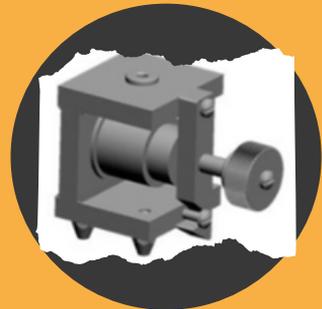# POLITEKNIK
MALAYSIA
PORT DICKSON

JIG AND
FIXTURES DESIGN
VERSION 1

NOOR HAPIZAH BINTI ABDULLAH
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JIG AND FIXTURE DESIGN
VERSION 1

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PREFACE

This book aims to provide a comprehensive guide to the design, construction, and application of jigs and fixtures. It covers fundamental concepts, design principles, material selection, and case studies, offering practical insights and techniques for engineers, technicians, and students in the field of manufacturing engineering.

By delving into the intricacies of jigs and fixtures, readers will gain a solid understanding of how these tools can be effectively utilized to enhance manufacturing processes, improve product quality, and drive innovation in production techniques.

Preface

1 INTRODUCTION TO JIG AND FIXTURE

2 SUPPORTING AND LOCATING

3 CLAMPING AND WORKHOLDING

INTRODUCTION TO JIG AND FIXTURE

CHAPTER

01

- Explain the purpose of tool design in manufacturing.
- Explain types and functions of jigs and fixtures.
- Solve the analysis for economic design

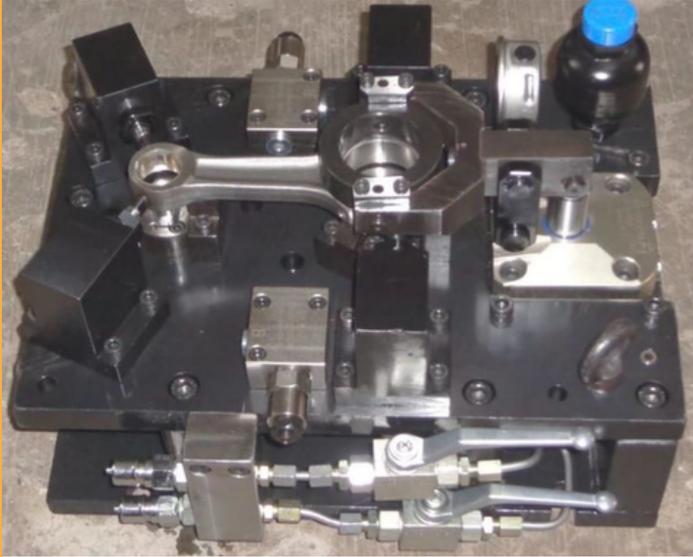# 1. 1 The purpose of tool design in manufacturing

a) The objectives of tool design

- **Primary Function:** The tool must perform its intended function effectively, whether it's cutting, shaping, measuring, or assembling.
- **Innovation:** Creativity in design can lead to tools that solve problems in new ways or provide competitive advantages.
- **Safety:** The design must prioritize the safety of the user, reducing the risk of accidents or injuries during operation.
- **Manufacturing Costs:** The design should minimize production costs, making the tool affordable to produce.
- **Simplicity:** The tool should be easy to operate, with intuitive controls and minimal complexity.

Figure 1.1 : Example of the machinist at a lathe machine
Source: https://en.wikipedia.org/wiki/Tool_and_die_maker

b. The process of planning design

There are three steps involved in the process of Planning Design :-

1. Part Drawing

- The tool designer obtains a duplicate of the part geometry that will be utilized to manufacture the part.
- Many part prints are supplied electronically and may contain a physical model referred to as the prototype.
- There factors must be considered to ensure functionality, efficiency, and precision when design jig and fixture:

  i. Workpiece Specifications
  ii. Material
  iii. Tolerances
  iv. Production Volume:
  v. Machine Tool Compatibility
  vi. Clamping and Locating
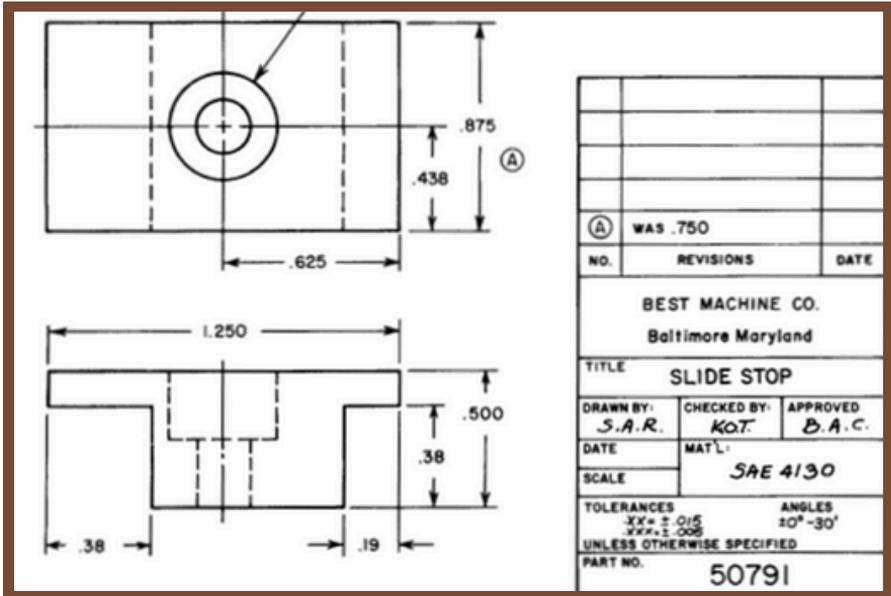 vii. Ease of Use:
  viii. Safety

Figure 1.2 : Example of part drawing

2. Production Plan

This strategy is also used by the tool designer to guide the design process. The production plan may comprise the following:

❏ Specification of machine tools for every task
❏ Specification of cutter use for every task.
❏ The process of task.
❏ The item has undergone prior machining processes.

3. Additional Plan

The tool designer needs to look into every relevant detail throughout this stage of the design process such as:

Should machines with several spindles or just one be used?

What type of machine or process will be used with the jig or fixture?

How will the design be maintained?

Is it better for the tool to have multiple uses or just one?

What are the cost constraints?

c. The responsibilities of the tool designer

i. Challenges To The Tool Designer

DESIGN

a The tool designer is in charge of developing and sketching the tool design concepts throughout this phase.

b A principal designer must frequently approve design drawings.

c Tooling decisions are often made by the tool designer in smaller organizations.

SUPERVISION

a A tool designer's go-to source for assistance in resolving design issues is the team of knowledgeable people kept in the tool room.

b The tool room is the area of a shop where skilled personnel and machine tools are stored.

c broad assortment of machine tools, including manual mills. Typical tool rooms contain lathes, grinders, jig mills, machining centers, and, in certain situations, their CNC equivalents.

d It's always a good idea to have a solid working relationship with your toolmakers.

e Collaboration between designers and tool makers is essential.

PROCUREMENT

- In most cases, the tool designer depends on suppliers or sales representatives to provide components and materials that match the design requirements.
- Select the business that provides the greatest level of customer service.
- Evaluating services like problem-solving and design support, in cases where their product is involved, is crucial before making a final decision.
- When needed, the vendor can also provide unique parts or components.
- Since most specialty suppliers provide these services, the choice should be based on which vendor can best fulfill the needs of the designer in the most reliable, timely, and efficient way.

INSPECTION

- Functional tryouts, also known as inspections, are typically carried out in two stages.
- The tool is examined to make sure it matches the tool drawing.
- The tool is used to create a number of test parts, which are then meticulously examined to make sure they match the details listed on the part print.
- To guarantee that the set tolerances are upheld during production, the tool designer should conduct routine inspections.

ii. Requirement to become a tool designer

1 A strong foundation in mathematics, science, and technical subjects is essential.

2 Proficiency in CAD software (e.g., AutoCAD, SolidWorks, CATIA) is critical, as these tools are used to create detailed designs and models.

3 Experience or training in tool and die making can be very valuable, especially for those without a formal degree.

4 Understanding manufacturing processes, materials, and the principles of tool and die making.

5 Strong grasp of geometry, algebra, calculus, and physics.

6 Precision is crucial in tool design to ensure the final product functions as intended.

7 Create a portfolio showcasing your design work, including CAD models, sketches, and completed projects, to demonstrate your skills to potential employers.

1.2. Explain types and functions of jigs and fixtures

A) **Distinguish between jig and fixture**

JIG

A jig is a special tool used to hold, support, or lay flat on the workpiece that is to be machined.

This manufacturing tool's function is to guide the cutting tool while also locating and holding the workpiece.

Hardened steel bushings are commonly used on jigs to guide drills and other cutting instruments.

FIXTURES

A fixture is a manufacturing tool used to locate, hold, and provide firm support for work so that necessary machining processes can be carried out.

A fixture needs to be fastened firmly to the machine's table so that work can be done there.

B) **The classses of jig**

i. Boring jig

- When drilling holes that are excessively large or need to be produced to an irregular size, boring jigs are employed.

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Figure 1.3 : Boring Jig

ii. Drill jig

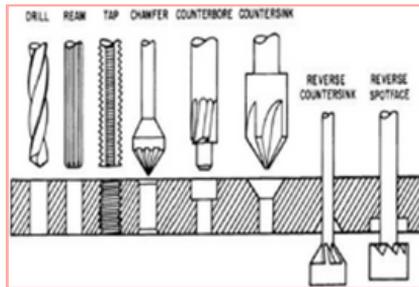- Drill jigs can be used for reverse spot-face, reverse countersink, counter-bore, tap, chamfer, and reaming.

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Figure 1.4 : Drill Jigs

C The general types of jigs

- Drill jigs can be classified into two types: open and closed.

- Utilized for straightforward tasks involving of a single side of an object.

- Closed, or box, jigs are used for objects that need to be machined on more than one side.

ii. Open jigs (Template, Plate, Table, Sandwich, Angle Plate)

a. Template Jig

- This kind of jig is typically not clamped; it fits over, on, or within the work.
- The cheapest and easiest kind of jig to use are templates.
- Bushings may or may not be present.
- In most cases, the entire jig plate is hardened when bushings are not utilized.
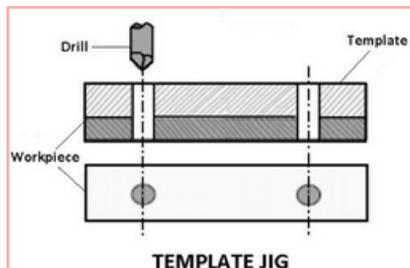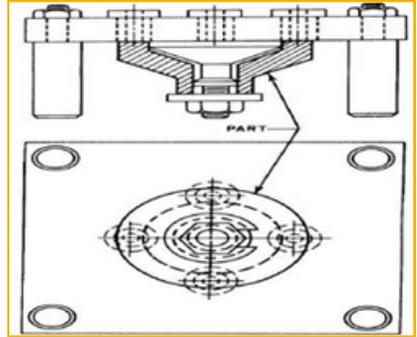

Figure 1.5 : Template Jig

ii. Plate Jig

- Improves by adding drill bushes to the template.

- Drills holes in massive items with precise spacing.

Figure 1.6 : Plate Jig

iii. Table Jig

- Table Jig is also known as a turn over jig since the workpiece is situated away from the face that will be drilled and clamped in the jig.
- The jig is then rotated over and drilled.
- Table jig has legs designed to lift the jig off the table for larger jobs.
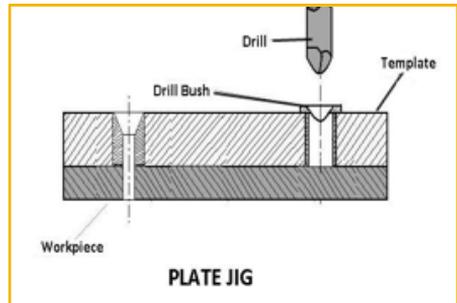
Figure 1.7 : Table Jig

iv. Sandwich Jig

- Sandwich jigs are a form of plate jig with a back plate.
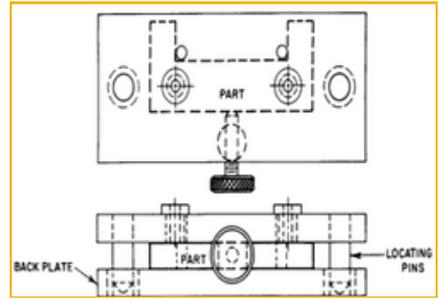- This jig is appropriate for thin or fragile items that might flex or warp in another type of jig.
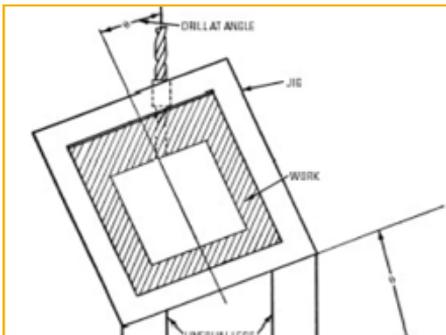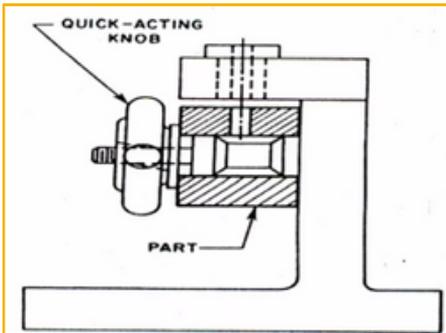

Figure 1.8 : Sandwich Jig

v. Angle plate jig

- Angle-plate jigs retain items machined at right angles to their mounting locators.
- This type of jig is used on a variety of items, including pulleys, collars, and gears.
- A version is the modified angle-plate jig, which is used to machine angles other than 90 degrees.

Figure 1.9 : Angle Plate Jig

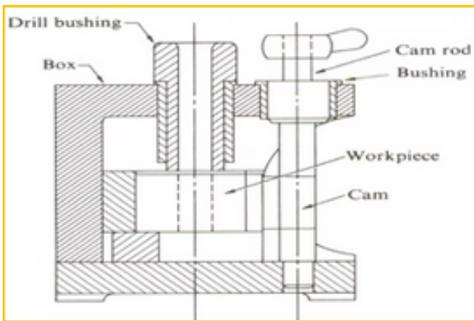## ii. Closed jigs (Box, Channel, Leaf)
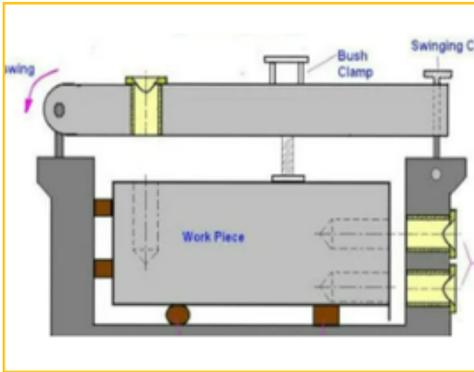
a) Box Jig

Figure 1.10 : Box Jig

- Box jigs, or tumble jigs, usually totally surround the part .
- This type of jig allows the part to be machined completely on all surfaces without having to reposition the work in the jig.
- The box jig allows for the drilling of a large number of holes at a low cost.
- One side is open for loading and unloading the workpiece, with specified bushing arrangements.
- The box jig allows for drilling holes on three sides of the workpiece, which saves time and increases output.
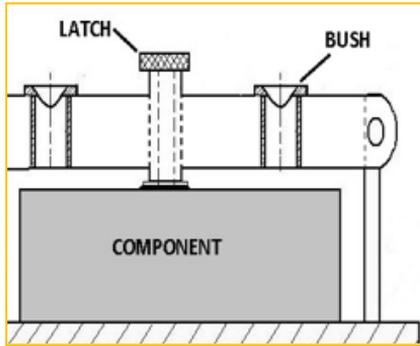
Figure 1.12 : Channel Jig

b) Channel Jig

- Channel jigs are simple jigs with a channel-like cross section.
- The part is positioned into the channel and secured by turning the knurled knob.
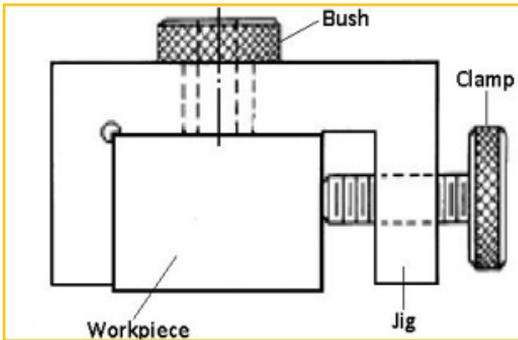- The tool is guided through the drill bush.

Figure 1.13 : Leaf Jig

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c) Leaf Jig

- To load or unload the workpiece, the leaf jig's can be swung open or closed.
- The primary distinctions between leaf jigs and box jigs are size and part position.
- Leaf jigs are often smaller than box jigs and are occasionally designed so that they do not completely encircle the part.
- They are typically provided with a handle to facilitate movement.

iii. Other variations jig (Indexing, Rotary, Trunnion, Pump and Multistation)

a) Indexing / Rotary Jig

- Indexing jigs are used to precisely position holes or other machined locations on an item.
- To do this, the jig employs either the part itself or a reference plate and plunger.
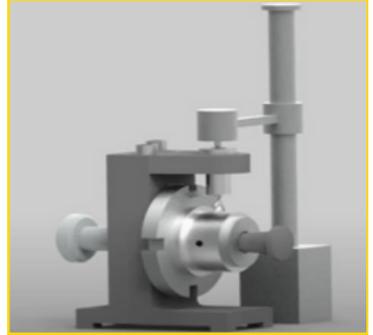- Rotary jigs are larger types of indexing jig.

Figure 1.14 : Indexing/ Rotary Jig

b) Trunnion

- A type of rotary jig used for very large or oddly shaped items is the trunnion jig (Figure 1.15).
- The component is loaded onto the trunnion after being placed within a box-style container.
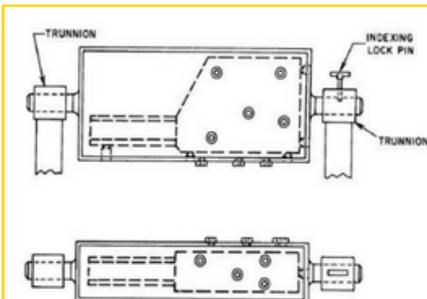

Figure 1.15: Trunnion

D) The Common Types of Fixtures

i. Plate Fixture

- Are the simplest type of fixture.
- A flat plate with multiple clamps and locators to hold and position the component makes up the basic fixture.
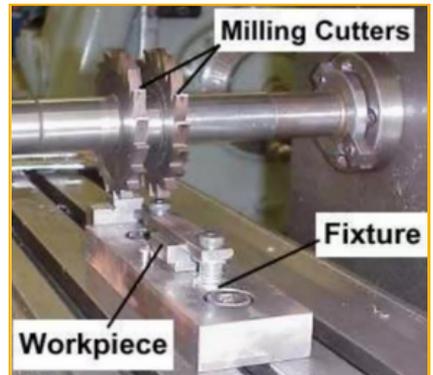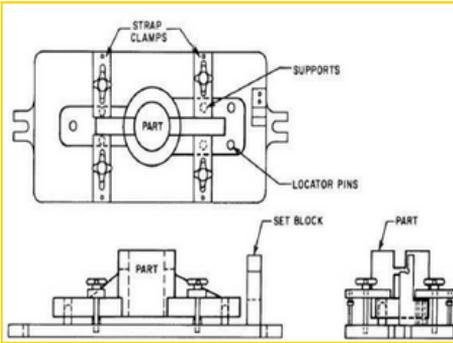- Suitable for most machining processes.

Figure 1.16 : Plate Fixture

Figure 1.17 : Angle Plate Fixture
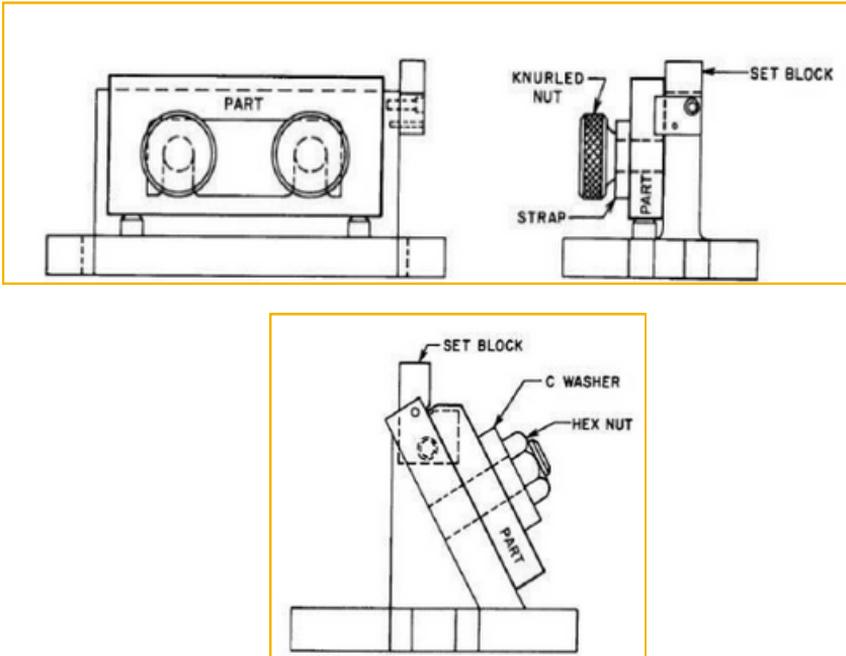
ii. Angle Plate Fixture

- A version of the plate fixture is the angle-plate fixture.
- The item is typically machined with this tool at a straight angle to its location.
- Although 90 degrees is the standard angle at which angle-plate fittings are constructed, different angles are occasionally required.
- A modified angle-plate fixture may be employed in these circumstances.

iii. Vise Jaw Fixture

- With this kind of tool, jaws that are made to fit the part are used in place of the typical vise jaws.
- The least expensive form of fixture to manufacture is the vise-jaw fixture.
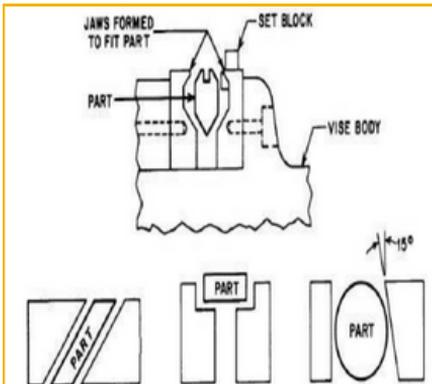- Only the sizes of the vises that are available restrict their use.

Figure 1.18 : Vise Jaw Fixture

iv. Indexing fixture

- Similar to indexing jigs.
- Used for machining parts that must have machined details evenly spaced.
- Examples of end parts using an indexing fixture.
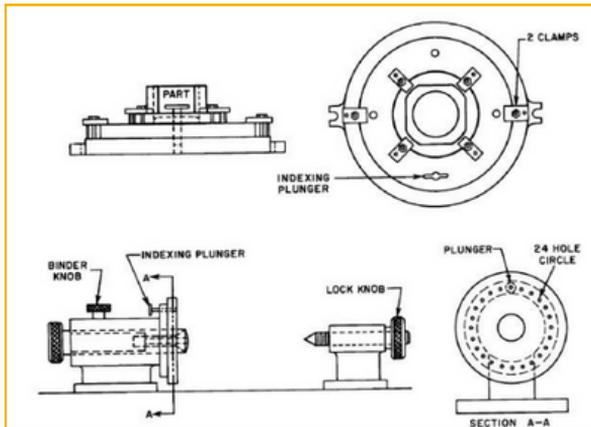
Figure 1.19 : Indexing fixture

Figure 1.20 : Example of end product using indexing fixture

v. Multi–Station Fixture

- Multi-station is mostly utilized for fixtures in high-volume, high-speed production runs when the machining cycle needs to be continuous.
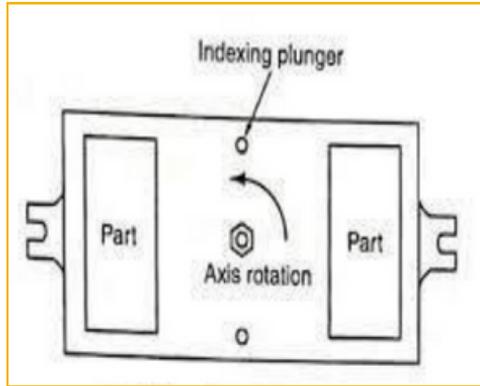

Figure 1.21 : Multi- Station Fixture

vi. Milling fixture

- Milling fixture is designed to be used on a milling machine.
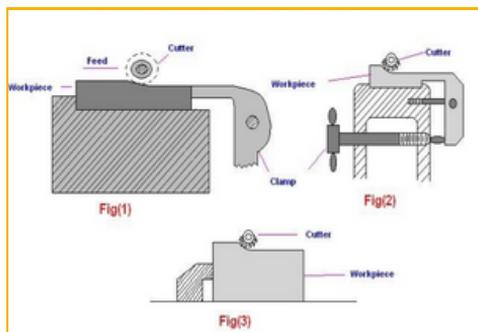
Figure 1.22 : Milling fixture

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1.3 The Analysis for Economic Design

a) The Principles of Economic Design

- The needs of modern industry for optimum production at the lowest cost present a challenge to the tool designer.
- In addition to designing efficient and accurate jigs and fixtures, the tool designer is responsible for minimizing the cost of special tools.
- To accomplish this, the tool designer must understand and implement the following economic design principles:
  - ❑ Simplicity
  - ❑ Preformed material
  - ❑ Standard components
  - ❑ Secondary operations
  - ❑ Tolerance and allowance
  - ❑ Simplified drawing

i. Simplicity

- The demands of modern industry for maximum output at the lowest possible cost provide a challenge to the tool designer.
- In addition to constructing efficient and accurate jigs and fixtures, the tool designer must reduce the cost of special tools.
- To do this, the tool designer must understand and use the following economic design principles.

ii. Preformed Material

- Preformed materials can significantly lower tooling costs by eliminating numerous machining steps.
- Design specifications should include preformed materials such drill rods, structural sections, pre-machined brackets, tooling plates, and precision-ground flat stock.

iii. Standard Components

- Commercially available standard jig and fixture components can significantly enhance tooling quality.
- Reduce labor and material costs significantly.
- Standard components, such as clamps, locators, supports, drill bushings, pins, screws, bolts, nuts, and springs, should be built into the design to save money on labor and materials.

iv. Secondary operations

- Secondary procedures include grinding, heat treatment, and some machining. Should be restricted to areas required for effective tool functioning.
- Grinding should only be done on regions that make contact with the item or the machine.
- Hardening activities should be limited to wear-prone regions such as supports, locators, and moving parts.
- Secondary machining of surfaces that do not directly affect the tool's precision should be avoided.

iv. Tolerance and Allowance

- In general, a jig or fixture should have a tolerance of 20 to 50 percent of the part tolerance.
- Overly accurate tooling is economically wasteful and no more value than tooling that meets the requisite tolerances.
- When the tolerance imposed to a tool design is excessively tight, the sole effect on the part is increased cost.

v. Simplified Drawings

- The following list provides a general approach to simplifying tool drawings:
- When practical, words should be used instead of drawn details.
- Remove unneeded or redundant views, projections, and information.
- Whenever feasible, replace drawn details with symbols.
- Templates and instructions might help you save time when drawing.
- Standard parts should be drawn for clarity, not intricacy.

b. Economic Analysis of a tool design

- The simplest method of figuring out a tool design's cost is to total up all of the labor and material costs involved in producing the tool.
- One method is to label every component of the tool and maintain a separate supply inventory (Figure 1.21).
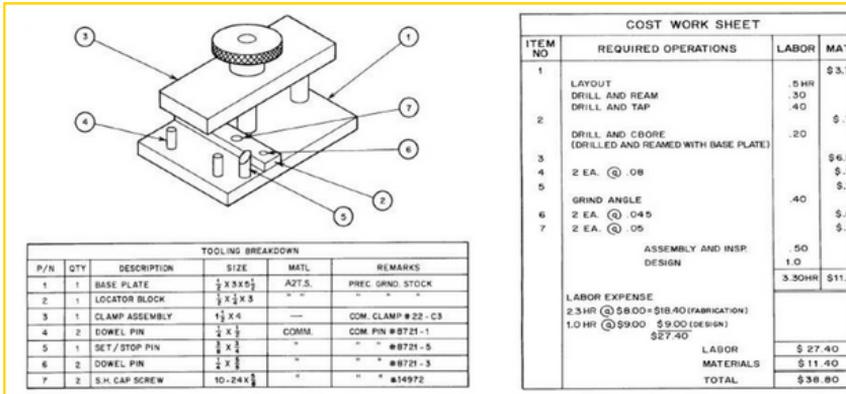- Compute the material and labor for each procedure by listing each element on a cost work sheet (Figure 1.21).

Figure 1.21 : Example of tool cost

i. Tool Cost and Productivity

1. Number of parts per hour the tool will produce.

The simplest method is to divide 1 hour by the single-part time, or the time it takes to load, machine, and unload each part. Expressed as a formula, this calculation becomes

> ***Ph= 1/s***
> **Where *Ph*= Parts per hour**
> **S= Single- part time**

Example:

Determine the number of parts per hour will produce of jig if the machining time is .0167 hour and it takes .0027 hour to load the part and another .0027 hour to unload it:

Solution:

$$Ph = \frac{1}{S}$$

$$= \frac{1}{0.0167 + 0.0027 + 0.0027}$$

$$= 45.25 \; per \; hour$$

$$\approx 45 \; per \; hour$$

2. Labor Expenses

- In most cases, jigs and fixtures cut down on machining time and minimize or do away with the requirement for specialized personnel.
- Since the necessary accuracy and skill are transferred from the operator to the tool through appropriate tooling.
- Accurate parts can be produced by unskilled workers at less money. The following formula can be used to get the labor cost:

> **L= *LS/Ph X w***
> **Where L= Cost of labor**
> **LS= Lot Size**
> **Ph= Part per hour**
> **w= Wage Rate**

Example:

Determine the cost of labor if five thousand parts are to be milled using a fixture capable of producing 60 parts per hour and the machine operator earns RM6.75 per hour

Solution: 👉

$$L = \frac{LS}{Ph} X w$$

$$= \frac{5000}{60} X \text{ RM6.75}$$

$$= 83.33 X \text{ RM6.75}$$

$$= RM562.50 \text{ } labor \text{ } expenses$$

3. Cost per part

- The tool designer cannot ascertain the actual economic potential of a design by comparing tool costs or labor expenses alone.
- The formula:

$$C_p = \frac{TC + L}{LS}$$

$Where\ C_p = Cost\ per\ part$

$TC = Tool\ Cost$

$L = Cost\ of\ Labor$

$LS = Lot\ Size$

Example:

Determine is the cost per part of a milling operation for 7000 parts when the fixture cost RM55.00 and the labor expense is RM784.12

Solution:

$$C_p = \frac{TC + L}{LS}$$

$$= \frac{55 + 784.12}{7000}$$

$$= RM0.119 \approx RM0.12\ per\ part$$

4. Total Savings

- To determine the most economical production method, the tool designer must compare production alternatives.

- The first formula, which assumes that both alternatives being considered require special tooling to produce the part, is:

Formula 1:

$$TS = LS(C_p1 - C_p2)$$

$$Where\ TS = Total\ saving$$

$$LS = Lot\ Size$$

$$C_p = Cost\ per\ part$$

Example:

A jig is to be used to drill six holes in a part. The pieces may be produced for RM0.20 a piece with the first tool and RM0.13 a piece with the second. How much would using the second tool save over a 1200-part production run?

Solution: 👉

$$TS = LS(C_p1 - C_p2)$$

$$= 1200(0.20 - 0.13)$$

$$= 1200(0.07)$$

$$= RM84.00\ total\ savings$$

33

In the case of production alternatives, where only one method requires special tooling, the formula used is:

Formula 2:

$$TS = LS(C_p1 - C_p2) - TC$$

$Where\ TS = Total\ saving$

$LS = Lot\ Size$

$C_p = Cost\ per\ part$

$TC = Tool\ Cost$

Example:

The cost of milling a flange-plate adapter without a fixture is RM0.15 per part; with a fixture, the cost is RM0.09 per part. Determine would the fixture save over a production run of 2500 pieces, assuming it costs RM130.00?

Solution:

$$TS = LS(C_p1 - C_p2) - TC$$

$$= 2500(0.15 - 0.09) - 130$$

$$= 2500(0.06) - 130$$

$$= 150 - 130$$

$$= RM20.00\ total\ savings$$

5. Break-Even Point (BP)

- The break-even point is the minimum number of parts a tool must produce to pay for itself.
- Any number less than this minimum results in a loss of money; any number more results in a profit.
- It is logical to assume that the lower the break-even point, the higher the profit potential.
- The formula used to find the break-even point is:

$$BP = \frac{TC}{(C_p1 - C_p2)}$$

$$Where\ BP = break - even\ point$$

$$TC = Tool\ Cost$$

$$C_p = Cost\ per\ part$$

Example:

A lathe fixture costs RM150.00 to build and produces parts at a cost of RM0.20. Determine the number of parts must it produce to pay for itself when compared to an alternate method that requires no special tooling and is capable of making the parts at a cost of RM0.40 each?

Solution:

$$BP = \frac{TC}{C_p1 - C_p2}$$

$$= \frac{150}{0.40 - 0.20}$$

$$= 750\ parts\ needed\ to\ break\ even$$

ii. Comparative Analysis

- When recommending tools to management, the tool designer has to weigh and examine multiple options.
- The tool designer can see the tooling requirements in terms of costs against savings by comparing each option.
- One might choose the strategy that maximizes returns for every dollar invested.

? Example

Five hundred guide plates must be milled to receive a locating block. The tool designer has determined three possible alternatives:

- Have a toolmaker, who earns RM12.00 per hour, mill the plates at a rate of 25 per hour.
- Use limited tooling that costs RM35.00 in the production department. The machine operator in this department, who earns RM7.00 per hour, can make a part every 1.2 minutes.
- Use a more expensive tool that costs RM110.00 but is capable of producing a part every 24 seconds. This would be done in the production department, where a machine operator earns RM7.00 per hour.

Which alternative should the tool designer select as the most efficient and economical?

COMPARISON WORK SHEET			
ECONOMIC & PRODUCTIVITY FACTORS	ALTERNATIVES		
	# 1	# 2	# 3
LOT SIZE	500	500	500
TOOL COST	0	$35.00	$110.00
PARTS PER HOUR	25		
LABOR/HOUR	$12.00	$7.00	$7.00
LABOR/LOT			
COST PER PART			

Solution:

Step 1:

The first values that should be calculated are the parts per hour that the
tools in alternatives 2 and 3 will produce.
The formula to do this is:

1 hour= 1.0 hour
1/2 hour= 0.5 hour
1/4 hour=0.25 hour
6 minutes= 0.1 hour
1 minute= 0.0167 hour
1 second= 0.000277 hour

$$Ph = \frac{1}{S}$$

For Alternative 2, the formula and calculations are:

$$Ph = \frac{1 hour}{1.20 minutes}$$

$$= \frac{1}{0.0167 + (20 \ X \ 0.000277)}$$

$$= \frac{1}{0.02224}$$

$$= 44.96$$

$$\approx 45 \ part \ per \ hour$$

For Alternative 3, the formula and calculations are:

$$Ph = \frac{1 hour}{24\ seconds}$$

$$= \frac{1}{(24\ x\ 0.000277)}$$

$$= \frac{1}{0.006648}$$

$$= 150.42$$

$$\approx 150\ parts\ per\ hour$$

The next calculation computed is the cost of labor for the entire production run. The formula is:

$$L = \frac{LS}{Ph}\ X\ w$$

For Alternative 1, the formula and calculation are :

$$L = \frac{500}{25}\ X\ RM12$$
$$= RM240\ labor\ cost$$

For Alternative 2, the formula and calculation are :

$$L = \frac{500}{45}\ X\ RM7$$
$$= Rm77.78\ labor\ cost$$

For Alternative 3, the formula and calculation are :

$$L = \frac{500}{150}\ X\ RM7$$
$$= RM23.33\ labor\ cost$$

COMPARISON WORK SHEET			
ECONOMIC & PRODUCTIVITY FACTORS	ALTERNATIVES		
	#1	#2	#3
LOT SIZE	500	500	500
TOOL COST	0	$35.00	$110.00
PARTS PER HOUR	25	45	150
LABOR/HOUR	$12.00	$7.00	$7.00
LABOR/LOT	$240.00	$77.78	$23.33
COST PER PART	$.48	$.226	$.267

How much is actually saved?

How many parts must this tool produce to pay for itself?

These questions can be answered by calculating the total savings and the break-even point.

The formula for calculating the total saving are:

$$TS = LS(C_p1 - C_p2)$$

or

$$TS = LS(C_p1 - C_p2) - TC$$

To calculate the total savings between alternative 1 and 2, the second formula is used:

$$TS = 500(RM0.48 - RM0.226) - RM35$$

$$= RM92 \text{ saved by using Alternative 2 rather than Alternative 1}$$

To calculate the total savings between alternative 2 and 3, the first formula is used:

$$TS = 500(RM0.267 - RM0.226)$$

$$= RM20.50 \text{ saved by using Alternative 2 than Alternative 3}$$

The formula to calculate the break-even point is:

$$BP = \frac{TC}{(C_p1 - C_p2)}$$

To calculate the break-even point between alternatives 1 and 2, the formula and calculations are:

BP= RM35/ (RM0.48 - RM0.226)
= 138 parts to break even

To calculate the break- even point between alternatives 2 and 3, the formula and calculations are:

BP= RM35/ (RM0.26 - RM0.226)
= 852 parts to break even.

FORMULA

Production

Ph = Parts per hour
S = Single-part time
Includes load time and unload time

$$Ph = \frac{1}{S}$$

Labor expense

L = Cost of labor
LS = Lot size
Ph = Parts per hour
w = Wage rate

$$L = \frac{LS}{Ph} \times w$$

Cost per part

Cp = Cost per part
TC = Tool cost
L = Cost of labor
LS = Lot size

$$Cp = \frac{TC + L}{LS}$$

Total savings-economical production

TS = Total savings
LS = Lot size
Cp 1 = Cost per part—first tool
Cp 2 = Cost per part—second tool

$$TS = LS \times (Cp\,1 - Cp\,2)$$

Production alternatives

TS = Lot size
LS = Lot size
Cp 1 = Cost per part—first tool
Cp 2 = Cost per part—second tool
TC = Tool cost

$$TS = LS \times (Cp\,1 - Cp\,2) - TC$$

Break-even point

BP = Break-even point
TC = Tool cost
Cp1 = First cost per part
Cp 2 = Second cost per part

$$BP = \frac{TC}{(Cp\,1 - Cp\,2)}$$

a. Give TWO (2) objectives the Process Planning Design. (2m)

b. There are TWO (2) classes in jig. Explain briefly the function between these jigs. (3m)

c. Determine the labor costs for milling 6500 pieces at a cost of RM0.15 per part and a fixture cost of RM60.00. (2m)

d. The cost of milling a flange-plate adapter without a fixture is RM.50 per part; with a fixture, the cost is RM.20 per part. Determine how much money the fixture saves throughout a production run of 1500 pieces, assuming the fixture costs RM140.00. (3m)

SUPPORTING AND LOCATING
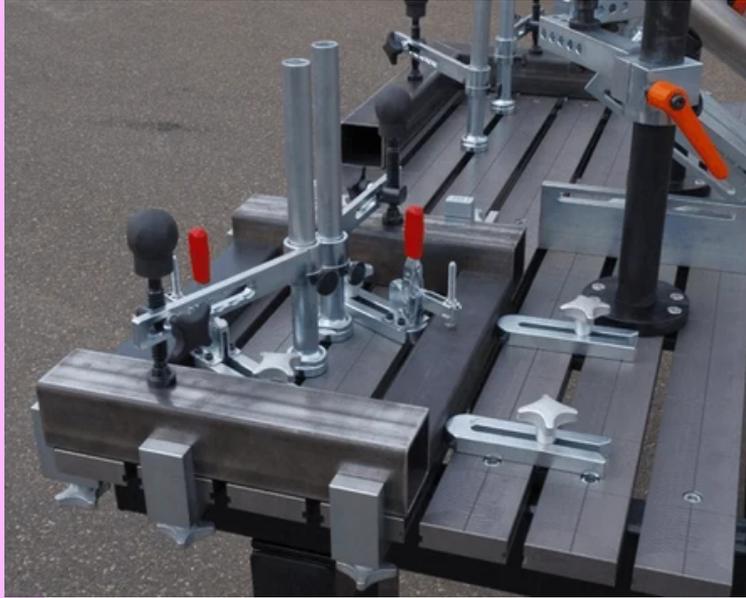
CHAPTER

02

- Explain the supporting and locating principles
- Sketch the types of locating.
- Sketch the types of ejector devices

2.1 Explain the supporting and locating principles

a) The concepts of referencing, repeatability and interchangeability

REFERENCING ───────────────

- "Referencing" refers to the practice of ensuring that workpieces are consistently and accurately positioned for machining or assembly operations.
- Devices for guiding or setting are used in this process.

REPEATABILITY ───────────────

- "Repeatability" refers to the workholder's ability to consistently manufacture components within tolerance limits, which is directly tied to the tool's reference capabilities.

b. The basic rules for locating

Positioning the locator

Part tolerances

Fool proofing

Duplicate location

Types of Locator
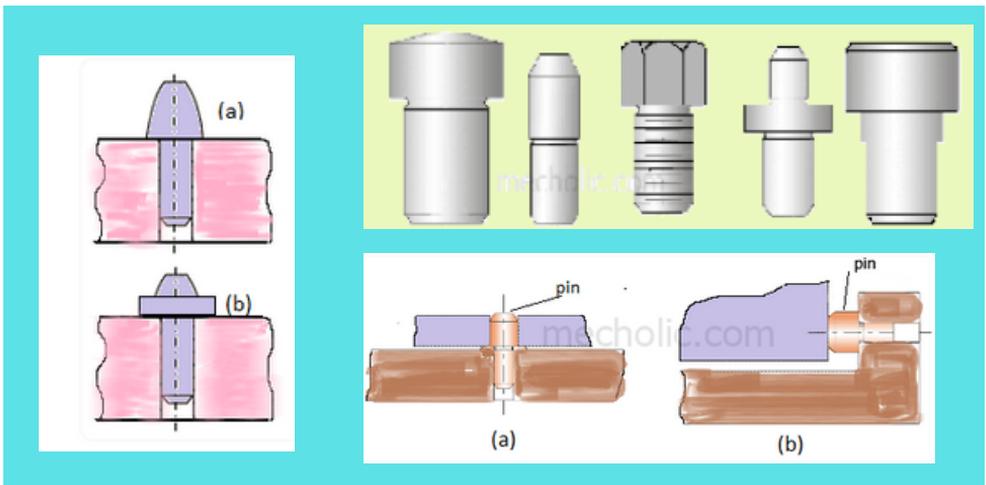
Figure 2.1 : Types of Locator

i. Positioning of Locator

- Locators should make touch with the work (ideally the machine's surface) at a firm, steady location.

- This allows for accurate part positioning in the tool and guarantees that the jig and fixture are repeatable.

- Placing them as far as feasible allows for fewer locators and ensures full contact with the locating surface.

Example
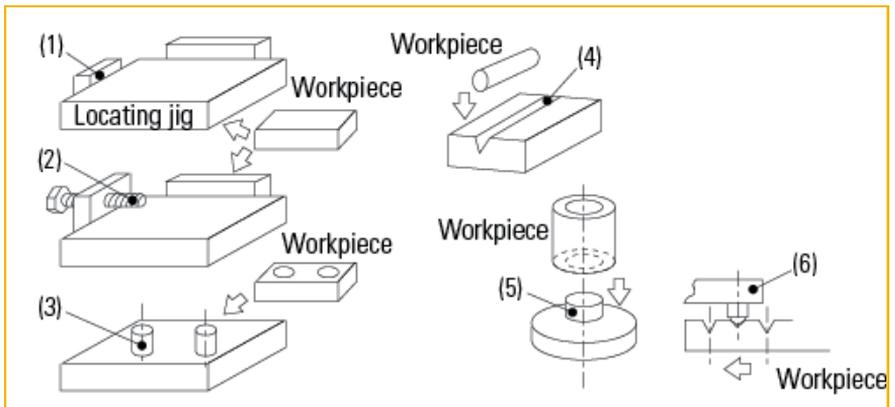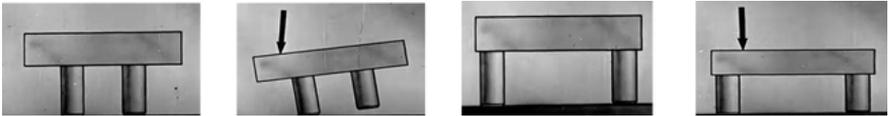
Figure 2.2 : Positioning of Locator

46

ii. Part Tolerance

- As the designer, part tolerances must put into consideration when creating a tool.

- As a general rule, the tool tolerance should be 20 to 50 percent of the part tolerance.

- Example: To ensure a hole in a part is within ±.010 inch tolerance, the hole in the jig should be between ±.002inch and ±.005inch.

Example
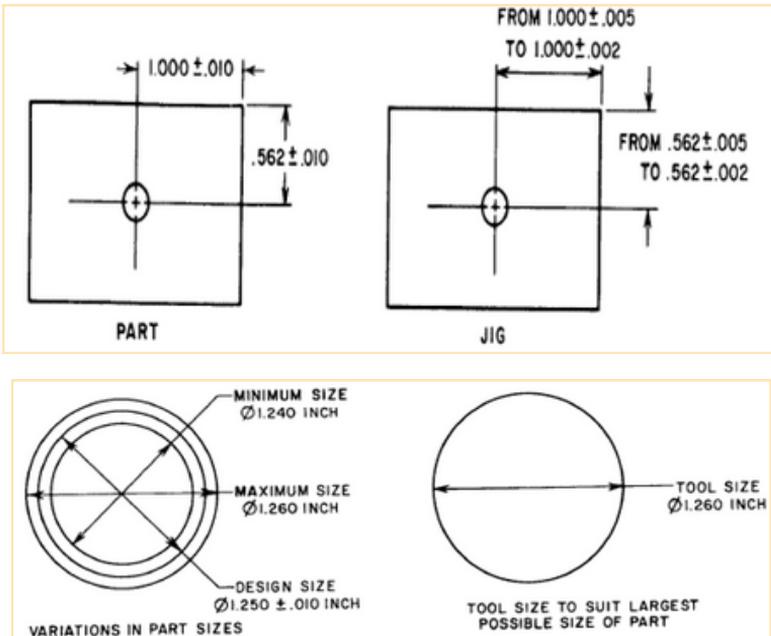
Figure 2.2: Part Tolerance

iii. Fool Proofing

- Ensures that the part will only fit into the tool in the correct position.
- The easiest and most cost-effective technique is to position a foolproof pin.

Example
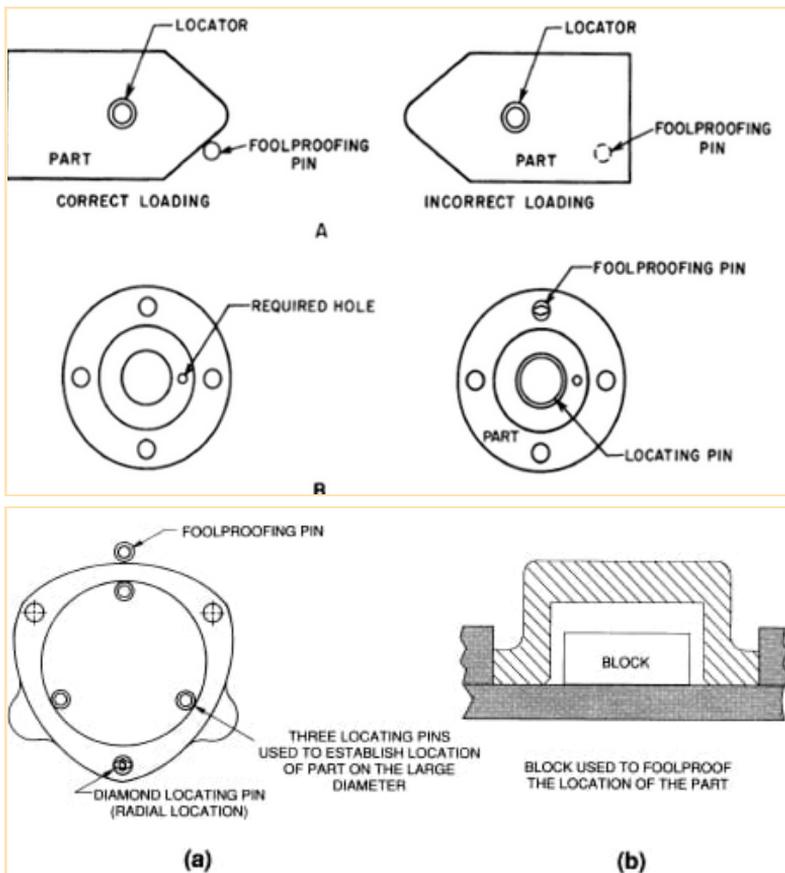
Figure 2.3 : Fool Proofing

iv. Duplicate Locators

- Duplicate locators can lead to misalignment, affecting the accuracy of the machining or assembly process.

- Duplicate locators can cause confusion, slowing down the operation and increasing the risk of errors.

Example
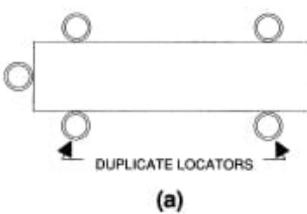
Part (a) shows that using two locators on flat surfaces that do the same job isn't necessary. Because parts vary slightly in size, they will unlikely touch both locators simultaneously.
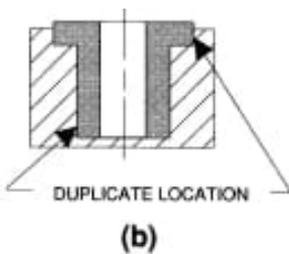
Part (b) highlights a similar issue with using two locators around a circle – you should only need one.
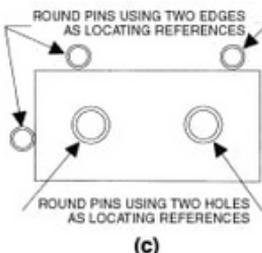
Part (c) illustrates the problem of using both hole and edge locators simultaneously, which can cause confusion and make it hard to place or remove parts properly.

C. The Planes of Movement

i. Degree of Freedom

- 12 degrees of freedom(not 6).

- 4 along each axis;2 translational and two rotational

Example
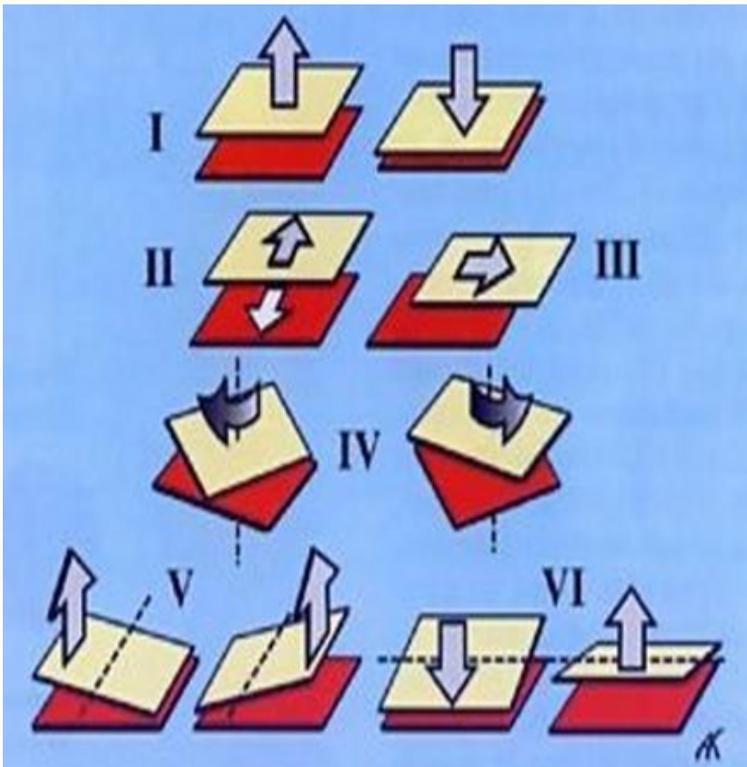
Figure 2.4: Degree of Freedom

- 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.
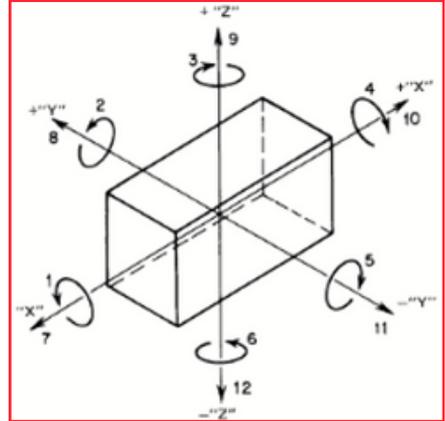
Figure 2.5 : Twelve Degree of Freedom

- As shown in Figure 2.5, 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.

ii. 3-2-1 Principles

Example the Principle of Restricting Movement   (Three Pin Base)
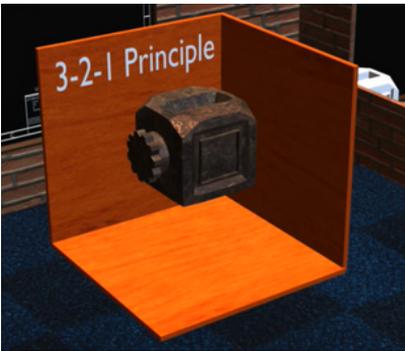
- The fixture for the part in Figure 2.6 illustrates the principle of restricting movement.
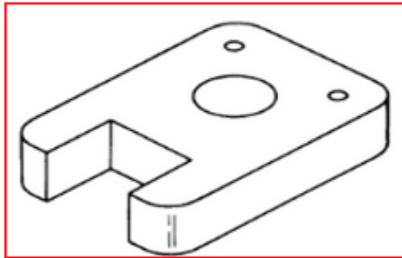
Figure 2.6 : Principle of Restricting Movement

- By placing the part on a three-pin base, five directions of movement (2, 5, 1, 4, and 12) are restricted (Figure 2.7).
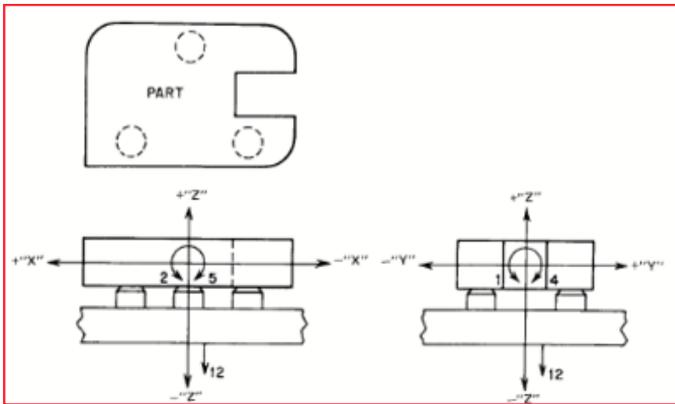

Figure 2.7 : Three-pin base

Example the Principle of Restricting Movement   (Five Pin Base)

- Three Pins: Positioned under the part to support it and restrict movement in the Z-axis. These are usually placed at the corners of the base, providing a stable three-point support, ensuring the part does not rock or tilt.
- Two Pins: Positioned on one side to restrict movement in the Y-axis. These are often aligned along one edge of the part, pressing it against the pins to ensure it remains in the correct position.
- The Five Pin Base method is a simplified version of the 3-2-1 principle. It restricts movement in five degrees of freedom, leaving one degree free for ease of loading or unloading the part, usually in the X-axis direction. This configuration is ideal for parts where access to one side is necessary during processing.
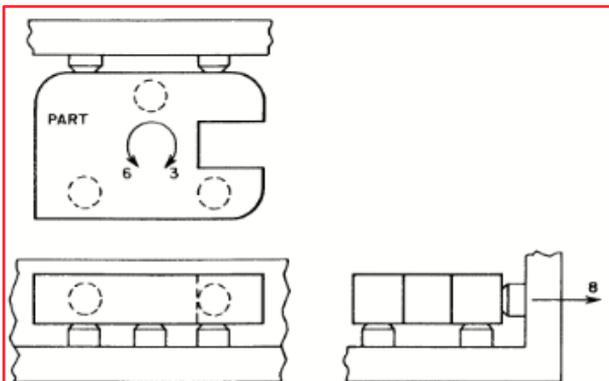
Figure 2.8 : Five Pin Base

2.2 Sketch the types of locating.

a) Flat Surface

b) Internal Diameter

Types of Locators

c) External Profile
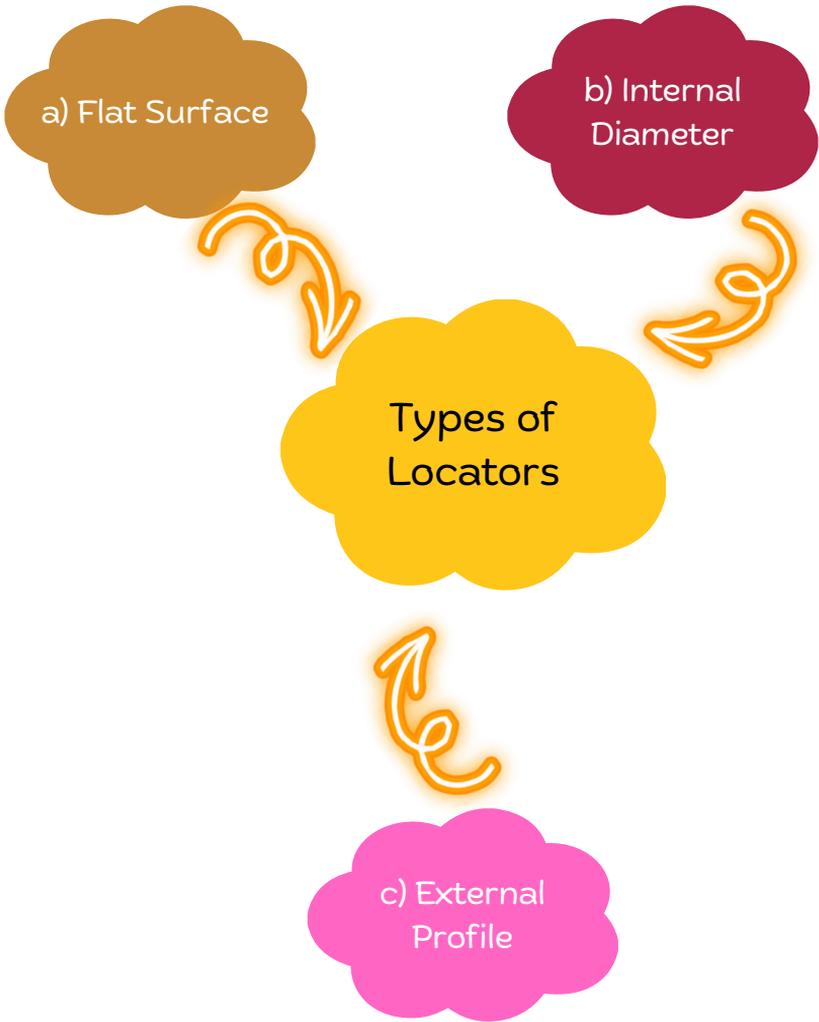
1 Flat Surface

Three Main Techniques of Locating Work from a Flat Surface

→ solid supports

→ adjustable supports

→ equalizing support

Solid Support

- refers to a structural element or component that provides a stable and rigid foundation to hold the workpiece in a fixed position during manufacturing or assembly processes.
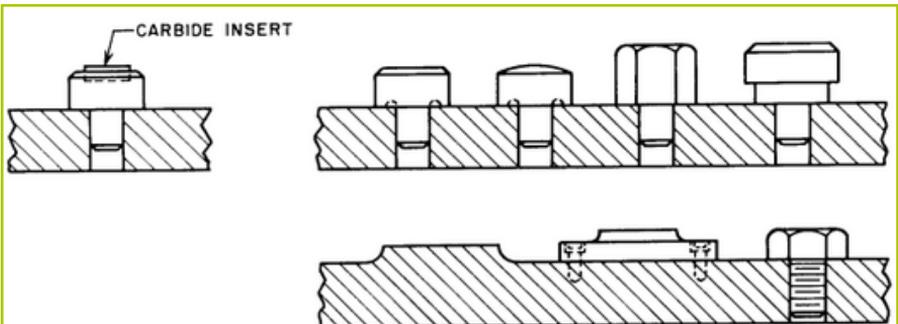

Figure 2.9 : Solid Support

Adjustable Support

- are utilized for surfaces that are rough or uneven, such as cast parts.
- Examples include threaded, spring, and push kinds.
- The threaded style is the simplest and most affordable, with a wider adjustment range than the others.
- Adjustable locators are typically used in conjunction with one or more solid locators to make any necessary adjustments to level the job.
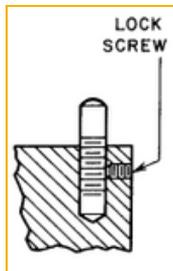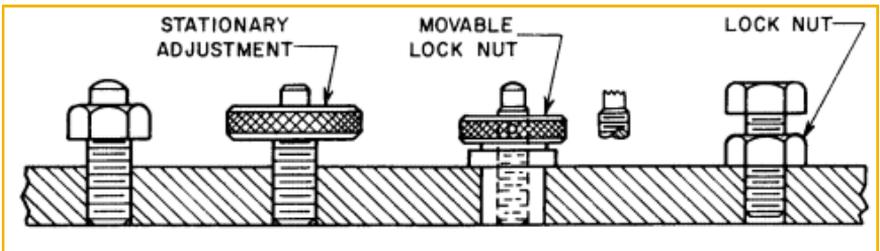
Figure 2.10 : Adjustable Support

Equalizing Support

- also a form of adjustable support
- provide equal support through two connected contact points.
- As one point is depressed, the other raises and maintains contact with the part.
- This feature is especially necessary on uneven cast surfaces.
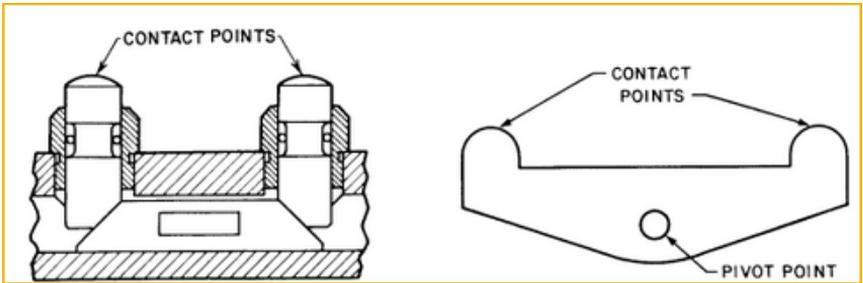
Figure 2.11 : Equalizing Support

2 Internal Diameter

- Locating a part from a hole or pattern is the most accurate technique to position work.

- Several types of locators are used to locate work in holes. Figure 2.12 depicts locating from holes (internal diameter)

- When significant holes are found in the job, secure the internal locator with screws and dowels.

- Under usual circumstances, two dowels and two screws are required to secure the locator.

- With increased force, it is preferable to utilize larger dowels and screws rather than increasing their number.
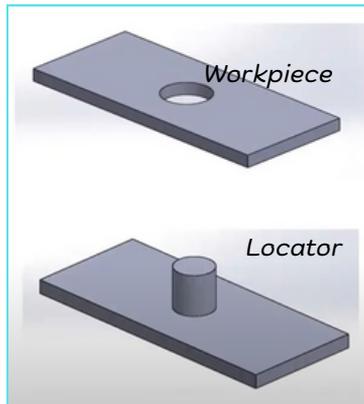
Figure 2.12: Locating from holes

Example

Shank locator

- use the press fit locator

Threaded locator

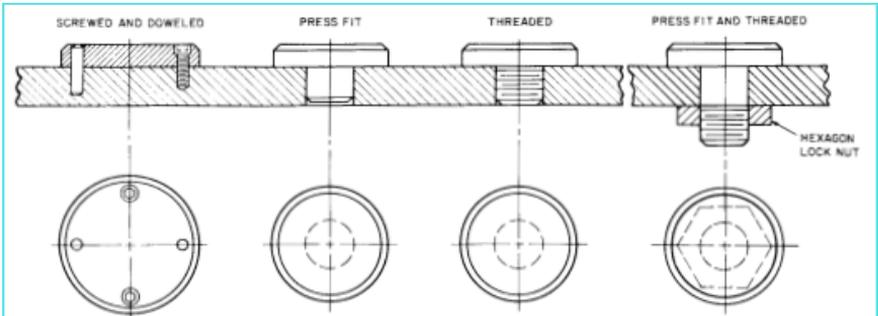- the construction of the tool will not permit the other type to be pressed out.

Figure 2.13 : Types of Locators

Example

Pin type locator
- used for smaller holes and for aligning members of the tool.

- Special bushings should also be utilized, which may be replaced as they wear. Pins used for part positioning have either tapered or rounded ends, allowing parts to be readily installed and removed.
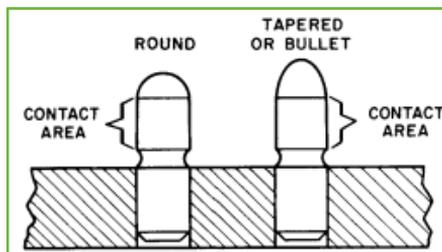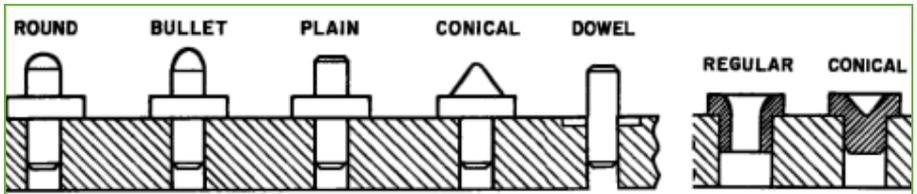

Figure 2.14 : Pin Locator

3 **External Profile**

- *An external profile locator refers to the outer shape or contour of a workpiece that a jig or fixture is designed to hold, guide, or support during a manufacturing process.*

Nesting locator or cavity locator
- Utilised to precisely place the work item in relation to the profile.
- Further locating devices are not required, although it is challenging to lift out of the cavity

Ring Nest
- used to workpieces that are cylindrical.
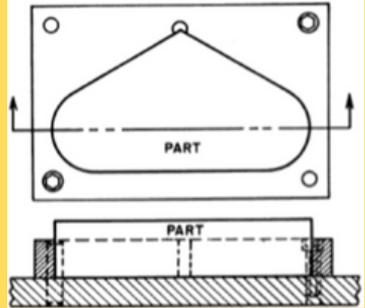- It completely encloses the workpieces.
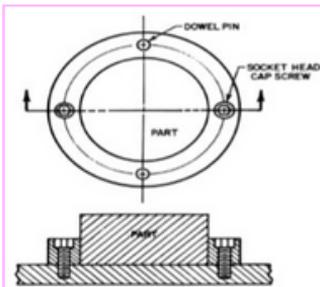
Figure 2.15 : Ring Nest

Full Nest
- for pieces of work that are not cylinders.
- fully encloses the work.

2.3 Sketch the types of ejector devices

a. The function of ejector devices

Ejectors are components used to remove or "eject" the workpiece from the fixture once the machining or assembly operation is complete.
- Speed up the operation by reducing unloading time

- They are 2 types:
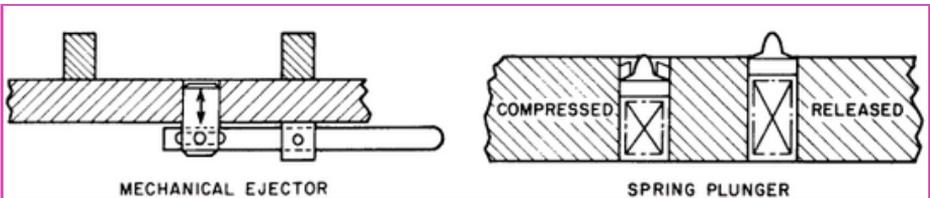 Mechanical type
  Spring plunger

Figure 2.17 : Type s of ejector devices.

EXERCISE

(a) Fill the suitable answer for supporting and locating principles as follows, refer to hints or keywords provided. (Keywords: referencing, fixed, fool proofing, cylindrical locator, locator, repeatability, nested locator, rest pads, plates, pin locators). (6m)

i. The best shape for location of a part for hole profile is _____

ii. _____ are longer and for horizontal locations.

iii. There are two types of V locators which are _____and adjustable.

iv. _____is a dual process of positioning the work piece relative to the work holder and the work holder relative to the cutting tool.

v. The most accurate location is_____

vi. _____is the ability of the work holder to consistently produce parts within tolerance limits, and is directly related to the referencing capability of the tool.
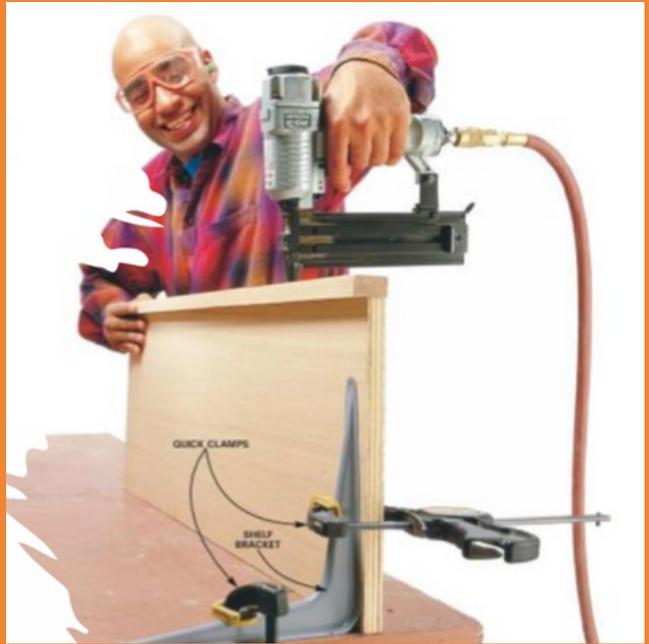
EXERCISE

(b) Write the name of the locators below .   (4m)
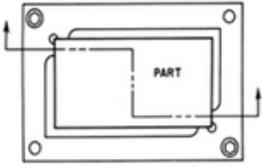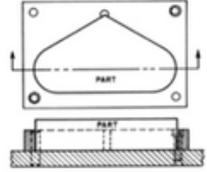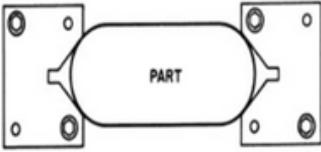
(c) Ejectors in jigs and fixtures are components used to remove or "eject" the workpiece from the fixture once the machining or assembly operation is complete. Sketch the TWO (2) types of ejectors.   (8m)

CLAMPING AND WORKHOLDING

CHAPTER

03

- Sketch the clamping and workholding devices
- Explain the Non-Mechanical Clamping .
- Sketch the types of clamping in special clamping operation
- Explain the clamping accessories to make the job easier

3.1. **Sketch the clamping and workholding devices**

a. The function of clamp and workholder

- Clamp and workholder are tools used in various manufacturing, woodworking, and metalworking processes to secure workpieces in place during machining, assembly, or other operations.

 Clamp

- Clamps are essential components used to securely hold a workpiece in place during machining, assembly, or inspection processes. The purpose of a clamp include:

  ➤ Securing Workpieces

  ➤ Providing Stability

  ➤ Allowing for Hands-Free Operation

  ➤ Variety of Applications

Workholder

A workholder is a broader term that encompasses devices designed to hold, position, and support a workpiece during various manufacturing processes. The functions of a workholder include:

➤ Positioning

➤ Securing

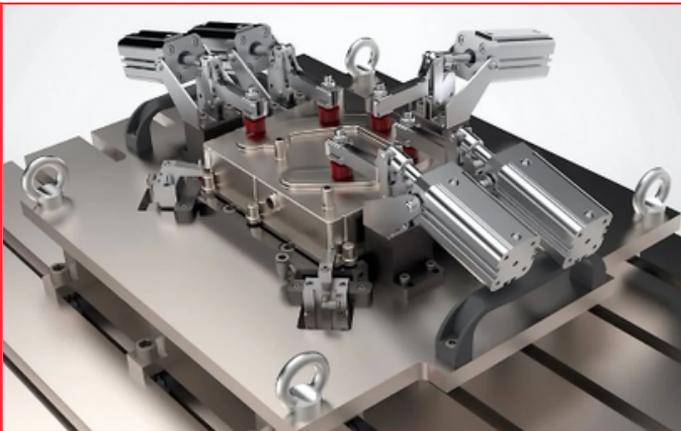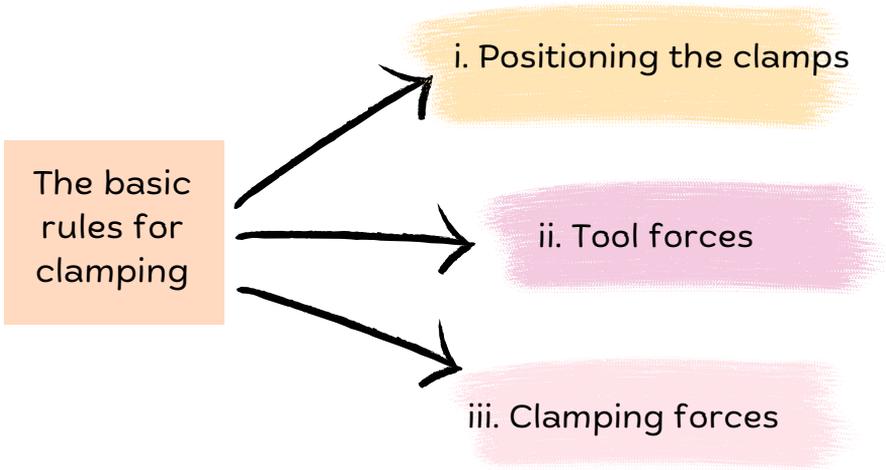➤ Supporting

➤ Customization

➤ Enhancing Productivity

Figure 3.1 : Clamp and Workholder
(https://youtu.be/6hzRK4oONNg?si=ArJ_76i1YPV1aD8U)

i. Positioning the clamps

The basic rules for clamping

ii. Tool forces

iii. Clamping forces

1 **Positioning the clamps**

▶ Positioning clamps in jigs and fixtures is crucial for ensuring that a workpiece is held securely and accurately during machining, assembly, or inspection processes.

▶ The correct placement of clamps not only prevents the workpiece from moving but also avoids deformation or damage.

▶ Key Factors for Positioning Clamps:
  - Stability and Rigidity:
  - Even Distribution of Forces:
  - Accessibility:
  - Support and Reference Points:
  - Minimizing Workpiece Deflection:
  - Type of Clamp:

2   **Tools Forces**

▶ Typically refers to the forces applied by a clamping tool to secure a workpiece in place during machining, assembly, or other processes.

▶ Key Factors in Clamping Forces:
1. Magnitude of Force
2. Direction of Force
3. Distribution of Force
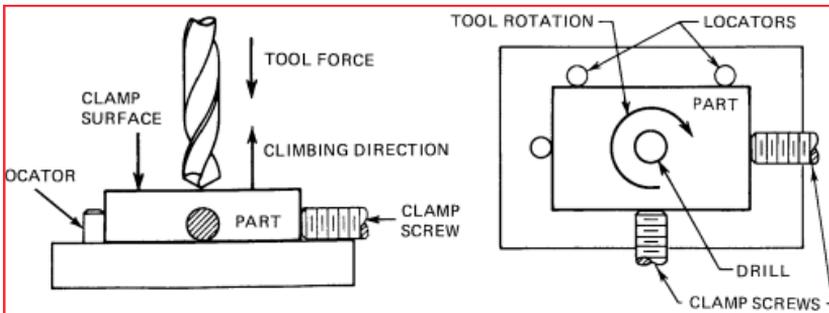4. Type of Clamping Too
5. Material and Surface Conditions

Figure 3.2 : Tools Forces

3 Clamping Forces

- The clamping force ensures that the workpiece remains securely in place during operations such as drilling, milling, or grinding.

- Properly applied clamping force prevents the workpiece from moving, vibrating, or deflecting, which can result in inaccurate machining, tool wear, or even damage to the workpiece.
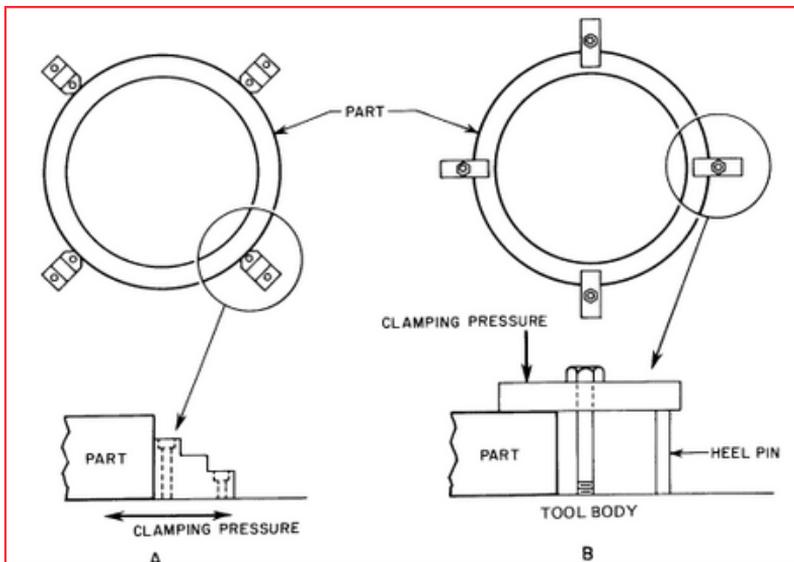

Figure 3.3 : Clamping Forces

The types of clamps

i. Strap clamps

- Are the simplest clamps.

- Function is the same as a lever.

- There are three types of clamps, each representing a form of lever

▶ First class lever- the fulcrum between the work and the effort.

▶ Second class lever-places the work between the fulcrum and the effort,

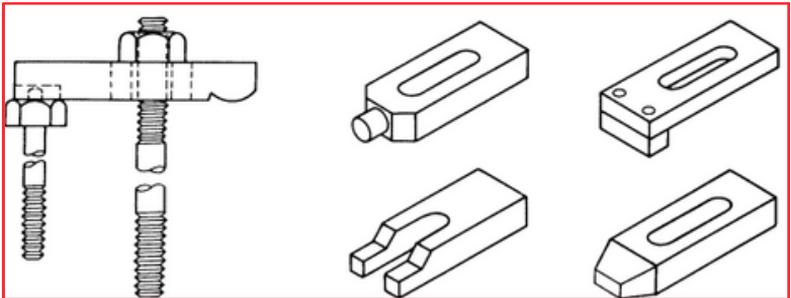▶ Third class lever- placing the effort between the work and the fulcrum.

Figure 3.4 : Strap Clamps
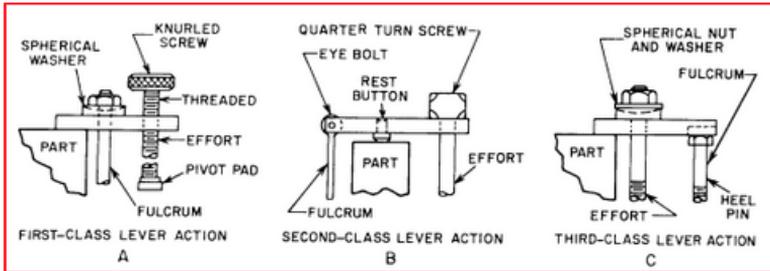*(https://youtu.be/N3zgJUCWomM?si=C_zrZChmGC9SO2Be)*

Figure 3.5: Three Classes of Strap Clamps

ii. Screw clamps

- Usually used in fittings.

- They give tool designers less expensive options, nearly infinite application possibilities, and, frequently, simpler designs.

- Utilizing a screw clamp has only one disadvantage: its slow operating speed.

- The basic screw clamp holds an object in place either directly or through its action on another clamp by using the torque produced by a screw thread.
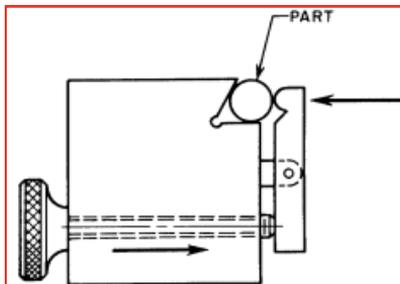

Figure 3.6: Screw clamps

iii. Swing clamp

- With a swinging arm that pivots on its mounting stud, swing clamps combine the functionality of a screw clamp.

- The screw in this clamp produces the holding force.

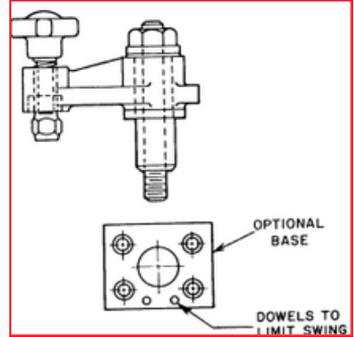- The swinging arm provides the necessary swift action.

Figure 3.7: Swing clamps

iv. Hook clamp

- Same as swing clamps but much smaller.

- They can especially handy when using multiple little clamps instead of a single large clamp or in confined spaces.

- It is helpful in confined spaces or areas where there could be a safety risk if the item is used from the front.
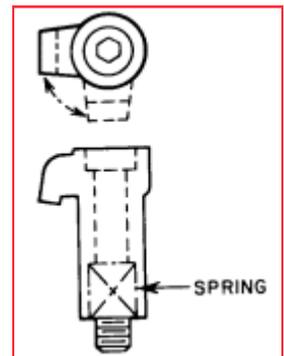

Figure 3.8: Hook clamps

v. Quick- Acting Knob

- Quick-acting knobs are useful for increasing the output of low-cost tools.

- These knobs are made so that when pressure is released, they can be tilted and slid off a stud.

- The knob is slid over the stud until it contacts the part. It is then tilted to engage the threads and is turned until tight.
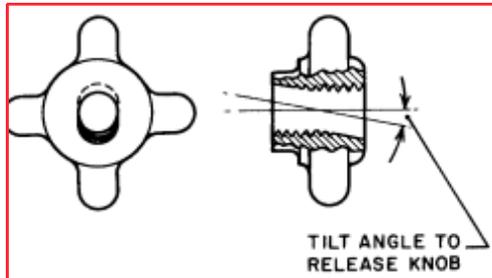

Figure 3.9:Quick- Acting Knob

vii. Wedge clamp

- Two types :
  - a) Flat wedges
  - b) Conical wedges

Flat wedges, or flat cams, bond the part in place by applying pressure to a solid section of the tool body between the clamp.

Have a slight angle, from 1 to 4 degrees, typically, hold the work in place without any extra attachments.
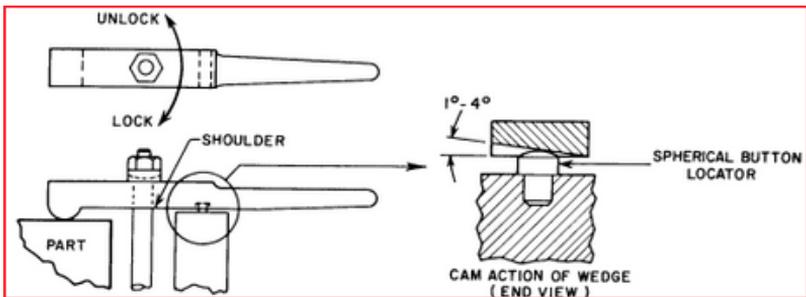

Figure 3.11:Flat wedges clamp

Conical wedges, also known as mandrels, are used to hold work through holes.

Conical wedges, also known as mandrels, are used to hold work through holes.

There are two types of mandrels: expandable and solid. One size hole can only be drilled using solid mandrels. Sizes are accommodated by the design of expansion mandrels.
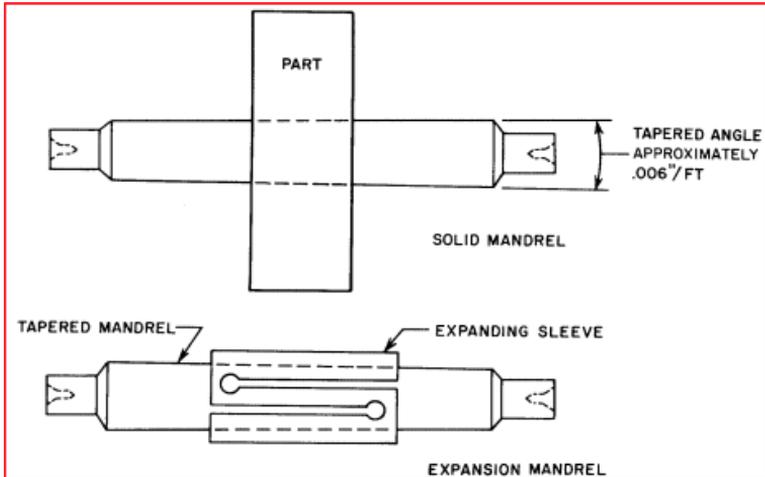

Figure 3.12: Conical wedges clamp

viii. Toggle- Action clamp

- The four primary clamping operations that toggle-action clamps are intended to perform are hold down, squeeze, pull, and straight line. Clamps with toggles have fast action.

- They can move independently of the task at hand, which makes part swapping faster.

- Three pivot points and a set of levers are used by toggle clamps to operate. The pivots and levers are positioned when retracted.
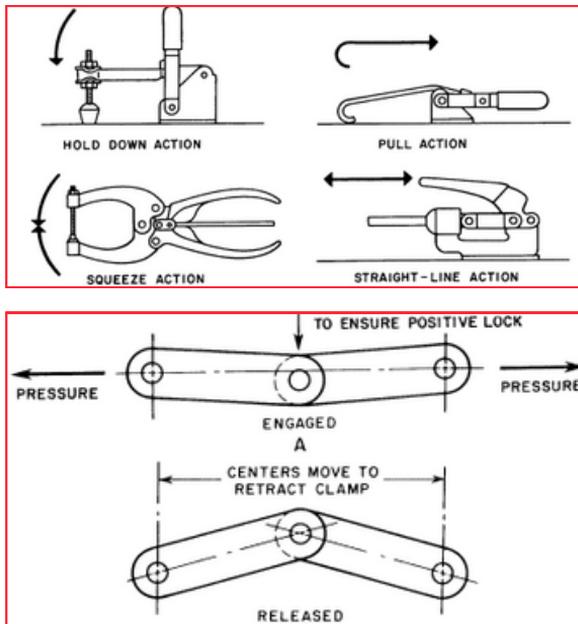

Figure 3.13:   Toggle- Action clamp

ix. Power clamp

- Is another alternative to manual clamping devices

- Function by using hydraulic or pneumatic power, or with an air-to-hydraulic booster.

- The air-to-hydraulic system is recommended - it operates on standard shop line pressure and does not require pumps or high-pressure valves.
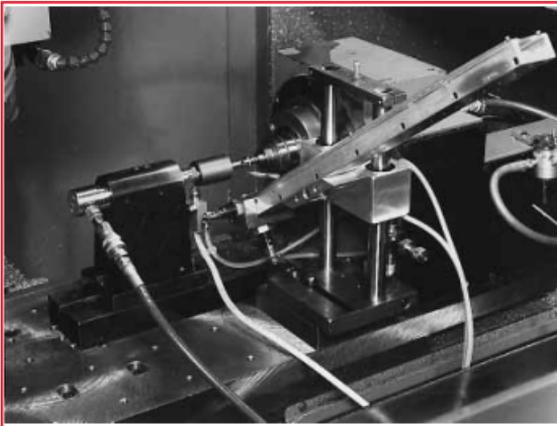

Figure 3.14: Power clamp
(https://youtu.be/Miauh1YyYOs?si=9Waiy2zZP2Rnsbpb)

x. Chucks and vises

- Tool designers can save tooling costs dramatically by customizing components like as vises and chucks that are readily accessible on the market.

- Because of limited resources, one chuck is frequently required to power multiple tools.

- To do this, the tool designer simply adjusts the jaws to fit the task at hand.

- Blank chuck jaws are simply changed to meet almost any clamping need.

- Blank vise jaws can also be customized to fit each job.

- Using standard chucks and vises for unique tools can save the tool designer significant time and money while enhancing job productivity.
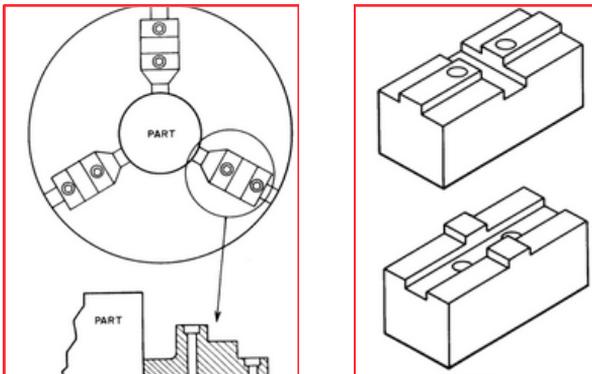

Figure 3.15: Chucks and vises

3.2 Sketch the clamping and workholding devices

a. The function of magnetic chucks
b. The function of vacuum chucks

a. Magnetic chucks

- Magnetic chucks are clearly appropriate for ferrous items.

- Other materials require the employment of mechanical devices in addition to magnetic chucks.

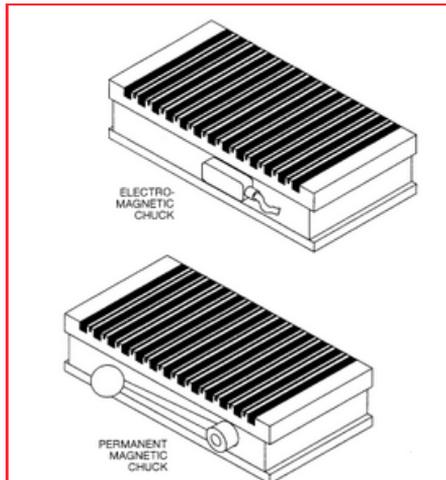- Magnetic chucks and accessories are available in a variety of designs and forms.

Figure 3.16: Magnetic chucks
(https://youtu.be/1yKUOdzfV_k?si=NQ8x1b8bHuiAWfo9)

b. Non- Magnetic chucks

- Vacuum chucks work well with non-magnetic items.

- Vacuum chucks equalize clamping pressure throughout the whole clamping surface.

- To clamp smaller components, cover the exposed chuck ports with a mask or close them by tightening the specific part screws.

Figure 3.17: Non- magnetic chucks
(https://youtu.be/-j5mH6L4SW0?si=_beiDoNu8XXEd6Cs)

3.3 Sketch the types of clamping in special clamping operation.

a. Clamping Odd Shapes Operation
b. Multiple Clamping Devices Operation

a. Clamping Odd Shapes

- The best way is to have the clamps and locators fit to the shape of the part.

- Casting is an alternative to machining for creating unique shapes.

- Epoxy resins and low-melt alloys are the most commonly used compounds for casting.

- Epoxy resins are used for casting specialized vise or chuck jaws.

- They can be used alone or in conjunction with a filler material like metal filings, sand, or powdered glass.

- A releasing agent is given to the part to make it easier to remove once the epoxy has cured.
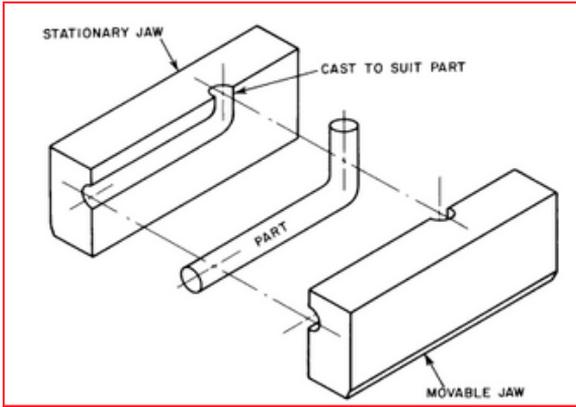
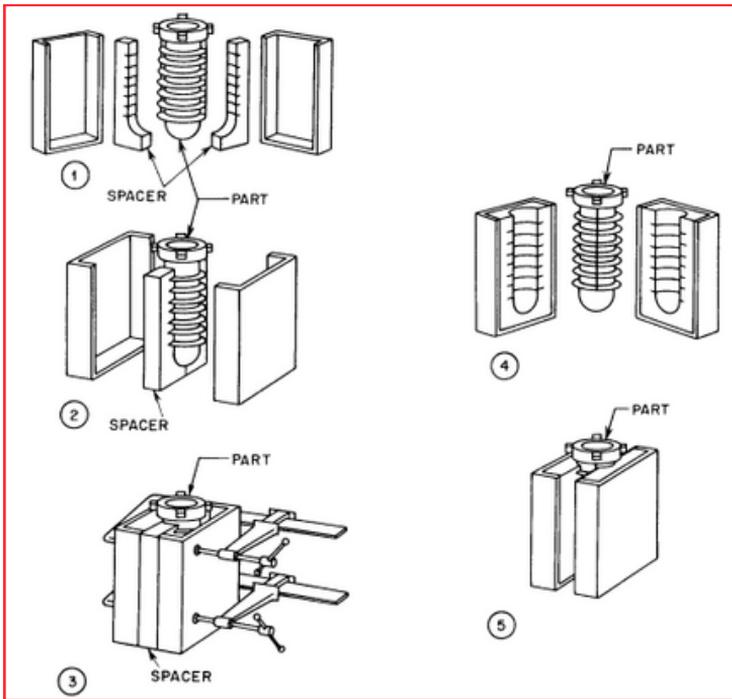*Figure 3.18 (a): Types of clamping Odd Shapes*

Figure 3.18 (b): Types of clamping Odd Shapes

b. Multiple Clamping Devices

- Manufacture processes frequently call for the manufacture of multiple parts at once.

- The two things when utilizing multiple clamps are that
  a) each part should have the same clamping pressure
  b) each clamp should have a single locking point.

- In the event that a part leaps off of the tool during the machining cycle, clamps that do not deliver equal pressure could harm the components being machined.
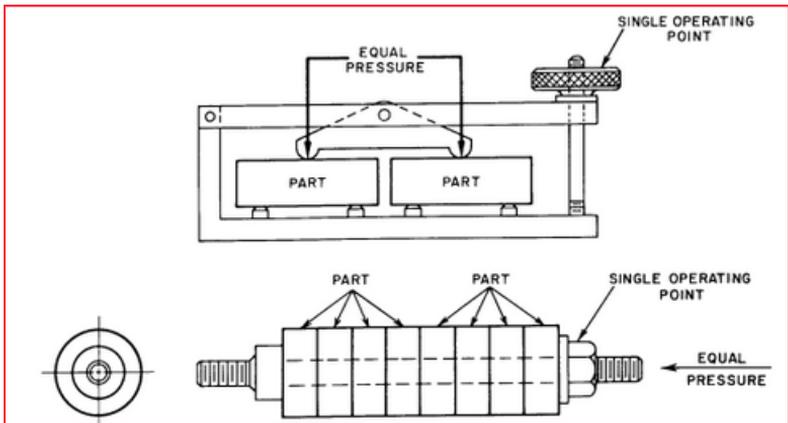

Figure 3.19: Multiple clamping devices

85

3.4 **Explain the clamping accessories to make the job easier**

- Several commercially available attachments improve the application and efficacy of clamps.

- Clamp screws, grips, jacks, leveling pads, and spring plungers are just a few of the attachments offered to help the tool designer do their work.

Figure 3.20: Types of clamping accessories

With suitable examples, explain two types of the non-mechanical clamping.
(4 m)

Write the characteristic or application of clamps type below.   (8m)

i. Screw Clamps:

ii. Swinging strap clamps:

iii. Edges clamps:

iv. Magnetic chuck clamps:

References

Edward G. Hoffman. (2011). Jig and Fixture Design. Fifth Edition. Delmar Publisher

Erik Karl Henriksen. (1973). Jig and Fixture Design   Manual. Industrial Press Inc.

Prakash Hiralal Joshi. (2010). Jig and Fixture. McGraw-Hill Education (India) Private Limited

JIG AND FIXTURE DESIGN VERSION 1

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