School of Mechanical Engineering

Course Code : BTME3056 Course Name: Product Design

DESIGN FOR MANUFACTURING ASSEMBLY

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DESIGN FOR MANUFACTURING AND ASSEMBLY

What is Design?

"Design establishes and defines solutions to and pertinant structures for problems not solved before , or new solutions to problems which have previously been solved in a different way"

"Ability to design combines science and art"

"the form , parts , or details of something according to a plan"

"Analysis and synthesis"

Decomposing into smaller parts.

Analysis $\rightarrow$ calculation of behavior of part

$\Rightarrow$Simplification of real through models.

Synthesis => Identification of design elements that comprise , its decomposition into parts , and the combination of the part solutions into a total workable system

Four `C ‘s of Design

1 Creativity

Something not existed before

2 Complexity

Decisions on many variables

3 Choice

Between many possible solutions at all levels

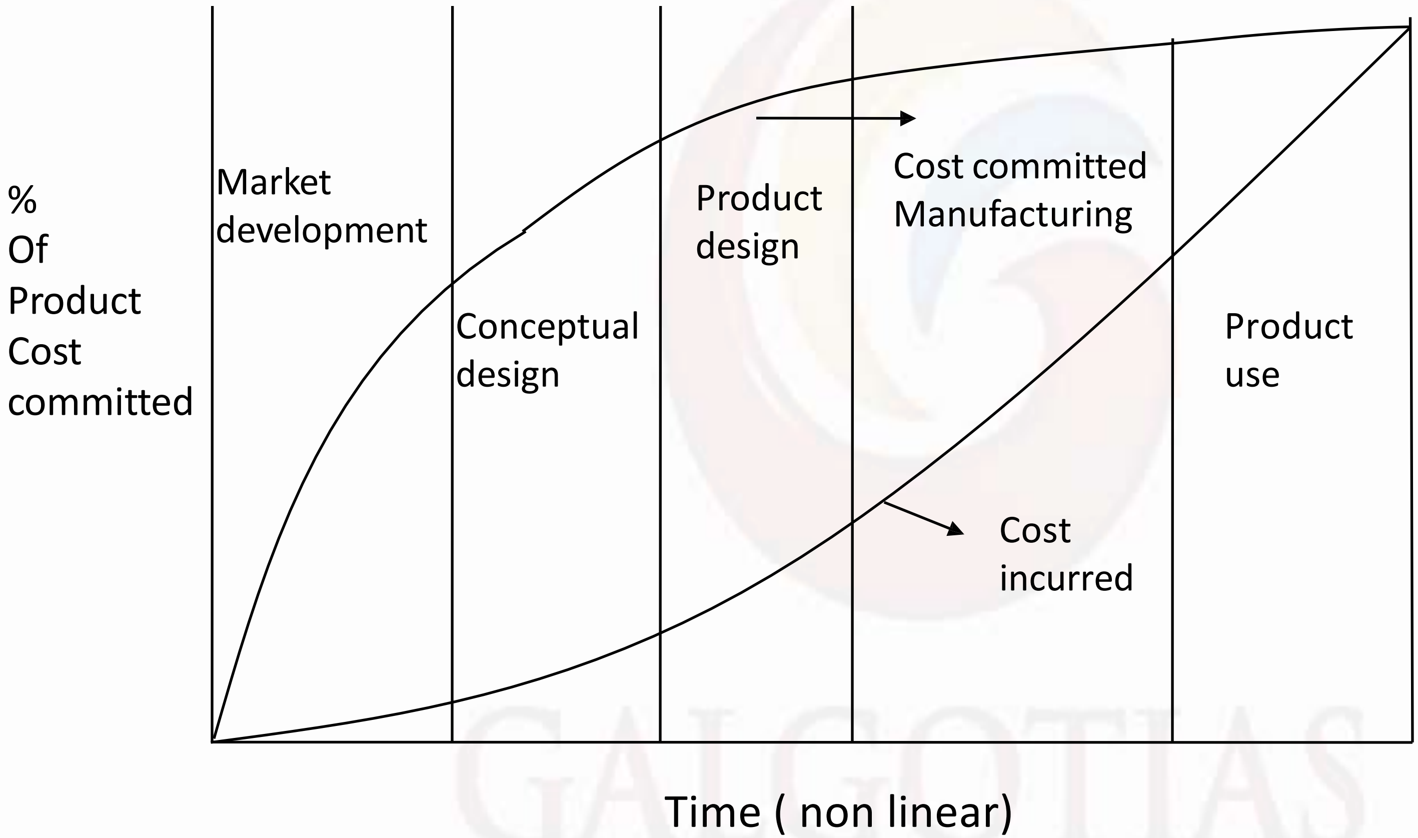
4 Compromise

Balancing multiple and sometimes comflicting requirements

“ A professional engineer can create many designs and have the satisfaction of seeing , them become working realities”

“ A scientist can discover a new star but an engineer can create one for him”

DESIGN PHILOSOPHY



Product cost Commitment during phases of the design process

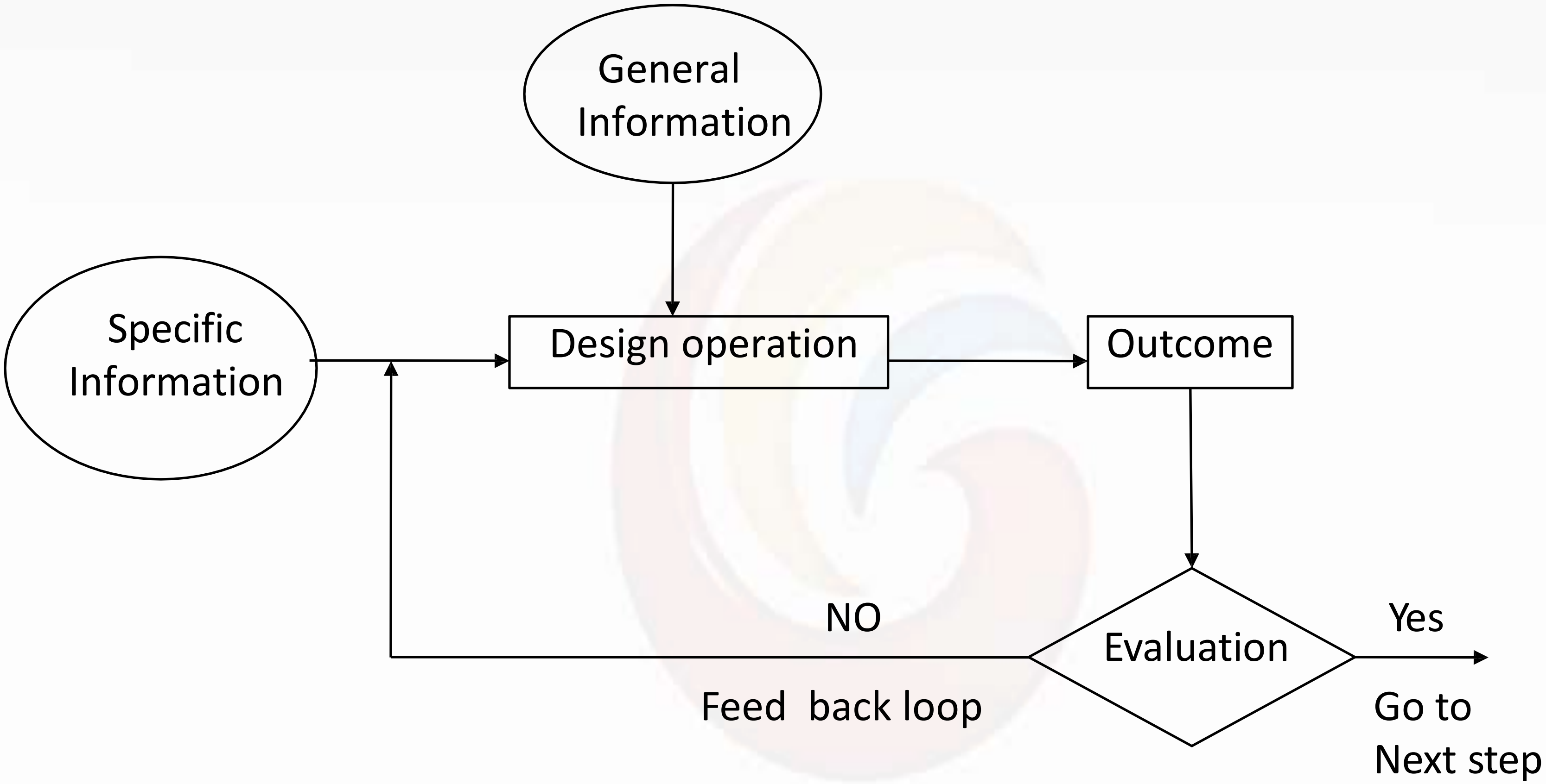
“ Decisions made in the design process cost very little in terms of the overall product cost but have a major effect on the cost of the product.”

“You cannot compensate in manufacturing for defects introduced in the design phase”

“The design process should be conducted so as to develop quality , cost – competitive products in the shortest time possible”

TYPES OF DESIGNS

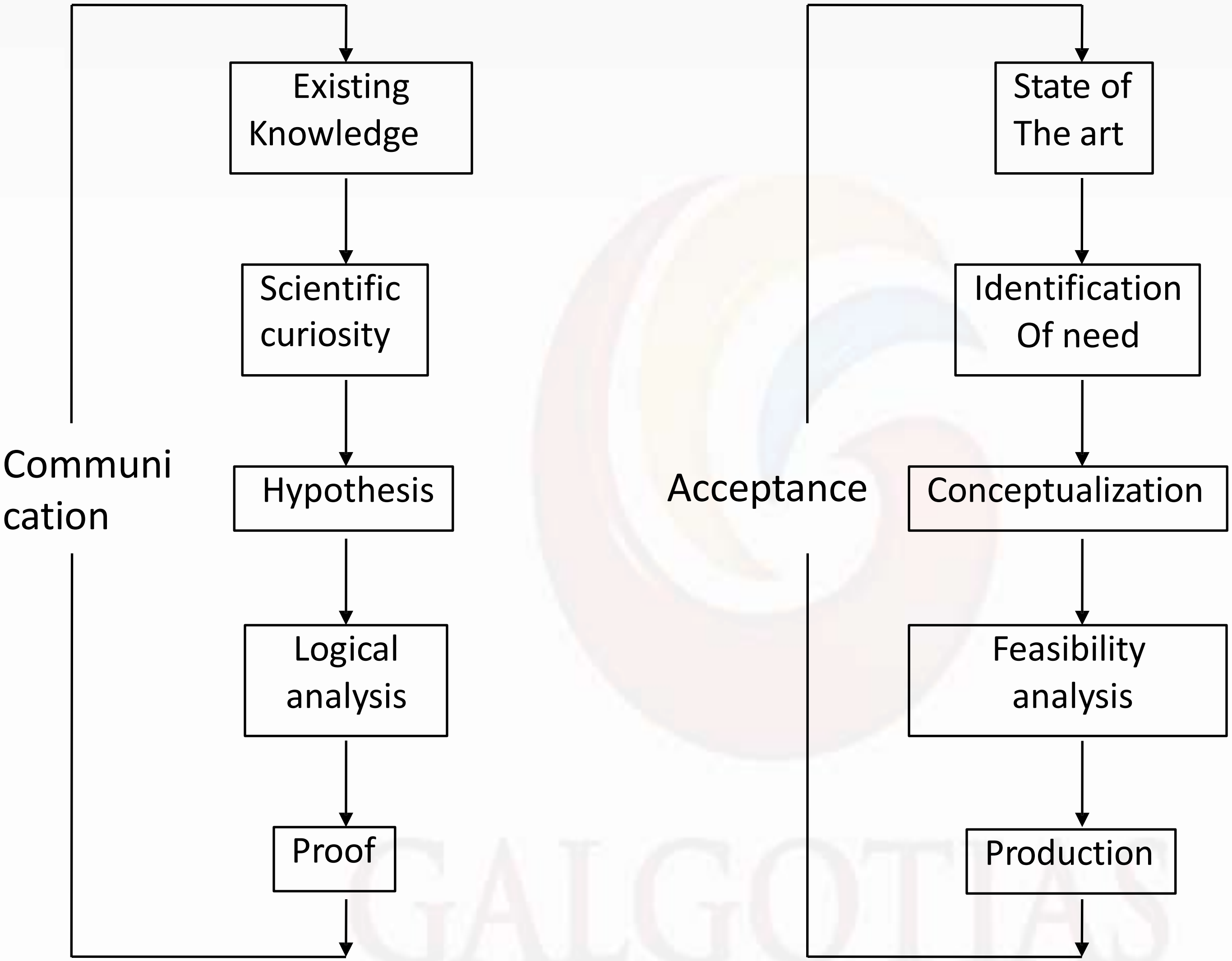
Original design	→	Innovation eg: Microprocessor
Adaptive design	→	Novel application eg: inkjet printing concept for rapid prototyping
Redesign	:	Without any change in concept of the original design
variant design	:	changing some of the design parameters
Selection design	:	Selecting the components with the needed performance , quality and cost from the catalogs of potential vendors
Industrial design	:	Appeal of product to human senses


General Information
Specific Information
Design operation
Outcome
NO
Evaluation
Yes
Feed back loop
Go to Next step

Basic Module in the design process

Eg: Maximum performance at minimum weight

- Aircraft
- Car
- Rocket
- Missiles



Scientific method

Design method

Comparison between scientific method and design method

PROBLEM SOLVING METHODLOGY

1 Problem definition
2 Information collection
3 Finding alternative solutions
4 Evaluation of alternatives and decision making
5 Communication of the results

1 Needs analysis

2 Technical reports (sponsored R&D) trade journals , patents

Catalogs , handbooks , literature of vendors and suppliers of material and equipment

What	?	Need
Where	?	To find
How	?	Accuracy
How	?	Interpret
When	?	Enough
What	?	Decisions

3 Creativity , stimulation , physical principles and quantitative reasoning , ability

4 Best among several options

- Simulation & testing
- Prototype

5 Needs of customer

Detailed drawings , computer programs , 3-D Computer models , Working models

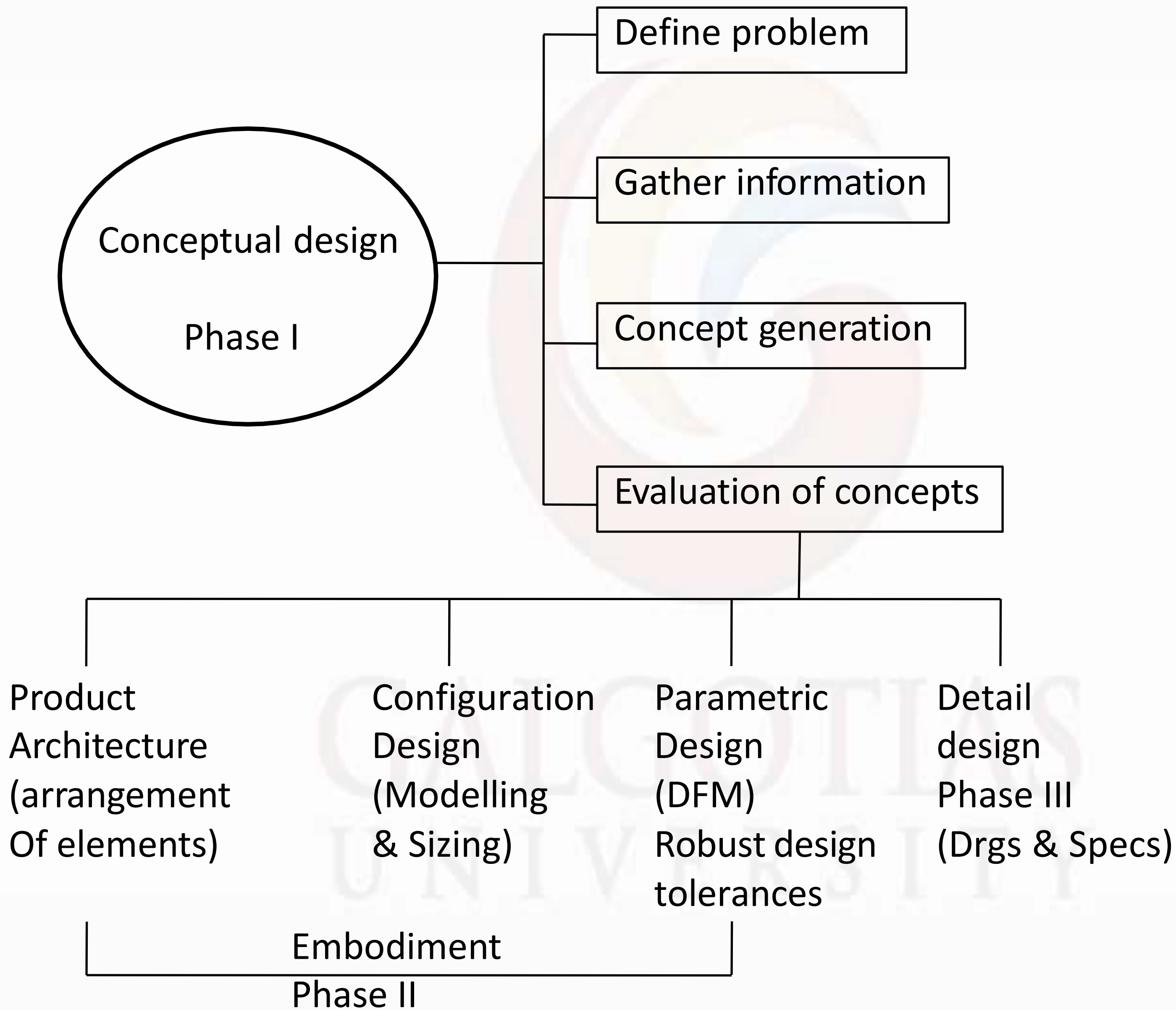
Good Design

Performance

Life cycle

Social and regulatory issues

DESIGN PROCESS



PHASE IV Planning for manufacture

PHASE V Planning for distribution

PHASE VI Planning for use

PHASE VII Planning for product retirement

7 Phases of design

1 Phase I Feasibility

Useful solutions to design problem computer aided modelling

2 Phase II Preliminary design

- Set of useful solutions
- Which of the preferred alternatives is the best design concept
- FEM for design analysis – to find stress concentration in critical areas
- Photo elasticity for accurate stress analysis
- Socio economic conditions
- Consumer tastes
- Competitors offerings
- availability of critical raw materials
- Rate of obsolescence
- Validation of design

Phase III

3 Detailed design

Final decision for a particular product to be made with regard to "design concept"

- Specification of components based on master layout
- Provisional synthesis paper design ; experimental design
- models construction
- components , prototype and testing
- redesign and refinement until an engineering description of a proven design accomplished

Phase IV

4 Planning Production process

1) Process planning for every part , sub assembly , final assembly

   process sheet : sequential list of operations ;

   Raw materials , tools , machines , special instructions

   Discussions with product designers , tool designers , metallurgists

2) Design of tools and fixtures

3) Planning – new production facilities required

4) Quality control system

5) Production personnel – job specifications

6) Production control work schedule , Inventory control, Labour cost , materials , service , Integrating with accounts

7) Information flow :

   Forms , Records → Integration with computers

8) Financial planning : Source , rate of recovering the capital

Phase V

5 Planning for distribution

- Production and consumption cycle

- Distribution
  - (i) Packaging
  - (ii) Ware housing
  - (iii) Sales promotion
  - (iv) Distribution

Phase VI

6 Planning for consumption

(i) Design for maintenance

(ii) Design for reliability

(iii) Design for safety

(iv) Design for convenience in use

(v) Design for aesthetic features

(vi) Design for operational economy

(vii) Design for adequate duration of services

(viii) Product improvement , next generation designs , related products

Phase VII

7 Planning for retirement

Disposal

1) Rate of obsolescence
2) Physical life to match anticipated service life
3) Several levels of use
4) Reuse of materials
5) Examining and testing of service terminated products in lab

25 steps – phases of design

(I) Feasibility study

1. Need analysis
2. Identification and formulation
3. Synthesis of possible solutions
4. Physical realizability
5. Economic analysis
6. Financial viability

25 steps – phases of design

(II) Preliminary design

1) Design concept
2) Mathematical model
3) Sensitivity analysis
4) Compatibility analysis
5) Stability analysis Formal
6) optimization Projections for
7) future Prediction of system
8) behavior
9) Testing design concept
10) simplification of design

25 steps – phases of design

(III) Detailed design

1. Preparation for design
2. Design for subsystems
3. Design for components
4. Design for parts
5. Assembly drawings
6. Experimental construction
7. Product test programme
8. Analysis and prediction
9. Redesign

Design rules for manufacturability

Information on

(1) Product life, volume

(2) Permissible tooling expenditure levels

(3) Possible part shape categories and complexity levels

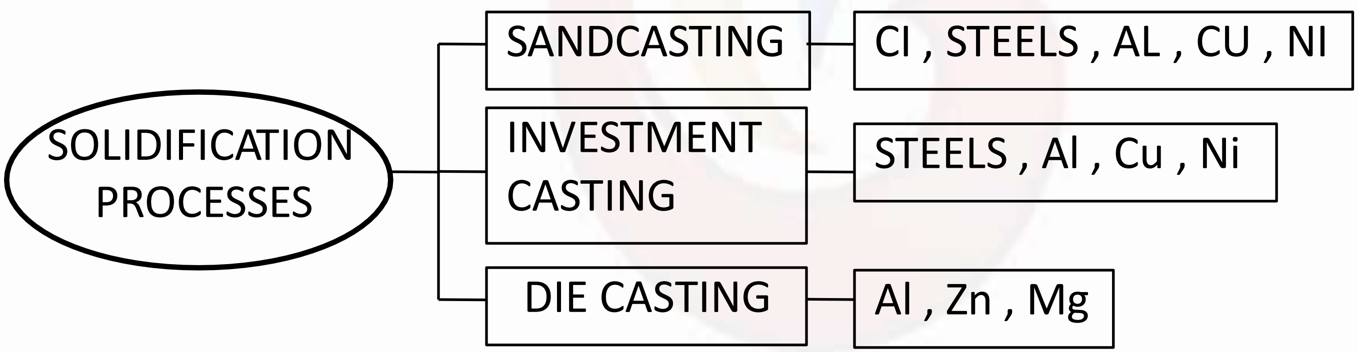
(4) Service or environment requirements

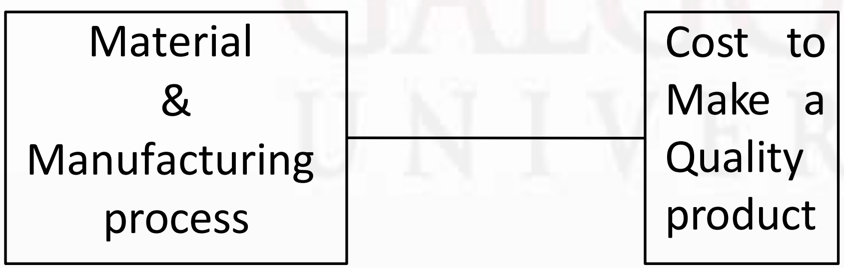
(5) Appearance factors

(6) Accuracy factors

SELECTION OF MANUFACTURING PROCESSES

COMPATIBILITY BETWEEN PROCESSES AND MATERIALS





COMPATIBILITY BETWEEN PROCESSES AND MATERIALS

Material selection

- Material composition ; grade
- Cost of material
- Form (bar , tube , wire , strip plate , plate , powders etc
- Size (dimension , tolerance)
- Heat treated condition
- Anisotrophy (directional properties)
- Quality level
- Ease of manufacture (workability , weldability , machinability)
- Ease of recycling

Manufacturing process

- Unit cost of manufacture
- Life cycle cost per unit
- Qty of parts
- Complexity of part
- Quality (Defect free)
- Surface finish
- Accuracy
- Availability of equipment
- Tooling (lead time)
- Make – buy decision

SELECTION OF MANUFACTURING PROCESSES

COMPATIBILITY BETWEEN PROCESSES AND MATERIALS

SELECTION OF MANUFACTURING PROCESSES

COMPATIBILITY BETWEEN PROCESSES AND MATERIALS

DFM guidelines

- Minimize number of parts
- Standardize
- Use common parts across product line
- Multifunctional
- Ease of manufacture
- Avoid two tight tolerances
- Avoid secondary mfg and finishing operations
- Utilize special characteristics of a process
- Designs functional and simple

Specific Design rules or Guide lines

- Spacing of holes
- Avoid generalized remarks
- Dimensioning
- Minimum weight
- General purpose tooling
- Minimize stress concentration
- Max operations in one position

SELECTION OF MANUFACTURING PROCESSES

COMPATIBILITY BETWEEN PROCESSES AND MATERIALS

DFA guidelines

General

1. Minimum parts
2. Assly of 20-30%
3. Minimize assembly surfaces
4. Use sub assemblies

Handling

1. Min fastener cost
2. Min handling in assembly

Insertion

1. Assembly direction
2. Unobstructed access
3. Compliance to assembly

Benefits of standardization

Cost reduction

Qty discounts , flexible delivery
Minimum work

Raw material standardization

1. Single bar size , tube , sheet metal
2. Metal casting , plastic single material
3. Automation

Feature standardization
1. Drilling , reaming , radii
(reduction of Inventory of tools)
2. Floor space
3. Overhead costs control

Benefits of standardization

Quality improvement

- Product quality
- Prequalification of parts (reducing testing charges)
- Minimum vendors (stronger supplier Relationship)

Benefits of standardization

Production flexibility

- Material logistics
  (fewer parts advantageous
- Reliable deivery
  (reduction of overhead costs)
- Flexible manufacturing
  (Batch sizes , finished
  goods inventory)

Benefits of standardization

Manufacturing responsiveness

- Parts availability
- Quick supplies
- Financially stronger suppliers

Group Technology (GT) — Common Characteristics

Design characteristics of part

1. External shape
2. Internal shape
3. Major dimension
4. Length / dia ratio
5. Shape of raw matl
6. Part function
7. Type of material
8. Tolerances
9. Surface finish
10. Heat treatment

Manufacturing characteristics of part

1. External shape
2. Major dimension
3. Length / dia ratio
4. Primary process used
5. Secondary processes
6. Annual production
7. Tooling and fixtures
8. Sequence of operation
9. Tolerances
10. Surface finish

Benefits of GT

1. Standardization of part design and elimination of duplication
2. Savings in cost and time
3. Less experienced engineers can work accessing previous designs , process plans
4. Set up times reduced , sharing of tools and fixtures
5. Cost estimates based on past experience
6. Manufacturing cell layout
7. Functional layout

Classification of parts

1. Experience based judgment (part shape and sequence of operation)
2. Production flow analysis (PFA) (parts –identical operations-family)
3. Classification and cooling (external shape features , internal features , flat surfaces , holes , gear teeth , materials , surface properties , manufacturing)
4. Engineering data base

Mistake proofing
(error proofing)

Zero defect concept

Common mistakes

1. Setting up work pieces and tools
2. Incorrect or missing parts in assemblies
3. Processing wrong work piece
4. Improve operations or adjustments of machines

Mistakes also in design and purchase

Inspection six sigma → 3.43 PPM

Frequent mistakes

Design

(1) Ambiguous information on drawings or specifications

(2) Mistakes in conversion units , wrong calculations

(3) Poor design concept

(4) Defective material

(5) Not all performance requirements considered

(6) Not upto quality standards

(7) Internal porosity or fine surface cracks

Assembly

(1)Omitted operations

(2)Omitted part

(3)Wrong orientation of part

(4)Misaligned part

(5)Wrong location of part

(6)Selection of wrong part

(7)Misadjustments

(8)Commit a prohibited action

(9)Added material or part

(10)Misread , mis measure , misinterpret

Mistake proofing solutions

1) **Control of variability**
2) **Control of complexity**
3) **Control of mistakes**

Devices

1) **Check list**
2) **Guide pins , guide ways , and slots**
3) **Specialized fixtures and jigs**
4) **Limit switches – sensors**
5) **Counters – operations , time**

Barriers to creative thinking "mental blocks"

Perpetual blocks

1. Stereotyping
2. Information overload
3. Limiting the problem unnecessarily
4. Fixtation
5. Priming or provision of cues

Environmental blocks

1) Fear of risk taking
2) Unease with chaos
3) Unable or unwilling to incubate new ideas

Creative thinking methods

1) Brain storming
2) Technological stretching

a) What happens if we push the conditions to the limit
b) Temperature up or down
c) Pressure up or down
d) Impurities up or down

Six key questions
1) Who (uses , wants , benefit)
2) What
3) When
4) Where
5) Why
6) How

GENERAL

1. DESIGN COMPONENT SO THAT IT CAN BE MACHINED ON ONE MACHINE TOOL
2. DESIGN COMPONENT SO THAT MACHINING IS NOT REQUIRED ON UNEXPOSED
   SURFACES OF THE WORK PIECES WHEN THE COMPONENT IS GRIPPED IN THE
   WORK HOLDING DEVICE
3. AVOID MACHINED FEATURES WHICH THE COMPANY CANNOT HANDLE
4. DESIGN COMPONENT IS RIGID WHEN GRIPPED IN WORK HOLDING DEVICE
5. VERIFY THAT WHEN FEATURES ARE TO BE MACHINED , THE TOOL , TOOL HOLDER ,
   WORK AND WORK HOLDING DEVICE , WILL NOT INTERFACE WITH EACH OTHER
6. ENSURE THAT AUXILIARY HOLES OR MAIN BORES ARE CYLINDRICAL AND HAVE L/D RATIOS THAT MAKE IT POSSIBLE TO MACHINE THEM WITH STANDARD

BENT HOLES

EG: TURNING OPERATION

$$Ra = 0.0321\, f^2/r_\varepsilon$$

Where Ra = Arithmetical mean surface roughness

$f \rightarrow$ feed

$r_\varepsilon \rightarrow$ tool corner radius

Machining time

$$t_m = l_w / f n_w$$

$l_w \rightarrow$ length of work piece

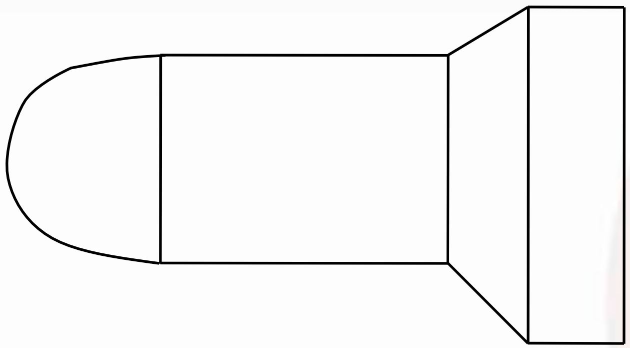
$n_w \rightarrow$ rotational speed of work piece

Process	Surface roughness (Typical) µm
SAW	25-6.3
TURN ,MILL,BORE	6.3-3.2
DRILL	5.3-2.4
REAM	4.0-2.0
GRIND	2.4-0.5
HONING	0.5-0.18
LAP,POLISH	0.3-0.025

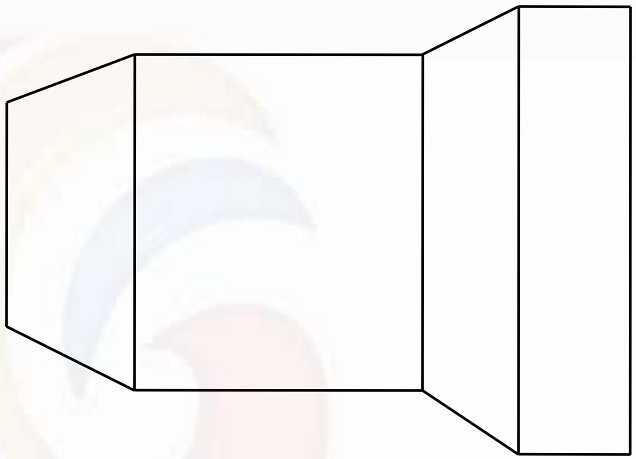
Factors for machining ease

1. Reduce amount of machining (Tolerances for mating suspects)
2. Convenient and reliable locating surfaces to setup work piece
3. Sufficient rigidity of work piece
4. Provision for advancing of cutting tool
5. Clearance recesses
6. Several work piece can be set up to be machined simultaneously
7. External surfaces of revolution upset heads , flanges , and shoulders should be extensively applied to reduce machining and to save metal
8. Retaining centre holes on the finished components
9. Elements of shank design should be unified
10. Spherical convex surfaced

Examples of Design for machining

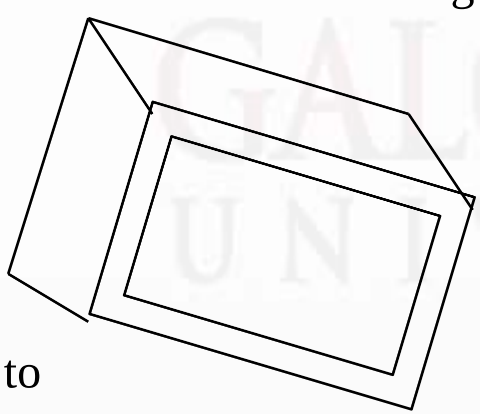


Bad design
2 different techniques required

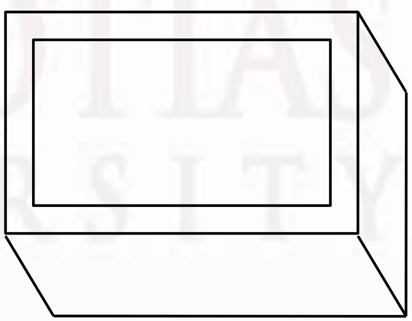


Better design
Profiles similar

Poor design



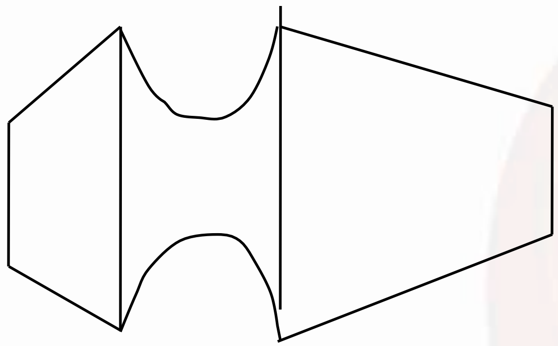
Sharp inside
Corners difficult to machine



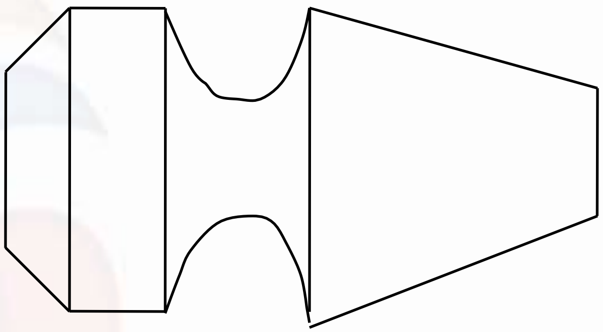
Better design

Chucking surface

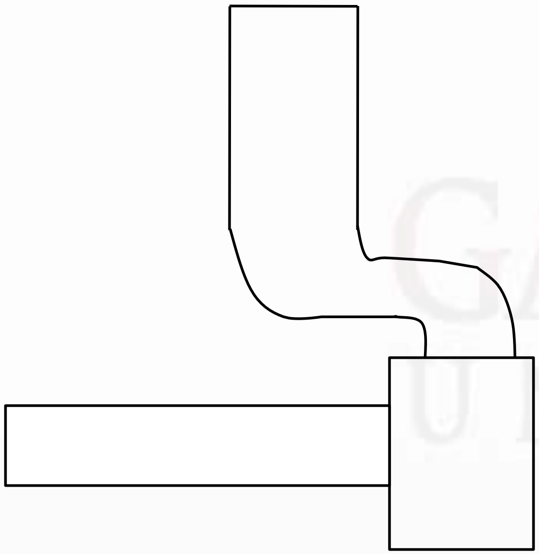
Poor no place for clamping



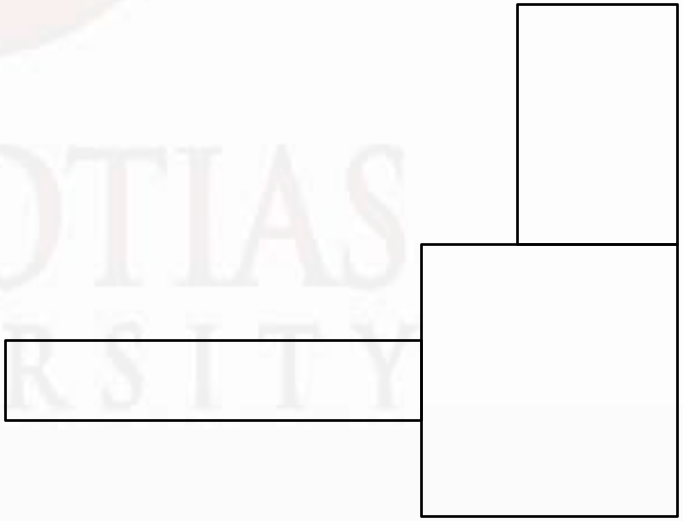
Better design Area for clamping



Restricted surface

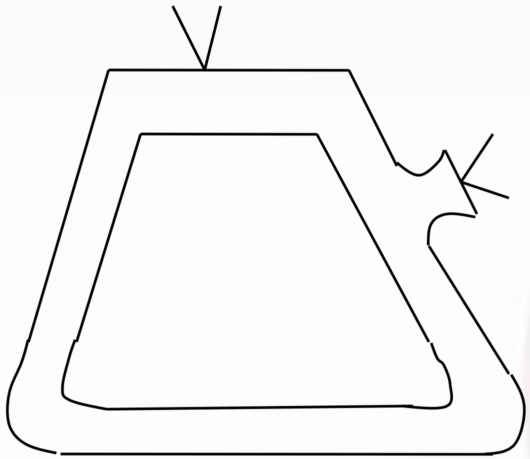


Poor design no



Good design

Simplifying drilling



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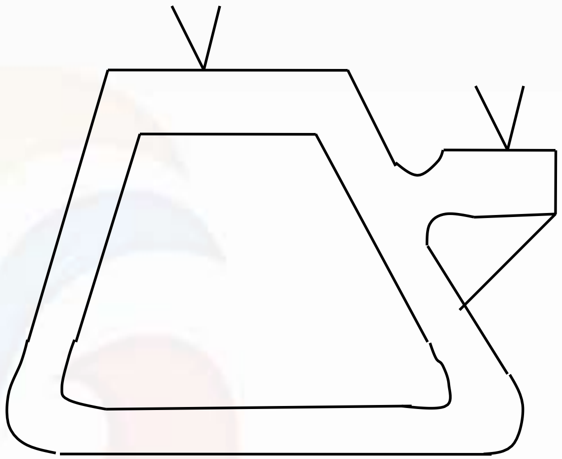
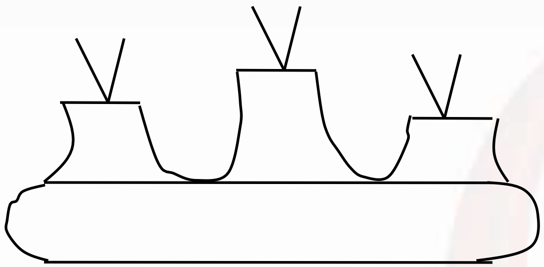


Good

Advantage of uniform pad height



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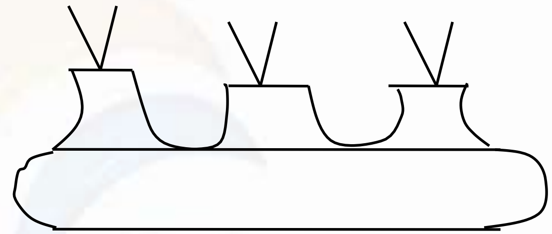

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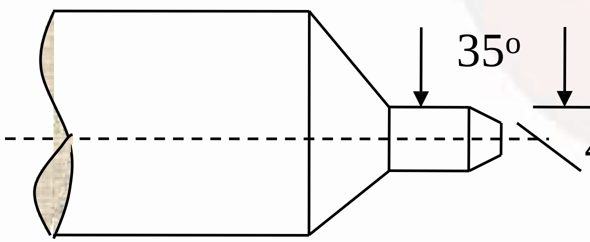

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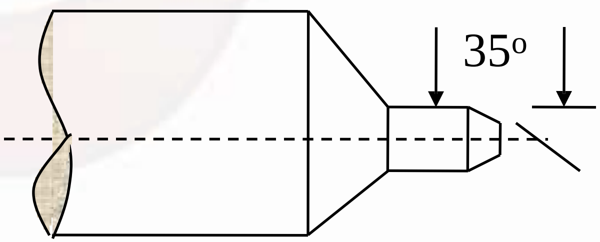


Good

Minimizing tooling

SELECTION OF CASTING PROCESS

PROCESS	MATERIALS	SECTION THICKNESS	WEIGHT	FINISH Ra
1. Sand mould	Fe,Low mp steels Cu , Al , Mg and alloys	Min: Al 4.8 mm Mg 4.0 mm Cu 2.4 mm Steels 6-12 mm Max : 1.2 meter	Min: 75-100g Max 2300 to 2700 kg	5-25 µm
2. Shell mould	Fe, Al and Cu alloys	Min : CI 3.18 mm Steel , Al , Mg 4.7 mm Max: 6.35 mm	Min 75-100 g Max : 13 kg usual : 45-90 kg	2-5 µm (ferrous) 150-250 µm
3. Investment (NF) Moulds	Hig mp steel alloys , Al , Ni	Min : 0.25–1.27 mm Max : 25-76 mm	Min:28.3kg Max: 2.3-2.7 kg	1.5-2.0 µm

SELECTION OF CASTING PROCESS

PROCESS	MATERIALS	SECTION THICKNESS	WEIGHT	FINISH Ra
5. Die castings	Non-ferrous Zn , Mg , Ni Cu , alloys Steel under Special condition	Min:Cu 1.2-2 mm Al. 0.7-2 mm Zn 0.4–1.27 mm	Min:28 g Max : 45 Kg Mg 18 Kg Zn 45 Kg Al	1-2 µm
6. Plaster mould casting	Non-ferrous metals , Al	Min 0.51 mm for CSA less	Min 28 g Max : 11 kg	30-50 µ inch
7. Centrifugal casting	Al metals	Min 1.5 – 6.35 mm Max:101.6 mm	Min:1.35 kg Centrifugi 100 g Max : 10 tons	5-25 µm
8. Slush mould	only non-ferrous metals	Min:1.58 mm Max:3.18 mm	Min:28.3 g Max:2.3 to 4.5 kg	1-2 µm

DESIGN Considerations for Casting

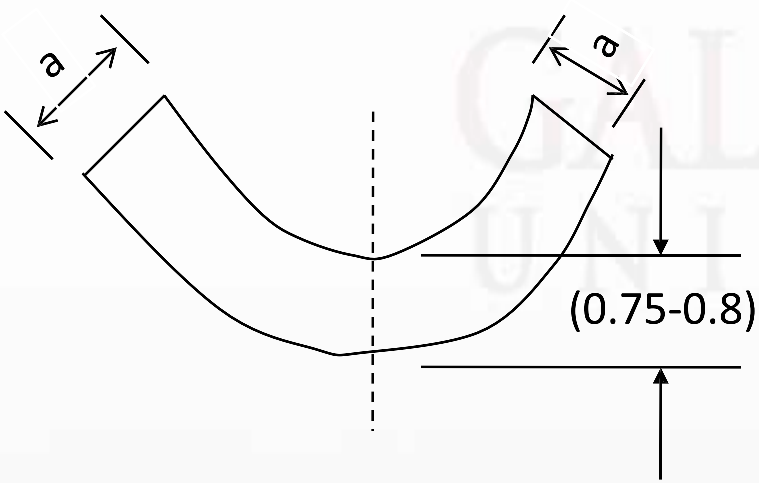
6. One datum surface along each of the three space coordinates

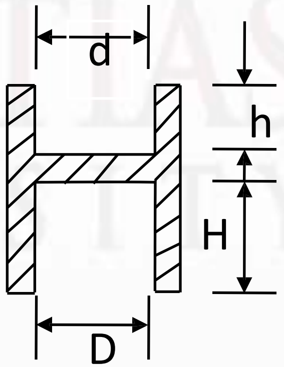
7. The size and weight of casting , type of alloy employed , and the casting method should be considered for designing wall thickness

8. Rib design depends on the overall dimensions of the casting and their size is in definite relation to wall thickness

9. Corner radii at junctions may range from 2 mm to 120 mm depending on overall dimensions and the angle between them

10. Rate of cooling for outside corners is always higher than that of inside corners





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Thank you