

Fixture Design

Training Objective

After watching the program and reviewing this printed material, the viewer will understand the principles of fixture design and the use of fixtures in manufacturing operations.

- Basic fixture design is explained
- Fixture components are shown
- Machine forces on the fixture are demonstrated
- Applications of various fixture types are detailed

Fixtures and Jigs

Fixtures are workholding devices designed to hold, locate and support workpieces during manufacturing operations. Fixtures provide a means to reference and align the cutting tool to the workpiece but they do not guide the tool. Fixtures that have the added function of guiding the tool during manufacturing are called jigs.

Fixturing devices include:

- Various standard clamps, chucks, and vises
- Metal plates containing dowel and/or tapped locating holes or key slots
- Dedicated fixtures with specific design and build requirements

Part Machining

To enable accurate machining, the part must be held in a setup that guarantees a definite location (or position) and an orientation in space in relation to the part's datum points and/or surfaces. Moreover, the setup must ensure repeatable part positioning throughout the production run.

Workholding or fixturing is accomplished by first visualizing the part as a solid object in space and in relation to a coordinate system referred to as the Twelve Degrees of Freedom. These 12 coordinates consist of:

- Plus and minus movement (2) and clockwise and counter-clockwise rotation (2) around the X axis
- Plus and minus movement (2) and clockwise and counter-clockwise rotation (2) around the Y axis
- Plus and minus movement (2) and clockwise and counter-clockwise rotation (2) around the Z axis

Once the workpiece is properly and securely fixed in the given space, these 12 degrees of freedom (movement) are cancelled. Fixture holding force can be applied mechanically, electrically, pneumatically or hydraulically.

Fixture Type and Design

The fixture must be designed to withstand the forces generated by the machining process. Allowances in fixture design, as well as part design, must be made with respect to firm clamping of the work and in the robustness of the fixture itself. Additionally, the forces generated by the tool should be directed toward the clamping whenever possible.

Fixture types fall generally into five groups:

1. Plate Fixtures – Plate fixtures are constructed from a plate with a variety of locators, supports and clamps. They are the most common type of fixture because their versatility makes them adaptable to a wide range of machine tools. They are made from many different kinds of materials, which are governed only by the part being machined and the process being performed.
2. Angle-Plate Fixtures – Angle-plate fixtures are a modification of plate fixtures in that rather than a reference surface parallel to the mounting surface, it is set perpendicular to the mounting surface.
3. Vise-Jaw Fixtures – Vise-jaw fixtures are modified inserts for vises designed to accommodate a particular workpiece. These fixtures are the least expensive and simplest to modify. The only limitations to these types of fixtures are size of the part and capacities of available vises.
4. Indexing Fixtures – Indexing fixtures are used to reference workpieces that need machining details set at prescribed spacings. Indexing fixtures must have a positive means to accurately locate and maintain the indexed position of the part.
5. Multi-Part or Multi-Station Fixtures – Multi-part or multi-station fixtures are normally used for either machining multiple parts in a single setup, or machining individual parts in sequence, performing different operations at each station.

In addition to their basic construction, fixtures may be classified in respect to the process or machine tool to be used in the machining process. The primary types include:

- Milling Fixtures – Milling fixtures are the most common type of fixture and include standard vises and clamps. However, as the workpiece size, shape and complexity becomes more sophisticated so does the fixture. Tombstones, which are commonly used on horizontal machining centers, come in a wide variety of configurations to hold multiple parts on up to four sides of the fixture. The t-slots of the machine table are standardized in size and spacing and are the primary means of holding work and fixturing devices for machining. Fixtures are typically mounted to the table using a variety of accessories such as clamps, straps, t-slot bolts, nuts and jacks.
- Lathe Fixtures – The same basic design principles that apply to milling fixtures also apply to lathe, or turning, fixtures, with one major difference. In most milling operations, the cutting tool rotates during machining, while with turning the part rotates. This situation creates another condition the tool designer must deal with - centrifugal, or rotational, force. Workholding devices include two to six jaw chucks and collets of varying shapes and diameters. Work may also be held between the head and tail stock of the lathe or “between centers.”
- Grinding Fixtures – Grinding fixtures are a family of fixtures rather than a single classification. The two major types of grinding fixtures are those used for surface grinding and cylindrical grinding. The magnetic table is the preferred workholding device on surface grinders. Cylindrical grinding is usually a secondary operation after turning. Often the same center holes used for between-centers turning may be used for grinding the part. As friction is more of a factor in grinding than in other processes, fixture design must allow for coolant flow and swarf removal. If not built into the grinding machine itself, the fixture design should include wheel dressing capability as well.
- Broaching Fixtures – Broaching fixtures hold and locate the part in relation to the broaching tool. Internal and external broaching requires different approaches to their respective designs. Internal broaching requires less clamping because the process tends to keep the part firmly seated on the fixture. External broaching requires resistance to both pull and push forces that are exerted on the part, requiring more sophisticated fixturing.

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Modular Fixturing

Modular systems allow the rapid construction of fixtures from kits of various components such as baseplates, supports, locators and clamping devices.

Modular systems start from a pattern of locating dowel holes and tapped holes, or from conventional t-slots.

A t-slot-based system starts with a t-slotted baseplate. Fixture elements like clamps are attached to the baseplate, angle-plate, and so on, to create the fixture. Like t-slotted machine tables, the t-slot system has one major disadvantage -- it lacks exact fixed references in the X and Y axes. Time is wasted when locating and reconstructing previous setups.

Precision dowel-pin-based modular fixturing systems do assure the exact position of each fixture element. Its disadvantage is that the dowel pin layout may restrict the location of clamping devices.

Fixture Economics

Of major concern in fixture design is the cost-to-benefit ratio. Fixture costs are amortized by production quantities, part quality requirements and tooling accuracy. Also to be considered are:

- Tool life
- Workpiece location
- Support and tool referencing
- Clamp requirements

To justify fixture cost and the lowest cost per part, the fixture must exhibit:

- Fast operational characteristics
- Ease of part loading and unloading
- Foolproof part locating during the production run

Fixture Function

Machining is basically a method of material or stock removal to a specified limit or tolerance. To control this removal, the machining tool is fitted with stops, gages or computer controls. Also, spatial relationships between the surface or edge being machined and any part of the fixture must be identified and controlled.

Tool positioning in relation to the workpiece, or vice versa, is commonly referenced from designated alignment or gaging surfaces that are part of, or secured to, the worktable or fixture. Gages and setup blocks are the standard means of setting these relationships. Optical methods may also be used effectively.

Review Questions

1. A fixture having the added function of guiding a tool is called a:
 - a. dedicated fixture
 - b. alignment bushing
 - c. CNC device
 - d. jig

2. The number of degrees of part freedom is:
 - a. 24
 - b. 6
 - c. 12
 - d. 18

3. With regard to question #2, clockwise and counter-clockwise rotation accounts for how many total degrees of freedom?:
 - a. 2
 - b. 12
 - c. 4
 - d. 6

4. An angle-plate fixture's reference surface is:
 - a. parallel to the mounting surface
 - b. perpendicular to the mounting surface
 - c. adjacent to the mounting surface
 - d. only used in horizontal milling operations

5. Indexing fixtures are used:
 - a. to ensure accurate repeatability
 - b. to program sequential operations
 - c. where there are prescribed locations and spacings to be machined
 - d. for parts of large diameter

6. Lathe fixture design is premised on the fact that:
 - a. the tool rotates
 - b. the work rotates
 - c. setup repeatability is easier
 - d. indexing is rarely required

7. Cylindrical grinding usually is performed:
 - a. without fixturing
 - b. after a milling operation
 - c. after a turning operation
 - d. with magnetic holding devices

8. Tool positioning is usually referenced from:
 - a. the center of the part
 - b. designated gaging surfaces
 - c. point of maximum tool travel
 - d. point of tool contact to the work

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Answer Key

1. d
2. c
3. d
4. b
5. c
6. b
7. c
8. b