ME 2029 DESIGN OF JIGS AND FIXTURES NOTES
UNIT I

LOCATING AND CLAMPING PRINCIPLES

Locating and clamping are the critical functions of any work holder. As such, the fundamental principles of locating and clamping, as well as the numerous standard components available for these operations, must be thoroughly understood.

BASIC PRINCIPLES OF LOCATING

To perform properly, workholders must accurately and consistently position the workpiece relative to the cutting tool, part after part. To accomplish this, the locators must ensure that the workpiece is properly referenced and the process is repeatable.

Referencing and Repeatability

"Referencing" is a dual process of positioning the workpiece relative to the workholder, and the workholder relative to the cutting tool. Referencing the workholder to the cutting tool is performed by the guiding or setting devices. With drill jigs, referencing is accomplished using drill bushings. With fixtures, referencing is accomplished using fixture keys, feeler gages, and/or probes. Referencing the workpiece to the workholder, on the other hand, is done with locators.

If a part is incorrectly placed in a workholder, proper location of the workpiece is not achieved and the part will be machined incorrectly. Likewise, if a cutter is improperly positioned relative to the fixture, the machined detail is also improperly located. So, in the design of a workholder, referencing of both the workpiece and the cutter must be considered and simultaneously maintained.

"Repeatability" is the ability of the workholder to consistently produce parts within tolerance limits, and is directly related to the referencing capability of the tool. The location of the workpiece relative to the tool and of the tool to the cutter must be consistent. If the jig or fixture is to maintain desired repeatability, the workholder must be designed to accommodate the workpiece's locating surfaces.

The ideal locating point on a workpiece is a machined surface. Machined surfaces permit location from a consistent reference point. Cast, forged, sheared, or sawed surfaces can vary greatly from part to part, and will affect the accuracy of the location.

The Mechanics of Locating

A workpiece free in space can move in an infinite number of directions. For analysis, this motion can be broken down into twelve directional movements, or "degrees of freedom." All twelve degrees of freedom must be restricted to ensure proper referencing of a workpiece.

As shown in Figure 3-1, the twelve degrees of freedom all relate to the central axes of the workpiece. Notice the six axial degrees of freedom and six radial degrees of freedom. The axial degrees of freedom permit straight-line movement in both directions along the three principal axes, shown as x, y, and z. The radial degrees of freedom permit rotational movement, in both clockwise and counterclockwise radial directions, around the same three axes.

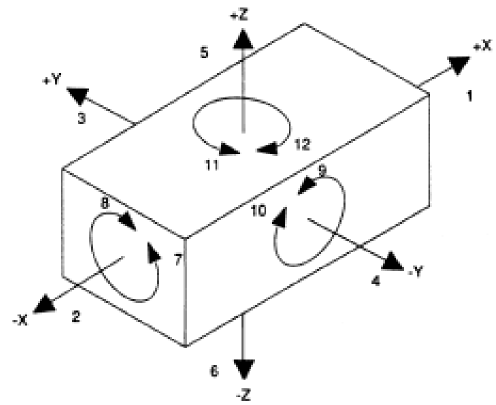


Figure 3-1. The twelve degrees of freedom.

The devices that restrict a workpiece's movement are the locators. The locators, therefore, must be strong enough to maintain the position of the workpiece and to resist the cutting forces. This fact also points out a crucial element in workholder design: locators, not clamps, must hold the workpiece against the cutting forces.

Locators provide a positive stop for the workpiece. Placed against the stop, the workpiece cannot move. Clamps, on the other hand, rely only upon friction between the clamp and the clamped surface to hold the workpiece. Sufficient force could move the workpiece. Clamps are only intended to hold the workpiece against the locators.

Forms of Location

There are three general forms of location: plane, concentric, and radial. Plane locators locate a workpiece from any surface. The surface may be flat, curved, or have an irregular contour. In most applications, plane-locating devices locate a part by its external surfaces, Figure 3-2a. Concentric locators, for the most part, locate a workpiece from a central axis. This axis may or may not be in the center of the workpiece. The most-common type of concentric location is a locating pin placed in a hole. Some workpieces, however, might have a cylindrical projection that requires a locating hole in the fixture, as shown in Figure 3-2b. The third type of location is radial. Radial locators restrict the movement of a workpiece around a concentric locator, Figure 3-2c. In many cases, locating is performed by a combination of the three locational methods.

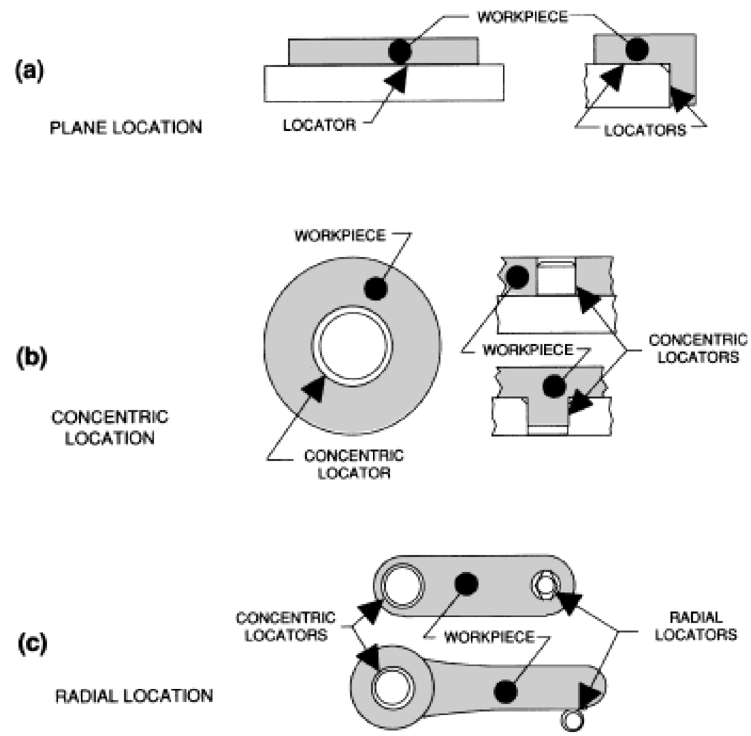


Figure 3-2. The three forms of location: plane, concentric, and radial.

Locating from External Surfaces

Flat surfaces are common workpiece features used for location. Locating from a flat surface is a form of plane location. Supports are the principal devices used for this location. The three major forms of supports are solid, adjustable, and equalizing, Figure 3-3.

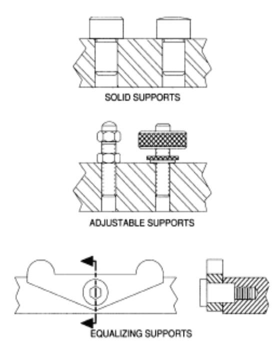


Figure 3-3. Solid, adjustable, and equalizing supports locate a workpiece from a flat surface.

Solid supports are fixed-height locators. They precisely locate a surface in one axis. Though solid supports may be machined directly into a tool body, a more-economical method is using installed supports, such as rest buttons.

Adjustable supports are variable-height locators. Like solid supports, they will also precisely locate a surface in one axis. These supports are used where workpiece variations require adjustable support to suit different heights. These supports are used mainly for cast or forged workpieces that have uneven or irregular mounting surfaces.

Equalizing supports are a form of adjustable support used when a compensating support is required. Although these supports can be fixed in position, in most cases equalizing supports float to accommodate workpiece variations. As one side of the equalizing support is depressed, the other side raises the same amount to maintain part contact. In most cases adjustable and equalizing supports are used along with solid supports.

Locating a workpiece from its external edges is the most-common locating method. The bottom, or primary, locating surface is positioned on three supports, based on the geometry principle that three points are needed to fully define a plane. Two adjacent edges, usually perpendicular to each other, are then used to complete the location.

The most-common way to locate a workpiece from its external profile is the 3-2-1, or six-point, locational method. With this method, six individual locators reference and restrict the workpiece.

As shown in Figure 3-4, three locators, or supports, are placed under the workpiece. The three locators are usually positioned on the primary locating surface. This restricts axial movement downward, along the -z axis (#6) and radially about the x (#7 and #8) and y (#9 and #10) axes. Together, the three locators restrict five degrees of freedom.

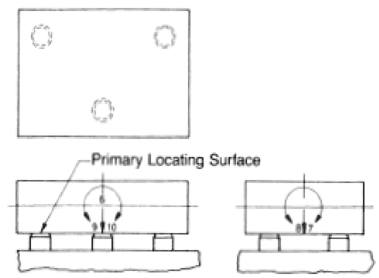


Figure 3-4. Three supports on the primary locating surface restrict five degrees of freedom.

The next two locators are normally placed on the secondary locating surface, as shown in Figure 3-5. They restrict an additional three degrees of freedom by arresting the axial movement along the +y axis (#3) and the radial movement about the z (#11 and #12) axis.

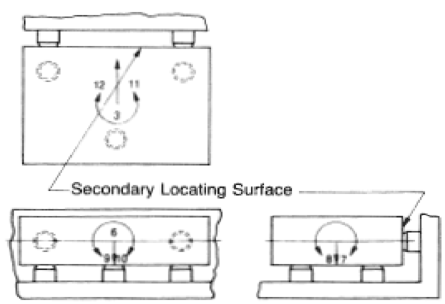


Figure 3-5. Adding two locators on a side restricts eight degrees of freedom.

The final locator, shown in Figure 3-6, is positioned at the end of the part. It restricts the axial movement in one direction along the -x axis. Together, these six locators restrict a total of nine degrees of freedom. The remaining three degrees of freedom (#1, #4, and #5) will be restricted by the clamps.

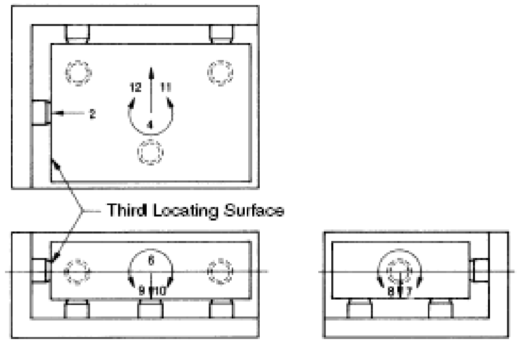


Figure 3-6. Adding a final locator to another side restricts nine degrees of freedom, completing the 3-2-1 location.

Although cylindrical rest buttons are the most-common way of locating a workpiece from its external profile, there are also other devices used for this purpose. These devices include flat-sided locators, vee locators, nest locators and adjustable locators.

Locating from Internal Surfaces

Locating a workpiece from an internal diameter is the most-efficient form of location. The primary features used for this form of location are individual holes or hole patterns. Depending on the placement of the locators, either concentric, radial, or both-concentric-and-radial location are accomplished when locating an internal diameter. Plane location is also provided by the plate used to mount the locators.

The two forms of locators used for internal location are locating pins and locating plugs. The only difference between these locators is their size: locating pins are used for smaller holes and locating plugs are used for larger holes.

As shown in Figure 3-7, the plate under the workpiece restricts one degree of freedom. It prevents any axial movement downward, along the -z (#6) axis. The center pin, acting in conjunction with the plate as a concentric locator, prevents any axial or radial movement along or about the x (#1, #2, #7, and #8) and y (#3, #4, #9, and #10) axes. Together, these two locators restrict nine degrees of freedom. The final locator, the pin in the outer hole, is the radial locator that restricts two degrees of freedom by arresting the radial movement around the z (#11 and #12) axis. Together, the locators restrict eleven degrees of freedom. The last degree of freedom, in the +z direction, will be restricted with a clamp.

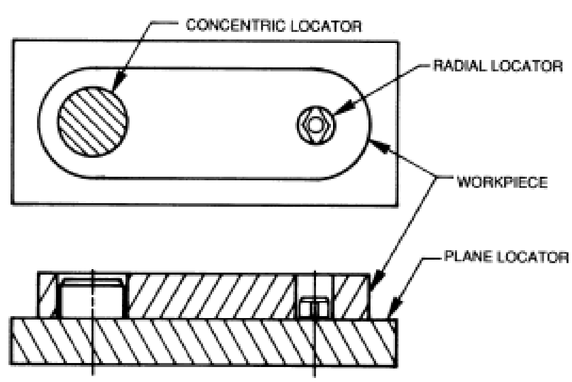


Figure 3-7. Two locating pins mounted on a plate restrict eleven-out-of-twelve degrees of freedom.

Analyzing Machining Forces

The most-important factors to consider in fixture layout are the direction and magnitude of machining forces exerted during the operation. In Figure 3-8, the milling forces generated on a workpiece when properly clamped in a vise tend to push the workpiece down and toward the solid jaw. The clamping action of the movable jaw holds the workpiece against the solid jaw and maintains the position of the part during the cut.

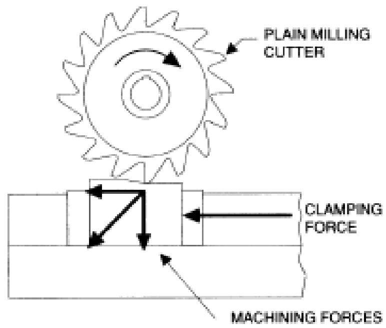


Figure 3-8. Cutting forces in a milling operation should be directed into the solid jaw and base of the vise.

Another example of cutting forces on a workpiece can be seen in the drilling operation in Figure 3-9. The primary machining forces tend to push the workpiece down onto the workholder supports. An additional machining force acting radially around the drill axis also forces the workpiece into the locators. The clamps that hold this workpiece are intended only to hold the workpiece against the locators and to maintain its position during the machining cycle. The only real force exerted on the clamps occurs when the drill breaks through the opposite side of the workpiece, the climbing action of the part on the drill. The machining forces acting on a correctly designed workholder actually help hold the workpiece.

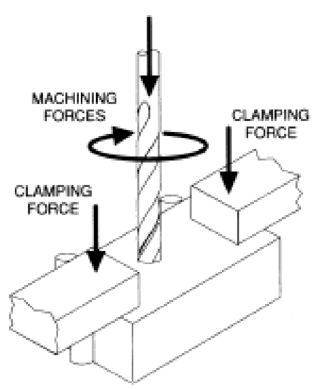


Figure 3-9. The primary cutting forces in a drilling operation are directed both downward and radially about the axis of the drill.

An important step in most fixture designs is looking at the planned machining operations to estimate cutting forces on the workpiece, both magnitude and direction. The "estimate" can be a rough guess based on experience, or a calculation based on machining data. One simple formula for force magnitude, shown in Figure 3-10, is based on the physical relationship:

$$\text{Force} = \frac{\text{Power}}{\text{Velocity}}$$

Please note: "heaviest-cut horsepower" is not total machine horsepower; rather it is the maximum horsepower actually used during the machining cycle. Typical machine efficiency is roughly 75% (.75). The number 33,000 is a units-conversion factor.

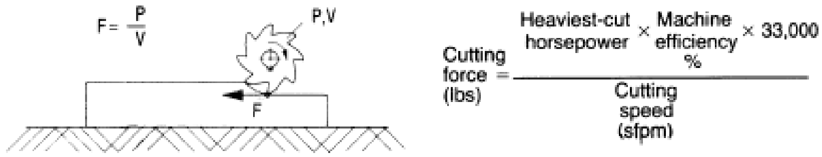


Figure 3-10. A simple formula to estimate the magnitude of cutting forces on the workpiece.

The above formula only calculates force magnitude, not direction. Cutting force can have x-, y-, and/or z-axis components. Force direction (and magnitude) can vary drastically from the beginning, to the middle, to the end of the cut. Figure 3-11 shows a typical calculation. Intuitively, force direction is virtually all horizontal in this example (negligible z-axis component). Direction varies between the x and y axes as the cut progresses.

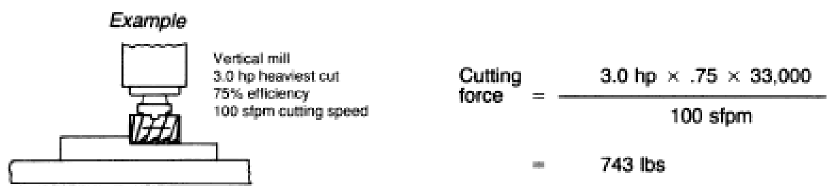


Figure 3-11. Example of a cutting force calculation.

LOCATING GUIDELINES

No single form of location or type of locator will work for every workholder. To properly perform the necessary location, each locator must be carefully planned into the design. The following are a few guidelines to observe in choosing and applying locators.

Positioning Locators

The primary function of any locator is to reference the workpiece and to ensure repeatability. Unless the locators are properly positioned, however, these functions cannot be accomplished. When positioning locators, both relative to the workholder and to the workpiece, there are a few basic points to keep in mind.

Whenever practical, position the locators so they contact the workpiece on a machined surface. The machined surface not only provides repeatability but usually offers a more-stable form of location. The workpiece itself determines the areas of the machined surface used for location. In some instances, the entire surface may be machined. In others, especially with castings, only selected areas are machined.

The best machined surfaces to use for location, when available, are machined holes. As previously noted, machined holes offer the most-complete location with a minimal number of locators. The next configuration that affords adequate repeatability is two machined surfaces forming a right angle. These characteristics are well suited for the six-point locational method. Regardless of the type or condition of the surfaces used for location, however, the primary requirement in the selection of a locating surface is repeatability.

To ensure repeatability, the next consideration in the positioning of locators is the spacing of the locators themselves. As a rule, space locators as far apart as practical. This is illustrated in Figure 3-12. Both workpieces shown here are located with the six-point locating method. The only difference lies in the spacing of the locators. In the part shown at (b), both locators on the back side are positioned close to each other. In the part at (a), these same locators are spaced further apart. The part at (a) is properly located; the part at (b) is not. Spacing the locators as far apart as practical compensates for irregularities in either the locators or the workpiece. Its also affords maximum stability.

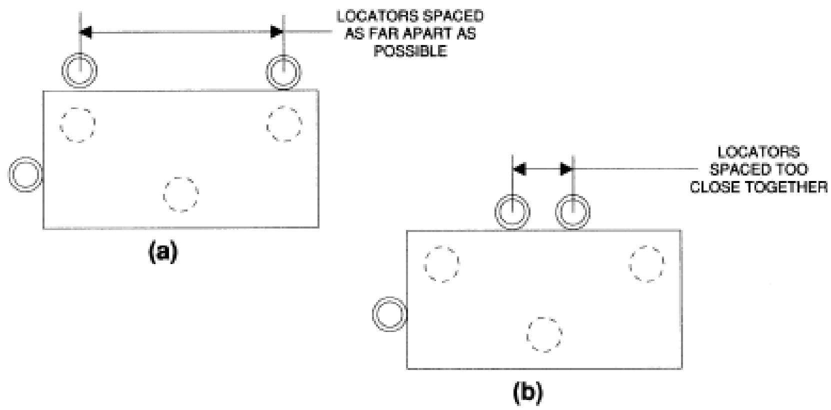


Figure 3-12. Locators should be spaced as far apart as practical to compensate for slight irregularities and for maximum stability.

The examples in Figure 3-13 show conditions that may occur when locators are placed too close together if the center positions of the locators are misaligned by .001". With the spacing shown at (a), this condition has little effect on the location. But if the locating and spacing were changed to that shown at (b), the .001" difference would have a substantial effect. Another problem with locators placed too close together is shown at (c). Here, because the locators are too closely spaced, the part can wobble about the locators in the workholder.

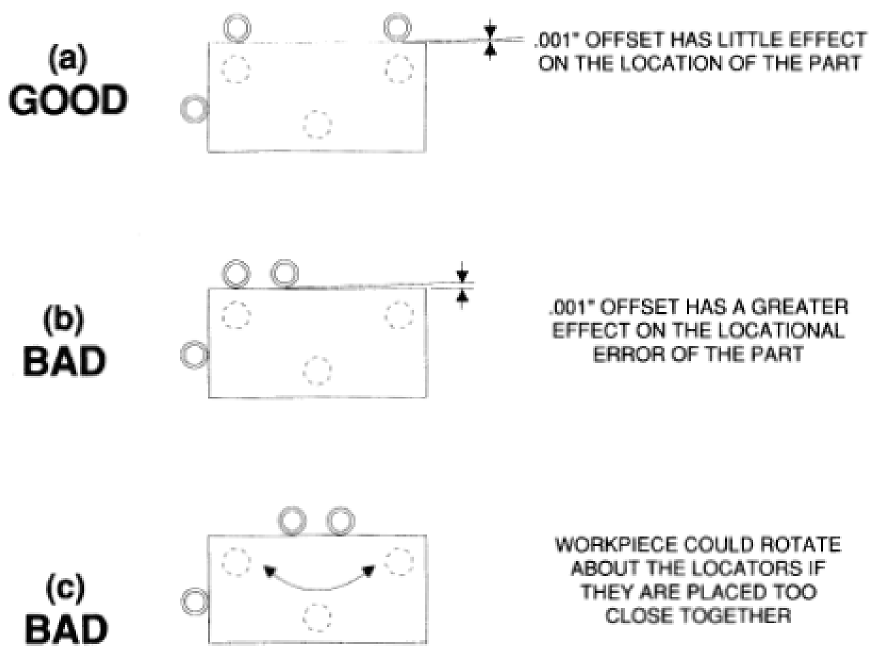


Figure 3-13. Positioning locators too close together will affect the locational accuracy.

Controlling Chips

The final consideration in the placement of locators involves the problem of chip control. Chips are an inevitable part of any machining operation and must be controlled so they do not interfere with locating the workpiece in the workholder. Several methods help minimize the chip problem. First, position the locators away from areas with a high concentration of chips. If this is not practical, then relieve the locators to reduce the effect of chips on the location. In either case, to minimize the negative effects of chips, use locators that are easy to clean, self-cleaning, or protected from the chips. Figure 3-14 shows several ways that locators can be relieved to reduce chip problems.

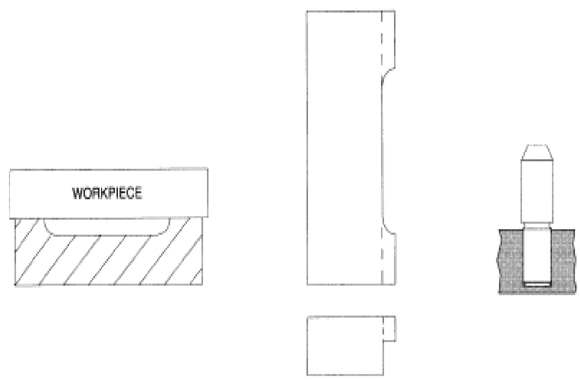


Figure 3-14. Locators should be relieved to reduce locational problems caused by chips.

Coolant build-up can also cause problems. Solve this problem by drilling holes, or milling slots, in areas of the workholder where the coolant is most likely to build up. With some workholders, coolant-drain areas can also act as a removal point for accumulated chips.

When designing a workholder, always try to minimize the chip problem by removing areas of the tool where chips can build up. Omit areas such as inside corners, unrelieved pins, or similar features from the design. Chip control must be addressed in the design of any jig or fixture.

Avoiding Redundant Location

Another condition to avoid in workholder design is redundant, or duplicate, location. Redundant locators restrict the same degree of freedom more than once. The workpieces in Figure 3-15 show several examples. The part at (a) shows how a flat surface can be redundantly located. The part should be located on only one, not both, side surfaces. Since the sizes of parts can vary, within their tolerances, the likelihood of all parts resting simultaneously on both surfaces is remote. The example at (b) points out the same problem with concentric diameters. Either diameter can locate the part, but not both.

The example at (c) shows the difficulty with combining hole and surface location. Either locational method, locating from the holes or locating from the edges, works well if used alone. When the methods are used together, however, they cause a duplicate condition. The condition may result in parts that cannot be loaded or unloaded as intended.

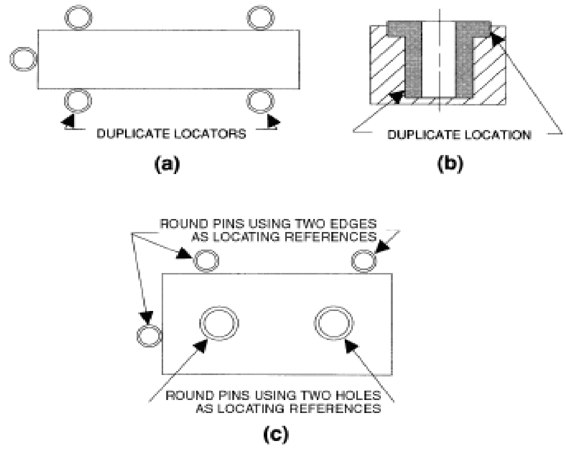


Figure 3-15. Examples of redundant location.

Always avoid redundant location. The simplest way to eliminate it is to check the shop print to find which workpiece feature is the reference feature. Often, the way a part is dimensioned indicates which surfaces or features are important. As shown in Figure 3-16, since the part on the left is dimensioned in both directions from the underside of the flange, use this surface to position the part. The part shown to the right, however, is dimensioned from the bottom of the small diameter. This is the surface that should be used to locate the part.

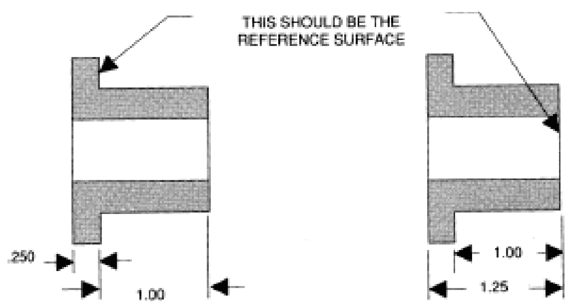


Figure 3-16. The best locating surfaces are often determined by the way that the part is dimensioned.

Preventing Improper Loading

Foolproofing prevents improper loading of a workpiece. The problem is most prevalent with parts that are symmetrical or located concentrically. The simplest way to foolproof a workholder is to position one or two pins in a location that ensures correct orientation, Figure 3-17. With some workpieces, however, more-creative approaches to foolproofing must be taken.

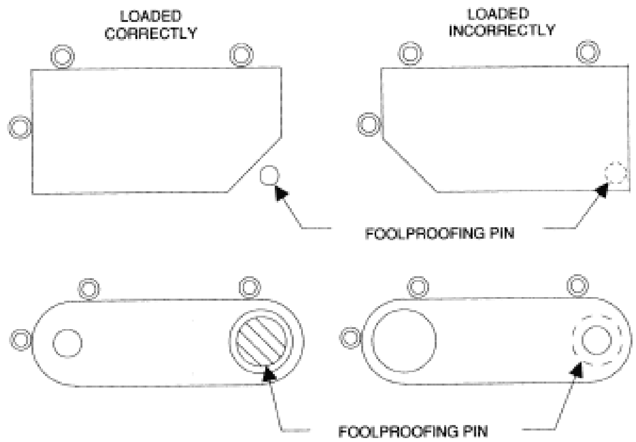


Figure 3-17. Foolproofing the location prevents improper workpiece loading.

Figure 3-18 shows ways to foolproof part location. In the first example, shown at (a), an otherwise-nonfunctional foolproofing pin ensures proper orientation. This pin would interfere with one of the tabs if the part were loaded any other way. In the next example, shown at (b), a cavity in the workpiece prevents the part from being loaded upside-down. Here, a block that is slightly smaller than the opening of the part cavity is added to the workholder. A properly loaded part fits over the block, but the block keeps an improperly loaded part from entering the workholder.

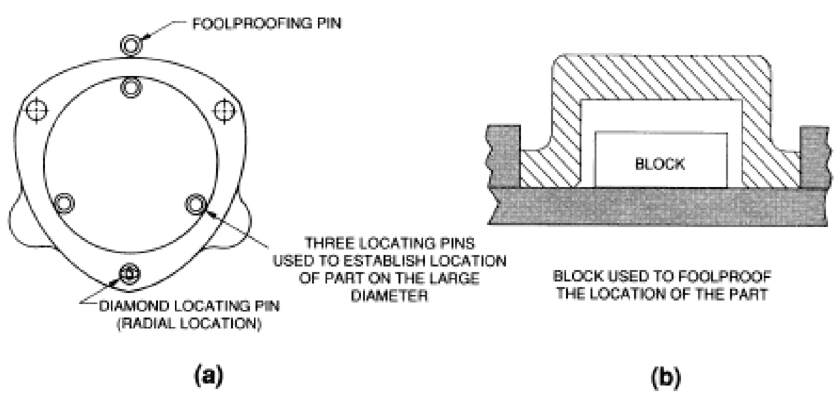


Figure 3-18. Simple pins or blocks are often used to foolproof the location.

Using Spring-Loaded Locators

One method to help ensure accurate location is the installation of spring-loaded buttons or pins in the workholder, Figure 3-19. These devices are positioned so their spring force pushes the workpiece against the fixed locators until the workpiece is clamped. These spring-loaded accessories not only ensure repeatable locating but also make clamping the workpiece easier.

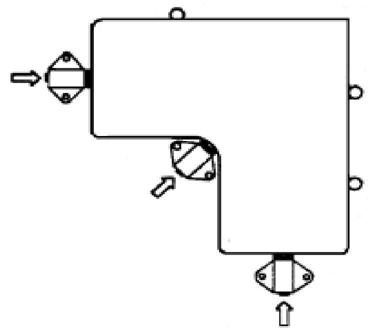


Figure 3-19. Spring-loaded locators help ensure the correct location by pushing the workpiece against the fixed locators.

Determining Locator Size and Tolerances

The workpiece itself determines the overall size of a locating element. The principle rule to determine the size of the workpiece locator is that the locators must be made to suit the MMC (Maximum-Material Condition) of the area to be located. The MMC of a feature is the size of the feature where is has the maximum amount of material. With external features, like shafts, the MMC is the largest size within the limits. With internal features, like holes, it is the smallest size within the limits. Figure 3-20 illustrates the MMC sizes for both external and internal features.

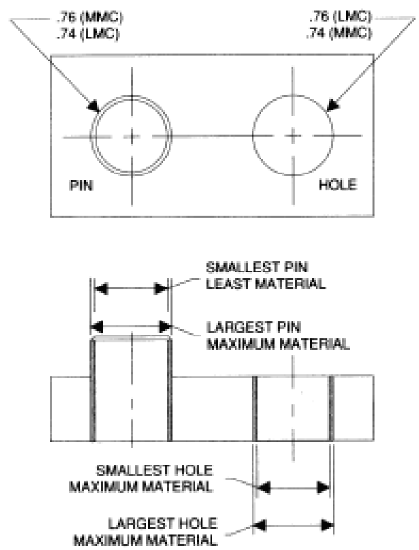


Figure 3-20. Locator sizes are always based on the maximum-material condition of the workpiece features.

Sizing cylindrical locators is relatively simple. The main considerations are the size of the area to be located and the required clearance between the locator and the workpiece. As shown in Figure 3-21, the only consideration is to make the locating pin slightly smaller than the hole. In this example, the hole is specified as .500-.510" in diameter. Following the rule of MMC, the locator must fit the hole at its MMC of .500". Allowing for a .0005 clearance between the pin and the hole, desired pin diameter is calculated at .4995". Standard locating pins are readily available for several different hole tolerances, or ground to a specific dimension. A standard 1/2" Round Pin with .4995"-.4992" head diameter would be a good choice.

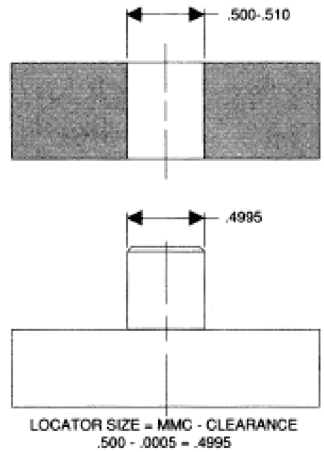


Figure 3-21. Determining the size of a single locating pin based on maximum-material conditions.

The general accuracy of the workholder must be greater than the accuracy of the workpiece. Two basic types of tolerance values are applied to a locator: the first are the tolerances that control the size of the locator; the second are tolerances that control its location. Many methods can be used to determine the appropriate tolerance values assigned to a workholder. In some situations the tolerance designation is an arbitrary value predetermined by the engineering department and assigned to a workholder without regard to the specific workpiece. Other tolerances are assigned a specific value based on the size of the element to be located. Although more appropriate than the single-value tolerances, they do not allow for requirements of the workpiece. Another common method is using a set percentage of the workpiece tolerance.

The closer the tolerance value, the higher the overall cost to produce the workpiece. Generally, when a tolerance is tightened, the cost of the tolerance increases exponentially to its benefit. A tolerance twice as tight might actually cost five times as much to produce.

The manufacturability of a tolerance, the ability of the available manufacturing methods to achieve a tolerance, is also a critical factor. A simple hole, for example, if toleranced to ±.050", can be punched. If, however, the tolerance is ±.010", the hole requires drilling. Likewise, if the tolerance is tightened to ±.002", the hole then requires drilling and reaming. Finally, with a tolerance of ±.0003", the hole must be drilled, reamed, and lapped to ensure the required size.

One other factor to consider in the manufacturability of a tolerance is whether the tolerance specified can be manufactured within the capability of the toolroom. A tolerance of .00001" is very easy to indicate on a drawing, but is impossible to achieve in the vast majority of toolrooms.

No single tolerance is appropriate for every part feature. Even though one feature may require a tolerance of location to within .0005", it is doubtful that every tolerance of the workholder must be held to the same tolerance value. The length of a baseplate, for example, can usually be made to a substantially different tolerance than the location of the specific features.

The application of percentage-type tolerances, unlike arbitrary tolerances, can accurately reflect the relationship between the workpiece tolerances and the workholder tolerances. Specification of workholder tolerances as a percentage of the workpiece tolerances results in a consistent and constant relationship between the workholder and the workpiece. When a straight percentage value of 25 percent is applied to a .050" workpiece tolerance, the workholder tolerance is .0125". The same percentage applied to a .001" tolerance is .00025". Here a proportional relationship of the tolerances is maintained regardless of the relative sizes of the workpiece tolerances. As a rule, the range of percentage tolerances should be from 20 to 50 percent of the workpiece tolerance, usually determined by engineering-department standards.

CLAMPING GUIDELINES

Locating the workpiece is the first basic function of a jig or fixture. Once located, the workpiece must also be held to prevent movement during the operational cycle. The process of holding the position of the workpiece in the jig or fixture is called clamping. The primary devices used for holding a workpiece are clamps. To perform properly, both the clamping devices and their location on the workholder must be carefully selected.

Factors in Selecting Clamps

Clamps serve two primary functions. First, they must hold the workpiece against its locators. Second, the clamps must prevent movement of the workpiece. The locators, not the clamps, should resist the primary cutting forces generated by the operation.

Holding the Workpiece Against Locators. Clamps are not intended to resist the primary cutting forces. The only purpose of clamps is to maintain the position of the workpiece against the locators and resist the secondary cutting forces. The secondary cutting forces are those generated as the cutter leaves the workpiece. In drilling, for example, the primary cutting forces are usually directed down and radially about the axis of the drill. The secondary forces are the forces that tend to lift the part as the drill breaks through the opposite side of the part. So, the clamps selected for an application need only be strong enough to hold the workpiece against the locators and resist the secondary cutting forces.

The relationship between the locators and clamps can be illustrated with a milling-machine vise. In Figure 3-22, the vise contains both locating and clamping elements. The solid jaw and vise body are the locators. The movable jaw is the clamp. The vise is normally positioned so that the locators resist the cutting forces. Directing the cutting forces into the solid jaw and vise body ensures the accuracy of the machining operation and prevents workpiece movement. In all workholders, it is important to direct the cutting forces into the locators. The movable vise jaw, like other clamps, simply holds the position of the workpiece against the locators.

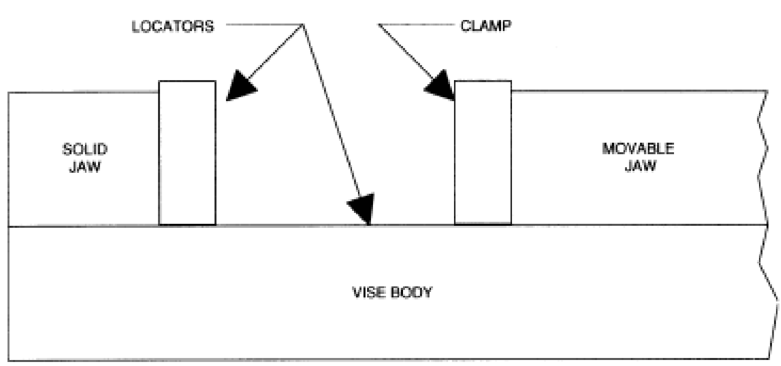


Figure 3-22. A vise contains both locating and clamping elements.

Holding Securely Under Vibration, Loading, and Stress. The next factors in selecting a clamp are the vibration and stress expected in the operation. Cam clamps, for example, although good for some operations, are not the best choice when excessive vibration can loosen them. It is also a good idea to add a safety margin to the estimated forces acting on a clamp.

Preventing Damage to the Workpiece. The clamp chosen must also be one that does not damage the workpiece. Damage occurs in many ways. The main concerns are part distortion and marring. Too much clamping force can warp or bend the workpiece. Surface damage is often caused by clamps with hardened or non-rotating contact surfaces. Use clamps with rotating contact pads or with softer contact material to reduce this problem. The best clamp for an application is one that can adequately hold the workpiece without surface damage.

Improving Load/Unload Speed. The speed of the clamps is also important to the workholder's efficiency. A clamp with a slow clamping action, such as a screw clamp, sometimes eliminates any profit potential of the workholder. The speed of clamping and unclamping is usually the most-important factor in keeping loading/unloading time to a minimum.

Positioning the Clamps

The position of clamps on the workholder is just as important to the overall operation of the tool as the position of the locators. The selected clamps must hold the part against the locators without deforming the workpiece. Once again, since the purpose of locators is to resist all primary cutting forces generated in the operation, the clamps need only be large enough to hold the workpiece against the locators and to resist any secondary forces generated in the operation. To meet both these conditions, position the clamps at the most-rigid points of the workpiece. With most workholders, this means positioning the clamps directly over the supporting elements in the baseplate of the workholder, Figure-3-23a.

In some cases the workpiece must be clamped against horizontal locators rather than the supports, Figure 3-23b. In either case, the clamping force must be absorbed by the locating elements.

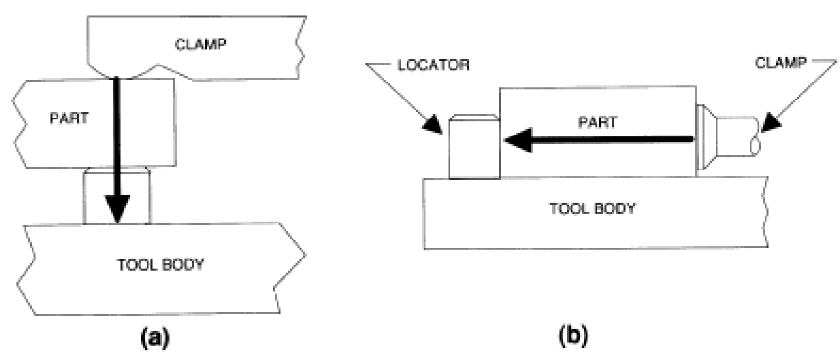


Figure 3-23. Clamps should always be positioned so the clamping force is directed into the supports or locators.

For workholders with two supports under the clamping area of the workpiece, two clamps should be used — one over each support, Figure 3-24a. Placing only one clamp between the supports can easily bend or distort the workpiece during the clamping operation. When the workpiece has flanges or other extensions used for clamping, an auxiliary support should be positioned under the extended area before a clamp is applied, Figure 3-24b.

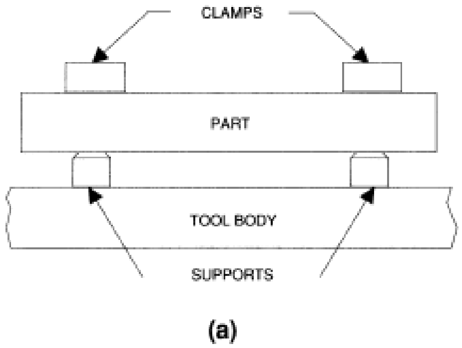


Figure 3-24. The number and position of clamps is determined by the workpiece and its supports.

Another consideration in positioning clamps is the operation of the machine tool throughout the machining cycle. The clamps must be positioned so they do not interfere with the operation of the machine tool, during either the cutting or return cycle. Such positioning is especially critical with numerically controlled machines. In addition to the cutters, check interference between the clamps and other machine elements, such as arbors, chucks, quills, lathe carriages, and columns.

When fixturing an automated machine, check the complete tool path before using the workholder. Check both the machining cycle and return cycle of the machine for interference between the cutters and the clamps. Occasionally programmers forget to consider the tool path on the return cycle. One way to reduce the chance of a collision and eliminate the need to program the return path is simply to raise the cutter above the highest area of the workpiece or workholder at the end of the machining cycle before returning to the home position.

Most clamps are positioned on or near the top surface of the workpiece. The overall height of the clamp, with respect to the workpiece, must be kept to a minimum. This can be done with gooseneck-type clamps, Figure 3-25. As shown, the gooseneck clamp has a lower profile and should be used where reduced clamp height is needed.

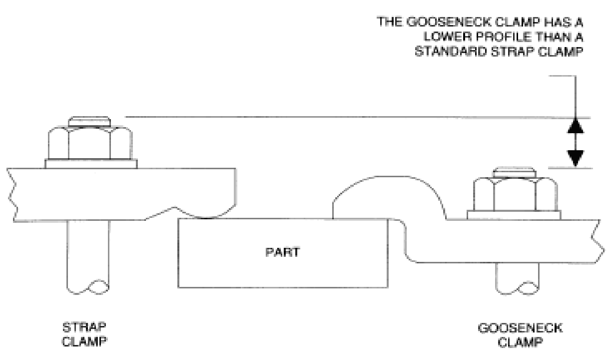


Figure 3-25. Using gooseneck clamps is one way to reduce the height of the clamps.

The size of the clamp-contact area is another factor in positioning a clamp. To reduce interference between the clamp and the cutter, keep the contact area as small as safely possible. A small clamping area reduces the chance for interference and also increases the clamping pressure on the workpiece. The overall size of the clamp is another factor to keep in mind. The clamp must be large enough to properly and safely hold the workpiece, but small enough to stay out of the way.

Once again, the primary purpose of a clamp is to hold the workpiece against the locators. To do this properly, the clamping force should be directed into the locators, or the most-solid part of the workholder. Positioning the clamping devices in any other manner can easily distort or deform the workpiece.

The workpiece shown in Figure 3-26 illustrates this point. The part is a thin-wall ring that must be fixtured so that the internal diameter can be bored. The most-convenient way to clamp the workpiece is on its outside diameter; however, to generate enough clamping pressure to hold the part, the clamp is likely to deform the ring. The reason lies in the direction and magnitude of the clamping force: rather than acting against a locator, the clamping forces act against the spring force of the ring resisting the clamping action. This type of clamping should only be used if the part is a solid disk or has a small-diameter hole and a heavy wall thickness.

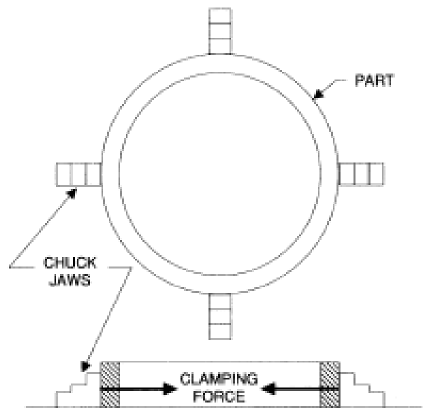


Figure 3-26. Directing the clamping forces against an unsupported area will cause this cylindrical part to deform.

To clamp this type of part, other techniques should be used. The clamping arrangement in Figure 3-27 shows the workpiece clamped with four strap clamps. The clamping force is directed into the baseplate and not against the spring force of the workpiece. Clamping the workpiece this way eliminates the distortion of the ring caused by the first method.

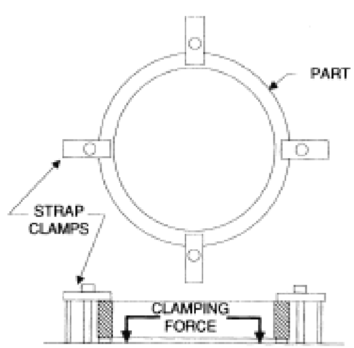


Figure 3-27. Strap clamps eliminate deformation by directing the clamping forces into the supports under the part.

A similar clamping method is shown at Figure 3-28. Here the workpiece has a series of holes around the ring that can be used to clamp the workpiece. Clamping the workpiece in this manner also directs the clamping force against the baseplate of the workholder. This type of arrangement requires supports with holes that permit the clamping screws to clamp through the supports.

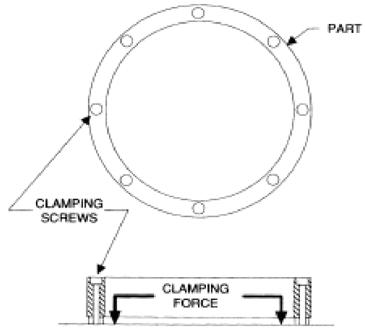


Figure 3-28. When possible, part features such as holes can be used to clamp the part.

If the part can be clamped only on its outside surface, one other method can be used to hold the part: a collet that completely encloses the part. As shown in Figure 3-29, the shape of the clamping contact helps control distortion. Depending on the size of the part, either a collet or pie-shaped soft jaws can be used for this arrangement.

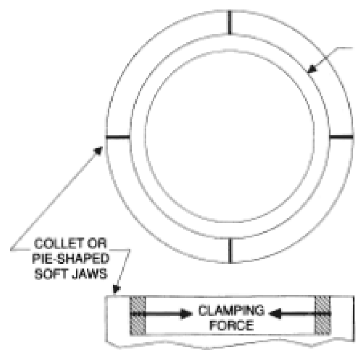
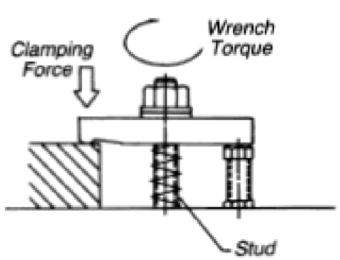


Figure 3-29. When the part can only be clamped on its outside surface, pie-shaped chuck jaws can be used to hold the part and reduce deformation.

Selecting Clamp Size and Force

Calculations to find the necessary clamping force can be quite complicated. In many situations, however, an approximate determination of these values is sufficient. The table in Figure 3-30 shows the available clamping forces for a variety of different-size manual clamp straps with a 2-to-1 clamping-force ratio.

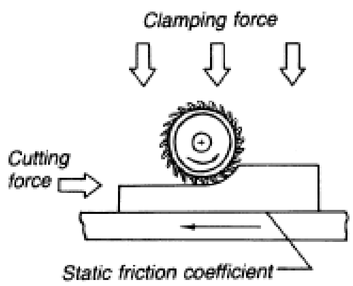


Stud Size	Recommended Torque* (ft.-lbs.)	Clamping Force (lbs.)	Tensile Force In Stud (lbs.)
#10-32	2	300	600
1/4-20	4	500	1000
5/16-18	9	900	1800
3/8-16	16	1300	2600
1/2-13	38	2300	4600
5/8-11	77	3700	7400
3/4-10	138	5500	11000
7/8-9	222	7600	15200
1-8	333	10000	20000

*Clean, dry clamping stud torqued to approximately 33% of its 100,000 psi yield strength (2:1 lever ratio).

Figure 3-30. Approximate clamping forces of different-size manual clamp straps with a 2-to-1 clamping-force ratio.

Alternatively, required clamping force can be calculated based on calculated cutting forces. A simplified example is shown in Figure 3-31. The cutting force is entirely horizontal, and no workpiece locators are used, so frictional forces alone resist the cutting forces.



$$\text{Required clamping force (lbs)} = \frac{\text{Cutting force (lbs)}}{\text{Static friction coefficient}} \times \text{Safety factor (usually 2)}$$

Contact surfaces	Friction coefficient (Dry)	Friction coefficient (Lubricated)
Steel on steel	.15	.12
Steel on cast iron	.19	.10
Cast iron on cast iron	.30	.19

Figure 3-31. A simplified clamping-force calculation with the cutting force entirely horizontal, and no workpiece stops (frictional force resists all cutting forces).

When workpiece locators and multi-directional forces are considered, the calculations become more complicated. To simplify calculations, the worst-case force situation can be estimated intuitively and then treated as a two-dimensional static-mechanics problem (using a free-body diagram). In the example shown in Figure 3-32, the cutting force is known to be 1800 lbs, based on a previous calculation. The workpiece weighs 1500 lbs. The unknown forces are:

F_R = Total force from all clamps on right side

F_L = Total force from all clamps on left side

R_1 = Horizontal reaction force from the fixed stop

R_2 = Vertical reaction force from the fixed stop

R_3 = Vertical reaction force on the right side

N = Normal-direction force = FL + FR + 1500

μ = Coefficient of friction = .19

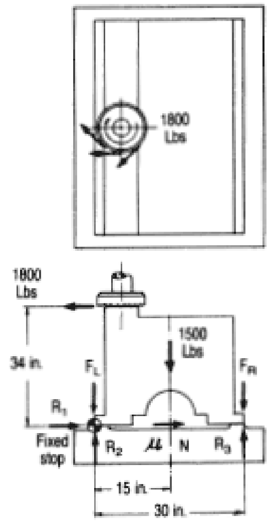


Figure 3-32. A more-complicated clamping-force calculation, using a two-dimensional free-body diagram.

The following equations solve the unknown forces assuming that for a static condition:

1. The sum of forces in the x direction must equal zero.
2. The sum of forces in the y direction must equal zero.
3. The sum of moments about any point must equal zero.

At first glance, this example looks "statically indeterminate," i.e., there are five variables and only three equations. But for the minimum required clamping force, R_3 is zero (workpiece barely touching) and F_L is zero (there is no tendency to lift on the left side). Now with only three variables, the problem can be solved:

$$\Sigma F_x = 0$$
$$= -1800 + R_1 + (.19)(1500 + F_R)$$
$$\Sigma F_y = 0$$
$$= R_2 - 1500 - F_R$$
$$\Sigma M = 0$$
$$= (34)(1800) - (15)(1500) - (30)(F_R)$$

Solving for the variables,

F_R = 1290 lbs
R_1 = 1270 lbs
R_2 = 2790 lbs

In other words, the combined force from all clamps on the right side must be greater than 1290 lbs. With a recommended safety factor of 2-to-1, this value becomes 2580 lbs. Even though F_L (combined force from all the clamps on the left side) equals zero, a small clamping force may be desirable to prevent vibration.

Another general area of concern is maintaining consistent clamping force. Manual clamping devices can vary in the force they apply to parts during a production run. Many factors account for the variation, including clamp position on the workpiece, but operator fatigue is the most-common fault. The simplest and often-best way to control clamping force is to replace manual clamps with power clamps.

The force generated by power clamps is not only constant but also adjustable to suit workpiece conditions. Another benefit of power clamps is their speed of operation: not only are individual power clamps faster than manual clamps, every clamp is activated at the same time.

UNIT 2 JIGS AND FIXTURES

Structure

2.1 INTRODUCTION

The jigs and fixtures are the economical ways to produce a component in mass. So jigs and fixtures are used and serve as one of the most important facility of mass production system. These are special work holding and tool guiding device. Quality of the performance of a process largely influenced by the quality of jigs and fixtures used for this purpose. What makes a fixture unique is that each one is built to fit a particular part or shape. The main purpose of a fixture is to locate and in the cases hold a workpiece during an operation. A jig differs from a fixture in the sense that it guides the tool to its correct position or towards its correct movement during an operation in addition to locating and supporting the workpiece.

An example of jig is when a key is duplicated, the original key is used as base for the path reader which guides the movement of tool to make its duplicate key. The path reader of a CWC machine here works as a jig and the original is called template. Sometimes the template and jig both are the name of same part of a manufacturing system.

Objectives

After studying this unit, you should be able to understand

- introduction of jigs and fixtures,
- purpose and advantages of jigs and fixtures,
- important considerations while designing jigs and fixtures,
- know the meaning and principles of location,
- describe the different types of locations,
- explain the clamping and its different type,
- the requirements of a good clamping device,
- know the different types of clamps,

- explain the jigs and their different types, and
- know about the milling fixtures.

2.2 PURPOSE AND ADVANTAGES OF JIGS AND FIXTURES

Following the purpose and advantages of jigs and fixtures :

(a) It reduces or sometimes eliminates the efforts of marking, measuring and setting of workpiece on a machine and maintains the accuracy of performance.

(b) The workpiece and tool are relatively located at their exact positions before the operation automatically within negligible time. So it reduces product cycle time.

(c) Variability of dimension in mass production is very low so manufacturing processes supported by use of jigs and fixtures maintain a consistent quality.

(d) Due to low variability in dimension assembly operation becomes easy, low rejection due to les defective production is observed.

(e) It reduces the production cycle time so increases production capacity. Simultaneously working by more than one tool on the same workpiece is possible.

(f) The operating conditions like speed, feed rate and depth of cut can be set to higher values due to rigidity of clamping of workpiece by jigs and fixtures.

(g) Operators working becomes comfortable as his efforts in setting the workpiece can be eliminated.

(h) Semi-skilled operators can be assigned the work so it saves the cost of manpower also.

(i) There is no need to examine the quality of produce provided that quality of employed jigs and fixtures is ensured.

2.3 IMPORTANT CONSIDERATIONS WHILE DESIGNING JIGS AND FIXTURES

Designing of jigs and fixtures depends upon so many factors. These factors are analysed to get design inputs for jigs and fixtures. The list of such factors is mentioned below :

(a) Study of workpiece and finished component size and geometry.

(b) Type and capacity of the machine, its extent of automation.

(c) Provision of locating devices in the machine.

(d) Available clamping arrangements in the machine.

(e) Available indexing devices, their accuracy.

(f) Evaluation of variability in the performance results of the machine.

(g) Rigidity and of the machine tool under consideration.

(h) Study of ejecting devices, safety devices, etc.

(i) Required level of the accuracy in the work and quality to be produced.

2.4 MEANING OF LOCATION

It is very important to understand the meaning of location before understanding abut the jigs and fixtures. The location refers to the establishment of a desired relationship between the workpiece and the jigs or fixture correctness of location directly influences the accuracy of the finished product. The jigs and fixtures are desired so that all undesirable movements of the workpiece can be restricted. Determination of the locating points and clamping of the workpiece serve to restrict movements of the component in any direction, while setting it in a particular pre-decided position relative to the jig. Before deciding the locating points it is advisable to find out the all possible degrees of freedom of the workpiece. Then some of the degrees of freedom or all of them are restrained by making suitable arrangements. These arrangements are called locators.

2.5 PRINCIPLES OF LOCATIONS

The principle of location is being discussed here with the help of a most popular example which is available in any of the book covering jigs and fixtures. It is important that one should understand the problem first.

Any rectangular body many have three axis along *x*-axis, *y*-axis and *z*-axis. It can more along any of these axes or any of its movement can be released to these three axes. At the same time the body can also rotate about these axes too. So total degree of freedom of the body along which it can move is six. For processing the body it is required to restrain all the degree of freedom (DOF) by arranging suitable locating points and then clamping it in a fixed and required position. The basic principle used to locate the points is desirable below.

Six Points Location of a Rectangular Block

Considering the six degree of freedom of a rectangular block as shown in Figure 4.1. It is made to rest on several points on the jig body. Provide a rest to workpiece on three points on the bottom *x*-*y* surface. This will stop the movement along *z*-axis, rotation with respect to *x*-axis and *y*-axis. Supporting it on the three points is considered as better support then one point or two points. Rest the workpiece on two points of side surface (*x*-*z*), this will fix the movement of workpiece along *y*-axis and rotation with respect to *z*-axis. Provide a support at one point of the adjacent surface (*y*-*z*) that will fix other remaining free movements. This principle of location of fixing points on the workpiece is also named as 3-2-1 principle of fixture design as number of points selected at different faces of the workpiece are 3, 2 and 1 respectively.

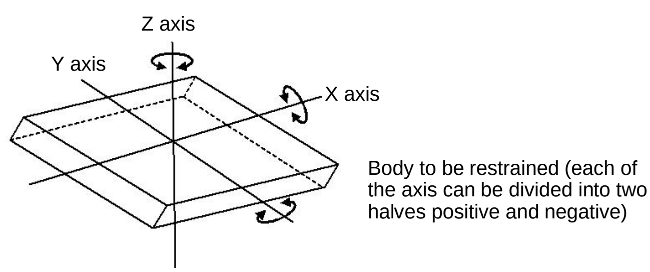


Figure 4.1 : Available Degree of Freedom of Rectangular Block

Location of a Cylinder on a Vee Block

The analysis of the principle of location of a cylinder on a Vee block is indicated in Figure 4.2. All the degrees of freedom of the cylindrical object are restrained. It is only fixed to move along axis *AB*. It can rotate about the axis *AB*. These free movements are also indicated in the figure. If the operation to be done on the cylindrical object requires restriction of the above mentioned free movements also than some more locating provisions must also be incorporated in addition to use of the Vee block.

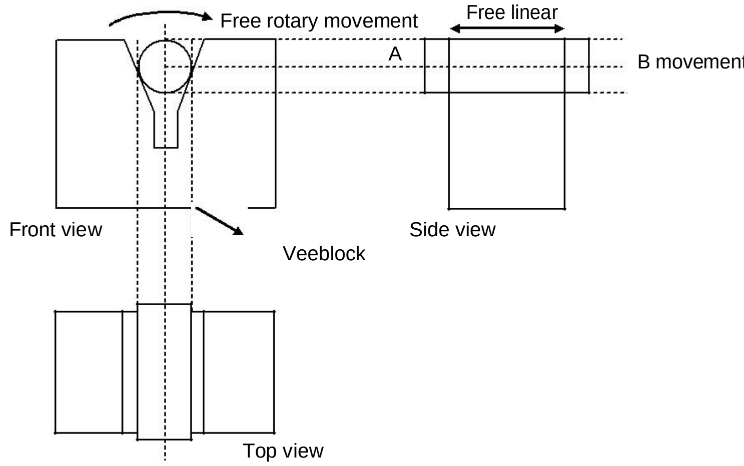


Figure 4.2 : Locating a Cylinder on a Vee Block

2.6 DIFFERENT METHODS USED FOR LOCATION

There are different methods used for location of a work. The locating arrangement should be decided after studying the type of work, type of operation, degree of accuracy required. Volume of mass production to be done also mattes a lot. Different locating methods are described below.

Flat Locator

Flat locators are used for location of flat machined surfaces of the component. Three different examples which can be served as a general principle of location are described here for flat locators. These examples are illustrated in Figure 4.3.

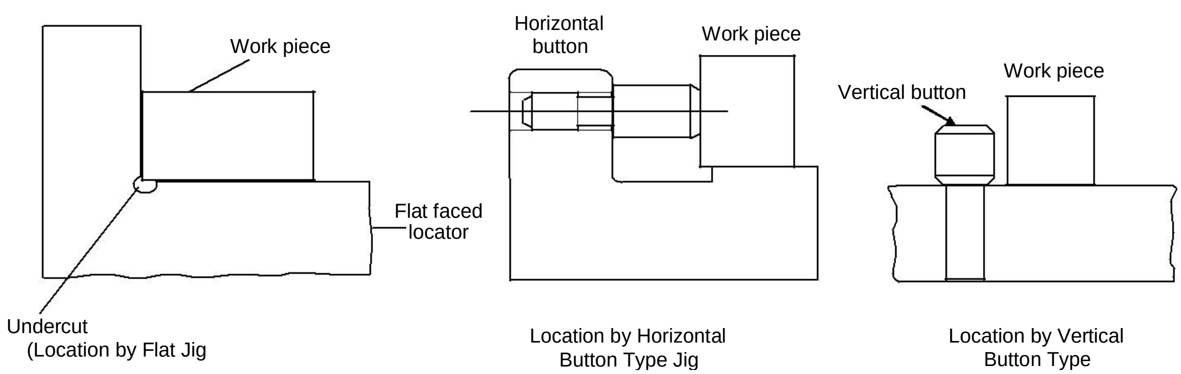


Figure 4.3 : Method of Locating using Flat Locators

A flat surface locator can be used as shown in first figure. In this case an undercut is provided at the bottom where two perpendicular surfaces intersect each other. This is made for swarf clearance. The middle figure shows flat headed button type locator. There is no need to made undercut for swarf clearance. The button can be adjusted to decide very fine location of the workpiece. There can be a vertical button support as shown in third figure, which is a better arrangement due to its capacity to bear end load and there is a provision for swarf clearance automatically.

Cylindrical Locators

A cylindrical locator is shown in Figure 4.4. It is used for locating components having drilled holes. The cylindrical component to be located is gripped by a cylindrical locator fitted to the jig□s body and inserted in the drilled hole of the component. The face of the jig□s body around the locator is undercut to provide space for swarf clearance.

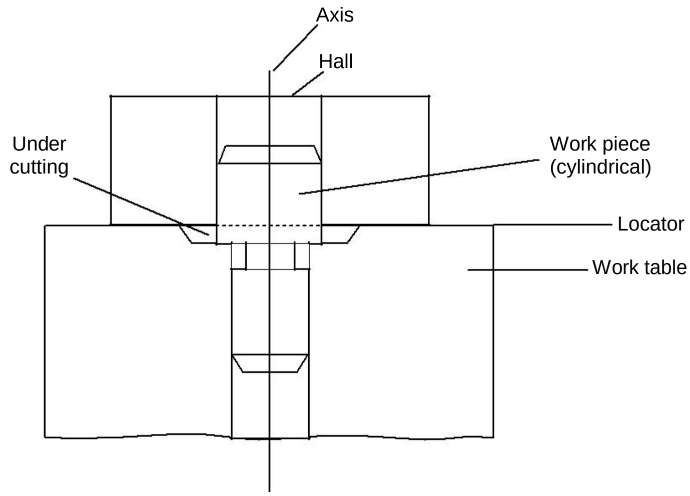


Figure 4.4 : Cylindrical Locator

Conical Locator

A conical locator is illustrated in Figure 4.5. This is used for locating the workpieces having cylindrical hole in the workpiece. The workpiece is found located by supporting it over the conical locator inserted into the drilled hole of the workpiece. A conical locator is considered as superior as it has a capacity to accommodate a slight variation in the hole diameter of the component without affecting the accuracy of location. Degree of freedom along *z*-axis can also be restrained by putting a template over the workpiece with the help of screws.

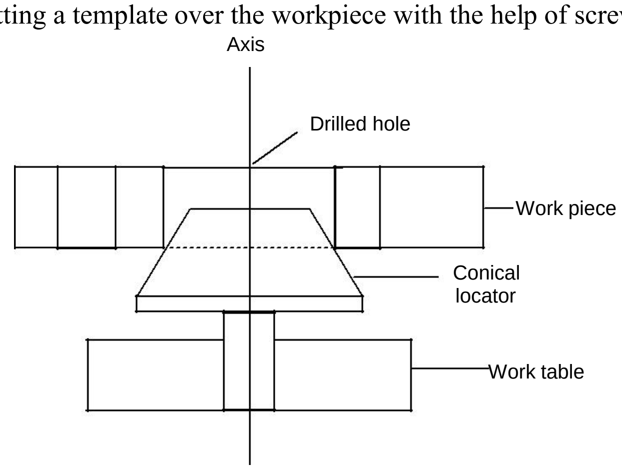


Figure 4.5 : Conical Locator

Jack Pin Locator

Jack pin locator is used for supporting rough workpieces from the button as shown in Figure 4.6. Height of the jack pin is adjustable to accommodate the workpieces having variation in their surface texture. So this is a suitable method to accommodate the components which are rough and un-machined.

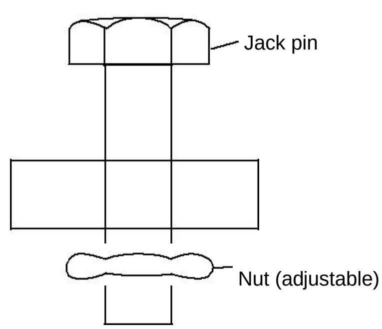


Figure 4.6 : Jack Pin Locator

Drill Bush Locator

The drill bush locator is illustrated in Figure 4.7. It is used for holding and locating the cylindrical workpieces. The bush has conical opening for locating purpose and it is sometimes screwed on the jig□s body for the adjustment of height of the work.

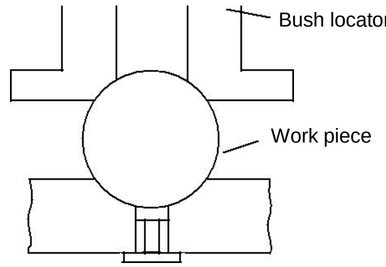
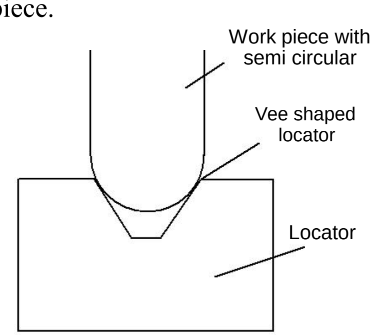


Figure 4.7 : Drill Bush Locator

Vee Locators

This is quick and effective method of locating the workpiece with desired level of accuracy. This is used for locating the circular and semi-circular type of workpieces as shown in Figure 4.8. The main part of locating device is Vee shaped block which is normally fixed to the jig. This locator can be of two types fixed Vee locator and adjustable Vee locator. The fixed type locator is normally fixed on the jig and adjustable locator can be moved axially to provide proper grip of Vee band to the workpiece.



Figur 4.8 : Fixed *V* Locator

2.7 CLAMPING

To restrain the workpiece completely a clamping device is required in addition to locating device and jigs and fixtures. A clamping device holds the workpiece securely in a jig or fixture against the forces applied over it during on operation. Clamping device should be incorporated into the fixture, proper clamp in a fixture directly influence the accuracy and quality of the work done and production cycle time. Basic requirement of a good clamping device are listed below :

(a) It should rigidly hold the workpiece.

(b) The workpiece being clamped should not be damaged due to application of clamping pressure by the clamping unit.

(c) The clamping pressure should be enough to over come the operating pressure applied on the workpiece as both pressure act on the workpiece in opposite directions.

(d) Clamping device should be capable to be unaffected by the vibrations generated during an operation.

(e) It should also be user friendly, like its clamping and releasing should be easy and less time consuming. Its maintenance should also be easy.

(f) Clamping pressure should be directed towards the support surfaces or support points to prevent undesired lifting of workpiece from its supports.

(g) Clamping faces should be hardened by proper treatments to minimize their wearing out.

(h) To handle the workpieces made of fragile material the faces of clamping unit should be equipped with fibre pads to avoid any damage to workpiece.

2.8DIFFERENT TYPES OF CLAMPS

Different variety of clamps used with jigs and fixtures are classified into different categories are discussed here.

Strap Clamp

This is also called edge clamp. This type clamping is done with the help of a lever pressure acting as a strap on the workpiece. Different types of strap clamps are discussed below.

Heel Clamp

The simple form of a heel clamp is shown in Figure 4.9. Rotation of the clamp in clockwise direction is prevented and it is allowed in anticlockwise direction. For releasing the workpiece the clamping nut is unscrewed. The free movement in anticlockwise direction takes place before un-securing the nut to release the workpiece.

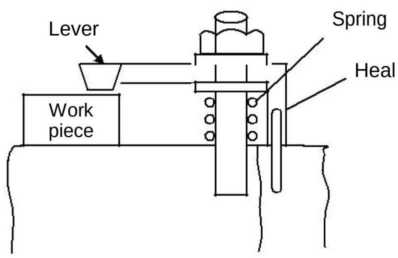


Figure 4.9 : Heel Clamp

Bridge Clamp

The bridge clamp is illustrated in Figure 4.10. It applies more clamping pressure as compared to heel clamp. The clamping pressure experienced by the workpiece depends on the distances „*x*□ and „*y*□ marked in the Figure 4.10. To release the workpiece the nut named as clamping nut is unscrewed. The spring lifts the lever to release the workpiece.

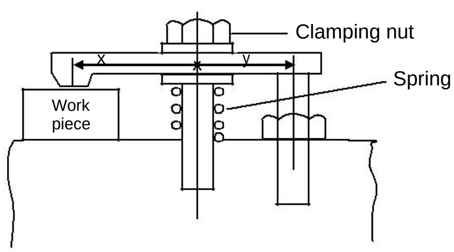


Figure 4.10 : Bridge Clamp

Edge Clamp or Side Clamp

A side clamp is also known as edge clamp. In this case the surface to be machined is always clamped above the clamping device. This clamping device is recommended for fixed length workpiece. The clamping device is illustrated in Figure 4.11. Releasing and clamping of the workpiece can be accomplished by unscrewing and screwing of the clamping nut respectively.

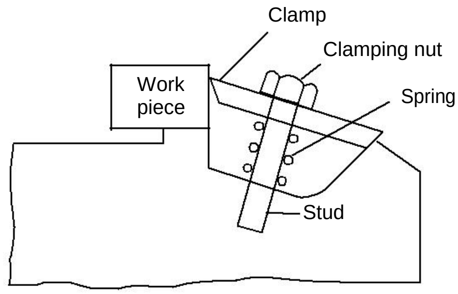


Figure 4.11 : Edge Clamp or Side Clamp

Screw Clamp

The screw clamp is illustrated in Figure 4.12. It is also known as clamp screw. This clamping apply pressure directly on the side faces of the workpiece. There is a floating pad at their end to serve the following purposes :

(a) It prevents displacement of workpiece and slip.

(b) It prevents denting of clamping area of workpiece.

(c) The available cushion prevents deflection of screw.

In addition to the above there are some disadvantages associated with this method. The clamping pressure largely depends on the workpiece, it varies from one workpiece to other. It is more time consuming and more efforts are required.

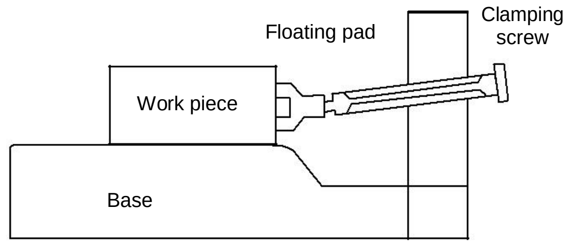


Figure 4.12 : Screw Clamp

Latch Clamp

Latch clamps are used to clamp the workpiece, the clamping system is normally locked with the help of a latch provided. To unload the workpiece the tail end of the latch is pushed that causes the leaf to swung open, so releasing the workpiece. Here time consumed in loading and unloading is very less as no screw is tightened but clamping pressure is not so high as in other clamping devices. Life of this type of clamping device is small.

Equalizing Clamps

Equalizing clamp is illustrated in Figure 4.13. It is recommended to apply equal pressure on the two faces of the work. The pressure applied can be varied by tightened or loosening the screw provided for the purpose.

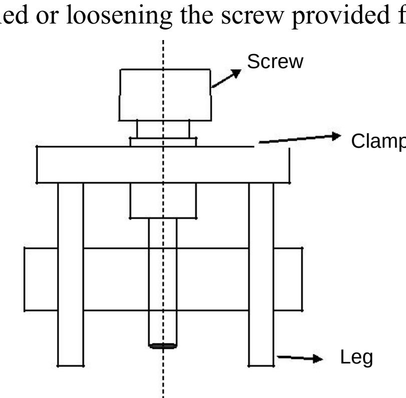


Figure 4.13 : Equalizing Clamp

Power Driven Clamping

Light duty clamps are used manually because small power is required to operate these clamps. Hand clamping leads to application of variable pressure, operator□s fatigue and more time consumed. The power driven clamping over comes the above mentioned problems of hand clamping. Power clamps are operated on the base of hydraulic or pneumatic power. Power clamps are high pressure clamping, these are quick acting, easily controllable, reliable and less time consuming.

2.9 JIGS

Jigs along with fixtures are specifically designated machine parts, which can be manufactured by any of the following methods : (a) Machining, (b) Forging, (c) Casting and (d) Complicated.

Jigs are fabricated in different pieces and joined together by welding.

Normally jigs are made of hardened steel, which are wear resistant, corrosion resistant, and thermally in sensitive. Their dimensional accuracy directly influences the accuracy of performance of the operations where these are used.

2.10 DIFFERENT TYPES OF JIGS

Different types of jigs used are described below :

Drilling Jigs

Drilling jigs are used for large number of operations. Different types of drilling jigs are described below.

Template Jig

This is a simple plate of metal or wood which carries correct locations of holes to be made in the workpiece. Size of template jig should be same as that of the workpiece. It is overlapped with the workpiece and drilling is done quickly. Use of this jig avoids the marking operation completely.

Plate Type Jig

If the work is to be done on very large scale, an improvement can be made to template jig that is plate type jig. This uses a plate having drill pushes and suitable means to hold and locate the works that it can be clamped to the plate and holds drilled directly through the bushes in correct positions.

Open Type Jig

In this jig the top is kept open and workpiece is placed on the base of the jig and the drill plate. Carrying the drill bushes is placed on the top to guide the tool. After the operation is over, the drill plate is removed and workpiece is replaced. It is shown in Figure 4.14.

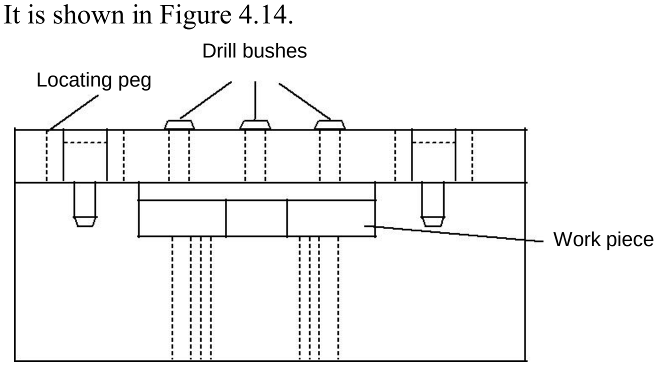


Figure 4.14 : Open Type Jig

Swinging Leaf Type Jig

This type of jig carries a leaf or plate, arranged at the top or on one side, which is capable of swinging about a fulcrum. It is normally the drill plate itself which is pivoted about a point at its one end. A swinging leaf type jig is shown in Figure 4.15. The work is loaded and unloaded with the help of swinging bolt.

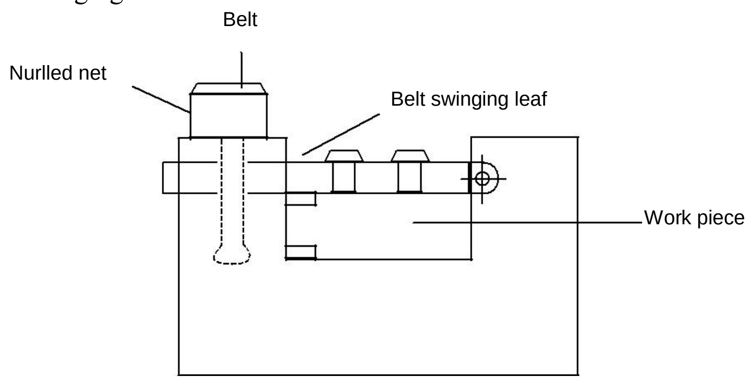


Figure 4.15 : Swinging Type Jig

Box Type Jig

Its construction is like a box and it is used for the components having irregular shape and to be operated at different places. This type of jig provides rigid support, so machining on the various places of workpiece becomes comfortable.

Solid Type Jig

This is also used for drilling holes in articles of simple shapes and relatively smaller sizes. This is made of standard section of rolled steel.

Pot Type Jig

This jig is used for drilling holes in hallow cylindrical components having smaller size. Here the body of the jig is like a pot that is used to accommodate the workpiece comfortably. Location on the inside surface of the component is provided by the clamp projecting from the bush plate located over the top of the workpieces.

Index Jigs

This type of jig is equipped with the facility of indexing, which creates positional division of the workpiece suitably. This jig is used for quick drilling of equidistant holes on the circular surface of the workpiece. By means of indexing device a hole is drilled then the workpiece is moved (indexed) to next position under the drill bush for drilling automatically.

Multi-station Jigs

These jigs are designed for multi-spindle machine where many operations can be performed simultaneously. Each spindle of the machine carries a different tool to perform a different operation. Tools and spindles are arranged in the sequence in which operations are to be performed.

Universal Jig

As indicated by the name universal jigs are meant to do large number of operations. These may have replaceable elements on them. Selection and mounting of an element depends on the type of operation to be performed.

2.11 FIXTURES

Fixtures are designed specifically for an operation and so these are named on the base of the operation to be carried out with their help. Fixtures are used to hold the workpiece properly to carryout the operations. Different types of fixtures are listed below.

(a) Turning fixtures

(b) Milling fixtures

(c) Fixture for grinding

(d) Fixture for broaching

(e) Fixture for boring/drilling

(f) Tapping fixture

(g) Fixture for welding

(h) Assembling fixture

Out of these fixtures two fixtures are described below.

Milling Fixtures

Fixtures used to perform different types of milling operations are called milling fixtures. The fixture is probably located on the table of the machine and secured in position by means of bolts and nuts. The workpiece located on the base of fixture and clamped. The fixture and associated jigs holds the workpiece and direct the tool to right position by avoiding frequent measurement and marking. The experience of varying forces by the workpiece are also overcome by the concerning fixtures and jigs. Proper locations of the fixture on the machine table is usually achieved with the help of two tons provided under the fixture base. These tons enter a T-slot of the table to provide the required location. The fixture base can then be secured to the table by means of T-bolts and nuts. The fixtures for milling operations are designed and described on the basis of milling operations, milling techniques and clamping power techniques.

(a) On the basis of types of operations the milling fixture may be of different types are listed below :

These are straddle milling fixture, face milling, slot milling, plain milling, side milling, form milling and gang milling fixtures.

(b) On the basis on technique of milling machining, milling fixtures are named as single piece milling fixture, string milling, reciprocal milling, index milling and abreast milling fixture.

(c) On the basis of clamping power and clamping method milling fixtures are named as fixture with mechanical clamping, hydraulic clamping, pneumatic clamping, automatic clamping and vice jaw clamping fixture. Some examples of sturdy fixtures which are 1/4″ steel are illustrated in Figure 4.16. The holes are spaced to go between the „*T*□ posts in the milling table. There is a 3/8″ holes in each corner, and that if for the cap head screws that may go into the „*T*□ slots nuts of the table. In third case the positioning bar holds the table absolutely parallel to the front of the table.

Figure 4.16

which is capable of preventing distortions in workpieces during welding. For this the locating elements need to be placed carefully, clamping has to be light but firm, placement of clamping elements has to be clear of the welding area and the fixture has to be quite stable and rigid to withstand the welding stresses. There is no limit of designing a welding fixture. Its design depends on and driven by the hard facts that are what you want, and how to overcome the problems appearing with the current fixture. Keeping the defect free fast production rate as major target. The famous saying "Need is the mother of invention" hold perfectly true in case of welding fixture design.

In many cases, most preferred practice is to first tack weld the structure by holding it in a welding jig and then transfers it to a holding fixture for full welding.

This helps in reducing the chances of distortion considerably and also the fixture is subjected to lesser stresses.

An example of a welding fixture is illustrated in Figure 4.17. The fixture is equipped with a rotatable clamp at variable speeds. There is an adjustable torch holder which can be moved to the right position in the limited space. This fixture is recommended for the welding on circular shaped objects.

Figure 4.16 : Examples of Welding Fixtures

Figure 4.17 : Example of a Welding Fixture

2.12 SUMMARY

The unit contents description of jigs and fixtures as a clamping tool for workpiece and guiding tool for the tool. Use of jigs and fixture directly influence the quality of performance of the operation. It improves efficiency of work by eliminating production

Welding Fixtures

Welding fixtures are normally designed to hold and support the various components (workpieces) to be welded. It is necessary to support them in a proper location of poor quality products and reducing the product cycle time. Design of jigs and fixtures truly depends on the type of operation and machine tool to be used for that operation. The use of jig and fixture involve locating the workpiece is right position on the machine tool. The meaning of location is determining the points on the work where it should be supported to restrain all the motions so that the work can be done without any problem. Some principles of locations are followed for this purpose like 3-2-1 principle of location, location on a „Vee‟ block, flat locator, cylindrical and conical and jack pin locators. The major objective of the principle of location is to clamp the rigidity of clamping. At the same time this all keep the processing area clear and available for processing. Different types of clamping devices and characteristics of a good clamping device are also described in the unit.

Along with the fixtures jigs are used to guide the tool movement during an operation. These are made of hardened steel, wear resistant and corrosion resistant steel. Different types are jigs are used for different types of operations. The commonly used fixtures are also described in the unit. Common fixtures are milling fixture and welding fixture.

UNIT 3 PRESS AND PRESS TOOLS

Structure

3.1 INTRODUCTION

Metal forming is one of the manufacturing processes which are almost chipless. These operations are mainly carried out by the help of presses and press tools. These operations include deformation of metal work pieces to the desired size and size by applying pressure or force. Presses and press tools facilitate mass production work. These are considered fastest and most efficient way to form a sheet metal into finished products.

Objectives

After studying this unit, you should be able to understand

- introduction of press tool,
- major components of press working system,
- different criteria of classification of presses,
- different types of presses,
- description of important parts of a press,

 specifications of a press,
 other press working tools, like punch and die,
 components of press working system,
 different types of die sets, and
 design considerations for die set design.

3.2 PRESS

A press is a sheet metal working tool with a stationary bed and a powered ram can be driven towards the bed or away from the bed to apply force or required pressure for various metal forming operations.

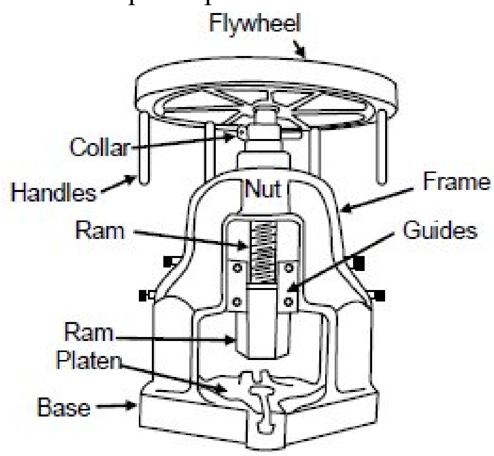


Figure 3.1 : Line Diagram of a Typical Press

Presses are available in a variety of capacities, power systems and frame type. Meaning of capacity of press is its capability to apply the required force to complete the operation.

Power and Drive System

Power systems on presses are either hydraulic presses use a large piston and cylinder to drive the ram. This system is capable to provide longer ram strokes than mechanical dries. It gives a consistent applied load. Its working is comparatively slower. These presses can be single action or double action or so on. Number of actions depends on the number of slides operating independently.

Mechanical presses are used several types of drive mechanisms. These drives includes eccentric, crankshaft, knuckle joint, etc. These drives are used to convert rotational motion given by a motor into linear motion of the ram. A fly wheel is generally used as reservoir of energy for forging operations. These presses are recommended for blanking and punching operations as the involved drives are capable to achieve very high forces at the end of their strokes.

Press working is used in large number of industries like automobile industry, aircraft industry, telecommunication electrical appliance, utensils making industry are major examples.

3.3 TYPES OF PRESSES

There are different criteria of classification of presses into different categories. These criteria, related classifications and their descriptions are discussed below.

According to the Power Source

These power source are categorized as :

Manually Operated or Power Driven

These presses are used to process thin sheet metal working operations where less pressure or force is required. These are operated by manual power. Most of manually operated presses are hand press, ball press or fly press.

Power Presses

Power presses are normally driven by mechanical mechanism or hydraulic system. Power source of these presses may be electric motor or engine.

According to the Type and Design of Frame

The type and design of frame depending on the design of frame these are classified as inclinable, straight side, adjustable bed, gap frame, horning and open end.

Press and Press Tools

Inclinable Frame Press

Its frame is called inclinable due to its capability to tilt back upto some angle. It can be locked into nay of its inclined position as shown in Figure 3.2. Its back is open to exit the scrap so it is also called open back inclinable press.

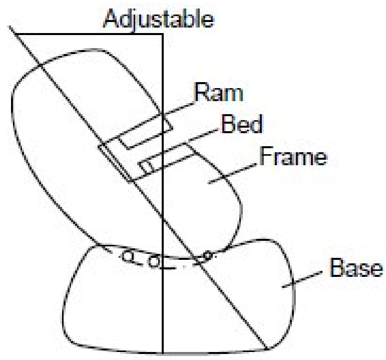


Figure 3.2 : Inclinable Frame Press

Gap Frame Press

These presses have larger frame openings, that means a wide gap between its base and ram to accommodate larger workpieces. It also has longer beds, as shown in Figure 3.3.

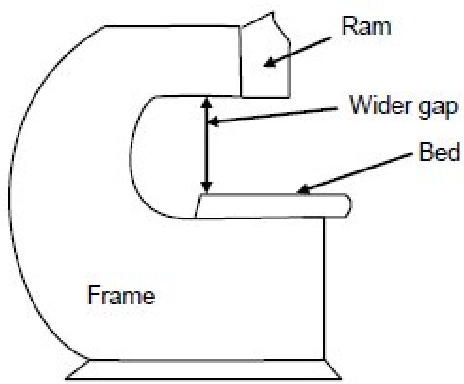


Figure 3.3 : Line Diagram of a Gap Frame Press

Straight Side Press

These presses have straight side type frame which is preferred for presses having larger bed area and high tonnage. This offers greater rigidity and capable of longer strokes. The frame consists of vertical and straight sides so it is called straight side press.

Adjustable Bed Type Press

It is also called column and knee type press because it has a knee type bed supported on its column shaped frame. Its bed (knee) can be adjusted at any desirable height by moving it vertically up or down with the help of power screws. In this structure there is slight lack of rigidity as compared to other structures. It is shown in Figure 3.4.

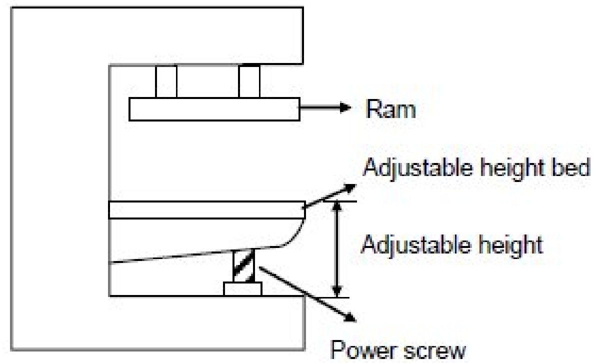


Figure 3.4 : Adjustable Bed Type Press

Open End Press

It has a solid type of vertical frame with all sides open. Driving mechanism is housed at the back and ram controlling mechanism at the front. It is easily to accommodate workpiece and dies in this type of structure. Its is identified as light duty machine.

Horning Press

It consist of a vertical frame, top of which over hangs towards the front. The over hanging portion serves for housing for driving mechanism and ram control. The frame consists of a front face as a work table called horn.

According to the Position of Frame

Presses can also be categorized by the position of frame as described below.

Inclinable Frame

Already described.

Vertical Frame

Vertical frame type of press is already been discussed, it cannot be adjusted like inclinable frame. Gap, adjustable bed, straight side, open end and honing presses are the example of vertical frames.

Horizontal Frame

It has a fixed frame in horizontal position. It provides the facility of auto ejection of produced part and scrap due to gravity.

Inclined Frame

Like inclinable frame, inclined frame press has an inclined frame but fixed, it cannot be adjusted to any other angle.

According to the Actions

According to the number of actions it can be categorized as single action, double action or triple action press. Here number of actions is same as the number of rams on the press.

According to Mechanism Used to Transmit Power to Ram

Crank Press

It consists of crankshaft driven by a flywheel, rotary motion of the crankshaft is converted into reciprocating motion with the help of a connecting rod connected to ram.

Cam Driven Press

In this press, a cam is used to press the ram down words and suitably located springs restore the original position of ram when pressure applied is removed. This mechanism has a limitation of size of the press.

Eccentric Press

In this press, the driving shaft carries an eccentric integral with it. One end of the connecting rod carried an attachment of revolving eccentric and its other end is connected to ram. As the eccentric shaft revolves, the offset between the eccentric centre and the centre of rotation of the shaft provides the required movement.

Knuckle Press

This press is driven with the help of knuckle joint mechanism. The main advantage of this press is partial back thrust is transferred to crankshaft, its major portion is transferred to back crown which is capable to hear. This

enables the application of this press for heavier jobs with high intensity of blows. These presses are recommended for coining, squeezing, extruding and embossing. They have a limitation of shorter stroke lengths.

Toggle Press

These presses work on toggle mechanism and used for double and triple action presses for driving the outer rams. However, crankshaft drive is used for the inner ram. These are used for large draw dies, in which this mechanism actuates the blank holder whereas the punch is operated by the crank driven inner ram.

Screw Press

This is known as power screw or percussion press. There is a vertical are like frame, its job forms a nut. There is a flywheel at the top of and engages the ram at its bottom. The flywheel is driven by a friction disc and the rotating screw lowers and raises the ram. The flywheel is accelerated by friction drive. Its total energy is expanded in striking the work, bringing it to a halt. The intensity of blow can be regulated by adjusting the height of the die. Higher the position of the die, lesser the speed of the flywheel and hence lower the intensity of blow. These presses have a limitation that the ram movement is slow so these are recommended for sheet metal work only.

Hydraulic Press

These presses have a piller type construction or carry the hydraulic cylinder at the top of the crown. These presses provide longer stroke than mechanical presses with adjustable intensity of blow. Their stroke length can also be adjusted with full tonnage. These are recommended for deep drawing, extruding and plastic moulding.

Rack and Pinion Press

Rack and pinion driven presses are called rack and pinion presses meant for long strokes. Major advantage is faster operation of this press due to involvement of quick return motion. There are some limitations of this press. Load bearing capability of rack and pinion mechanism is very low so these are light duty machines. Ram movement is slightly slower. These presses have very limited use now-a-days.

According to Number of Drive Gears

Number of drive gears means number of gears attached at the ends of crankshaft, used to drive it. Smaller presses have single drive and larger presses may be double drive crankshafts. Very large presses with longer beds, carry long crankshafts. They have risk of twisting. These crankshafts are provided with one driving gear at each ends, these presses are named as twine drive presses. If a press carries two crankshafts each having a twin drive, such presses are called quadruple drive presses.

According to Number of Crankshaft in a Press

According to the number of crankshafts used in a press, these are directly classified as single crank (having one crankshaft) double crank (having two crankshafts).

Method of transmission of power from Motor to Crankshaft

The method used for transmission of power from motor to crankshaft categorized presses into following **categories :**

Direct Drive Press

In this case, power is directly transferred through gears pair. Smaller gear is mounted on the motor shaft, called pinion, its mating gear which is larger, mounted on the crankshaft. The larger gear also acts as flywheel. The flywheel is attached to the crankshaft through clutch and equipped with the facility of disengaging it as per the need. Such presses have shorter strokes and these are light duty presses.

Flywheel Driven Presses

These presses consists no gears so also called “No geared presses”. For the transmission of power motor pulley is connected to flywheel driven crankshaft by Vee belt and pulley system. A clutch is used to engage or disengage the flywheel with the crankshaft. These presses are light duty presses providing shorter and quicker strokes.

Single Geared Drive Presses

This press consists of a counter shaft between motor shaft and crankshaft. Flywheel is mounted on the countershaft. Power is transferred from motor to flywheel (countershaft) through „Vee. belt drive and then from counter shaft to crankshaft through pinion and gear. Clutch is mounted between pinion and flywheel to disengaged the power transmission as per the requirements. In these presses there are two steps for rpm reduction and torque enhancement so these are heavy duty mechanics with longer strokes.

Double Geared Drive Presses

In these type of presses an additional shaft named as intermediate shaft is introduced between the countershaft mounted flywheel and the crankshaft of a single geared drive. Twin drive is possible in this case by having similar gear train on other sides of two shafts. This provides slow stroke with larger power.

According to the Purpose of Use

Some of the operations require low stroke strength and some lager stroke strength. In the same way requirements of stroke length is different for different operations. So depending on power and stroke length presses are classified as given below depending on their suitability of performing different operations.

(a) Shearing press
(b) Seaming press
(c) Straightening press
(d) Punching press
(e) Extruding press
(f) Caining press
(g) Forging press
(h) Rolling press
(i) Bending press.

3.4 MAIN PARTS OF A TYPICAL POWER PRESS

Different types of presses have almost common types of main parts. These parts are described below.

Base

The all machine tool, base is the one of the parts of a press. It is main supporting member for workpiece holding dies and different controlling mechanisms of press. Size of the table limits the size of workpiece that can be processed on a press. In case of some special presses the base carries mechanism for tilting the frame in any desirable inclined position too.

Frame

Frame constitute main body of the press located at one edge of its base. It houses support for ram, driving mechanism and control mechanisms. Some of the press have column shaped frame.

Ram

This is main operating part of the press which works directly during processing of a workpiece. Ram reciprocates to and fro within its guideways with prescribed stroke length and power. The stroke length and power transferred can be adjusted as per the requirements. Ram at its bottom end carries punch to process the workpiece.

Pitman

It is the part which connects the ram and crankshaft or ram eccentric.

Driving Mechanism

Different types of driving mechanisms are used in different types of presses like cylinder and piston arrangement in hydraulic press, crankshaft and eccentric mechanisms in mechanical press, etc. these mechanisms are used to drive ram by transferring power from motor to ram.

Controlling Mechanisms

Controlling mechanisms are used to operate a press under predetermined controlled conditions. Normally two parameters are adjusted by controlling mechanisms length of stroke of ram and power of stroke. Transfer of power can be disengaged with the help of clutch provided with driving mechanisms as per need. In most of the presses controlling mechanisms is in built with the driving mechanisms. Now-a-days compute controlled presses are being used in which controlling is guided by microprocessor. These presses provides reliable and accurate control with automation.

Flywheel

In most of the presses driven gear or driven pulley is made of the shape of flywheel, which is used for storing the energy reserve wire of energy) for maintaining constant speed of ram when punch is pressed against the workpiece. Flywheel is placed in the driving mechanism just before the clutch is sequence of power transmission.

Brakes

Brakes are very urgent in any mobile system. Generally two types of brakes are used normal brake, which can bring the driven shaft to rest quickly after disengaging it from flywheel. Other is emergency brakes which are provided as foot brake to any machine. These brakes include power off switch along with normal stronger braking to bring all motions to rest quickly.

Balster Plate

It is a thick plate attached to the bed or base of the press. It is used to clamp the die assembly rigidly to support the workpiece. The die used in press working may have more than one part that is why the phrase die assembly is being used at the place of die.

3.5 SPECIFICATIONS OF A PRESS

Expressing size of a machine (press) includes expressing each of the parameters pertaining to it quantitatively in appropriate units. Expressing size in the above mentioned way is the specifications of press. The following parameters are expressed as specifications of a press.

(a) Maximum Force : Maximum force that its ram can exert on the workpiece, this is expressed in tones and called tonnage. It varies from 5 to 4000 tonnes for mechanical press. It may be up to 50,000 tonnes by hydraulic press.

(b) Maximum Stroke Length : Maximum distance traveled by the ram from its top most position to extreme down position. It is expressed in mm. the stroke length is adjustable so different values that can be obtained between minimum and maximum of stroke length, these are also the part of specifications.

(c) Die Space : Total (maximum) surface area, along with (b . d), of bed, base, ram base. This the area in which die can be maintained.

(d) Shut Height : Total opening between the ram and base when ram is at its extreme down position. This is the minimum height of the processed workpiece.

(e) Press Adjustments : Different stroke lengths (already covered in point number 2). Different tonnage that can be set as per the requirement.

(f) Ram Speed : It is expressed as number of strokes per minute. Generally it can be 5 to 5000 strokes per minute.

3.6 PRESS TOOL

Commonly used tools which are major components of press working are punches and dies. Punch is an important part of the system which is fastened to the ram and forced into the die where workpiece to be processed is supported. Die is a work holding device, designed specifically for a particular design of a product. Die is rigidly held on the base of the press. Die carries an opening which . is perfectly aligned with the punch and its movement. Both die and punch work together as a unit and this is called a die set. Punch and die both are made of high speed steel. Die is the part where strength and wear resistant both properties are required. So normally working surface of the die is made of satellite or cemented carbide. Details of the die set are described below.

Punch

Lower end of the ram holds punch holder which is equipped with the punch plate. Punch plate is generally made of stainless steel or HSS. The punch plate holds the punch rigidly and accurately. Different ways of holding the punch are described below :

(a) Punch can be fastened by forcing it to punch plate, top end of the punch is flattened to fit in the countersunk recess as shown in Figure 3.5.

(b) Punch can be clamped to the punch plate by a set screw. The correct position of the punch is located by cutting a slot into the punch plate as shown in Figure 3.5.

(c) Shank of the punch is forced into the punch plate top end of the punch is made flat to fit into the countersunk recess as shown in Figure 3.5.

(d) Punch can be tightly secured to the punch plate with the help of grubs screws as shown in Figure 3.5.

(e) Set screws are used to fastened the punch to the punch plate as shown in Figure 3.5.

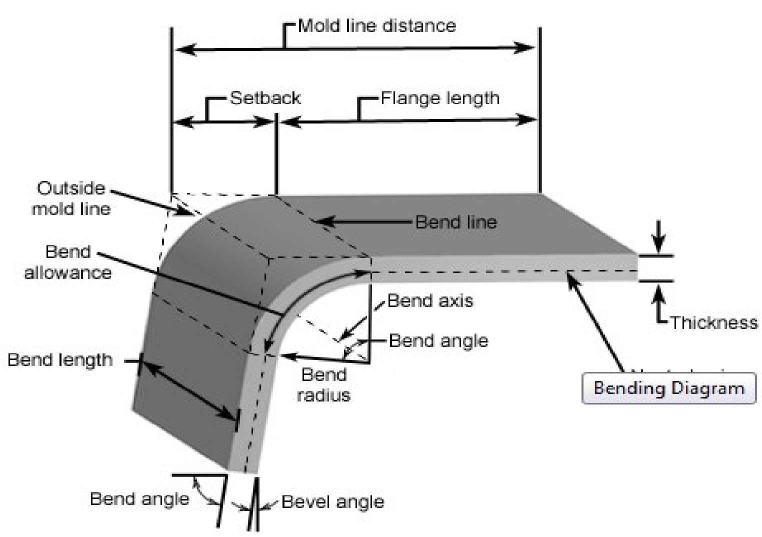
(f) Fastening of punch with the help of a set screw and it is located during fastening with the help of two dowel pins shown in Figure 3.5.

(g) Flange end of the punch is secured to the punch plate

UNIT 4 BENDING FORMING AND DRAWING DIES

Bending

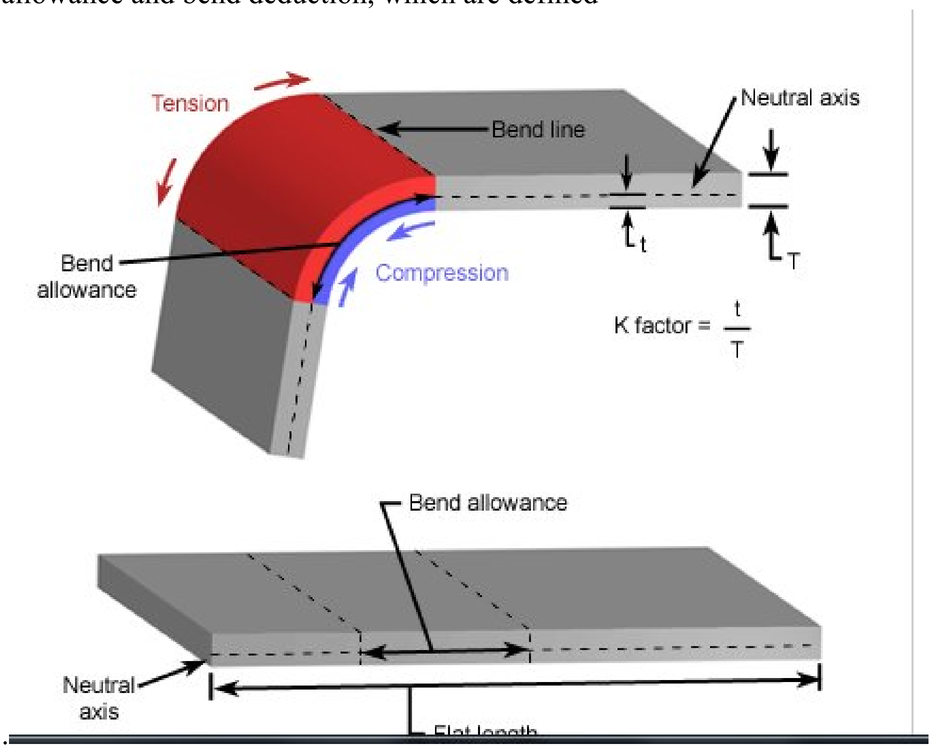
Bending is a metal forming process in which a force is applied to a piece of sheet metal, causing it to bend at an angle and form the desired shape. A bending operation causes deformation along one axis, but a sequence of several different operations can be performed to create a complex part. Bent parts can be quite small, such as a bracket, or up to 20 feet in length, such as a large enclosure or chassis. A bend can be characterized by several different parameters, shown in the image below.



- *Bend line* - The straight line on the surface of the sheet, on either side of the bend, that defines the end of the level flange and the start of the bend.
- *Outside mold line* - The straight line where the outside surfaces of the two flanges would meet, were they to continue. This line defines the edge of a mold that would bound the bent sheet metal.
- *Flange length* - The length of either of the two flanges, extending from the edge of the sheet to the bend line.
- *Mold line distance* - The distance from either end of the sheet to the outside mold line.

- *Setback* - The distance from either bend line to the outside mold line. Also equal to the difference between the mold line distance and the flange length.
- *Bend axis* - The straight line that defines the center around which the sheet metal is bent.
- *Bend length* - The length of the bend, measured along the bend axis.
- *Bend radius* - The distance from the bend axis to the inside surface of the material, between the bend lines. Sometimes specified as the inside bend radius. The outside bend radius is equal to the inside bend radius plus the sheet thickness.
- Bend angle - The angle of the bend, measured between the bent flange and its original position, or as the included angle between perpendicular lines drawn from the bend lines.
- *Bevel angle* - The complimentary angle to the bend angle.

The act of bending results in both tension and compression in the sheet metal. The outside portion of the sheet will undergo tension and stretch to a greater length, while the inside portion experiences compression and shortens. The neutral axis is the boundary line inside the sheet metal, along which no tension or compression forces are present. As a result, the length of this axis remains constant. The changes in length to the outside and inside surfaces can be related to the original flat length by two parameters, the bend allowance and bend deduction, which are defined



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- *Neutral axis* - The location in the sheet that is neither stretched nor compressed, and therefore remains at a constant length.
- *K-factor* - The location of the neutral axis in the material, calculated as the ratio of the distance of the neutral axis (measured from the inside bend surface) to the material thickness. The K-factor is dependent upon several factors (material, bending operation, bend angle, etc.) and is typically greater than 0.25, but cannot exceed 0.50.
- *Bend allowance* - The length of the neutral axis between the bend lines, or in other words, the arc length of the bend. The bend allowance added to the flange lengths is equal to the total flat length.

- *Bend deduction* - Also called the bend compensation, the amount a piece of material has been stretched by bending. The value equals the difference between the mold line lengths and the total flat length.

Roll forming

Roll forming, sometimes spelled rollforming, is a metal forming process in which sheet metal is progressively shaped through a series of bending operations. The process is performed on a roll forming line in which the sheet metal stock is fed through a series of roll stations. Each station has a roller, referred to as a roller die, positioned on both sides of the sheet. The shape and size of the roller die may be unique to that station, or several identical roller dies may be used in different positions. The roller dies may be above and below the sheet, along the sides, at an angle, etc. As the sheet is forced through the roller dies in each roll station, it plastically deforms and bends. Each roll station performs one stage in the complete bending of the sheet to form the desired part. The roller dies are lubricated to reduce friction between the die and the sheet, thus reducing the tool wear. Also, lubricant can allow for a higher production rate, which will also depend on the material thickness, number of roll stations, and radius of each bend. The roll forming line can also include other sheet metal fabrication operations before or after the roll forming, such as punching or shearing

Spinning

Spinning, sometimes called spin forming, is a metal forming process used to form cylindrical parts by rotating a piece of sheet metal while forces are applied to one side. A sheet metal disc is rotated at high speeds while rollers press the sheet against a tool, called a mandrel, to form the shape of the desired part. Spun metal parts have a rotationally symmetric, hollow shape, such as a cylinder, cone, or hemisphere. Examples include cookware, hubcaps, satellite dishes, rocket nose cones, and musical instruments.

Spinning is typically performed on a manual or CNC lathe and requires a blank, mandrel, and roller tool. The blank is the disc-shaped piece of sheet metal that is pre-cut from sheet stock and will be formed into the part. The mandrel is a solid form of the internal shape of the part, against which the blank will be pressed. For more complex parts, such as those with reentrant surfaces, multi-piece mandrels can be used. Because the mandrel does not experience much wear in this process, it can be made from wood or plastic. However, high volume production typically utilizes a metal mandrel. The mandrel and blank are clamped together and secured between the headstock and tailstock of the lathe to be rotated at high speeds by the spindle. While the blank and mandrel rotate, force is applied to the sheet by a tool, causing the sheet to bend and form around the mandrel. The tool may make several passes to complete the shaping of the sheet. This tool is usually a roller wheel attached to a lever. Rollers are available in different diameters and thicknesses and are usually made from steel or brass. The rollers are inexpensive and experience little wear allowing for low volume production of parts.

Design for Sheet Metal Forming Processes

Instructional objectives

By the end of this lecture, the student will learn the principles of several sheet metal forming processes and measures to be taken during these process to avoid various defects.

Sheet Metal Forming Processes

Sheet metals are widely used for industrial and consumer parts because of its capacity for being bent and formed into intricate shapes. Sheet metal parts comprise a large fraction of automotive, agricultural machinery, and aircraft components as well as consumer appliances. Successful sheet metal forming operation depends on the selection of a material with adequate formability, appropriate tooling and design of part, the surface condition of the sheet material, proper lubricants, and the process conditions such as the speed of the forming operation, forces to be applied, etc. A numbers of sheet metal forming processes such as *shearing, bending, stretch forming, deep drawing, stretch drawing, press forming, hydroforming etc.* are available till date. Each process is used for specific purpose and the requisite shape of the final product.

Shearing

Irrespective of the size of the part to be produced, the first step involves cutting the sheet into appropriate shape by the process called shearing. Shearing is a generic term which includes stamping, blanking, punching etc. *Figure 3.4.1* shows a schematic diagram of shearing. When a long strip is cut into narrower widths between rotary blades, it is called *slitting. Blanking* is the process where a contoured part is cut between a punch and die in a press. The same process is also used to remove the unwanted part of a sheet, but then the process is referred to *punching*. Similarly, *nibbling, trimming* are a few more examples of cutting process using the same principle of shearing process.

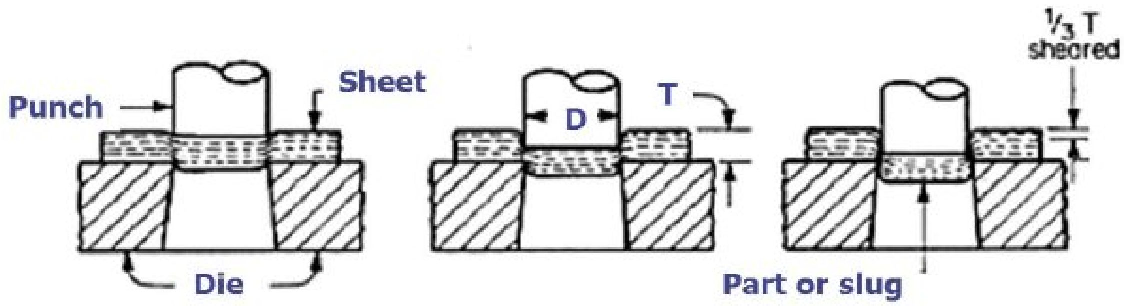

Figure 3.4.1 Schematic set-up of shearing operation[1]

Bending

Bending is the operation of deforming a flat sheet around a straight axis where the neutral plane lies. It is a very common forming process for changing the sheets and plates into channel, drums, tanks, etc. Two different scheme of bending are shown in the *figure 3.4.2*. **Spring back** is a major problem during bending of sheets that occurs due to elastic recovery by the material causing a decrease in the bend angle once the pressure is removed. The springback can be minimized by introducing excess amount of bending so that the finished bending angle is the same after the elastic recovery. However, a careful estimate of the elastic recovery based on the mechanical behaviour of the sheet material is necessary to achieve the same.

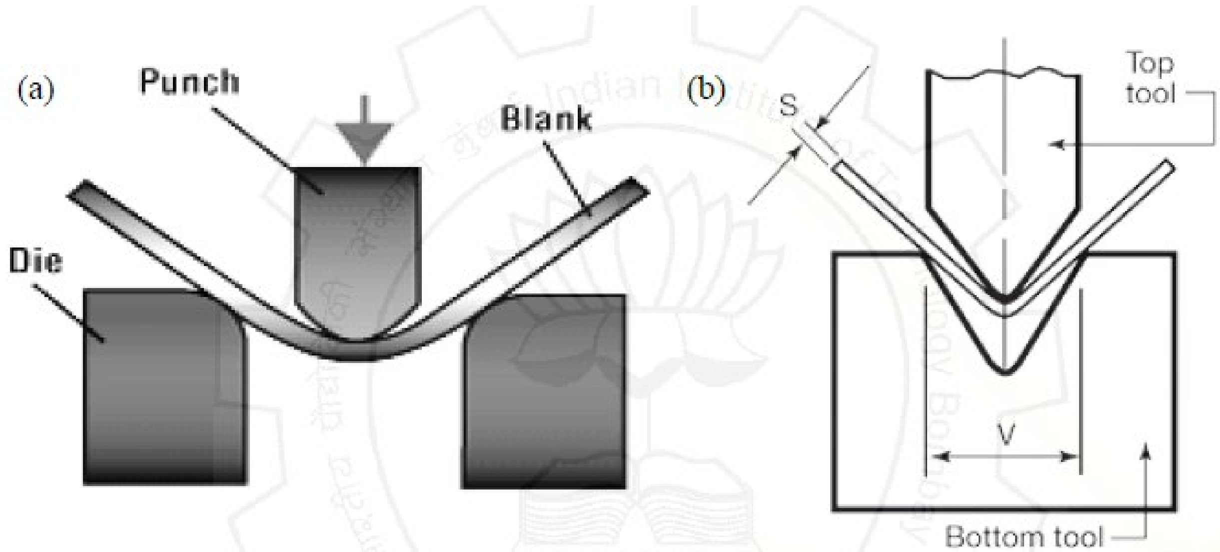

Figure 3.4.2 Schematic set-up of (a) air vee bending, and (b) die bending [3]

Stretch Forming

It is a method of producing contours in sheet metal. In a pure stretch forming process, the sheet is completely clamped on its circumference and the shape is developed entirely at the expense of the sheet thickness. Figure 3.4.3 presents a schematic set-up of stretch forming process. The die design for stretch forming is very crucial to avoid defects such as excessive thinning and tearing of the formed part. The stretch forming process is extensively used for producing complex contours in aircraft and automotive parts.

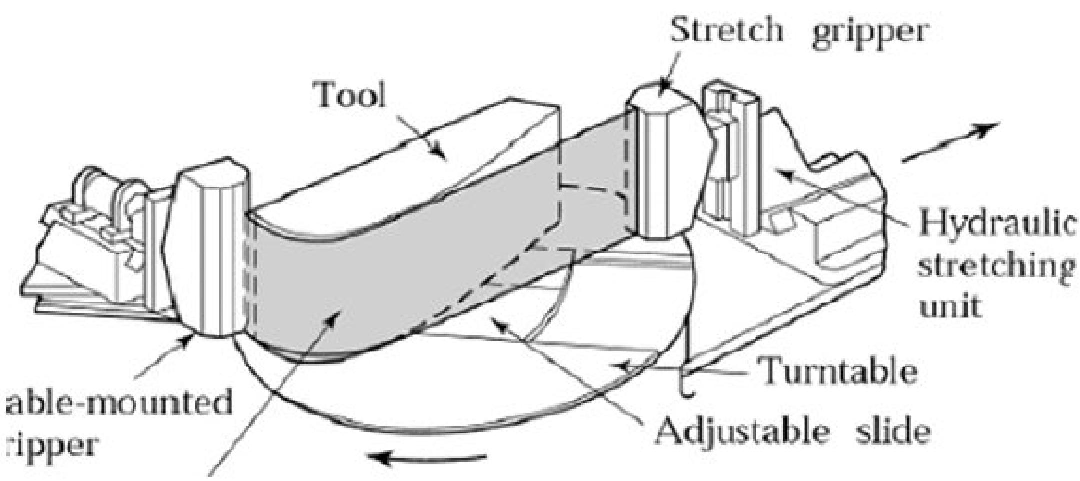

Figure 3.4.3 Schematic illustration of typical stretch forming process [3]

Deep Drawing

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. This can be achieved by redrawing the part through a series of dies.

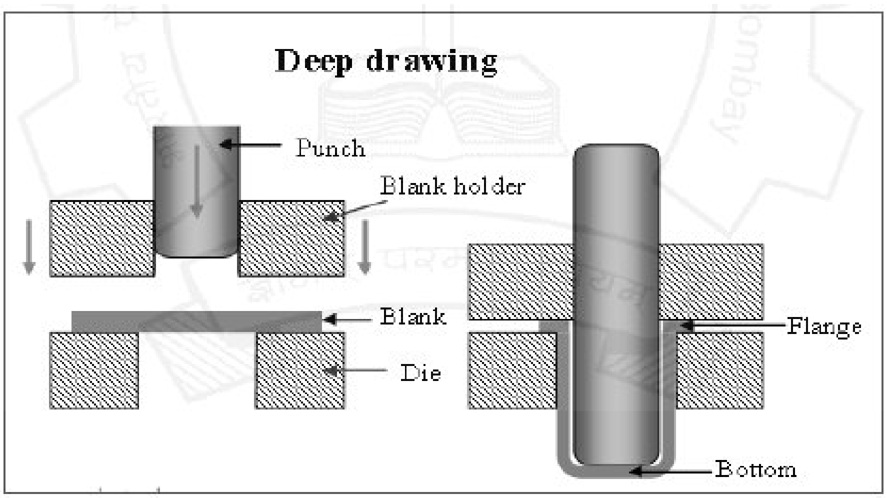

Figure 3.4.4 Schematic outline of Deep Drawing Process [3]

The metal flow during deep drawing is extensive and hence, requires careful administration to avoid tearing or fracture and wrinkle. Following are a few key issues affecting metal flow during deep drawing process and each of them should be considered when designing or troubleshooting sheet metal deep drawing stamping tools.

Type of material used and its thickness

Slightly thicker materials can be gripped better during the deep drawing process. Also, thicker sheets have more volume and hence can be stretched to a greater extent. However, the drawing force will increase with the sheet thickness. The percentage elongation property or ductility of the material is an essential quality for materials to be used for deep drawing.

Tool surface finish and use of Lubricant

Die surface finishes and lubricants are important to reduce the friction between the tool surfaces and metal being drawn, thus allowing materials to flow through tools more easily. Die temperatures can affect the viscosity of the lubricants. Slower deep drawing speed allows better metal flow.

Blank size and shape

Blank that are too large can restrict metal flow. The geometry of parts can also affect the ability of metal to flow during deep drawing process.

Blank Holding Force

Control of the blank holding force (BHF) enables control of friction on the flange during deep drawing process and significantly influences the quality of drawn part. Greater blank holding force may lead to tearing of the flange while inadequate blank holding force may lead to wrinkling of the flanges.

Punching speed

Sufficient punching speed allows time for materials to flow through the tool. Corner cracking will always occur if press speed is tool fast in deep drawing process.

Draw radius

Radius on the draw die where the material flows through should be optimum. Too big a die or punch radius can result in wrinkling where as too small a die radius would create cracking at the bottom radius of drawn part.

Draw Bead Height and Shape

This should be selected properly to control metal flow and gripping pressure in deep drawing process. Draw bead height and shape can cause materials to bend and unbend to create restrictive forces going into a tool. Increasing pressure will exerts more force on a material, creating more restraint on material going into the tool