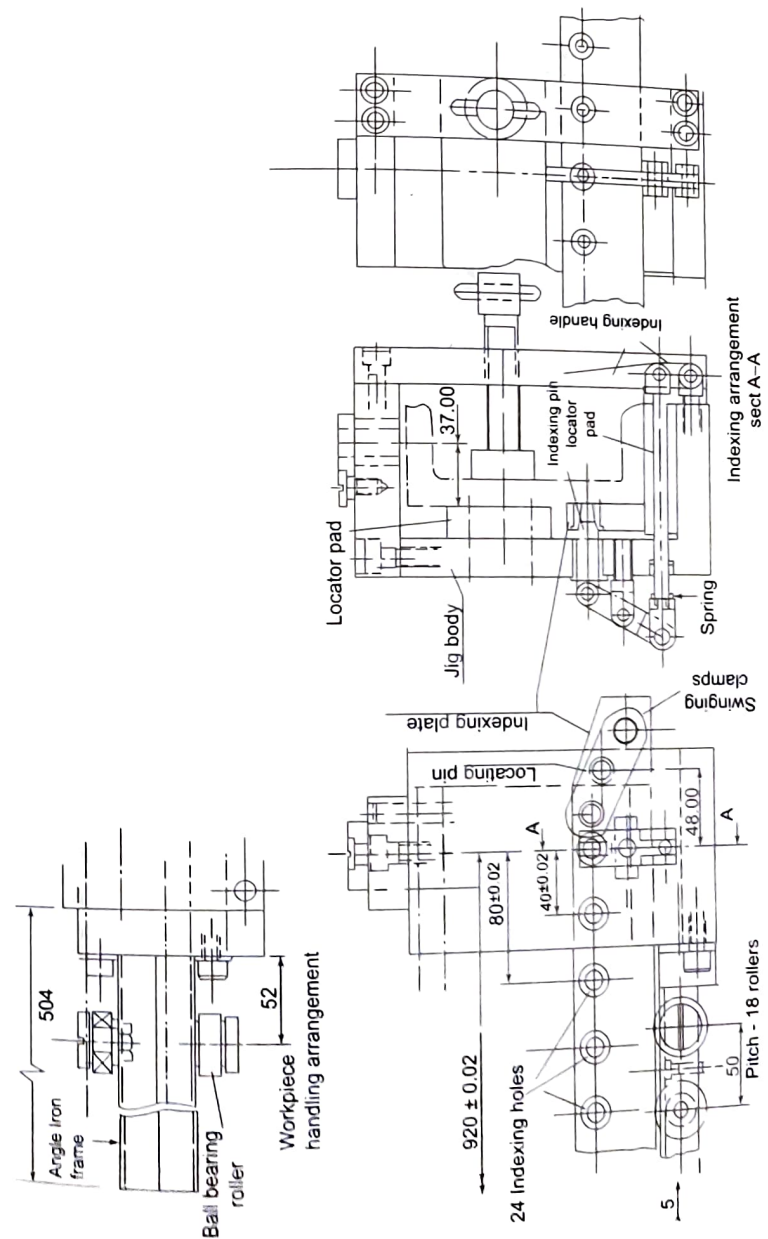


Fig. 4.2d Drill jig for workpiece in Fig. 4.2b

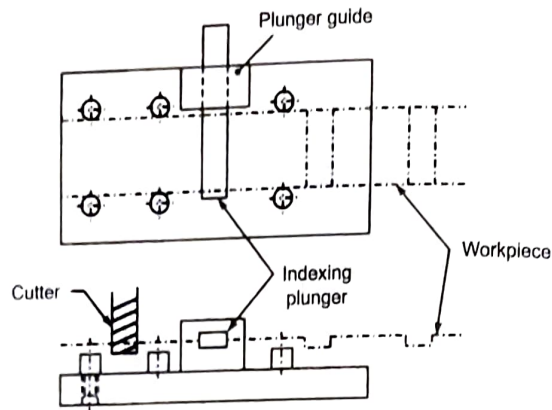


Fig. 4.3 Linear indexing milling fixture

for drilling the next hole. The workpiece is clamped again before drilling the next hole. Thus, rotary indexing can be used to drill any number of equispaced holes with only two guides bushes.

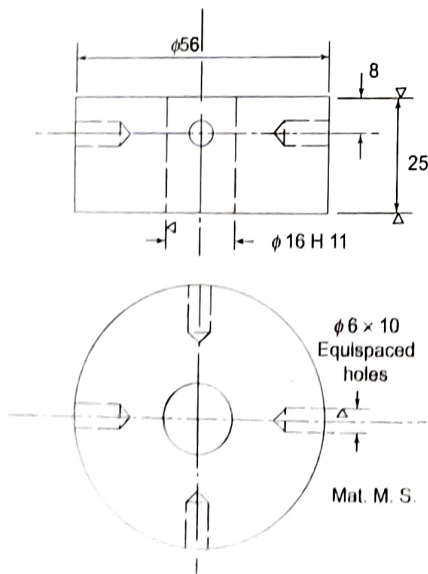


Fig. 4.4a Workpiece for rotary indexing jig in Fig 4.4b

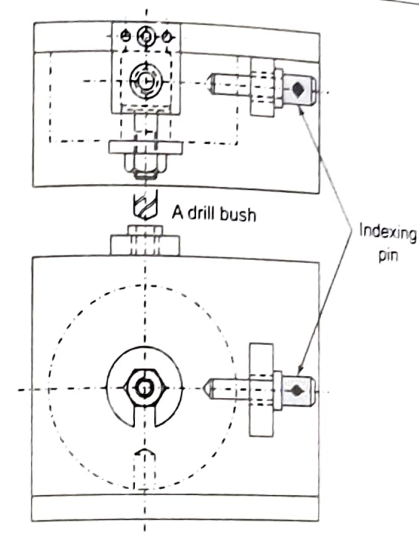


Fig. 4.4b Rotary indexing drill jig

Indexing Plate

For more precise indexing, the workpiece is located and clamped on an accurate indexing plate which moves along with the workpiece (Fig. 4.5). The indexing plate is provided with hardened bushes or slots to minimise wear caused by repeated operation of indexing arrangement in mass manufacture.

The indexing plate can be rotated about the central pivot and clamped in position with a hand knob. The pivoted indexing lever engages in accurately machined slots of hardened indexing plate to position the workpiece precisely.

The slots can be tapered (Fig. 4.6) to prevent inaccuracies resulting from wear. Similarly, a round bush and indexing pin can be tapered to counter the effect of wear (Fig. 4.6).

Instead of an indexing pin and bush, we can use a ball and conical dimple arrangement for indexing (Fig. 4.7). The ball is pushed against the conical dimple by a spring. When the indexing plate is rotated with some force, the ball is pressed downwards against the spring and remains there till its centre aligns with the next conical dimple in the indexing plate. As soon as the dimple aligns with the ball, the spring pushes the ball into the dimple and the indexing plate is indexed. For indexing the next position, the indexing plate must again be rotated with some force to drive the ball out of the

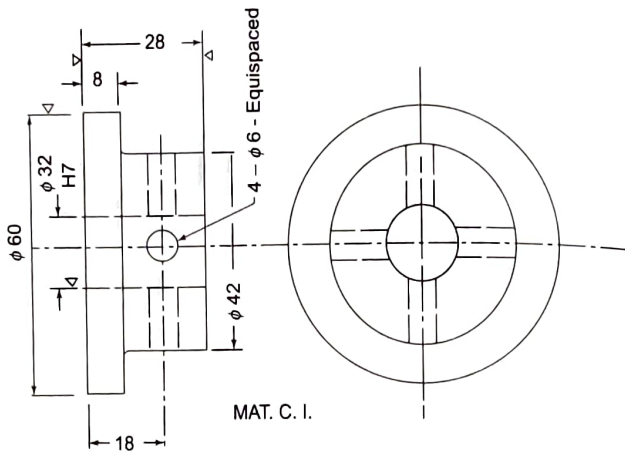


Fig. 4.5a Workpiece for jig in Fig 4.5b

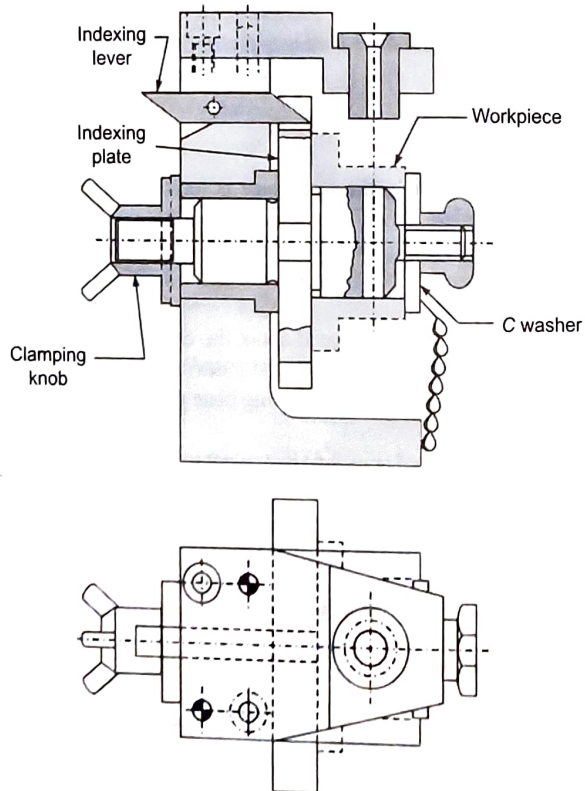


Fig. 4.5b Drill jig with indexing plate

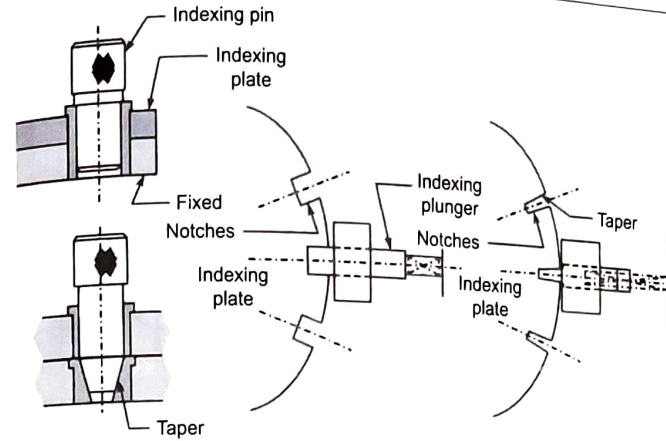


Fig. 4.6 Indexing plungers

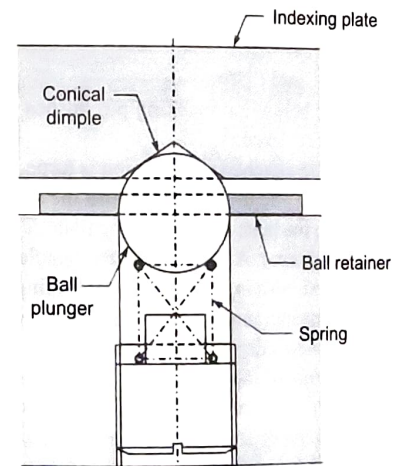


Fig. 4.7 Indexing by a ball

dimple against the spring. After indexing, the indexing plate must be clamped in position for the operation. It must be unclamped during indexing.

Rotary Indexing Tables

In rotary tables rack and pinion are often used for withdrawal of the indexing pin (Fig. 4.8). A pinion engages with the gear teeth of a rack in the

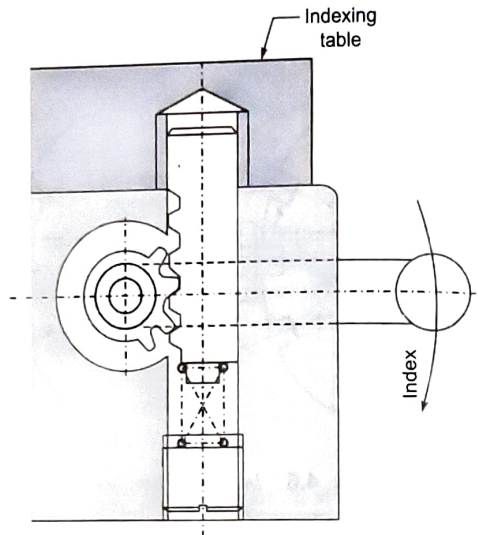


Fig. 4.8 Indexing in rotary tables

indexing pin. The spring below the indexing pin pushes the indexing pin into the bush in the indexing plate.

For indexing, the handle attached to the pinion is turned clockwise. This rotates the pinion clockwise and the gear teeth push the indexing pin downwards to withdraw it from the bush in the indexing plate. The indexing table can now be rotated for indexing. After rotation, the handle can be released. When the centre to the next bush in the indexing table aligns with the centre of the indexing pin, the spring automatically pushes the indexing pin into the bush and the table is indexed.

Figure 4.9 shows a standard indexing table with 12 indexing positions. Figure 4.10 shows another standard indexing (dividing) fixture with a built-in-collet clamping arrangement for round parts. This fixture can be used conveniently for milling flats, squares and hexagons on round workpiece of various sizes. For different diameters of round workpieces, different collets are required. If the collet clamping arrangement is replaced by a self-centring chuck (Chapter 7), it can clamp a wide range of round workpieces eliminating the need for a number of collets of different diameters.

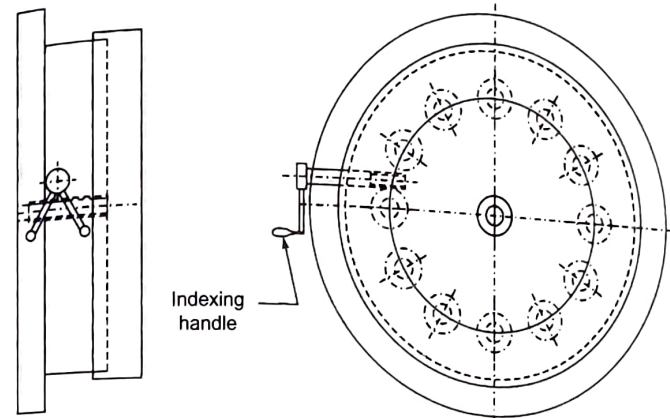


Fig. 4.9 Standard indexing table

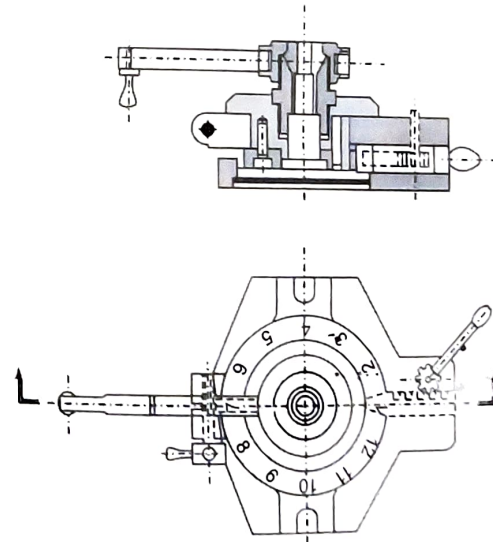


Fig. 4.10 Standard dividing fixture

Inspection Devices

Along with the manufacturing, the inspection of the components must also be speeded up in the mass production. The skills required for inspection must be reduced to lower the labour costs. This is achieved by replacing standard measuring instruments such as the vernier and micrometer by gauges. The gauges do not measure the actual size of the manufactured component but merely check if the dimensions of the component fall within the high and low limits specified on the drawing. They ensure the desired fit in assembly.



Standard Gauges

Cylindrical holes can be inspected by simple plug gauges (Fig. 12.1). A plug gauge consists of two hardened plugs with a connecting handle. The longer *go* plug is passed through the hole to ensure that the hole size is bigger than the low (minimum) limit. The shorter *not go* plug should not pass through the hole, if it is lesser than the high (maximum) limit specified on

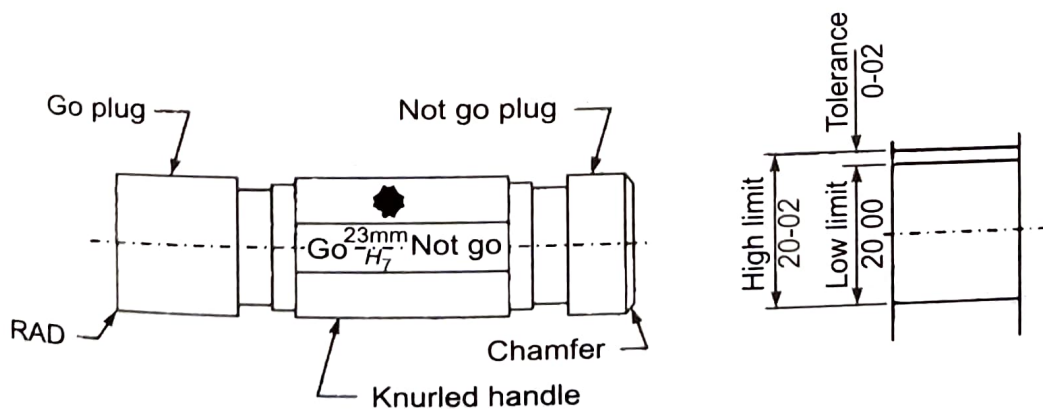


Fig. 12.1 Plug gauge

the drawing. Thus, an unskilled inspector can pass the component merely by checking that the *go* plug enters the component and the *not go* plug does not.

Similarly, outside diameters can be inspected by caliper or snap gauges. (Fig. 12.2). Length gauges are also used in a similar manner. For the male parts in all the gauges, *go* gap through which the component must pass would be bigger than the *not go* gap into which the component should not enter.

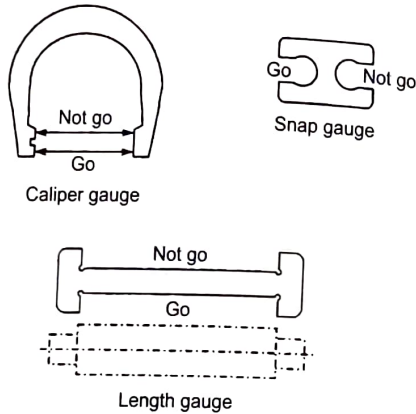


Fig. 12.2 Caliper gauges

Plug gauges and outside diameter gauges (caliper and snap gauges) have been standardised by the Indian Standards Institution and are readily available in the market. Length gauges must, however, be manufactured to suit the components.

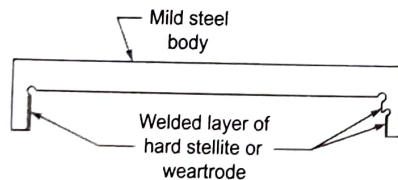


Fig. 12.3 Large caliper gauges

Special Gauges

Slots, gaps and key-ways are checked by gauges which function like plug gauges. They are made from plates and are rectangular in section (Fig. 12.4).

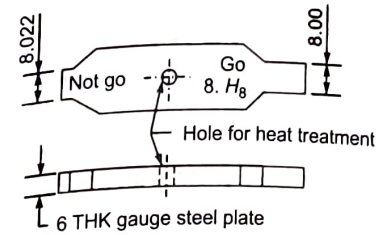


Fig. 12.4 Key-way and slot checking gauge

Tapered holes are inspected for the diameter of the bigger end by a tapered plug with a step at big end. The lower face of the step corresponds to the low limit of the hole size and the upper face with the higher limit. If the face of the workpiece falls within the upper and lower faces of the step, the workpiece is within the limits (Fig. 12.5). The inspection is carried out by seeing or by the feel of the finger.

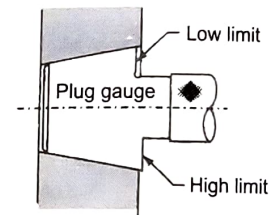


Fig. 12.5 Flush surface gauge for tapered hole

A similar method is used for checking distances between parallel faces of the workpieces. Figure 12.6 shows a flush surface gauge for checking the shoulder to end face length of the pin. If the length is within the limits, the small end of the pin falls between the two limiting faces of the gauge. Flush surfaces are sometimes built in a pin. Then, the gauge is called a flush pin gauge (See Fig. 12.7). Flush pin gauges can be used conveniently for inspection of the distance between two conical bores.

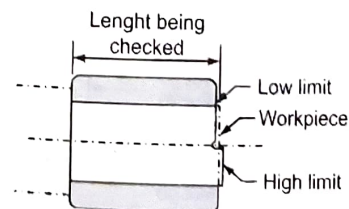


Fig. 12.6 Flush surface length gauge

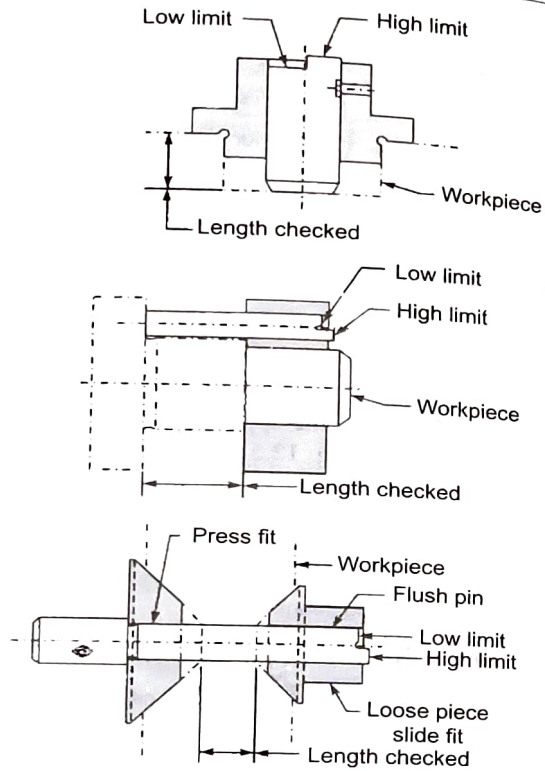


Fig. 12.7 Flush pin gauges

The centre distance between two cylindrical holes can be inspected with a snap gauge (Fig. 12.8). The holes should be first inspected individually for

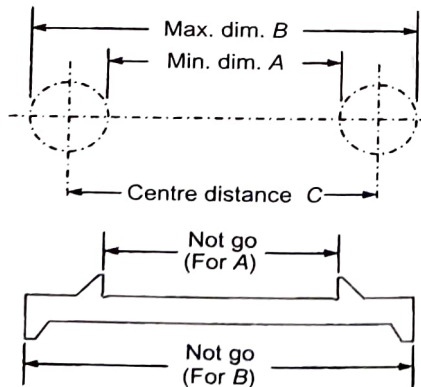


Fig. 12.8 Snap gauge for checking centre distance

accuracy of the diameters before the centre distance is checked. In this type of centre distance gauge, there is no go. Instead, there are two not gos. One inspects dim. A for the minimum centre distance limit and the other dim. B for the maximum centre distance. If none of the not go enter the workpiece, the centre distance is within the limits specified on the drawing.

Receiver Gauges

The centre distance as well as the diameters of the holes can be inspected at one go by using a receiver gauge. These are used for checking the suitability of the workpiece for assembly with other mating parts. If a receiver gauge accepts a workpiece, it can be assembled easily in the final product. A receiver gauge does not measure the extent of inaccuracies in the workpiece. The gauge just checks the possibility of easy assembly.

Figure 12.9a shows a receiver gauge for a gear box cover. Centre distance C between the shafts A and B is exactly equal to the centre distance of the

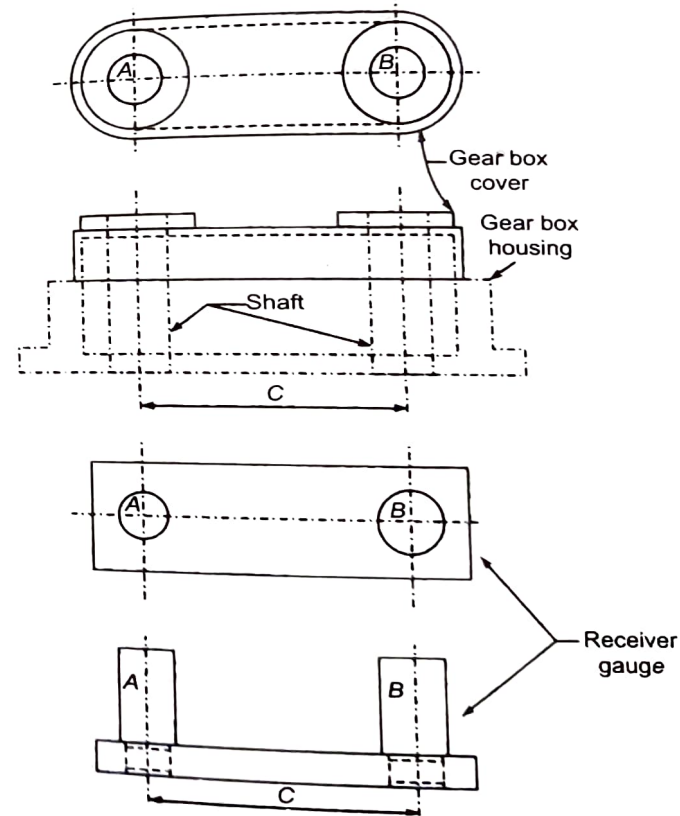


Fig. 12.9a Receiver gauge for gear box cover

shaft holes in the corresponding gear box housing. The diameters of the posts *A* and *B* are manufactured to the maximum limit of the shafts mating with the holes in the gear box cover. Thus, the receiver gauge is a plate fitted with two plugs *A* and *B*. If the gear box cover to be checked enters both plugs *A* and *B* we can be sure that the hole sizes as well as the centre distance between the shafts and gear box housing. If the receiver gauge does not accept the work-piece, it cannot be assembled with the corresponding mating parts.

Checking keyway centrality of shafts and hubs

Checking centrality of a keyway *precisely* is rather tricky. According to the prevailing practice, the shaft is kept on 'V' blocks and rotated slowly, inched, to make the keyway horizontal. This is checked by a dial gauge. But the keyway depth is usually very small: only 3–4 mm only for a 8 wide X7 deep key. So small a face, even after truing by a dial gauge, cannot be considered precisely horizontal.

After making the face horizontal the centrality is checked by measuring the distance from the keyway face and the external diameter of the shaft, on the both sides (Fig. 12.9b). The difference between the readings on both the sides gives the error in the centrality of the keyway.

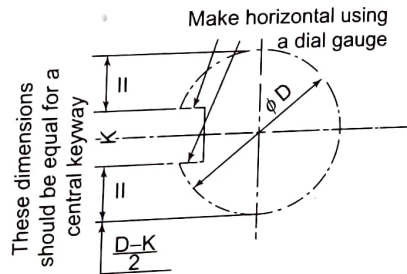


Fig. 12.9b Checking centrality of a keyway in a shaft

Figure 12.9c shows keyway dimensions for a 24 diameter shaft and the keyway centrality checking gauge. The segmental construction facilitates the precise machining and accurate measurement. The two halves (1A and B) can be held together face to face—their radii aligned—to grind the seating surface for the key (2) and the segments alignment—to grind the seating surface ground after screwing the two halves together, along with the aligning key (3). The edges of the segments are ground parallel to the keyway faces. They provide a resting face during finishing of the keyway face and measuring the dimension 8.00 between the keyway face and the 24 G6 diameter: the distances shown by equal marks in Fig. 12.9b. Such faces machined to

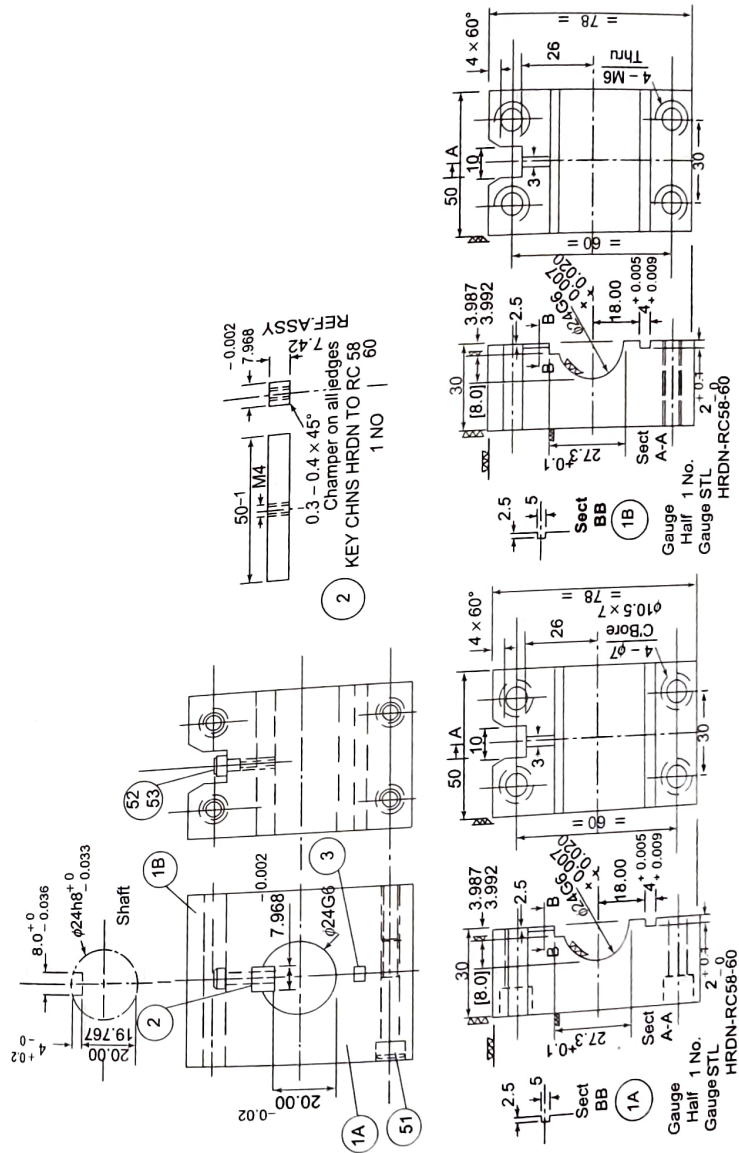


Fig. 12.9c Receiver gauge for keyway centrality [shaft]

facilitate accurate machining and measurement are called **Tooling face**. The 78 long tooling face allows more precise truing for horizontality than much smaller (3.3 long) face of the keyway. Consequently, the gauge is a better and faster method of checking centrality of the keyway.

A receiver gauge should admit the biggest size of shaft; hence the 24 G6 tolerance. The keyway size, on the other hand should suit the minimum size of the keyway: $24.00 - 0.036 = 23.964$. Furthermore, the key insert should have a wear allowance: 10% of the workpiece tolerance of 0.036. Even this should have a manufacturing tolerance of 0.002; hence the size $7.968 - 0.002$. Like all new gauges, this one too will not pass the workpieces within the tolerance but differing very, very marginally from the minimum size (range 23.968–23.964) due to the wear allowance.

Fig. 12.9d shows a gauge for checking the centrality of a keyway in a hub. The plug mounted with the key is made suitable for the minimum bore of the hub: $24.00 - 0.004 = 23.996$. The key insert is made suitable for the minimum ($8.00 - 0.018 = 7.982$) keyway size, with the added wear allowance of 0.004 and manufacturing tolerance of 0.002. Keeping the gauge body square, with two edges parallel with the keyway depth face, facilitates accurate manufacture and measurement of the keyway faces from the 23.996 diameter. Due to the wear allowance, the gauge will not pass the keyways in the width range $7.982 - 7.986$, despite being within the workpiece tolerance range.

Receiver gauges can be used conveniently to simultaneously check a number of dimensions in a workpiece in a single handling. A multi-dimensional receiver gauge holds a number of locators which engage simultaneously with the workpiece to check its suitability for assembly.

Figure 12.10 shows an inspection device for checking the various dimensions of a workpiece. The workpiece is inserted into the flush surface gauge and a plug is inserted into the gauge and workpiece cross hole C. If these three can be assembled together we can be sure that:

1. Workpiece diameter d is less than the high limit;
2. Cross hole diameter C is more than the low limit, the plug acts as a go gauge; and
3. Cross hole C is at the centre of diameter d within the given centrality limits and the mating parts in the crosshole can be assembled without any trouble.

Thus, the flush surface gauge and the plug together act as a receiver gauge.

After the plug, flush surface gauge and the workpiece have been assembled together, the distances of cross-hole C from collar (l_1) and end face of the small diameter (l_2) can be checked. The end face of diameter d should be within two flush steps of the gauge. The distance of crosshole C from collar (l_1) can be checked by checking the gap between the collar and the unstepped face of the flush surface gauge with go, not go snap gauges. During this inspection, the assembly serves as an inspection fixture.

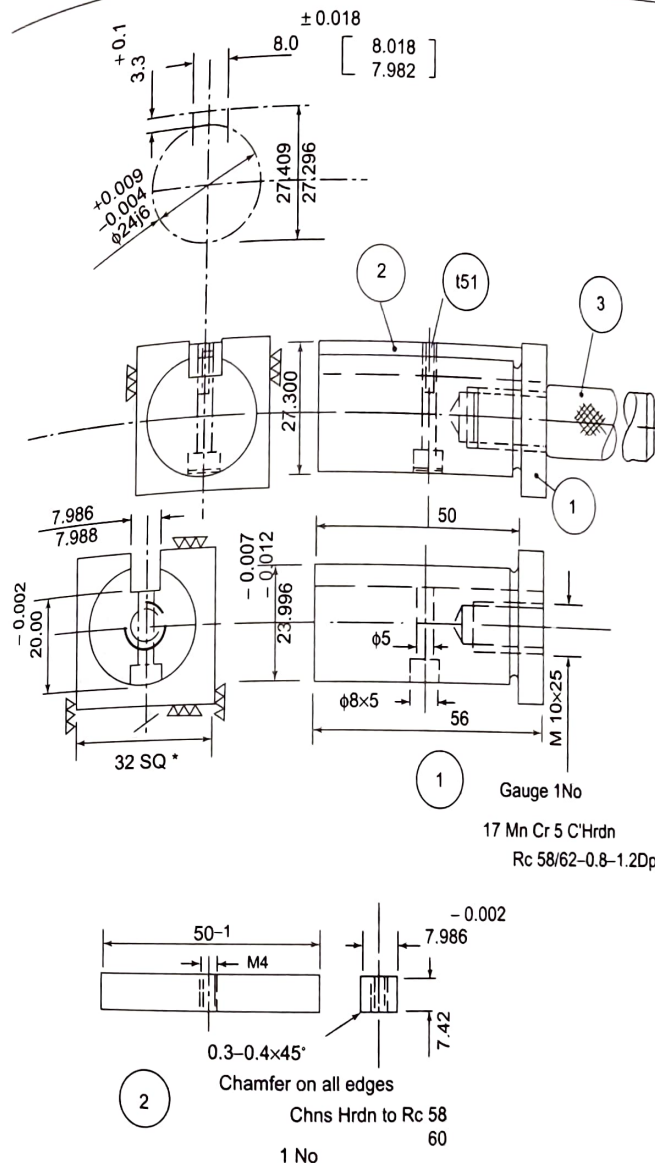


Fig. 12.9d Receiver Gauge for keyway centrality in hub

Inspection fixtures often have workpiece holding and moving arrangement for convenience. Figure 12.11 shows an inspection fixture for checking the concentricity of the angular seat of the valve with respect to its stem. The stem is guided in a hardened bush, and there is an arrangement for

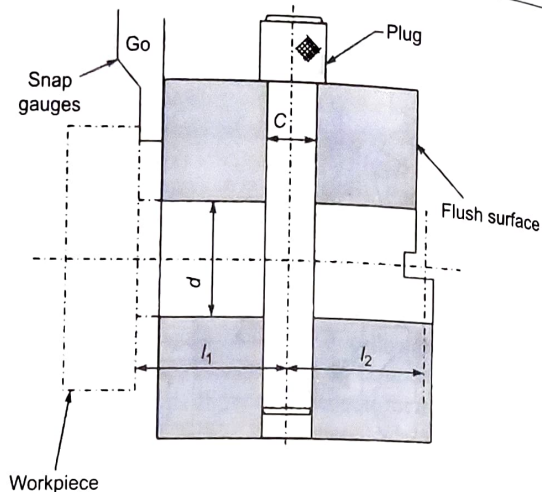


Fig. 12.10 Inspection device for checking four sizes

mounting a dial gauge in the suitable position. The valve has to be simply loaded in the guide bush and rotated around the stem axis to measure the concentricity of the angular seat with the dial gauge. Thus, the inspection fixture simplifies and speeds up the inspection of the valve.



Workpiece Marking and Setting Gauges

Machining allowances on castings and forgings often vary considerably. Consequently, the amount of material to be machined away must be varied in such a manner that the holes in the workpiece would be at the centres of the

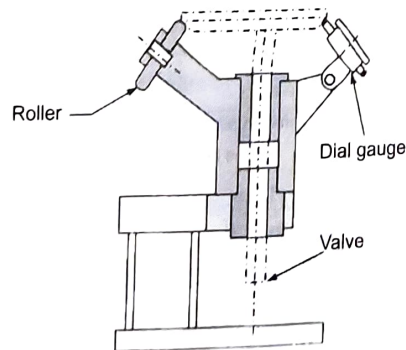


Fig. 12.11 Valve concentricity inspection fixture

corresponding bosses. So, we have to locate on the bosses while machining reference faces, which would later be used as locations while making holes in the bosses. This can be done by using marking and setting gauges.

Figure 12.12 shows a marking gauge for a casting with two bosses *P* and *Q*. The casting is levelled with wedges and its height is adjusted in such a way that the pointers for bosses *P* and *Q* top and bottom are more or less symmetrical with respect to the bosses. The casting can be marked in this position by two markers for the top and bottom faces to be machined. The marking can be used for levelling the workpiece during machining operation. Furthermore, if there is insufficient machining allowance on either of the faces, the fact would be discovered before commencing costly machining operation, which might turn out to be wasteful at a later stage when the workpiece is rejected due to insufficient machining allowance.

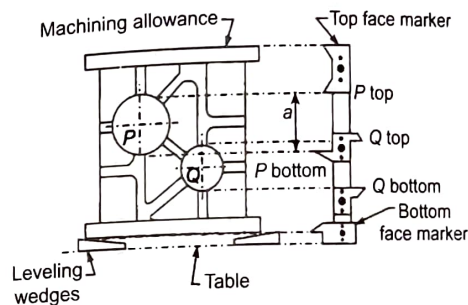


Fig. 12.12 Marking gauge for casting

Figure 12.13 shows a setting gauge for the workpiece shown in the figure. The fixture has got two location pins *A*, which can be engaged with guide bushes *B* in the loose setting gauge. The gauge has four small circular discs which serve as templates for positioning the workpiece in the fixture. After engaging pins *A* in bushes *B* of the setting gauge, the workpiece is moved in the fixture to align the workpiece bosses with the circular disc templates on the gauge. After alignment, the workpiece is clamped in position in the fixture by four hexagonal headed bolts.

The gauge can then be removed and the end face of the workpiece can be machined. The loose setting gauge is used mainly to position (locate) the workpiece correctly in the fixture.



Materials and Wear Allowance

Since gauges might be used hundreds of times in every shift, they are subjected to abrasion and wear. This is countered by hardening the working surfaces of gauges to 60–65 HRC. Over and above this, plug gauges are

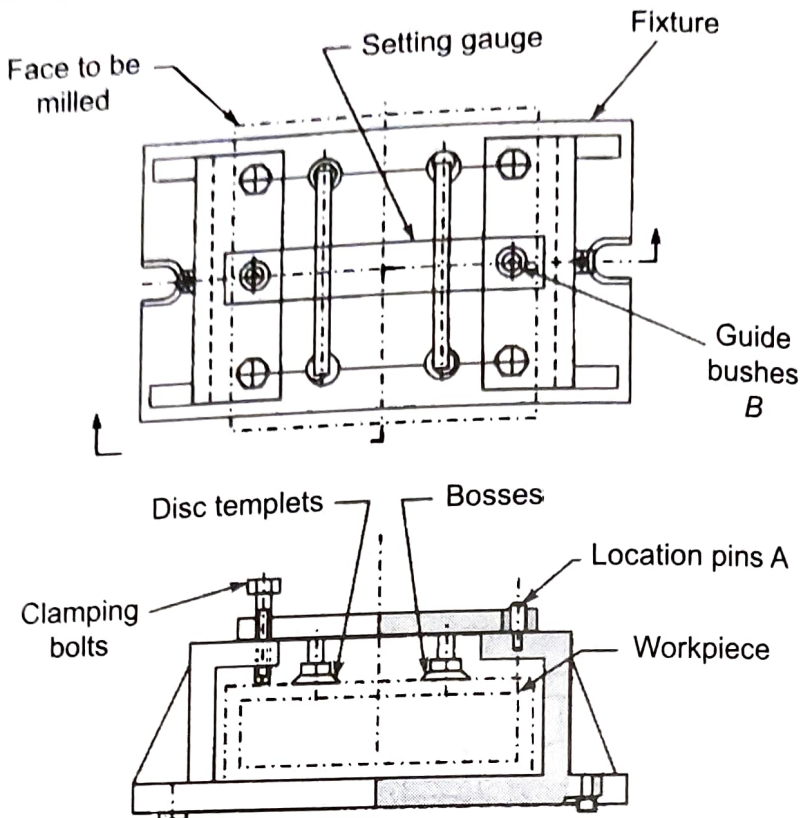


Fig. 12.13 *Setting gauge for casting*

made slightly oversized and gauges for male parts are made slightly undersize to provide wear allowance. The allowance is generally 10% of the tolerance on the component. For example, a 70 mm ϕ H7 hole has got a tolerance of + 0.03 mm. So, the go size plug would have wear allowance of 0.003 mm. The plug diameter would be 20.003 mm when new, so that it can be used till the gauge wears by 0.003 mm.

The steel used for gauges should be suitable for hardening to 60–65 HRC. Moreover, it should have low coefficient of thermal expansion so that the gauge size does not change much due to climatic temperature variations. Many types of commercial gauge steel are readily available in the market. Most of them contain about 1% carbon.

For economy in material as well as hardening costs, gauges are designed such that only the parts subjected to wear are made of hardened steel. Handles and unimportant constituents are made of cheaper mild steel. In bigger gauges, the entire body is made of mild steel and only the surfaces subjected to wear are deposited with a welded layer of hard material such as stellite or weartride (Fig. 12.3).

Gauges are often handled a large number times in every shift. Consequently, they should be made as light in weight as possible to reduce handling fatigue.