INTRODUCTION

Over the past century, manufacturing has made considerable progress. New machine tools, high-performance cutting tools, and modern manufacturing processes enable today's industries to make parts faster and better than ever before. Although work holding methods have also advanced considerably, the basic principles of clamping and locating are still the same.

Mass production methods demand a fast and easy method of positioning work for accurate operations on it. Jigs and fixtures are production tools used to accurately manufacture duplicate and interchangeable parts. Jigs and fixtures are specially designed so that large numbers of components can be machined or assembled identically, and to ensure interchangeability of components. The economical production of engineering components is greatly facilitated by the provision of jigs and fixtures. The use of a jig or fixture makes a fairly simple operation out of one which would otherwise require a lot of skill and time. Both jigs and fixtures position components accurately; and hold components rigid and prevent movement during working in order to impart greater productivity and part accuracy. Jigs and fixtures hold or grip a work piece in the predetermined manner of firmness and location, to perform on the work piece a manufacturing operation.

A jig or fixture is designed and built to hold, support and locate every component (part) to ensure that each is drilled or machined within the specified limits. The correct relationship and alignment between the tool and the work piece is maintained. Jigs and fixtures may be large (air plane fuselages are built on picture frame fixtures) or very small (as in watch making). Their use is limited only by job requirements and the imagination of the designer. The jigs and fixtures must be accurately made and the material used must be able to withstand wear and the operational (cutting) forces experienced during metal cutting. Jigs and fixtures must be clean, undamaged and free from chips and grit. Components must not be forced into a jig or fixture. Jigs and fixtures are precision tools. They are expensive to produce because they are made to fine limits from materials with good resistance to wear. They must be properly stored or isolated to prevent accidental damage, and they must be numbered for identification for future use.
Jigs and fixtures are devices used to facilitate production work, making interchangeable pieces of work possible at a savings in cost of production. A jig is a guiding device and a fixture a holding device. Jigs and fixtures are used to locate and hold the work that is to be machined. These devices are provided with attachments for guiding, setting, and supporting the tools in such a manner that all the work pieces produced in a given jig or fixture will be exactly alike in every way. The employment of unskilled labor is possible when jigs and fixtures can be used in production work. The repetitive layout and setup (which are time-consuming activities and require considerable skill) are eliminated. Also, the use of these devices can result in such a degree of accuracy that work pieces can be assembled with a minimum amount of fitting. A jig or fixture can be designed for a particular job. The form to be used depends on the shape and requirement of the work piece to be machined.
JIGS

A jig is a special device that holds, supports, or is placed on a part to be machined. It is a production tool made so that it not only locates and holds the workpiece but also guides the cutting tool as the operation is performed. Jigs are usually fitted with hardened steel bushings for guiding drills or other cutting tools.

A jig is any of a large class of tools in woodworking, metalworking, and some other crafts that help to control the location or motion (or both) of a tool. Some types of jigs are also called templates or guides. The primary purpose for a jig is for repeatability and exact duplication of a part for reproduction. An example of a jig is when a key is duplicated, the original is used as a jig so the new key can have the same path as the old one. Since the advent of automation and CNC machines, jigs are often not required because the tool path is digitally programmed and stored in memory.

The most-common jigs are drill and boring jigs. These tools are fundamentally the same. The difference lies in the size, type, and placement of the drill bushings. Boring jigs usually have larger bushings. These bushings may also have internal oil grooves to keep the boring bar lubricated. Often, boring jigs use more than one bushing to support the boring bar throughout the machining cycle.

Jig that expedites repetitive hole center location on multiple interchangeable parts by acting as a template to guide the twist drill or other boring device into the precise location of each intended hole center. In metalworking practice, typically a hardened bushing lines each hole on the jig to keep the twist drill from cutting the jig.

Jigs or templates have been known long before the industrial age. There are many types of jigs, and each one is custom-tailored to do a specific job. Many jigs are created because there is a necessity to do so by the tradesmen. Some are to increase productivity, to do repetitious activities and to do a job more precisely. Because jig design is fundamentally based on logic, similar jigs used in different times and places may have been created independently.

Specialized industry applications have led to the development of specialized drill jigs. For example, the need to drill precisely located rivet holes in aircraft fuselages and wings led to the design of large jigs, with bushings and liners installed, contoured to the
surface of the aircraft. A portable air-feed drill with a bushing attached to its nose is inserted through the liner in the jig and drilling is accomplished in each location.

![Diagram](image1.png)

**Fig.** A jig guides the cutting tool, in this case with a bushing.

Jigs may be divided into two general classes: boring jigs and drill jigs. Boring jigs are used to bore holes that either are too large to drill or must be made an odd size. Drill jigs are used to drill, ream, tap, chamfer, counter bore, countersink and reverse. Basic jig is almost the same for either machining operation. The only difference is in the size of the bushings used.

![Diagram](image2.png)

**Fig.** Boring jig.
FIXTURES

A fixture is a device for locating, holding and supporting a workpiece during a manufacturing operation. It is a production tool that locates, holds, and supports the work securely so the required machining operations can be performed.

Fixtures have a much-wider scope of application than jigs. These workholders are designed for applications where the cutting tools cannot be guided as easily as a drill. With fixtures, an edge finder, center finder, or gage blocks position the cutter. Examples of the more-common fixtures include milling fixtures, lathe fixtures, sawing fixtures, and grinding fixtures. Moreover, a fixture can be used in almost any operation that requires a precise relationship in the position of a tool to a workpiece.

Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations. Fixtures must correctly locate a workpiece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the workpiece in that location for the particular processing operation. There are many standard work holding devices such as jaw chucks, machine vises, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications.

Fixtures are normally designed for a definite operation to process a specific workpiece and are designed and manufactured individually. Jigs are similar to fixtures, but they not only locate and hold the part but also guide the cutting tools in drilling and boring operations. These work holding devices are collectively known as jigs and fixture. Set blocks and feeler or thickness gauges are used with fixtures to reference the cutter to the work piece. A fixture should be securely fastened to the table of the machine upon which the work is done. Though largely used on milling machines, fixtures are also designed to hold work for various operations on most of the standard machine tools. Fixtures vary in design from relatively simple tools to expensive, complicated devices. Fixtures also help to simplify metalworking operations performed on special equipment.
Fixtures are most often identified by the machine tool where they are used. Examples include mill fixtures or lathe fixtures. But the function of the fixture can also identify a fixture type. So can the basic construction of the tool. Thus, although a tool can be called simply a mill fixture, it could also be further defined as a straddle-milling, plate-type mill fixture. Moreover, a lathe fixture could also be defined as a radius-turning, angle-plate lathe fixture. The tool designer usually decides the specific identification of these tools. It, use set blocks and thickness, or feeler, gages to locate the tool relative to the workpiece (as shown in figure).

Fig. A fixture references the cutting tool, in this case with a set block.

Fixtures are normally classified by the type of machine on which they are used. Fixtures can also be identified by a subclassification. For example, if a fixture is designed to be used on a milling machine, it is called a milling fixture. If the task it is intended to perform is straddle milling, it is called a straddlemilling fixture. The same principle applies to a lathe fixture that is designed to machine radii. It is called a lathe-radius fixture.
The following is a partial list of production operations that use fixtures:

<table>
<thead>
<tr>
<th>Operation</th>
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<tr>
<td>Assembling</td>
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<td>Honing</td>
<td>Turning</td>
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<tr>
<td>Inspecting</td>
<td>Welding</td>
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TYPES OF JIGS

Drill jigs may be divided into two general types, open and closed. Open jigs are for simple operations where work is done on only one side of the part or sometimes two sides of a workpiece. Closed jigs, on the other hand, operate on two or more sides. The most-common open jigs are template jigs, plate jigs, table jigs, sandwich jigs, and angle plate jigs.

Typical examples of closed jigs include box jigs, channel jigs, and leaf jigs. Other forms of jigs rely more on the application of the tool than on their construction for their identity. These include indexing jigs, trunnion jigs, and multi-station jigs. The names used to identify these jigs refer to how the tool is built. Template jigs are normally used for accuracy rather than speed. This type of jig fits over, on, or into the work and is not usually clamped. Templates are the least expensive and simplest type of jig to use. They may or may not have bushings. When bushings are not used, the whole jig plate is normally hardened.

Template jigs

Template jigs are normally used for accuracy rather than speed. This type of jig fits over, on, or into the work and is not usually clamped. Templates are the least expensive and simplest type of jig to use. They may or may not have bushings. When bushings are not used, the whole jig plate is normally hardened.
**Plate jigs**

Plate jigs are similar to templates. The only difference is that plate jigs have built-in clamps to hold the work. These jigs can also be made with or without bushings, depending on the number of parts to be made.
**Table jig**

Plate jigs are sometimes made with legs to raise the jig off the table for large work. This style is called a table jig.
**Sandwich jigs**

Sandwich jigs are a form of plate jig with a back plate. This type of jig is ideal for thin or soft parts that could bend or warp in another style of jig. Here again, the use of bushings is determined by the number of parts to be made.

![Sandwich jigs](image1)

**Angle-plate jigs**

Angle-plate jigs are used to hold parts that are machined at right angles to their mounting locators. Pulleys, collars, and gears are some of the parts that use this type of jig.

![Angle-plate jigs](image2)
Modified angle-plate jig

A variation in the angle-plate jig is called as modified angle-plate jig, which is used for machining angles other than 90 degrees. Both of these examples have clearance problems with the cutting tool. As the drill exits the product being drilled, it has little or no room for the drill point to clear the product completely, produce a round hole all the way through the part wall, and avoid drilling the part locator. This is most noticeable in Figure, where an angled hole requires additional clearance to the relieved portion of the part locator. Additional clearance here would allow the drill to complete the hole and avoid drilling the relieved portion of the locator. The part locator will most likely be hardened and the drill will be lost as a result of any attempted drilling. Additional clearance on the relieved diameter of the part locator may be possible. A larger clearance hole in the locator could also be added if the relieved diameter cannot be reduced. The additional design consideration added to the locator would include the feature to provide the correct orientation of this clearance hole or machined relief to line up with the bushing location.

Fig. Modified angle-plate jig
**Box jigs**

Box jigs, or tumble jigs, usually totally surround the part. This style of jig allows the part to be completely machined on every surface without the need to reposition the work in the jig.

![Box jigs](image)

**Channel jigs**

Channel jigs are the simplest form of box jig. The work is held between two sides and machined from the third side. In some cases, where jig feet are used, the work can be machined on three sides.

![Channel jigs](image)
**Leaf jigs**

Leaf jigs are small box jigs with a hinged leaf to allow for easier loading and unloading. The main differences between leaf jigs and box jigs are size and part location. Leaf jigs are normally smaller than box jigs and are sometimes made so that they do not completely surround the part. They are usually equipped with a handle for easier movement.

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**Fig. Leaf jigs**
Indexing jigs

Indexing jigs are used to accurately space holes or other machined areas around a part. To do this, the jig uses either the part itself or a reference plate and a plunger. Larger indexing jigs are called rotary jigs.

Trunnion jigs

Trunnion jigs are a form of rotary jig for very large or odd-shaped parts. The part is first put into a box-type carrier and then loaded on the trunnion. This jig is well suited for large, heavy parts that must be machined with several separate plate type jigs.
Pump jigs

Pump jigs are commercially made jigs that must be adapted by the user. The lever-activated plate makes this tool very fast to load and unload. Since the tool is already made and only needs to be modified, a great deal of time is saved by using this jig.
Multistation jigs

Multistation jigs are made in any of the forms already discussed. The main feature of this jig is how it locates the work. While one part is drilled, another can be reamed and a third counter bored. The final station is used for unloading the finished parts and loading fresh parts. This jig is commonly used on multiple-spindle machines. It could also work on single-spindle models.

There are several other jigs that are combinations of the types described. These complex jigs are often so specialized that they cannot be classified. Regardless of the jig selected, it must suit the part, perform the operation accurately, and be simple and safe to operate.
TYPES OF FIXTURES

The names used to describe the various types of fixtures are determined mainly by how the tool is built. Jigs and fixtures are made basically the same way as far as locators and positioners are concerned. The main construction difference is mass. Because of the increased tool forces, fixtures are built stronger and heavier than a jig would be for the same part.

Plate fixtures

Plate fixtures are the simplest form of fixture. The basic fixture is made from a flat plate that has a variety of clamps and locators to hold and locate the part. The simplicity of this fixture makes it useful for most machining operations. Its adaptability makes it popular.

Fig. Plate fixtures
Angle-plate fixture

The angle-plate fixture is a variation of the plate fixture. With this tool, the part is normally machined at a right angle to its locator.

Modified angle-plate fixture

While most angle-plate fixtures are made at 90 degrees, there are times when other angles are needed. In these cases, a modified angle-plate fixture can be used.
Vise-jaw fixtures

Vise-jaw fixtures are used for machining small parts. With this type of tool, the standard vise jaws are replaced with jaws that are formed to fit the part. Vise-jaw fixtures are the least expensive type of fixture to make. Their use is limited only by the sizes of the vises available.

Indexing fixtures

Indexing fixtures are very similar to indexing jigs. These fixtures are used for machining parts that must have machined details evenly spaced. The parts shown in Figure are examples of the uses of an indexing fixture.
Fig. Indexing fixtures

Fig. Parts machined with an indexing fixture.
**Multistation fixtures**

Multistation fixtures are used primarily for high-speed, high-volume production runs, where the machining cycle must be continuous.

**Duplex fixtures**

Duplex fixtures are the simplest form of multistation fixture, using only two stations. This form allows the loading and unloading operations to be performed while the machining operation is in progress. For example, once the machining operation is complete at station 1, the tool is revolved and the cycle is repeated at station 2. At the same time, the part is unloaded at station 1 and a fresh part is loaded.

Fig. Duplex fixtures
Profiling fixtures

Profiling fixtures are used to guide tools for machining contours that the machine cannot normally follow. These contours can be either internal or external. Since the fixture continuously contacts the tool, an incorrectly cut shape is almost impossible. The operation in Figure 2–24 shows how the cam is accurately cut by maintaining contact between the fixture and the bearing on the milling cutter. This bearing is an important part of the tool and must always be used.

Fig. Profiling fixtures
**Jig design**

A fixture is a means through which a part is securely fastened to the machine tool table to accurately locate, support and hold the part during the machining operation. A jig is a special class of fixture, which in addition to provide all the functions as above, also guides the cutting tool during machining. This is generally used for the operations such as drilling, boring, reaming, tapping, counter boring, etc.

Jigs should be of light construction, consistent with rigidity to facilitate handling, especially when jigs have to be turned over so that holes can be drilled from more than one side. All unnecessary metal should be cored out of the jig body. A jig which is not bolted to the machine table should be provided with feet, preferably four, opposite all surfaces containing guide bushings, so that it will 'rock' if not standing square on the table and so warn the operator.

Drill jigs provide methods for correctly locate the workpiece with respect to the tool, Securely clamp and rigidly support the workpiece during the operation and Guide the tool Position and/or fasten the jig on a machine.

While designing the jig we have to take process considerations like,

- Type of Operations (drilling, reaming, other)
- Number of Operations
- Similar vs. different
- Sequential vs. simultaneous
- Sequence
- Inspection Requirements
Materials used in Jigs and fixtures are made from a variety of materials, some of which can be hardened to resist wear. It is sometimes necessary to use nonferrous metals like phosphor bronze to reduce wear of the mating parts, or nypons or fibre to prevent damage to the work piece. Given below are the materials often used in jigs, fixtures, press tools, etc.

- Hardened steel
- Carbide
- Bronze
- Stainless steel

Make all component clamping devices as quick acting as possible. Design the jig fool-proof by the use of foul pins and similar devices, that is arrange it so that the component, tools or bushes cannot be inserted except in the correct way. Make some locating points adjustable when the component is a rough casting and may be out of alignment. Locate clamps so that they will be in the best position to resist the pressure of the cutting tool when at work. If possible, make all clamps integral parts of the jig and avoid the use of loose parts. Avoid complicated clamping and locating arrangements which are liable to wear or need constant attention. Place all clamps as nearly as possible opposite some bearing point of the component to avoid springing the component and in accessible positions.

All sharp edges should be removed from the various detail parts of the jig. Provide handles or other devices wherever these will make the handling of the jig more convenient. If possible, place all tool guide bushings inside the geometrical figure formed by connecting the points of location of the feet. Make, all locating points visible to the operator when placing the component in position in the jig so that the component can be seen to be correctly located. The operator should also be able to have an unobstructed view of the clamps.

Before using the jig in the machine shop for commercial purposes, test all jigs as soon as they are made. The location points, which are hardened if necessary, are
established with considerations to machining operations, if any, to follow and that any mating parts are located from the same datum surface.

Locating and clamping arrangements are designed to reduce idle time to a minimum by using simple clamps which are easy and quick to operate and also operate without damaging the component. Springs should be used whenever possible to elevate the clamps clear of the component whilst being loaded or unloaded. Clamps should be positioned above the points supporting the component, in order to avoid distortion and should be strong enough to hold the component without bending. Generally clamps should not be relied upon for holding the work against the pressure exerted by the cutting tool.

Locating and supporting surfaces should, whenever possible, be renewable. Such surfaces should be of hard material. The process of inserting and withdrawing the component from the jig should be as easy as possible. Ample space should be left between the jig body and the component for hand movements. Some means of ejection should exist to release the component if it sticks in the jig.

The design of the jig must be safe. Handles or levers should be large enough to clear adjacent parts so that pinched fingers are avoided. If necessary, make provision for the use of coolant. Position locations at places where there is no flash or burr on the Component. If possible, eliminate spanners by the use of levers. If spanners have to be used, make one spanner fit all the clamp operating bolts and nuts.
Tolerances should be given at the design stage to the use of standardized jig components.

Torque, $M = K A f^{0.8} d^{1.8}$

Thrust, $T = 2 K B f^{0.8} d^{0.8} + K E d^{2}$

Where, $d = \text{drill diameter}$

$K, A, B, E - \text{Constants}$
### Work-Material Constants for Calculating Torque and Thrust

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### Torque and Thrust Constants Based upon Ratios \( c/d \) or \( w/d \)

<table>
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<tr>
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* \( c \) = chisel edge length, in. (mm)

* \( d \) = drill diameter, in. (mm)

* \( w \) = web thickness, in. (mm)

### Torque and Thrust Terms Based upon Feed

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Jig Bushes

To position and guide the cutting tool for cutting, we use bushes to reduce the wear and tear.

Headless Bush

Headless Bush most popular, least expensive and light axial load is expected. Headless press fit bushes are generally used where replacement due to wear is not anticipated during the life of the tooling, and where a single operation such as drilling or reaming is performed. Their benefits are that they can be mounted flush with the jig plate, and where space is at a premium they can be placed closer together than headed bushes.

Fig. Headless Bush
**Headed Drill Bush**

Headed press fit bushes are generally used where replacement due to wear is not anticipated during the life of the tooling, and where a single operation such as drilling or reaming is performed. The shoulder is convenient for pressing the bush home and is also useful when it is desired to feed down to a dead stop. They are generally preferable where heavy axial loads may force a headless bush out of the jig plate. Headed drill bush for this Jig plate can be thinner.

![Headed drill bush](image)

**Fig. Headed drill bush**

**Lock Screw Locating Jigs**

These jigs are designed to locate the lock screw position accurately and quickly, in relation to the liner used. The spigot fits the inside diameter of the liner for location.

![Lock Screw Locating Jigs](image)

**Fig. Lock Screw Locating Jigs**

**Clearance between Bush and Part**
Clearance holes or burr slots should be provided in the jig to allow for the burr formed when the drill breaks through the component and for swarf clearance, particularly from locating faces.

Burr clearance

Fig. Burr clearance

**Slip Renewable Bush**
Fixed & slip renewable bushes are used where more than one operation is performed in the same hole of the component, such as drilling, and then reaming or counter boring. The renewable bush is held in place by a locking screw.

Lock screws are used with fixed & slip renewable bushes to ensure that they do not turn or move during operation.

Fig. Slip renewable bush

Fig. chip clearance for multiple operations
Slip bush arrangement

Extended bush
Drill bushing position for angular entry

Fig. Drill bushing position for angular drill entry
Modification of standard bushings for close hole drilling

Fig. Drilling irregular work surfaces
Basic Design Steps

1. Method of locating the part – identify the standard components required for locating
Purpose.

2. Design the clamping method. Make a proper choice of clamps – C-washer, swing washer, nut, strap clamp, toggle clamp, etc.

3. Design any supports required

4. Design the jig bushes required.

5. Design the jig body.

**Basic Design  Drill Jig**

1. Method of locating the part – The central hole which helps in locating as well as indexing for the hole.

2. Clamping can be done with a nut and a C-washer

   Indexing will have to be done with a plunger type retracting.