Manufacturing Methods and Material Selection

ENM 214



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Mechanical Engineering Department

MAK 208

Introduction: Design Process

Product design – the process of defining all of the product characteristics

- Product design must support product manufacturability (the ease with which a product can be made)
- Product design defines a product's characteristics of:
  - appearance,
  - materials,
  - dimensions,
  - tolerances,
  - performance standards

Process Selection – the development of the process necessary to produce the designed product.

Manufacturing Process

What is Manufacturing Process?

A sequence of operations, often done on a machine or at a given area.

Examples: welding, casting, cutting, assembling, etc.

During a manufacturing process, we add, subtract, or form materials in order to give a desired property/shape to the workpiece. Therefore, different manufacturing processes, manufacturability of a material, processing tools, environmental aspects etc., have become important issues for manufacturing processes.

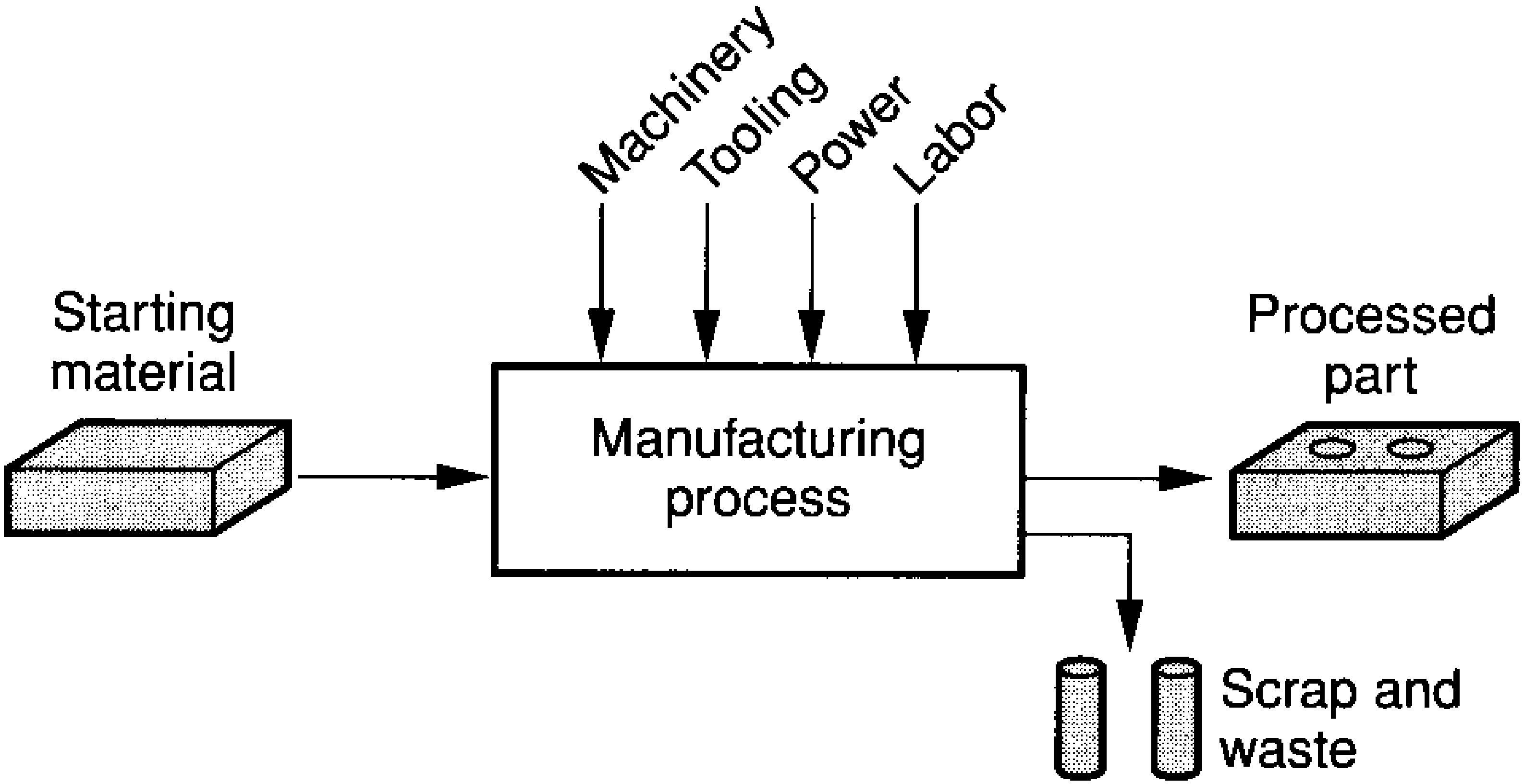
Manufacturing Process

- Literal: Manufacture = Manus (hand) + Factus (make) → Made by hand
- Technological: Application of physical and chemical processes to make parts or products, including assembly of products.
- Economical: Transformation of materials into items of greater value by means of processing and/or assembly operations.
- CIRP definition: Design + production + assembly

(CIRP = International Academy for Production Eng.)

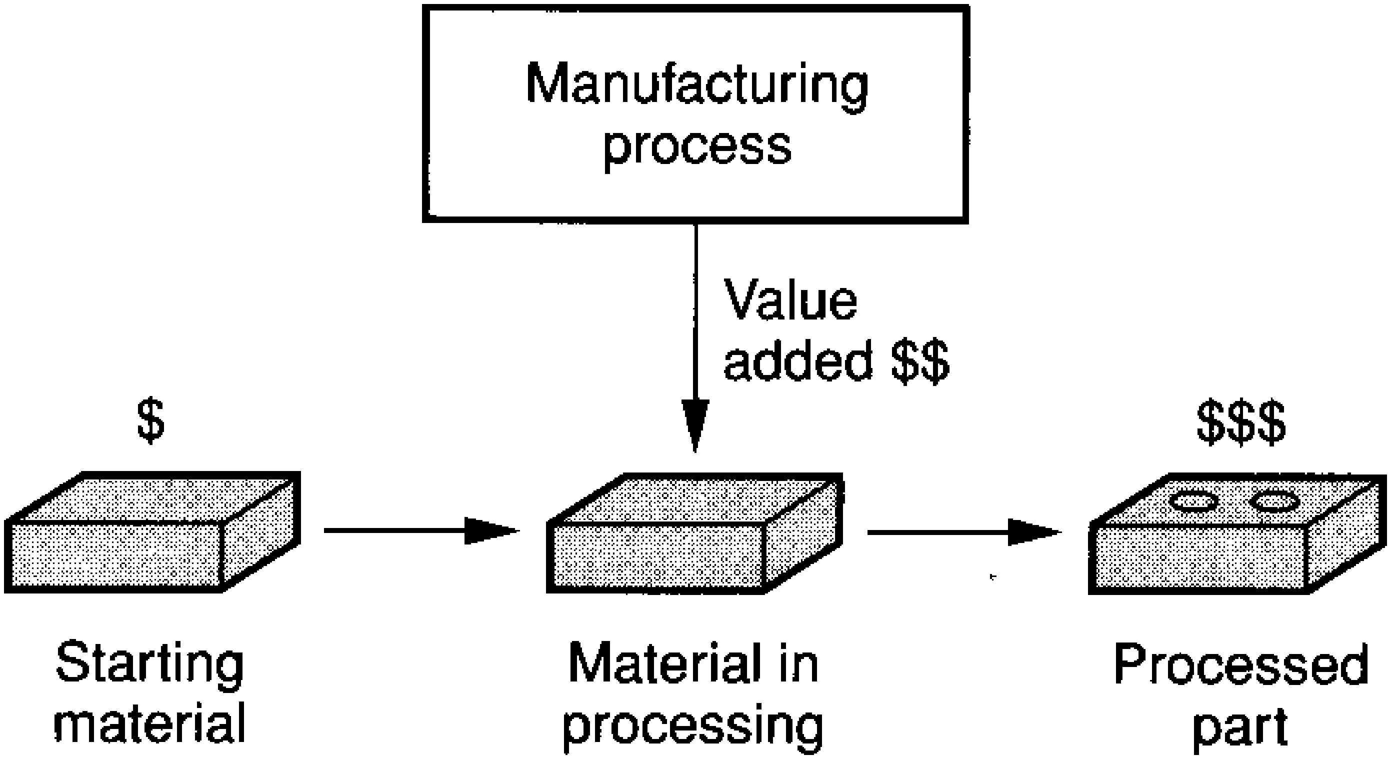
Manufacturing Process

‘*Manufacturing*’ in a technological way



Manufacturing Process

'*Manufacturing*' in a economical way



Manufacturing Process

Production Quantity (Q)

Number of units of a given part or product produced annually

Three quantity ranges:

1. Low production – 1 to 100 units
2. Medium production – 100 to 10,000 units
3. High production – 10,000 to millions of units

Product Variety (P)

Number of different product or part designs or types

- ‘Hard’ product variety – products differ greatly

  Few common components

- ‘Soft’ product variety – small differences between products

  Many common components

Manufacturing Process

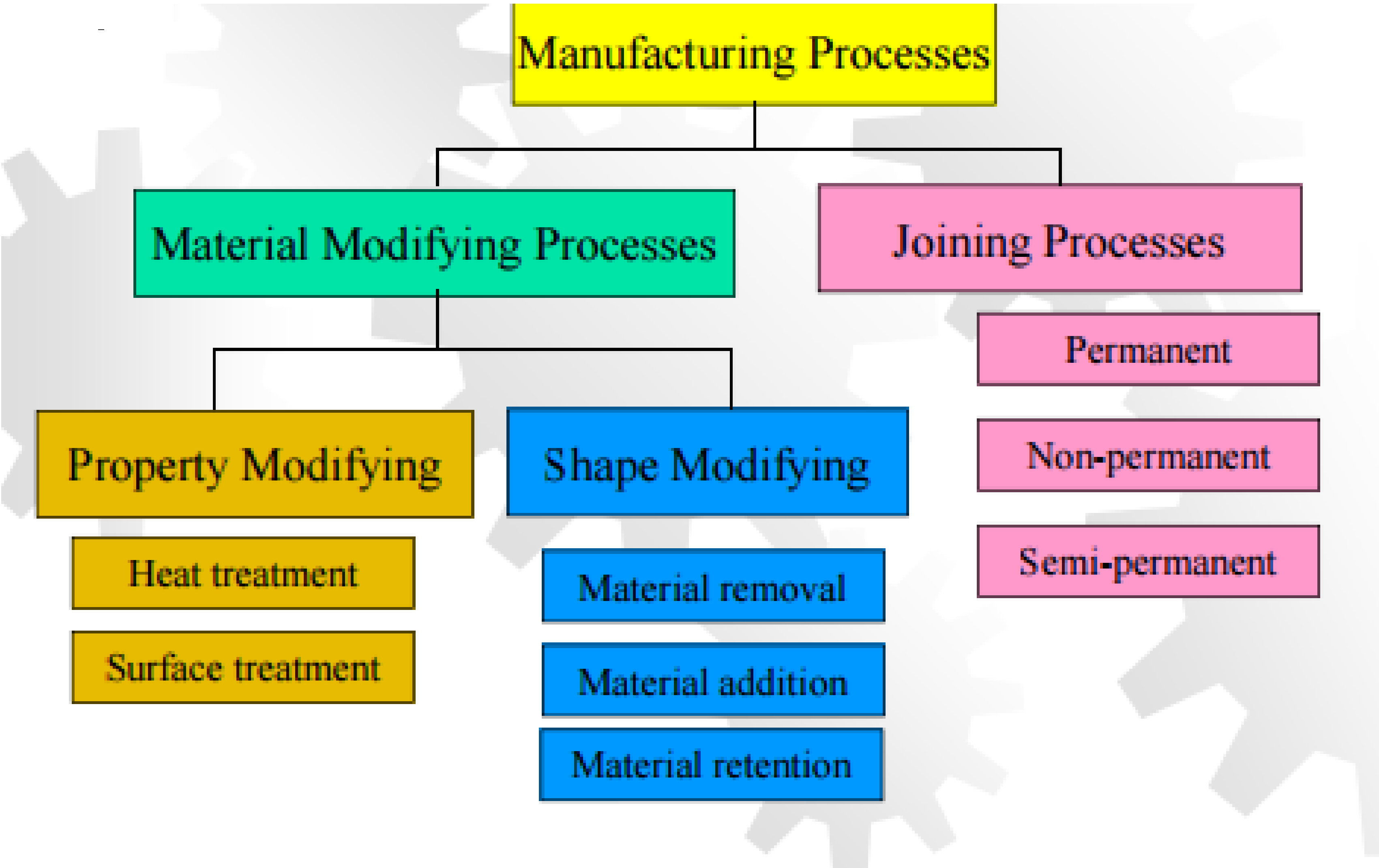
Manufacturing capability

- Technological Processing capability
  - Available processes and machines
  - Outsourcing of some operations (casting, heat treatment, etc.)

- Physical product limitations
  - Size, weight
  - Machine dimensions, handling

- Production capacity (Plant capacity)
  - Production quantity in a given time, output

Manufacturing Process



Manufacturing Process

Materials in Manufacturing

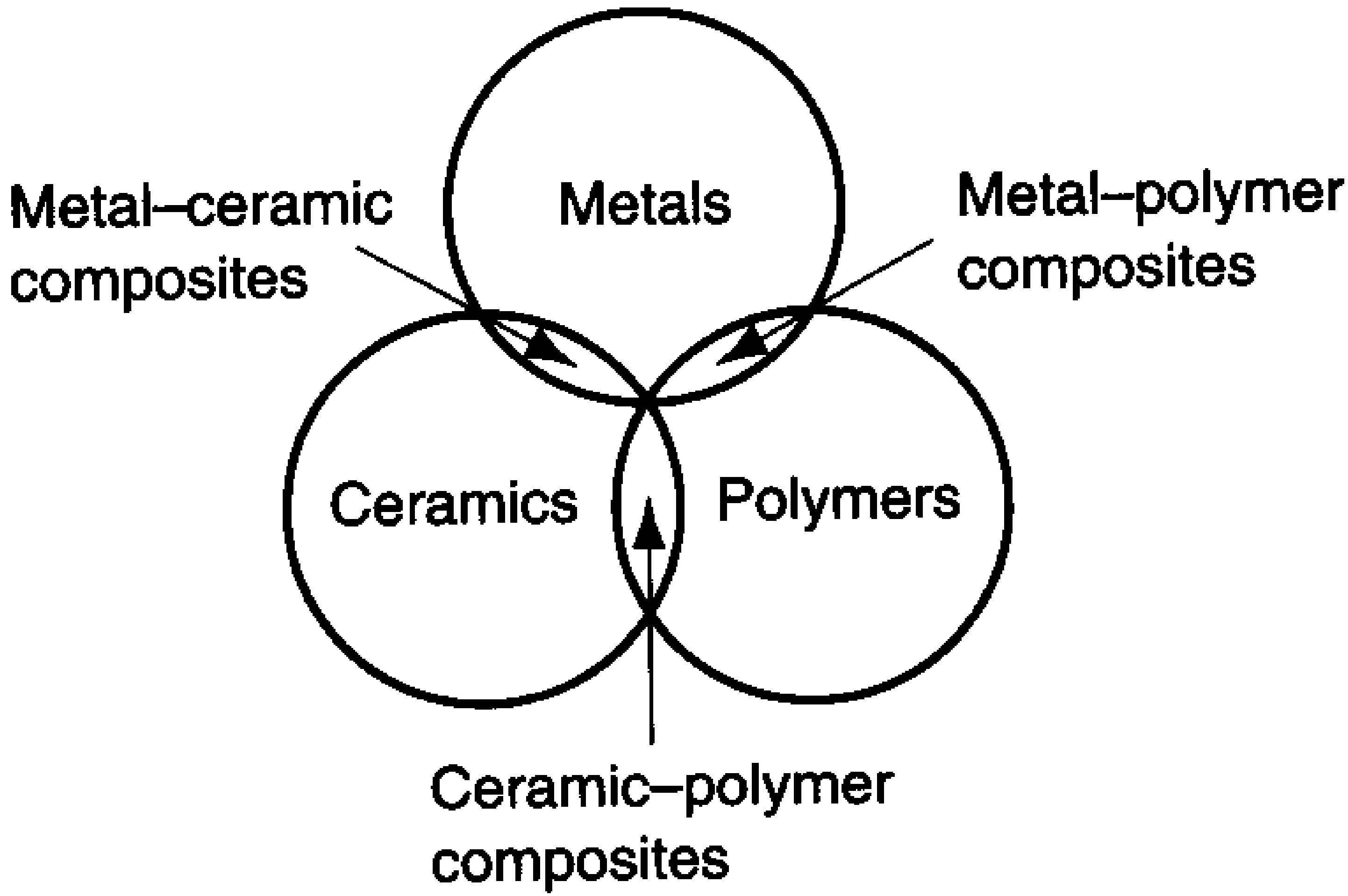
- Metals
  - Ferrous: Steel (iron-carbon, 0,02% - 2,11% C)
    Cast iron (iron + 2% - 4% C + silicon)
  - Nonferrous: copper, aluminium, nickel, alloys

- Ceramics: clay, silica, carbides (Al, Si), nitrides (Ti)

- Polymers
  - Thermoplastic polymers: PE, PP, PS, PVC
  - Thermosetting polymers: phenolics, epoxies
  - Elastomers: rubber, neoprene, silicone, PU
- Composites: more phases, particles/fibres + matrix
  glass reinforced plastic, Kevlar, WC in cobalt

Manufacturing Process

Materials in Manufacturing



Manufacturing Process

Processing Operations

Shaping operations

- Solidification processes → casting of metals, moulding of plastics
- Particulate processing → powder metallurgy
- Deformation processes → forging, extrusion
- Material removal processes → machining, non-traditional, grinding

Property enhancing processes

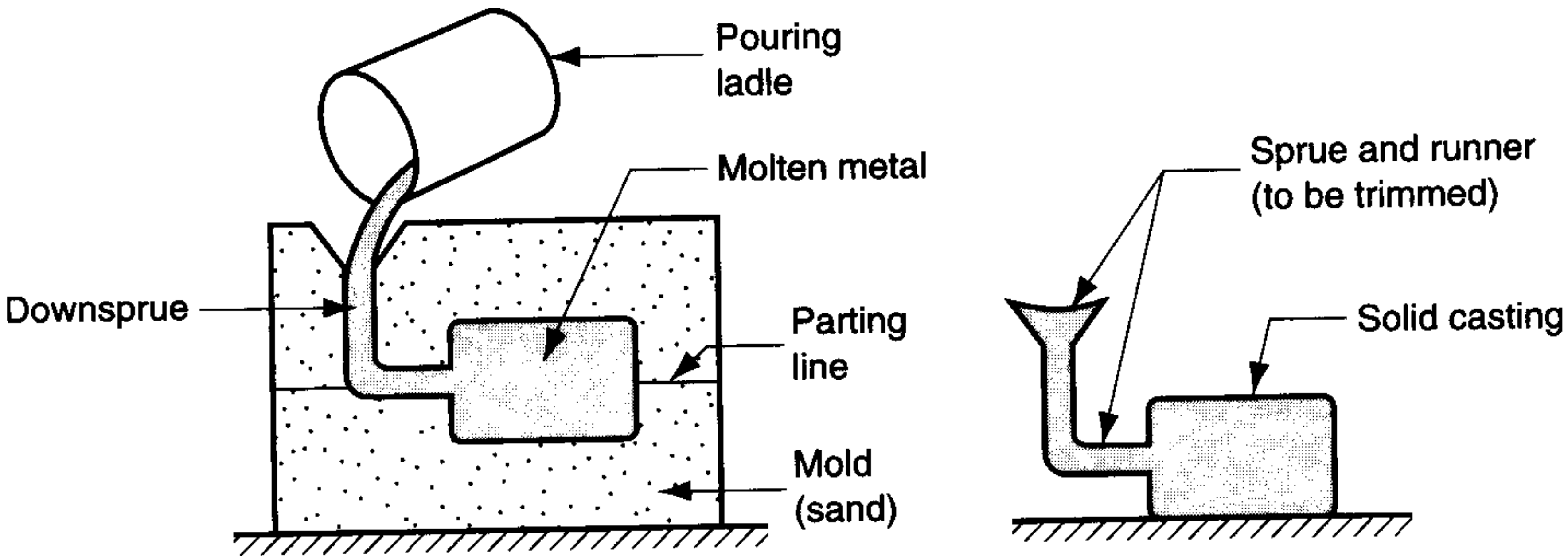
- Heat treatments, sintering

Surface processing

- Cleaning, coating, plating, deposion

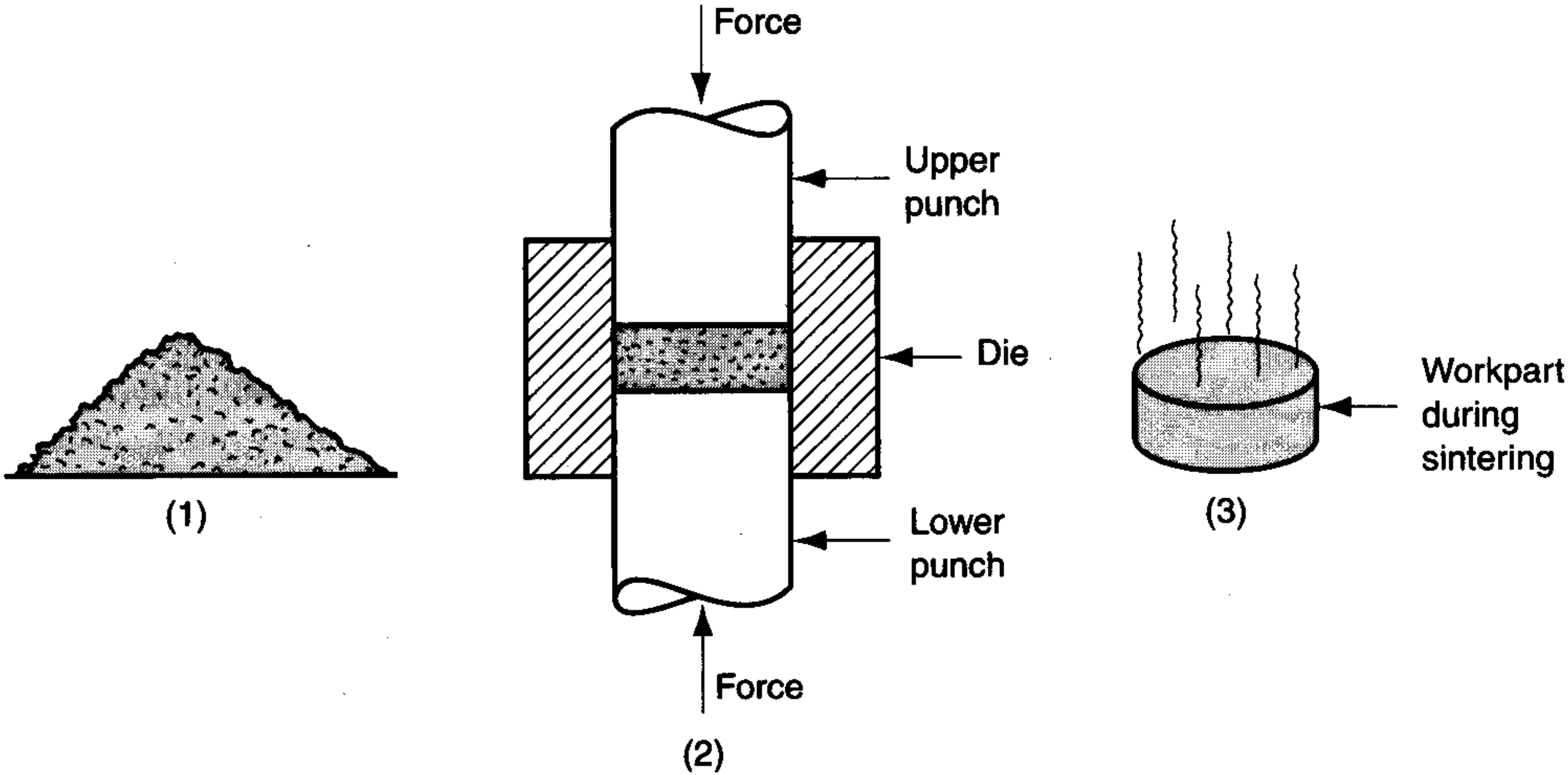
Manufacturing Process

Shaping Operations



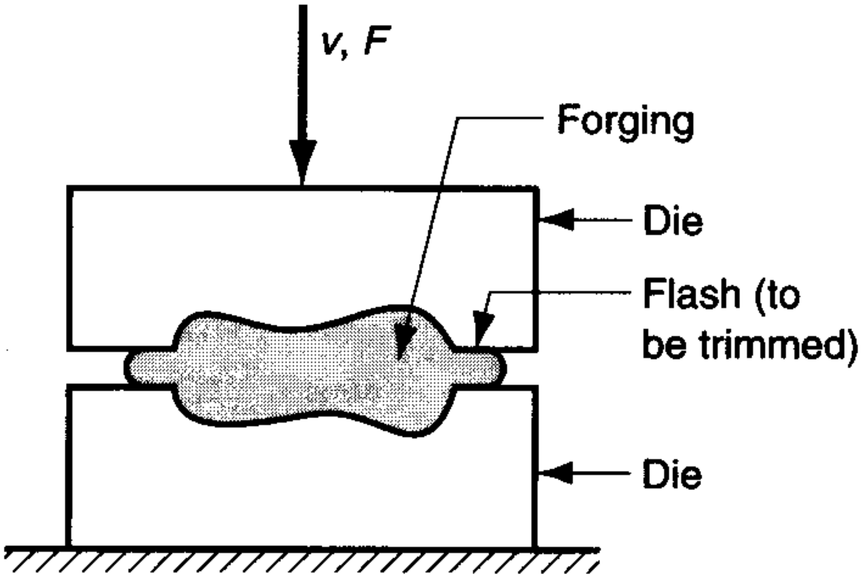
Manufacturing Process

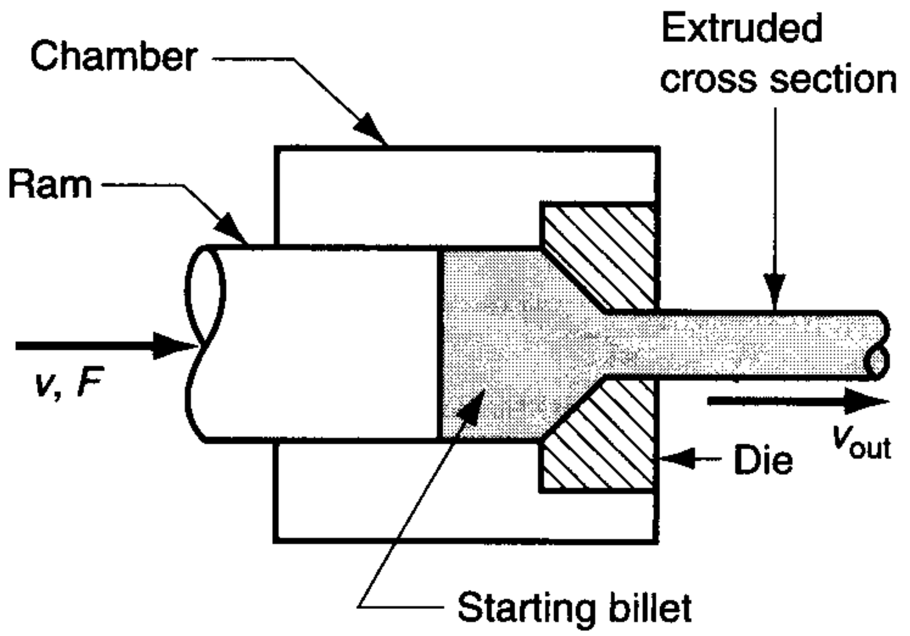
Shaping Operations



Manufacturing Process

Shaping Operations

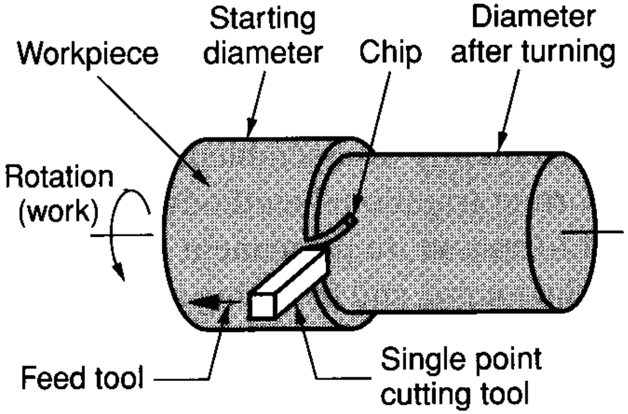




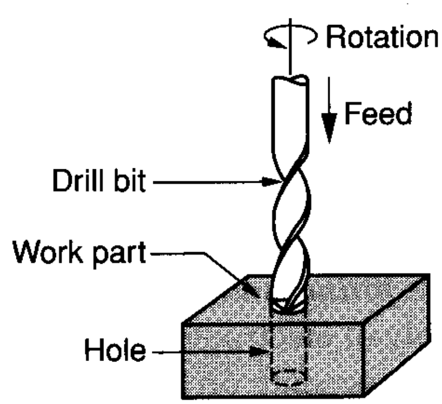
Manufacturing Process

Shaping Operations

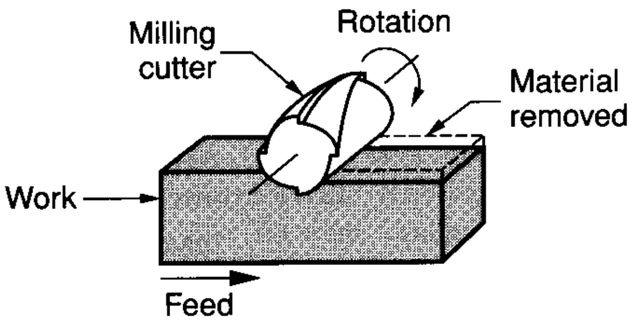
- General aim: Minimize waste and scrap!!!
- Net shape processes → no subsequent machining



Turning



Drilling



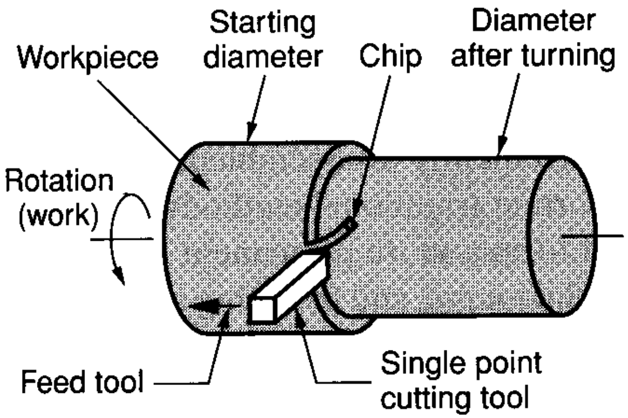
Milling

Manufacturing Process

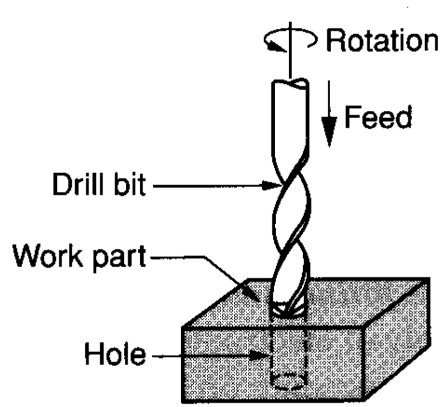
Shaping Operations

General aim: Minimize waste and scrap!!!

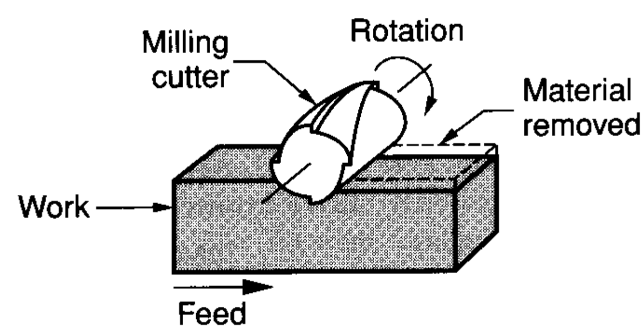
- Net shape processes → no subsequent machining
- Near net shape processes → minimum machining



Turning



Drilling



Milling

Manufacturing Process

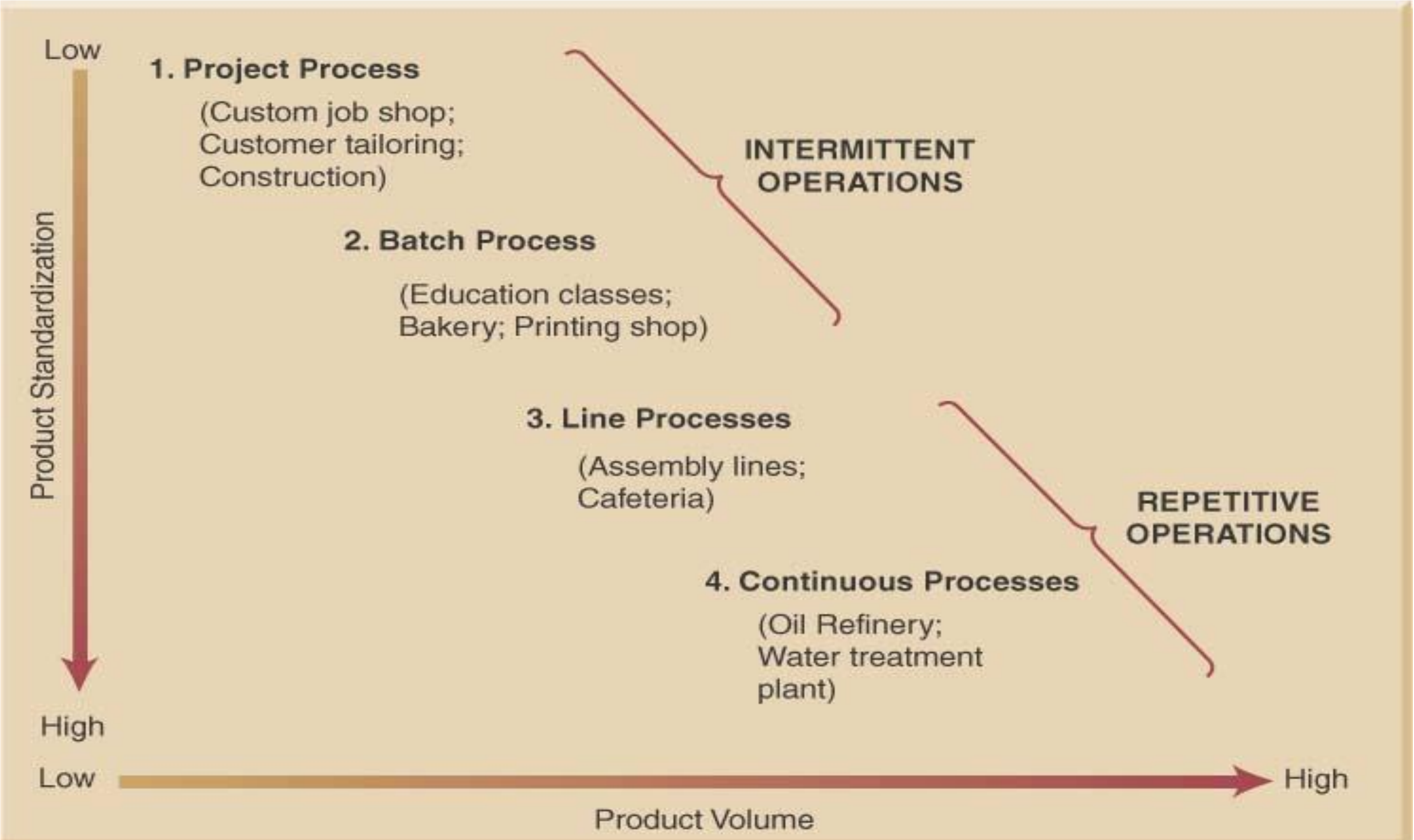
1) Processing operations

2) Assembly operations
   - Permanent joining: welding, brazing, adhesives
   - Mechanical assembly: bolts, screws, rivets, etc.

3) Production machines and tooling
   - Machine tools: lathe, milling machine, etc.
   - Presses, forge hamers, rolling mills
   - Welding machines and equipment
   - General and special purpose equipment
   - Tooling

Manufacturing Process

The same product can be processed differently



Production System

Key Success Factors

- Low cost production efficiency
- Quality of process
- Skilled labour
- Low cost location
- Flexibility

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Production System

Manufacturing Shop Layout

The efficiency of a manufacturing facility depends on a number of factors, including the layout of machinery and departments.

Typical plant layout procedures determine how to arrange the various machines and departments to achieve minimization of overall production time, maximization of turnover of work-in-process, and maximization of factory output

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Production System

Types of arrangement of the facilities

1. Static or fixed position layout

2. Process based layout

3. Cell or group layout

4. Product based layout

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Production System

Static or fixed position layout

Process are brought to the product -not the product to the process

Product that has constraining characteristics such as being very large, heavy or has some other constraint that prevents its location from being altered while under manufacturing

Production equipment and personnel are transported to the product and generally involves low volume products with small lot sizes.

Example: Airplane manufacturing, shipyards, railway systems

Production System

Static or fixed position layout

Production System

Process based layout

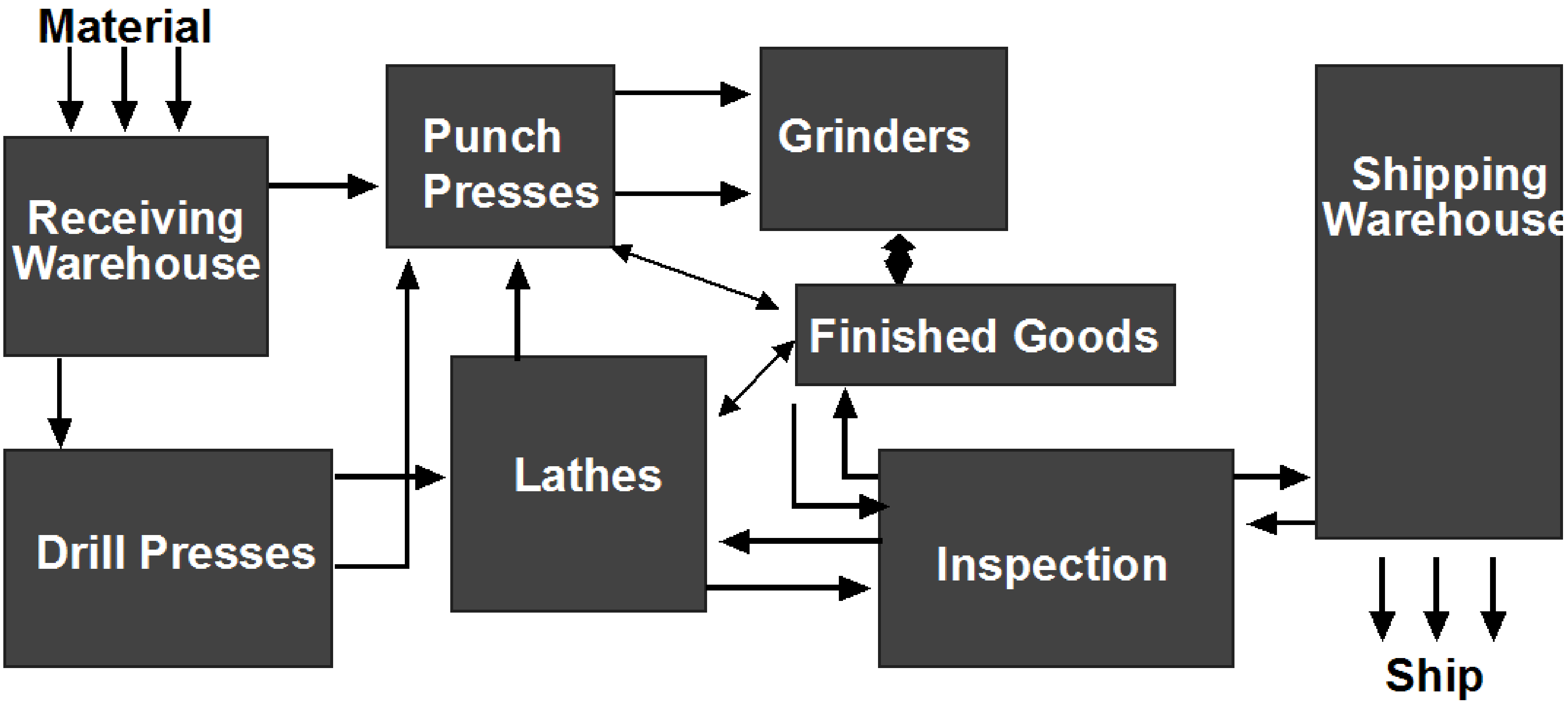
The process based layout is used in manufacturing are arranged according to the particular process type.

All machines are grouped according to their function (process) such as lathes, mills, injection moulding, drilling etc.

Machines with similar functions are grouped together. This type of layout is used from job shopping or batch production companies such as different types of car production and even in service industries.

Production System

Process based layout

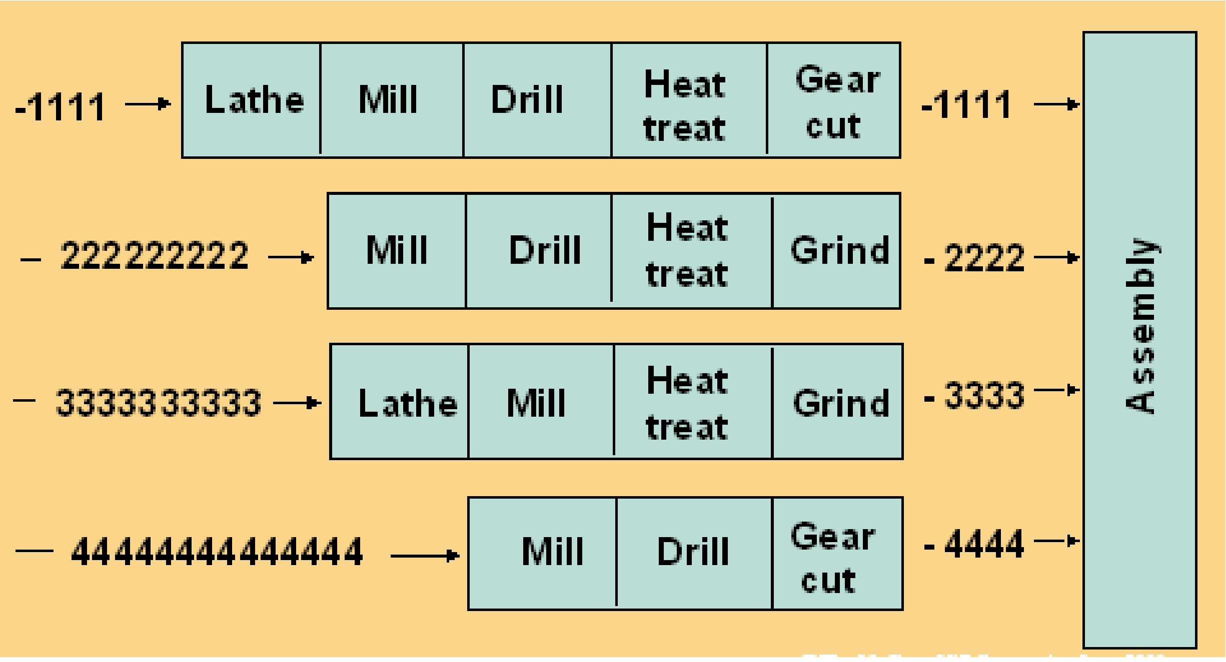


Production System

Cell or group layout

The shop arrangement is based on product type. Such arrangement reduces the part travelling time and easy to supervise

Beneficial for volume high and the number of production type less

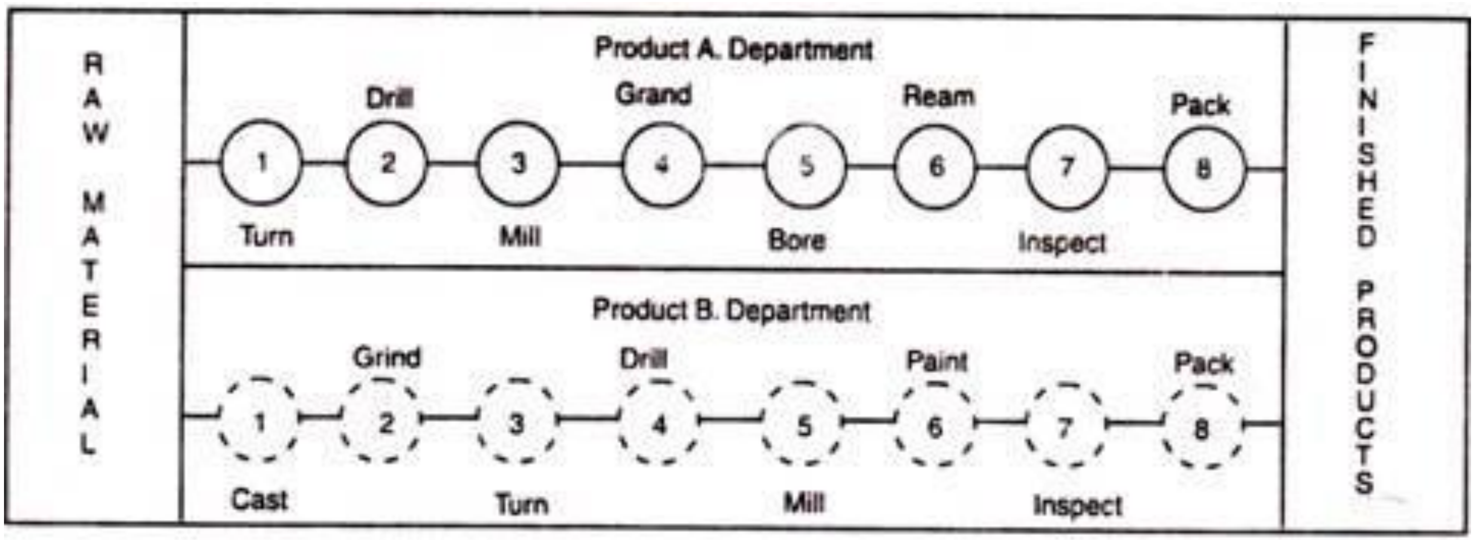


Production System

Product based layout

The layout conforms to the sequence of operations required to produce a product.

An example is automobile assembly, where almost all variants of the same model require the same sequence of process



Production System

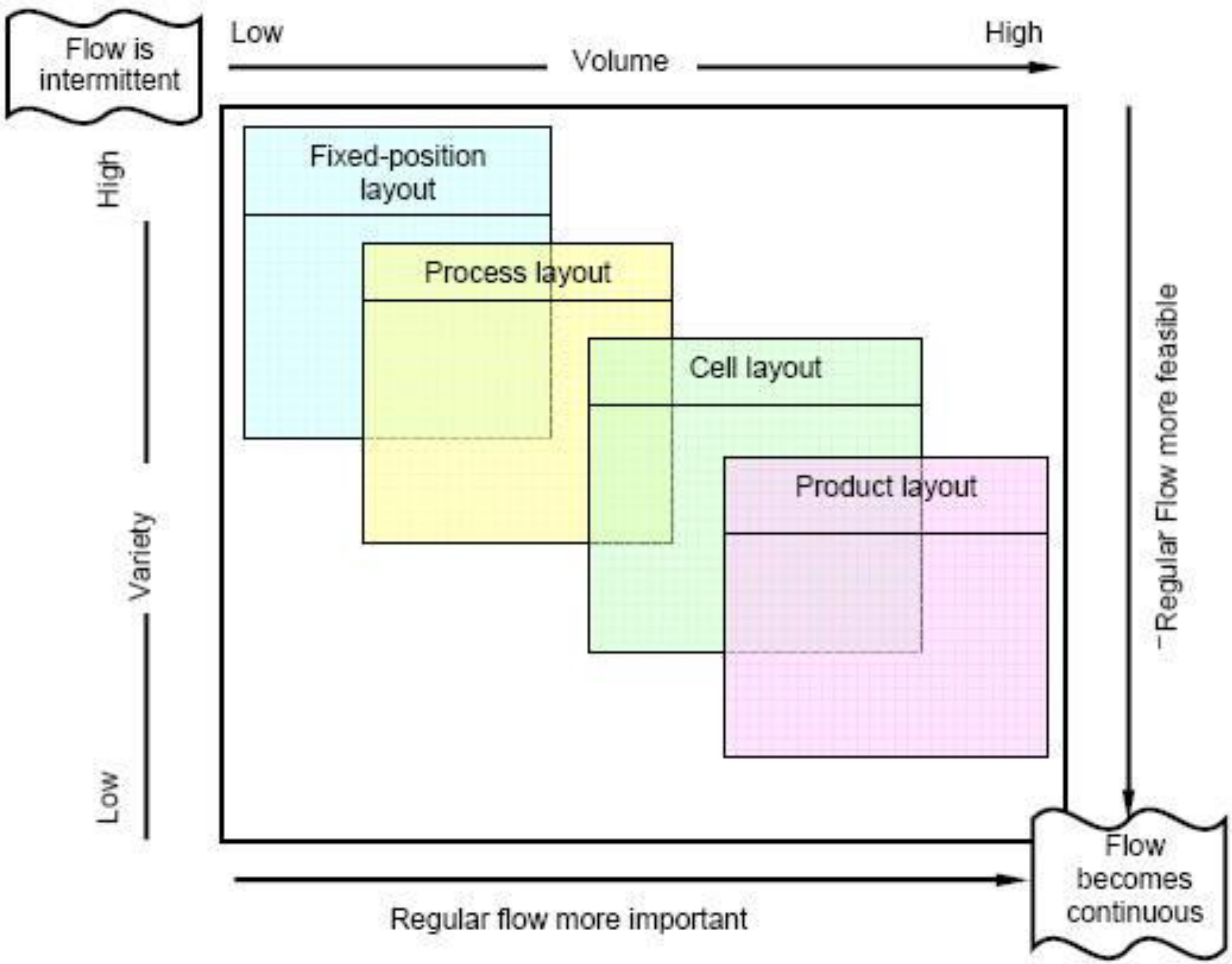
Comparison Chart

2) Advantages and disadvantages

	Fixed	Process	Cell	Product
Advantages	- Very high mix and product flexibility - Product/customer not moved or disturbed. - High variety of tasks for staff	- High mix and product flexibility - Relatively robust if in the case of disruptions - Easy supervision of equipment of plant	- Good compromise between cost and flexibility - Fast throughput. - Group work can result in good motivation	Lo- w unit costs for high volume - Gives Opportunities for specialization of equipment - Gives Opportunities for specialization of equipment
Disadvantages	- Very high unit cos - Scheduling space and activities can be difficult.	Low utilization of resources. Can have very high WIP Complex flow.	Can be costly to rearrange existing layout Can need more plan and equipment	Can have low mix and flexibility Not very robust to disruption Work can be very repetitive.

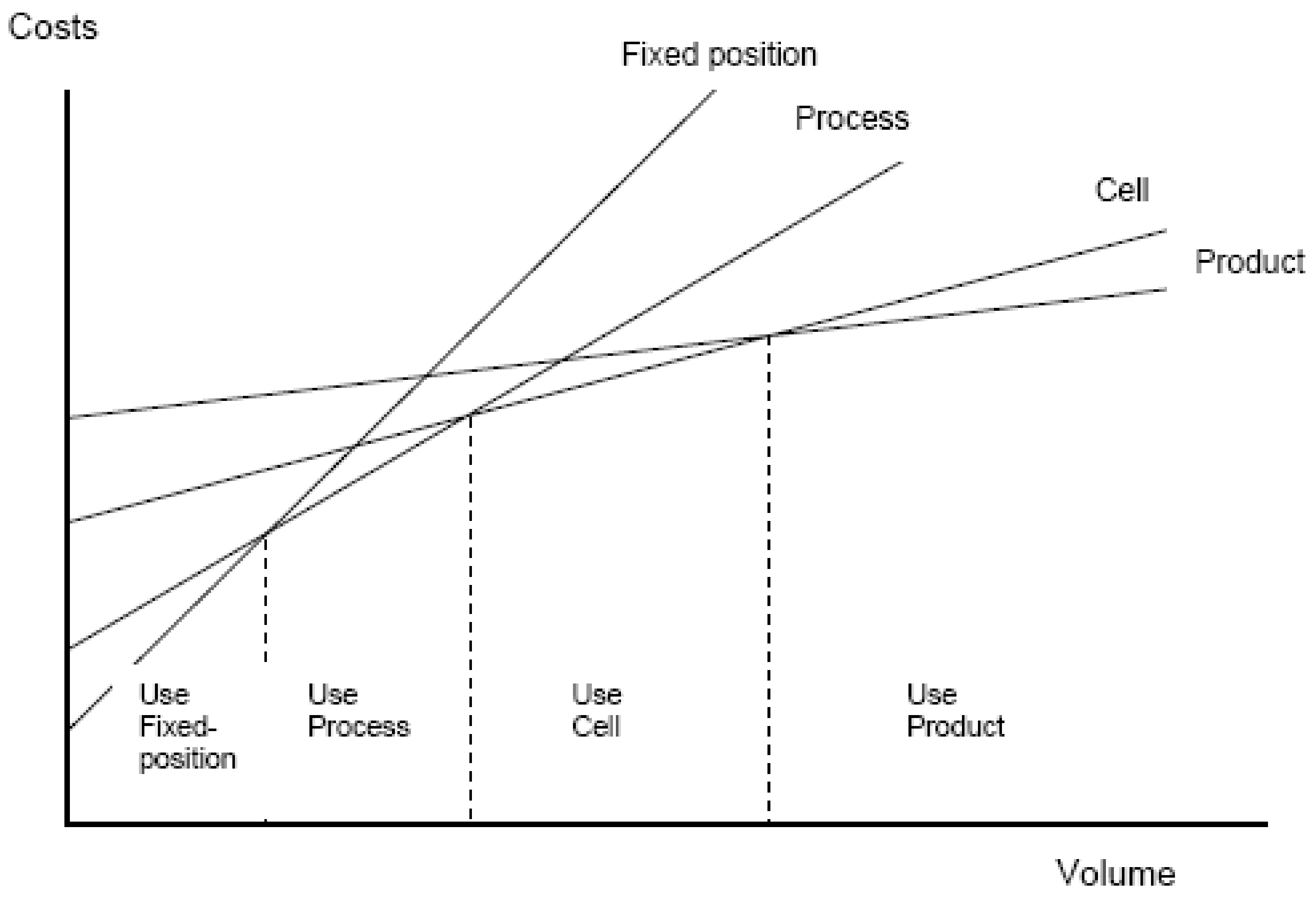
Production System

Layout Type Selection by production volume



Production System

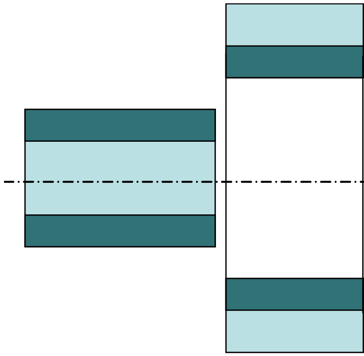
Layout Type Selection by cost



Fit Description

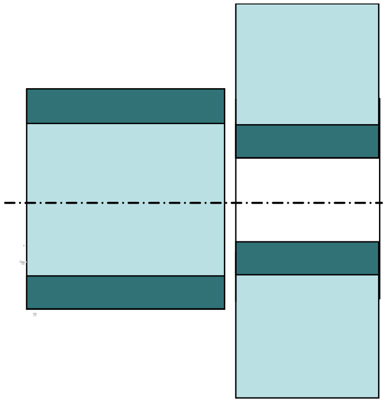
When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a **fit**.

Three fit types



- Clearance Fit

  Maximum shaft dimension < Minimum hole dimension

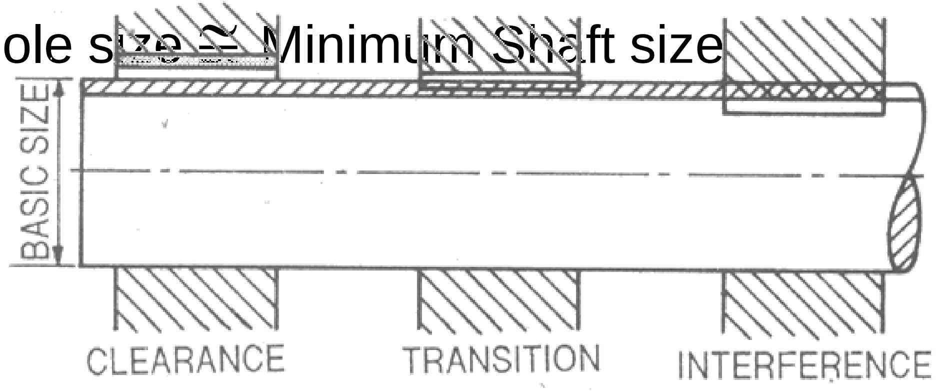


- Interference Fit

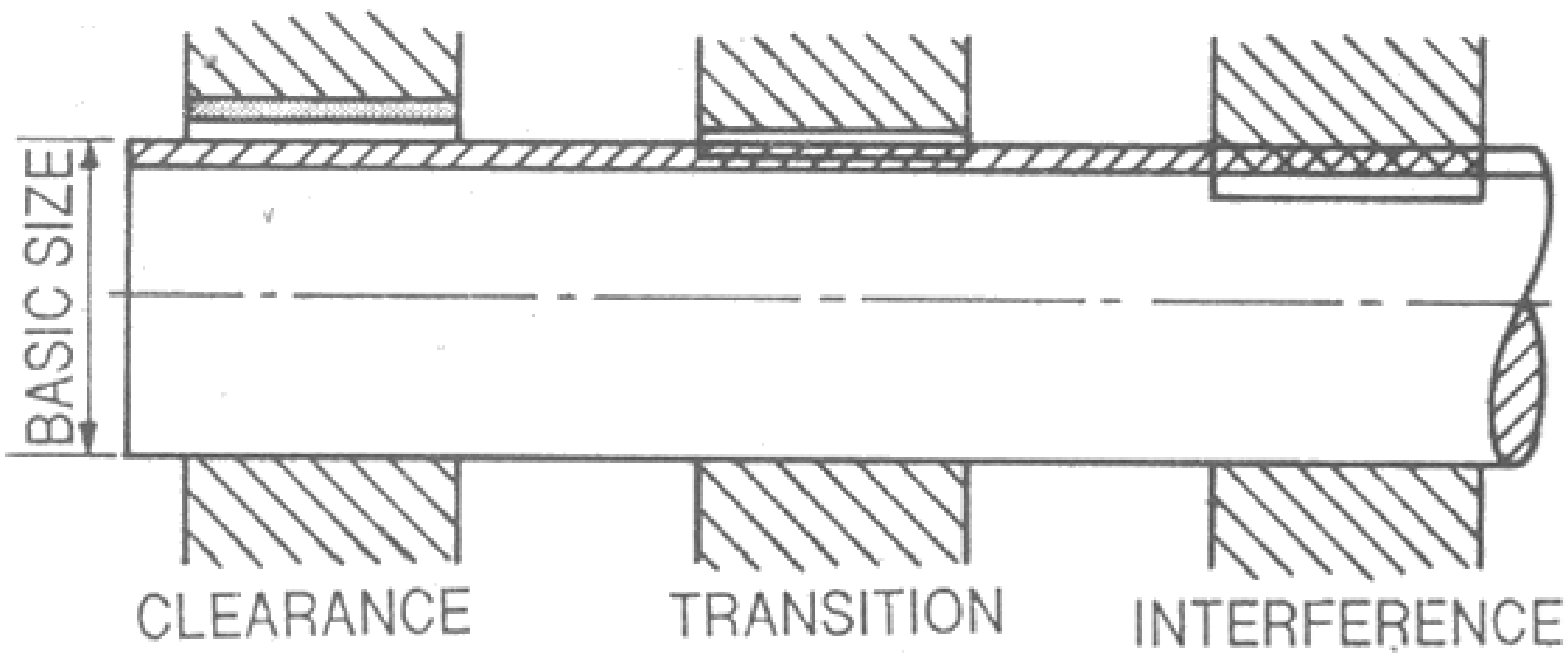
  Maximum Hole size < Minimum Shaft size

- Transition Fit

  Maximum Hole size ≅ Minimum Shaft size



Fit

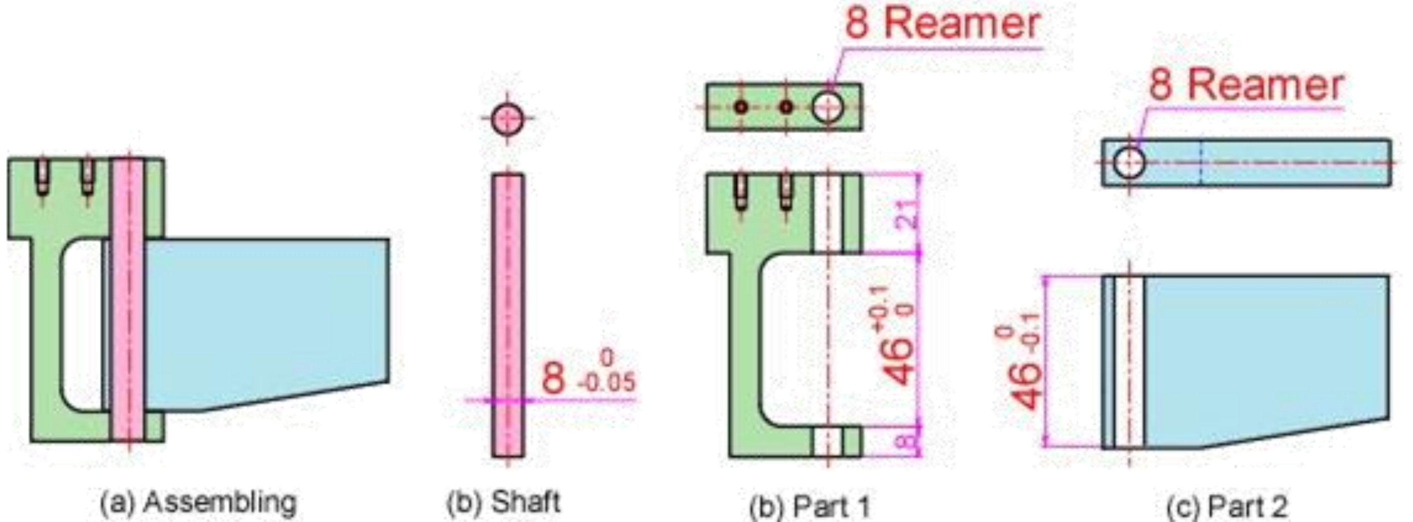


Tolerances Description

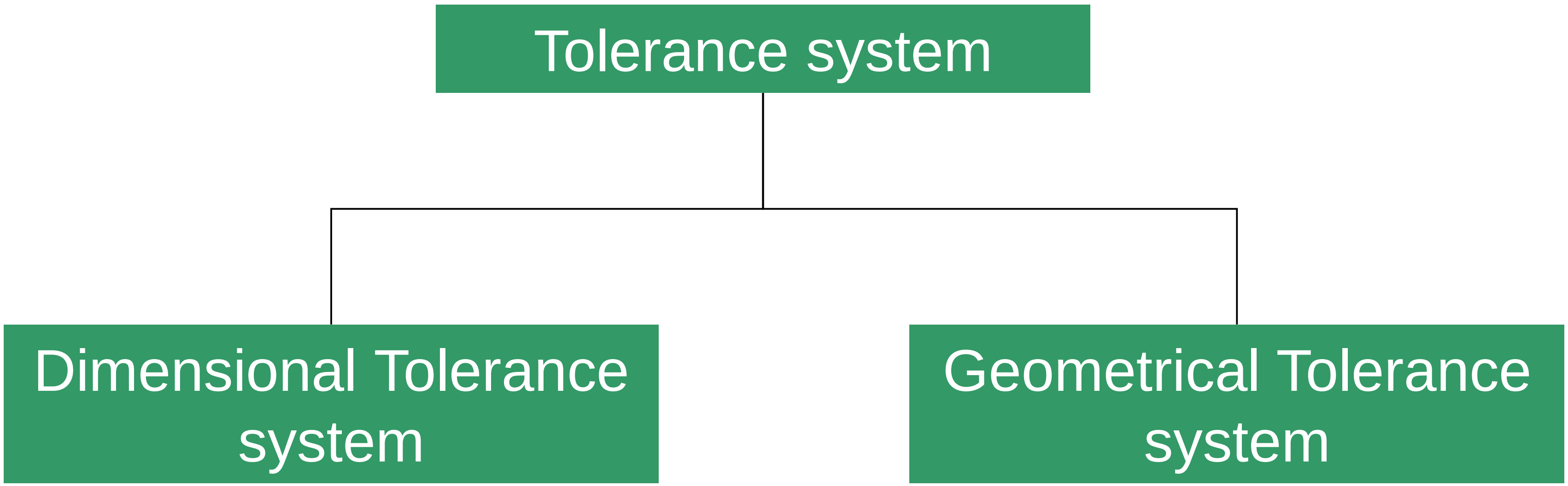
It is almost impossible (and sometimes uneconomical) to maintain the strict degree of accuracy as listed on a plan.

Due to the inevitable inaccuracy of manufacturing methods, a part cannot be made precisely to a given dimension, the difference between maximum and minimum limits of size is the **tolerance**.

Care needs to be taken however when determining such +/- tolerance, particularly where there are mating parts.



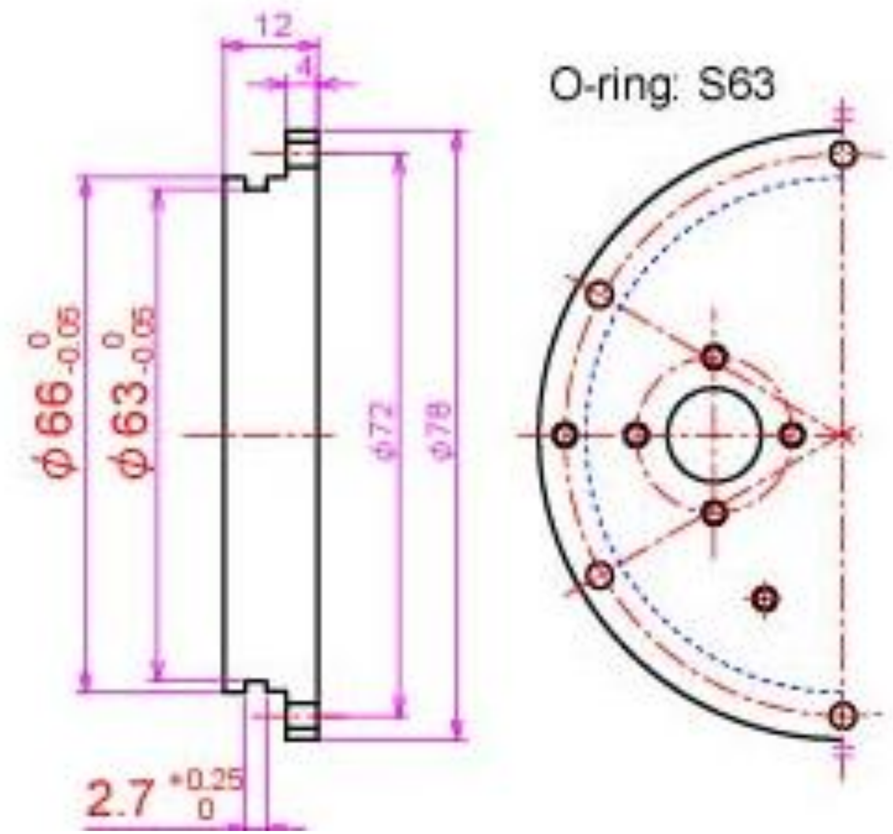
Tolerances


Tolerance system
Dimensional Tolerance system
Geometrical Tolerance system

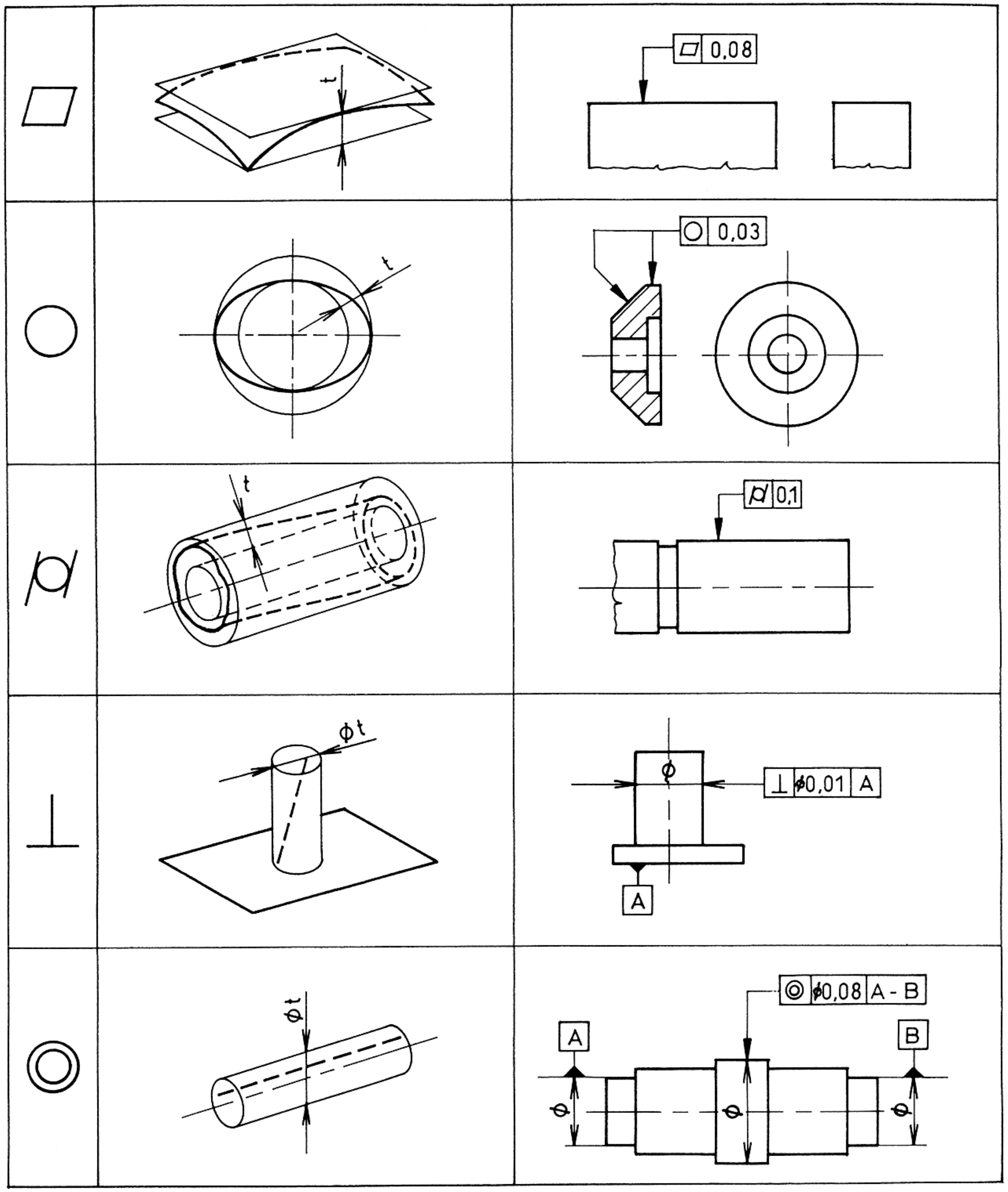
Dimensional Tolerances

Gives dimensional information of local section

Defines only allowable max, min errors



Geometric Tolerances



a. Flatness

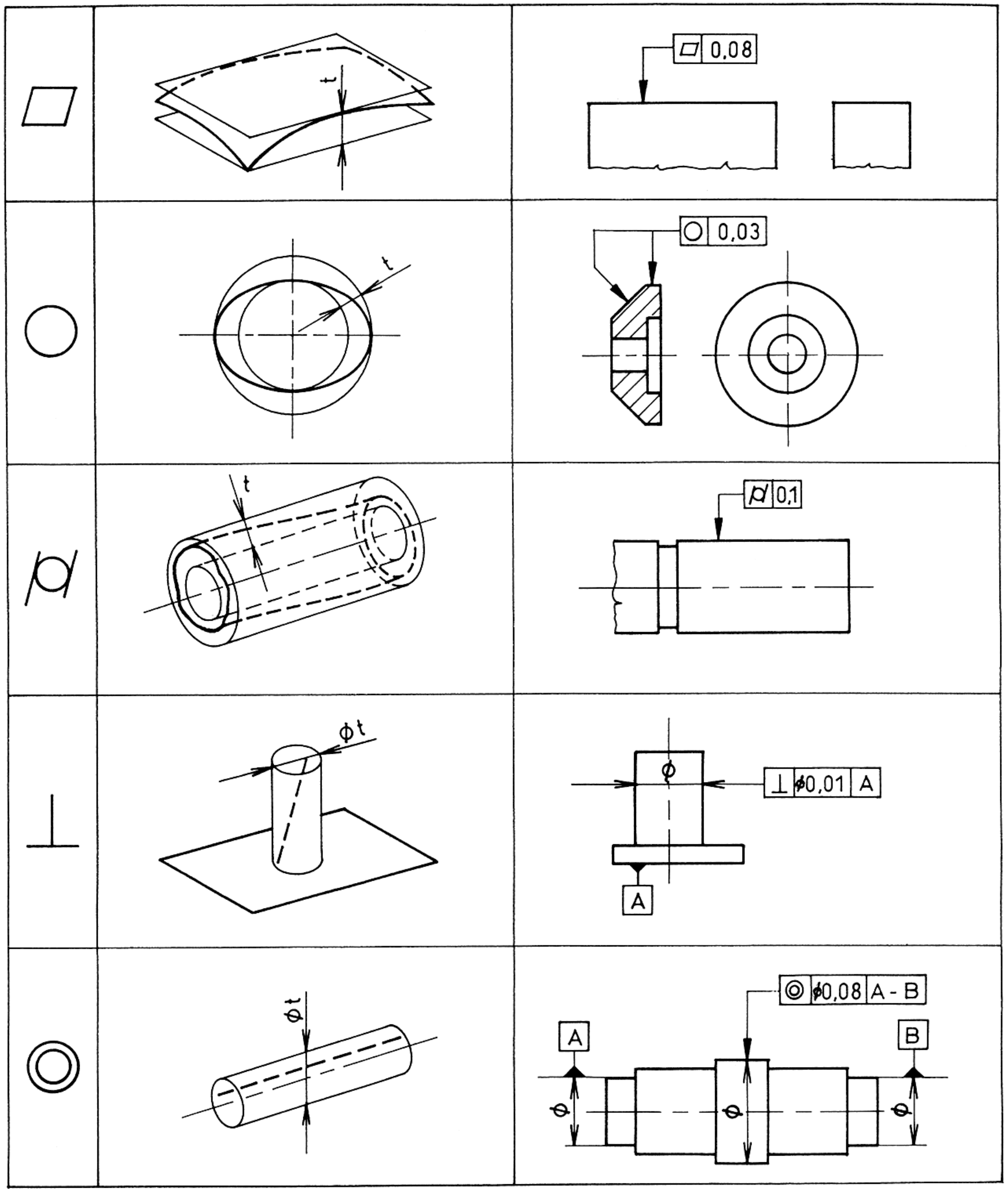
b. Circularity

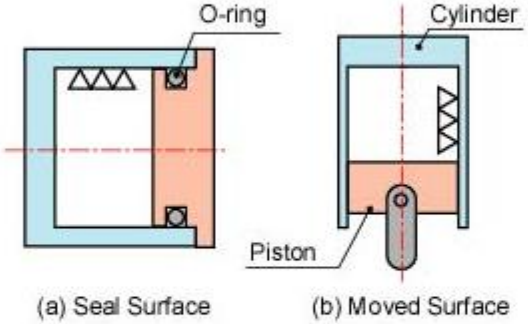
c. Cylindricity

d. Perpendicularity

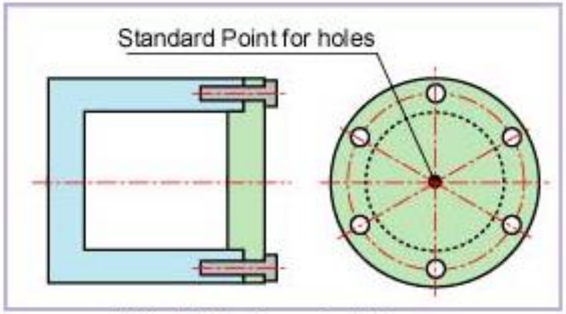
e. Concentricity

Geometric Tolerances





Examples of a Flat Surface



Holes of a Flange

Tolerances: Example

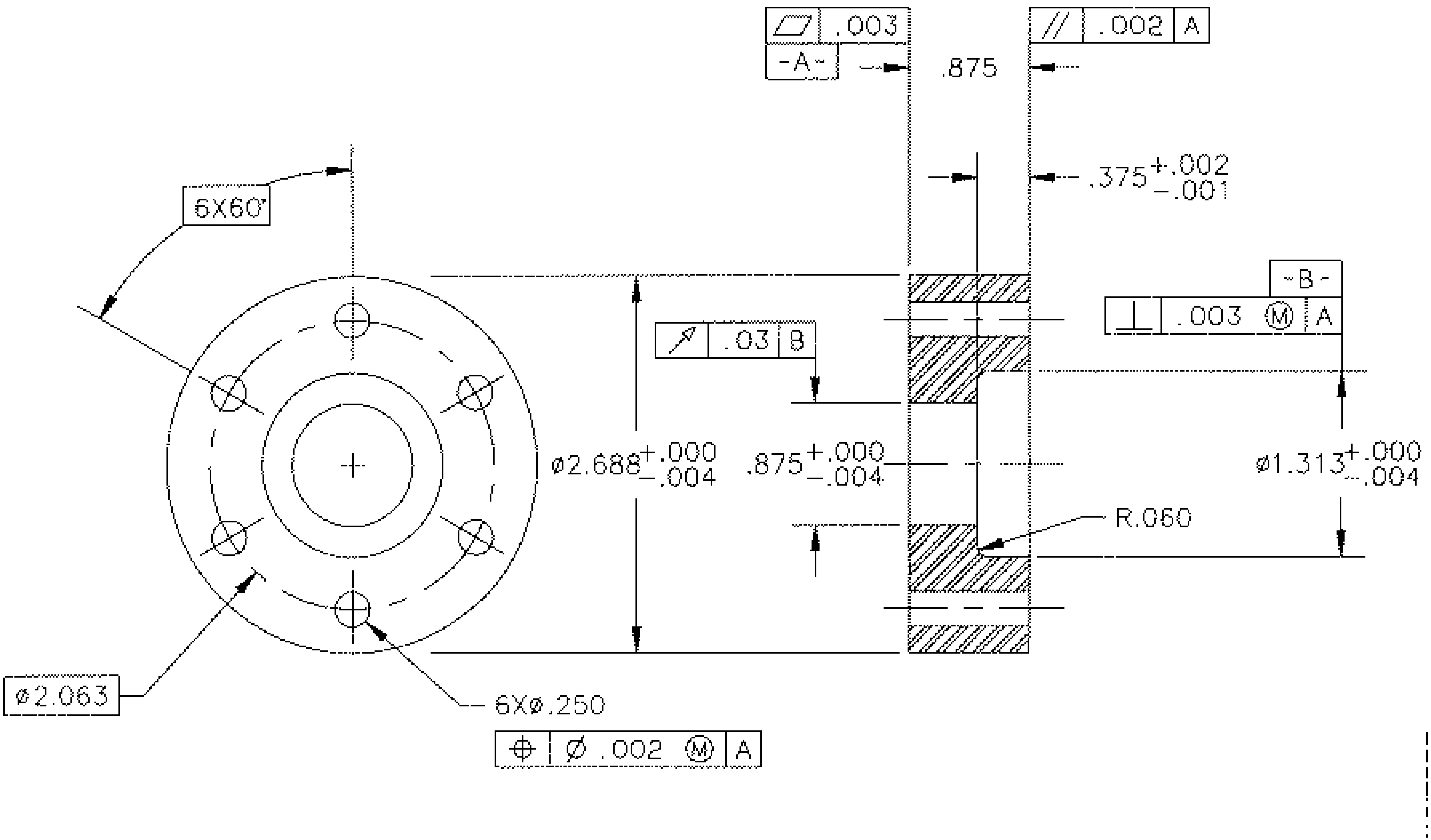


Figure 6.7 — Typical Uses of Geometric Tolerancing

Surface Quality

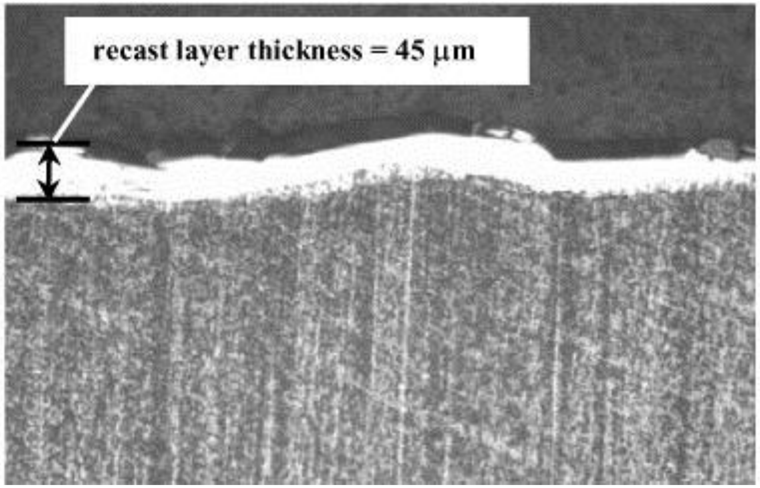
- Importance of surface quality
  - Aesthetic reasons
  - Safety aspects
  - Influence on friction and wear
  - Influence on mechanical and physical properties
  - Important for assembly
  - Better electrical contact

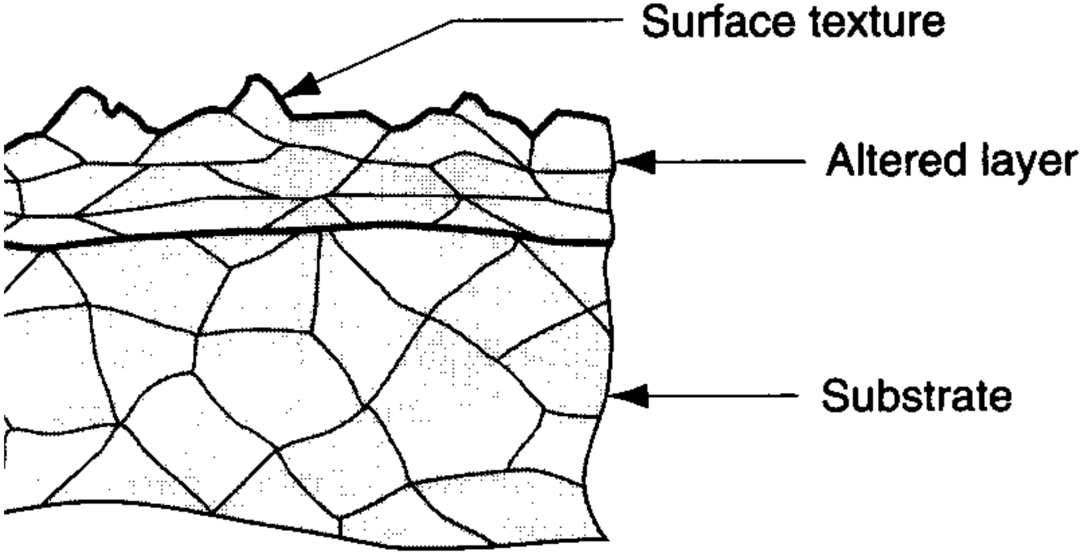
- Surface technology is concerned with
  - Surface texture
  - Surface integrity
  - Relationship with manufacturing processes

Surface Quality

A microscopic view shows:

- Substrate → bulk material
- Altered layer → Layer affected by process
- Surface texture → exterior part with roughness
- In addition: Mostly an oxide film





Surface Quality

Surface texture

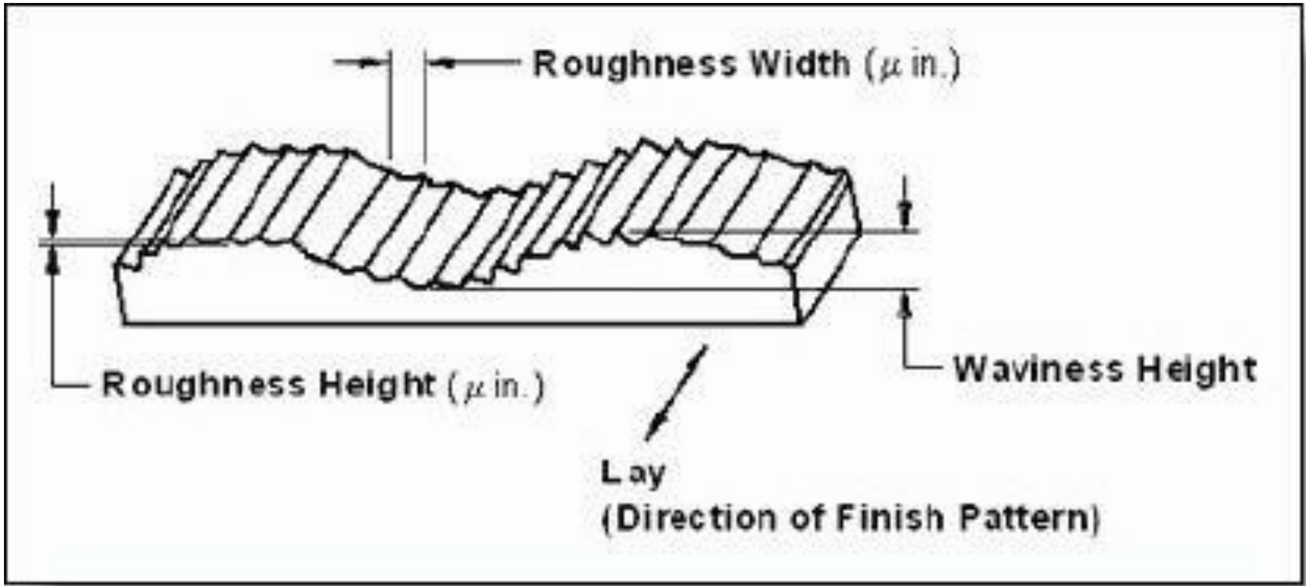
Deviations from the surface

Roughness: small deviations

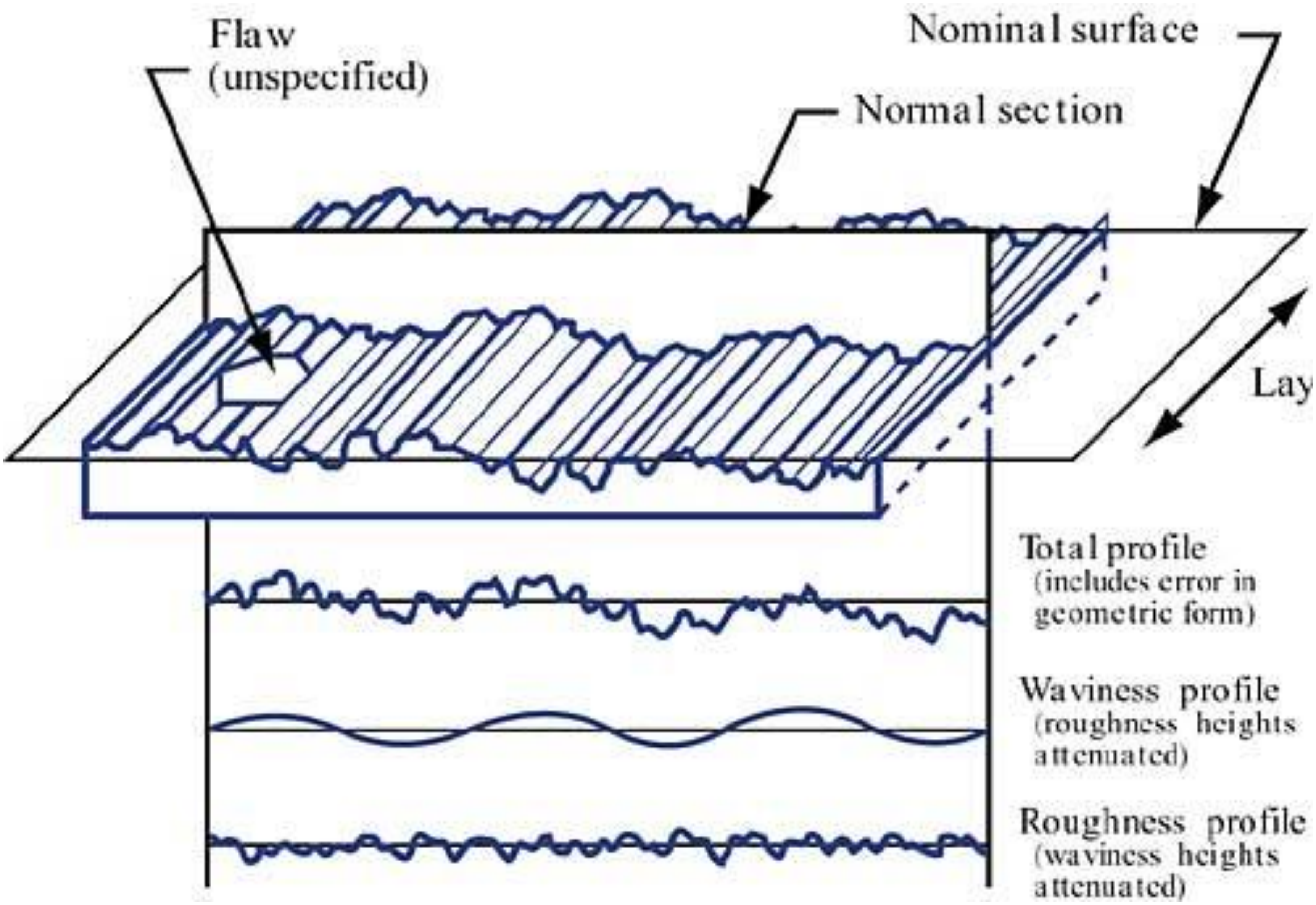
Waveness: deviations with much larger spacing

Lay: predominant direction or pattern of the surface

Flaws: irregularities like cracks, inclusions, etc.



Surface Quality

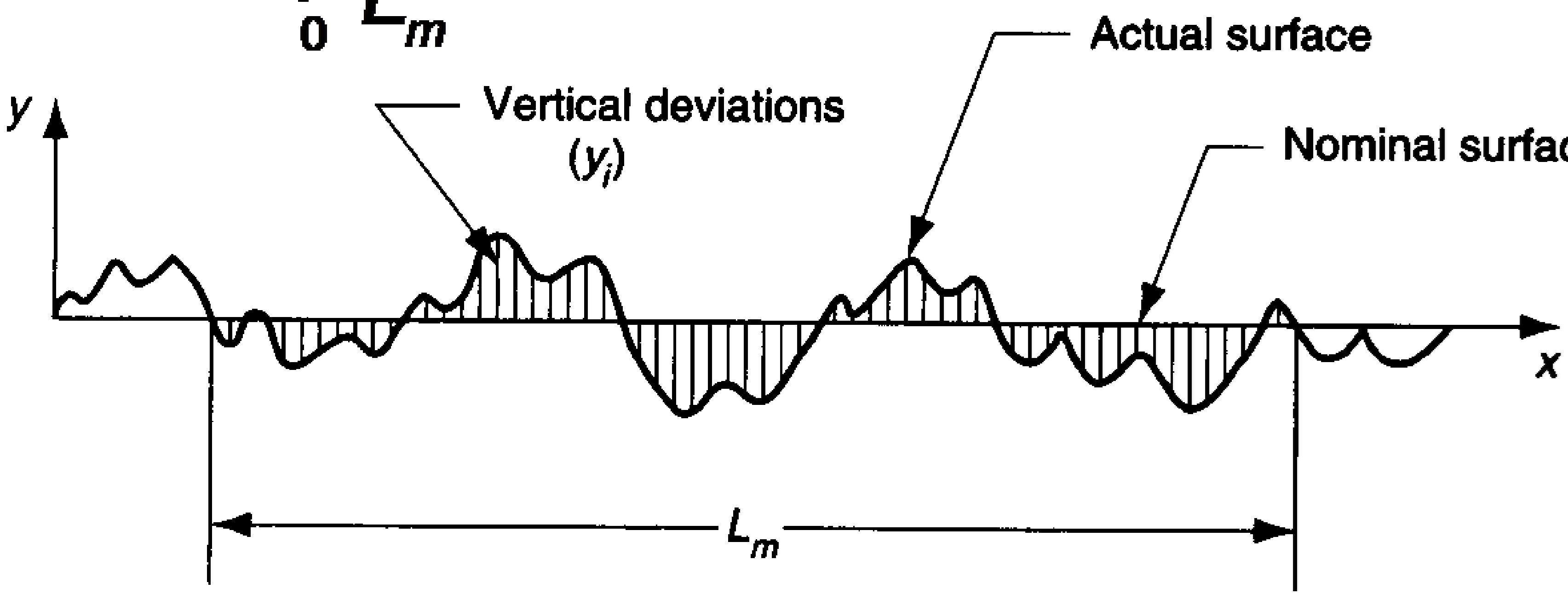


Surface Quality

Surface Roughness Value

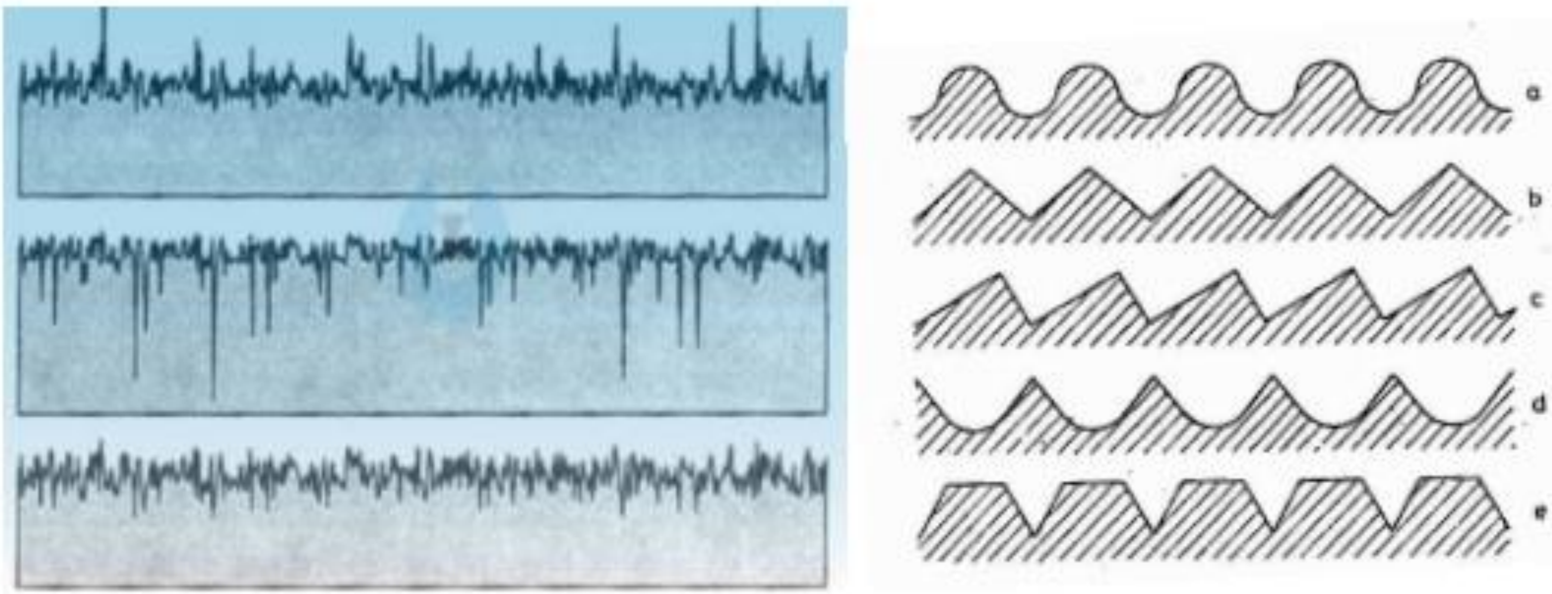
Arithmetic average (AA) of the vertical deviations from the normal surface over a specified surface length.

$$R_a = \int_0^{L_m} \frac{|y|}{L_m} . dx$$



Surface Quality

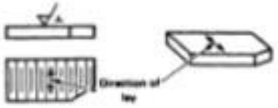
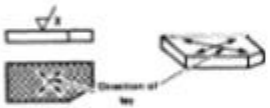
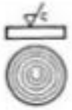
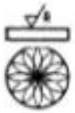
Surface Roughness Value (Ra)



(Figure 4: Surfaces with same Ra, but a lot of difference)

Surface Quality

Surface lay symbols

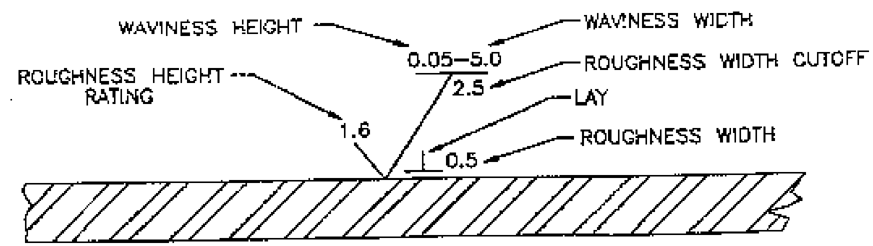
symbol	Interpretation	
=	Parallel to the plane of projection of the view in which the symbol is used	
⊥	Perpendicular to the plane of projection of the view in which the symbol is used	
X	Crossed in two slant direction relative to the plane of projection of the view in which the symbol is used	
M	Multidirectional	
C	Approximately circular relative to the centre of the surface to which the symbol is applied	
R	Approximately radial relative to the centre of the surface to which the symbol is applied	

Surface Quality

Surface texture obtained by any manufacturing process (e.g., turning, grinding, plating, bending)

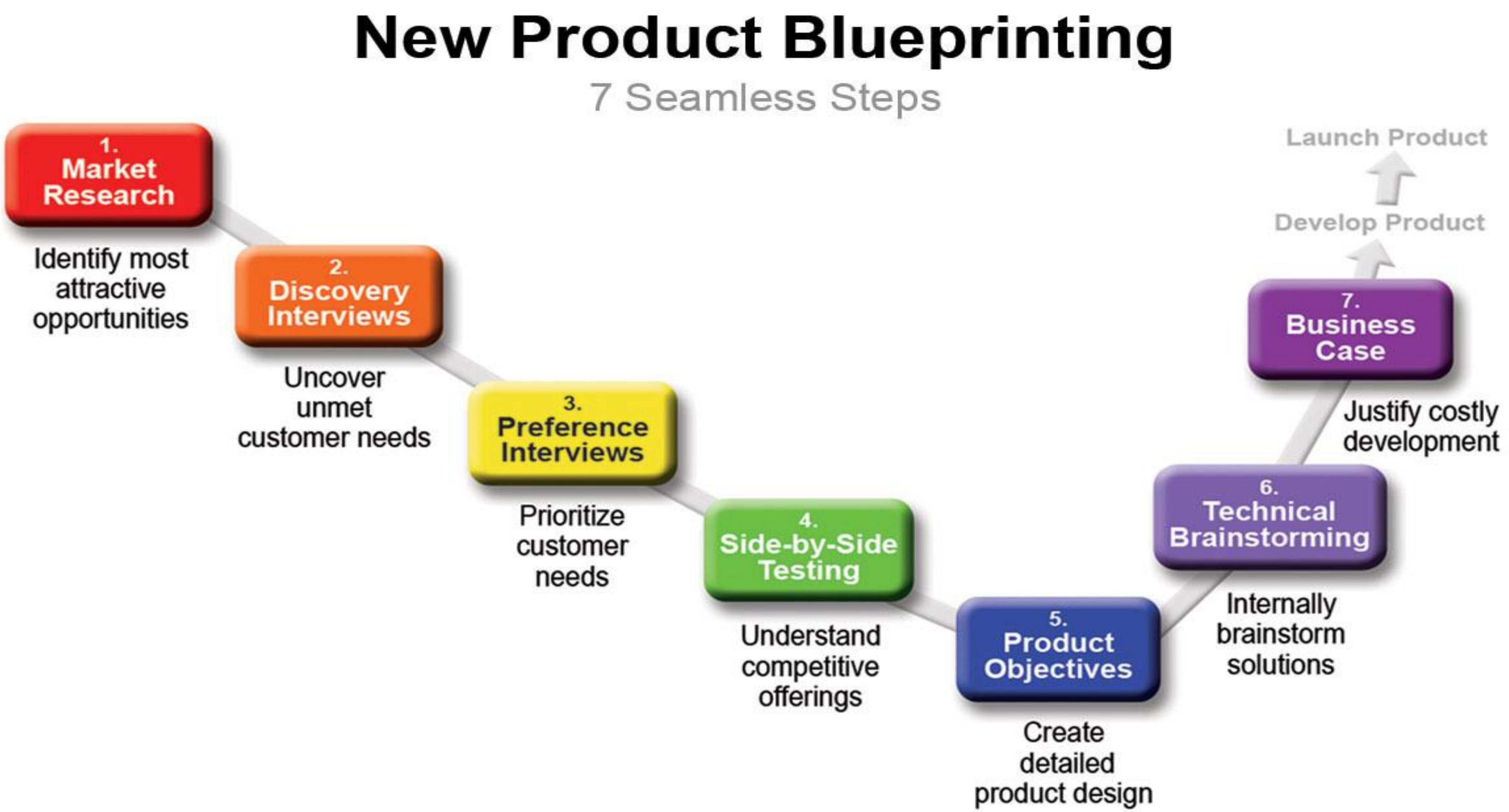
Surface texture obtained by material removal by machining Operation (e.g., turning, drilling, Milling, slotting)

Surface texture obtained by WITHOUT removal of material (e.g., casting surfaces, welding faces, Procurement size surface)



SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION
1.6	Roughness height rating is placed at the left of the long leg. The specification of only one rating shall indicate the maximum value and any lesser value shall be acceptable.	1.6 0.8 0.05-5.0 ⊥	Lay designation is indicated by the lay symbol placed at the right of the long leg.
1.6 0.8	The specification of maximum value and minimum value roughness height ratings indicates permissible range of value rating.	1.6 0.8 0.05-5.0 2.5 ⊥	Roughness-width cutoff rating is placed below the horizontal extension. When not value is shown, 0.80 is assumed.
1.6 0.8 0.05	Maximum waviness height rating is placed above the horizontal extension. Any lesser rating shall be acceptable.	1.6 0.8 0.05-5.0 2.5 ⊥ 0.5	Where required, maximum roughness width rating shall be placed at the right of the lay symbol. Any lesser rating shall be acceptable.
1.6 0.8 0.05-5.0	Maximum waviness width rating is placed above the horizontal extension and to the right of the waviness height rating. Any lesser rating shall be acceptable.	3.5 1.6	Material removal by machining is required to produce the surface. The basic amount of stock provided for material removal is specified at the left of the short leg of the symbol.
90%	Minimum requirements for contact or bearing area with a mating part or reference surface shall be indicated by a percentage value placed above the extension line as shown. Further requirements may be controlled by notes.	1.6	Removal of material is prohibited.

Design Process



Excerpted from *New Product Blueprinting*, by Dan Adams

Introduction: Design Process

Idea development:

all products begin with an idea whether from:

- customers,
- competitors
- suppliers

Reverse engineering:

buying a competitor’s product

Introduction

Understanding of Design

- ❑ Objective / purpose
- ❑ Function
- ❑ Working Environment

Understanding of Customer

- ❑ Cost
  - ❑ Logistics
- ❑ Service life
- ❑ Environmental impact

Understanding of Material

- ❑ Material Properties
- ❑ Material Behavior
- ❑ Manufacturability

Introduction

Understanding of Design

- ❑ Objective / purpose
- ❑ Expected failures/

Critical Design location

- ❑ Working Environment

Fly in long distance

Should be mobile

Hit to ground when landing

sunny days, salt water, 15-35°C

Introduction

Cheap

Durable

Understanding of Customer

- Cost
    - Logistics
- Service life
- Environmental impact

Introduction

Understanding of Material

- ❑ Material Properties
- ❑ Material Behavior

Cheap (low material/manuf. cost)

Fly in long distance (low density)

Durable (impact resistive)

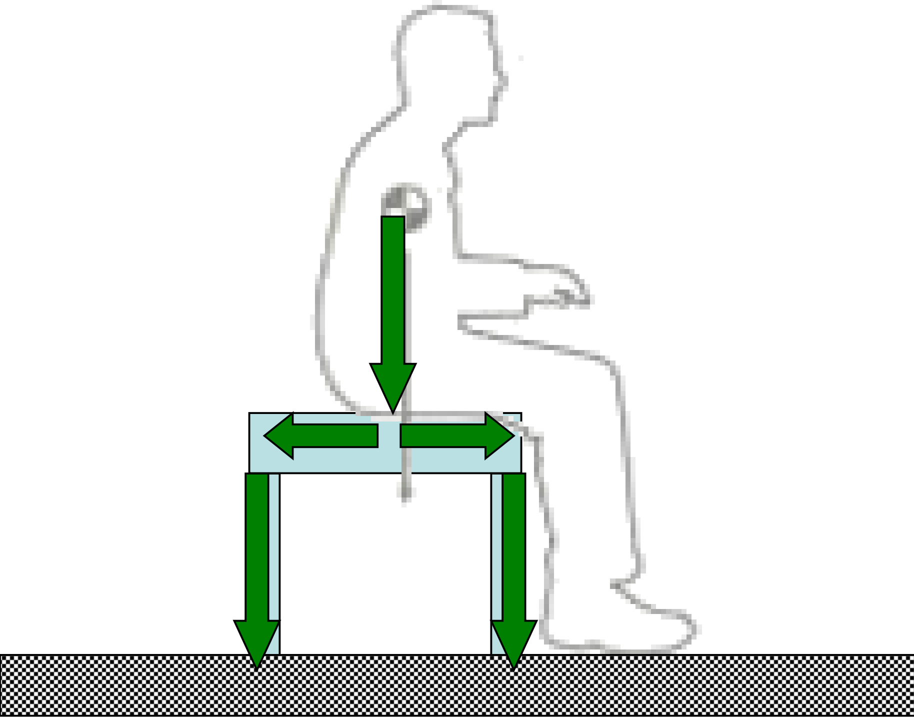
Should be mobile (low density)

Hit to ground when landing (easily absorb impacts)

sunny days, salt water, 15-35°C (non-corrosion)

Introduction

Chair



Understanding of Design : System Analysis

break the system down into individual components

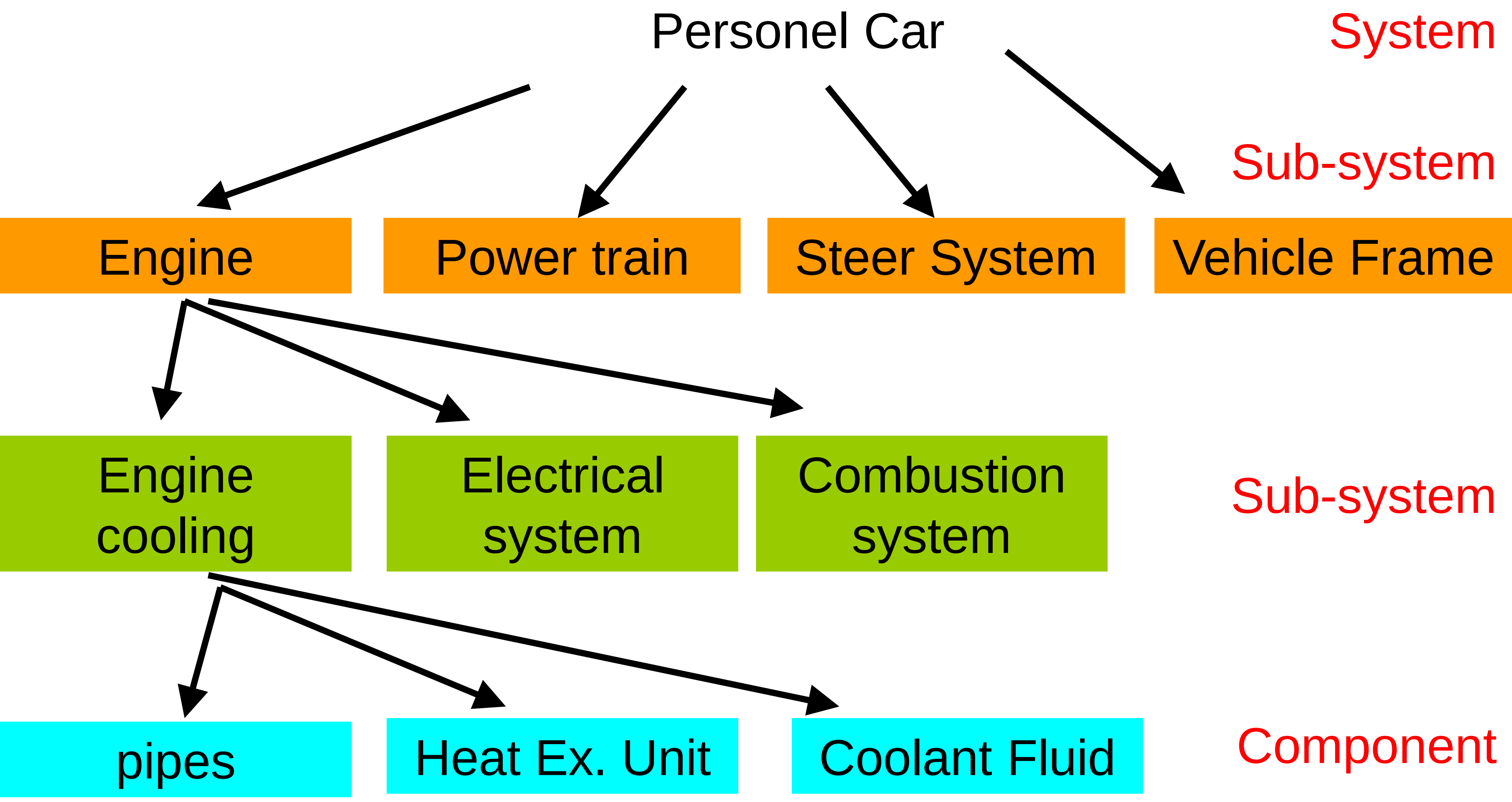
then analyze each one

System : combination of sub-system or component

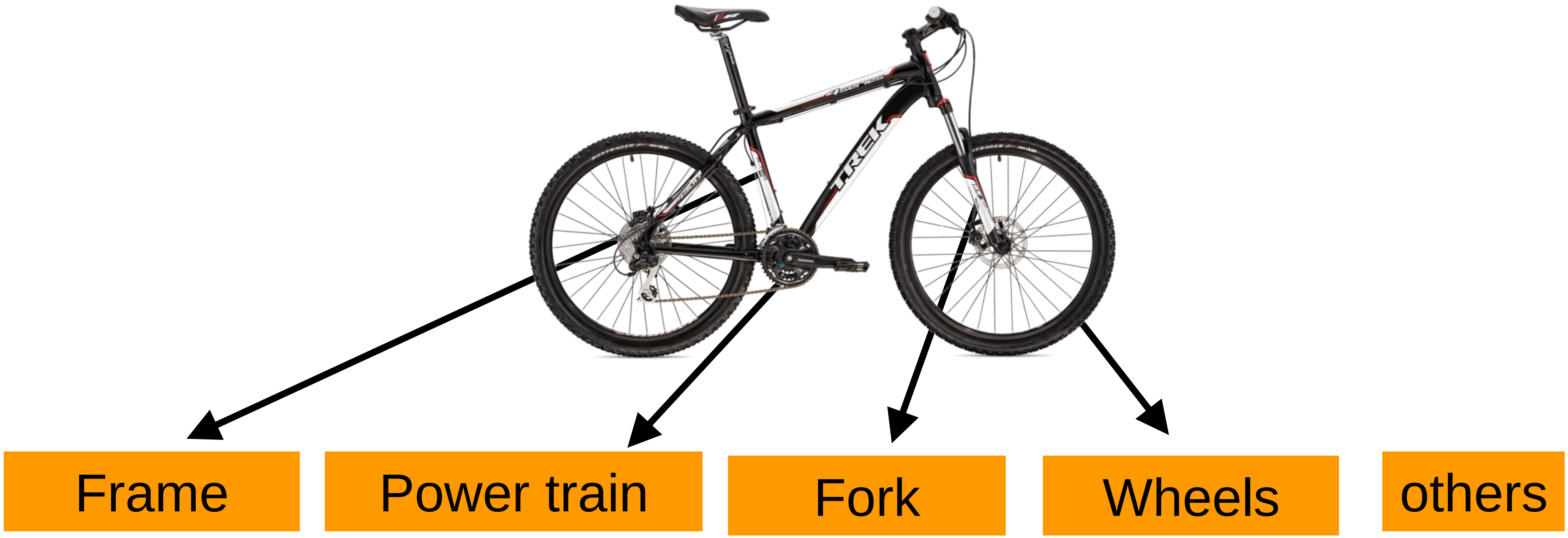
Sub-system: it is a part of system and it can be divided into sub-systems or components

Component : is a sub-system that cannot be split anymore

Understanding of Design : System Analysis



Understanding of Design : System Analysis



- ❑Requirements (mechanical, ergonomic, aesthetic etc.)
- ❑Function
- ❑How many are going to be made?
- ❑What manufacturing methods are we going to use?

Understanding of Design : System Analysis

Frame

❑Steel

Strong, stiff, heavy, but cheap

❑Aluminium

weaker, lighter, more expensive than steel

❑Composite (CFRP)

strong, stiff, very light, but expensive to buy and to fabricate

Understanding of Customer :

Customer Needs

Environment – High/low temperature, sea, desert

Product Life – Operational cost, profitability

Special needs – Low weight, wear resistivity, bio compatibility

Safety – Failure strategy

Mission – Acceleration/decelaration, start/stop

Govermantal requlations

COST !!!!!

Understanding of Customer :

Turbine blade

Environment – High temperature up to 2000 K

Special needs – Low weight

Product Life – 4000 h of operations

Safety – cannot be damaged (partially)

Mission – special mission requirement

COST !!!!! (each stage contain 20-60 blades)

(each engine consists of 1 or 2 stage)

Understanding of Material & Process

What are the critial properties

Mechanical	–	Strength, modulus etc.
Physical	–	Density, melting point.
Electrical	–	Conductivity, resistivity
Thermal	–	Conductivity, heat capacity
Optical	–	Absorption, transmission and scattering
Aesthetic	–	Appearance, texture, color
Processability	–	Ductility, weldability

Process Material Relation

What are the requirements?

- Leak free
- Comply with food standards & protect liquid from health hazards
- Withstand pressure
- Brand image & identity
- Easy to open
- Easy to store & transport
- Envorimental friendly
- Cheap for high volumes

Which material ?

ceramic, glass, steel, aluminum, plastic