DESIGN FOR MANUFACTURING AND ASSEMBLY

Course code:AME520

VI. B. Tech II semester

Regulation: IARE R-16

BY

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CO's	Course outcomes
CO1	Understand various general design rules for manufacture ability and criteria for material selection.
CO2	Apply various machining process and tolerance aspects in machining.
CO3	Analyze the design considerations for casting and welding process.
CO4	Apply the conceptual design factors to be considered in forging, extrusion and sheet metal work,design guidelines for manual assembly and development of DFA methodology

UNIT– I
INTRODUCTION

CLOs	Course Learning Outcome
CLO1	Identify and understand of basic concepts of DFM and DFA
CLO2	Understand and Apply concepts of Generative DFMA
CLO3	Understand the Various types of materials, its classification, suitable materials for product design

Design for Assembly (DFA)

DFA involves design for a product’s ease of assembly. It is concerned with reducing the product assembly cost and minimising the number of assembly operations.

Both DFM and DFA seek to reduce material, overhead, and labour costs.

Design for Manufacturing and Assembly (DFMA)

Design for Manufacture and Assembly (DFMA) is design approach that focuses on ease of manufacture and efficiency of assembly.

Main principles of DFMA

- Minimise the number of components: Thereby reducing assembly and ordering costs, reducing work-in-process, and simplifying automation.
- Design for ease of part-fabrication: The geometry of parts is simplified and unnecessary features are avoided.
- Tolerances of parts: Part should be designed to be within process capability.
- Clarity: Components should be designed so they can only be assembled one way.
- Minimise the use of flexible components: Parts made of rubber, gaskets, cables and so on, should be limited as handling and assembly is generally more difficult.
- Design for ease of assembly: For example, the use of snap-fits and adhesive bonding rather than threaded fasteners such as nuts and bolts. Where possible a product should be designed with a base component for locating other components quickly and accurately.
- Eliminate or reduce required adjustments: Designing adjustments into a product means there are more opportunities for out-of-adjustment conditions to arise.

Design for Manufacture and Assembly (DFMA) is design approach that focuses on ease of manufacture and efficiency of assembly.

By simplifying the design of a product it is possible to manufacture and assemble it more efficiently, in the minimum time and at a lower cost.

It involves two methodologies – Design for Manufacture (DFM) and Design for Assembly (DFA):

Design for Manufacture (DFM)

DFM involves designing for the ease of manufacture of a product's constituent parts. It is concerned with selecting the most cost-effective materials and processes to be used in production, and minimising the complexity of the manufacturing operations.

Objectives of DFMA

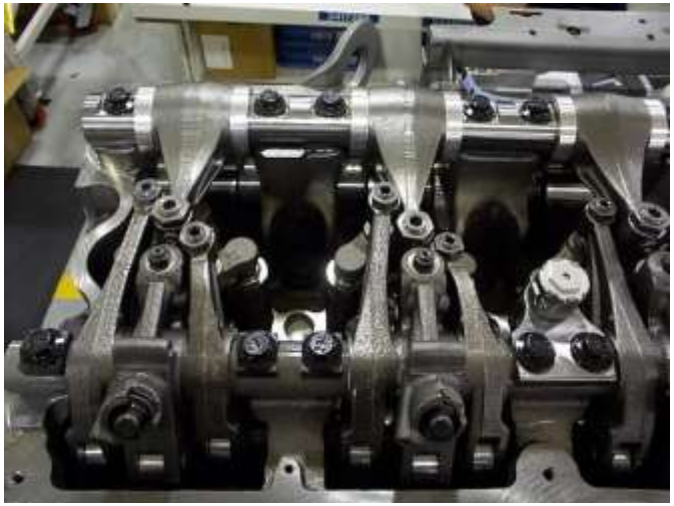
Participants will understand:

- Differences and Similarities between Design for Manufacturing and Design for Assembly
- Describe how product design has a primary influence
- Basic criteria for Part Minimization
- Quantitative analysis of a design's efficiency
- Critique product designs for ease of assembly
- The importance of involving production engineers in DFMA analysis

Design for Assembly

Definition: DFA is the method of design of the product for ease of assembly.

'Optimization of the part/system assembly'



DFA is a tool used to assist the design teams in the design of products that will transition to productions at a minimum cost, focusing on the number of parts, handling and ease of assembly.

Design for Manufacturing

Definition: DFM is the method of design for ease of manufacturing of the collection of parts that will form the product after assembly.

"...Optimization of the manufacturing process..."

DFA is a tool used to select the most cost effective material and process to be used in the production in the early stages of product design.

Differences

Design for Assembly (DFA)

- concerned only with reducing product assembly cost
  - minimizes number of assembly operations
  - individual parts tend to be more complex in design

Design for Manufacturing (DFM)

- concerned with reducing overall part production cost
  - minimizes complexity of manufacturing operations
  - uses common datum features and primary axes

Similarities

- Both DFM and DFA seek to reduce material, overhead, and labor cost.
- They both shorten the product development cycle time.
- Both DFM and DFA seek to utilize standards to reduce cost

Terminology

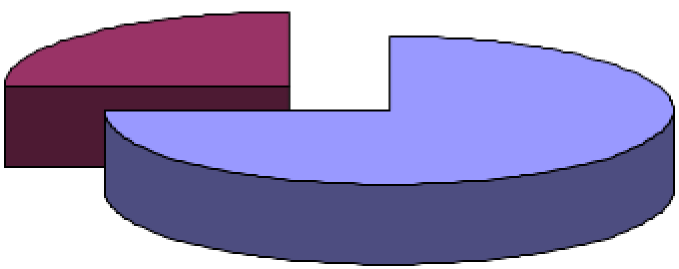
- Design for Manufacturing (DFM) and Design for Assembly (DFA) are now commonly referred to as a single methodology, Design for Manufacturing and Assembly **(DFMA)** .

Similarities

- What Internal Organization has the most Influence over Price, Quality, & Cycle Time?

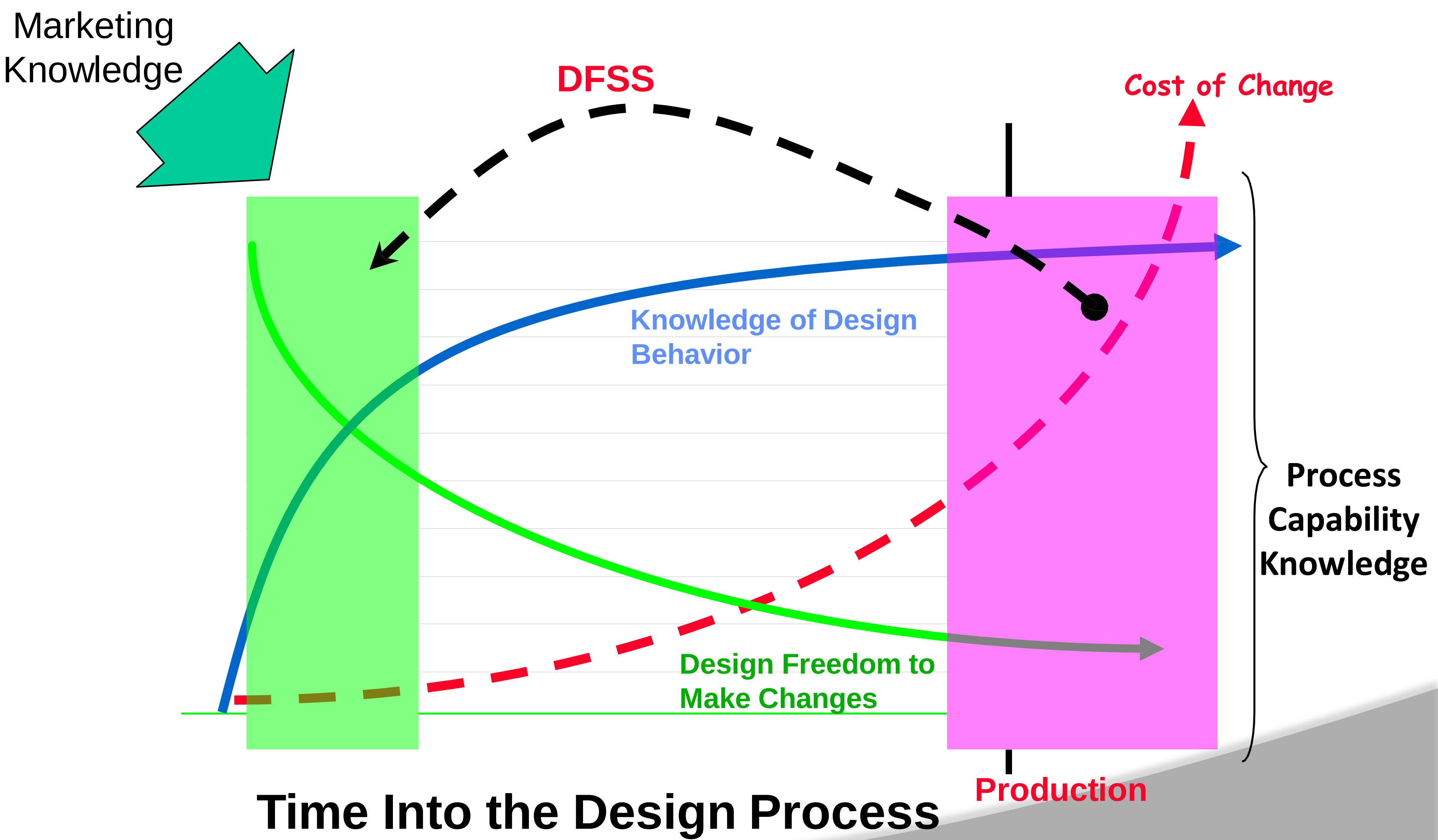
Manufacturing

20 - 30%



- Design 70 - 80%

Knowledge and Learning



Sequence of Analysis

Concept Design

↓

Design for Assembly

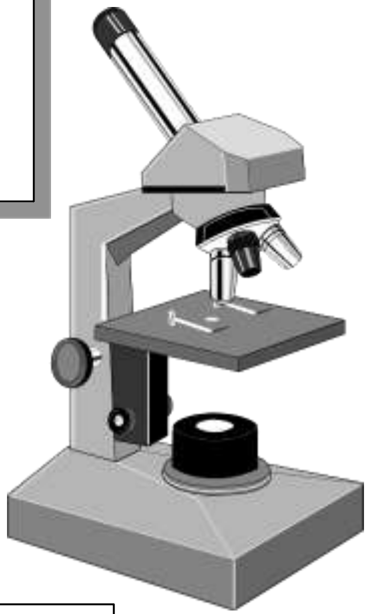
↓

Design for Manufacturing

↓

Detailed Design

Optimize Design for Part Count and Assembly



Optimize Design for Production Readiness

Design for Assembly

DFA is a process that **REQUIRES** involvement of Assembly Engineers

Design for Assembly Principles

- Minimize part **count**
- Design parts with **self-locating features**
- Design parts with **self-fastening features**
- **Minimize reorientation** of parts during assembly
- Design parts for **retrieval, handling, & insertion**
- Emphasize **‘Top-Down’** assemblies
- **Standardize** parts…minimum use of fasteners.
- Encourage **modular** design
- Design for a **base part** to locate other components
- Design for component **symmetry** for insertion

Objective

- Designers need to study the nature of materials
- Classification of materials that determines their applicability
- Relation between design, production and utilization of materials

Classifying materials:

In manufacturing of a product, a raw material is converted into a finished product. There are various types of classifications available in the literature. Materials come under three basic categories: metals, ceramics and polymers. A mixture of these fundamental types forms a composite.

Two classification schemes are shown below:

Type 1 classification

- Engineering materials can be classified into six broad families as shown in Figure M1.3.1.

Introduction to Materials and Material Selection

- – Metals
- – Polymers
- – Elastomers
- – Ceramics
- – Glasses
- – Hybrid composite materials

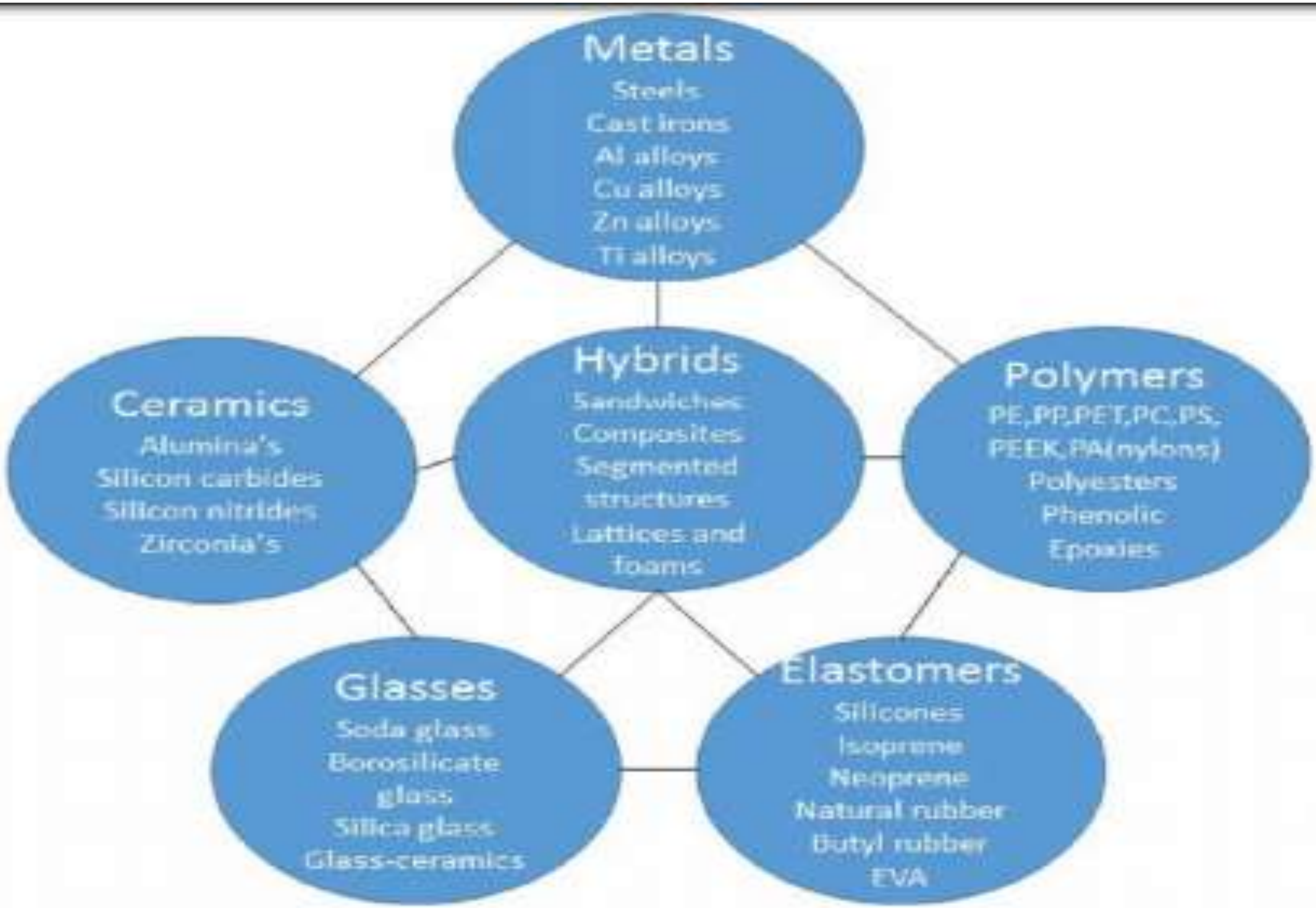


Figure M1.3.1: Classification of engineering materials in to six broad families.

Type 2 classification

In this type of classification, engineering material can be classified into two categories: Metals and non-metals as shown in Figure

Again non-metals are classified into organic & inorganic as shown in Figure M1.3.3 & Figure M1.3.4 respectively.

Metals can be classified into two categories: ferrous and non-ferrous metal

Introduction to Materials and Material Selection

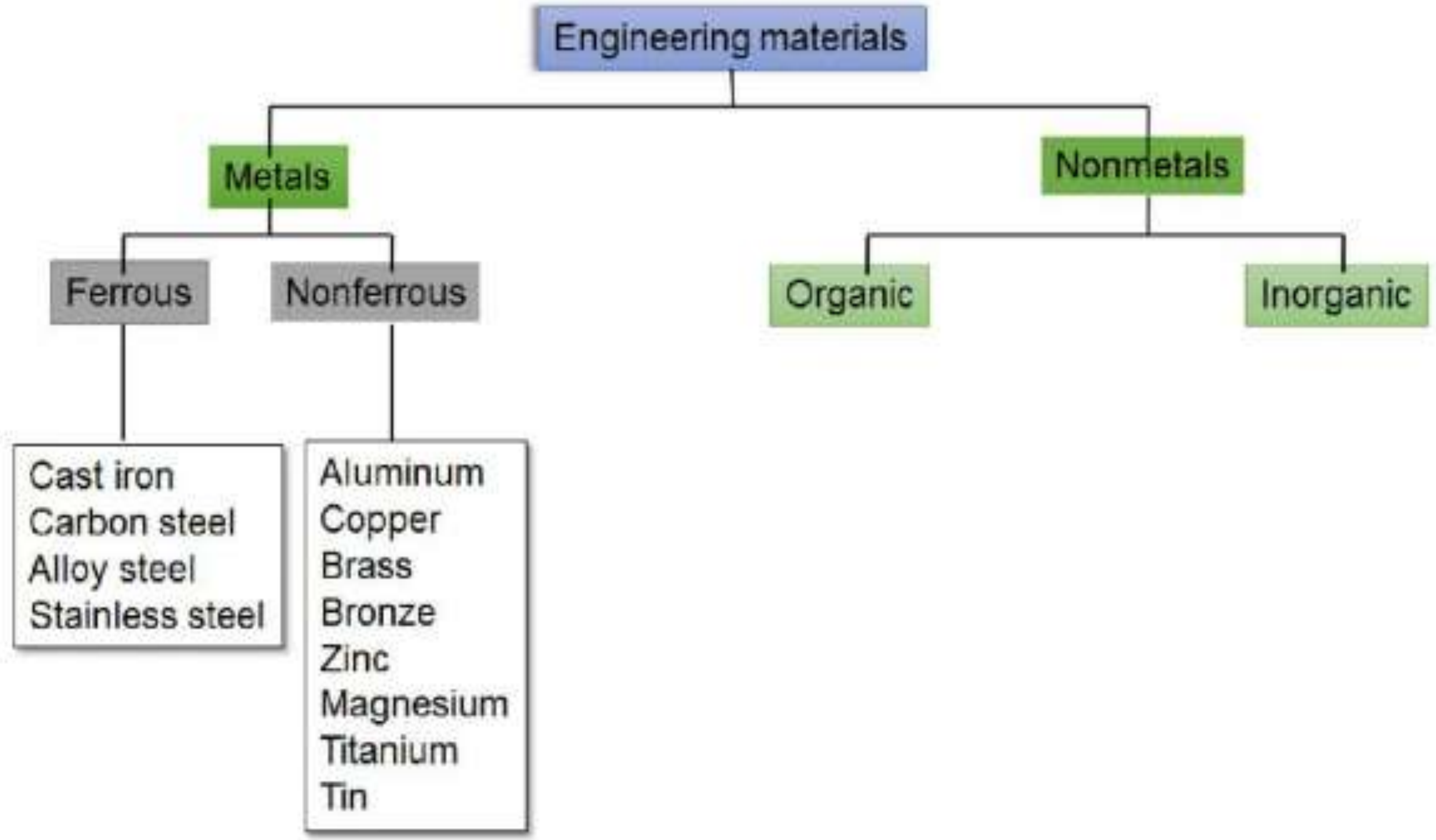


Figure M1.3.2: Classification of engineering materials in two groups

Ceramics are compounds. These compounds contain a metallic and a non-metallic part. The non-metals can be oxygen, nitrogen and carbon. Examples of ceramics include carbides, clay, silica, alumina etc.

Polymers are compounds which consist of repeating units in them called as “mers”. Mers share electrons to form very large molecules - usually of carbon and some other elements like oxygen, hydrogen, nitrogen, chlorine etc. Polymers are further classified into thermosetting, thermoplastics and elastomers. Some of the common polymers are polythene, PVC, etc.

Composites consist of two or more phases of materials. The phases are processed separately and then bonded together to achieve properties superior to the constituents. Some of the materials used in the phases are wood or fiber etc. which are a homogenous mass bonded together with epoxy. Some of the common applications of composites are aircraft, tennis rackets, car bodies, etc.

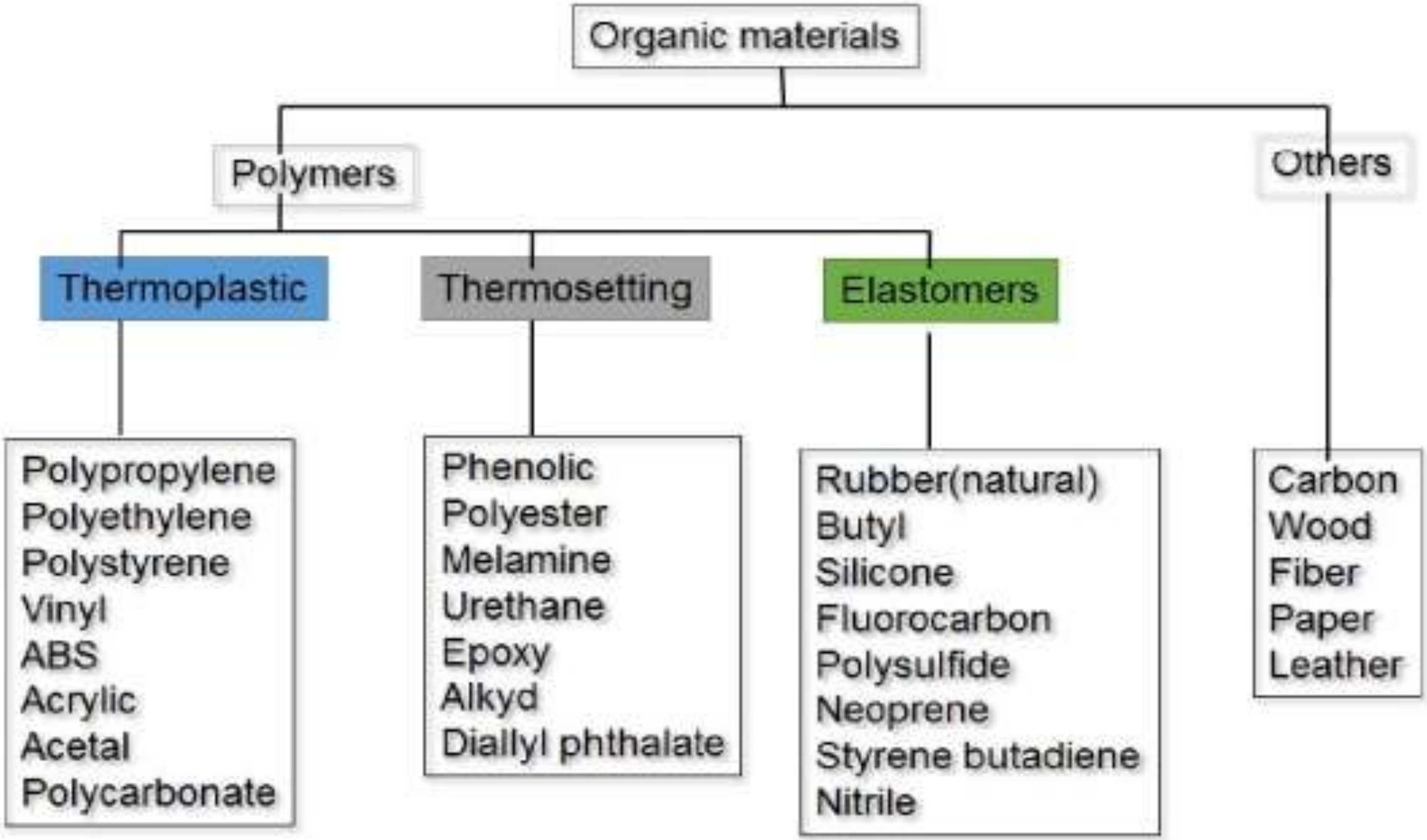


Figure M1.3.3: Classification of organic materials

Material selection for product design

Material selection seeks to improve the following five basic elements:

- the life cycle performance of a material in an application
- the design and manufacturing of a component taking advantage of a material's characteristics
- the properties of a material
- the structure of a material
- synthesis and processing of the material

In material selection, a set of design requirements is converted into a list of viable materials and processes as shown in Figure M1.3.5. There are several methods for material selection:

- Selection by analysis
- Selection by synthesis
- Selection by similarity
- Selection by inspiration

1. Selection by analysis

The inputs to this method are the technical requirements. The analysis proceeds in four steps:

- Translation of requirements: It is often expressed initially in non-technical terms into statement of objectives and constraints the design must meet.
- Analysis of the component for which a material is sought, identifying performance matrices and expressing these as equations that measure performance.
- Identification from these equations of the material properties that determine performance.
- Screening of a database of materials and their properties, eliminating those that fail to meet the constraints, and ranking those that remain by their ability to maximize the performance matrices.

2. Selection by synthesis

- This process is experimental and depends on experience of the designer. The inputs here can include the design requirements expressed as features showing intentions, aesthetics and perceptions.
- Basically the solution will depend on previously solved problems that have some features common with the problem at hand. While this may be seen as a drawback since the method uses past experience,
- it encourages a kind of cross pollination where developments in one field can be adapted for use in another. This methodology is called technology coupling.

3. Selection by similarity

A substitute material may be sought when the existing material is no longer available or fails to meet a design requirement. In such cases an established material can be used instead of the existing one, simply because it may have the right mix of attributes and may be meeting the design requirements.

4. Selection by inspiration

Designers usually get their ideas from other designers, colleagues and from their environments. And many ideas are triggered by accident, perhaps by some chance encounter with someone or some situation. The encounter thus becomes inspiring and provokes creative thinking. Such encounters can include interaction with materials, with products or by browsing books.

Material Selection

Kinds of Materials (What kind of materials can I use?)

- Metals
  - Iron
  - Aluminum
  - Copper
  - Magnesium
- Composites
- Ceramics
  - Glass
  - Semi-conductors
  - Structural ceramics (SiN, SiC)
  - Refractory Composites
- Polymers
  - Rubber
  - Plastics
- Liquids
- Gases

Material Selection

- As mechanical engineers we deal mostly with metals. Metal properties tend to be well understood and metals are somewhat forgiving materials. We can make small mistakes (sometimes big ones) and get away with a poor design as a result of metal's forgiving nature.
- We see ceramics and composites all around us, but they tend to be used in special applications because of fabrication costs. This however, is changing.
- Plastics are among the most common modern material choices. In large volume production, plastics are inexpensive. In small volume productions, plastics can be an extremely expensive choice due to high tooling costs.

Material Properties

As mechanical engineers we are most concerned with characteristics such as:

- Mechanical Properties
  - Strength
    - Yield Strength
    - Ultimate Tensile Strength
    - Shear Strength
  - Ductility
  - Young's Modulus
  - Poisson's ratio
  - Hardness
  - Creep
  - High or low temperature behavior
  - Density
  - Anisotropy
- Fatigue strength
- Fracture Toughness
- Thermal Properties
  - Thermal expansion coefficient Thermal conductivity
  - Specific heat capacity

Magnetic Properties

Fabrication Properties

- Ease of machining
- Ease of welding, casting, etc
- Hardening ability
- Formability
- Availability
- Joining techniques

Environmental Properties

- Corrosion properties
- Toxic effects
- Out-gassing properties

Gas and Liquids

- Viscosity

Introduction to Materials and Material Selection

The choice of a material is frequently the result of several compromises. For example, the technical appraisal of an alloy will generally be a compromise between corrosion resistance and several other properties such as strength and weldability. And the final selection may come down to a compromise between technical and economic factors. In identifying a material, approach the task in three stages:

List the material requirements for the design. Use the list of characteristics given above to help you in defining ALL the critical requirements. Rank the requirements in importance to the design's success.*

Select and evaluate candidate materials. By researching the various handbooks and resources, attempt to rank your candidate materials as to how well they meet the requirements. Use a decision table to identify the best choices.

Choose the most economical material. Research material costs and production costs based upon your anticipated production run. Choose the least expensive of your best choice candidate materials.

Cummins Tools

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DFA Analysis Worksheet

Assembly Name: ______________________ Team: ______________

---------------------- Enter 'Y' or 'N' (without quotation marks). Values will be automatically c

	Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing		Handling			Insertion				Secondary Operations				
	Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni) (part a to part b = 1)	Theoretical Minimum Part (Functional Analysis chart)	Part can be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble wrong part / Omit part	Assemble part wrong way around	Tangle / Nest / Stick Together	Flexible / Fragile / Sharp / Slippery	Pliers / Tweezers / Magnifying glass	Difficult to align / Locate	Holding down required	Resistance to insertion	Obstructed access / visibility	Re-orientated Work Piece	Screw / Drill / Twist / Rivet / Bend / Crimp	Weld / Solder / Glue	Paint / Lube / heat / Apply liquid or gas	Test / Measure / Adjust
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- Product Information: ***functional requirements***
- **Functional analysis**
- Identify parts that can be standardized
- Determine part count efficiencies

Considerations/Assumptions

- The first part is essential (base part)

- Non-essential parts:
  - Fasteners
  - Spacers, washers, O-rings
  - Connectors, leads

- Do not include liquids as parts
  (e.g.. glue, gasket sealant, lube)

Parts Identification

- List of parts in the order of assembly
- Assign/record part number

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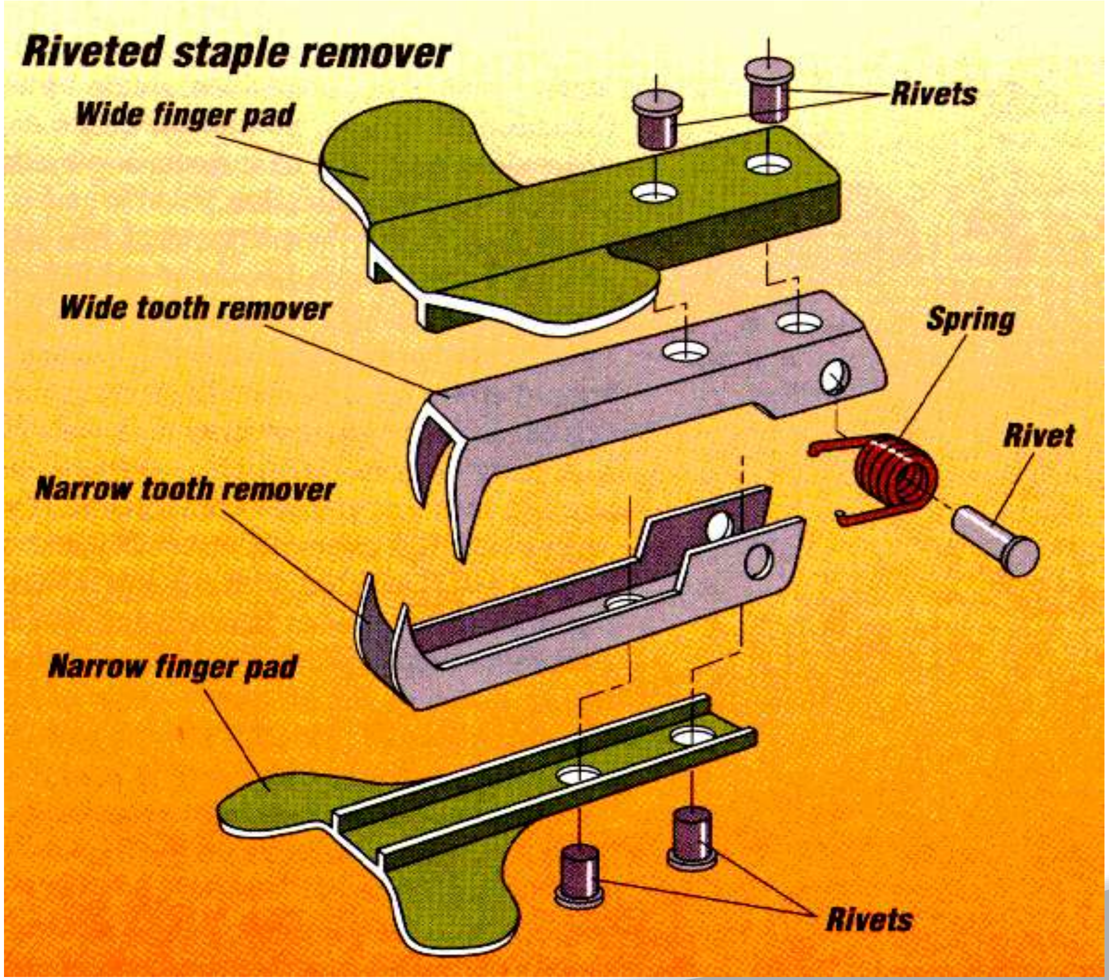
DFA Analysis Worksheet

Assembly Name: Staple Remover

	A	B	C	D	E
4		Part	DFA Complexity		Func Rede
5	Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni) (part a to part b = 1)	Theoretical Minimum Part (Functional Analysis chart)
6	1	Lower Arm Sub.			
7	1.1	***Base Part*** - Lower Arm			
8	1.2	Lower Arm cover			
9	1.3	Rivet			
10	2	Upper Arm Sub.			
11	2.1	Upper Arm			
12	2.2	Upper Arm cover			
13	2.3	Rivet			
14	3	Spring			
15	4	Pivot			
16					
17		***Totals***			

So take it apart!



Count Parts & Interfaces

- List number of parts (Np)
- List number of interfaces (Ni)

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DFA Analysis Worksheet

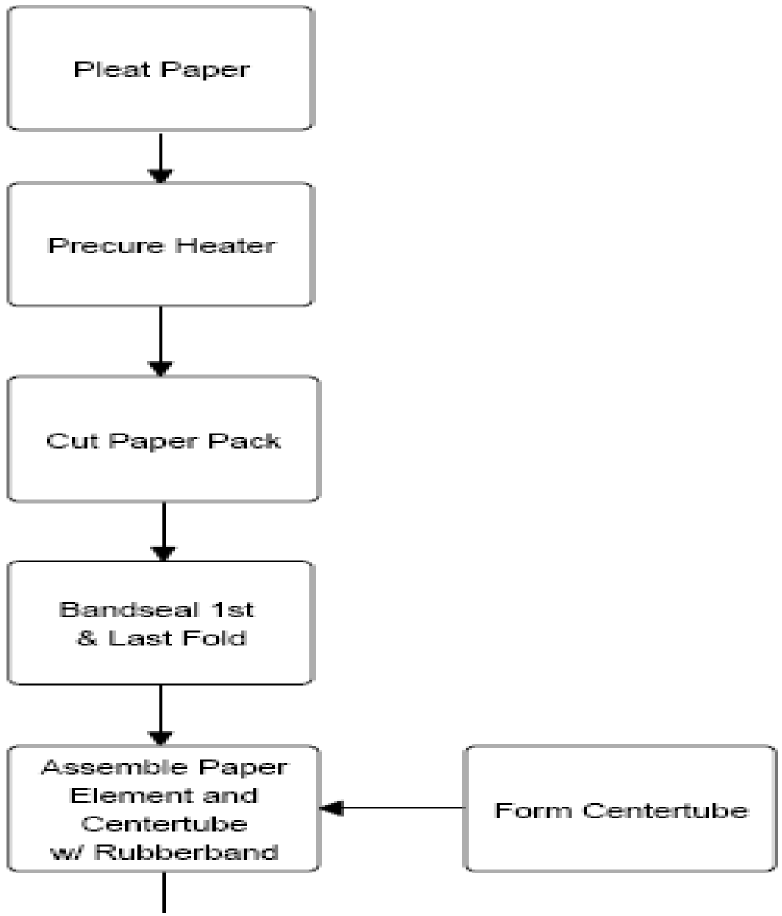
Assembly Name: Staple Remover

	Part		DFA Complexity		Func Rede
	Part Number	 Part Name	Number of Parts (Np)	Number of Interfaces (Ni) (part a to part b = 1)	Theoretical Minimum Part (Functional Analysis chart)
6	1	Lower Arm Sub.			
7	1.1	*Base Part* - Lower Arm	1		
8	1.2	Lower Arm cover	1		
9	1.3	Rivet	2		
10	2	Upper Arm Sub.			
11	2.1	Upper Arm	1	6	
12	2.2	Upper Arm cover	1	3	
13	2.3	Rivet	2	4	
14	3	Spring	1	3	
15	4	Pivot	1	3	
16					
17		*Totals*	10	32	

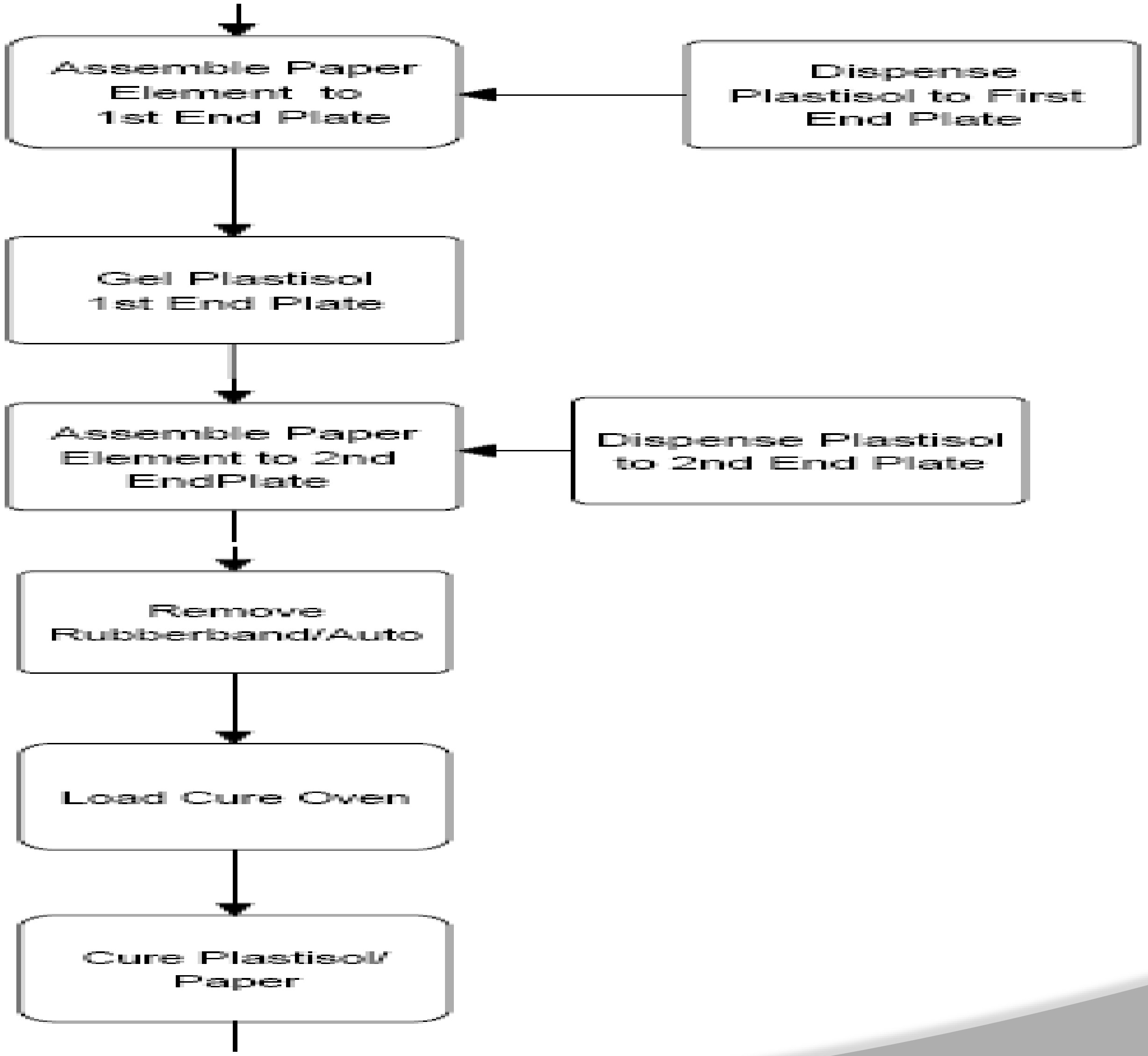
I1: Arm to rivet
I2: Arm to rivet
I3: Arm to cover
I4: Arm to pivot
I5: Arm to spring
I6: Arm to Arm

Process Flow Diagram

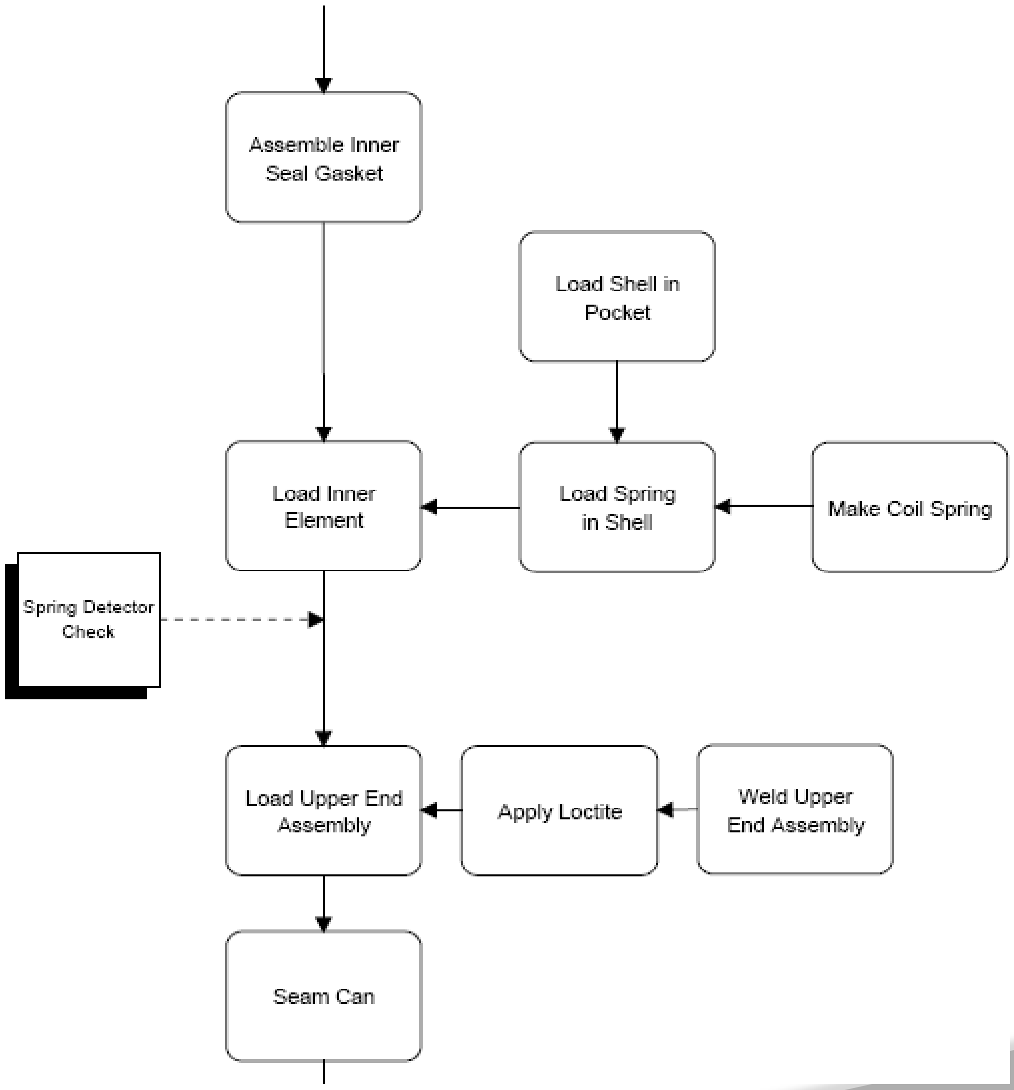
Dept. 1310 Process Flow Diagram



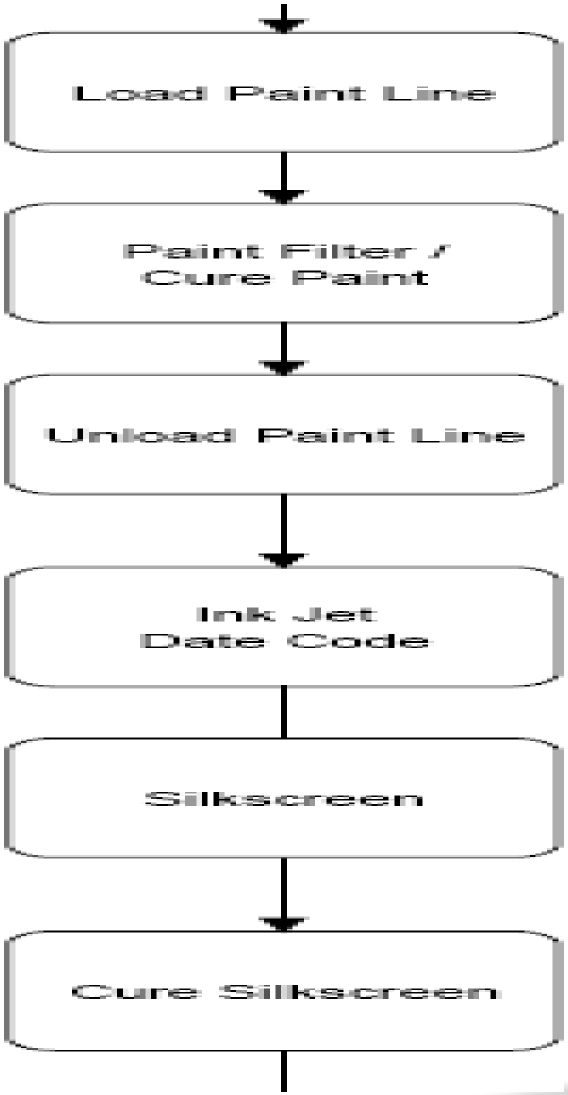
Process Flow Diagram



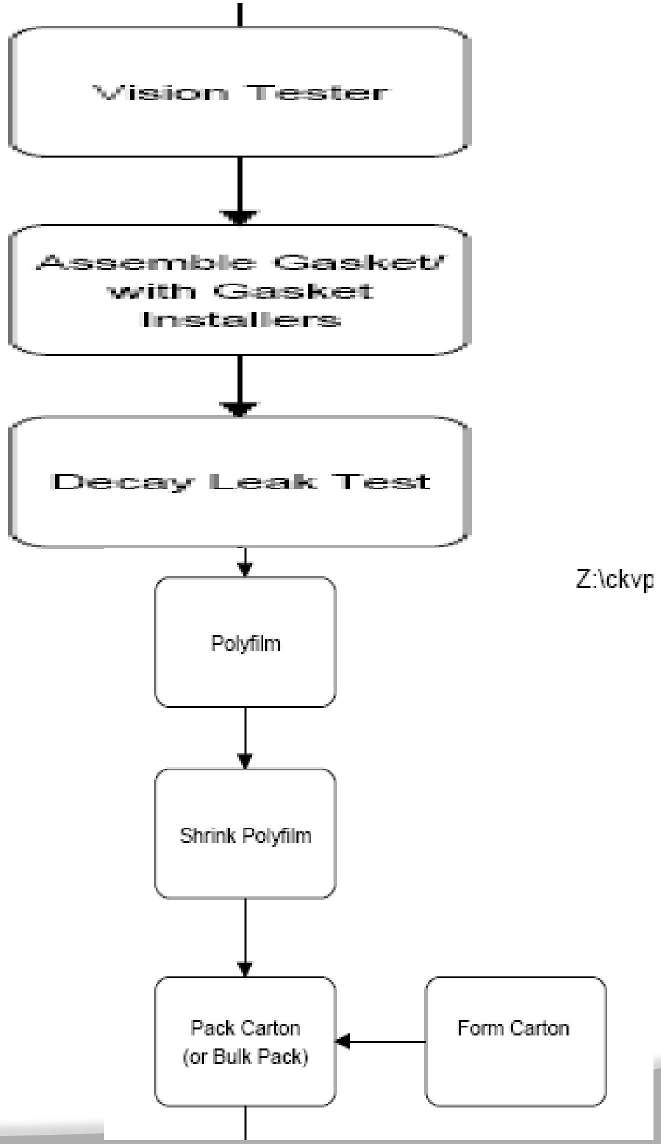
Process Flow Diagram



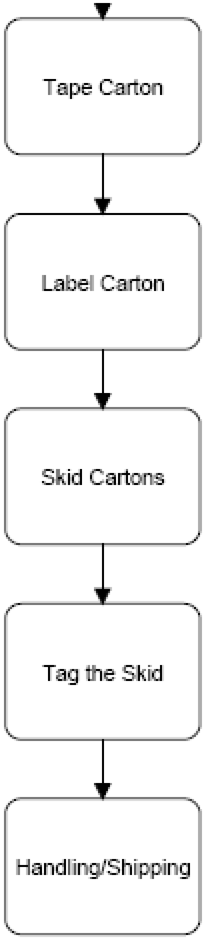
Process Flow Diagram



Process Flow Diagram



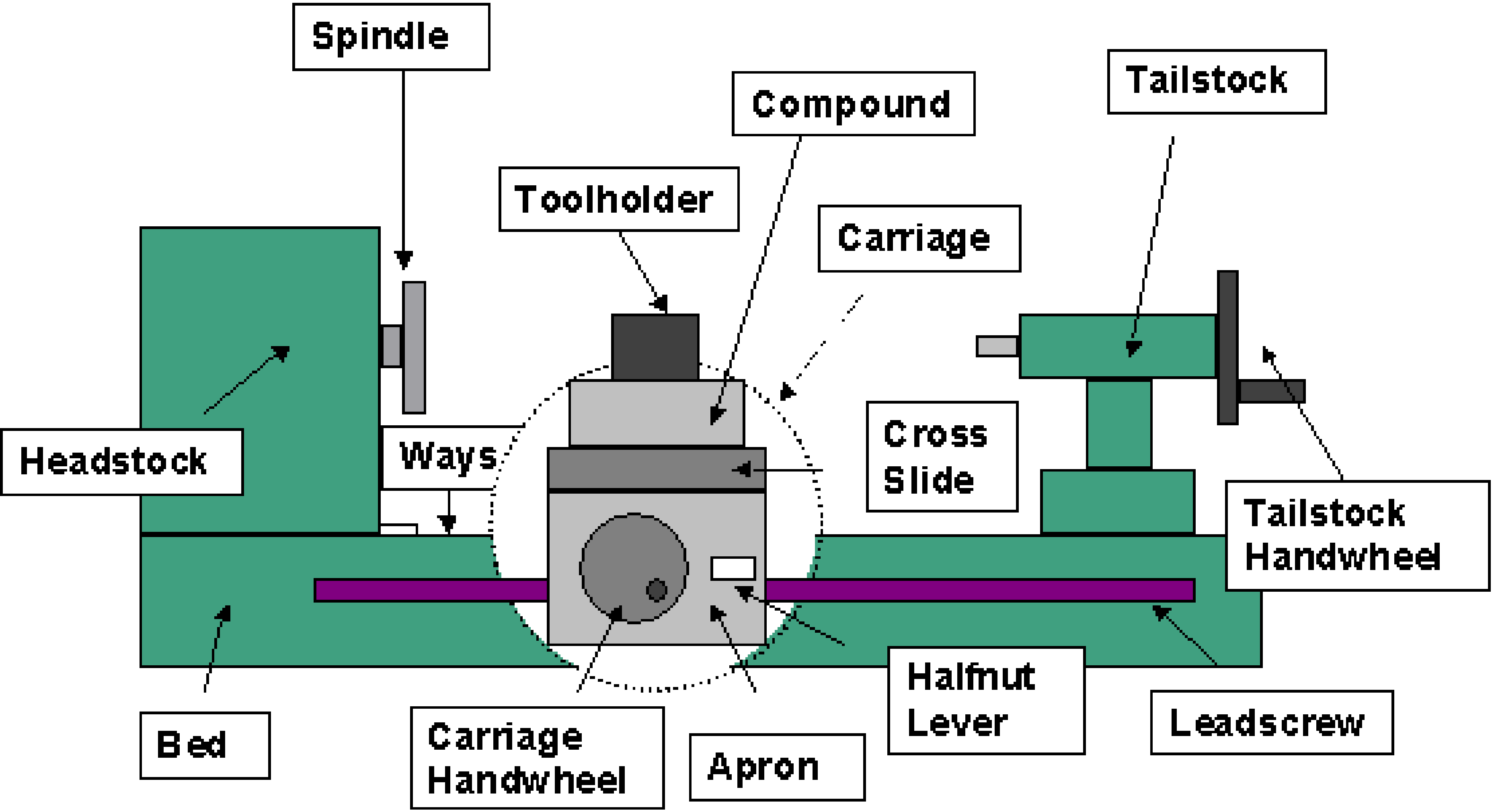
Process Flow Diagram



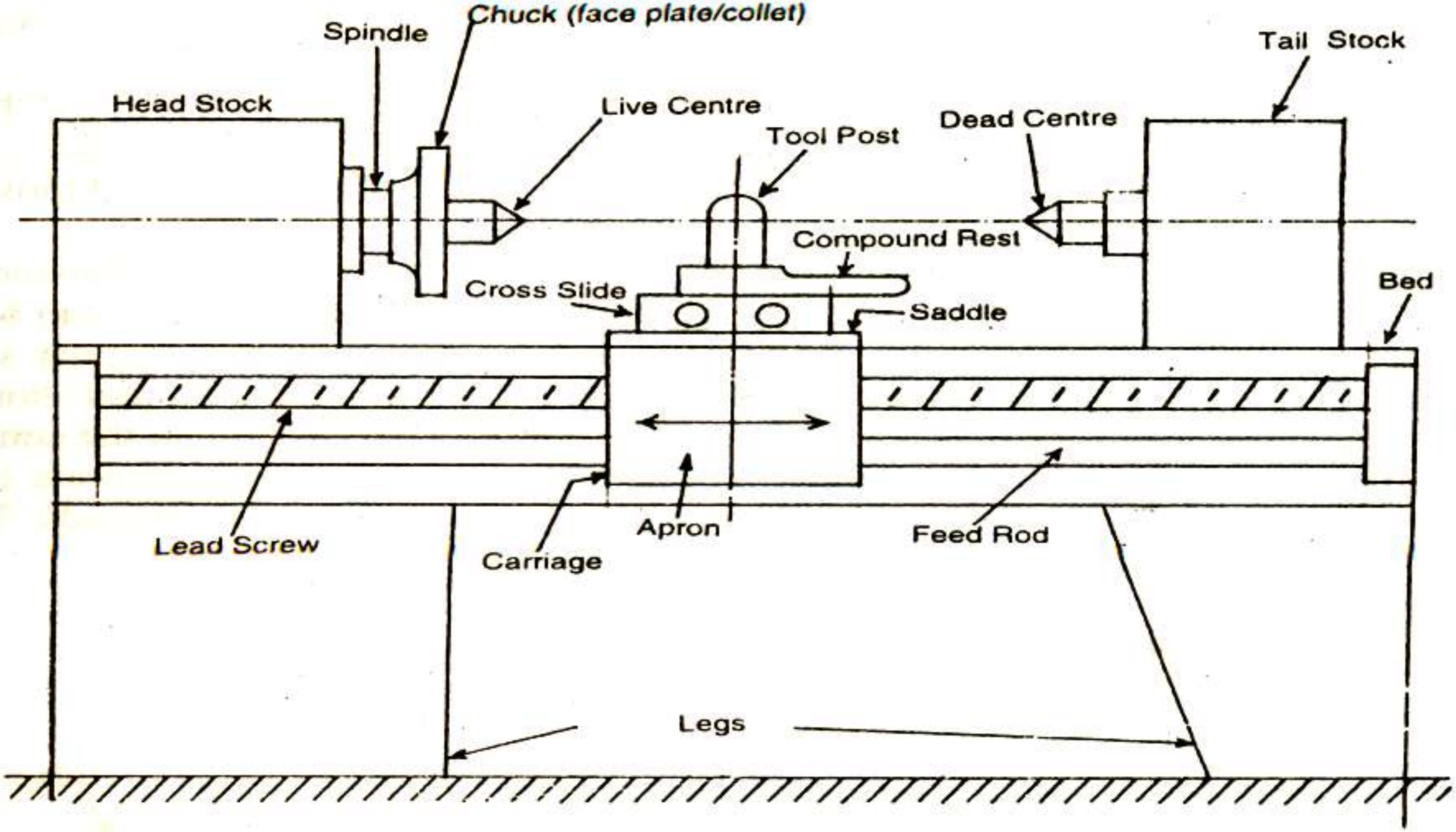
UNIT II
MACHINING PROCESS, CASTING

CLOs	Course Learning Outcome
CLO 4	Understand the selection of manufacturing sequences and optimal selection
CLO 5	Identify the reasons for optimal selection of machining parameters.
CLO 6	Identify the various casting design, machining design, designing of formed components.

Lathe


Spindle
Compound
Tailstock
Toolholder
Carriage
Headstock
Ways
Cross Slide
Tailstock Handwheel
Halfnut Lever
Leadscrew
Bed
Carriage Handwheel
Apron

Lathe



Block Diagram of an Engine Lathe

Geared Head Stock

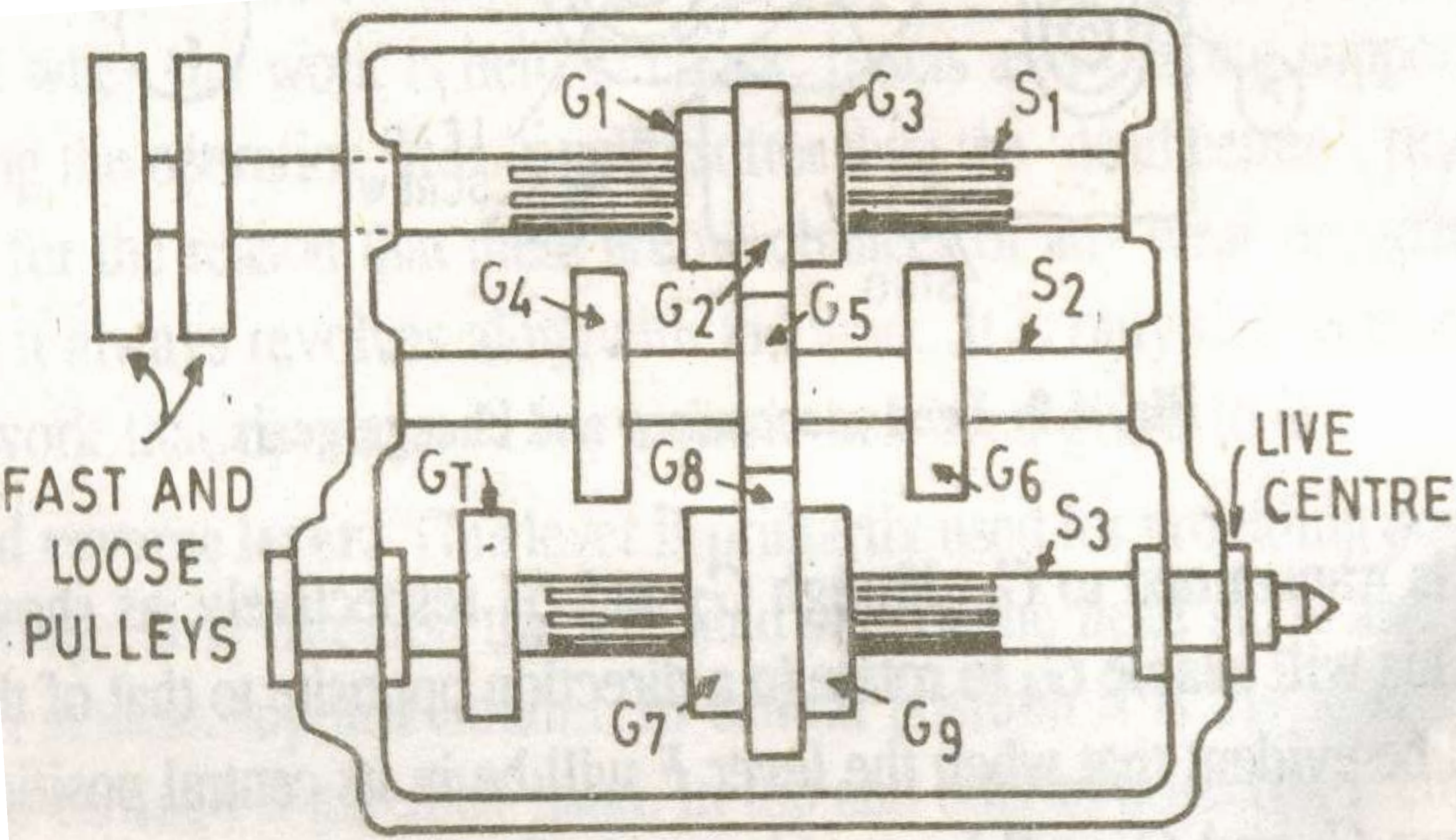


Fig. 6.10. A Geared head stock.

Tailstock -

It’s on the other end of the bed from the headstock. It’s chief function is to hold the dead centre so that long work pieces can be supported between centres.

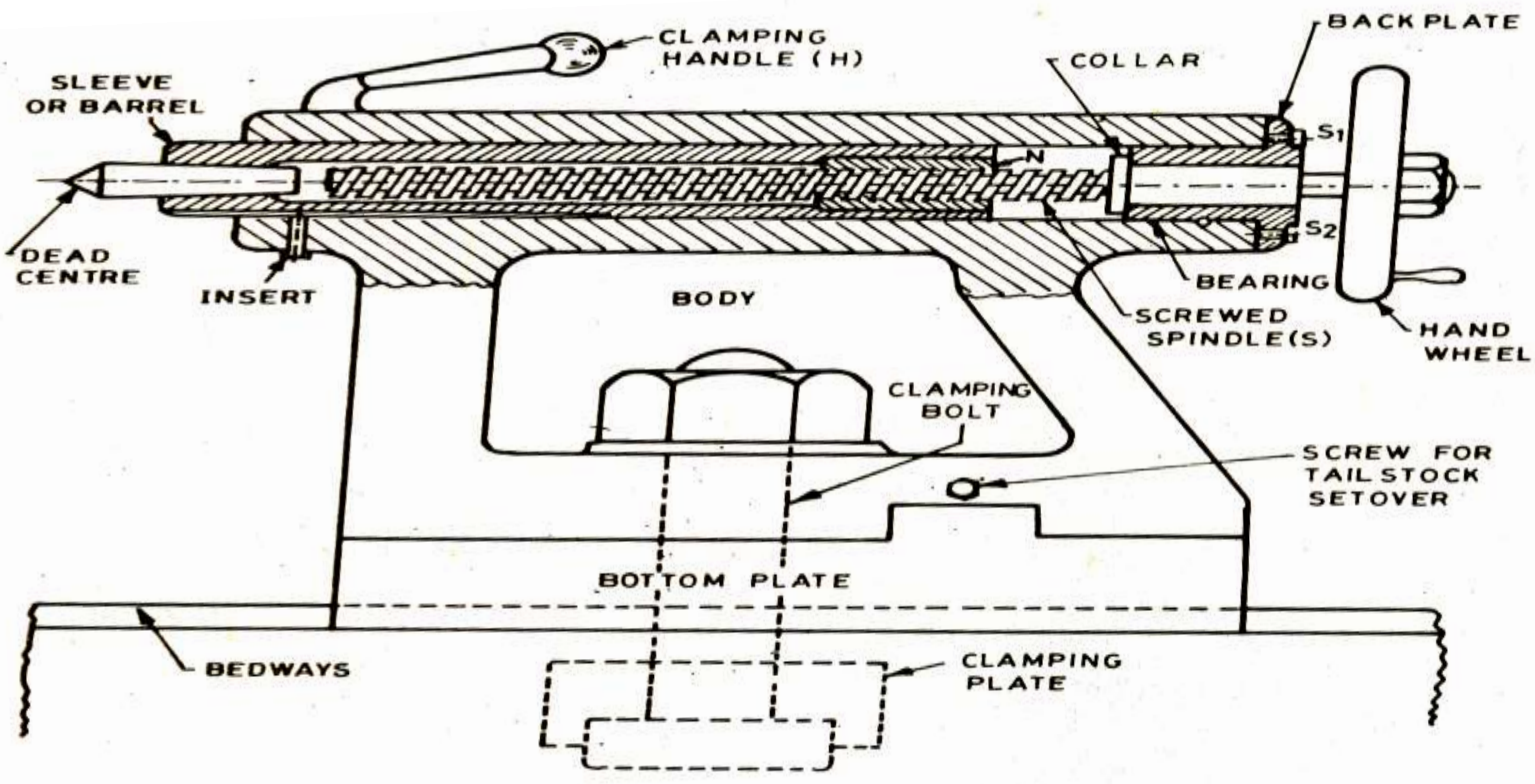


Fig. 6.11. Tail stock of a lathe.

Lathe Spindle

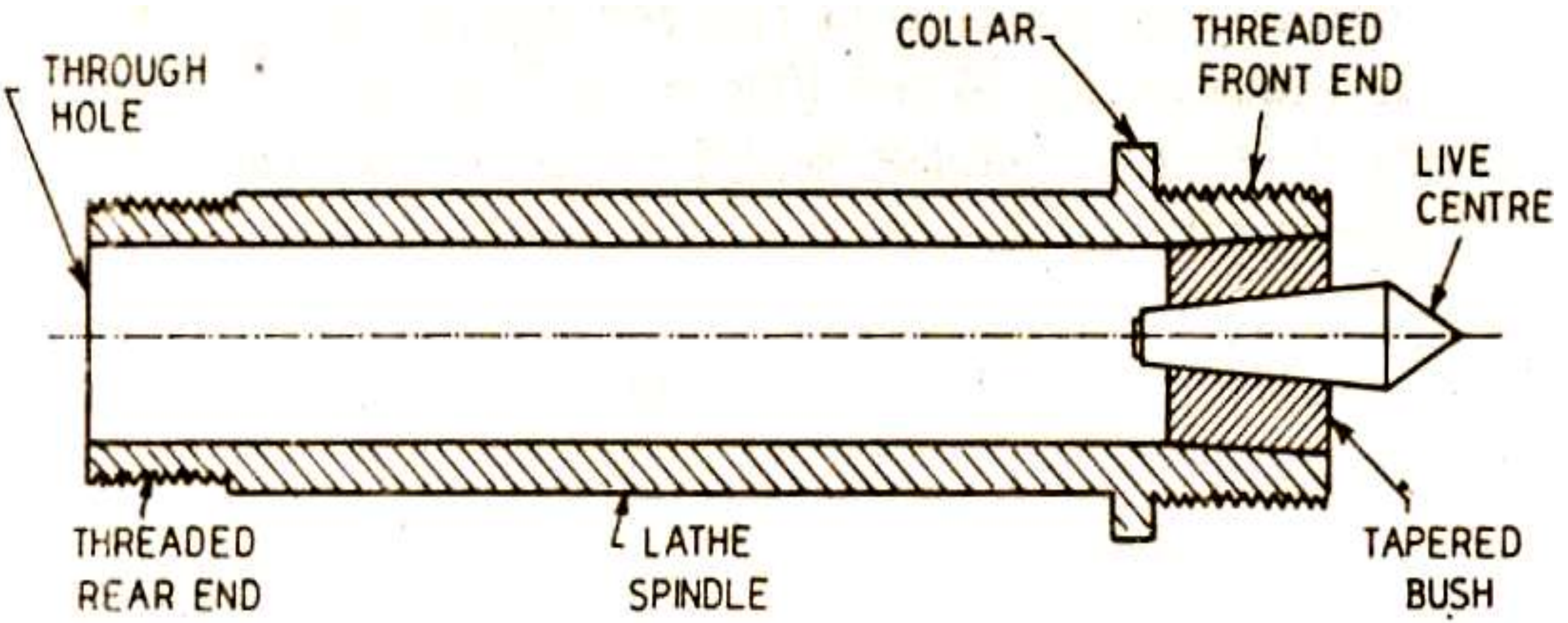


Fig. 6.8. A Lathe spindle.

Carriage

In between the headstock & tailstock is the carriage. It's movable on the bed ways and it's purpose is to hold the cutting tool & to impart to it either longitudinal or cross feed. It has five major parts:

a) Saddle

b) Cross slide

c) Compound rest

d) Tool post

e) Apron

Lathe Carriage

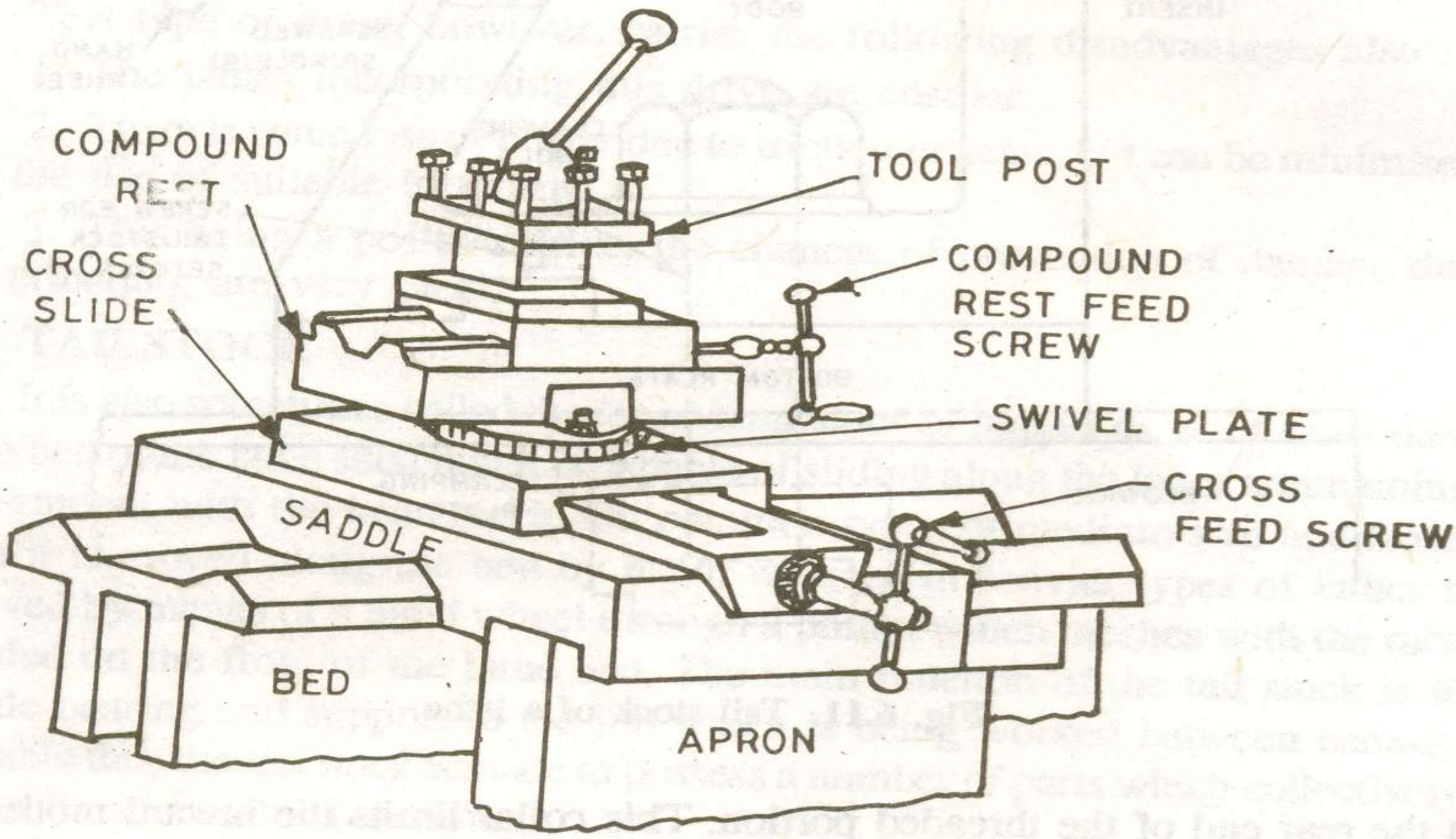


Fig. 6.12. The carriage.

Carriage

a) ***Saddle*** **–** The base of the carriage is the saddle which slides along the ways of the lathe bed and supports the cross-slide, compound rest & tool post.

b) ***Cross slide*** **–** It's mounted on top of saddle. It provides cutting tool motion which is perpendicular to the centre line of the lathe itself. The cross feed movement may be controlled by manual or by power feed.

c) ***Compound rest***– It's also known as tool rest. It's mounted on top of the cross-slide. It has a graduated circular base & can be swiveled around a vertical axis. It can be clamped to remain at any angular setting.

d) ***Tool post-*** It is mounted on the compound rest & slides in a T-slot. Cutting tool/ tool holder is firmly held in it.

e) ***Apron*** It's the hanging part in front of the carriage. It is secured underneath the saddle & hangs over the front of the bed.

Lead Screw

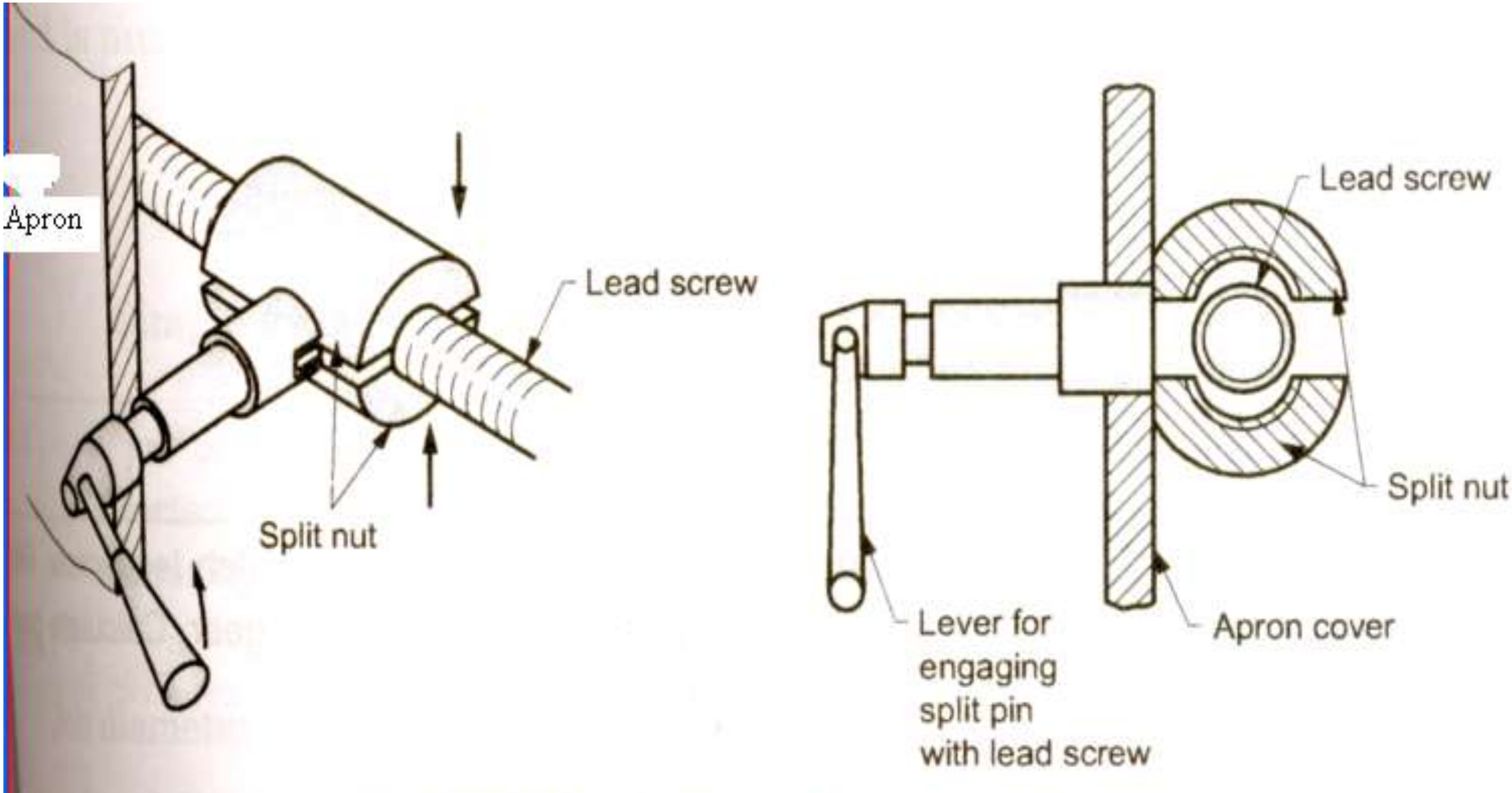


Fig. 4.9.13(b) : Split nut for screw cutting

Lathe Operations : Turning

A single point cutting tool removes material from a rotating work piece to generate a rotationally symmetric shape

Machine tool is called a ***lathe***

Types of cuts:

- Facing
- Contour turning
- Chamfering
- Parting (Cut-off) / Grooving
- Threading

Turning Parameters Illustrated

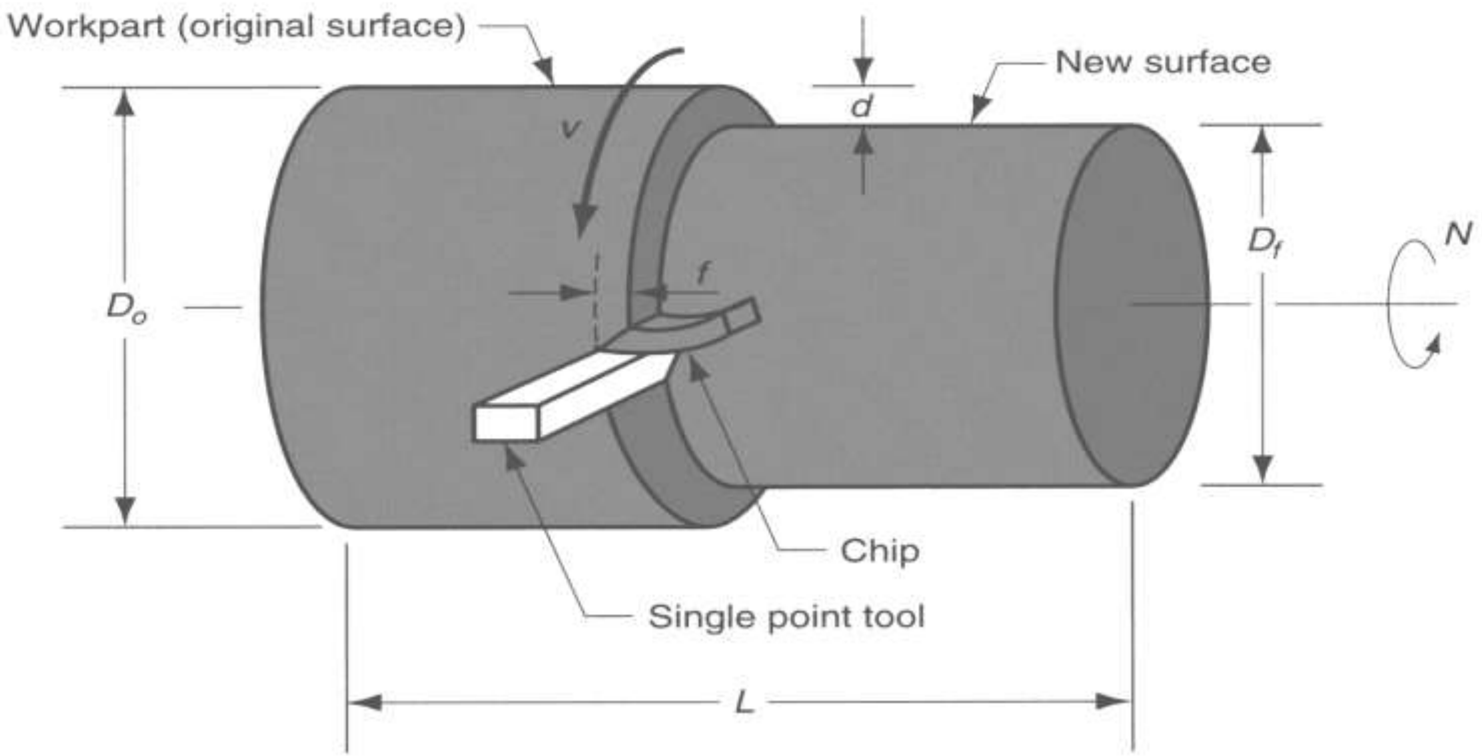
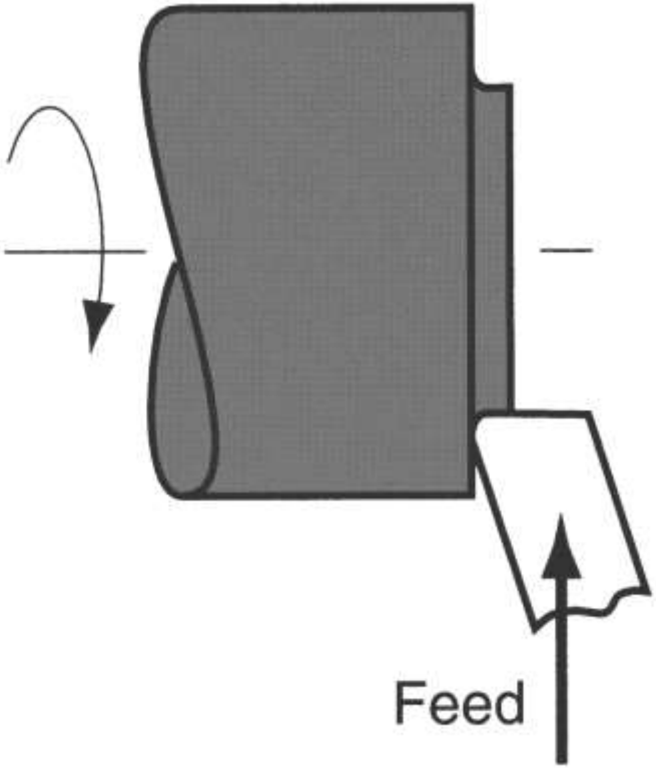


Figure 22.5 - Turning operation **[Groover (2004), p.503]**

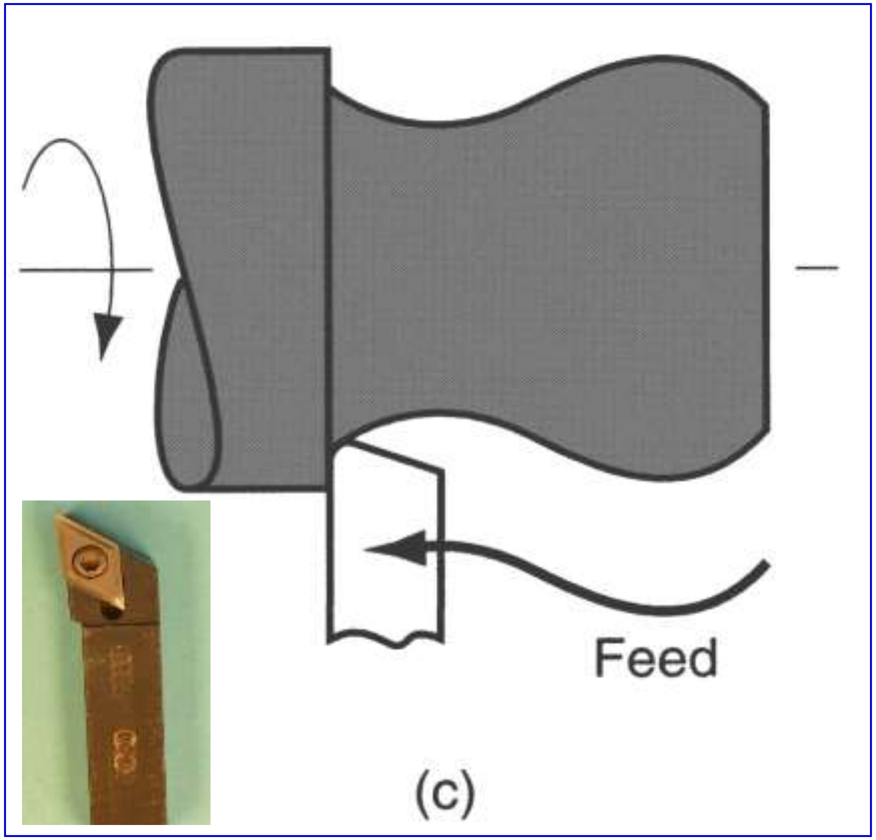
Facing

Tool is fed radially inward

Figure 22.6 (a) facing



Contour Turning



Instead of feeding the tool parallel to the axis of rotation, tool follows a contour that is not necessarily straight (thus creating a contoured form).

Figure 22.6 (c) contour turning

Right & Left Hand Tools

- Right Hand Tool:
  - Cuts from right to left

- Left Hand Tool:
  - Cuts from left to right

Chamfering

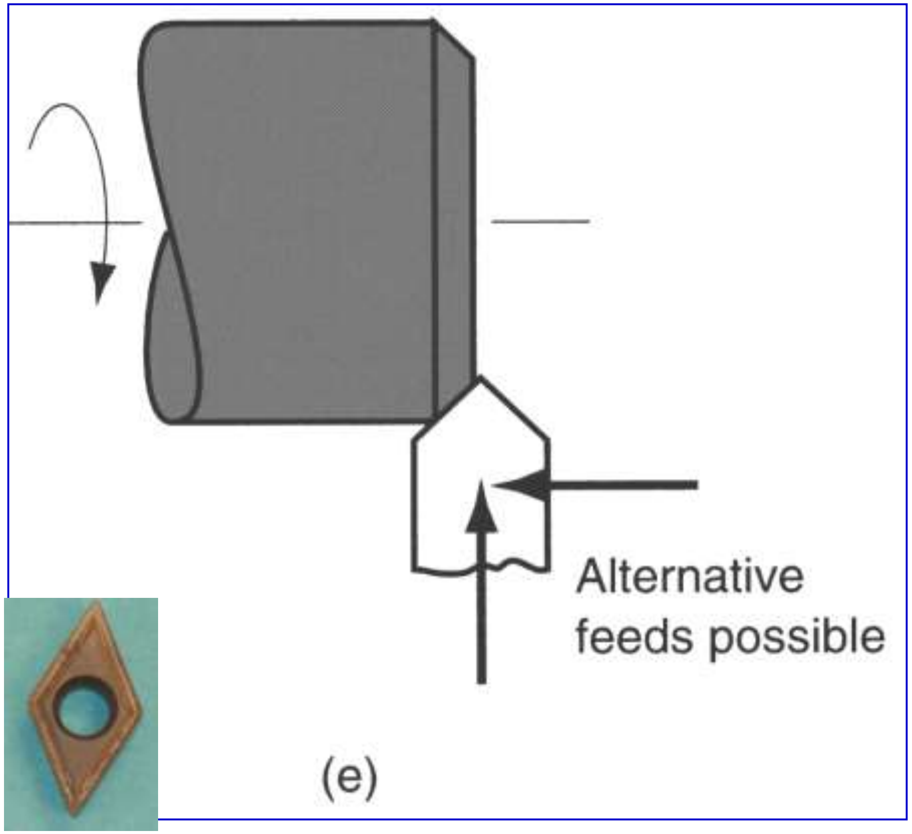


Figure 22.6 (e) chamfering

Cutting edge cuts an angle on the corner of the cylinder, forming a "chamfer"

Parting (Cutoff) / Grooving

Tool is fed radially into rotating work at some location to cut off end of part, or provide a groove

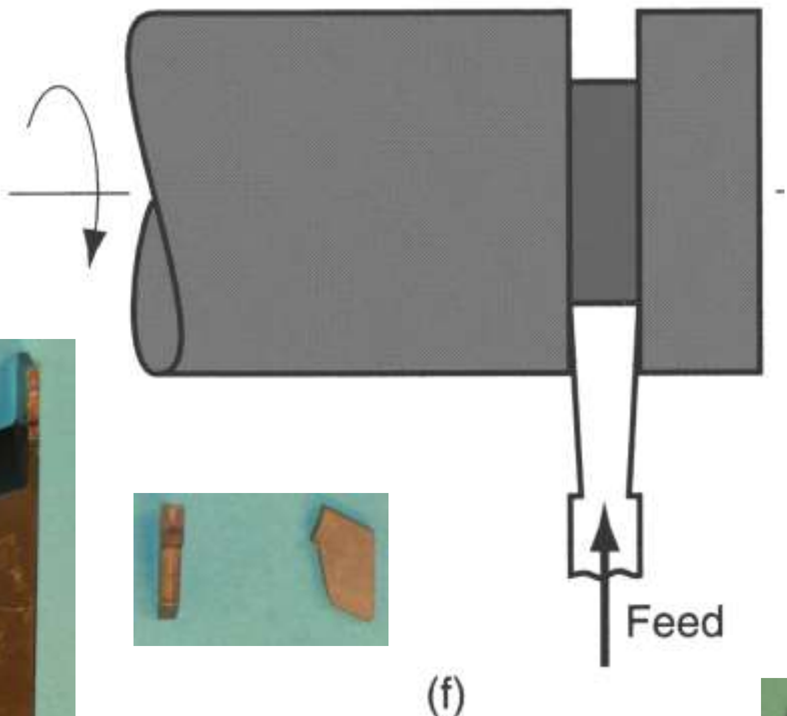


Figure 22.6 (f) cutoff

Threading

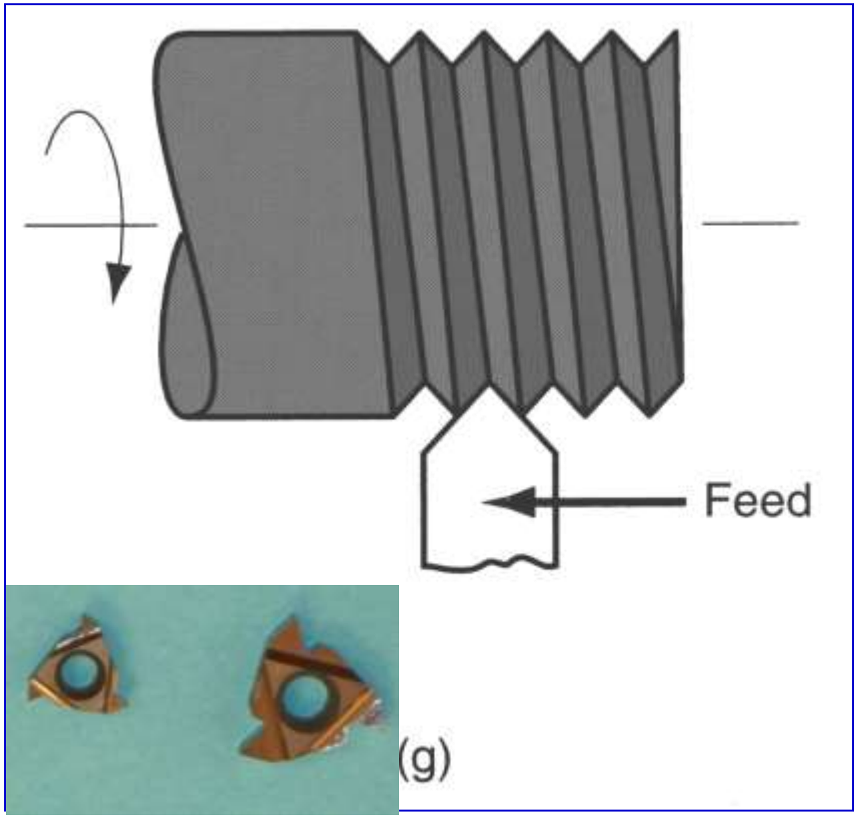
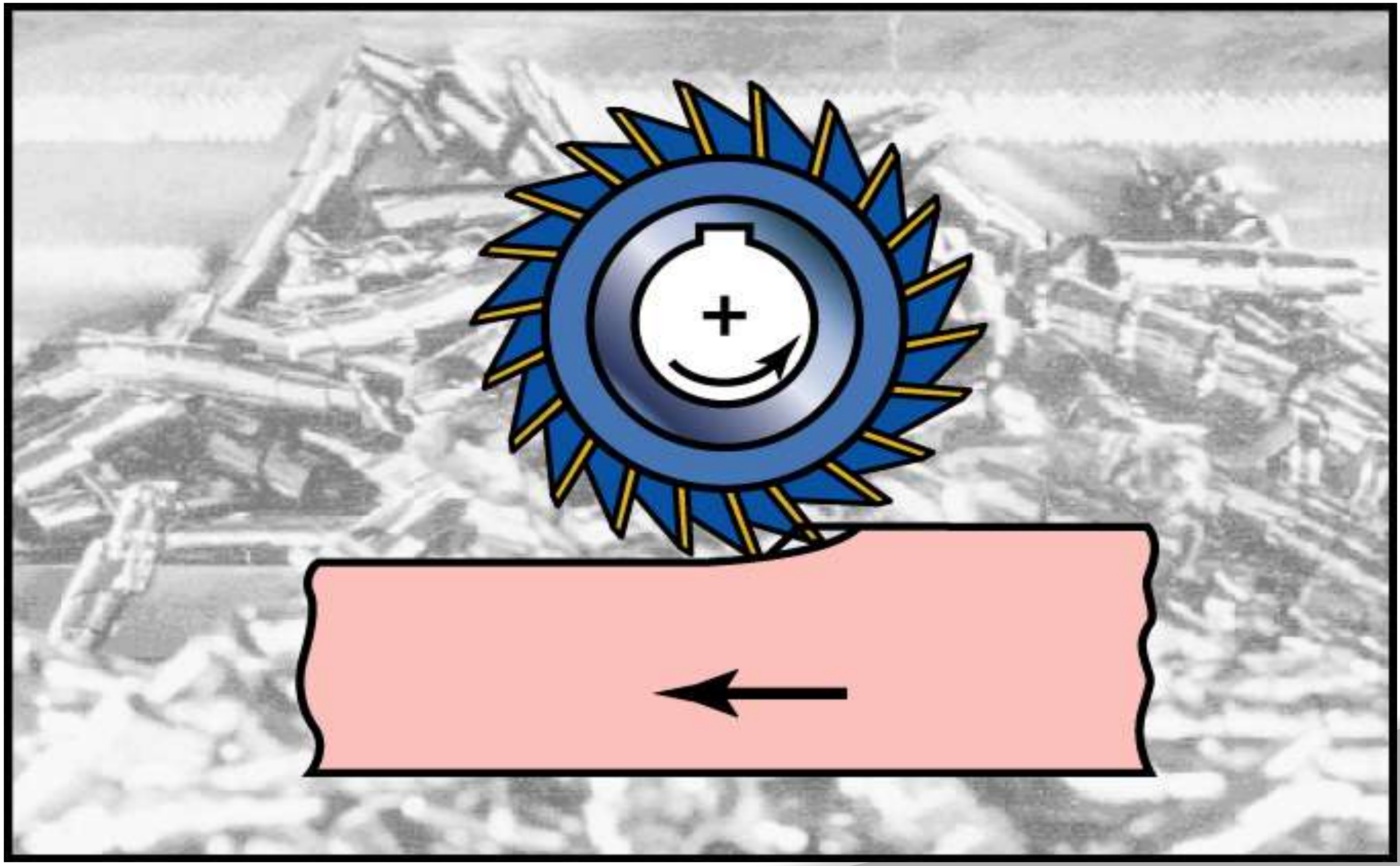


Figure 22.6 (g) threading

Pointed form tool is fed linearly across surface of rotating work part parallel to axis of rotation at a large feed rate, thus creating threads

Machining Processes Used to Produce Various Shapes: Milling



Milling and Milling Machines, Milling operations

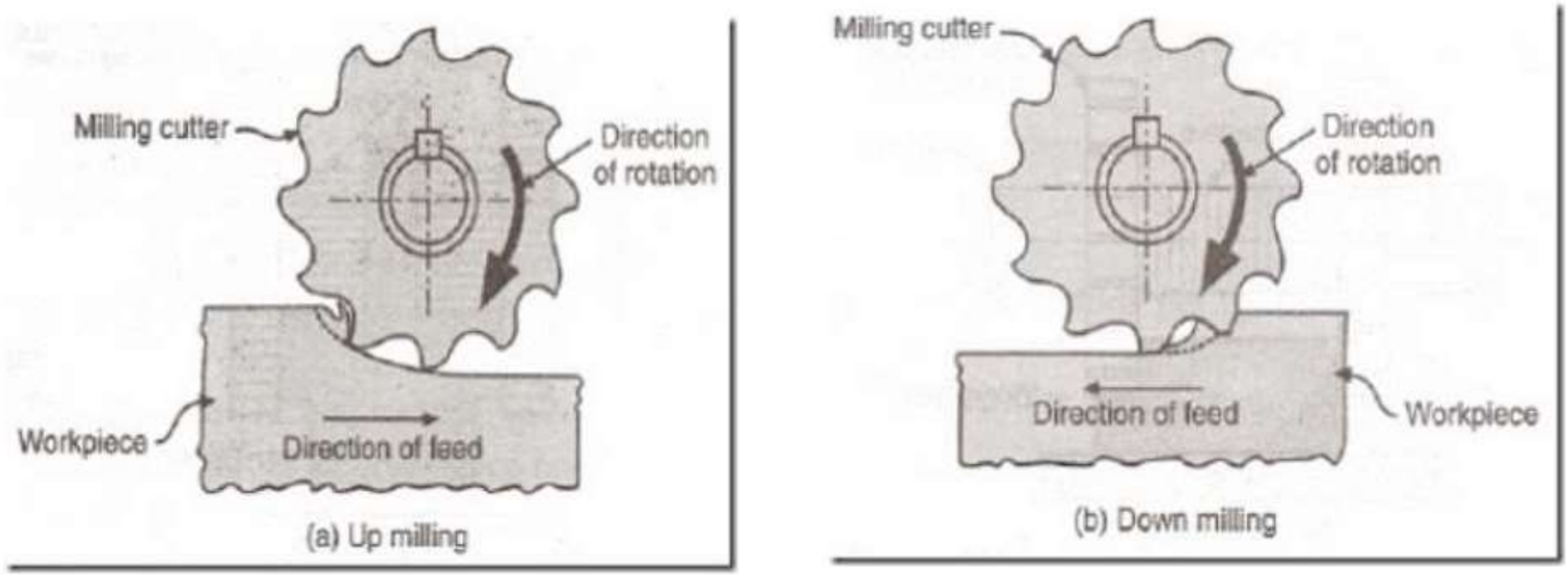
Milling: a process in which a rotating multi-tooth cutter removes material while traveling along various axes with respect to the work-piece.

Figure 24.2: basic types of milling cutters & milling operations

In peripheral milling (also called plain milling), the axis of cutter rotation is parallel to the work-piece surface.

When the cutter is longer than the width of the cut, the process is called slab milling

PRINCIPLE OF MILLING



CLASSIFICATION OF MILLING MACHINES

1. Column and knee milling machines
    a. Plain column & knee type milling machine
        - Horizontal spindle type
        - Vertical spindle type

2. Bed type milling machine

3. Planer type milling machine

4. Special purpose milling machine
    a. Tracer controlled milling machine
    b. Thread milling machine
    c. CNC milling machine

Horizontal Milling Machines

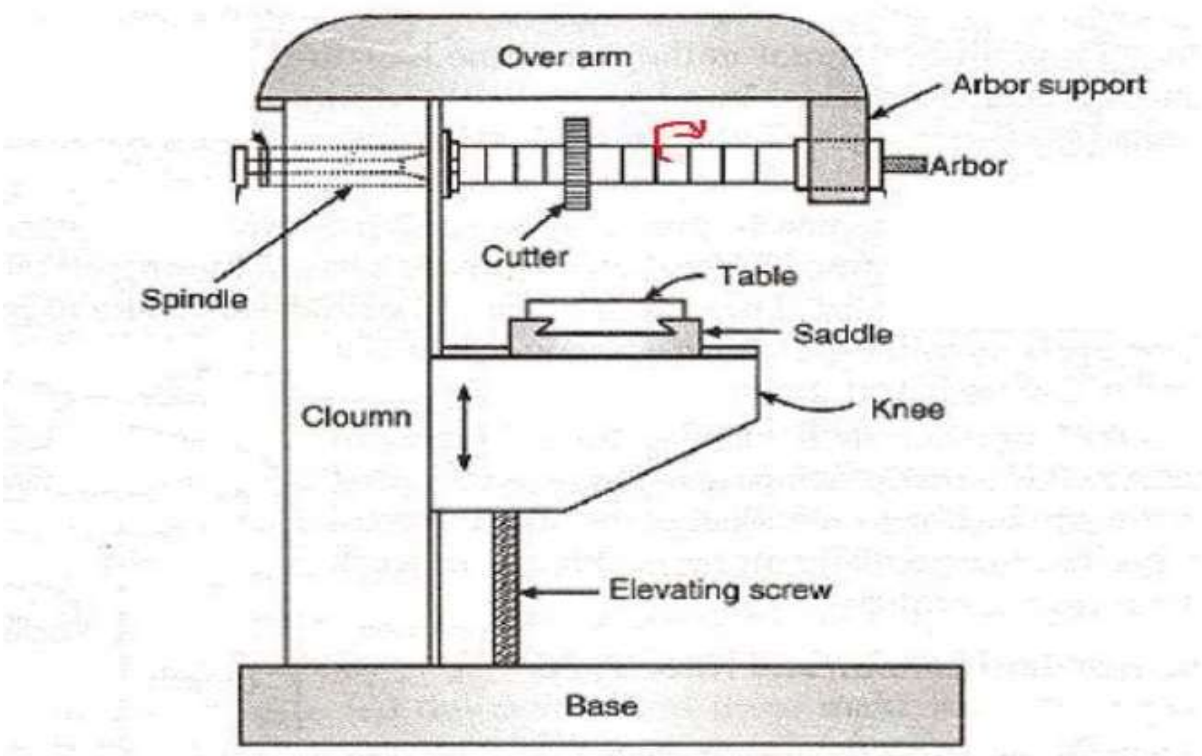
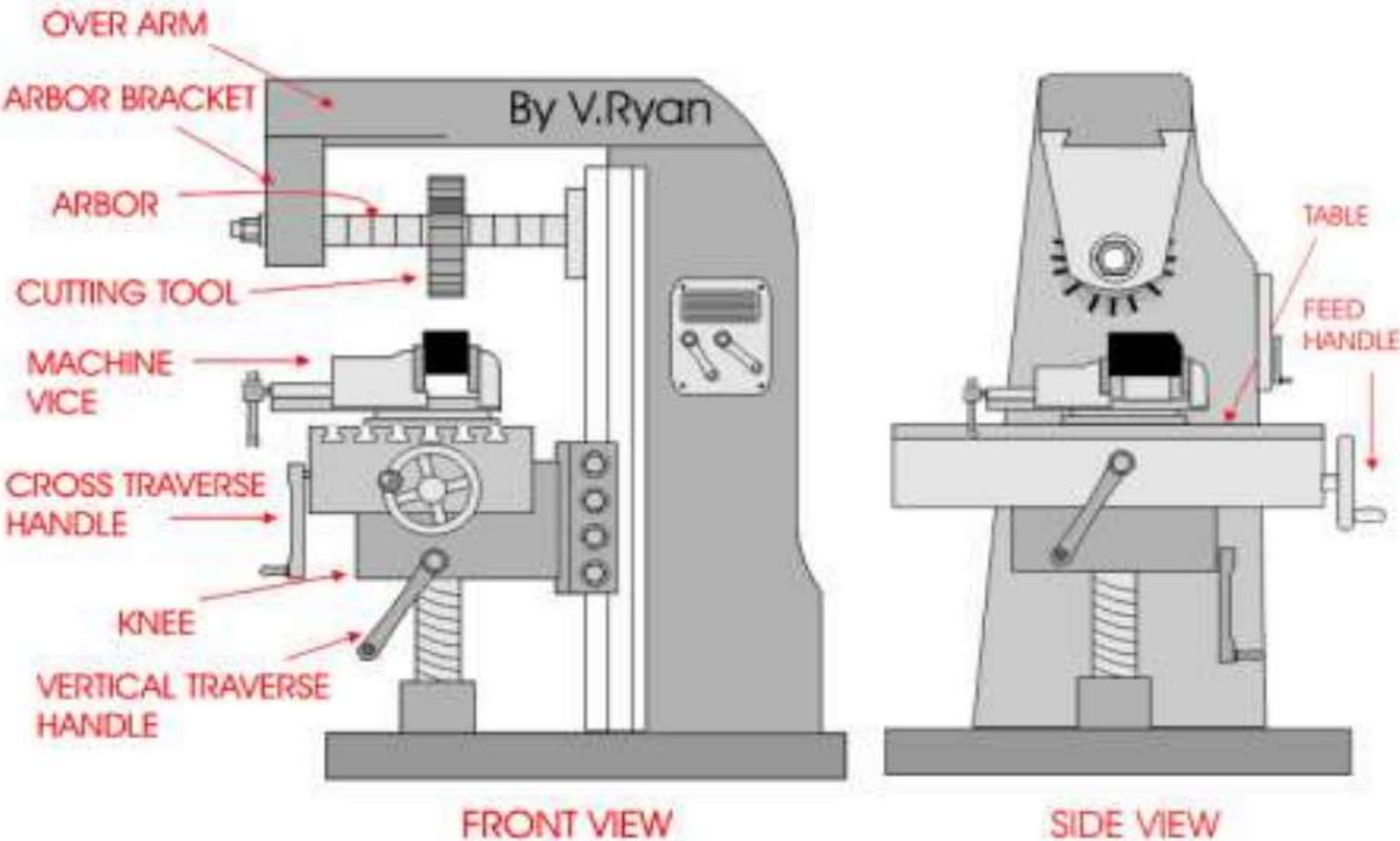


FIG. HORIZONTAL MILLING MACHINE

MAJOR PARTS :

1. BASE
2. COLUMN
3. SPINDLE
4. OVERARM
5. KNEE
6. SADDLE
7. WORKTABLE


OVER ARM
ARBOR BRACKET
By V.Ryan
ARBOR
CUTTING TOOL
MACHINE VICE
CROSS TRAVERSE HANDLE
KNEE
VERTICAL TRAVERSE HANDLE
TABLE
FEED HANDLE
FRONT VIEW
SIDE VIEW

VERTICAL MILLING MACHINE

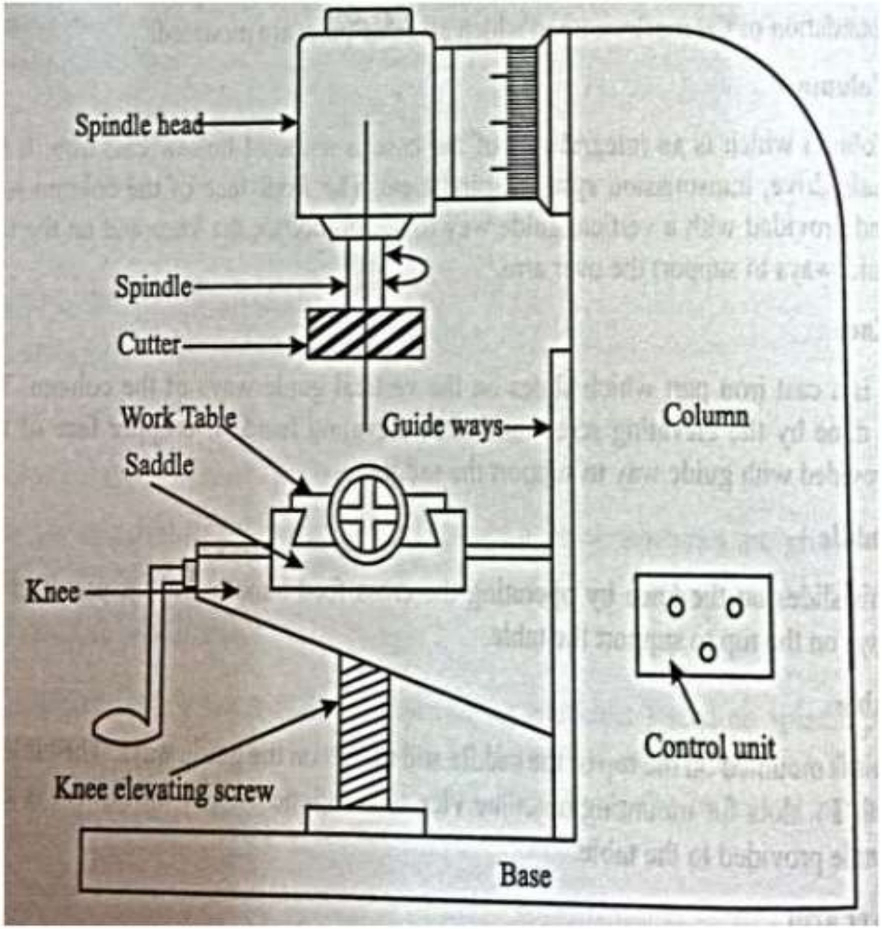
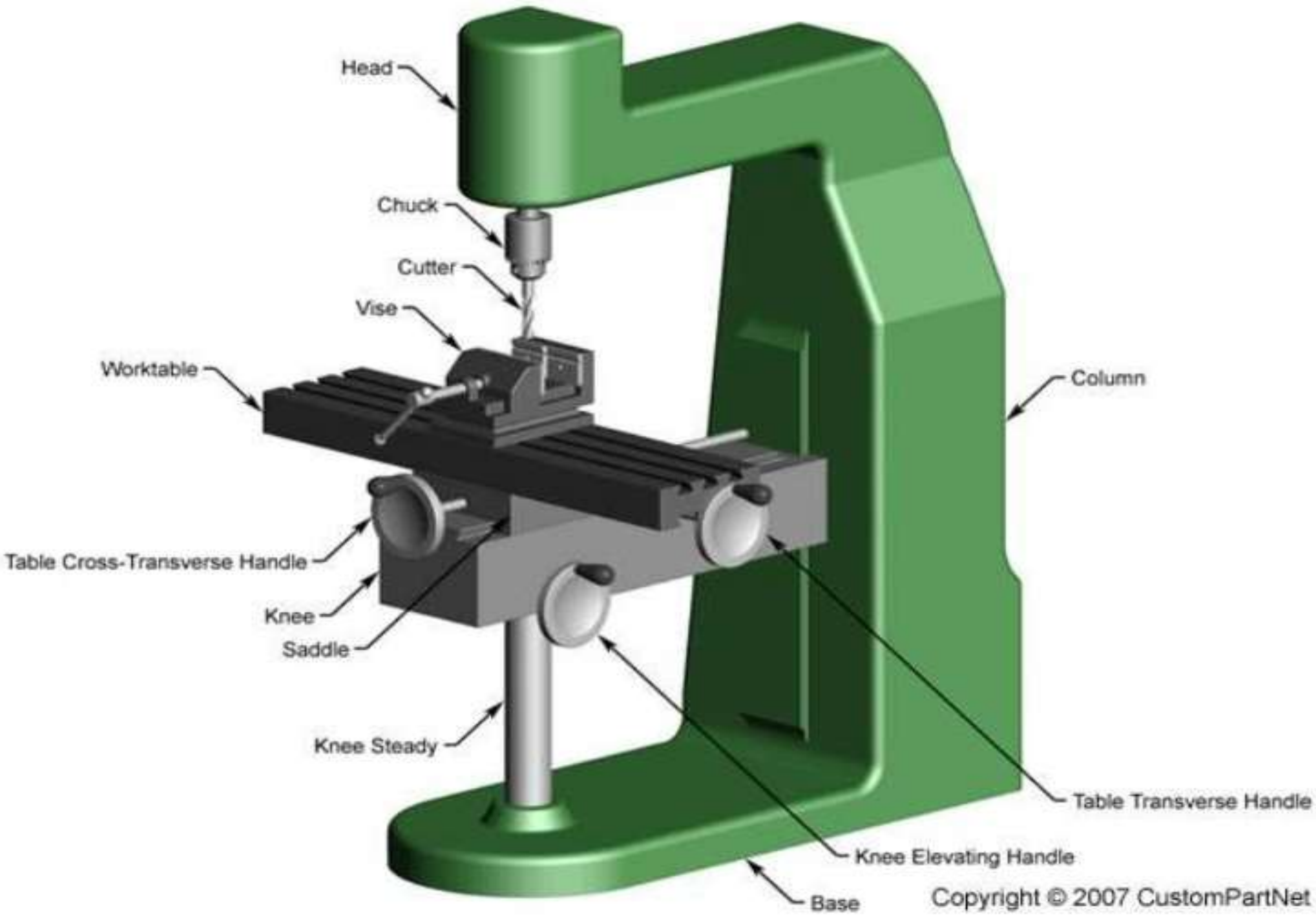


FIG. VERTICAL MILLING MACHINE

MAJOR PARTS :

1. BASE
2. COLUMN
3. SPINDLE
4. SPINDLE HEAD
5. KNEE
6. SADDLE
7. WORKTABLE

VMM


Head
Chuck
Cutter
Vise
Worktable
Column
Table Cross-Transverse Handle
Knee
Saddle
Knee Steady
Table Transverse Handle
Knee Elevating Handle
Base
Copyright © 2007 CustomPartNet

DIFFERENCES BETWEEN HORIZONTAL & VERTICAL MILLING MACHINES

SL. NO.	HORIZONTAL MILLING MACHINE	VERTICAL MILLING MACHINE
01	Spindle is horizontal & parallel to the worktable.	Spindle is vertical & perpendicular to the worktable.
02	Cutter cannot be moved up & down.	Cutter can be moved up & down.
03	Cutter is mounted on the arbor.	Cutter is directly mounted on the spindle.
04	Spindle cannot be tilted.	Spindle can be tilted for angular cutting.
05	Operations such as plain milling, gear cutting, form milling, straddle milling, gang milling etc., can be performed.	Operations such as slot milling, T-slot milling, angular milling, flat milling etc., can be performed and also drilling, boring and reaming can be carried out.

MILLING OPERATIONS

- Plain or slab milling
- Face milling
- End milling
- Slot milling
- Angular milling
- Form milling
- Straddle milling
- Gang milling
- Slitting or saw milling
- Gear cutting

Milling Cutters and Milling Operations

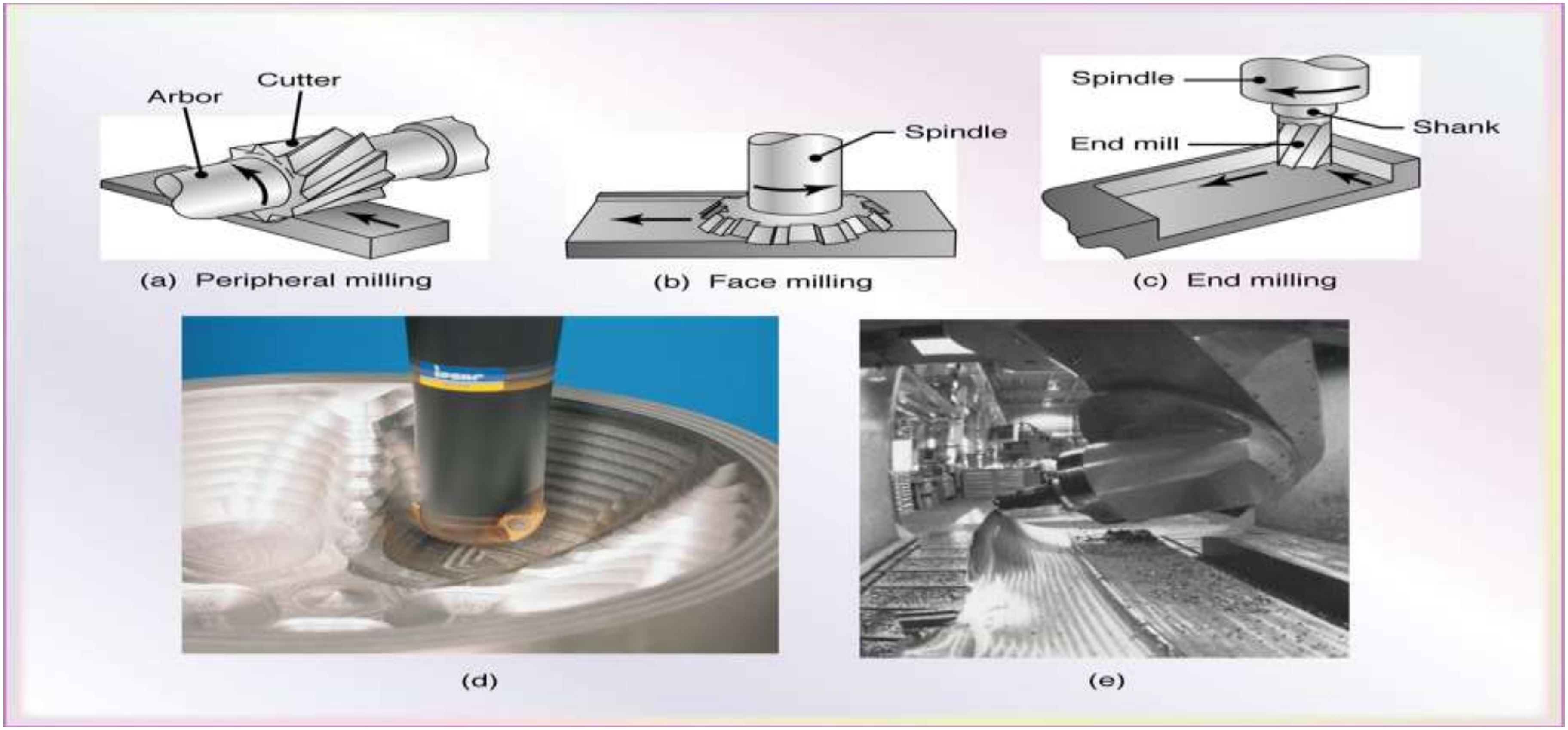


Figure 24.2 Some basic types of milling cutters and milling operations. (a) Peripheral milling. (b) Face milling. (c) End milling. (d) Ball-end mill with indexable coated-carbide inserts machining a cavity in a die block. (e) Milling a sculptured surface with an end mill, using a five-axis numerical control machine. *Source*: (d) Courtesy of Iscar. (e) Courtesy of The Ingersoll Milling Machine Co.

Milling Operations

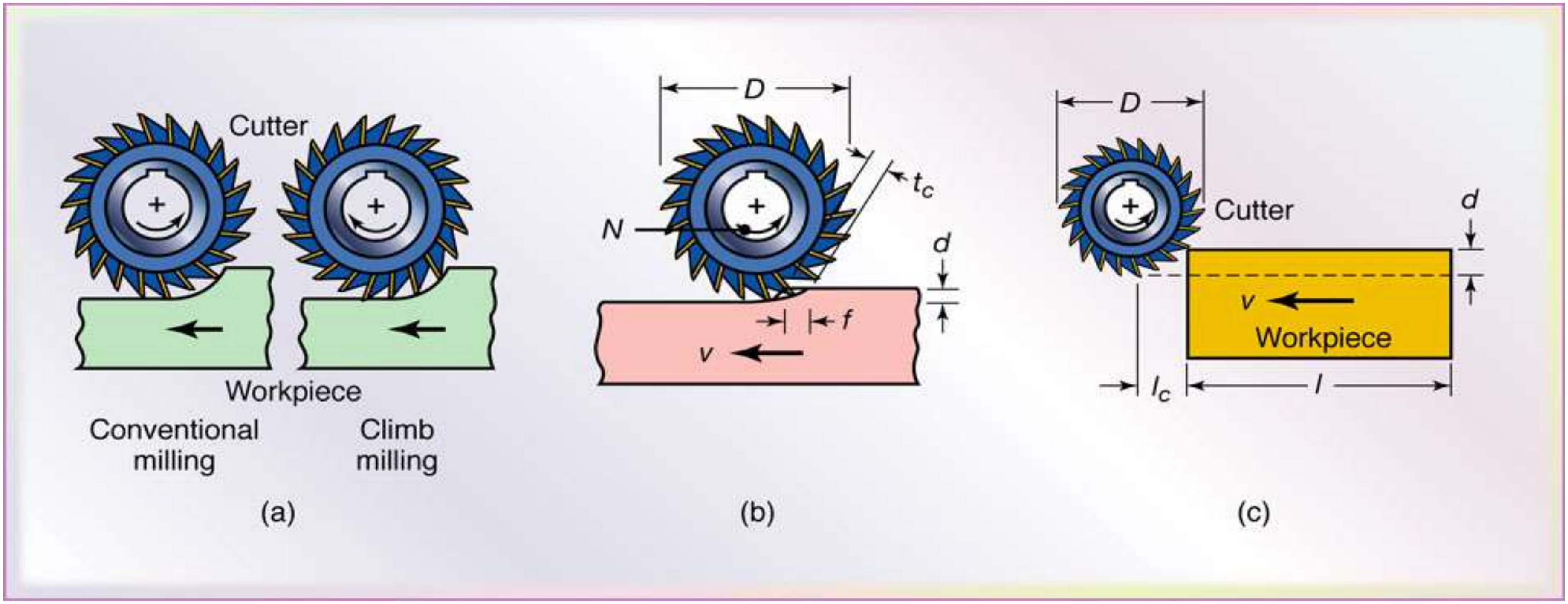


Figure 24.3 (a) Schematic illustration of conventional milling and climb milling. (b) lab-milling operation showing depth-of-cut, *d*; feed per tooth, *f*; chip depth-of-cut, t_c; and workpiece speed, *v*. (c) Schematic illustration of cutter travel distance, l_c, to reach full depth-of-cut.

Milling operations: up milling

Conventional Milling (Up Milling)

- Max chip thickness is at the end of the cut
- Advantage: tooth engagement is not a function of work piece surface characteristics, and contamination or scale on the surface does not affect tool life.
- Cutting process is smooth
- Tendency for the tool to chatter
- The work piece has a tendency to be pulled upward, necessitating proper clamping.

Milling operations: Down milling

- **Climb Milling (Down Milling)**
- Cutting starts at the surface of the work piece.
- Downward compression of cutting forces hold work piece in place
- Because of the resulting high impact forces when the teeth engage the work piece, this operation must have a rigid setup, and backlash must be eliminated in the table feed mechanism
- Not suitable for machining work piece having surface scale.

Milling Parameters

- N = Rotational speed of the milling cutter, rpm
- f = Feed per tooth, mm/tooth (in/tooth) = υ /N n
- D = Cutter diameter, mm (in)
- n = Number of teeth on cutter
- υ = Linear speed of the workpiece or feed rate, mm/min (in/min)
- V = Surface speed of cutter, m/min (ft/min) = π D N
- l = Length of cut, mm (in)
- t = Cutting time, s or min=(l+lc) / υ
- lc =extent of the cutter's first contact with workpiece lc=$\sqrt{Dd}$
- MRR = mm3/min or in3/min = w d υ , where w is the width of cut
- Torque = N.m (lb.ft) =(Fc) (D/2)
- Power = kW (hp) = (Torque) (ω), where ω = 2π N radians/min

Advanced Casting

- One of the oldest materials shaping methods.
- Casting means pouring molten metal into a mold with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the mold either by breaking the mold or taking the mold apart. The solidified object is called the casting.
- Intricate parts can be given strength and rigidity frequently not obtainable by any other manufacturing process.

Advantages:

- Molten material can flow into very small sections so that intricate shapes can be made by this process.
- It is possible to cast practically any material that is ferrous or non-ferrous.
- As the metal can be placed exactly where it is required, large saving in weight can be achieved.
- The necessary tools required for casting molds are very simple and inexpensive.
- Size and weight of the product is not a limitation for the casting process.

- **Limitations:**

Dimensional accuracy and surface finish of the castings

❖**SAND CASTING PROCESS**

There are six basic steps in making sand castings:

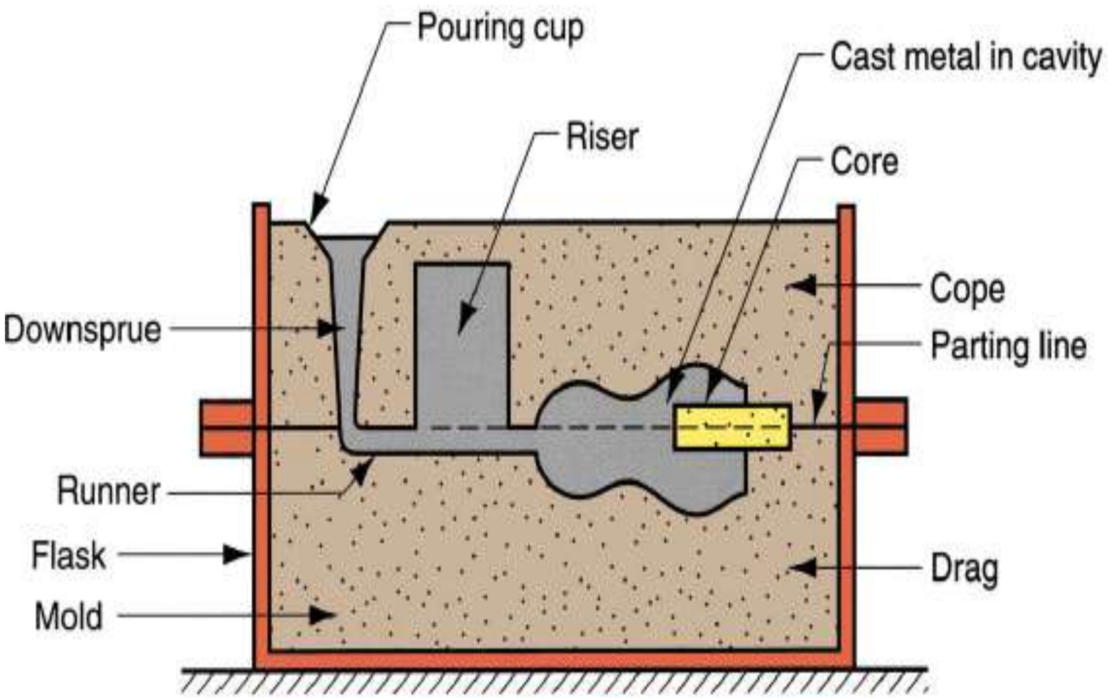
1. Patternmaking

2. Core making

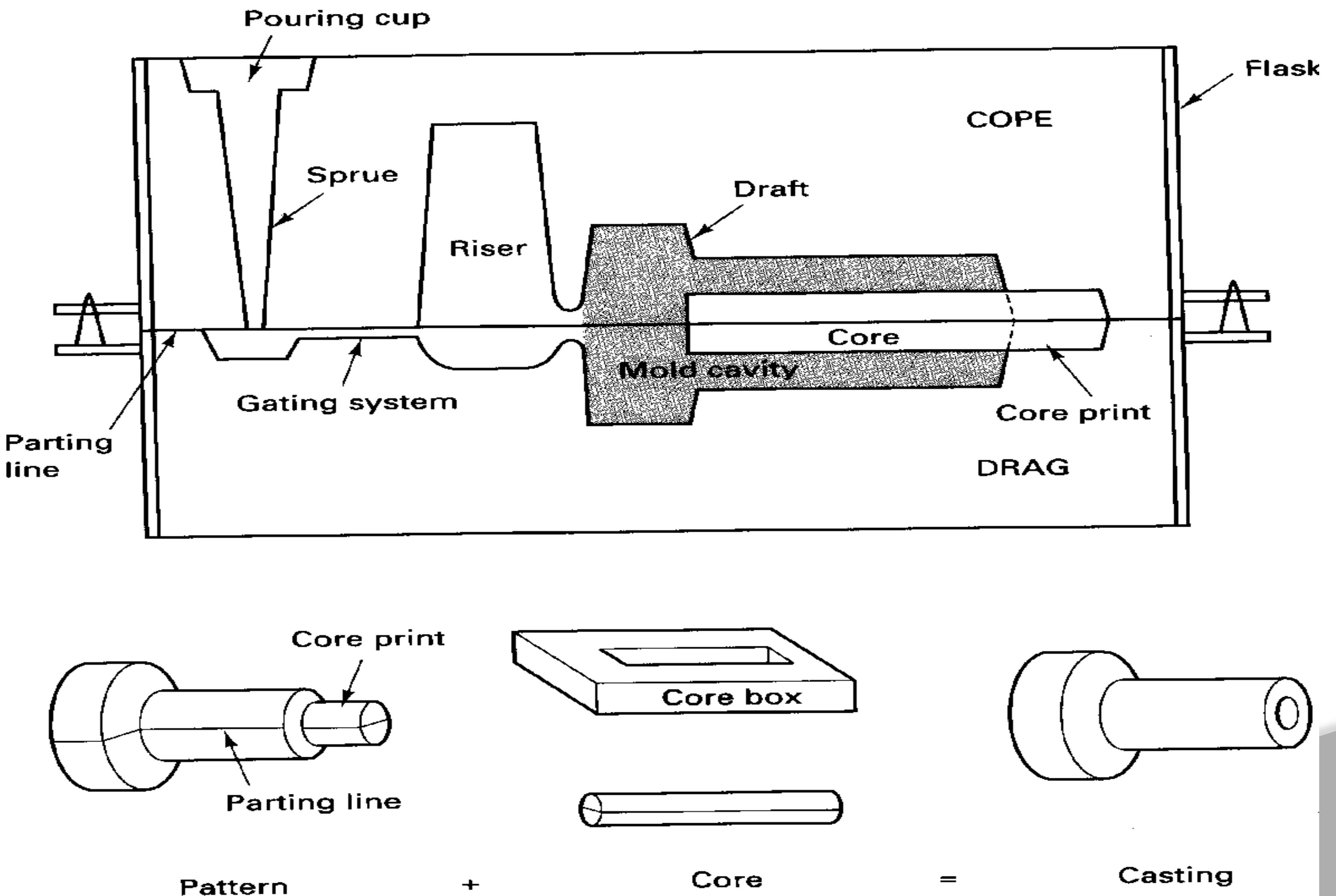
3. Molding

4. Melting and pouring

5. Cleaning



Conventional casting process

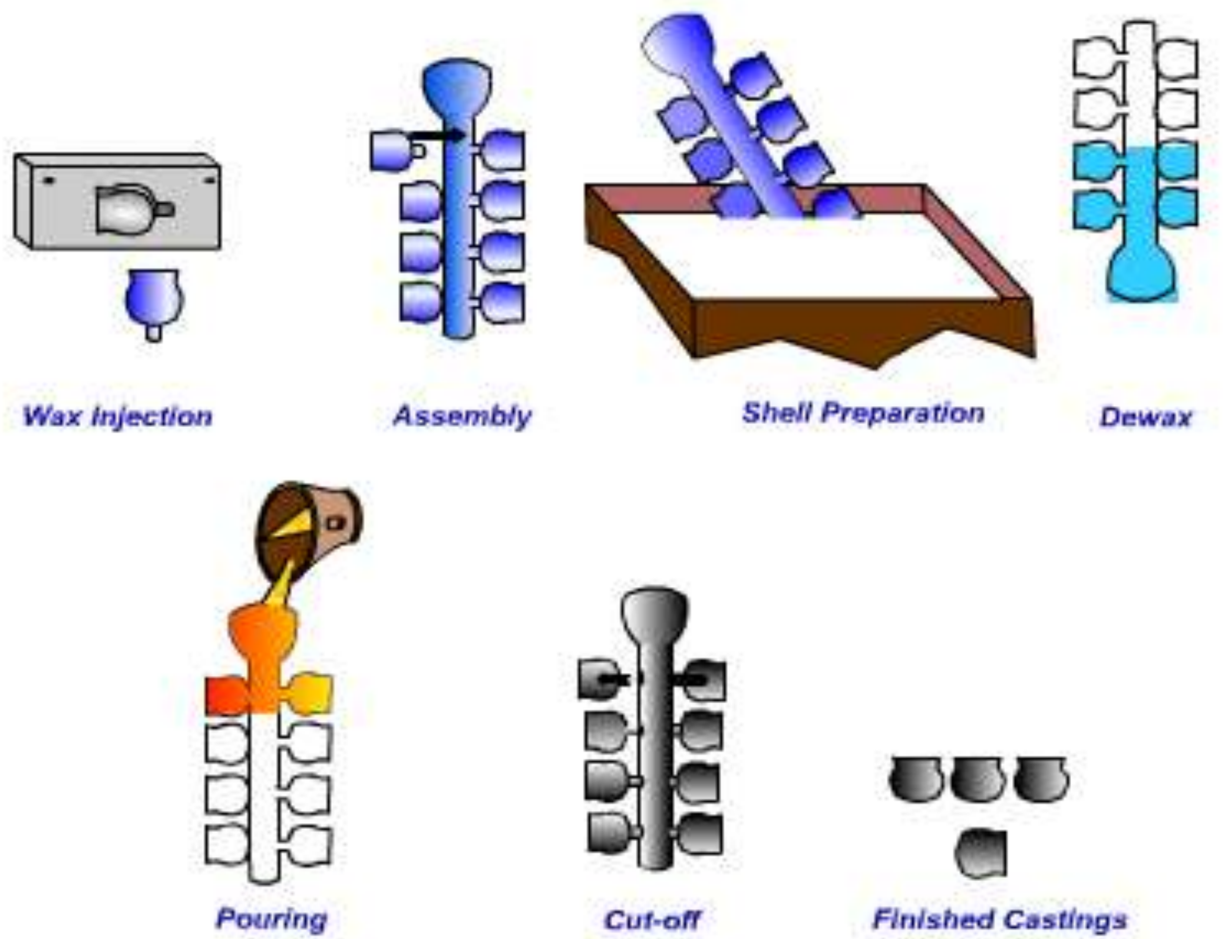


DIE CASTING

- The process in which we use a die to make the castings is called permanent mold casting
- The die consist of two part, one called the stationary die or cover die which is fixed with to the casting m/c & 2nd part called the ejector die is moved out for the extraction of the casting .
- Because of the high pressure involved in die casting, any narrow sections, complex shape and fine surface finished can be easily produced.
- Die casting m/c are of two type: hot chamber die casting & cold chamber die casting

INVESTMENT CASTING

- In this process , the preparation of the pattern for every casting made.
- To do this , molten wax which is used as a pattern material is injected under pressure into a metallic die which has of the cavity of the casting to be made.
- Wax when allowed to solidify would produce the pattern.
- Products artefacts , jewellery, & surgical instrument, presently vanes & blades for gas turbines, wave guider for radar and triggers for fire arms.


Wax Injection
Assembly
Shell Preparation
Dewax
Pouring
Cut-off
Finished Castings

CENTRIFUGAL CASTING

- the mold is rotated rapidly about its central axis as the metal is poured into it.
- Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other inclusions being lighter, get separated from the metal and segregate towards the center.
- This process is normally used for the making of hollow pipes, tubes, hollow bushes, etc ., which are axisymmetric with a concentric hole.
- The mold can be rotated about a vertical, horizontal or an inclined axis or about its horizontal and vertical axes simultaneously

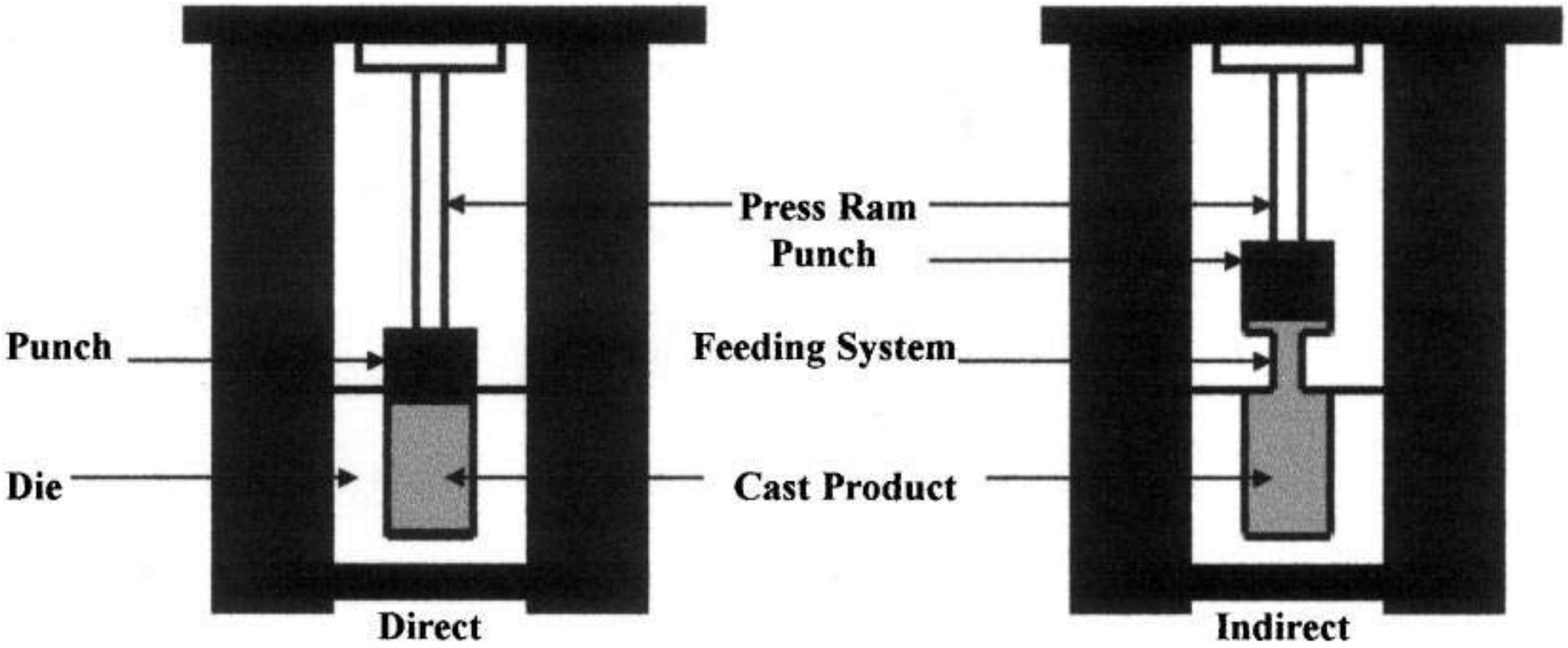
Semi-solid manufacturing process of magnesium alloys by twin-roll casting:

- Magnesium is 36% lighter per unit volume than aluminum and 78% lighter than iron. When alloyed, magnesium has the highest strength-to-weight ratio of all the structural metals.
- Utilization of magnesium alloys has mainly depended on casting technology and SSM.
- Unfortunately, the major barrier to greatly increased magnesium alloy use in cars is still primarily high manufacturing cost. So for solving this problem is to develop semi-solid roll strip casting technology to manufacture magnesium sheet alloys economically while maintaining high quality.

Squeeze casting

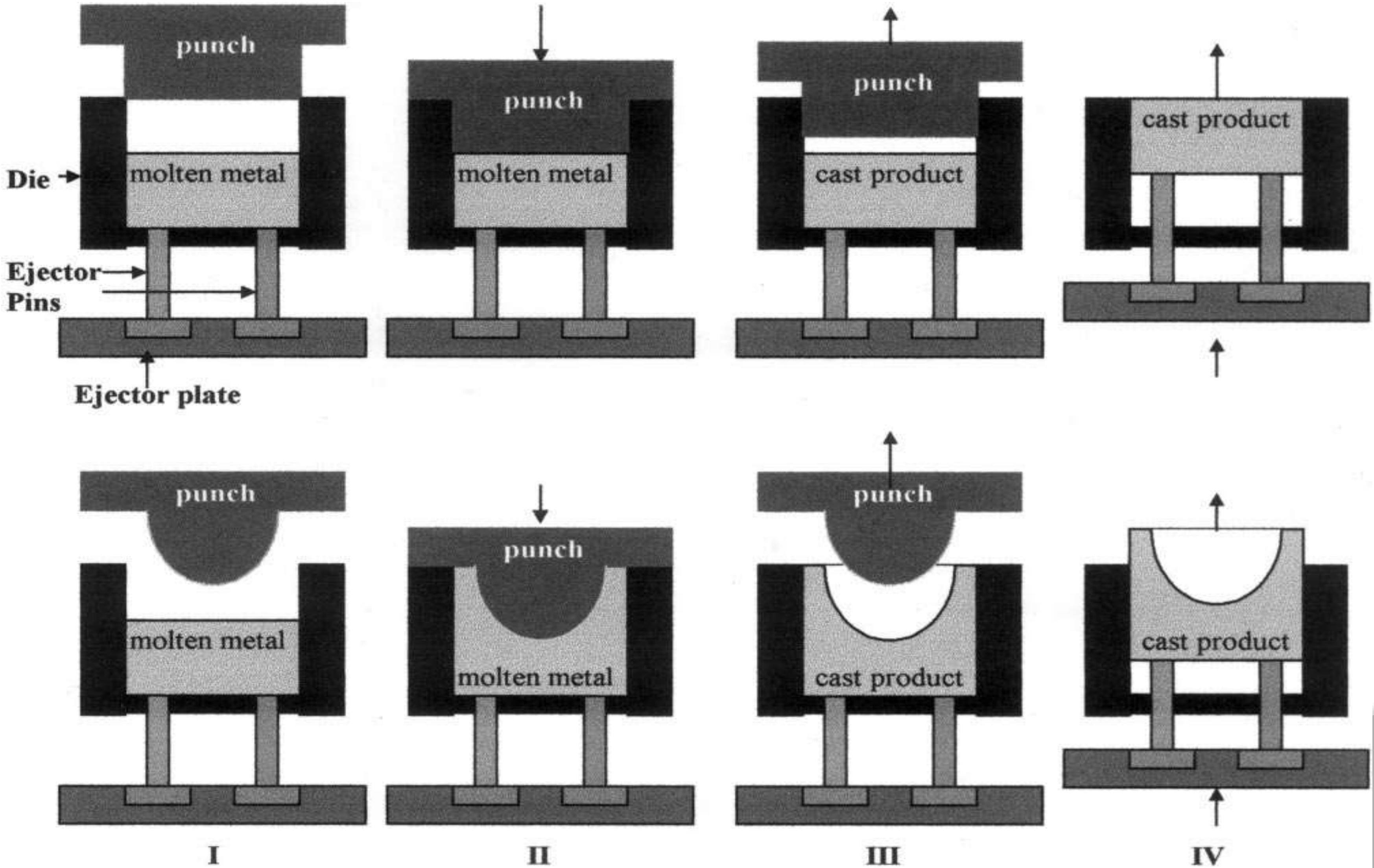
- squeeze casting has greater potential to create less defective cast components.
- Squeeze casting (SC) is a fabrication technique where solidification is promoted under high pressure within a re-usable die.
- It is a metal-forming process, which combines permanent mould casting with die forging into a single operation where molten metal is solidified under applied hydrostatic pressure.
- In this process a die set is placed on a hydraulic press and preheated, and the exact amount of molten alloy is poured into the lower half of the open die set, the press closed so that the alloy fills the cavity and the pressure maintained until complete solidification occurs.

Squeeze casting



the SC-fabricated engineering components are fine grained with excellent surface finish and have almost no porosity. The mechanical properties of these parts are significantly improved over those of conventional castings.

Squeeze casting



Squeeze casting

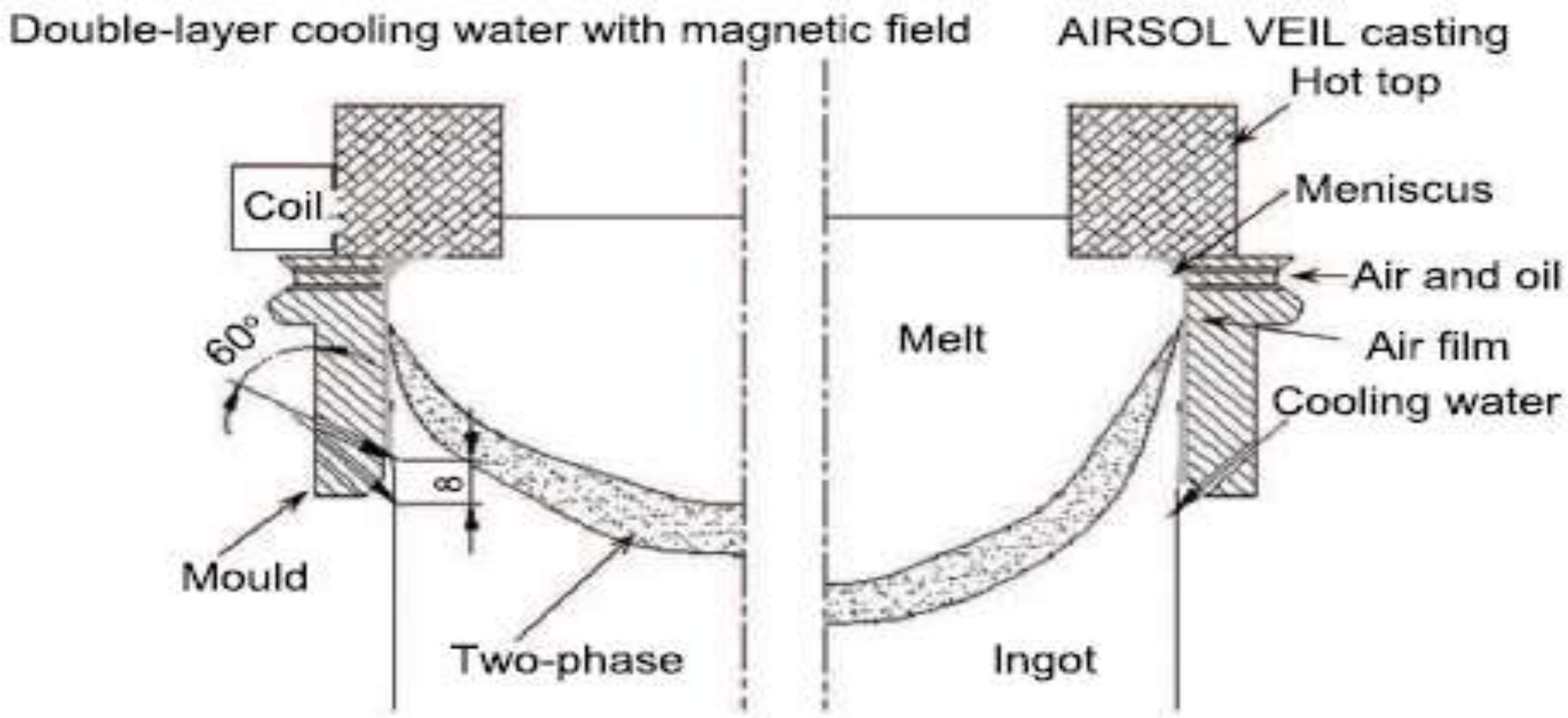
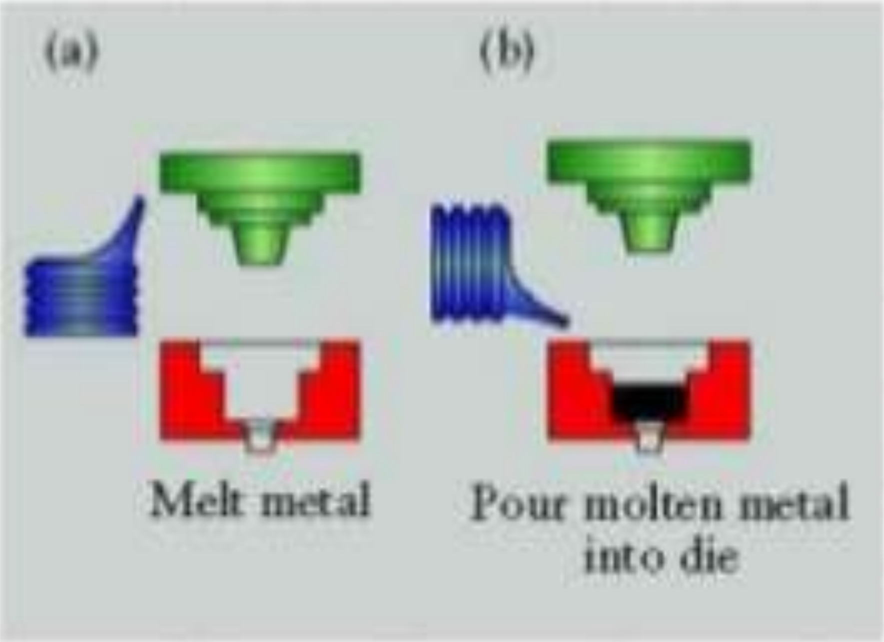


Fig.1 Schematic diagram of air film semi-continuous casting with static magnetic field.

Squeeze casting process

- Squeeze casting consists of entering liquid metal into a preheated, lubricated die and forging the metal while it solidifies



Casting Parameters

Casting parameters

- **Casting temperatures** depend on the alloy and the part geometry. The starting point is normally 6 to 55 °C above the liquidus temperature.
- **Tooling temperatures** ranging from 190 to 315 °C are normally used
- **Pressure levels** of 50 to 140 MPa are normally used
- **Lubrication** For aluminum, magnesium, and copper alloys, a good grade of colloidal graphite spray lubricant has proved satisfactory when sprayed on the warm dies prior to casting

Advantages

Advantages

- Offers a broader range of shapes and components than other manufacturing methods.
- Little or no machining required post casting process
- Low levels of porosity
- Good surface structure
- Fine micro-structures with higher strength components
- No waste material 100% utilization.

UNIT III
METAL JOINING, FORMING

CLOs	Course Learning Outcome
CLO 7	Identity various design recommendation for permanent joining such as welding, soldering and brazing.
CLO 8	understand the different design factors for forging, closed dies forging design.
CLO 9	Apply the different Design guidelines for extruded sections.
CLO 10	Understand various design principles for punching, blanking, bending, deep drawing.

Classifications of Welding

- Welding is defined as an localized coalescence of metals, where in coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler metal.

- OR

- Welding is a process of joining similar metals by application of heat with or without application of pressure and addition of filler material

Classifications of Welding

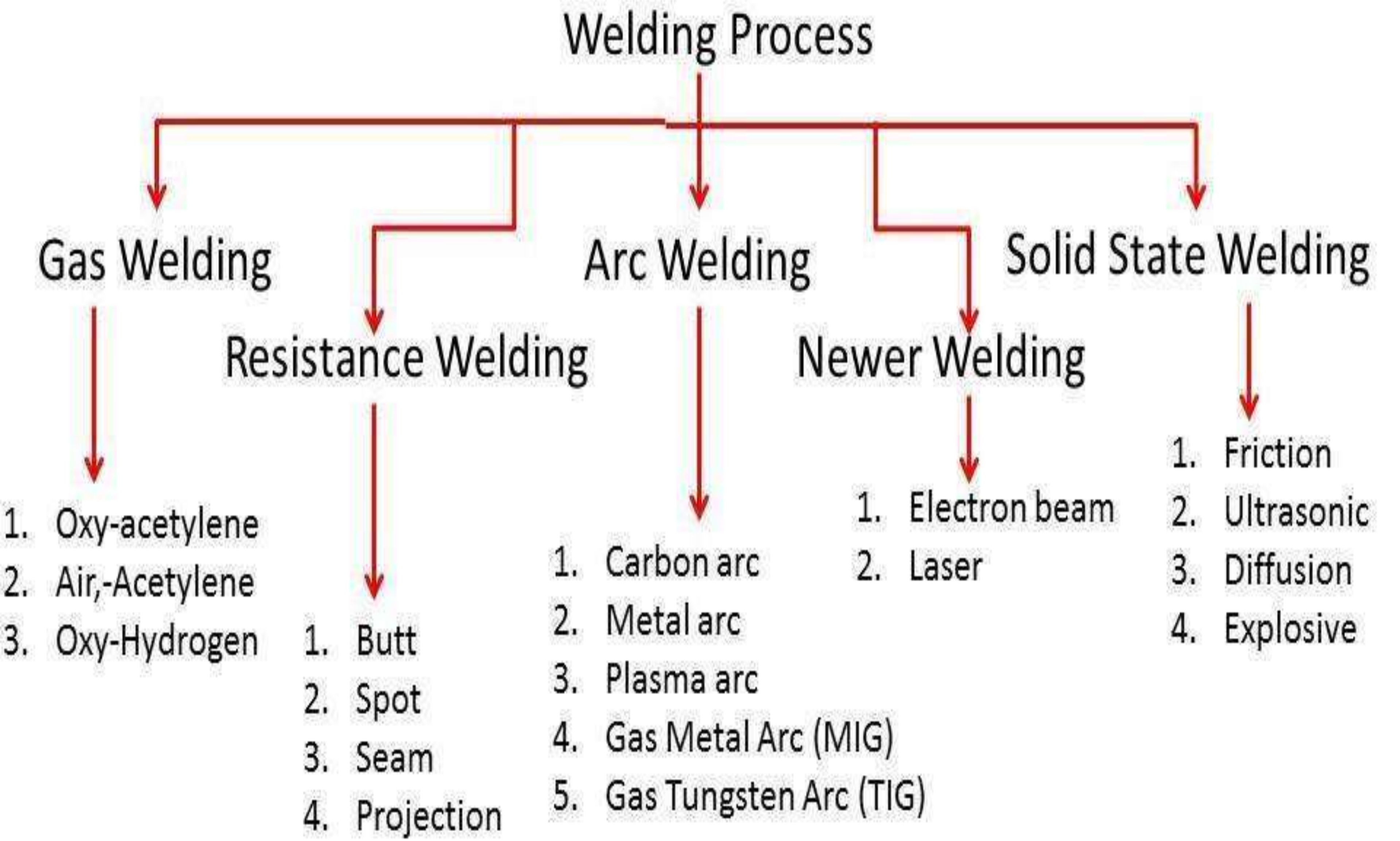
Welding process can be classified into different categories depending upon the following criteria :

(a)It can be classified as fusion welding or pressure welding depending upon on the application of heat. If application of heat is not required, it is called pressure welding.

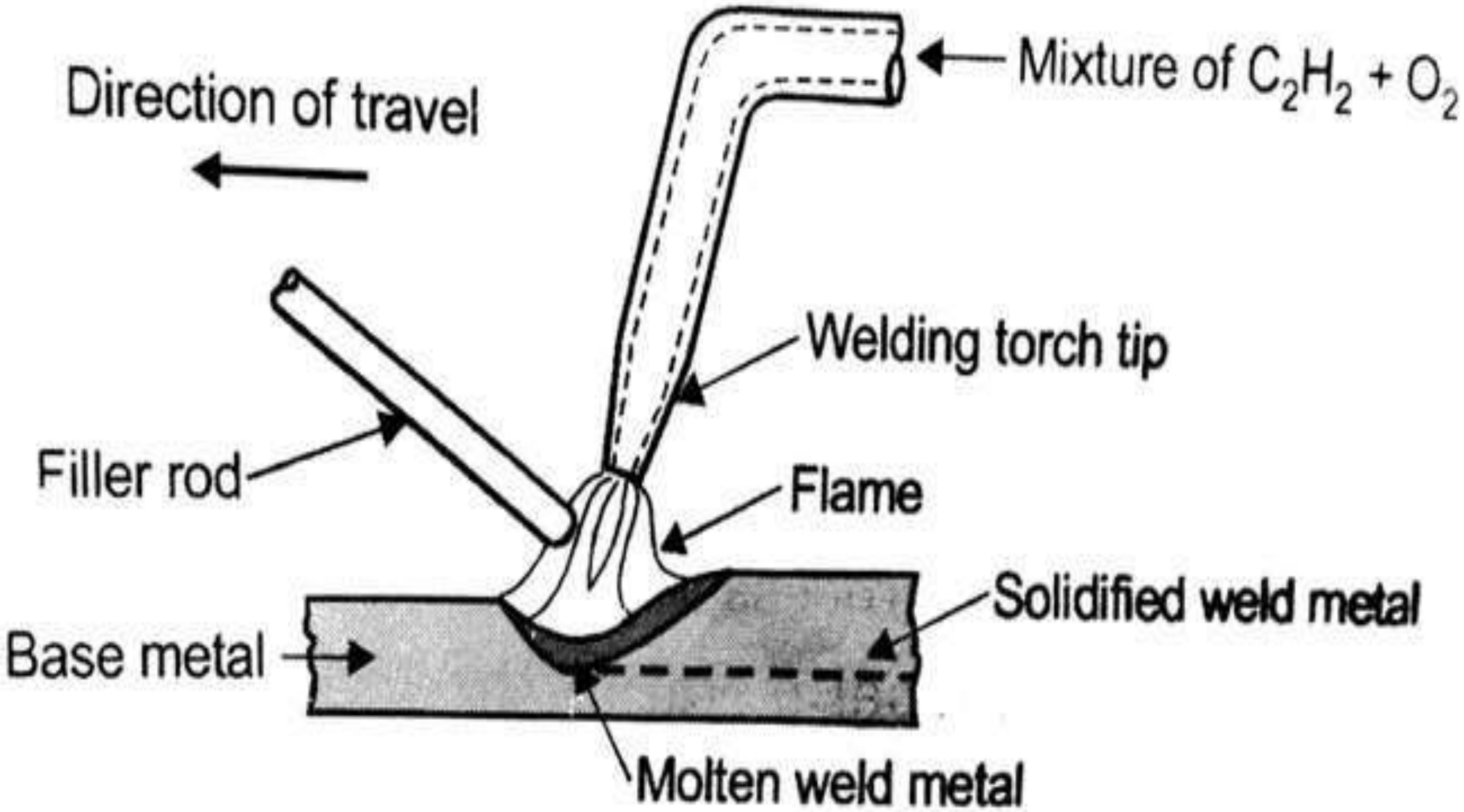
(b)In case of fusion welding it can classified low temperature welding and high temperature welding. When heat is generated to develop low temperature it is called low temperature welding like soldering and brazing. Other fusion welding methods are high temperature welding methods.

(c) Fusion welding can also be classified on the basis of method of heat generation

like gas welding, electric arc welding, resistance welding, thermit welding, etc.


Welding Process
Gas Welding
Resistance Welding
Arc Welding
Newer Welding
Solid State Welding
1. Oxy-acetylene
2. Air,-Acetylene
3. Oxy-Hydrogen
1. Butt
2. Spot
3. Seam
4. Projection
1. Carbon arc
2. Metal arc
3. Plasma arc
4. Gas Metal Arc (MIG)
5. Gas Tungsten Arc (TIG)
1. Electron beam
2. Laser
1. Friction
2. Ultrasonic
3. Diffusion
4. Explosive

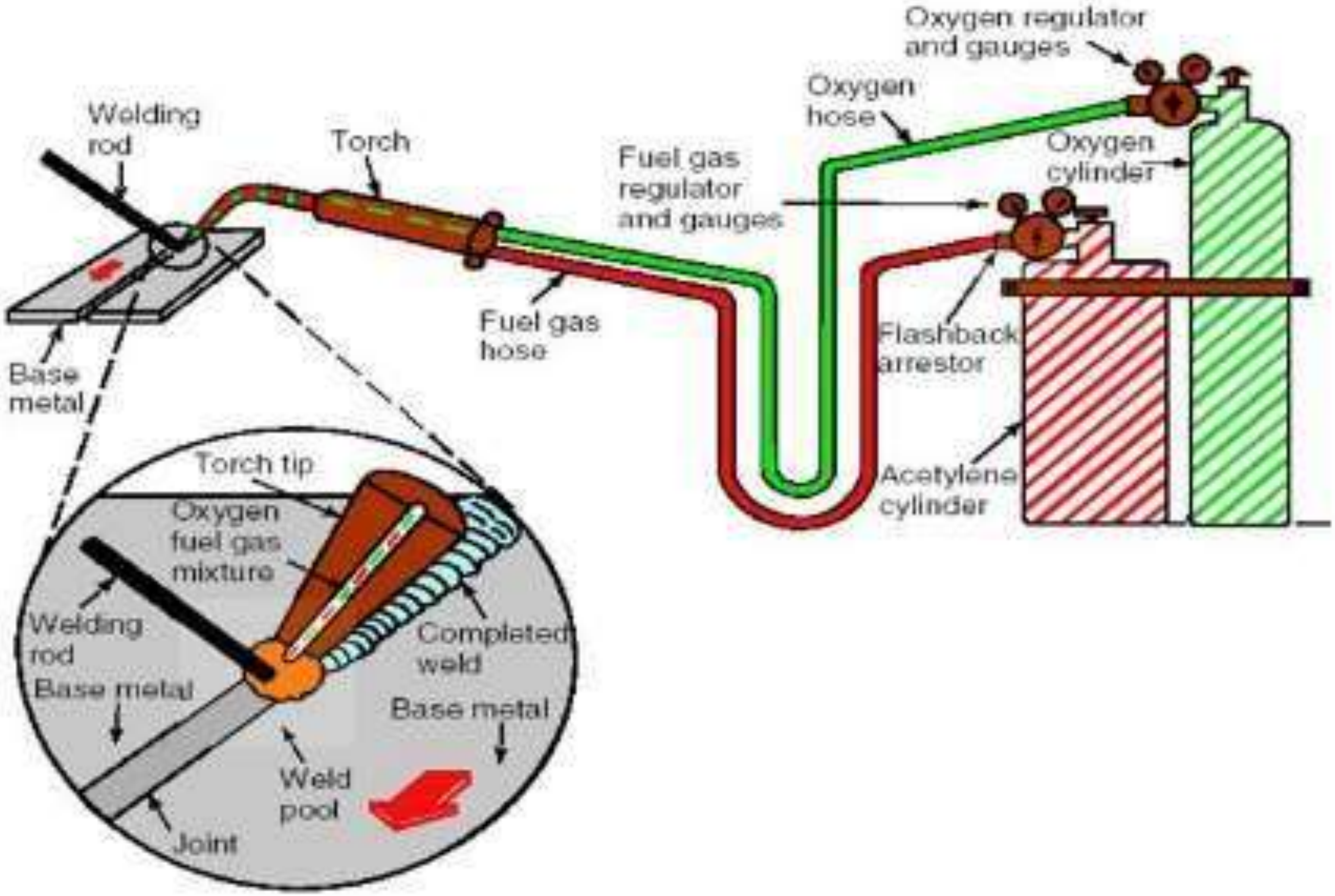
Oxy acetylene Welding



Materials Suitable for Oxy acetylene welding

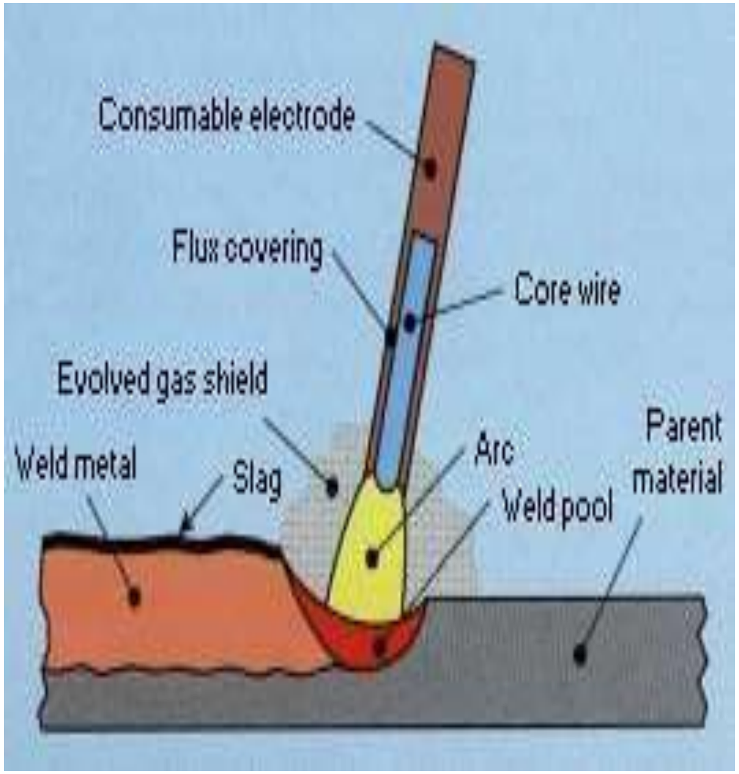
- Plain carbon steel and low –alloy steel.
- Cast iron (best results)
- Stainless steel
- Aluminum and magnesium
- Copper and copper alloys
- Mild steel
- lead

OXY-ACETYLENE WELDING(OAW) STATION



Manual Metal-Arc welding (MMA)

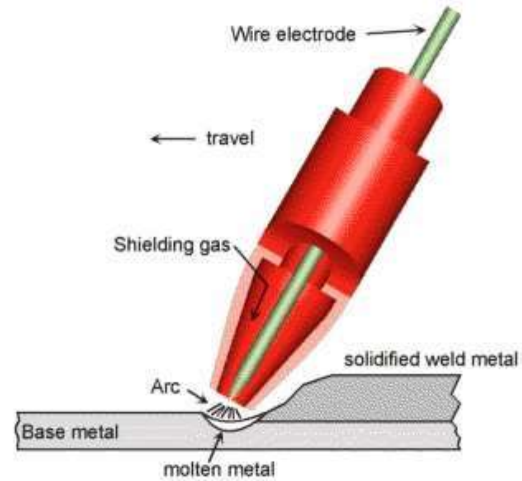
When an arc is struck between the metal rod(electrode) and the work piece, both the rod and work surfaces melt to form a weld. Simultaneous melting of the flux coating on the rod will form gas and slag which protects the weld pool from the surrounding atmosphere. The slag will solidify and cool and must be chipped off the weld bead once the weld run is complete



Submerged Arc Welding

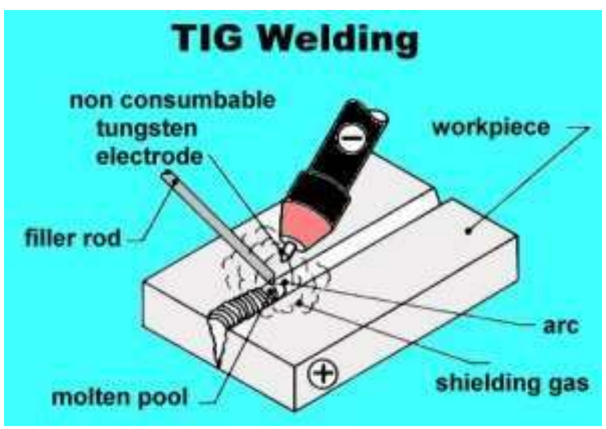
Types of welding techniques

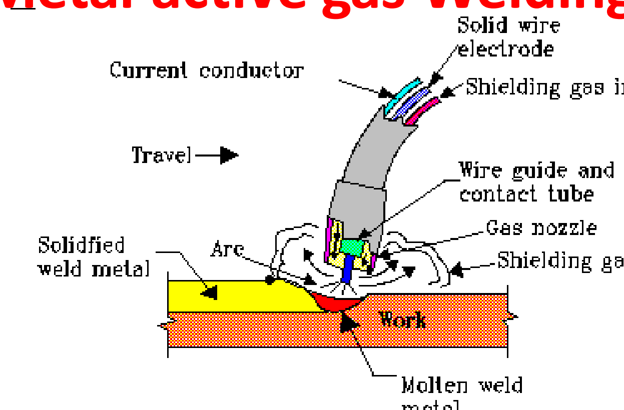
4. Metal-Active Gas welding (MAG)



Types of welding techniques

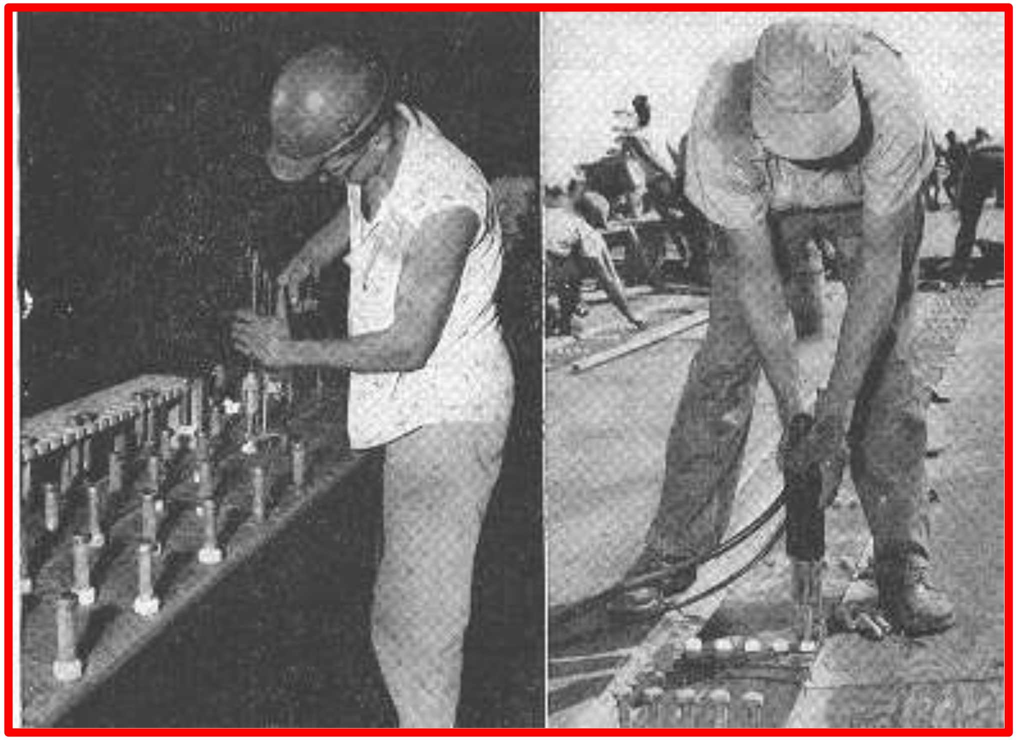
Metal active gas Welding





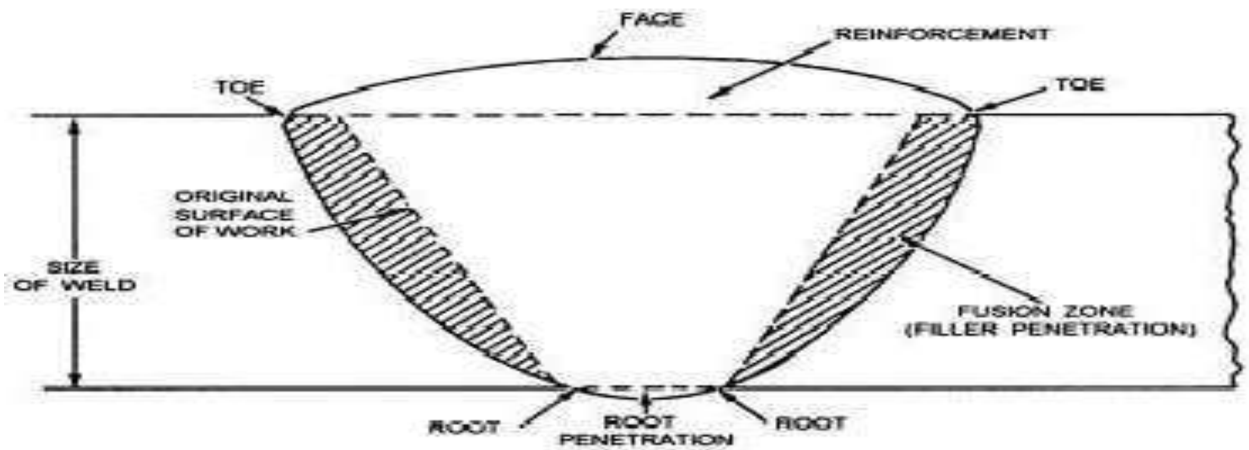
Metal inert gas Welding 152

Stud Welding

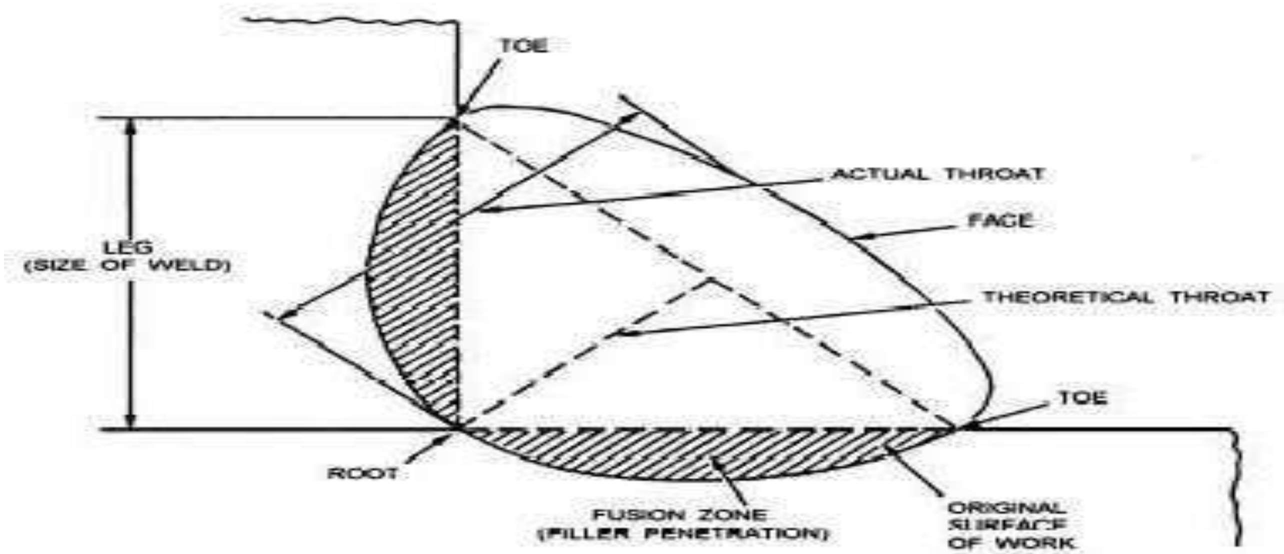


Shop welding **Field welding**

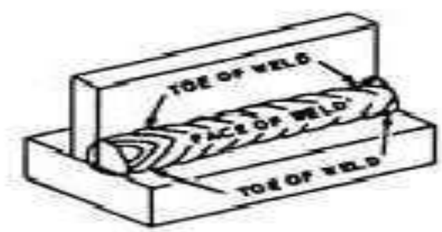
Welding process



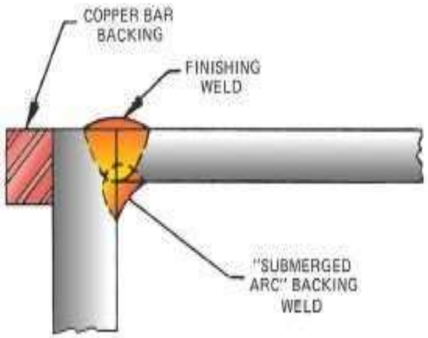
A. GROOVE WELD

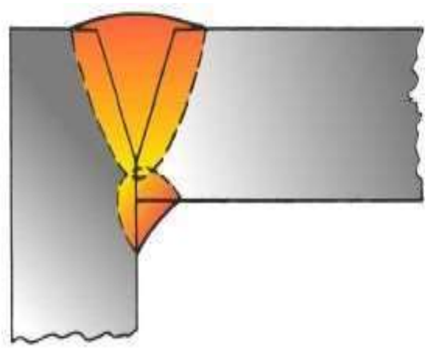


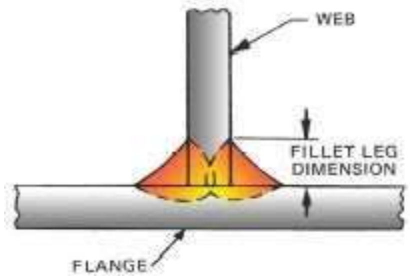
B. FILLET WELD

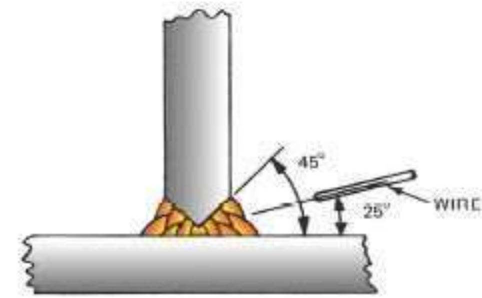


Weld Types





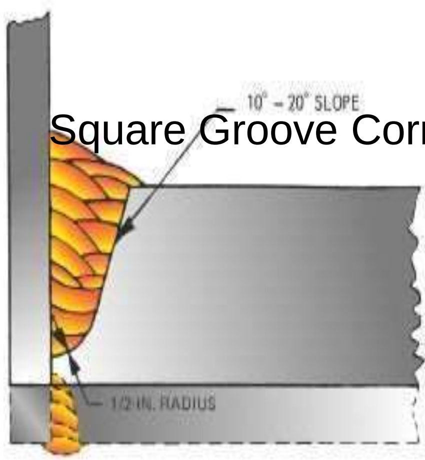




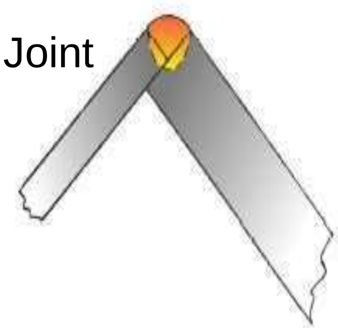
Groove Corner Joint

Horizontal Fillet Weld

Double-Vee, Groove Weld



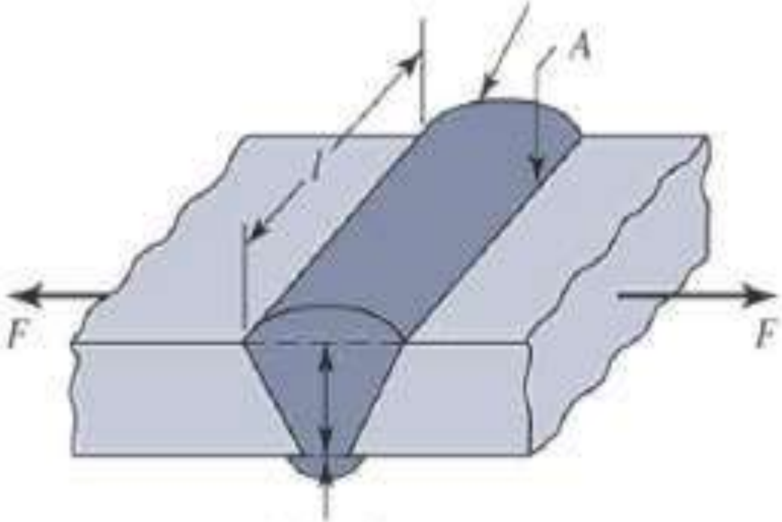
Square Groove Corner Joint



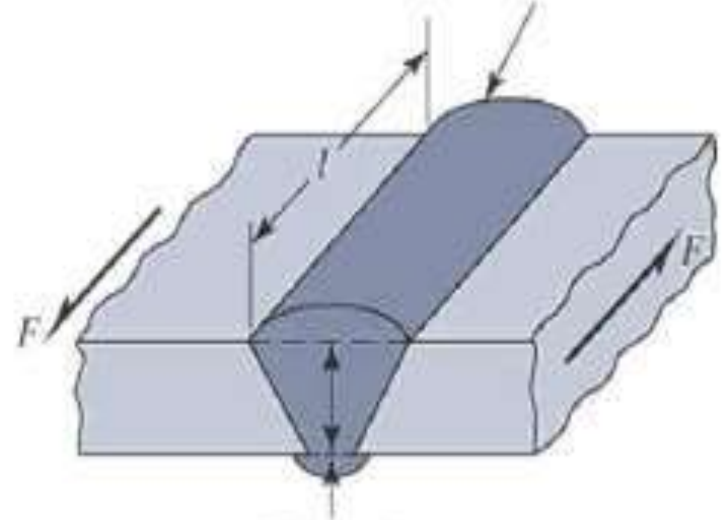
Corner Fillet Joint

J Groove Corner Joint (Single or Double J)

Types of stresses in welds



(a) Tensile loading



(b) Shear loading

Applications

- ***Cutting a rail just before renewing the rails***

Applications

•Oxygen cutting would be useful only for those materials which readily get oxidized and the oxides have lower melting points than the metals. So it is most widely used for ferrous materials. ƒ

- Oxygen cutting is NOT used for materials like aluminium, bronze, stainless steel

which resist oxidation. ƒ

- Cutting of high carbon steels and cast irons require special attention due to

formation of heat affected zone (HAZ) where structural transformation occurs.

Arc welding

The arc welding is a fusion welding process in which the heat required to fuse the metal is obtained from an electric arc between the base metal and an electrode.

The electric arc is produced when two conductors are touches together and then separated by a small gap of 2 to 4 mm, such that the current continues to flow, through the air. The temperature produced by the electric arc is about 4000°C to 6000'

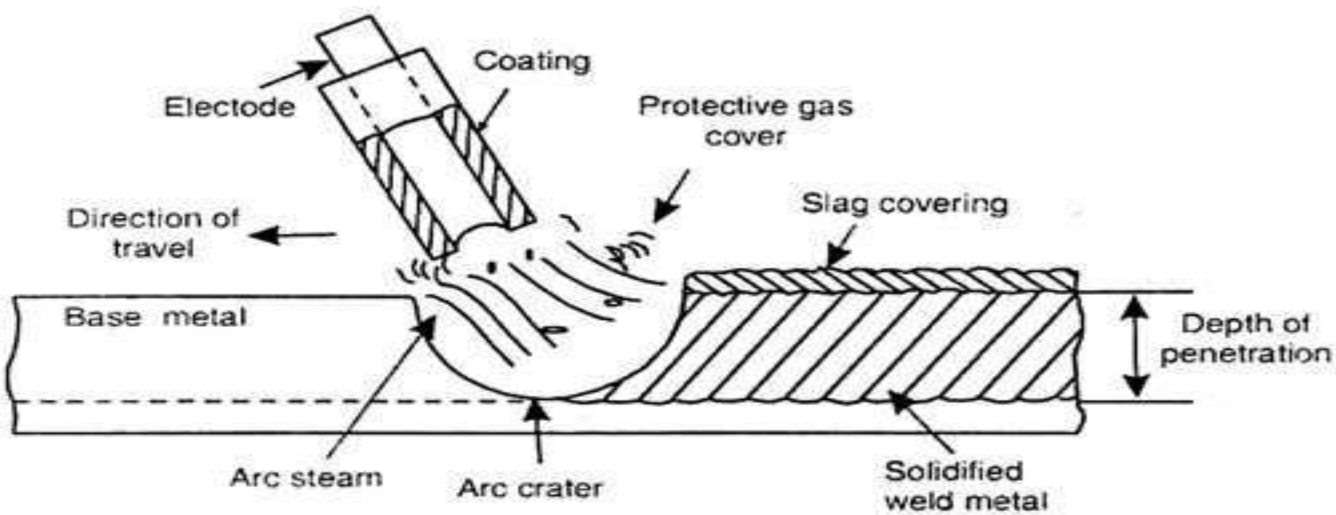


Fig. 7.14. Cut away view of the arc welding with a coated electrode.

Types of stresses in welds

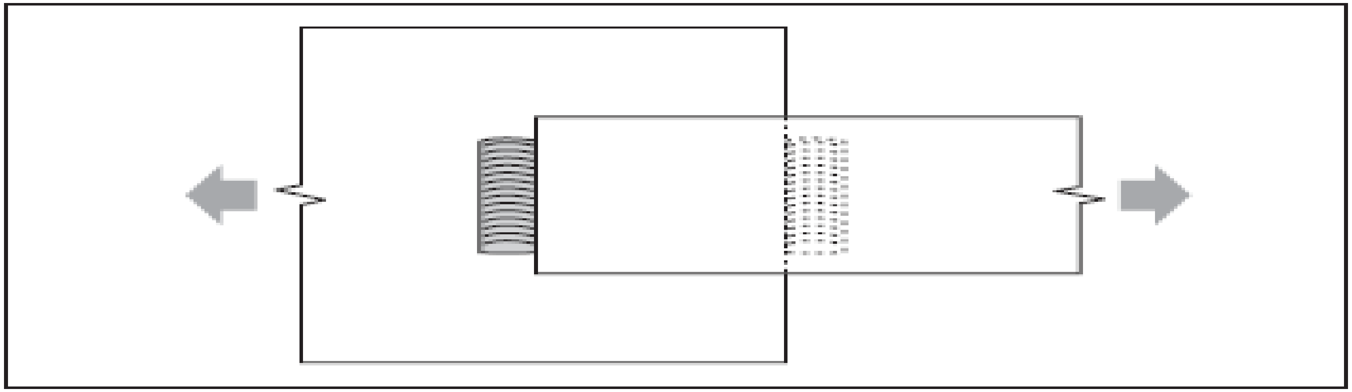


Figure 2. Lap joint with fillet welds loaded perpendicularly.

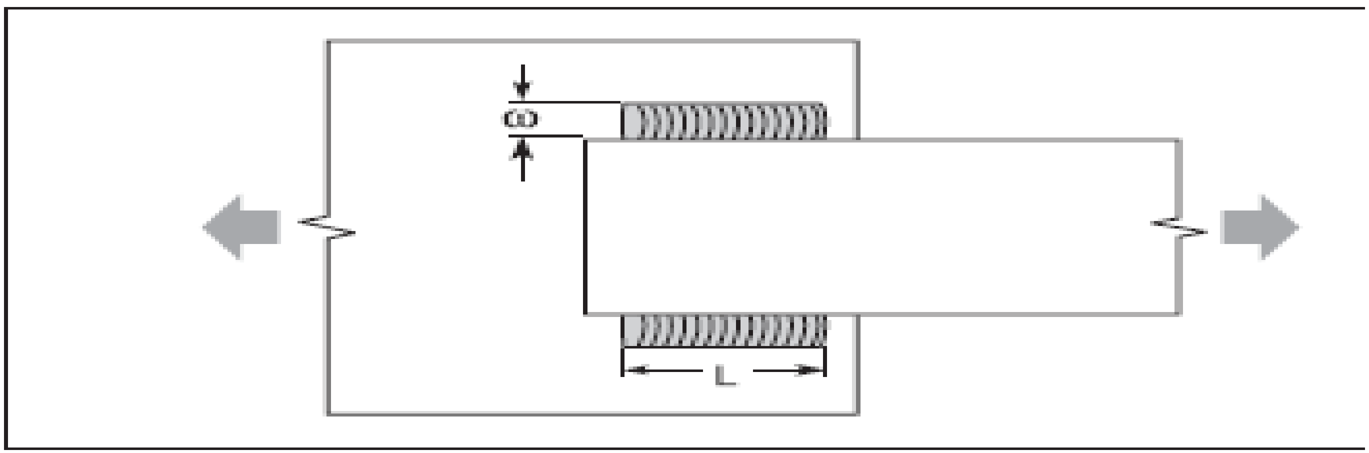
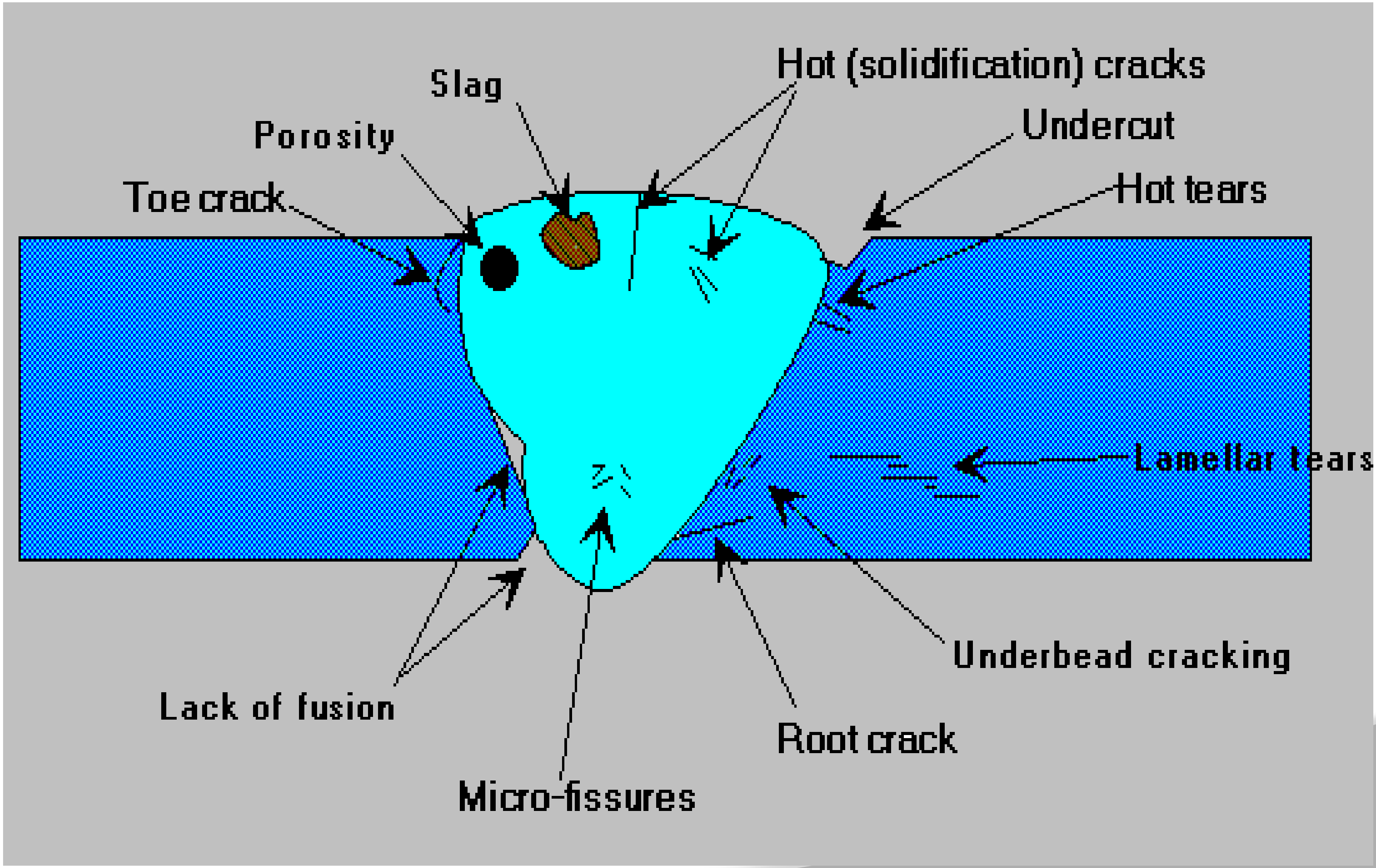


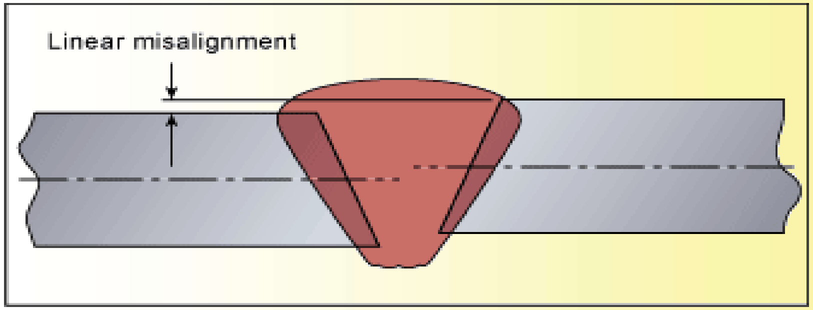
Figure 1. Lap joint with fillet welds loaded in parallel.

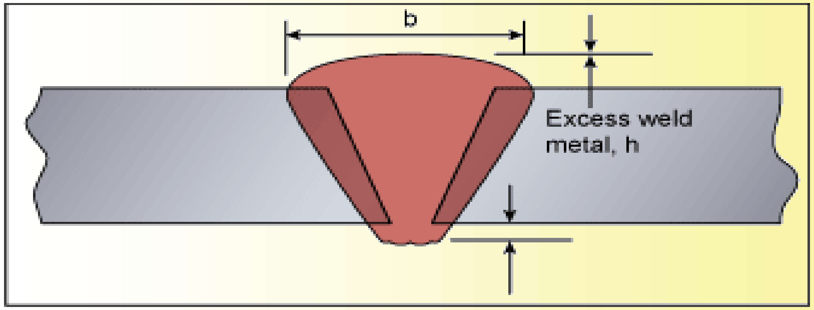
Commonly encountered weld defects



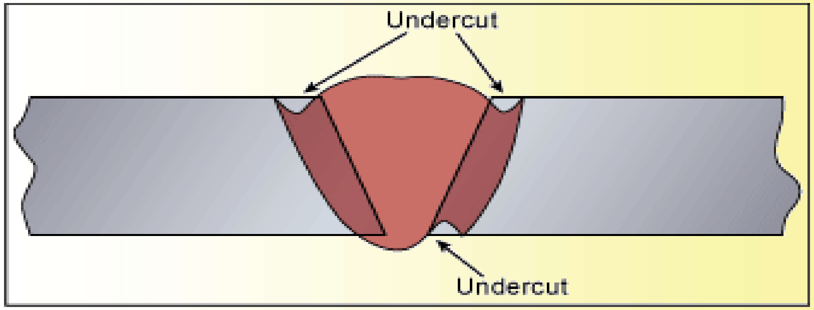
Commonly encountered weld defects

Linear misalignment

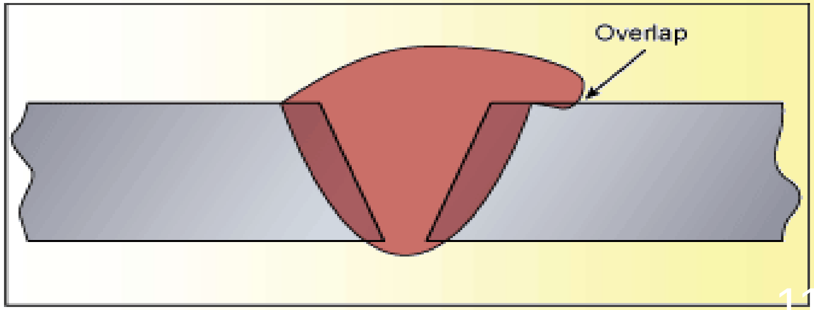




Undercut



Overlap



FORGING

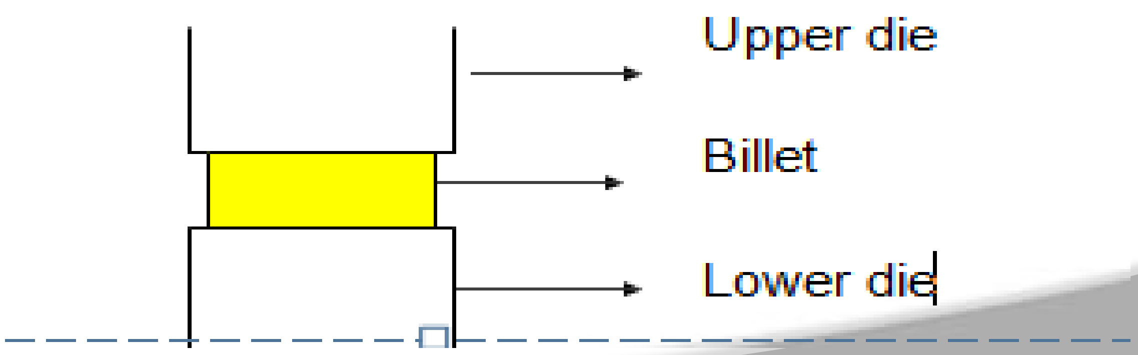
Forging may be defined as a metal working process by which metals and alloys are plastically deformed to desired shapes by the application of compressive force. Forging may done either hot or cold.

- Forging - defined as metal working process by which metals and alloys are plastically deformed to the desired shapes by the application of compressive forces.
- Classification:
  - ➢ Open Die Forging
  - ➢ Impression / closed die forging

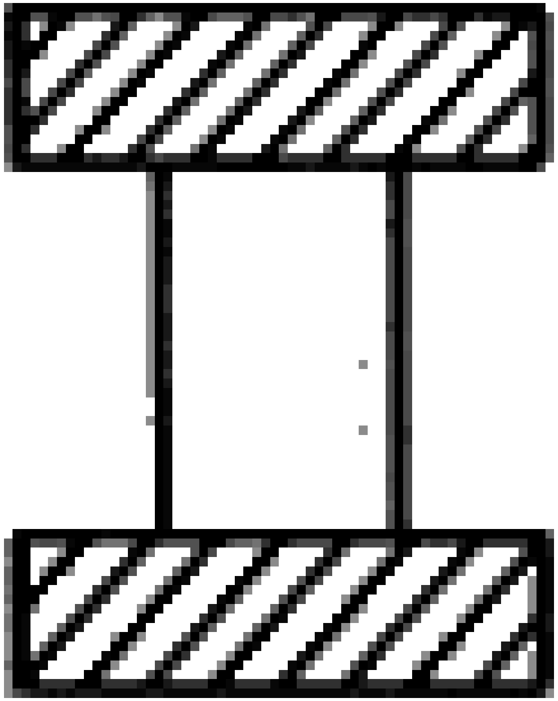
OPEN DIE FORGING

1. Open die forging is performed between flat dies with no pre cut profiles in the dies.
2. Larger parts over 200,000 lbs. and 80 feet in length can be hammered or pressed into shape this way.

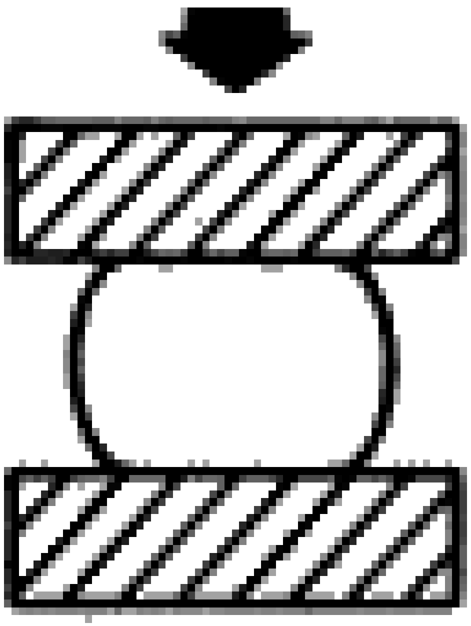
1. It is used
2. Number of components to be forged is too small
3. Size of the component is too large



STARTING STOCK



PRELIMINARY UPSETTING

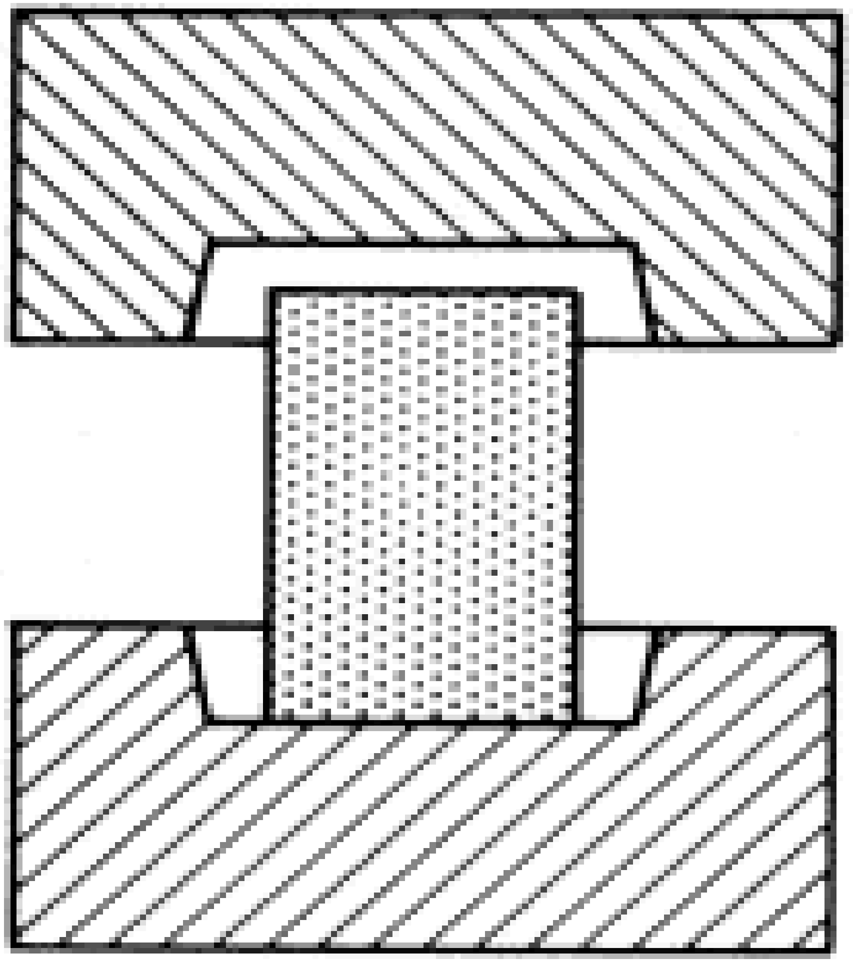


IMPRESSION DIE FORGING

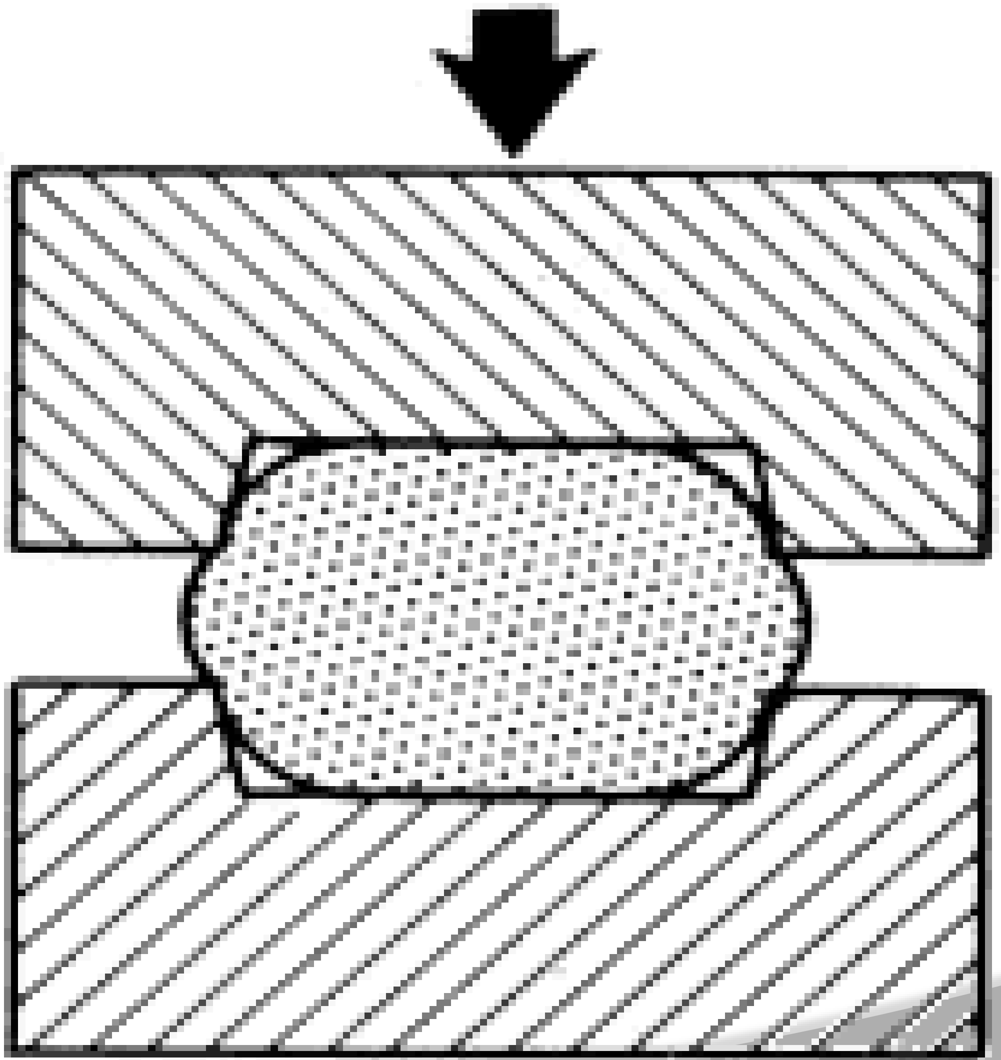
1. Impression Die Forging Process operations. In impression die forging, two dies are brought together and the work piece undergoes plastic deformation until its enlarged sides touch the side walls of the die. Then, a small amount of material begins to flow outside the die impression forming flash that is gradually thinned.

2. The flash cools rapidly and presents increased resistance to deformation and helps build up pressure inside the bulk of the work piece that aids material flow into unfilled impressions.

Impression Die



Impression Die Forging



Forging Defects

1. Incomplete forging penetration (Dentritic structure will not be broken at the interior surface)
2. Surface crack
3. High sulphur concentration in the furnace atmosphere can produce HOT SHORTNESS in Steel & Nickel
4. Crack at Flash
5. Cold shut
6. Loose Scale or lubricant may accumulate in deep recess of the die
7. Incomplete decaling of work piece
8. Internal cracks can develop during upsetting
9. Laps (Metal Fold)
10. Mismatch

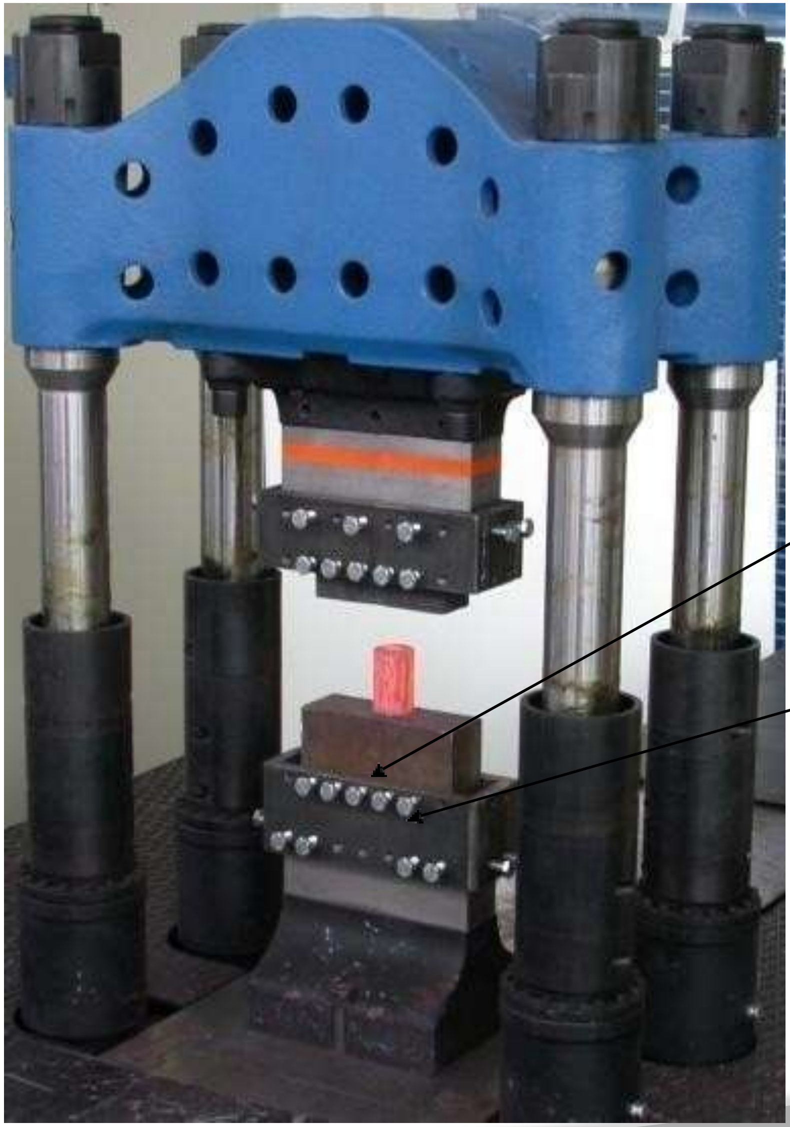
Forging operations

1. UPSETTING
2. HEADING
3. FULLERING
4. FLATTENING
5. EDGING
6. DRAWING OR NECKING
7. SETTING DOWN
8. SWAGING
9. PUNCHING
10. PIERCING
11. BENDING

Swaging

Swaging--This operation is related to the open die forging process whereby the stock is drawn out between flat, narrow dies. But instead of the stock, the hammer is rotated to produce multiple blows, sometimes as high as 2,000 per minute. It is a useful method of primary working, although in industrial production its role is normally that of finishing. Swaging can be stopped at any point in the length of stock and is often used for pointing tube and bar ends and for producing stepped columns and shafts of declining diameter.

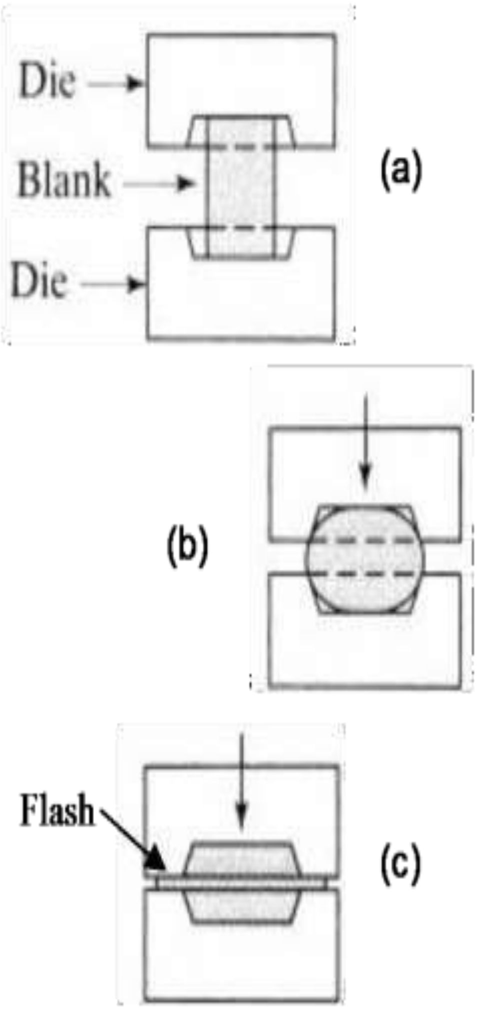
Forging Methods

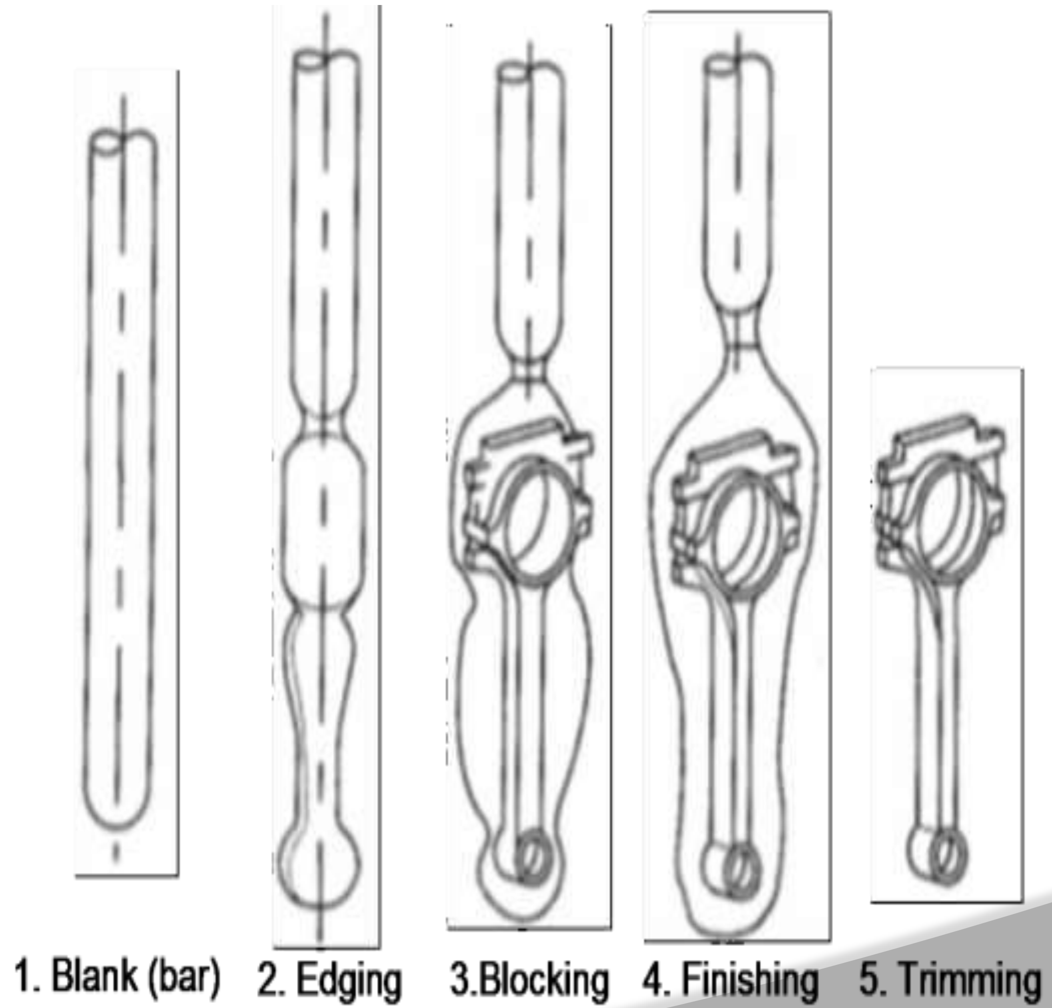


Hot Forging,

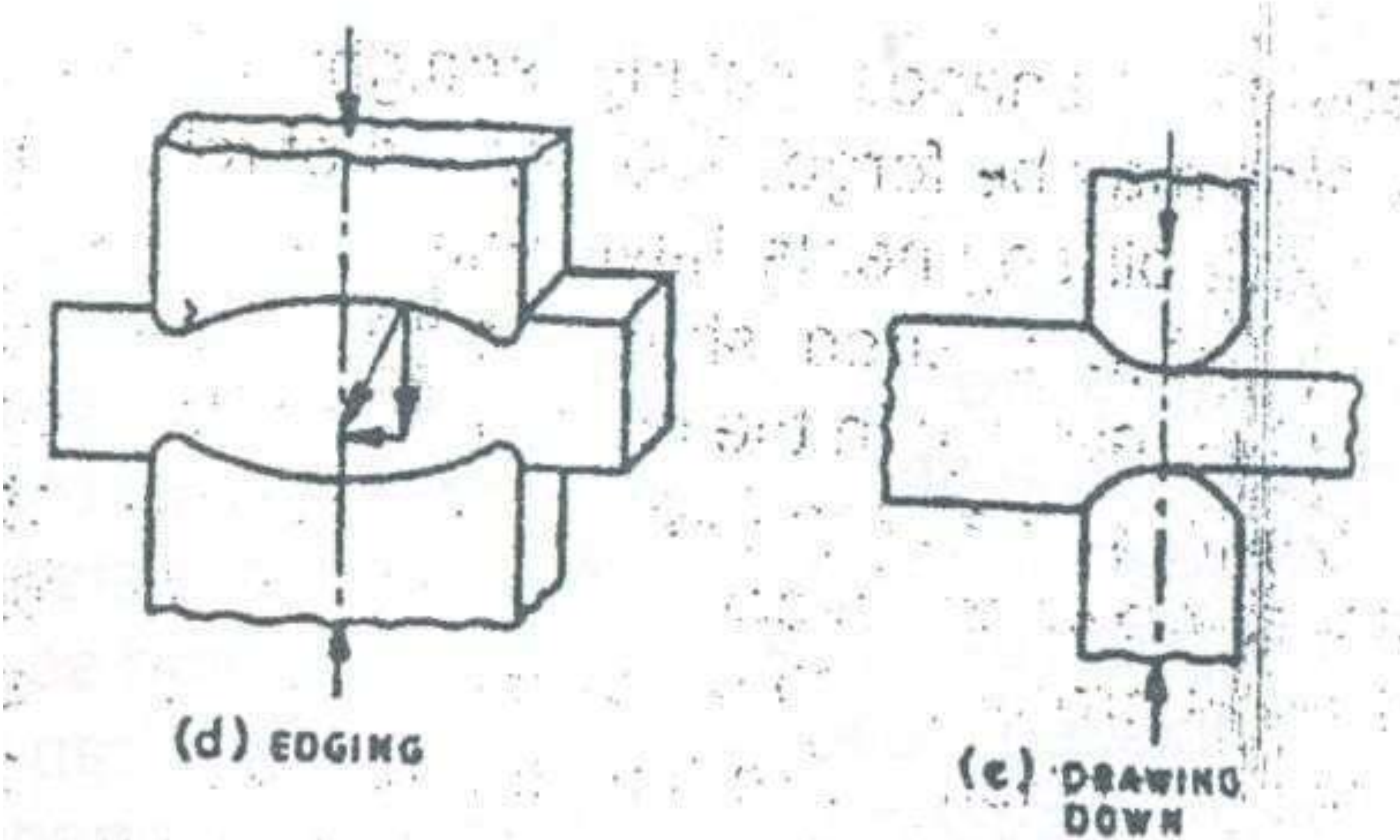
Open Die

Forging Methods

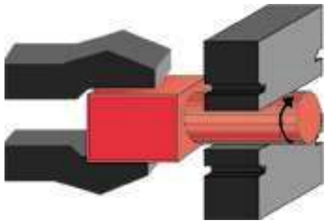




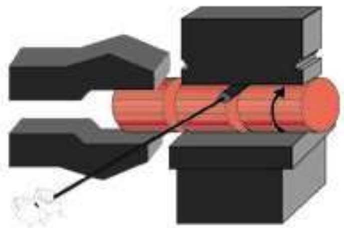
Forging Methods



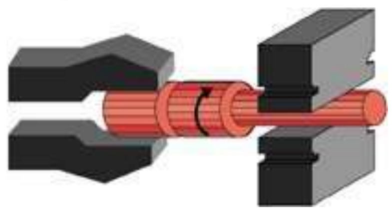
Forging Methods



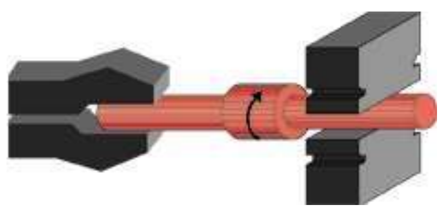
(a) forge hot billet to max diameter



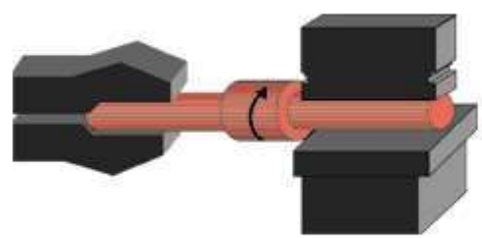
(b) “fuller: tool to mark step-locations



c) Forge right side

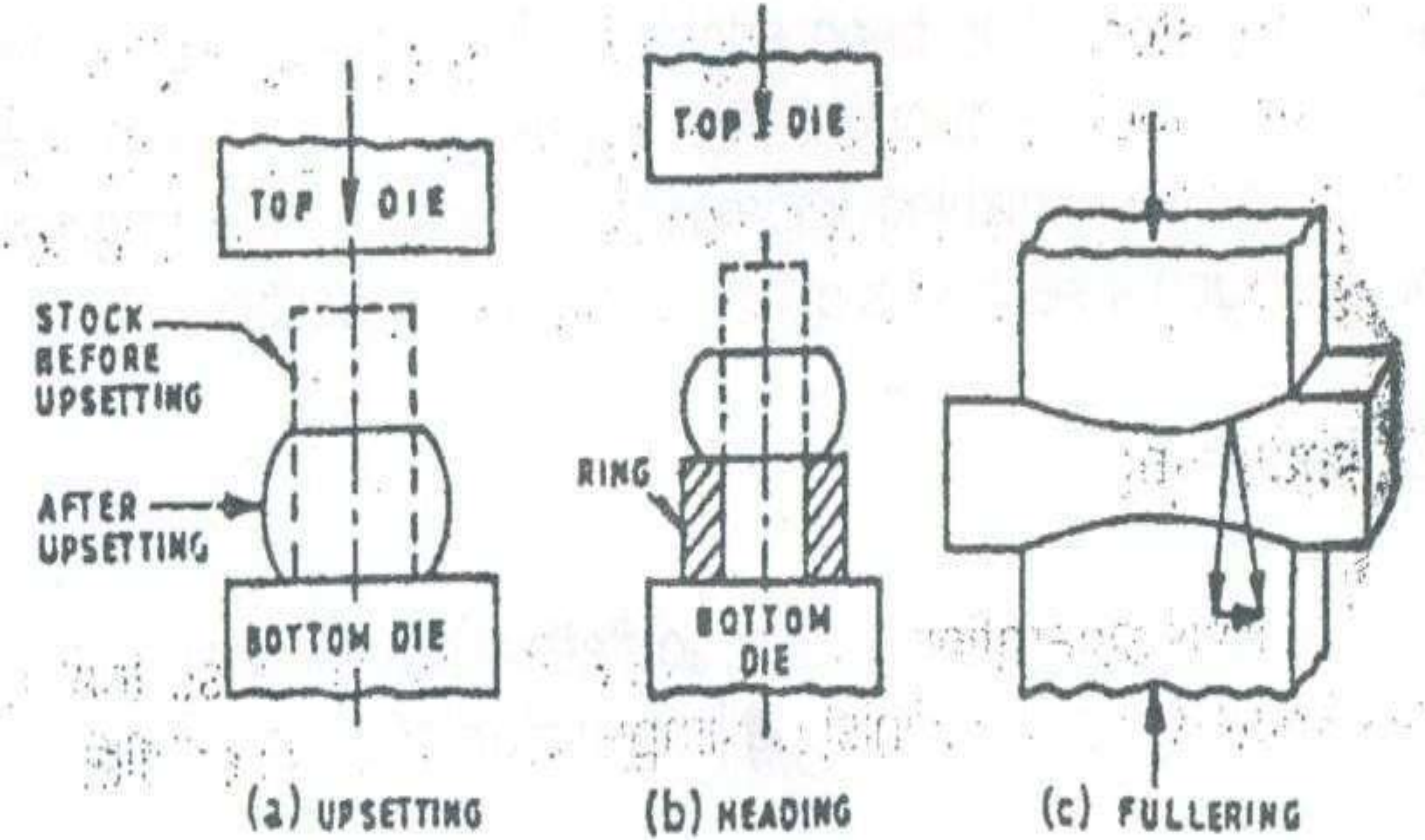


d) reverse part, forge left side



(e) finish (dimension control)

Forging Methods



UNIT – IV
DESIGN FOR FORGING

CLOs	Course Learning Outcome
CLO11	Understand the different conventional approach and Assembly optimization processes
CLO12	Create the knowledge on cost consciousness & an awareness of Designers’ accountability in product design lifecycle .
CLO13	Understand the cost factors that play a part in DFA

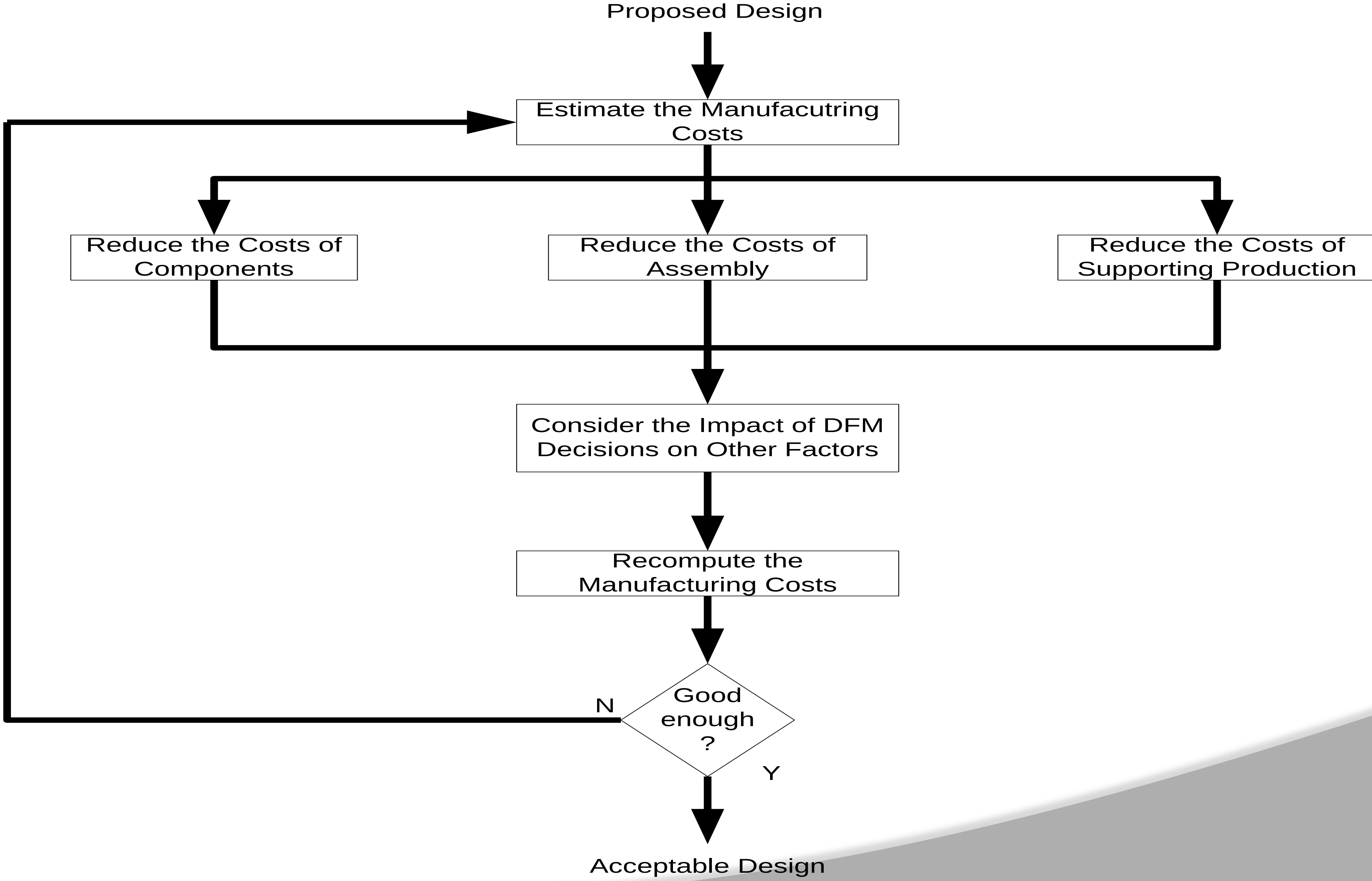
Design for X Topics

- Design for Manufacturing
- Design for Production
- Design for Assembly
- Design for Recycling/Disposal
- Design for Life Cycle
- Prototyping

Gathering DFM Information

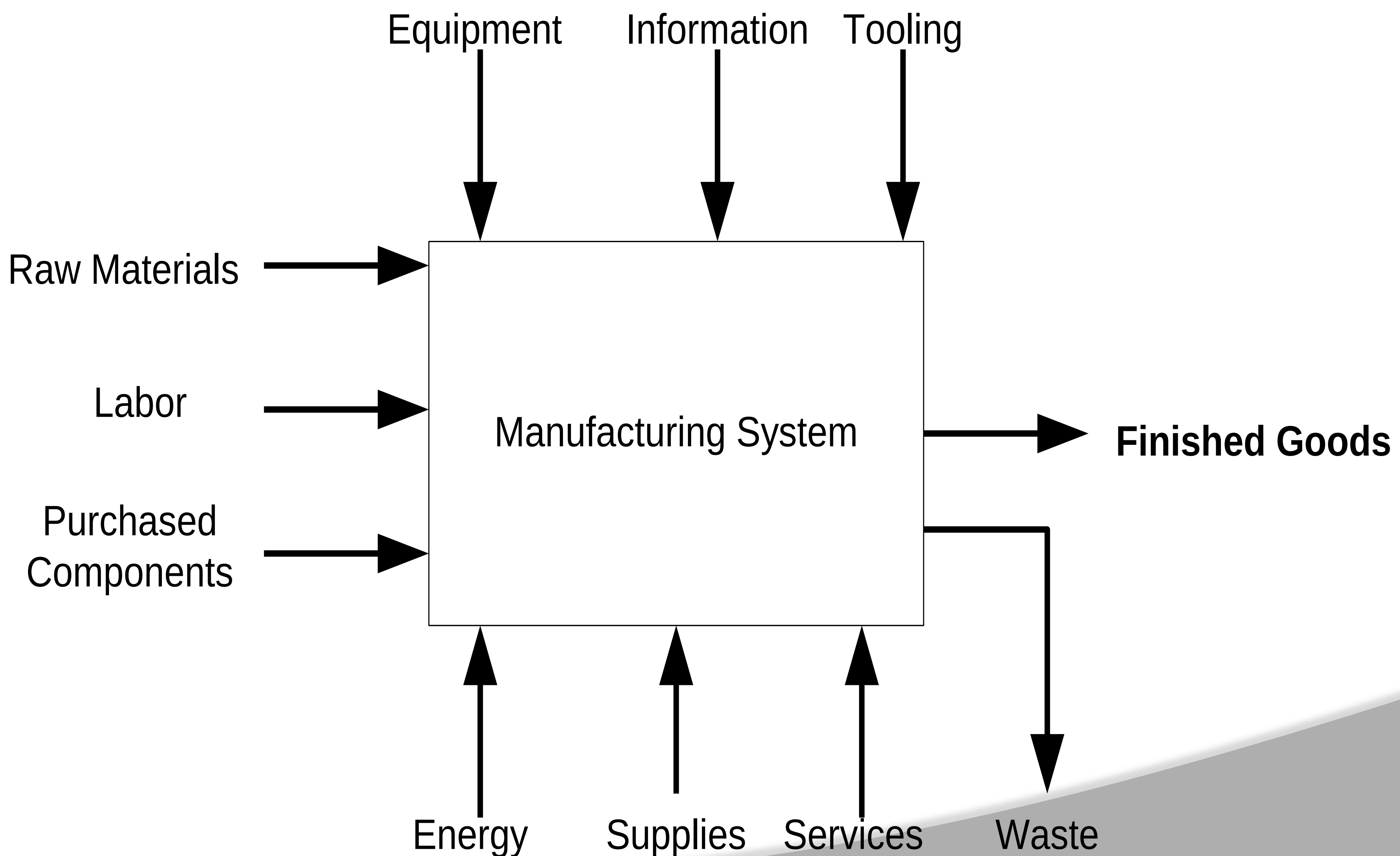
- Sketches, drawings, product specifications, and design alternatives.
- A detailed understanding of production and assembly processes
- Estimates of manufacturing costs, production volumes, and ramp-up timing.

DFM Method



Proposed Design
Estimate the Manufacutring Costs
Reduce the Costs of Components
Reduce the Costs of Assembly
Reduce the Costs of Supporting Production
Consider the Impact of DFM Decisions on Other Factors
Recompute the Manufacturing Costs
Good enough ?
N
Y
Acceptable Design

Estimate the Manufacturing Costs

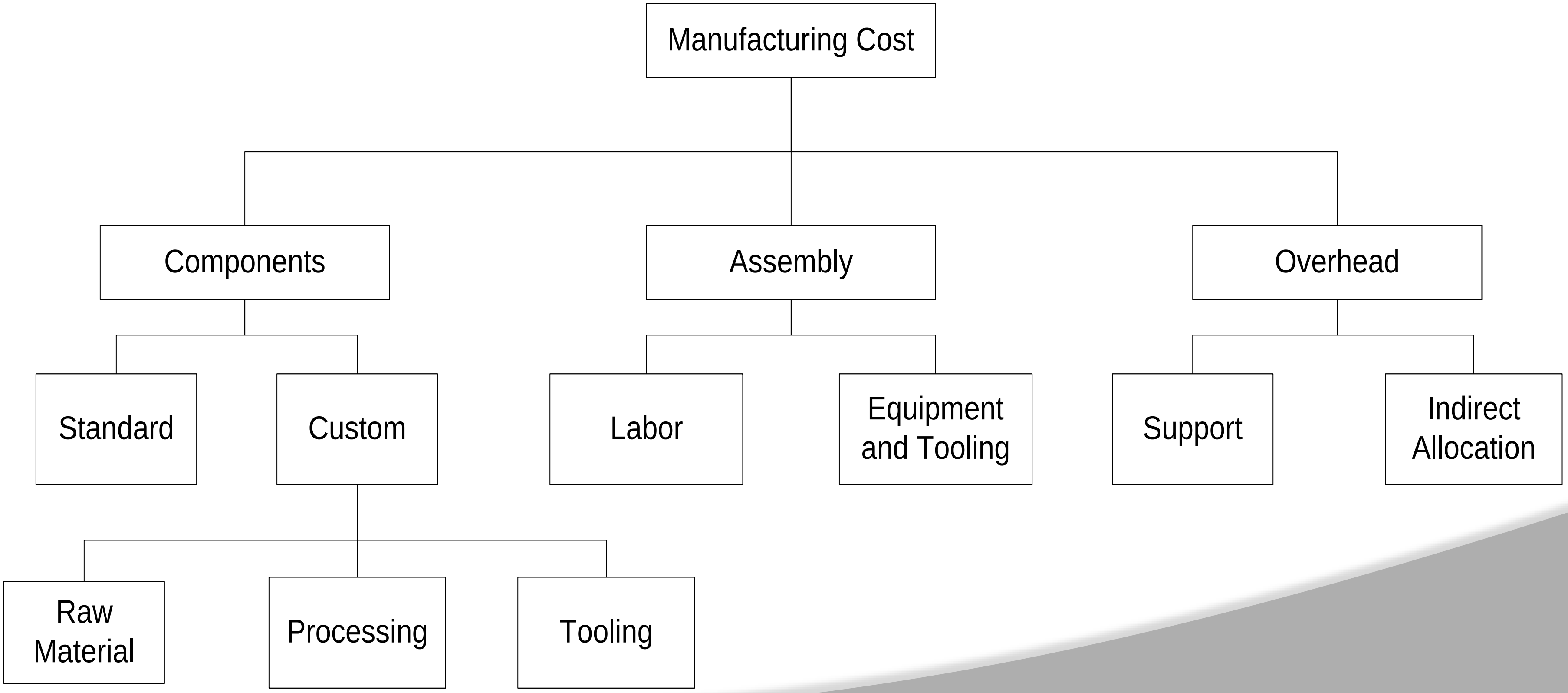


Manufacturing Costs Defined

- **Sum of all the expenditures for the inputs of the system (i.e. purchased components, energy, raw materials, etc.) and for disposal of the wastes produced by the system**

Elements of the Manufacturing Cost of a Product

Definition: Sum of all the expenditures for the inputs of the system (i.e. purchased components, energy, raw materials, etc.) and for disposal of the wastes produced by the system



Manufacturing Cost of a Product

- Component Costs (parts of the product)
  - Parts purchased from supplier
  - Custom parts made in the manufacturer’s own plant or by suppliers according to the manufacturer’s design specifications
- Assembly Costs (labor, equipment, & tooling)
- Overhead Costs (all other costs)
  - Support Costs (material handling, quality assurance, purchasing, shipping, receiving, facilities, etc.)
  - Indirect Allocations (not directly linked to a particular product but must be paid for to be in business)

Fixed Costs vs. Variable Costs

- Fixed Costs – incurred in a predetermined amount, regardless of number of units produced (i.e. setting up the factory work area or cost of an injection mold)

- Variable Costs – incurred in direct proportion to the number of units produced (i.e. cost of raw materials)

Reduce the Cost of Components

- Understand the Process Constraints and Cost Drivers.
- Redesign Components to Eliminate Processing Steps.
- Choose the Appropriate Economic Scale for the Part Process.
- Standardize Components and Processes.
- Adhere to “Black Box” Component Procurement.

Understand the Process Constraints and Cost Drivers

- Redesign costly parts with the same performance while avoiding high manufacturing costs.

- Work closely with design engineers—raise awareness of difficult operations and high costs.

Redesign Components to Eliminate Processing Steps

- Reduce the number of steps of the production process
  - Will usually result in reduce costs
- Eliminate unnecessary steps.
- Use substitution steps, where applicable.
- Analysis Tool – Process Flow Chart and Value Stream Mapping

Choose the Appropriate Economic Scale for the Part Process

Economies of Scale – As production volume increases, manufacturing costs usually decrease.

- Fixed costs divided among more units.
- Variable costs are lower since the firm can use more efficient processes and equipment.

Standardize Components and Processes

- Economies of Scale – The unit cost of a component decreases as the production volume increases.
- Standard Components—common to more than one product.
- Analysis tools – group technology and mass customization.

Adhere to "Black Box" Component Procurement

- Black box—only give a description of what the component has to do, not how to achieve it.

- Successful black box design requires clear definitions of the functions, interfaces, and interactions of each component.

Reduce the Costs of Assembly

- Design for Assembly (DFA) index
- Integrated Parts (Advantages and Disadvantages)
- Maximize Ease of Assembly
- Consider Customer Assembly

DFA Systems

- Boothroyd Dewhurst DFM & A
- Munro & Assoc. (Design Prophet/Profit)
- Others

Design for Assembly Index

$$\text{DFA index} = \frac{\text{(Theoretical minimum number of parts)} \times \text{(3 seconds)}}{\text{Estimated total assembly time}}$$

Determining the Theoretical Minimum Number of Parts

- Does the part need to move relative to the rest of the assembly?
- Must the part be made of a different material from the rest of the assembly for fundamental physical reasons?
- Does the part have to be separated from the assembly for assembly access, replacement, or repair?

Advantages of Integrated Parts

- Do not have to be assembled
- Often less expensive to fabricate rather than the sum of each individual part
- Allows critical geometric features to be controlled by the part fabrication process versus a similar assembly process

Disadvantages of Integrated Parts

- Conflict with other sound approaches to minimize costs
- Not always a wise strategy

Minimize Ease of Assembly

- Part is inserted from the top of the assembly
- Part is self-aligning
- Part does not need to be oriented
- Part requires only one hand for assembly
- Part requires no tools
- Part is assembled in a single, linear motion
- Part is secured immediately upon insertion

Consider Customer Assembly

- Customers will tolerate some assembly
- Design product so that customers can easily and assemble correctly
- Customers **will likely ignore directions**

Reduce the Costs of Supporting Production

Minimize Systemic Complexity (inputs, outputs, and transforming processes)

- Use smart design decisions

Error Proofing (Poka Yoke)

- Anticipate possible failure modes
- Take appropriate corrective actions in the early stages
- Use color coding to easily identify similar looking, but different parts

Consider the Impact of DFM Decisions on Other Factors

- Development Time
- Development Cost
- Product Quality
- External Factors
  - Component reuse
  - Life cycle costs

Design for Production

1. Design Organization
2. Timing of Production
3. Material Identification
4. Specific Design

Production Input

- **At various design stages**
  - **Concept**
    - **Production Input**
  - **Functional**
    - **None**
  - **Transition**
    - **Tactics**
  - **Work Instruction**
    - **Production Preparation**

New Idea:
Provide Production Inputs

1. In proper level of detail at proper stage
2. In proper form
3. Just-in-time

Problems with Old Approach

- Work is carried out from beginning to end at each stage
- Too slow
- Needs continuous recycling

Design for Production General Principles

1. Use Common Sense
2. Plan and Define
3. Consider Available Facilities
4. Consider Available Tools
5. Consider Available Worker Skills
6. Employ Simplicity
7. Standardize

Design for Production Guidelines

1. Minimize Total Number of Parts
2. Develop a Modular Design
3. Minimize Part Variations
4. Design Parts to be Multifunctional
5. Design Parts for Multiuse
6. Design Parts for Ease of Fabrication
7. Avoid Separate Fasteners
8. Minimize Assembly Direction (Top Down Direction Preferred)
9. Maximize Compliance in Assembly
10. Minimize Handling in Assembly
11. Minimize complexity of Design
12. Maximize common Jigs and Fixtures
13. Optimize Work Position
14. Ease Access

Types of Prototypes

- Two dimensions
  - Physical vs. Analytical
  - Comprehensive vs. Focused

Physical vs. Analytical

Physical

- Tangible artifacts created to approximate the product
- Used for testing and experimentation

Analytical

- Represents the product in a nontangible, usually mathematical manner
- Product is analyzed, not built

Comprehensive vs. Focused

- **Comprehensive**
  - Implement all (or most) of the attributes of the product
  - Full-scale
  - Fully operational version of the product
- **Focused**
  - Implement a few of the attributes of the product
  - Use two or more focused prototypes together to investigate the overall performance of a product

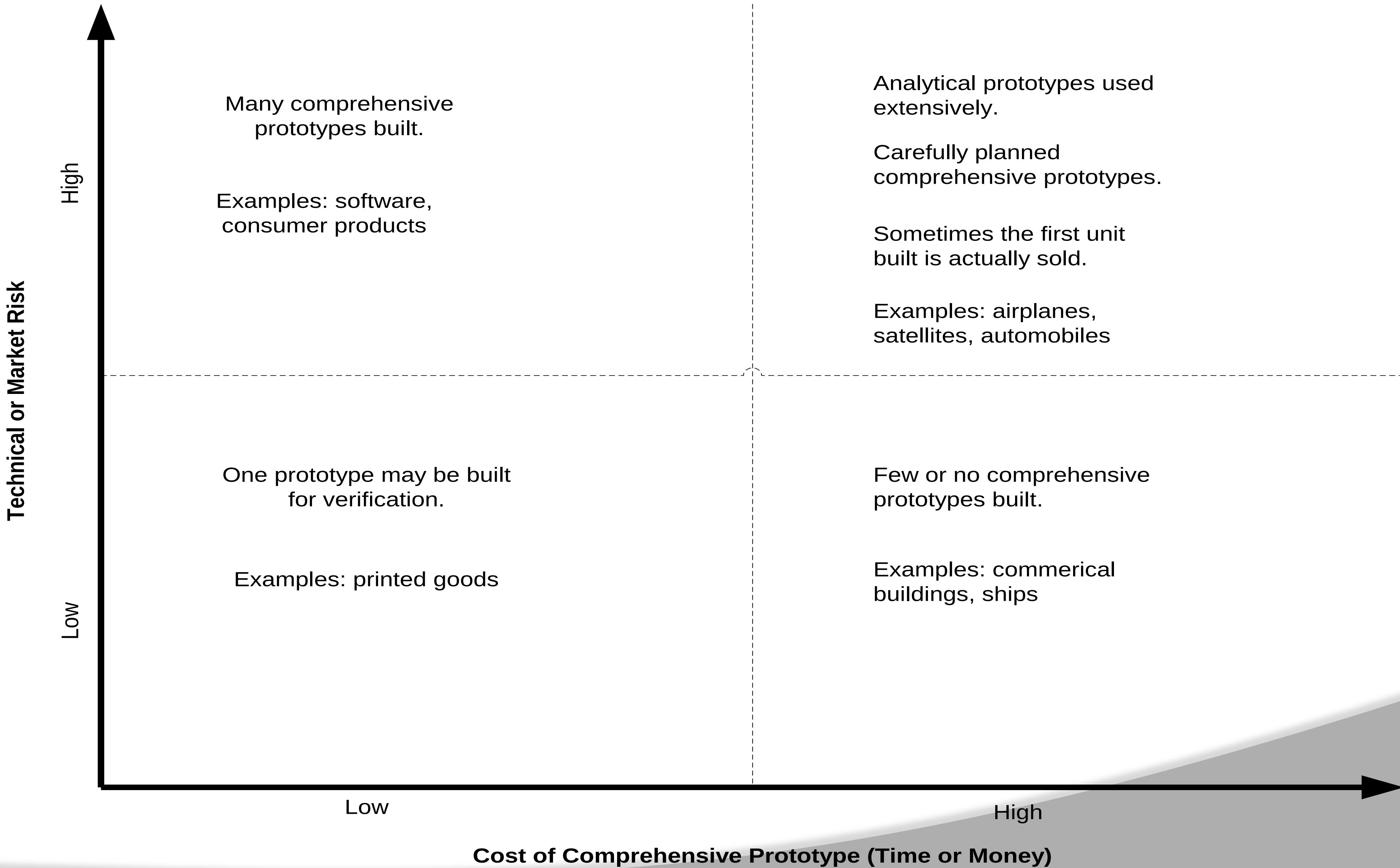
Prototype Uses

- **Learning**
  - Will it work?
  - How well does it meet the customer needs?
- **Communication**
  - Within the company
  - With customers, vendors, and suppliers
- **Integration**
  - Subsystems and components work together
- **Milestones**
  - Product achieved a desired

Principles of Prototyping

- Analytical Prototypes are generally more flexible than Physical Prototypes
- Physical Prototypes are required to detect unanticipated phenomena
- A Prototype may reduce the risk of costly iterations
- A Prototype may expedite other development steps
- A Prototype may restructure task dependencies

Use of comprehensive prototypes



Prototyping Technologies

- 3D Computer Modeling
  - Easily visualize the 3D form of the design
  - Automatically compute physical properties
  - Other more focused descriptions can be created based on one design
  - Detect geometric interference
- Free-Form Fabrication (or Rapid Prototyping)
  - 3D printers that create physical objects directly from 3D computer models
  - Less expensive
  - Reduce product development time, improve resulting product.

Planning for Prototypes

- Define the purpose of the prototype
- Establish the level of approximation of the prototype
- Outline an experimental plan
- Create a schedule for procurement, construction, and test

Define the Purpose

- List specific learning and communication goals
- List any integration needs
- Determine if the prototype is intended to be one of the major milestones of the overall product development

Establish the Level of Approximation

- Determine physical or analytical prototype
- Choose the simplest prototype that will serve the purpose established in step 1.
- Consider existing prototypes or a another prototype being built that can be borrowed

Outline an Experimental Plan

- Use prototype for experimentation
- Extract the maximum value from the prototyping activity.
- Identify the variables of the experiment, test protocol, plan for analyzing the resulting data

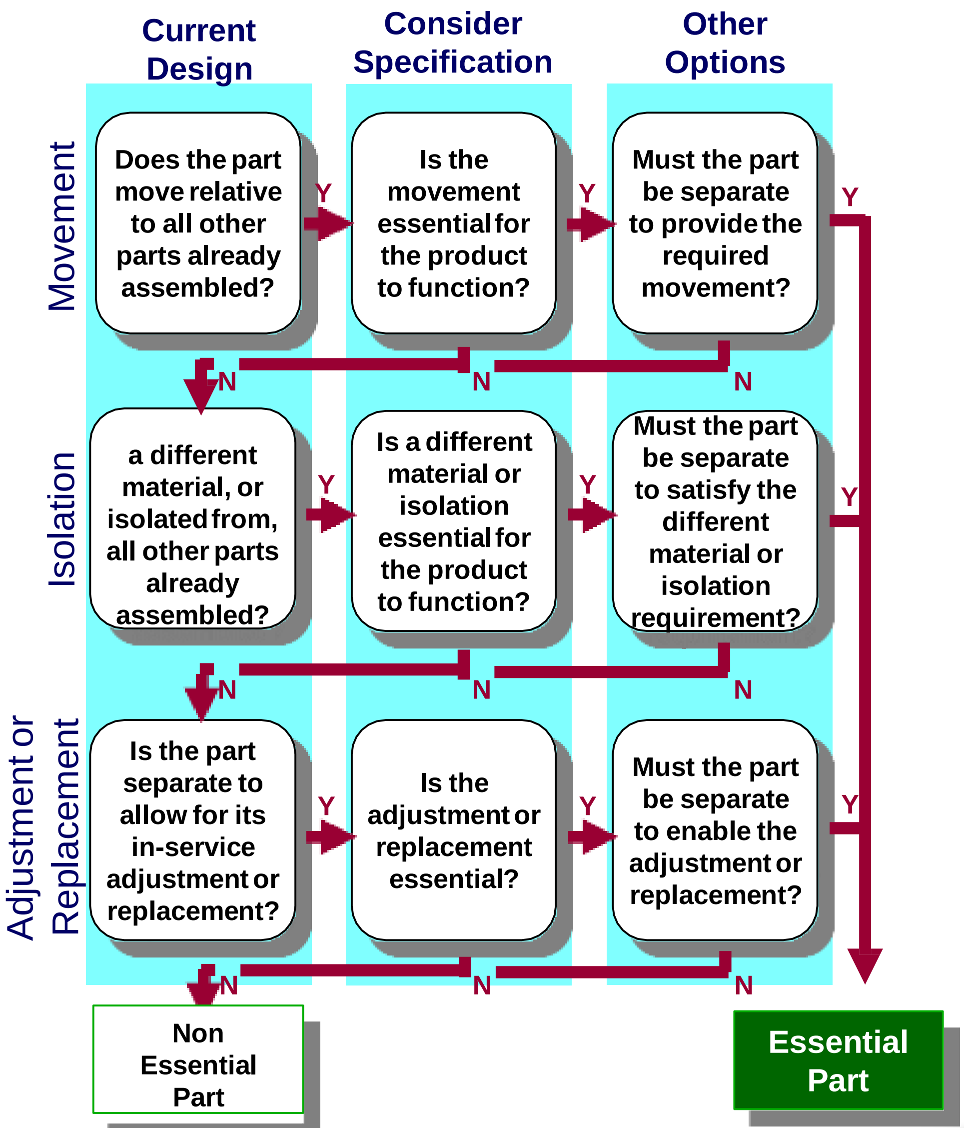
Create a Schedule for Procurement, Construction, and Test

- Determine when parts are ready to be assembled
- Determine the date when prototype will be first tested
- Determine expectations for completed testing and final results

Milestone Prototypes

- Alpha Prototypes – assess whether the product works as intended
- Beta Prototypes – assess reliability and to identify any bugs in the product
- Preproduction Prototypes – first products produced by the entire production process

Determine Theoretical Min. No. of Parts

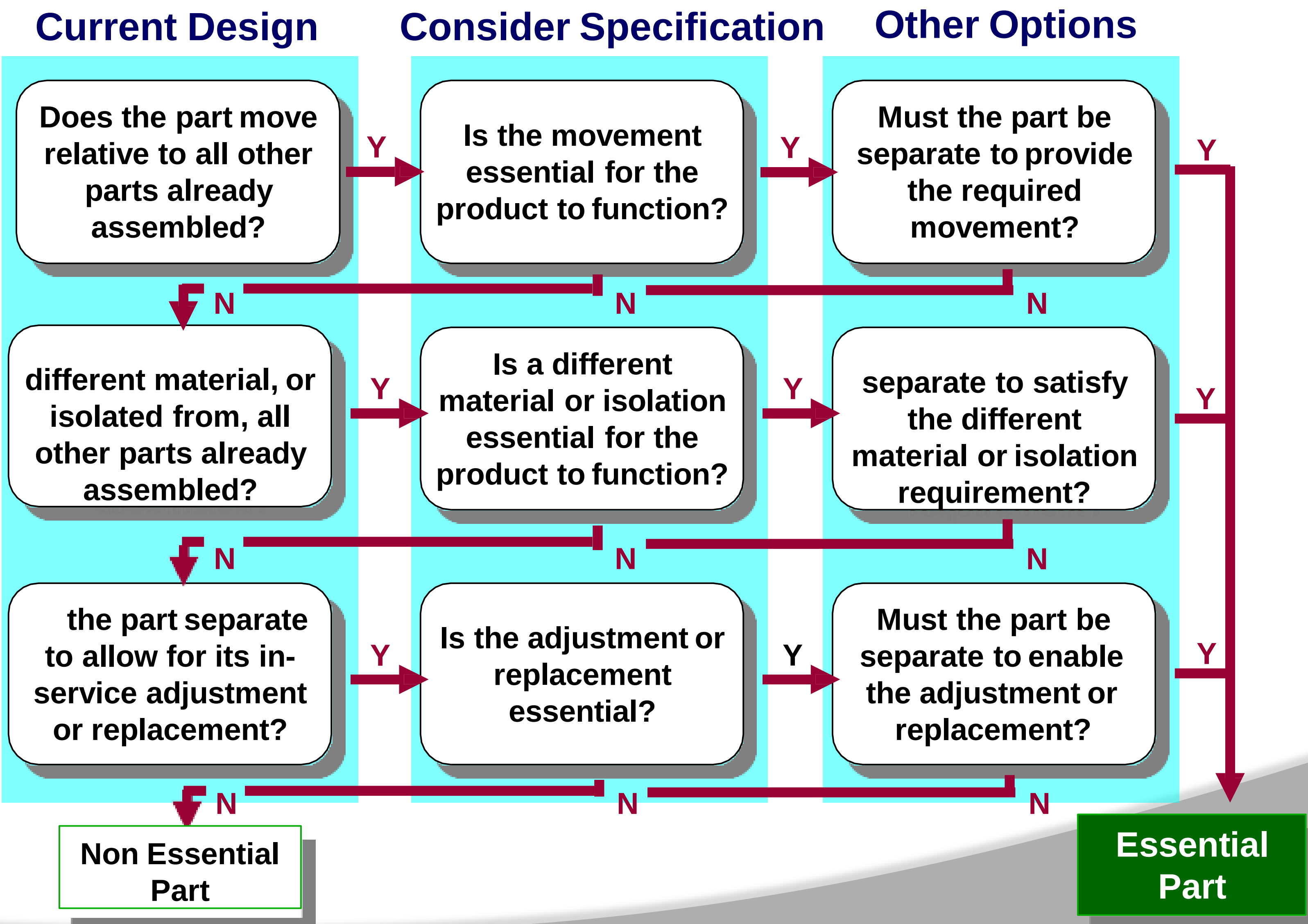


DFA Analysis Worksheet

Assembly Name: Staple Remover

	A	B	C	D	E
4	Part		DFA Complexity		Func Red
5	Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni) (part a to part b = 1)	Theoretical Minimum Part (Functional Analysis chart)
6	1	Lower Arm Sub.			
7	1.1	***Base Part*** - Lower Arm	1	6	Y
8	1.2	Lower Arm cover	1	3	N
9	1.3	Rivet	2	4	N
10	2	Upper Arm Sub.			
11	2.1	Upper Arm	1	6	N
12	2.2	Upper Arm cover	1	3	N
13	2.3	Rivet	2	4	N
14	3	Spring	1	3	N
15	4	Pivot	1	3	N
16					
17		*Totals*	10	32	1

Functional Analysis



Determine if Parts Can be Standardized

- **Can the current parts be standardized?:**
  - **Within the assembly station**
  - **Within the full assembly**
  - **Within the assembly plant**
  - **Within the corporation**
  - **Within the industry**
- **Should they be?**
- **(Only put a “Y” if both answers are yes…)**

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DFA Analysis Worksheet

Assembly Name: Staple Remover

Row	Part Number	Part Name	DFA Complexity: Number of Parts (Np)	DFA Complexity: Number of Interfaces (Ni) (part a to part b = 1)	Functional Redesign C: Theoretical Minimum Part (Functional Analysis chart)	Functional Redesign C: Part can be Standardized (if not already standard)
6	1	Lower Arm Sub.				
7	1.1	*Base Part* - Lower Arm	1	6	Y	N
8	1.2	Lower Arm cover	1	3	N	Y
9	1.3	Rivet	2	4	N	N
10	2	Upper Arm Sub.				
11	2.1	Upper Arm	1	6	N	N
12	2.2	Upper Arm cover	1	3	N	Y
13	2.3	Rivet	2	4	N	N
14	3	Spring	1	3	N	N
15	4	Pivot	1	3	N	N
16						
17		*Totals*	10	32	1	2
18		*Design for Assembly Metrics*	17.89		10%	← Theo Pract.
19		*Targets*	0.00		>60%	0

Theoretical Part Count Efficiency

Theoretical Part Count Efficiency

$$\frac{\textbf{Theoretical Min. No. Parts}}{\textbf{Total Number of Parts}}$$

Theoretical Part Count Efficiency $= \frac{1}{10} * 100$

Theoretical Part Count Efficiency **10%**

Rule of Thumb – Part Count Efficiency Goal > 60%

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DFA Analysis Worksheet

Assembly Name: Staple Remover

	Part Number	Part Name	DFA Complexity: Number of Parts (Np)	DFA Complexity: Number of Interfaces (Ni) (part a to part b = 1)	Func Red: Theoretical Minimum Part (Functional Analysis chart)
6	1	Lower Arm Sub.			
7	1.1	***Base Part -*** Lower Arm	1	6	Y
8	1.2	Lower Arm cover	1	3	N
9	1.3	Rivet	2	4	N
10	2	Upper Arm Sub.			
11	2.1	Upper Arm	1	6	N
12	2.2	Upper Arm cover	1	3	N
13	2.3	Rivet	2	4	N
14	3	Spring	1	3	N
15	4	Pivot	1	3	N
16					
17		***Totals***	10	32	1
18		***Design for Assembly Metrics***	17.89		10%
19		***Targets***	0.00		>60%

DFA Complexity Factor – Definition

- Cummins Inc. metric for assessing complexity of a product design
- Two Factors
    - Np – Number of parts
    - Ni – Number of part-to-part interfaces
  - Multiply the two and take the square root of the total

$$\sqrt{\Sigma \text{ Np x } \Sigma \text{ Ni}}$$

  - This is known as the DFA Complexity Factor

Cost Breakdown

- Media paper 21.4%
- Centertube 3.6%
- Endplates (2) 3.0%
- Plastisol 2.6%
- Inner Seal 4.0%
- Spring 0.9%
- Shell 31.4%
- Nutplate 21.0%
- Retainer 4.8%
- Loctite 0.3%
- End Seal 7.0%

UNIT – V

DESIGN FOR ASSEMBLY AND AUTOMATION

CLOs	Course Learning Outcome
CLO14	Understand the general design guidelines for manual assembly and development of the systematic DFA methodology
CLO15	Using CAD, apply design for manufacturing and assembly techniques to mechanical designs.
CLO16	Using CAD, apply design for manufacturing and assembly techniques to mechanical designs.

Determine Practical Minimum Part Count

- Team assessment of practical changes
- Tradeoffs between part cost and assembly cost

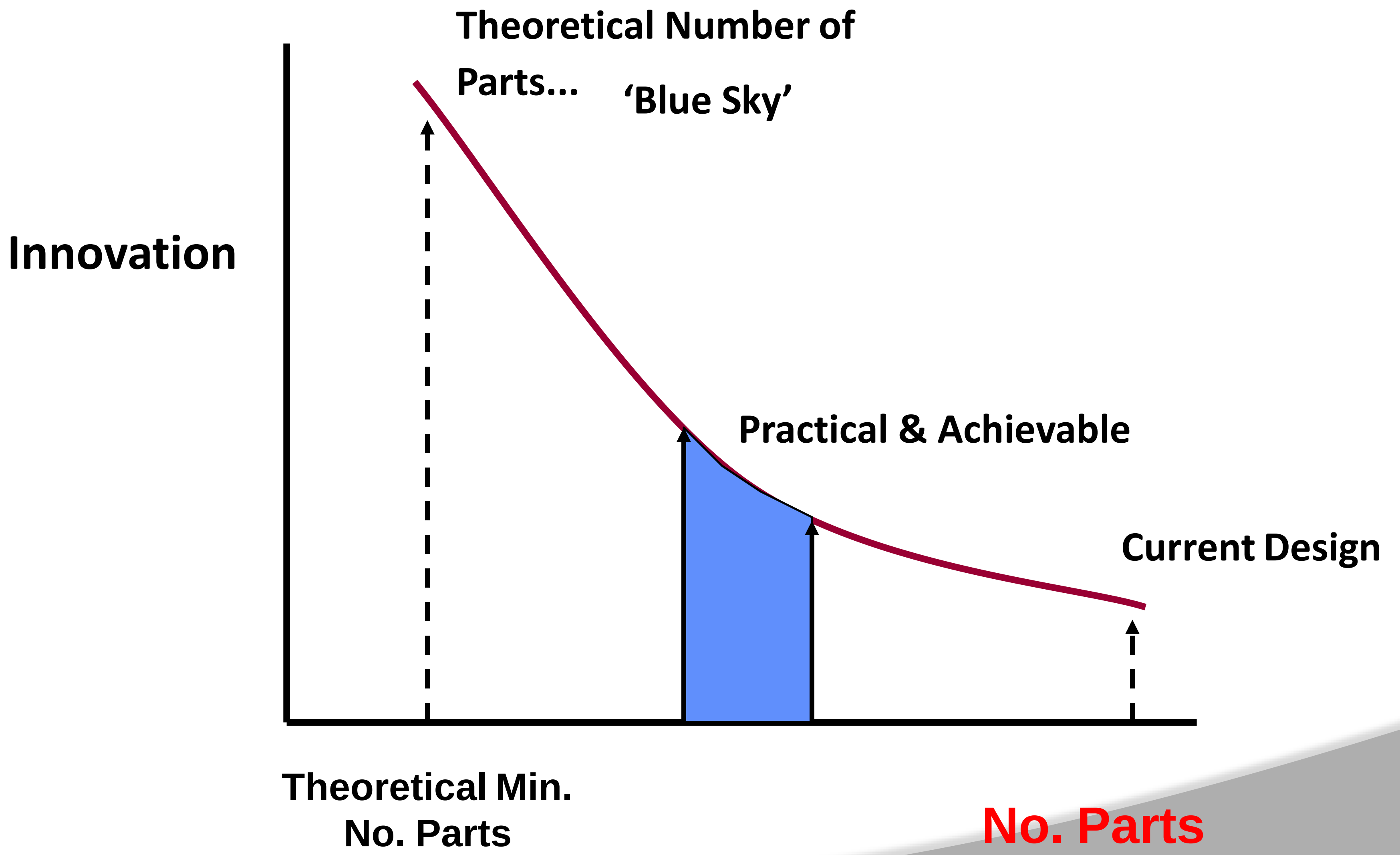
DFA Analysis Worksheet

Assembly Name: Staple Remover

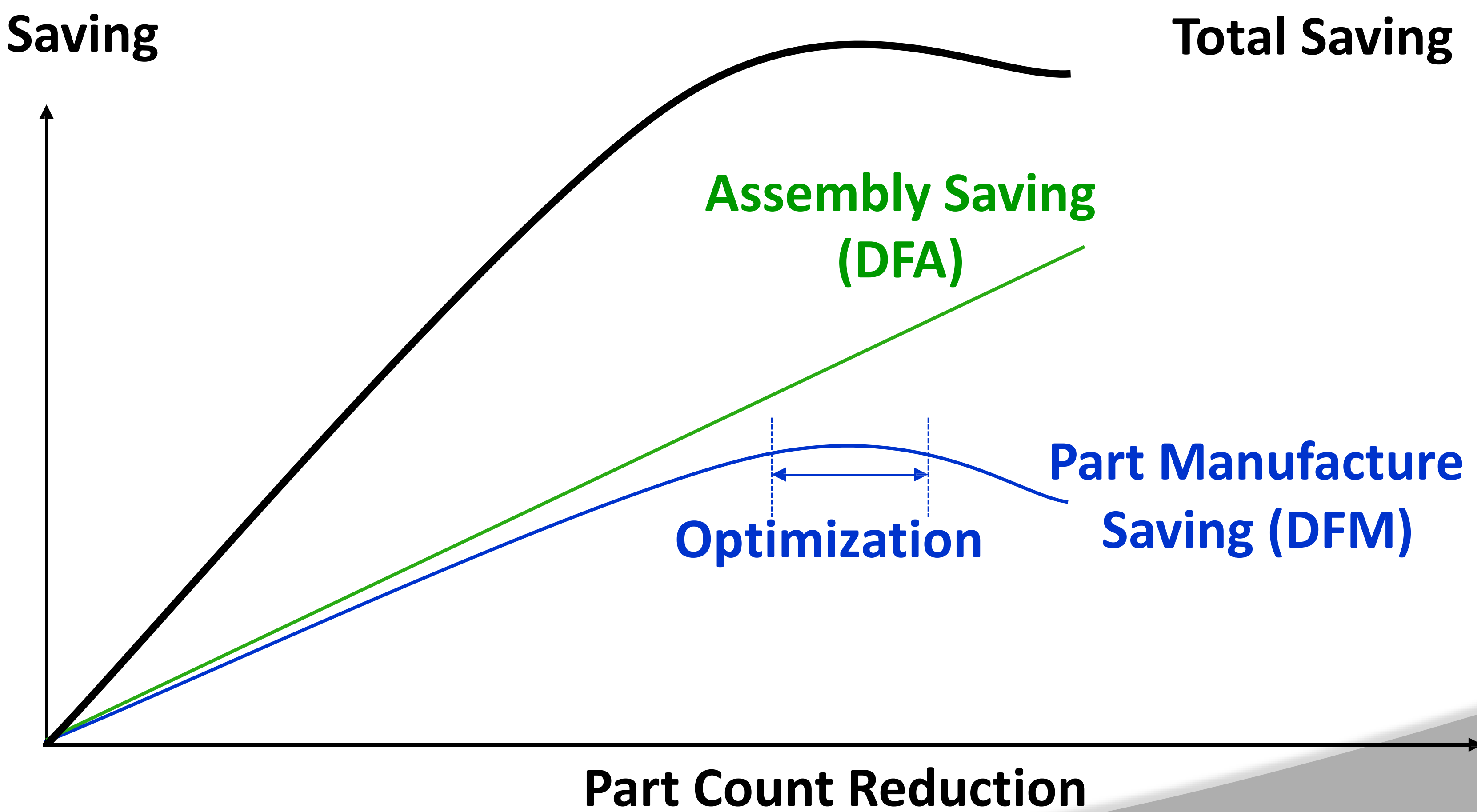
------------------------ *Enter 'Y'*

Part		DFA Complexity		Functional Analysis / Redesign Opportunity			
Part Number	 Part Name	Number of Parts (Np)	Number of Interfaces (Ni) (part a to part b = 1)	Theoretical Minimum Part (Functional Analysis chart)	Part can be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part
1	Lower Arm Sub.						
1.1	***Base Part*** **-** Lower Arm	1	6	Y	N	L	Y
1.2	Lower Arm cover	1	3	N	Y	L	N
1.3	Rivet	2	4	N	N	L	N
2	Upper Arm Sub.						
2.1	Upper Arm	1	6	N	N	L	Y
2.2	Upper Arm cover	1	3	N	Y	L	N
2.3	Rivet	2	4	N	N	L	N
3	Spring	1	3	N	N	L	Y
4	Pivot	1	3	N	N	L	Y
	Totals	10	32	1	2		4

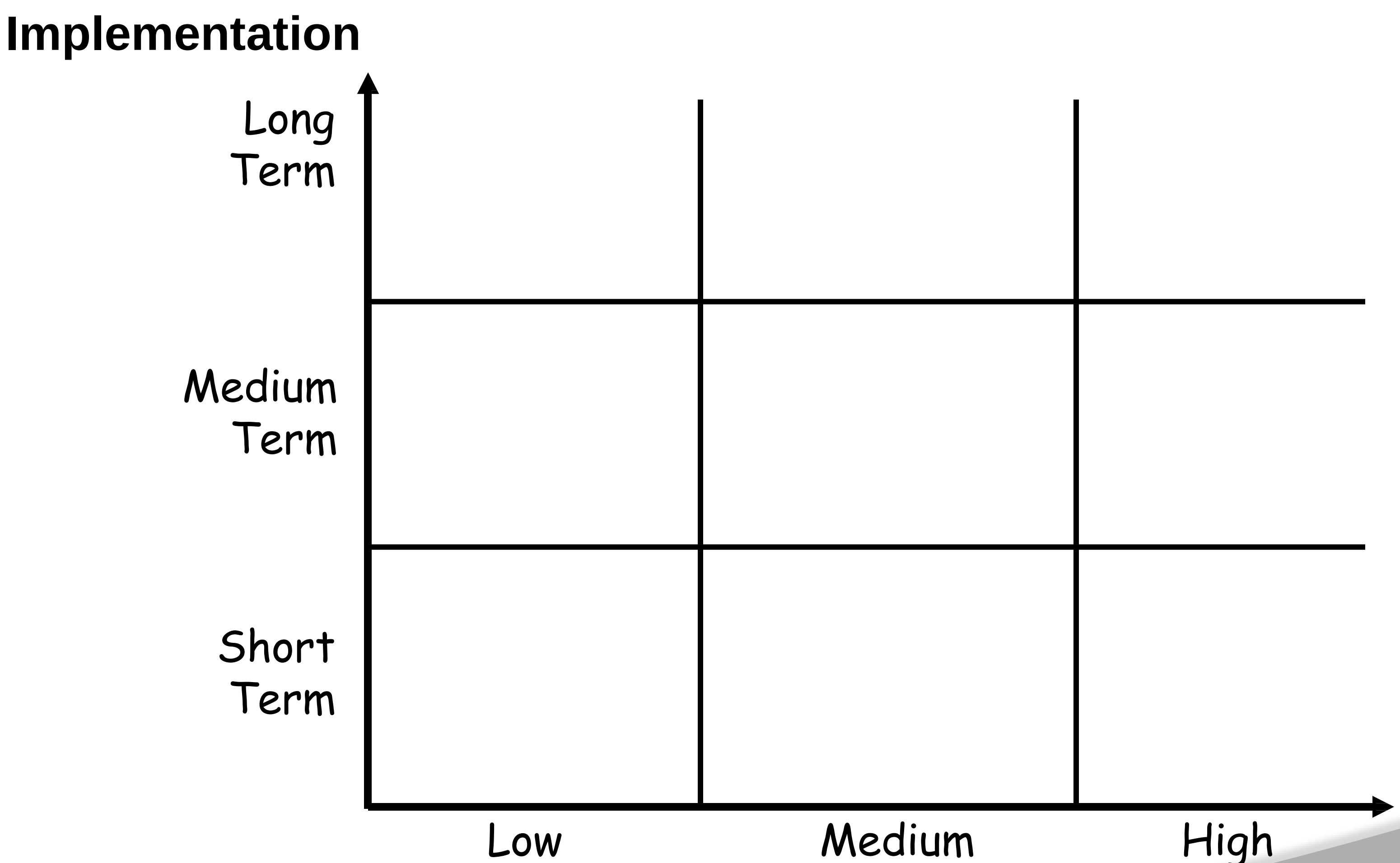
Creativity & Innovation



Cost of Assembly Vs Cost of Part Manufacture



Idea Classification



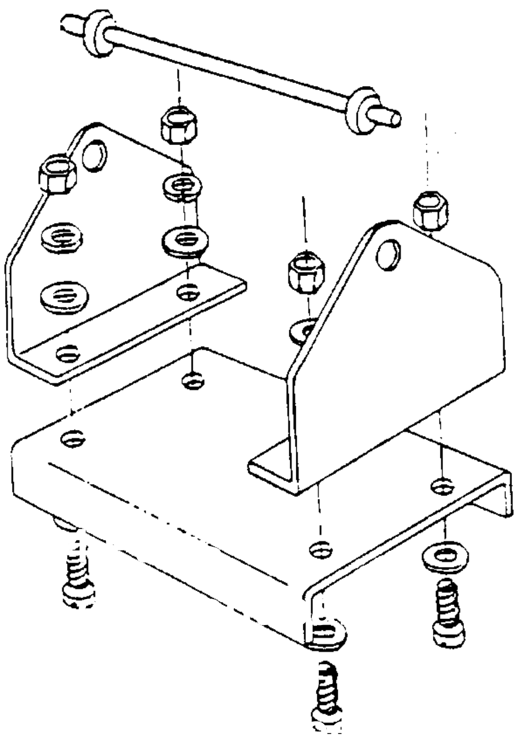
- Product Information: ***functional requirements***
- Functional analysis
- Identify parts that can be standardized
- Determine part count efficiencies
- Determine your **practical** part count

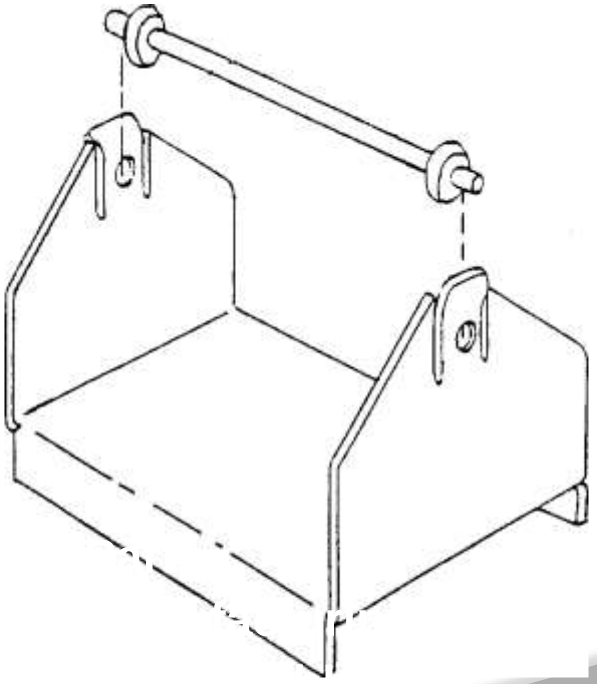
Fasteners

- A study by Ford Motor Co. revealed that threaded fasteners were the most common cause of warranty repairs
- This finding is echoed in more recent survey of automotive mechanics, in which 80% reported finding loose or incorrect fasteners in cars they serviced

Component Elimination Example: Rollbar Redesign

'..If more than 1/3 of the components in a product are fasteners, the assembly logic should be questioned.'





Fasteners: Cummins Engines

Engine type	Number of Components	Number of Fasteners	Percent Fasteners
B Series, 6 Cyl 5.9L	1086	436	40%
B Series, 4 Cyl 3.9L	718	331	46%
C Series, 8.3L	1111	486	44%

Standard Bolt Sizes

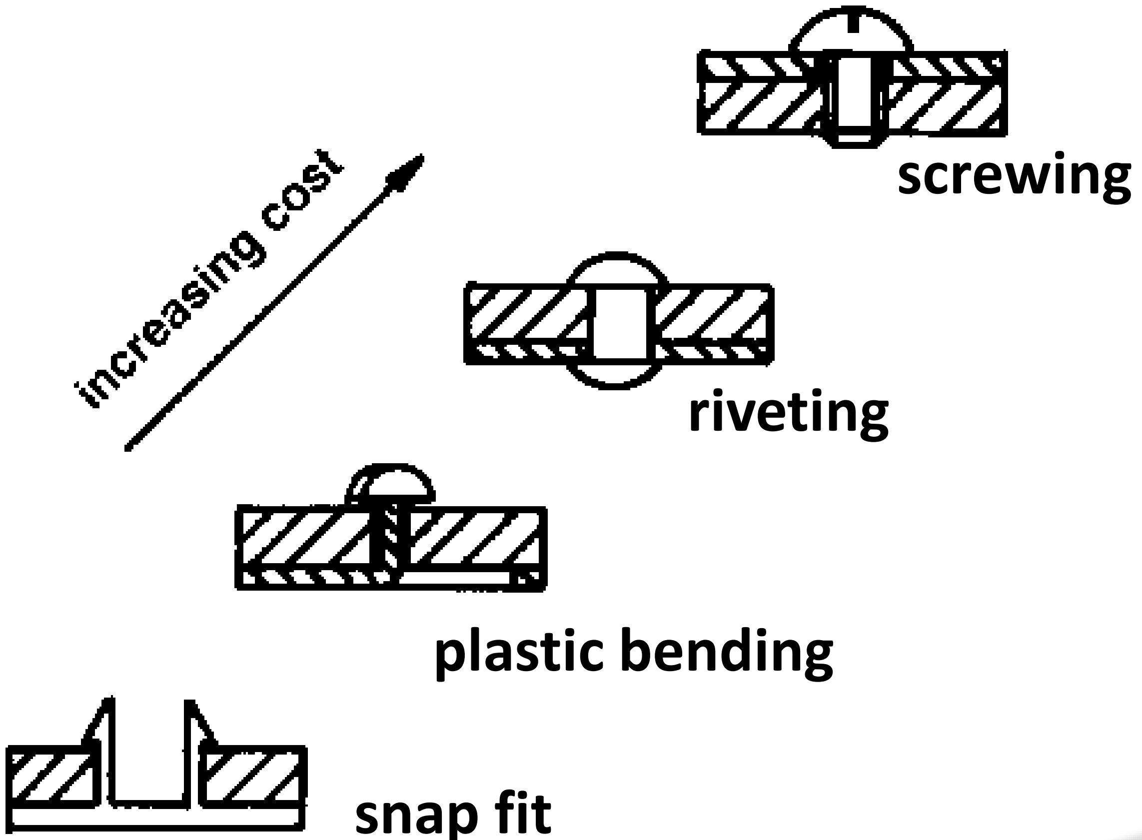
- Minimize extra sizes to both reduce inventory and eliminate confusion during assembly

Candidates for elimination

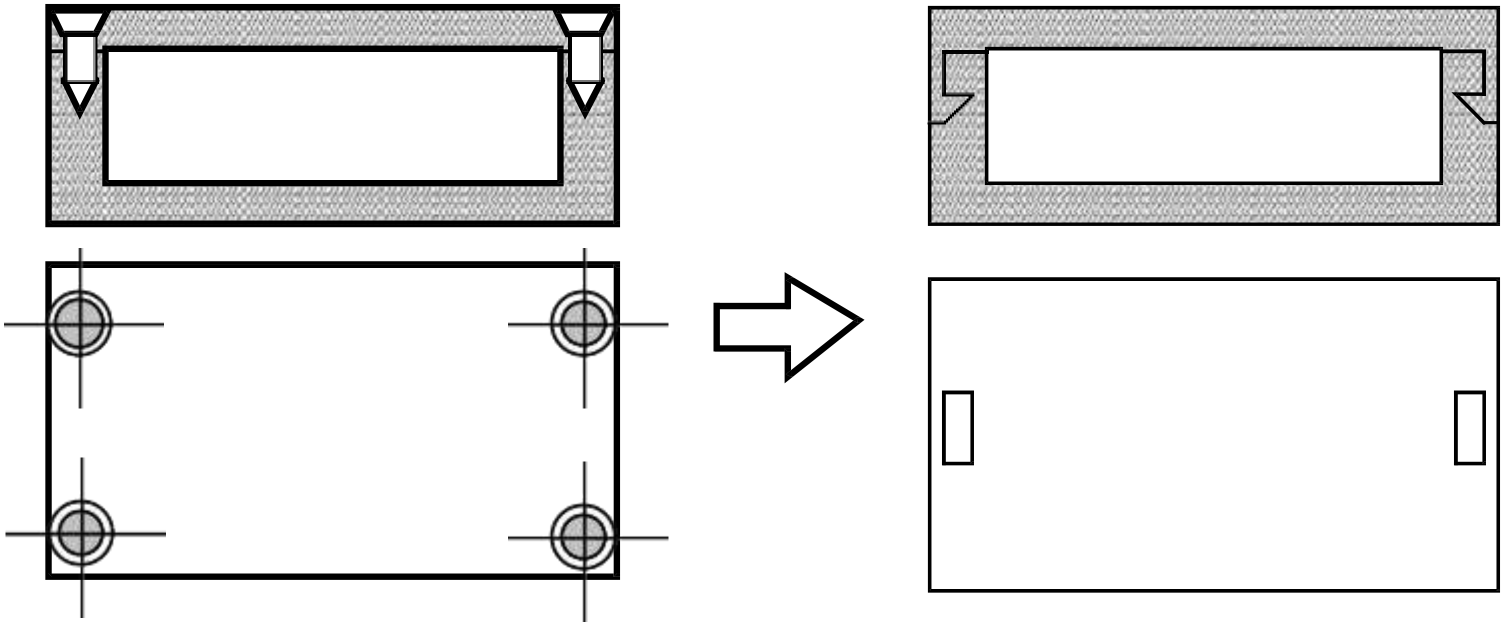
	M5 x .8	M6 x 1.0	M8 x 1.25	M10 x 1.5	M11 x 1.25	M12 x 1.25	M12 x 1.75	M14 x 1.5	M16 x 2.0	Qty Required
12mm										0
14mm	2									2
16mm		3								3
20mm			4	8	8					20
25mm				6	6					12
30mm			3	8						11
35mm			10	35						45
39.5mm			32	12	10	4				58
40mm				41	27		6			74
45mm			22	9					1	32
50mm		4	9	25	18	12				68
60mm			13	8			15			36
70mm					6					6
Required	2	7	93	152	75	16	21	0	1	367

Fastener Cost

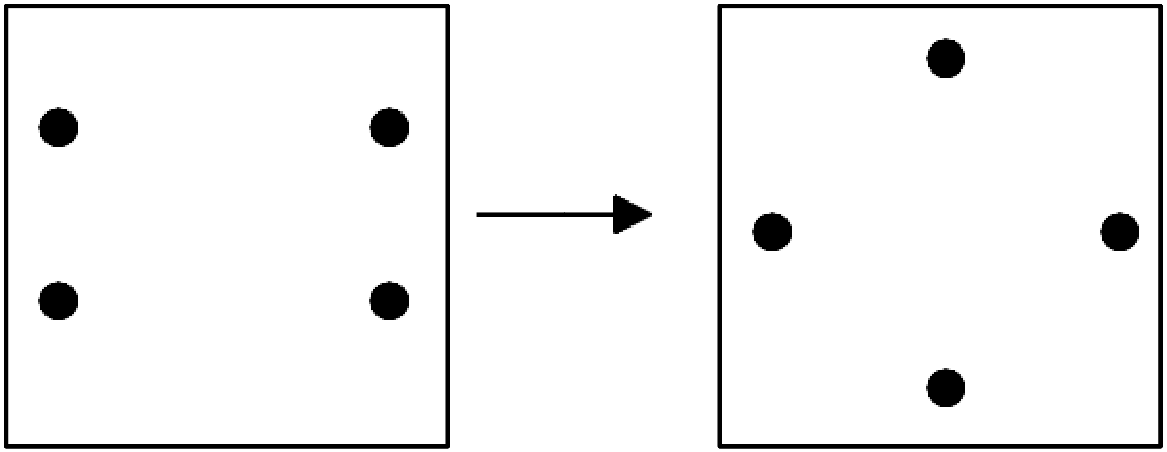
- Select the most inexpensive fastening method required



General Design Principles

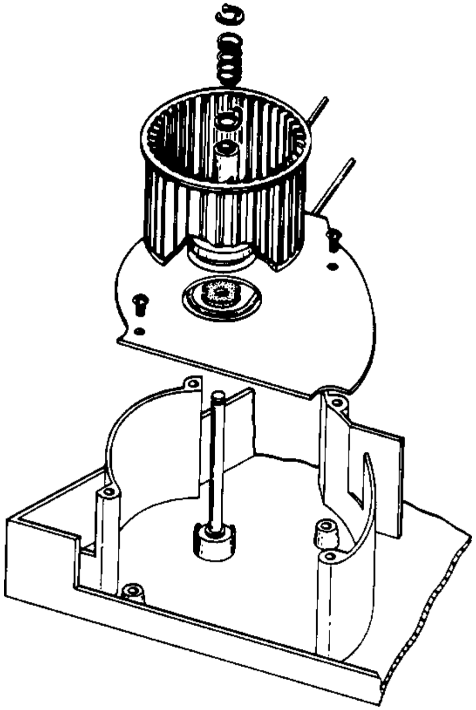


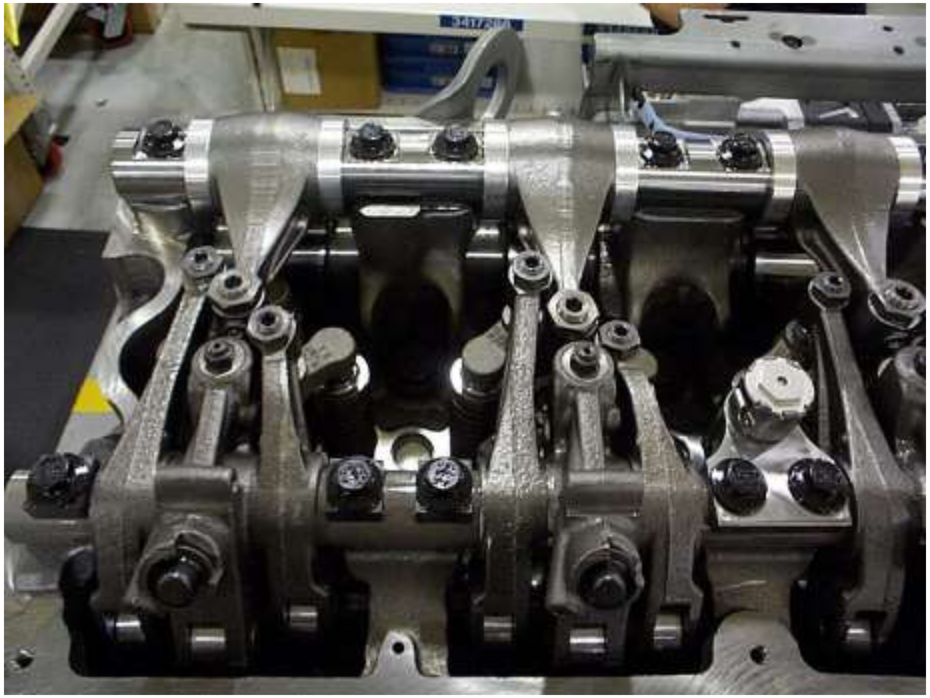
Symmetry eliminates reorientation



Symmetry of a part
makes assembly easier

Top-Down Assembly

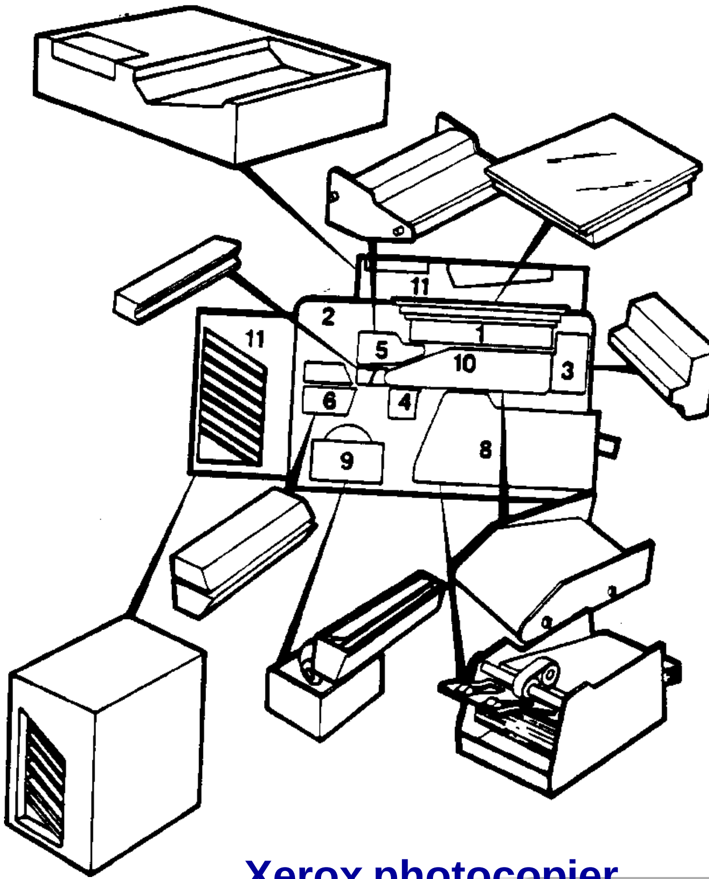




General Design Principles

Modular Assemblies

1. Imaging
2. Drives
3. Development
4. Transfer/Stripping
5. Cleaning
6. Fusing
7. Charge/Erase
8. Copy Handling
9. Electrical Distribution
10. Photoreceptor
11. Input/Output Devices



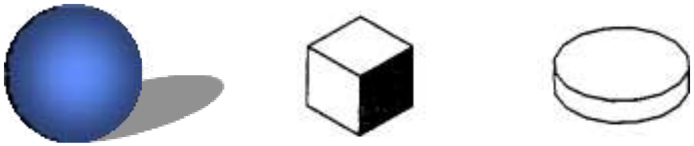
Xerox photocopier

Eliminated Parts are NEVER…

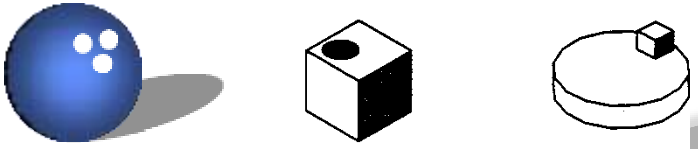
- Designed
- Detailed
- Prototyped
- Produced
- Scrapped
- Tested
- Re-engineered
- Purchased
- Progressed
- Received
- Inspected
- Rejected
- Stocked
- Outdated
- Written-off
- Unreliable
- Recycled
- late from the supplier!

Mistake Proofing Issues

- Cannot assemble wrong part
- Cannot omit part
- Cannot assemble part wrong way around.



symmetrical parts



asymmetrical parts

Quantitative criteria

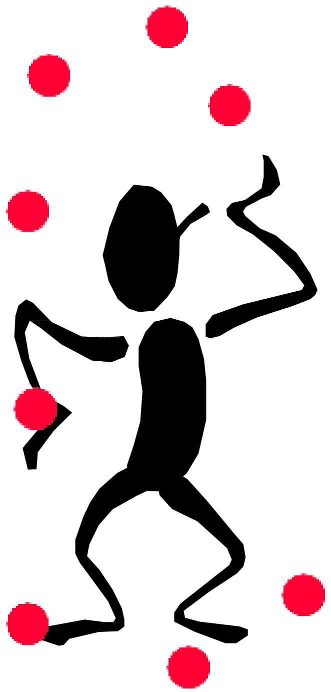
- **Handling Time:**

and complexity of parts

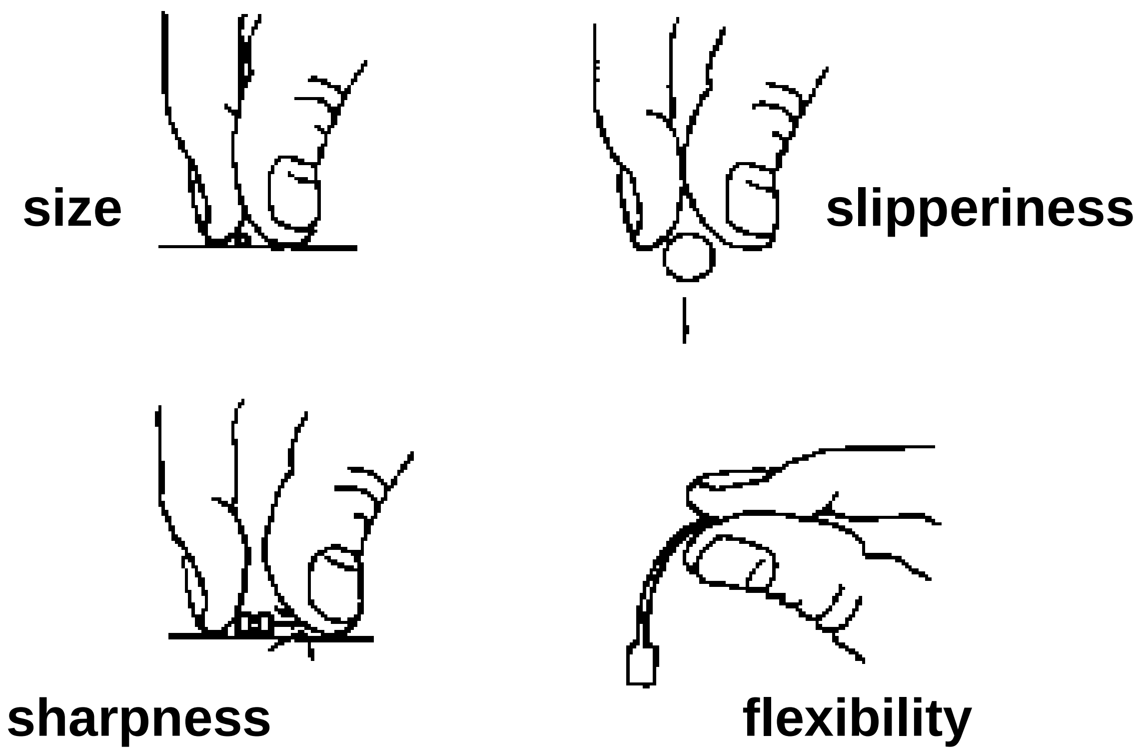
- How many hands are required?
- Is any grasping assistance needed?
- What is the effect of part symmetry on assembly?
- Is the part easy to align/position?

Handling Difficulty

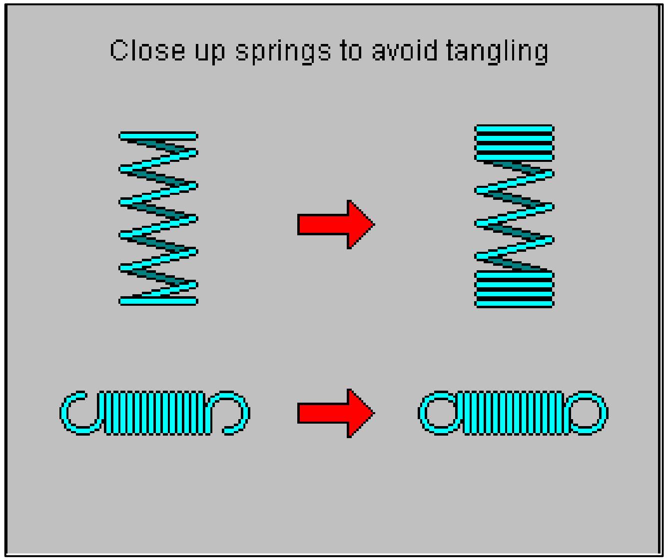
- Size
- Thickness
- Weight
- Fragility
- Flexibility
- Slipperiness
- Stickiness
- Necessity for using 1) two hands, 2) optical magnification, or 3) mechanical assistance

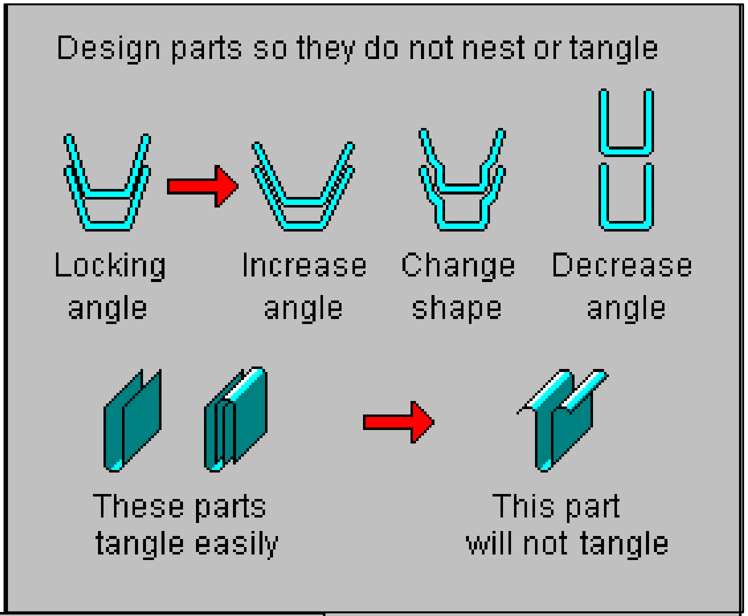


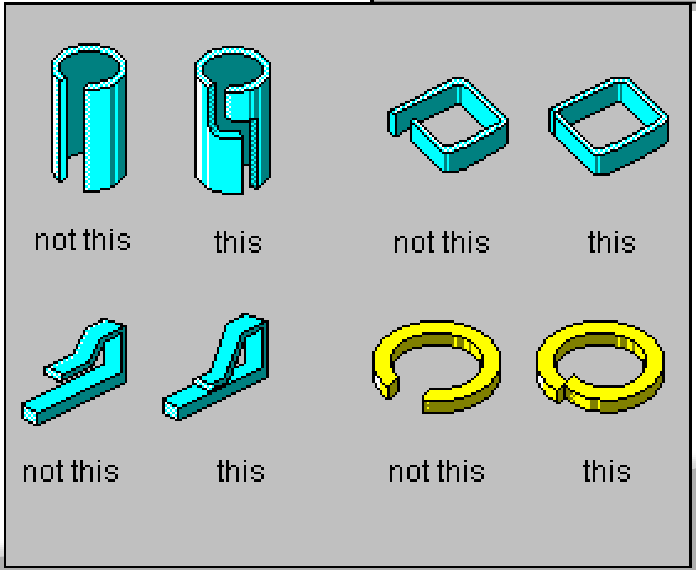
Handling Difficulty



Eliminate Tangling/Nesting







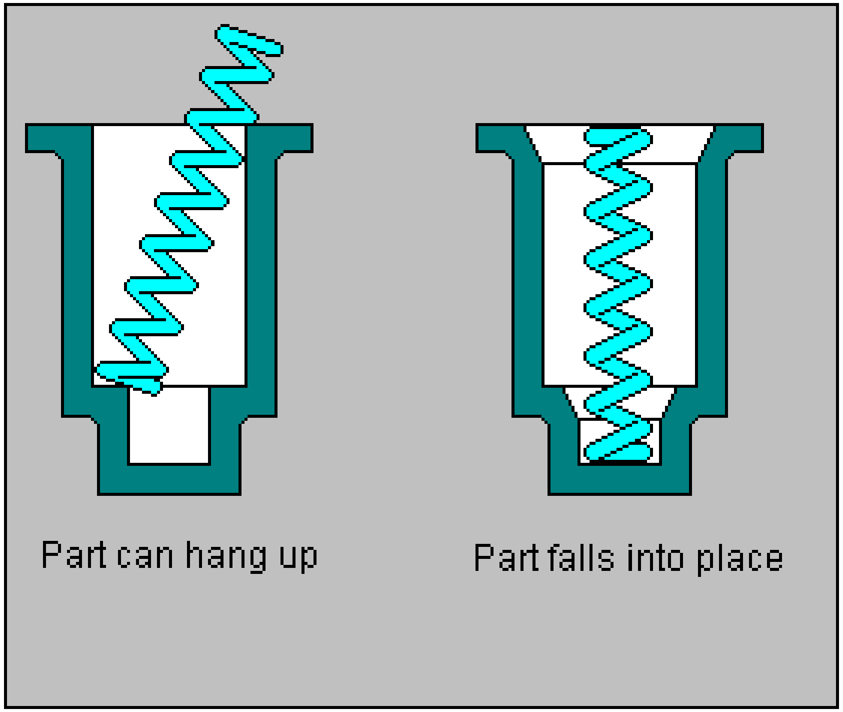
Quantitative criteria

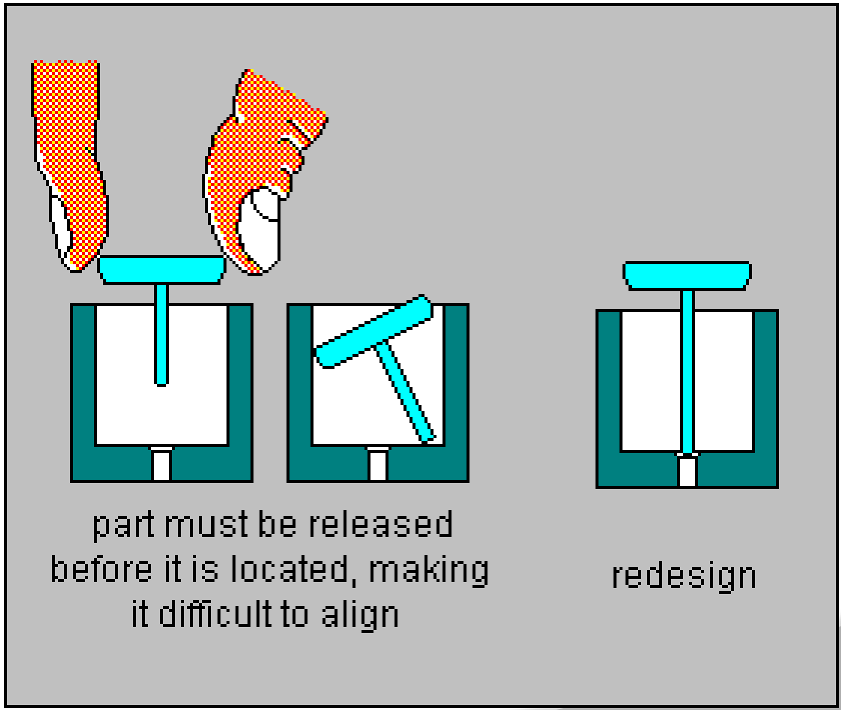
Insertion timeset on difficulty required

- for each component insertion
  - Is the part secured immediately upon insertion?
  - Is it necessary to hold down part to maintain location?
  - What type of fastening process is used? (mechanical, thermal, other?)
  - Is the part easy to align/position?

Insertion Issues

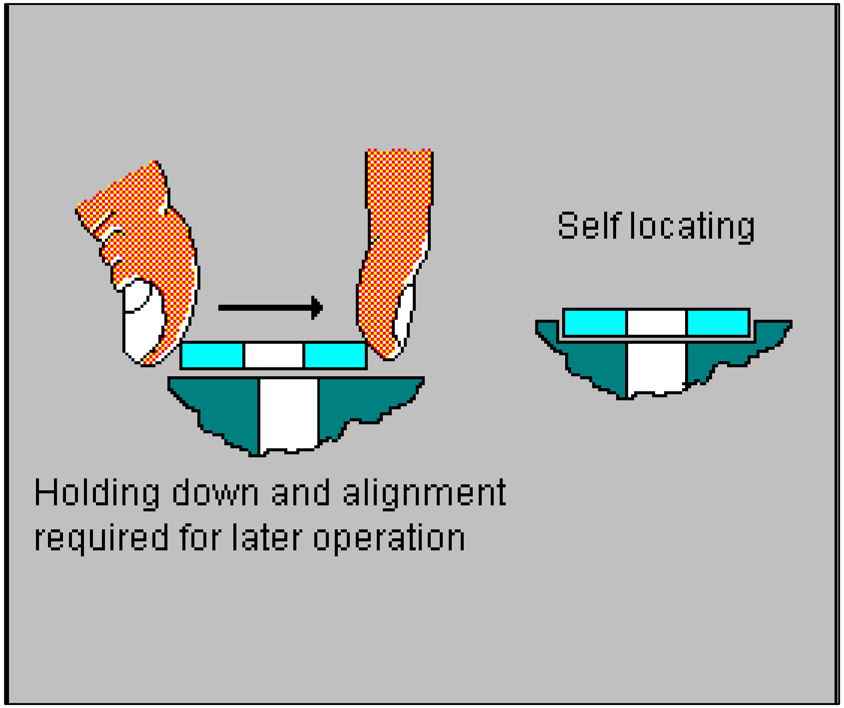
- Provide self-aligning & self locating parts

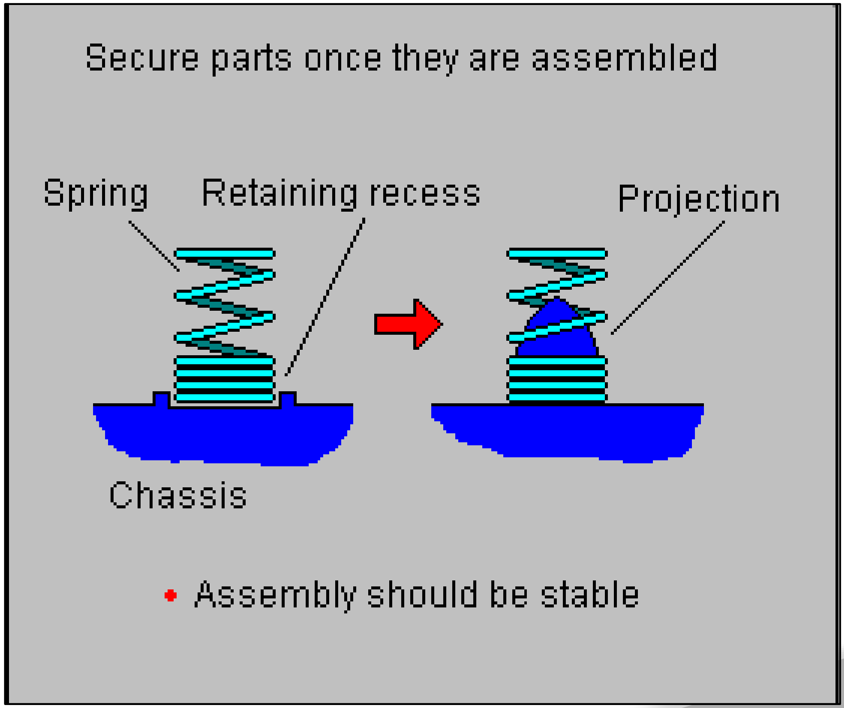




Insertion Issues

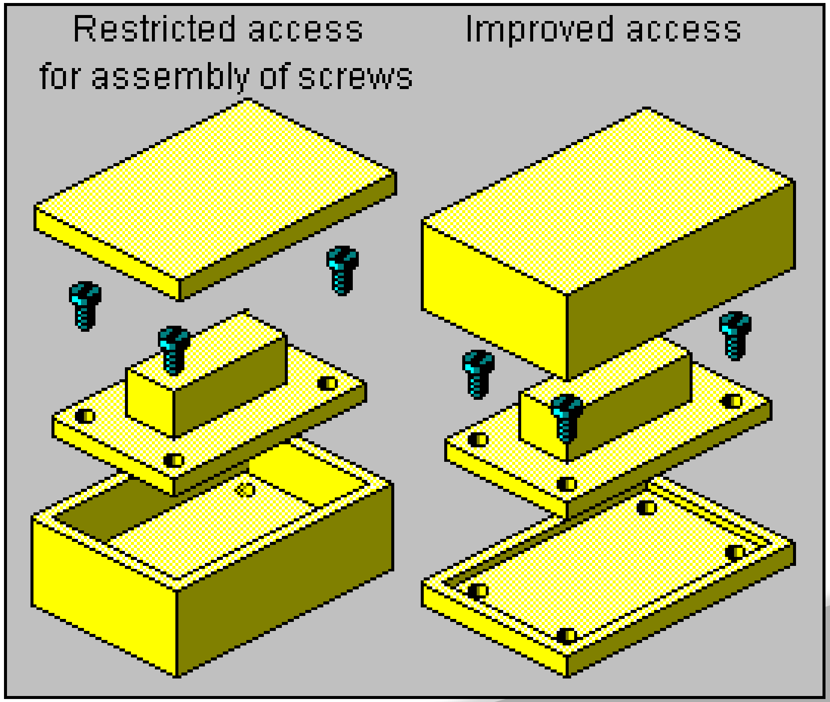
- Ensure parts do not need to be held in position





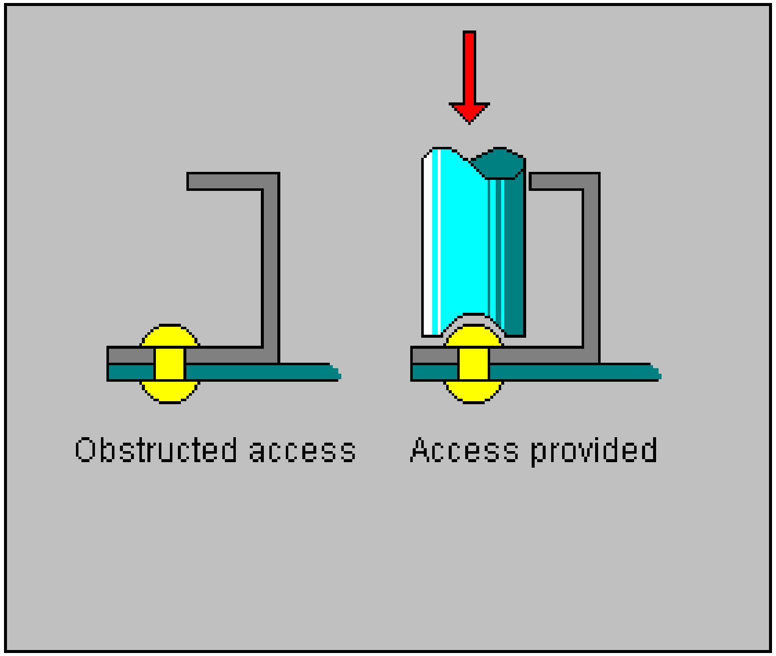
Insertion Issues

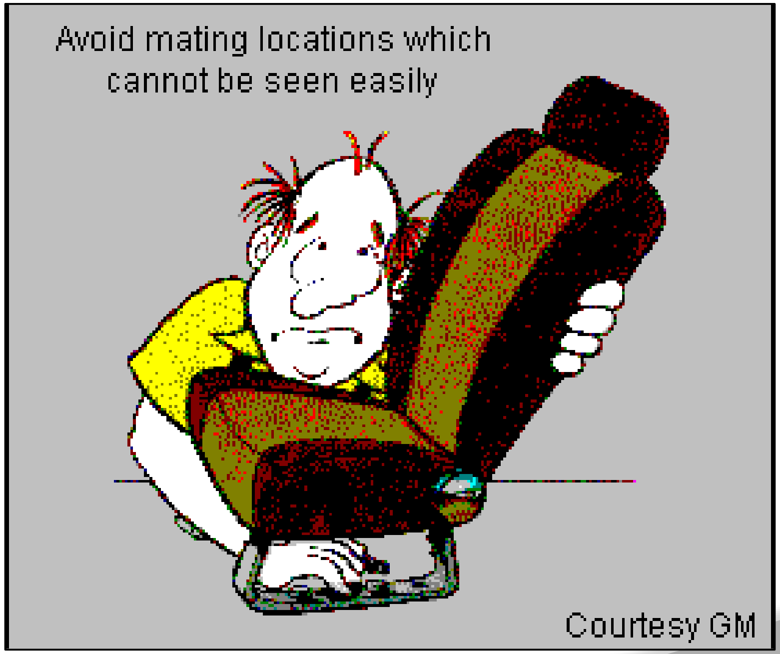
- Parts are easy to insert.
- Provide adequate access & visibility



Insertion Issues

- Provide adequate access and visibility





Eliminate Secondary Operations

- Re-orientation (assemble in Z axis)
- Screwing, drilling, twisting, riveting, bending, crimping.