DESIGN FOR MANUFACTURING AND ASSEMBLY

Course Code:A70339,JNTUH R-15

IV B-TECH, I-SEM

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UNIT I

INTRODUCTION
DESIGN PHILOSOPHY
DEFINITION OF DESIGN

UNIT 1

"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 → calculation of behavior of part

⇒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

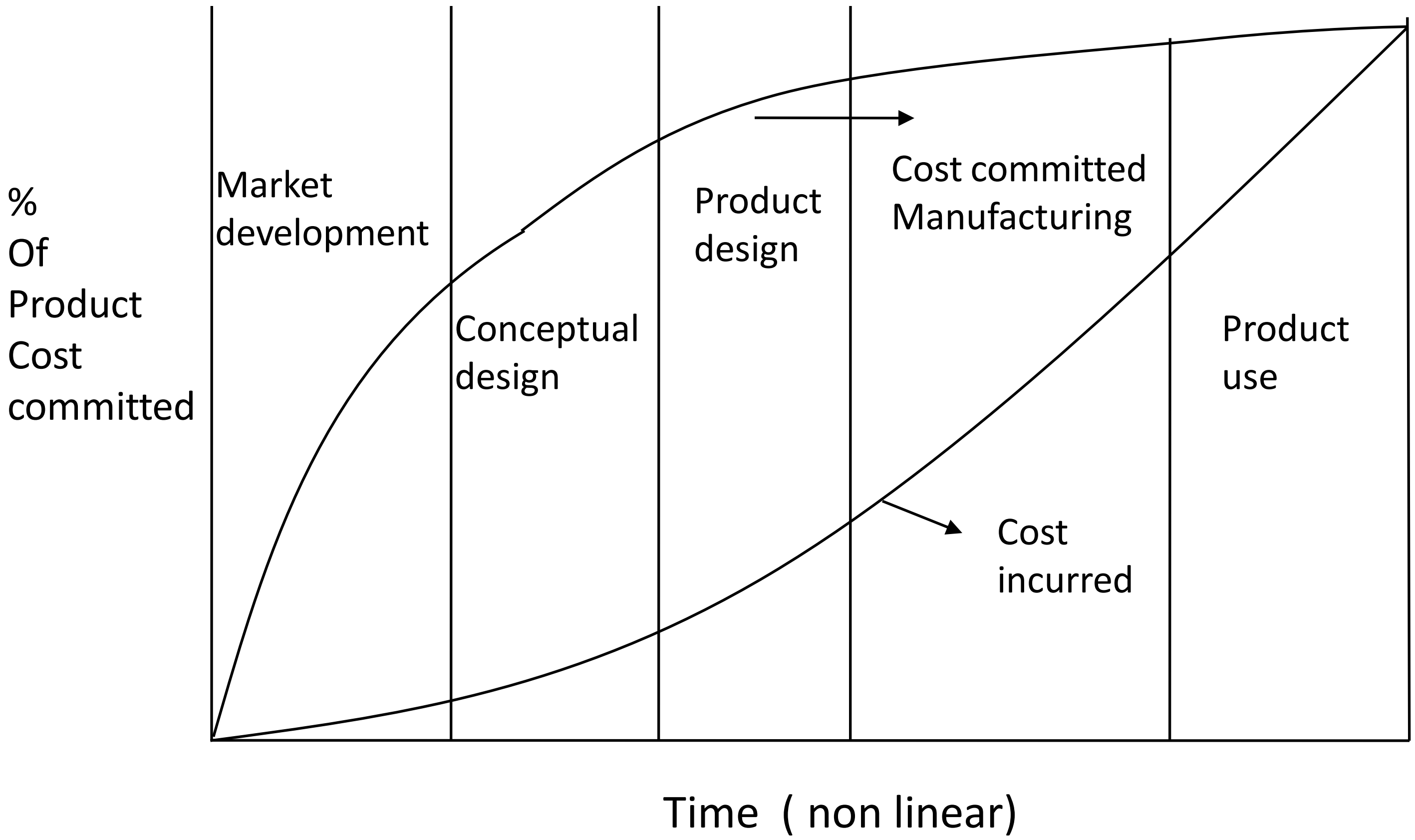
4 Compromise

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

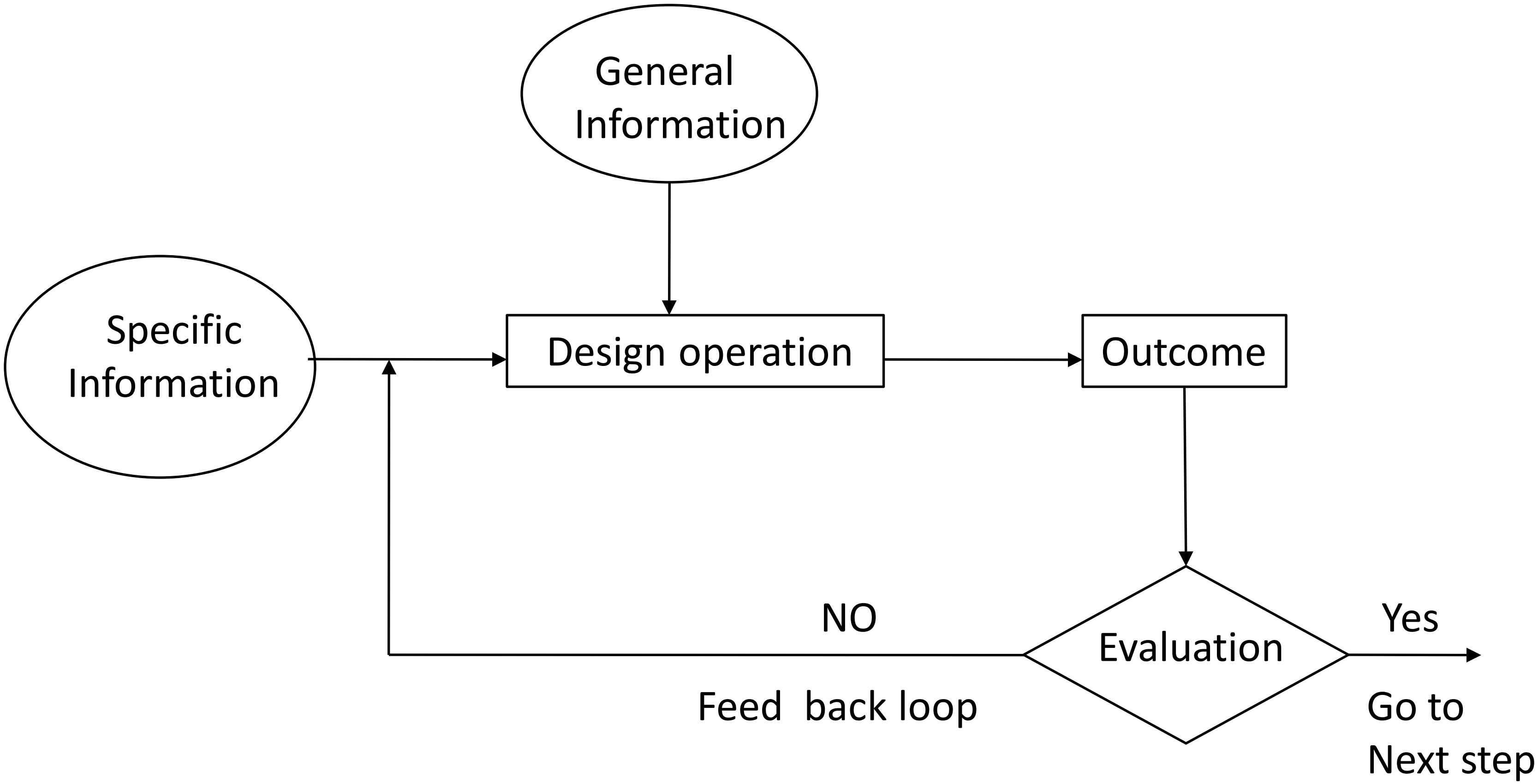
“ Decisions made in the design process cost very little in terms of the overall product cost but have a major effect on the cost of the product.”

“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

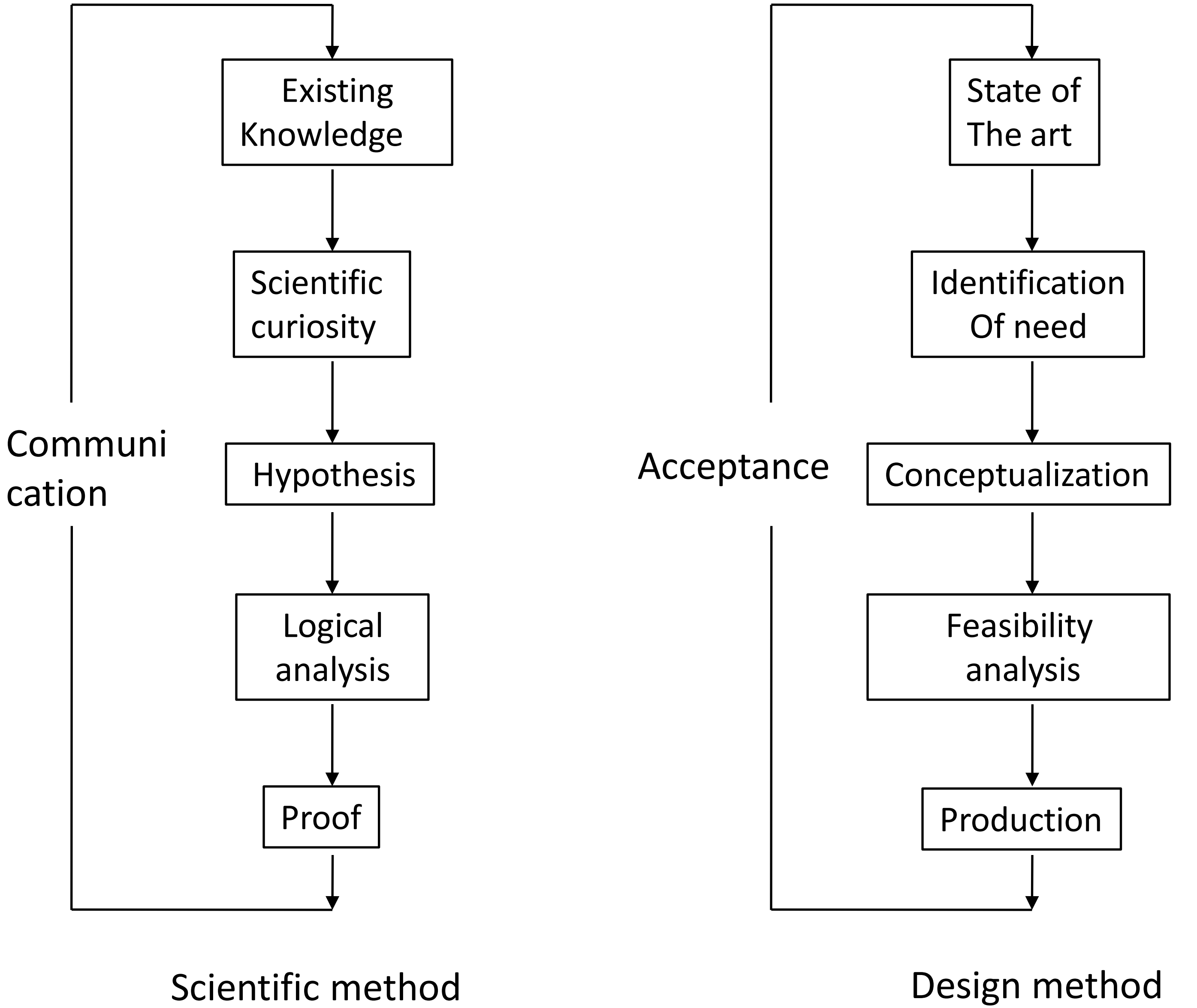
Original design	→	Innovation eg: Microprocessor
Adaptive design	→	Novel application eg: inkjet printing concept for rapid prototyping
Redesign	:	Without any change in concept of the original design
variant design	:	changing some of the design parameters
Selection design	:	Selecting the components with 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



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

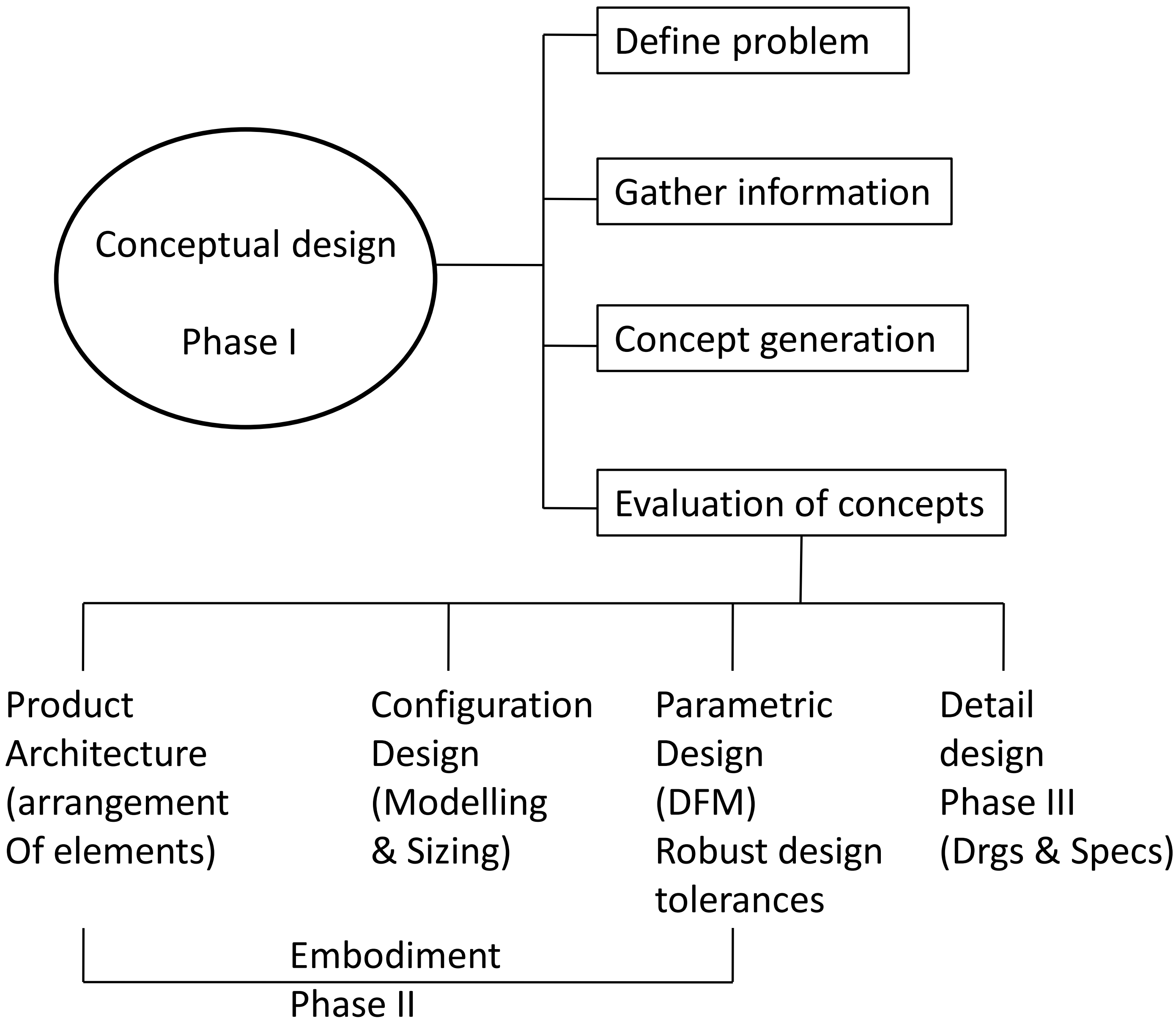
Good Design

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
6) Formal optimization
7) Projections for future
8) Prediction of system 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

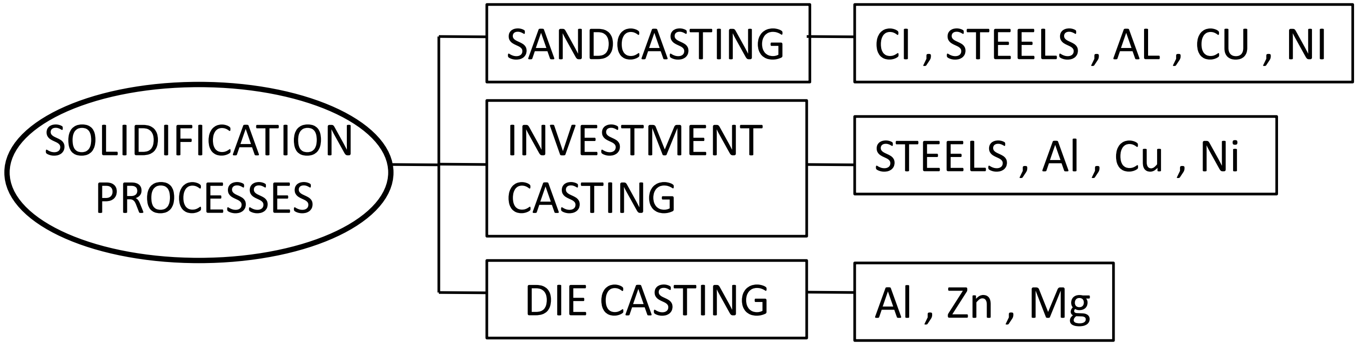
(4) Service or environment requirements

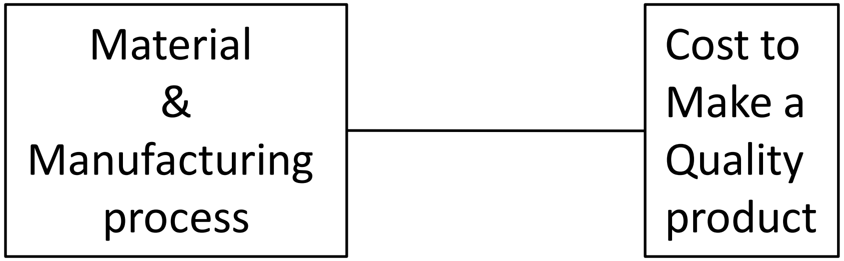
(5) Appearance factors

(6) Accuracy factors

SELECTION OF MANUFACTURING PROCESSES

COMPATIBILITY BETWEEN PROCESSES AND MATERIALS





SELECTION OF MANUFACTURING PROCESSES

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

Creative methods for design

1) Checking concept ideas for feasibility
2) Systematic methods for designing
a) Functional decomposition and synthesis (logical)
b) Morphological analysis (alternatives)
c) Creative problem solving
d) Axiomatic design
e) Design optimization
f) Decision based design

UNIT II
MACHINING PROCESS

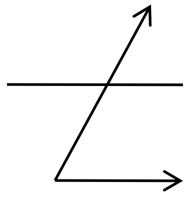
OVERVIEW OF VARIOUS MACHINING PROCESSES

“REMOVAL OF MATERIAL TO GIVE REQUIRED SHAPE”

1. CUTTING MOTION – RELATIVE MOTION BETWEEN WORK PIECE AND TOO
2. FEEDING MOTION – FRESH SURFACE FOR CUTTING TO THE TOOL

GENERATRIX → CUTTING

DIRECTRIX → FEED



SHAPING AND PLANNING , BROACHING

TURNING

DRILLING

MILLING

GRINDING

LAPPING

HONING

SUPER FINISHING

ABRASIVE JET MACHINING

ULTRASONIC MACHINING

ELECTRO CHEMICAL MACHINING

ELECTRO DISCHARGE MACHINING

EECTRON BEAM MACHINING

LAZER BEAM MACHINING

MACHINABILITY – EASE OF MATERIAL REMOVAL

FACTORS :
1) WORK PIECE MATERIAL
2) TOOL MATERIAL AND GEOMETRY
3) TYPE OF MACHINING
4) OPERATING CONDITIONS

DFM GUIDE LINES FOR MACHINING

1) MINIMIZE AREA OF MACHINING
2) SEQUENCE OF MACHINING (SOFTWARE)
3) UTILIZE STANDARD COMPONENTS AS MUCH AS POSSIBLE
4) PRESHAPE THE WORKPIECE – USE CASTING , FORGING , WELDING ETC
5) USE STANDARD PRESHAPED WORKPIECEES
6) EMPLOY STANDARD MACHINED FEATURES RAW MATERIALS
   1) CHOOSING TO REDUCE COST
   2) USE RAW MATERIAL IN STANDARD FORMS COMPONENT DESIGN

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

ROTATIONAL COMPONENTS

1) CYLINDRICAL SURFACES CONCENTRIC , PLANE SURFACES
   NORMAL TO THE COMPONENTS AXIS
2) DIAMETER OF EXTERNAL FEATURES INCREASE FROM
   THE EXPOSED FACE OF THE WORK PIECE
3) DIAMETER OF INTERNAL FEATURES DECREASE FROM
   THE EXPOSED FACE OF THE WORK PIECE
4) INTERNAL CORNERS – RADII EQUAL TO THE RADIUS OF
   THE STANDARD ROUNDED TOOL CORNER
5) AVOID INTERNAL FEATURES FOR LONG COMPONENTS
6) AVOID COMPONENTS WITH VERY LARGE OR VERY SMALL L/D RATIOS

NON – ROTATIONAL COMPONENTS

1. **PROVIDE A BASE FOR WORK HOLDING AND REFERENCE**
2. **EXPOSED SURFACES CONSIST OF A SERIES OF MUTUALLY ┘r PLANE SURFACES $||^{lel}$ to and normal to base**
3. **ENSURE THAT INTERNAL CORNERS NORMAL TO THE BASE HAVE A RADIUS EQUAL TO A STANDARD TOOL RADIUS**
   ENSURE THAT FOR MACHINED POCKETS , THE INTERNAL CORNERS NORMAL TO THE BASE HAVE AS LARGE A RADIUS AS POSSIBLE
4. **RESTRICT PLANE–SURFACE MACHINING (SLOTS , GROOVES ETC) TO ONE SURFACE OF THE COMPONENT**
5. **AVOID CYLINDRICAL BORES IN LONG COMPONENTS**
6. **AVOID MACHINED SURFACES ON LONG COMPONENTS BY USING WORK MATERIAL PERFORMED TO THE CROSS SECTION REQUIRED**
7. **AVOID EXTREMELY LONG OR EXTREMELY THIN COMPONENTS**
8. **ENSURE THAT IN FLAT OR CUBIC COMPONENTS , MAIN BORES ARE NORMAL TO THE BASE AND CONSIST OF CYLINDRICAL SURFACES DECREASING IN DIAMETER FROM THE EXPOSED FACE OF THE WORK PIECE**
9. **AVOID BLIND BORES IN LARGE CUBIC COMPONENTS**

ASSEMBLY

1) ENSURE THAT ASSEMBLY IS POSSIBLE
2) ENSURE THAT EACH OPERATING MACHINED SURFACE ON A COMPONENT HAS A CORRESPONDING MACHINED SURFACE ON MATING COMPONENT
3) ENSURE THAT INTERNAL CORNERS DO NOT INTERFACE WITH A CORRESPONDING EXTERNAL

ACCURACY AND SURFACE FINISH

1) SPECIFY WIDEST TOLERANCES AND ROUGHEST SURFACE THAT WILL GIVE THE REQUIRED PERFORMANCE FOR OPERATING SURFACES
2) ENSURE THAT SURFACES TO BE FINISH GROUND ARE RAISED AND NEVER INTERSECT TO FORM INTERNAL CORNERS

DIMENSION TOLERANCES AND SURFACE FINISH

FUNCTION INTENDED FOR MACHINED SURFACE

MANUFACTURING COST INCREASES UNNECESSARILY IF TOO CLOSE TOLERANCES
OR TOO SMOOTH FINISH IS GIVEN CRITERIA SHOULD BE ACCEPTABLE PERFORMANCE

GUIDELINES

1. TOLERANCES 0.127 TO 0.25 MM CAN BE READILY OBTAINED
2. TOLERANCES 0.025 TO 0.05 MM ARE SLIGHTLY MORE DIFFICULT TO OBTAIN
   AND CAN INCREASE PRODUCTION COST
3. TOLERANCES 0.0127 MM OR SMALLER REQUIRE GOOD EQUIPMENT AND
   SKILLED OPERATORS AND ADD SIGNIFICANTLY TO PRODUCTION COSTS

SURFACE FINISH : 1µm ARITHMATICAL MEAN AND BETTER WILL REQUIRE SEPARATE

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

$$t_m = l_w / fn_w$$

$l_w \rightarrow$ 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

$Tm = 0.18\, l_w / [\, n_w \, (Ra.r_\varepsilon)^{0.5}]$

Machining time inversely proportional to $\sqrt{\text{surface finish}}$
Machining cost increases with lesser surface roughness

Designing for machining ease

Machinability

1) Hardness → steels below 300 HB are easy to machine
2) Microstructure → High carbon steels → Tool wear
   Cast Iron → good finish(due to free graphite)
3) Free cutting properties
   MnS inclusious in steel → free machining
   Pb in brass → free machining
4) Ductility → Discontinuous or powdery
   Chip show high machinability
   Continuous chips – harm to operator

Machinability index or rating Metal removed rate ratio

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

11.

a) Through holes are to be used whereever possible
b) Holes should not be located closer to a certain minimum distance from an adjacent wall of the part
c) Centre distances of holes to be specified considering the possibility of using multi spindle drilling heads
d) Holes to be drilled should have their top and bottom surface square to the hole axis to prevent drill breakage
e) Several holes along same axis
f) In drilling holes at the bottom of a slot , their dia should be less by 0.5-1 mm than slot width
g) In stepped holes , maximum accuracy should be specified for the through step
h) Concave spherical surfaces should have through hole or blind hole
i) Avoid recesses

12) Threads

a) Entering chamfer on threaded holes

b) No. of incomplete threads in a blind hole with no recess should be equal to three for Grey Iron Casting and five for steel parts

c) A neck at the end of a thread is not required for milled threads

d) Preferred thread standards should pertain

e) Flat surfaces

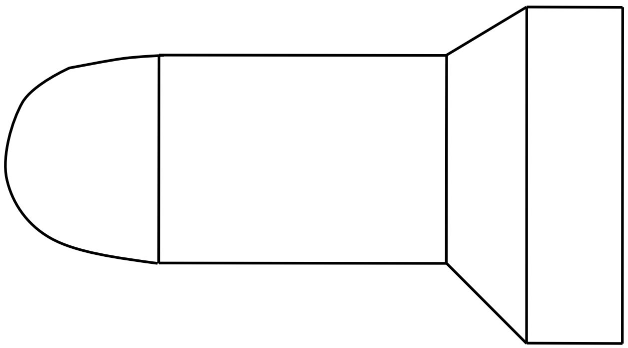
    a) Uniform and impact less chip removal

    b) Size of machined flat surface should ensure using of standard milling cutters

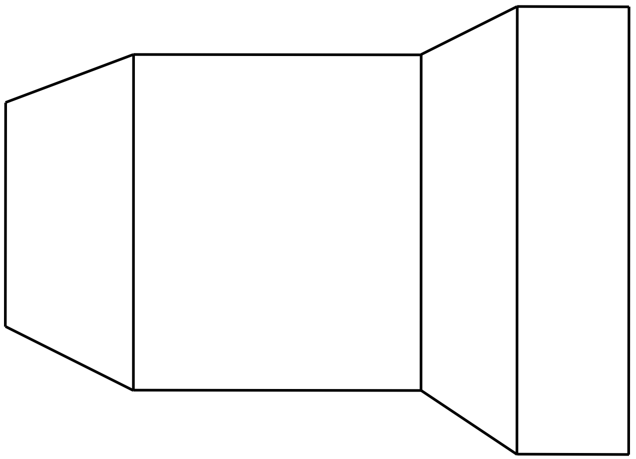
Goals of design for Machining

1. Reduce machining time
2. Reduce material costs
3. Reduce tooling costs
4. Reduce setup cost

Examples of Design for machining

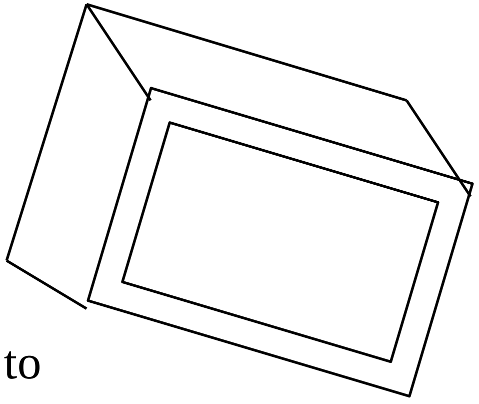


Bad design
2 different techniques
required



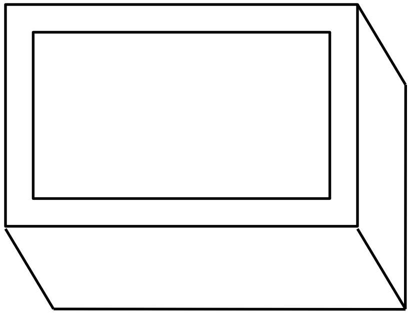
Better design
Profiles similar

Poor design



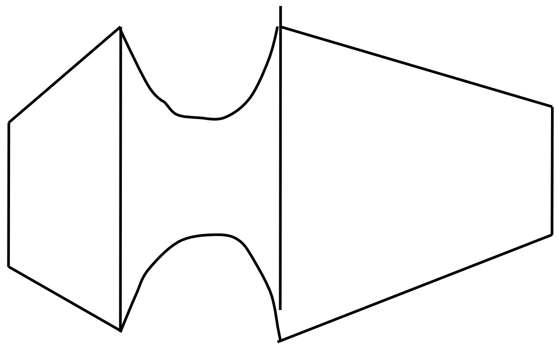
Sharp inside
Corners difficult to
machine

Better design

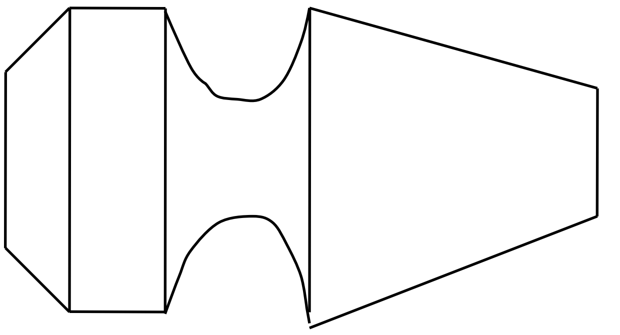


Chucking surface

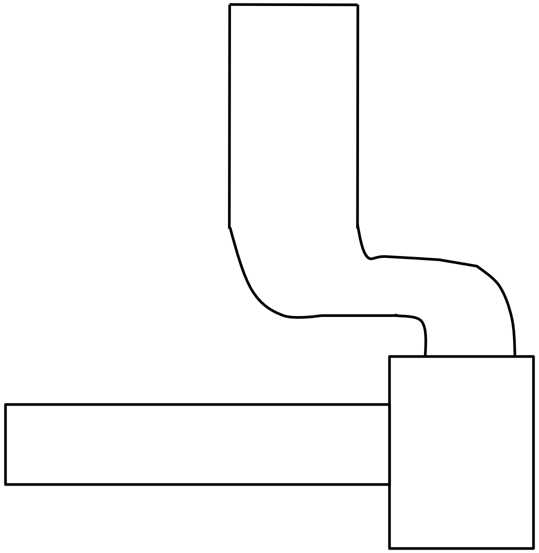
Poor no place for clamping



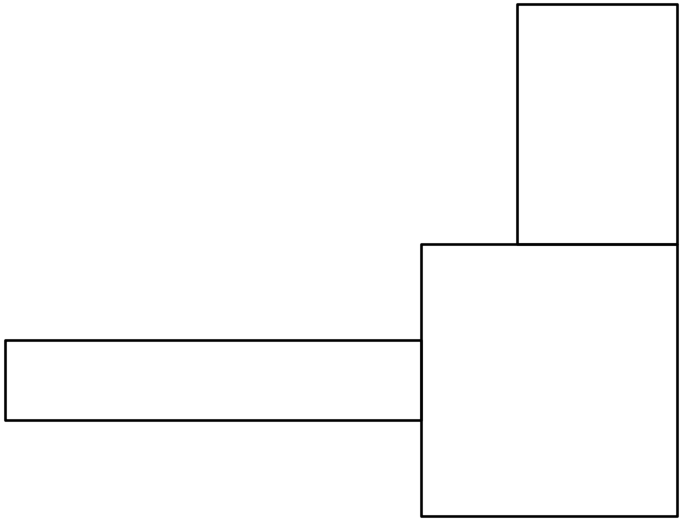
Better design Area for clamping



Restricted surface

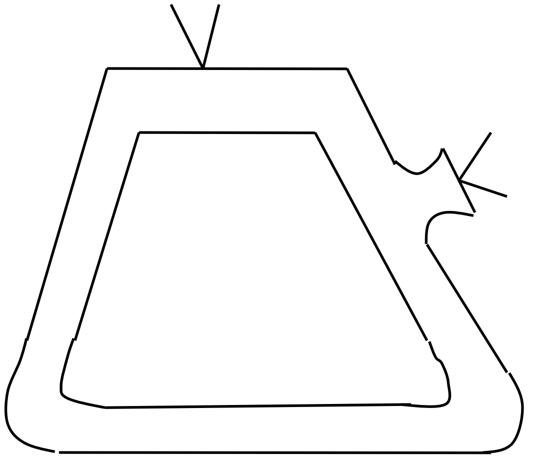


Poor design no access

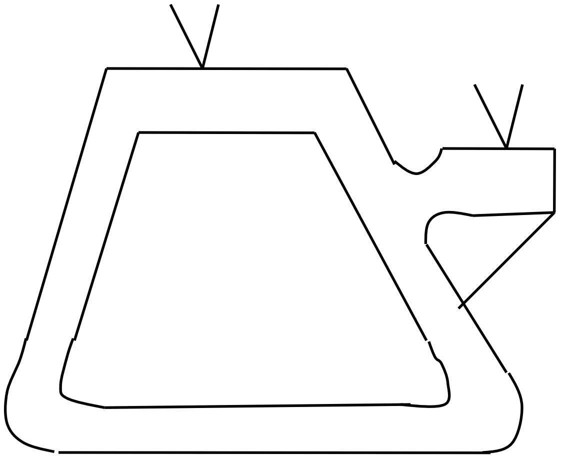


Good design

Simplifying drilling

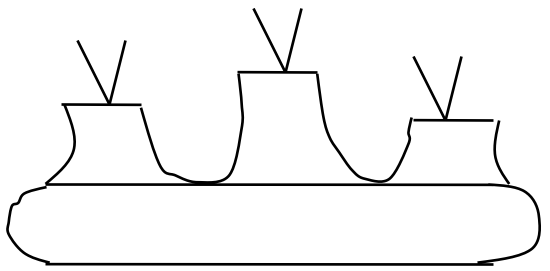


Poor

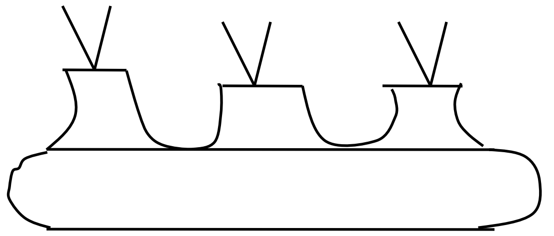


Good

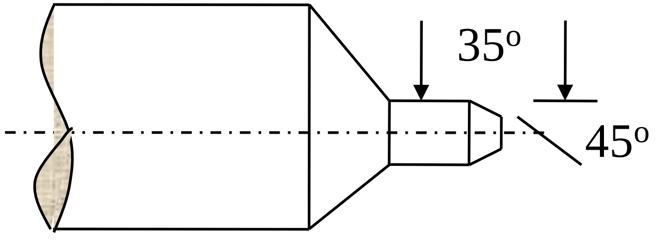
Advantage of uniform pad height



poor



Good



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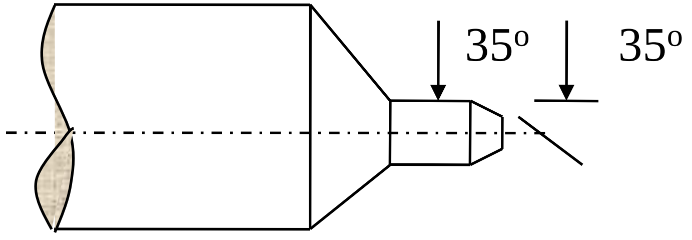

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Minimizing tooling

UNIT III

METAL CASTING

APRAISAL OF VARIOUS CASTING PROCESSES

MINIMUM DISTANCE BETWEEN RAW MATERIAL AND PRODUCT

POURING MOLTEN METAL INTO MOULD CAVITY AND AFTER SOLIDIFICAT
THE METAL ASSUMES SHAPE O MOULD CAVITY PRODUCT IS CALLED CAS

1) SAND CASTING
2) SHELL MOULDING
3) CERAMIC SHELL CASTING
4) INVESTMENT CASTING
5) CENTRIFUGAL CASTING
6) PERMANENT MOULD CASTING
7) GRAVITY DIE CASTING
8) LOW PRESSURE DIE CASTING
9) HOT CHAMBER DIE CASTING
10) COLD CHAMBER DIE CASTING

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

1. Pattern allowances : Free withdrawal of pattern : Draft on the vertical faces of casting based on surface height. For internal surfaces , draft values should be higher than those for external ones. Loose parts and complex parting lines should be avoided , if possible , if possible on the patterns.

2. Avoiding large horizontal surfaces on the top of mould , since gas evolved by the metal and in the mould may be trapped on the surfaces causing cavities and pinholes.

3. Avoiding abrupt changes in the path of molten metal

4. Equal rate of cooling in all section of castings and allow unrestricted shrinkage

5. Form of casting should be such that all feeding heads , risers , runners , sprues and gates can be easily cut off , all cores knocked out and core irons removed.

DESIGN Considerations for Casting

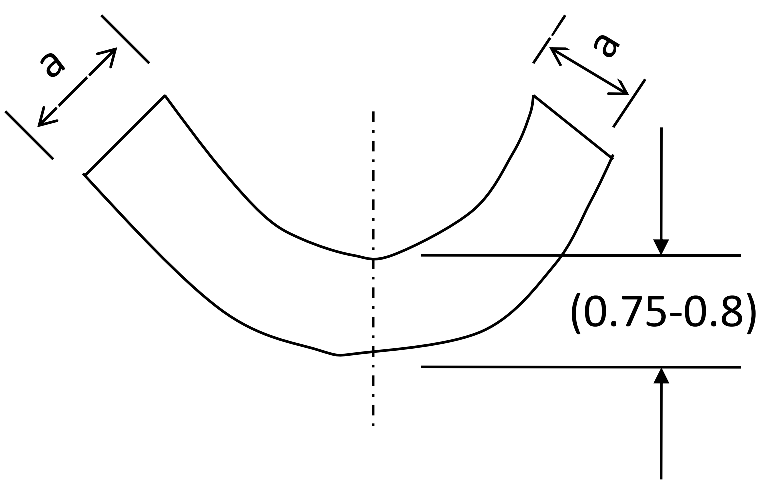
6. One datum surface along each of the three space coordinates

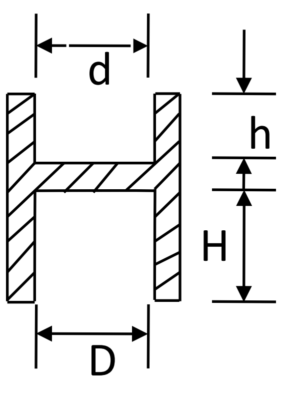
7. The size and weight of casting , type of alloy employed , and the casting method should be considered for designing wall thickness

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





DESIGN Considerations for Casting

$H \leq D$	$H \leq 0.5D$
M/C moulding	$H \leq 0.15d$

Unify cores when large number of core cavities are present in the casting

11. Bosses are provided at places where holes are to be drilled

Design principles for die casting

1. Die casting should be thin walled structures
   Zn →1 to 1.5 mm
   Al,Mg → 30-50% thicker
   Cu → 2 to 3 mm thick
   Fine grain structure with minimum amount of porosity and good mechanical properties.
   Large die castings are designed with 5 mm thick walls and sections with 10 mm thick

2. As a general rule thickness of projections where they meet main wall should not exceed 80% of the main wall thickness

3. Features projecting from the side walls of casting should not , if possible lie behind one another when viewed in the direction of the die opening

4. Internal wall depressions or internal undercuts should be avoided in casting design ; since moving internal core mechanisms are virtually impossible to operate with die casting

SUMMARY OF DESIGN CONSIDERATIONS

(I) Mould heat transfer characteristics

(II) Metals thermal conductivity

(III) Metals freezing range / crystallization

(IV) Hot spots / location of risers ; hot tearing

(V) Control of directional solidification

Design consideration

(i) Maintain uniform section thickness

(ii) Ribs and webs may be staggered to eliminate hot spots

(iii) At points of metal concentration cored holes may be provided

(iv) Design to promote directional solidification

(v) Avoid thin sections between heavy sections and risers

(vi) Prevent occurrence of isolated hot spots difficult to feed

(vii) Keep plates in tension and ribs in compression according to performance requirement

(viii) Minimum section thickness is determined by the flowability of metal being cost

Casting tolerances

Factors:

1) Casting design
2) Material being cast
3) Condition of pattern and material
4) Mould material
5) Assembly of mould boxes
6) Mould swelling
7) Felting
8) Heat treatment

TOLERANCES FOR SAND CASTINGS

	mm (upto 300 mm thick
Steel castings	1.5
Cast Irons	1.2
Alluminium alloys	0.8
Copper alloys	2.4

Tolerances expected on shell moulds and
Sand moulds for Grey Iron and steel castings

Basic size	Tolerance in mm sand moulds hand moulding	Machine moulds Metal / Epoxy	Shell moulding
0-25 mm	2-2.5	1.2-2.0	0.8-1
26-50 mm	2.5-3.5	2-2.5	1-1.2
51-100	3.5-4.5	2.5-3.5	1.2-1.5
200 mm	4.5-6.0	3.5-4.5	1.5-1.8
400 mm	6-8	4.5-6.0	1.8-2.4
800 mm	8-11	6-7.5	2.4-3.2

SOLIDIFICATION

Directional solidification :

Factors :

1. High thermal conductivity and high heat capacity mould material High degree of progressive solidification

2. Short liquidous to solidous range solidifying metals – high degree

3. Low thermal conductivity of solidifying metal high degree

4. High solidification temperature – steep thermal gradient – high degree

Measures :

1. Proper gating and risering
2. Control of pouring rate and temperature
3. Differential heating using exothermic riser
4. Differential cooling using chills
5. Use of padding
6. Use of mould materials with different thermal conductivities for different mould parts

Requirements for sound casting

1. Progressive solidification
2. Directional solidification Proceed from most distant points towards the riser
3. temperature gradient to be steep enough to keep the angle α large to eliminate shrinkage void
4. If progressive solidification is not proper all the points from outer to inner of the casting do not reach centre line at the same time , causing centre line shrinkage / micro shrinkage / shrinkage porosity

Simulation of solidification

Complete and physically accurate simulation of metal casting process is difficult programs

AUTO CAST	BOMBAY
CAP/WRAFTS	USA
CAST FLOW	FINLAND
JS CAST	AUSTRALIA
MAGM SOFT	JAPAN
MAVIS	GERMANY
MAVIS	UK

Casting simulation is a powerful tool to visualize mould filling , solidification and cooling , predicting defect location.

Trouble shooting existing castings and developing new castings

INPUT DATA

1) 3D CAD MODEL OF CASTING
2) MATERIAL
3) GEOMETRY
4) PROCESS

GEOMETRY
(I) PART FEACTURES
CONVEX AND CONCAVE REGIONS
CORED HOLES
POCKETS
BOSSES
RIBS
VARIOUS JUNCTIONS (2D AND 3D)

THESE AFFECT SOLIDIFICATION OF METAL

(II) LAYOUT IN MOULD
NO. OF CAVITIES , LOCATIONS (INTER CAVITY GAP AND CAVITY TO WALL GAP)
(III) FEED AIDS
INCLUDING NUMBER , SHAPE , SIZE , LOCATION OF INSULATING SLEEVES AND COVERS , CHILLS (EXTERNAL AND INTERNAL) AND PADDING

THESE INFLUENCE RATE OF HEAT TRANSFER MATERIAL

(I) THERMO-PHYSICAL PROPERTIES OF METAL ; DENSITY , SPECIFIC HEAT , THERMAL CONDUCTIVITY , LATENT HEAT , VOLUMETRIC CONTRACTION DURING SOLIDIFICATION , COEFFICIENT OF LINEAR EXPANSION VISCOSITY AND SURFACE TENSION
THERMO PHYSICAL PROPERTIES OF MOULD :
CORE , AND FEED AID MATERIALS , INCLUDING DENSITY , SPECIFIC HEAT , THERMAL CONDUCTIVITY , COEFFICIENT OF LINEAR EXPANSION AND MODULOUS EXTENSION FACTOR
(II) CHANGES IN PROPERTIES WITH COMPOSITION AND TEMPERATURE , RELEVANT TRANSFORMATIONS (GRAIN SHAPE , STRUCTURE , DISTRIBUTION) AND RESULTANT MECHANICAL PROPERTIES

PROCESS :

(1) FLOW PATTERN OF MOLTEN METAL :

(2) SOLIDIFICATION (HEAT TRANSFER)

(3) SOLID STATE COOLING

(4) PROCESS PARAMETERS

(COMPOSITION OF METAL , MOULD SIZE , MOULD COMPACTION , MOULD COATING , MOULD TEMPERATURE , POURING TEMPERATURE AND RATE , MOULD COOLING , SHAKE OUT ETC.

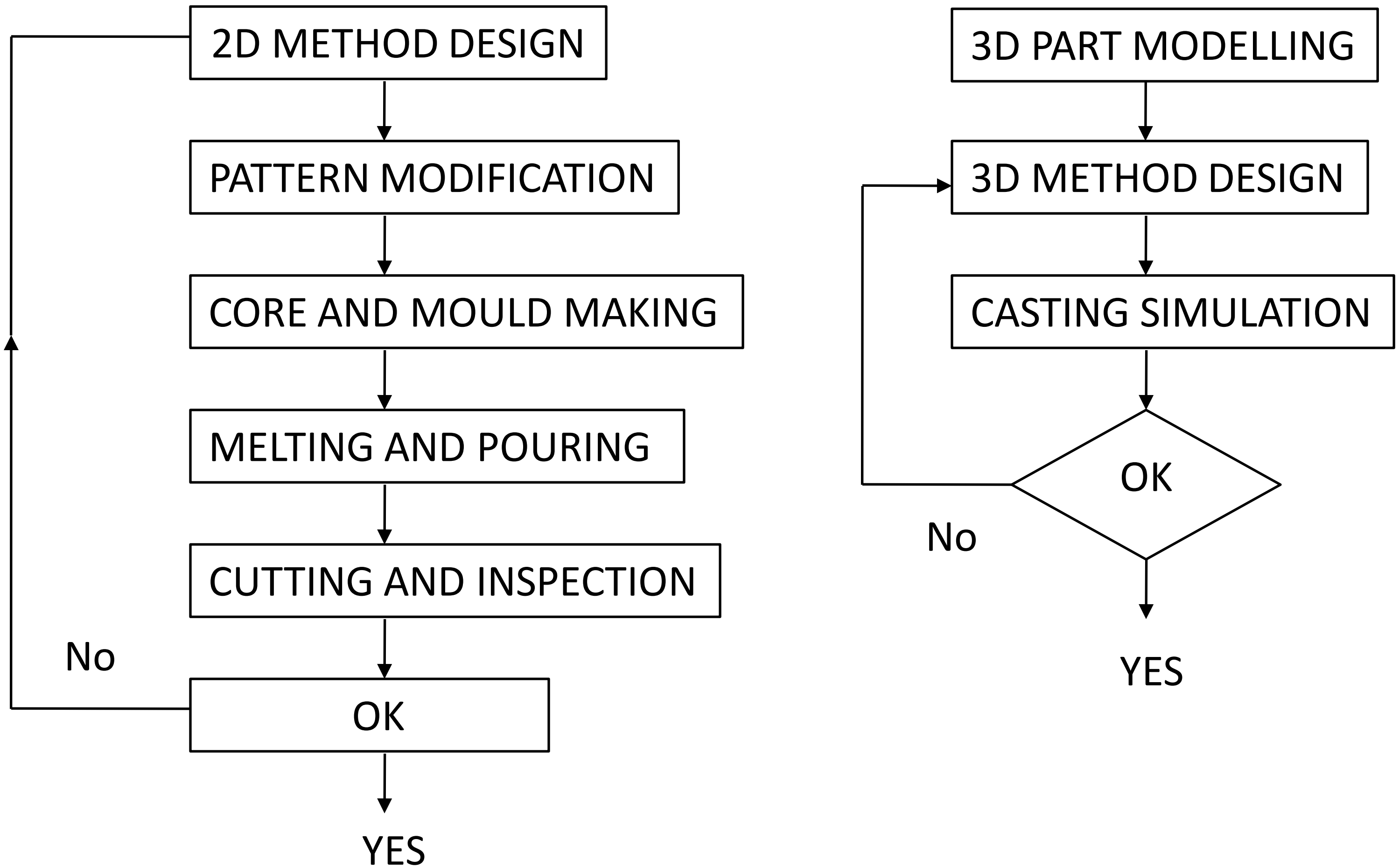
OUTPUT OF SIMULATION PROGRAMME

(1) ANIMATED VISUALIZATION OF MOULD FILLING
CASTING SOLIDIFICATION
COOLING TO ROOM TEMPERATURE
MOULDING FILLING SIMULATION
PREDICTING ; TOTAL FILLING TIME ,
MOULD EROSION , INCOMPLETE FILLING
AIR ENTRAPMENT
BLOW HOLES CAUSED BY ENTRAPMENT OF GASES OWING TO POOR VENTING , - DIFFICULT TO PREDICT
CASTING SIMULATION
SHOWS THE TEMPERATURES , GRADIENTS , COOLING RATES – PREDICTION OF SHRINKAGE , MICROSTRUCTURE , MECHANICAL PROPERTIES , RESIDUAL STRESSES , DISTORTION

SIMULATION CANNOT IMPROVE METHOD BY ITSELF

MAIN APPLICATIONS
(1) CASTING TROUBLE SHOOTING
(2) METHOD OPTIMIZATION

SHOPFLOOR   VIRTUAL CASTING



Part design → "decides fate"
Modelling helps in improving manufacturability without affecting functionability

BENEFITS OF CASTING SIMULATION

1) CUSTOMER SATISFACTION
2) FASTER DEVELOPMENT
3) LOWER REJECTION
4) HIGHER YIELD
5) COST REDUCTION

BOTTLENECKS
1) TRAINED MANPOWER REQUIRED
2) TECHNICAL SUPPORT
3) MAINTENANCE
4) INITIAL COST

MAJOR ADVANTAGES :
1) REDUCED SHOP FLOOR TRIALS
2) VALUE ADDITION
3) KNOWLEDGE MANAGEMENT

INDIA : ONLY 5% USE SIMULATION WHERE AS GERMANY 90% USA 75%
HYDERABAD : SNIT (IIF R&D CENTRE)

GENERAL GUIDELINES FOR SAND CASTING (CH12 P538 BOOTHROYD)

1) COMPUTER – BASED SOLIDIFICATION MODELLING
2) SHAPE OF THE CASTING SHOULD ALLOW FOR ORDERLY SOLIDIFICATION
3) DIFFERENCE IN THICKNESSES OF ADJOINING SECTIONS SHOULD NOT EXCEED 2 TO 1%
4) WEDGE – SHAPED CHANGES IN WALL THICKNESS SHOULD NOT EXCEED TAPER 1 TO 4
5) THICKNESS OF BOSS OR PAD
6) RADIUS FOR GOOD SHRINKAGE CONTROL SHOULD BE FROM 1 ½ to 1/3 OF THE SECTION THICKNESS
7) TWO RIBS SHOULD NOT CAUSE EACH OTHER
8) A DRAFT OR TAPER OF FROM 6 TO 3 DEGREES IS REQUIRED ON VERTICAL FACES SO THAT PATTERN CAN BE REMOVED FROM MOULD

1. AVOID SHARP ANGLES AND MULTIPLE-SECTION JOINTS
2. DESIGN SECTIONS OF UNIFORM THICKNESS
3. PROPORTION INNER WALL THICKNESS
4. CONSIDER METAL SHRINKAGE IN DESIGN
5. USE A SIMPLE PARTING LINE
6. DEFINE APPROPRIATE MACHINING ALLOWANCE
7. USE ECONOMICAL TOLERANCES

DESIGN FOR DIE CASTING , INVESTMENT CASTING NEED TO BE UNDERSTOOD WITH REGARD TO FACTORS SPECIFIC TO THESE PROCESSES

UNIT IV

Forging : Design factors for forging

Forging : “Pastically deformed solid”

Design guidelines for closed – die forging

1. Vertical surfaces of a forging must be tapered to permit removal of the forging from die cavity external (5 to 7 ^{o}C) internal (7 to 10^{o}C)
2. The maximum flash thickness should not be greater than ¼ in or less than 1/32 in on average
3. Webs are the sections of a forging normal to the motion of the moving die and ribs are the relatively thin sections parallel to die motion. These features are easiest to form by the deforming metal when ribs are not too high and narrow and the web is relatively thick and uniform
4. The parting line , where the die halves meet , is an important design consideration because its location helps to influence grain flow , die costs , and die wear. For optimum economy it should be kept to a single plane if at all possible , since that will make die sinking , forging and trimming less costly.

5. Wherever possible in the design of forgings , as in the design of castings , it is desirable to keep the thickness of adjacent sections as uniform as possible. Rapid changes in section thickness should be avoided. To avoid defects like laps , cracks generous radii must be provided.
6. Most forging is done at elevated temperature where the flow stress of material is much lower than at room temperature. In order to account for oxidation , correcting for warpage and mismatch , and for dimensional mistakes due to thermal contraction or die wear , machining allowance has to be given.

Design guidelines for forging

"Net shape technology" Bulk deformation processes press is used for causing extensive bulk plastic deformation

Extrusion → high L/d ratio

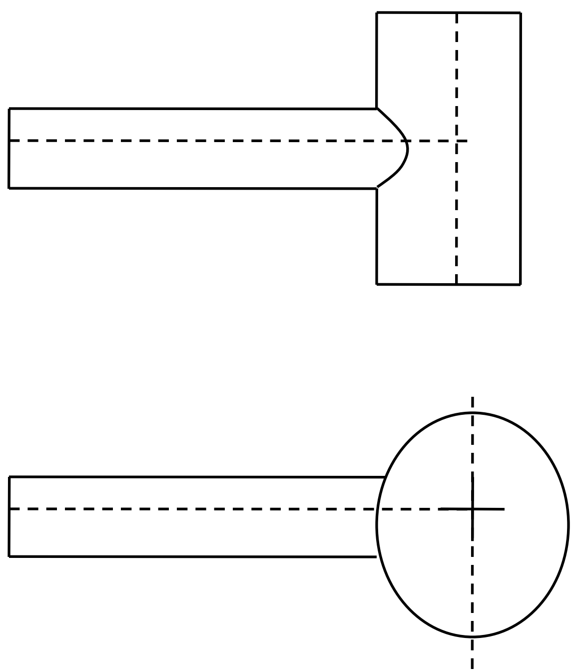
Drawing →

Rolling →

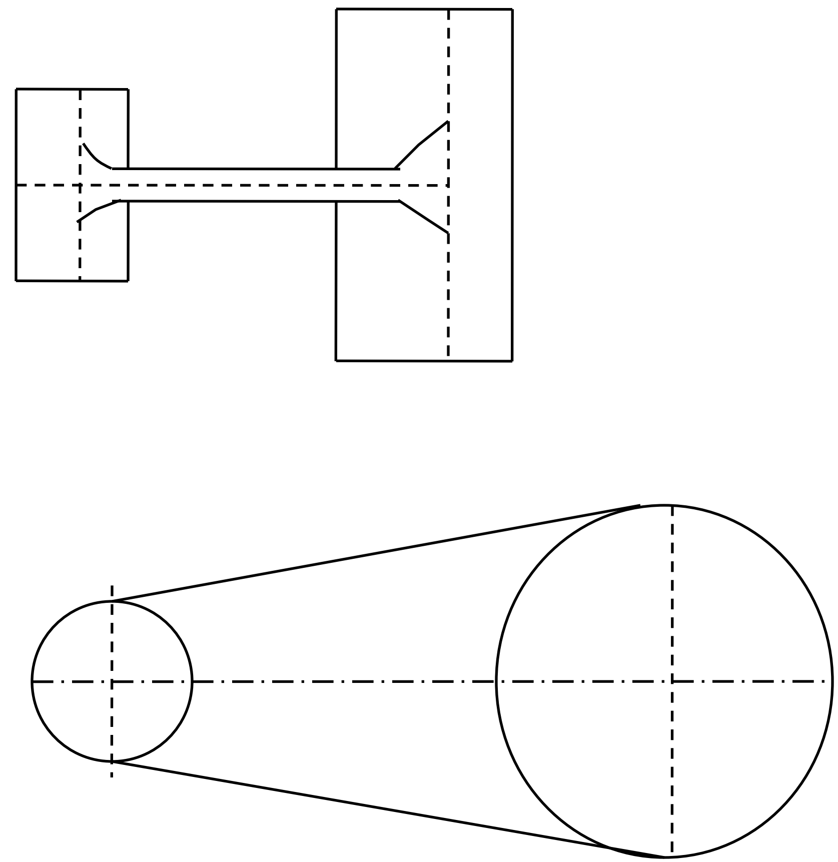
Generally hot working carried out Extensive plastic deformation causes metallurgical changes porosity closed up , grain structure and second phases are deformed and elongated in the principal directions of working , creating a fiber structure". Properties are not same on all directions of maximum plastic deformation(longitudinal) should be aligned with the direction of the part that needs to carry the maximum stress. Open die forging use flat dies for simple shapes.

Forging design guidelines

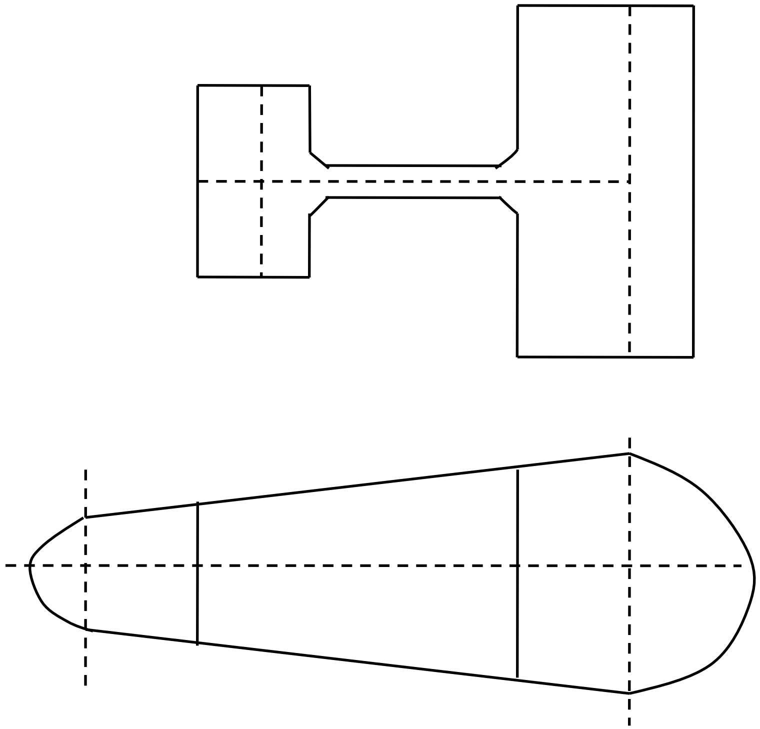
1. For flat die forging , intersections of two or more cylindrical elements should be avoided



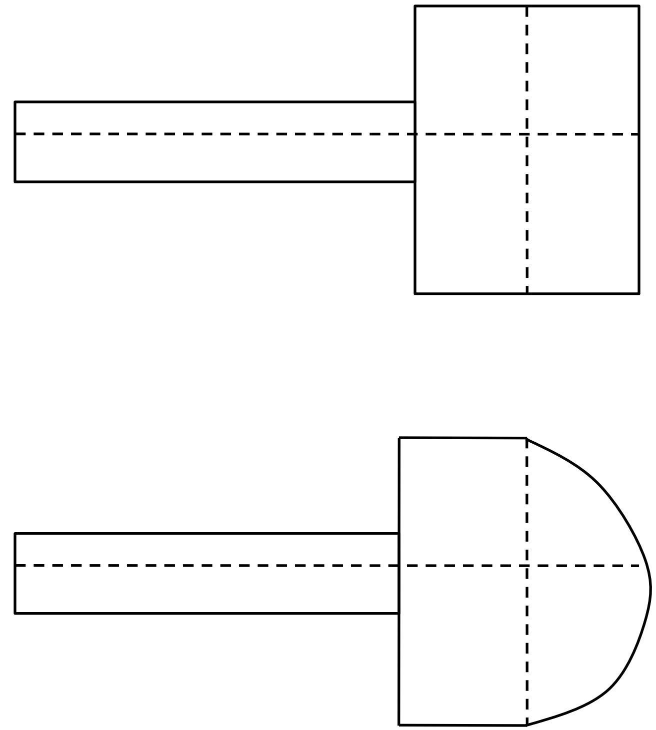
Undesirable



Undesirable



Desirable for flat die forging



Desirable for flat die forging

Ribbed cross sections should be avoided

Bosses , projections , pads etc should be avoided on the main surfaces of forging projects inside the prongs of fork type parts to be avoided.

2. Replace components having complex shape by units consisting of simple welded or assembled elements

DESIGNING FORGINGS FOR HORIZONTAL FORGING MACHINES

1. THE WALL THICKNESS OF FORGING WITH DEEP , THROUGH OR BLIND HOLES SHOULD NOT BE LESS THAN 0.15 OF THE OUTSIDE DIAMETER
2. REDUCTIONS IN CROSS-SECTION ALONG THE LENGTH OF FORGING SHOULD BE AVOIDED BECAUSE THEY IMPEDE METAL FLOW DURING FORGING PROCESS
3. SHANKS OF TAPER FORM ARE ALSO DIFFICULT TO FORGE AND THEY SHOULD BE REPLACED BY CYLINDRICAL SHANKS
4. VOLUME OF THE LOCATED AT THE ENDS OR IN THE MIDDLE OF A FORGING MUST NOT EXCEED THE VOLUME OF A BAR HAVING THE GIVEN DIAMETER ‘D’ AND LENGTH OF 10-12 d

5. DRAFT FOR THIS TYPE OF FORGING MAY BE VERY SMALL AND DRAFT OF 0.5^{O} IS SUITABLE FOR THE CYLINDRICAL SECTION OF THE FORGING UP-SET WITHIN PUNCH CAVITY AND OF A LENGTH MORE THAN 1 ½ OF THE DIAMETER. A DRAFT OF $0.5\text{-}1.5^{O}$ IS SUITABLE FOR SHOULDERS FORMED IN THE CIRCULAR IMPRESSIONS OF DIES AND $0.5\text{-}3^{O}$ ON THE WALL OF BLIND HOLES WITH A LENGTH OF 5 OR MORE DIAMETERS
6. TRANSITION FROM ONE SURFACE TO ANOTHER MUST HAVE FILLETS WITH RADII FROM 1.5-2 mm.
7. CARBON AND ALLOY STEEL FASTENERS AND SIMILAR PARTS HAVING AN ANNEALED HARDNESS 120-207 BHN ARE PRODUCED BY COLD HEADING

IN COLD HEADING , THE HEAD SHOULD BE SIMPLE FORM WITH A MINIMUM VOLUME AN DIAMETER. CLOSE TOLERANCE SHOULD NOT BE SPECIFIED FOR THE HEADED PARTS AS DIE LIFE WILL BE REDUCED. FILLETRADII 0.2 mm TO BE PROVIDED AT ALL CORNERS

DESIGN GUIDELINES FOR EXTRUDED SECTIONS

1) AREAS OF BILLET AND EXTRUSION ; OR CORRESPONDING DIAMETERS TO BE CONSIDERED (A_O , A_1 , d_O , d_1)
2) ENGINEERING STRAIN TO BE ACCOUNTED (A_O - A_1) / A_O
3) STRAIN RATE EFFECT TO BE CONSIDERED
4) HOT EXTRUSION TEMPERATURE AND ITS EFFECT ON OXIDATION ; FLOW OF MATERIAL , SURFACE FINISH
5) SELECTION OF TYPE OF EXTRUSION – COLD , HOT , IMPACT , HYDROSTATIC
6) SELECTION OF EXTRUSION PROCESS BASED ON MATERIAL

   EG :

   1) IMPACT EXTRUSION FOR SOFT METALS
   2) HOT EXTRUSION FOR STEELS
   3) COLD EXTRUSION FOR DUCTILE MATERIALS
   4) CLADDED EXTRUSION FOR ZIRCONIUM ALLOYS

EXTRUSION DESIGN TIPS

1. WALL THICKNESS :
   BASED ON STRENGTH AND COST PROFILES WITH UNIFORM WALL THICKNESS ARE THE SIMPLEST TO PRODUCE
   WALL THICKNESS WITHIN A PROFILE CAN BE VARIED
2. RADI USED CORNERS , SOFT LINES
3. BE SYMMETRICAL
4. HAVE A SMALL CIRCUMSCRIBING CIRCLE
5. NOT HAVE , DEEP , NARROW CHANNELS
6. SOLID PROFILES IF POSSIBLE
7. FEWER CAVITIES IN HOLLOW PROFILES
8. PROFILES – WIDTH TO HEIGHT RATIO 1:3
9. DECORATION
10. SYMMETRICAL SHAPE
11. NARROW SHAPES WITH DEEP GAPS CAN CAUSE PROBLEMS

DESIGN GUIDELINES FOR SHEET METAL BENDING

1) MINIMUM INSIDE RADIUS EQUAL TO MATERIAL THICKNESS
2) BEND RADIUS 4 TO 8 TIMES MATERIAL THICKNESS TO AVOID CRACKING
3) MINIMUM FLANGE LENGTH 4 TIMES MATERIAL THICKNESS
4) BEND RELIEF → LENGTH GREATER THAN RADIUS OF BEND

   THE BEND ALLOWANCE L_{BA}, THE LENGTH OF THE NEUTRAL AXIS IN BEND IS GIVEN BY

   $L_{BA} = \alpha \ (R_b + K_t)$

   α IS BEND ANGLE IN RADIANS ,

   R_b IS THE BEND RADIUS (MEASURED TO THE INSIDE OF THE BEND)

   and t is thickness of the sheet

   If Rb > 2t ; K=0.5

   If Rb > 2t ; K=0.5

   DURING BENDING THERE IS A "SPRING BACK" , TO ACCOUNT FOR THIS , THE METAL MUST BE BENT TO A SMALLER ANGLE AND SHARPER RADIUS , SO THAT WHEN THE METAL SPRINGS BACK , IT IS AT THE DESIRED VALUES.

   ANOTHER METHOD IS TO ADVANCE PUNCH MORE THAN WHAT IS REQUIRED TO BEND RADIUS
5) BENDING ACROSS "METAL GRAIN" AVOIDS CRACKING
6) BEND RADIUS SHOULD NOT BE LESS THAN SHEET THICKNESS

DESIGN GUIDELINES FOR BLANKING

1) SIMPLE BLANK CONTOURS TO BE USED AS DIE COST DEPENDS ON THE LENGTH AND THE INTRICACY OF THE CONTOUR OF BLANK
2) IT MAY BE LESS EXPERIENCE TO CONTRUCT A COMPONENT FROM SEVERAL SIMPLE PARTS THAN TO MAKE AN INTRICATE BLANKED PART
3) NOTCHING A BLANK ALONG ONE EDGE RESULTS IN AN UNBALANCED FORCE THAT MAKES IT DIFFICULT TO CONTROL DIMENSIONS AS ACCURATELY AS WITH BLANKING AROUND THE ENTIRE CONTOUR. USUAL TOLERANCES ON BLANKED PARTS ARE ± 0.075 mm
4) DIAMETER OF PUNCHED HOLES SHOULD NOT BE LESS THAN THE THICKNESS OF SHEET
5) MINIMUM DISTANCE BETWEEN HOLES OR BETWEEN HOLE AND THE EDGE TO THE SHEET THICKNESS
6) IF HOLES HAVE TO BE THREADED , THE SHEET THICKNESS MUST BE AT LEAST ONE-HALF THE THREAD DIAMETER

DESIGN GUIDELENES FOR STRETICHING AND DEEP DRAWING

1) DEEP DRAWING DEFORMATION CONDITIONS ARE DIFFERENT THAN IN STRETCHING
2) SUCCESS IN DEEP DRAWING IS ENHANCED BY FACTORS THAT RESTRICT THINNING : DIE RADIUS ABOUT 10 TIMES THE SHEET THICKNESS ; A LIBERAL PUNCH RADIUS , AND ADEQUATE CLEARANCE BETWEEN PUNCH AND DIE
3) DEEP DRAWING IS FFACILITATED IF CRYSTALLOGRAPHIC TEXTURE OF SHEET IS SUCH THAT THE SLIP MCHANISMS FAVOR DEFORMATION IN THE WIDTH DIRECTION OVER THE SHIP IN THE THICKNESS DIRECTION OF THE SHEET

   PLASTIC STRAIN RATIO 'r' GIVEN BY

   $$r = \frac{\text{strain in width direction of tension specimen}}{\text{strain in thickness direction}}$$

4) KEELER – GOODWIN FORMING LIMIT DIAGRAM → A MATERIAL OF GREATER FORMABILITY IN WHICH THE FORMING LIMIT DIAGRAM WAS AT HIGHER VALUES COULD BE SAFE TO AVOID FAILURE
5) THE FAILURE COULD BE ELIMINATED BY CHANGING METAL FLOW BY EITHER DESIGN CHANGES TO DIE OR TO PART SO THAT STRAIN STATE IS IN THE SAFE ZONE

DESIGN RULES FOR BLANKING COMPONENTS

POFILE SHAPE SHOULD NOT CONTAIN NARROW PROJECTIONS

INTERNAL PUNCHED HOLES SHOULD BE SEPARATED FROM EACH OTHER

DIMENSION ‘a’ TO ‘d’ SHOULD BE GREATER THAN (TWICE OF THICKNESS) SHEET THICKNESS

IT IS GOOD PRACTICE TO HAVE RELIEF CUTOUTS DIMENSIONED AS ‘d’ AT THE ENDS OF PROPOSED BENDS

TENSILE STRAINS FOR DIFFERENT MATERIALS MUST BE ESTIMATED AND COMPARED TO THE PERMISSIBLE MAXIMUM VALUE

6) LOUVERS ARE FORMED FOR COOLING PURPOSE. THE LENGTH OF THE FRONT EDGE OF LOUVER MUST BE GREATER THAN A CERTAIN MULTIPLE OF LOUVER OPENING HEIGHT , DETERMINED BY THE MATERIAL DUCTILITY , AND THE END RAMP ANGLES

7) THE TENSILE STRAIN AROUND THE TOP EDGE OF THE FORMED FLANGE IS TO BE LESS THAN THE PERMISSIBLE MATERIAL DUCTILITY

   TYPICAL VALUES OF FLANGE HEIGHT IS 2 TO 3 TIMES SHEET THICKNESS

8) RIBS (GEOMETRY) TO BE CHOSEN BASED ON DUCTILITY OF MATERIAL

9) PUNCHED SLOTS ADJACENT TO A BEND → CLEARANCE SHOULD INCREASE TO 4 TIMES SHEET THICKNESS

10) DESIGN OF LAYOUT SHOULD ATTEMPT MINIMUM SCRAP LOSS

UNIT V

DESIGN GUIDELINES FOR MANUAL ASSEMBLY

1) HANDLING (ACQUIRING , ORIENTING AND MOVING PARTS)
   a) end to end symmetry
   b) rotational symmetry
   c) or maximum symmetry
   d) features to prevent jamming of parts
   e) avoid features that will allow tangling of parts when stored in bulk
   f) avoid parts that stick together

2) INSERTION AND FASTENING
   a) providing of chambers to guide insertion of two mating parts
   b) standardize by using common parts
   c) use pyramid assembly
   d) self location feature

DEVELOPMENT OF SYSTEMATIC DFA METHODOLOGY

1. MINIMIZE TOTAL NUMBER OF PARTS
   IDENTIFY THE PARTS AS PER FUNCTION AND ELIMINATE PARTS NOT REQUIRED

   CRITIERIA :
   1) RELATIVE MOTION
   2) PART MADE OF A DIFFERENT MATERIAL THAN FOR ALL OTHER PARTS
   3) ESSENTIAL CONNECTION BETWEEN PARTS
   4) MAINTENANCE REQUIRES DISASSEMBLY AND REPLACEMENT OF PART
   5) PARTS USED FOR FASTENING OR CONNECTING OTHER PARTS ARE PRIME
   CANDIDATES FOR ELIMINATION

   DESIGN ASSEMBLY =

   $$\eta = \frac{3 \times \text{"THEORITICAL MIN. PARTS}}{\text{TOTAL ASSEMBLY TIME OF PARTS}}$$

   NOTE: 3 SEC IS BASIC ASSEMBLY TIME OF ONE PART

2) MIINIMIZE THE ASSEMBLY SURFACES SIMPLIFY DESIGN SO THAT FEWER SURFACES NEED TO BE PREPARED IN ASSEMBLY AND ALL WORK ON ONE SURFACE IS COMPLETED BEFORE MOVING TO THE NEXT ONE

3) USE SUBASSEMBLIES:

(i) SUBASSEMBLIES CAN BE TESTED ELSE WHERE

(ii) SUBASSEMBLIES CAN BE BOUGHT

4) MISTAKE PROOF THE DESIGN AND ASSEMBLY

CRITERIA (i) CAN BE ASSEMBLED IN ONE WAY

(ii) ORIENTATION NOTCHES , ASYMMETRICAL HOLES , AND STEPS IN ASSEMBLY FIXTURES ARE COMMON WAYS TO MISTAKE PROOF THE ASSEMBLY PROCESS

GUIDELINES FOR HANDLING

(1) AVOID SEPARATE FASTNERS

A) SNAP FITS

B) FEWER LARGE FASTENERS

C) STANDARDIZATION

D) SINGLE TYPE AND AUTO-FEED POWER SCREWD RIVERS

(2) MINIMIZE HANDLING IN ASSEMBLY

A) SYMMETRY

B) GUIDE AND LOCATE PARTS

C) IN CASE ROBOTS ARE USED , THE SURFACES TO BE FLAT AND SMOOTH FOR
VACCUM GRIPPERS OR AN INNER HOLE FOR SPEARING OR A CYLINDRICAL
OUTER SURFACE FOR GRIPPER PICK UP

(3) GUIDELINES FOR INSERTION

A) MINIMIZE ASSEMBLY DIRECTION

B) PROVIDE UNOBSTRUCTED ACCESS FOR PARTS AND TOOLS

C) MAXIMIZE COMPLIANCE IN ASSEMBLY

DESIGN GUIDELINES FOR THE MANUAL HANDLING INSERTION OF PARTS

1. AVOID CONNECTIONS

   TWO PARTS TO BE LOCATED AT THE SAME POINT
2. ACCESS FOR ASSEMBLY OPERATIONS IS NOT RESTRICTED
3. AVOID ADJUSTMENTS

   INSTEAD OF MANY MATERIALS , IF THE ASSEMBLY WERE REPLACED BY ONE PART MANUFATURED FROM THE MORE EXPENSIVE MATERIAL , DIFFICULT AND COSTLY OEPRATIONS WOULD BE AVOIDED
4. USE KINEMATIC DESIGN PRINICPLES 3 POINT CONSTRAINTS ARE NEEDED TOGETHER WITH CLOSING

TYPES OF MANUAL ASSEMBLY METHODS

BENCH ASSEMBLY FOR SMALLER PARTS

MULTI STATION ASSEMBLY CONVEYOR SYSTEM

MODULAR ASSEMBLY CENTER

VARIOUS STORAGE SHELVES

STORAGE RACKS

STORAGE BINS

AUXILLIARY TOOL TABLE

CUSTOM ASSEMBLLY LAYOUT

FLEXIBLE ASSEMBLY LAYOUT

MULTI STATION ASSEMBLY OF LARGE PRODUCTS

INSTALLATION AND ASSEMBLY AT SITE

DESIGN FOR HIGH – SPEED AUTOMATIC ASSEMBLY AND ROBOT ASSEMBLY

GENERAL RULES FOR PRODUCT DESIGN FOR AUTOMATION

1. REDUCING NUMBER OF PARTS
2. REDESIGN OF PART FOR EASE OF ASSEMBLY
3. LAYERED ASSEMBLY (ONE OVER OTHER)
4. AVOID DESIGNING O PARTS THAT WILL TANGLE , NEST OR SHINGLE
5. MAKE THE PARTS SYMMETRICAL
6. IF PARTS CANNOT BE MADE SYMMETRICAL , AVOID SLIGHT ASYMMETRY OR ASYMMETRY RELUTING FROM SMALL OR NON GEOMETRICAL FEATURES
7. PROVIDE CHAMFERS , TAPERS ,
8. AVOID TIME CONSUMING FASTENING OPERATIONS (SCREWS , SOLDERING ETC

PRODUCT DESIGN FOR ROBOT ASSEMBLY

1. REDUCE PART COUNT
2. FEATURES SUCH AS LEADS , LIPS , CHAMFERS – SELF ALIGNING IN ASSEMBLY.

   CONSISTENT FAULT FREE PART INSERTIONS
3. SELF LOCATION – IMPORTANT FOR MULTI STATION ROBOT ASSEMBLY OR ON ARM SINGLE STATION SYSTEMS. SPECIAL FIXTURING , TOOLING
4. GRIPPING AND INSERTION BY SAME ROBOT GRIPPER
5. ASSEMBLED IN LAYER FASHION ‘Z’ AXIS ASSEMBLY
6. AVOID THE NEED FOR REORIENTING THE PARTIAL ASSEMBLY

EFFECT OF PART SYMMETRY ON HANDLING TIME

FACTORS :

1) ALIGNMENT OF AXIS OF PART THAT CORRESPONDS TO THE AXIS OF INSERTIONS
2) ROTATION OF THE PART ABOUT THIS AXIS

TWO KINDS OF SYMMETRY FOR A PART

1. ALPHA SYMMETRY :
   DEPENDS ON THE ANGLE THROUGH WHICH A PART MUST BE ROTATED ABOUT AN AXIS PERPENIDICULAR TO THE AXIS OF INSERTION TO REPEAT ITS ORIENTATION
2. BETA SYMMETRY
   DEPENDS ON THE ANGLE THROUGH WHICH A PART MUST BE ROTATED ABOUT THE AXIS OF INSERTION TO REPEAT ITS ORIENTATION

TWO SYSTEMS

MTM SYSTEM : METHODS TIME MEASUREMENT

WF : WORK FACTOR

WF SYSTEM : SYMMETRY OF A PART IS CLASSIFIED BY THE RATIO OF THE

NUMBER OF WAYS THE PART CAN BE INSERTED

NUMBER OF WAYS PART CAN BE GRASPED PREPARATORY TO INSERTION

EG: SQUARE PRISM INTO SQUARE HOLE

4 WAYS IT CAN BE INSERTED

8 WAYS IT CAN BE GRASPED

WF = $\frac{4}{8}$ = ½ ; 50% ORIENTATION

TOTAL ANGLE OF SYMMETRY = $\alpha + \beta$

EFFECT OF PART THICKNESS AND SIZE ON HANDLING TIME

CYLINDER : THICKNESS = DIA

THICKNESS GREATER THAN 2mm PRESENT NO GRASPING OR HANDLING PROBLEM

SIZE : LARGEST NON DIAGONAL DIMENSION

"LENGTH OF THE PART"

EFFECT OF WEIGHT ON HANDLING TIME