UNIT 1
MECHANICAL SYSTEM DESIGN

- *Chapter 1-Engineering Process and Approach*
- *Chapter 2- Problem Formulation*

ENGINEERING PROCESS AND SYSTEM APPROACH

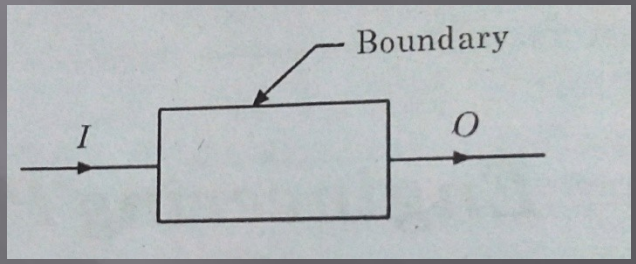
Chapter -1

What is a System

- An organizing relationship b/w functioning units and components to achieve objectives.
- Proper coordination required for effective work.
- System consists components like physical parts or managerial steps either in simple or complex forms.
- Each components do some different work to achieve the goal.

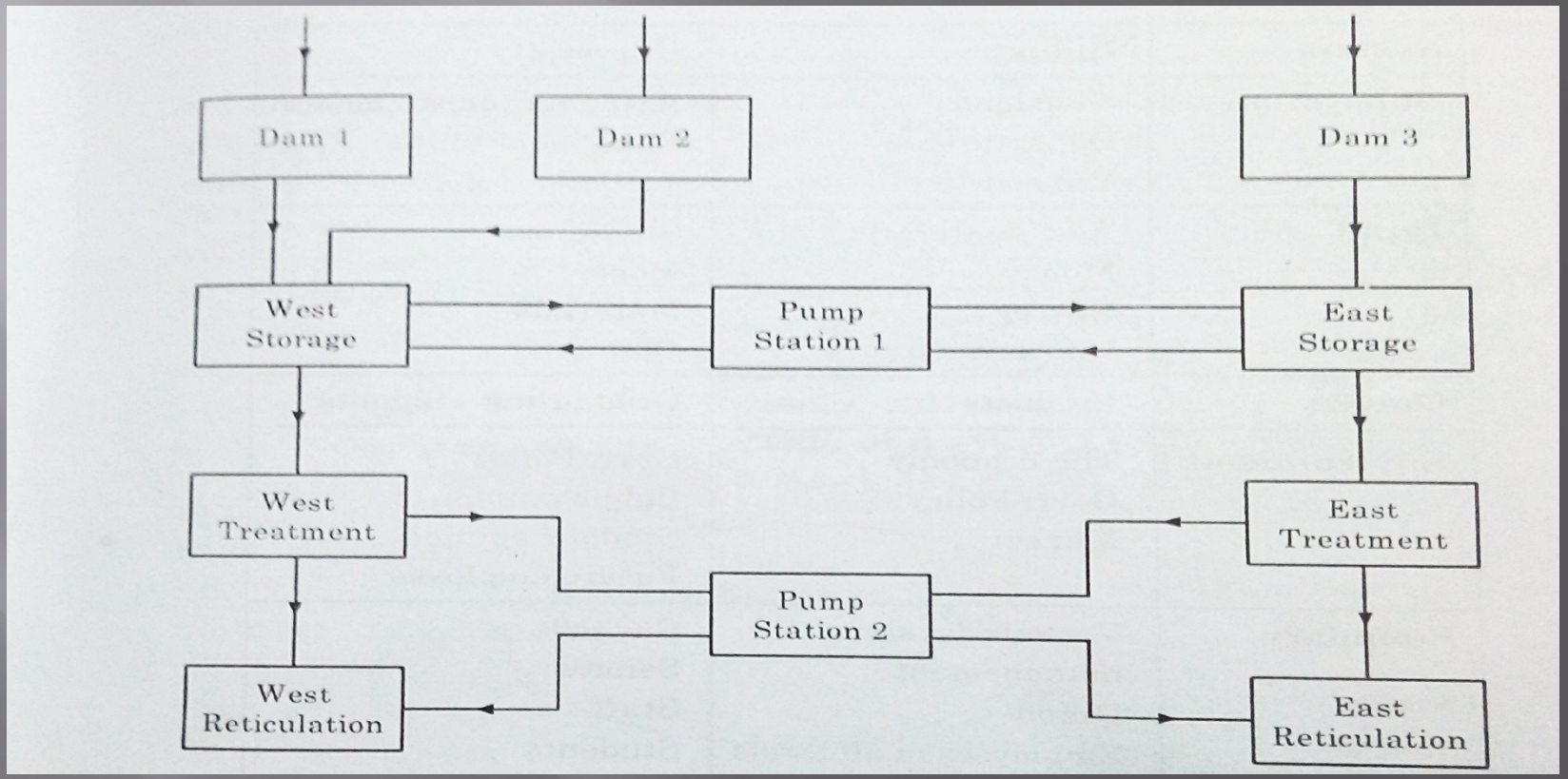
System inputs/outputs

- Inputs and outputs commonly take for of a flow of matter, energy or information through the boundaries of the system.
- System consisting of i/p and o/p can be represented with boxes to denote components and directed lines to indicate i/p and o/p



City water supply system

•Here inputs and outputs are quantity of water of varying quality which flow into sys
•There are command signals for water to be pumped from one component to other.
•Electricity may be input for some components.



Different terms in system concepts

- INPUT: The element that system require from outside.
- OUTPUT: Element obtained by response of system to input.
- ENVIRONMENT: Thing around system within which system exists.
- BOUNDARY: The system remains inside it.
- SUB-SYSTEMS: A system can be broken into sub systems

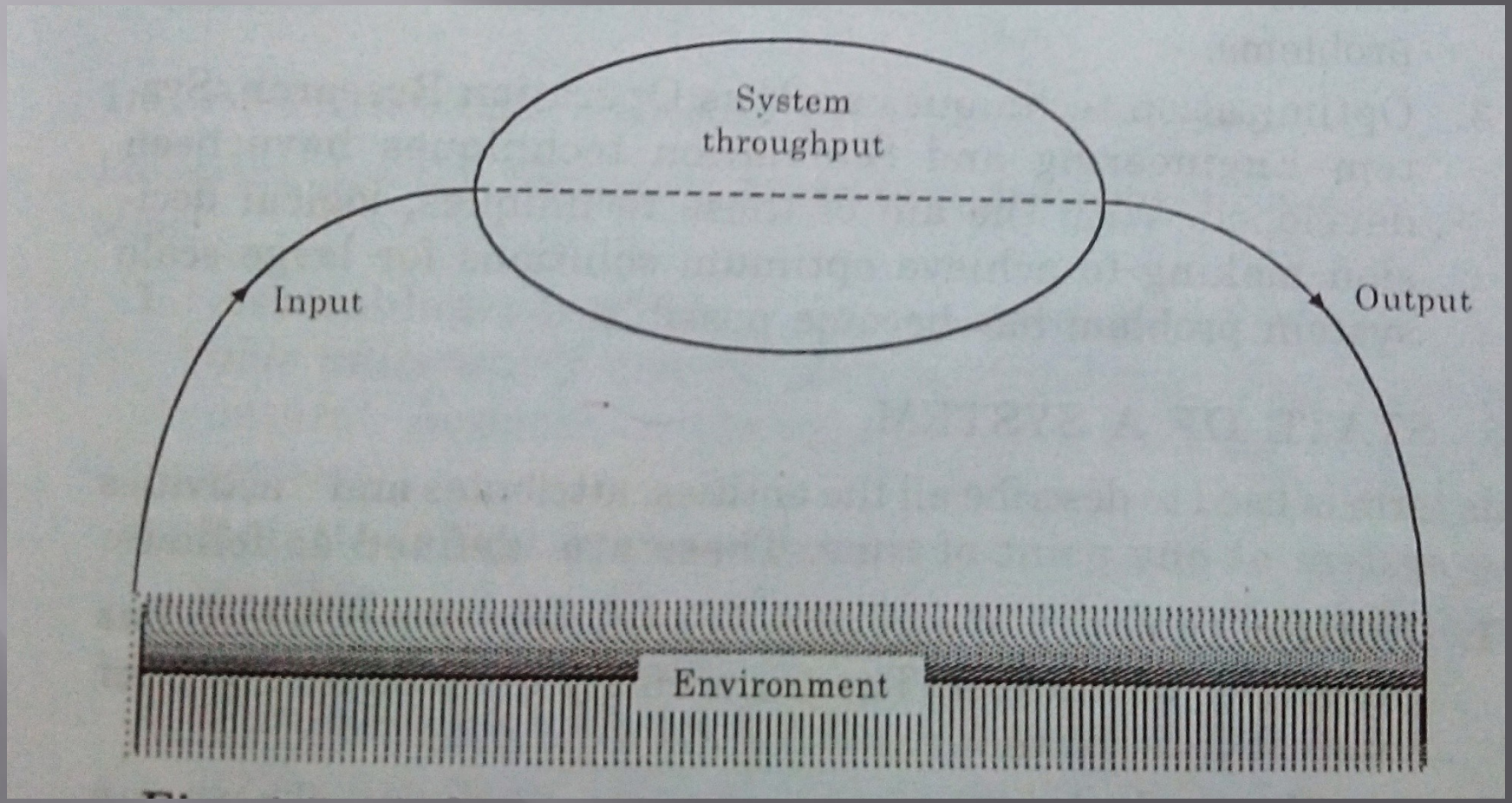
Various concepts of system

System	Industry	University
Subsystem	Divisions Departments Projects	Academic departments Functional units
Input	Raw materials Money Energy Information	Students Money Materials Opinions
Output	Products	Graduating students
Environment	The economy Govt. Policy Market	Govt. Policy Public opinion Student opinion Future employee
Boundary	Various levels of management Union Employees of all levels	Councils Senate Staff Students

Basic concepts of system approach

- Initially only closed system was taken under consideration.
- A biologist VON BERTALANFFY practically thought the possibility of an open system.
- Organism are open system as they interact with other system outside of themselves.
- Interaction is through input, environment and output
- To clarify about inside and outside of a system, we need to distinguish between system itself and it's environment.
- Human body is an example for above.

System in interaction with it's environment



Basic aspects of system approach

- Optimization
- Input-output analysis
- Simulation
- Cost-benefit analysis
- WHY TO GO BY SYSTEM APPROACH:

Recent globalization, Computer progress, Optimization and simulation techniques, all these need system approach to give optimum output.

State of a system

- **Entity:** A [illegible] n.
- **Attribute:** The properties of that entity.
- **Activity:** A process causing change in system.
- Example:

Traffic system:

Entity: Cars, scooters.

Attribute: Speed, distance.

Activity: Driving

Attributes that characterize system

- Assemblage: Group of units or subsystems. It is a system comprises of distinguishable units.
- Relationship: Several groups to qualify as a part of system must have some form of relationship. Eg. Between planets of solar system.
- Goal seeking: As system performs certain functions or objectives. When they are performed system optimization said to be performed.
- Adaptability to environment: As human body does.

Classification of a system

- Natural systems: solar system, ecological system.
- Human activity system: Political system
- Physical designed system: Tools, machines etc.
- Abstracted designed system: Computer language, religion.

Classification of a system contd.

- Those system which operates in perfectly predicted environment are Deterministic and opposites are called probabilistic systems.
- Those systems which does not interact with environment are closed system and those who do so are open system. Practically all systems are open systems.
- Those systems who change their state with time are dynamic systems and those who don't are static system.

Classification of a system contd.

- On basis of input output relationship:

  A system is linear if it satisfies property of proportionality and homogeneity.

  $Y=f(x)$

  $KY=K.f(x)$

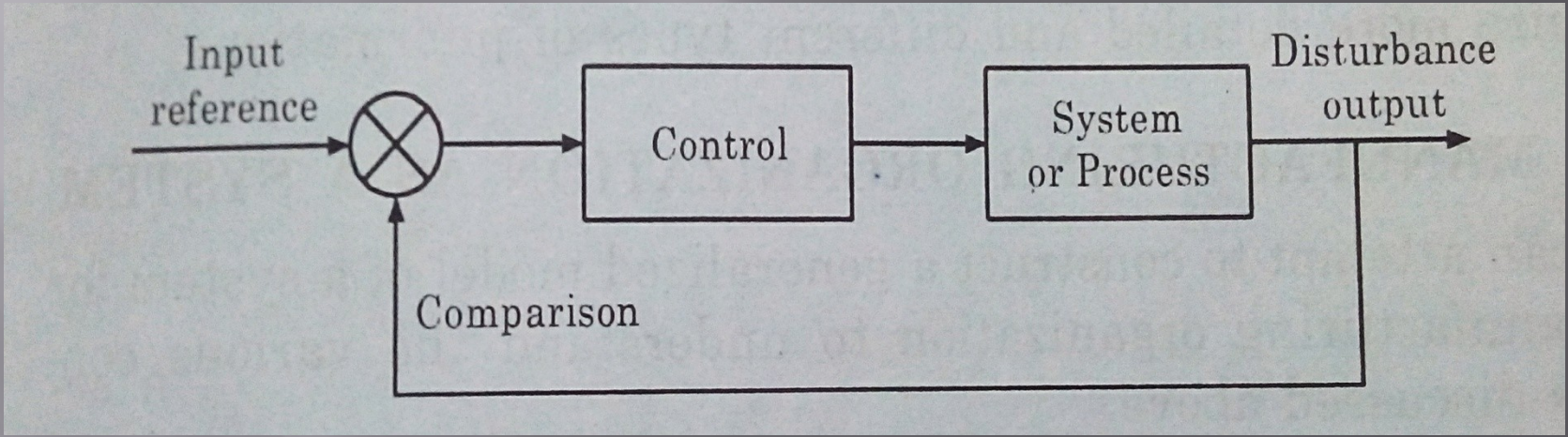
Or may be additive systems

$Y=f(x_1 + x_2)=f(x)$

If additive and homogeneous properties are not satisfied the system is nonlinear.

Classification of a system contd.

- On basis of control following is a closed loop system.

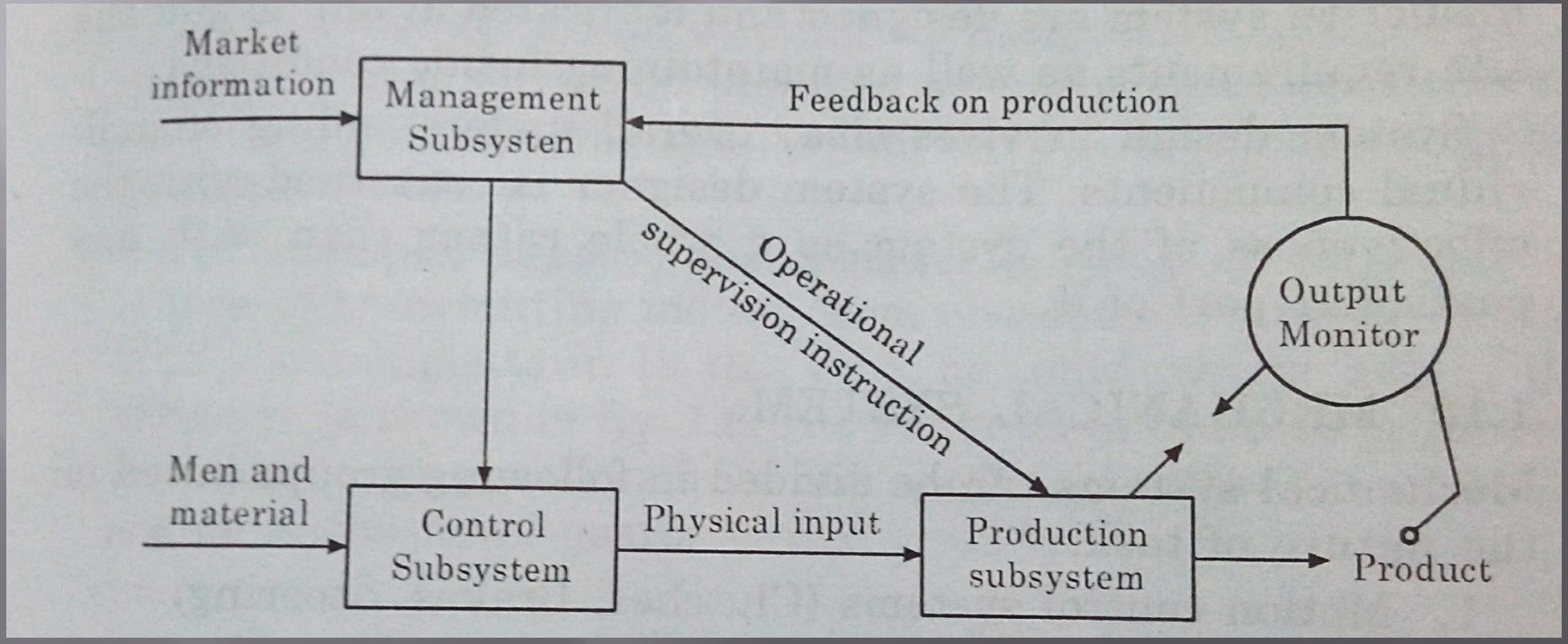


•Above is a basic control model. Control effects output of system.
•A complete loop is formed. This is also called feedback system.

•If there is not any automatic sensing of output and no control based action.
•This is called OPEN SYSTEM

Manufacturing Organization as a system

Inputs are men and material and market information. Control subsystem maintain flow by instructions from management subsystem.



Application of system concept in engineering

Automobile must fit into following systems:

- Road network
- Traffic control system
- Legal system

And automobile itself is a system made by many components.

Other example is central air-conditioning system.

Mechanical system

- Motion control system: clutch, brakes
- Power control system: engine, motors, turbines.
- Power generating systems: Gear box, chain drive.
- Power consuming system: pumps, blowers, machine tools.

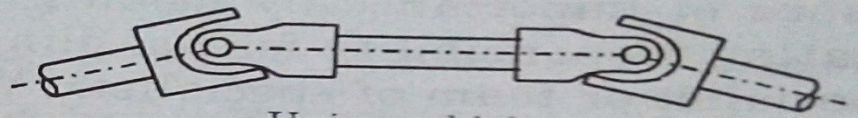
System Design

- This study is done with an objective to produce such a system that meet some specifications.
- Components are chosen to construct a system.
- Model is made and performance is predicted from this model.
- If predicted performance is okay then design is accepted.

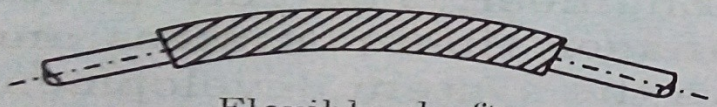
Various ways of system design

- Different designer may be assigned different design and they should consider each design's effect. Following are different way to choose transmitting motion from one shaft to other.

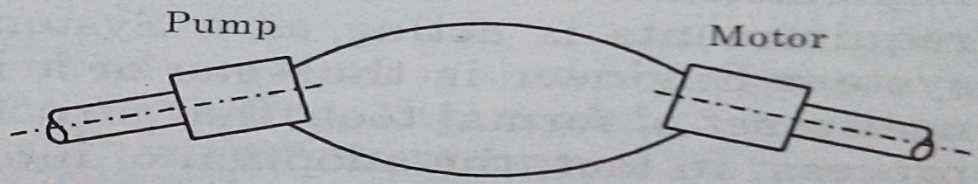
Bevel gears



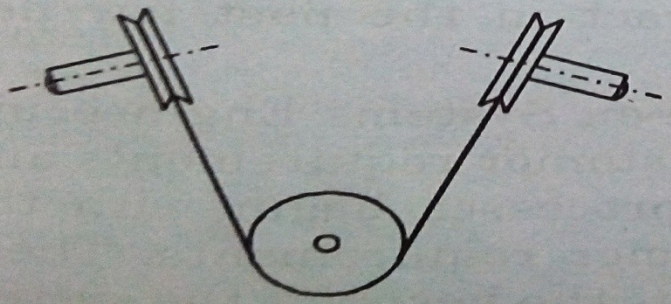
Universal joints



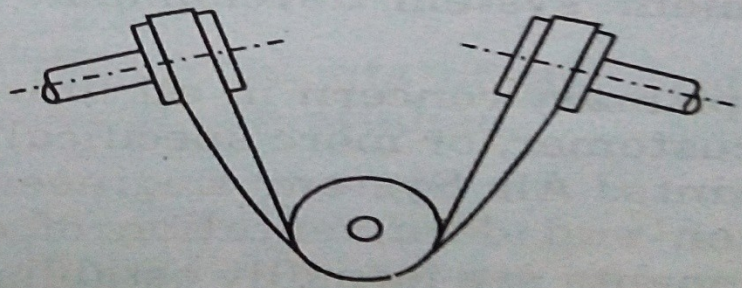
Flexible shaft



Hydraulic system



Cable system



Belt system

Role of Engineer

- To do constructive activities.
- Be familiar with various means of production.
- Uses skills to ensure satisfactory work.
- Makes technological and managerial decisions with far reaching consequences.

SYSTEM ENGINEER AND HIS ROLE

- Acts like a specialist for different responsibilities.
- Responsible for implementations of total system.
- His role is of a manager who uses a set of formal tools that structure the system development.

Engineering Problem Solving

- It is a process of logical sequence.
- Need of a decision maker for identification and analysis part. Steps included are:

1. Model building-to formulate problem.
2. Testing the model.
3. Decision analysis-Optimal solution is needed and analysed.

Engineering Problem Solving cont.

Some psychologist describe problem solving process in terms of a four stage model:

1. Stage 1-Preparation: examine interrelation of elements.
2. Stage 2-Incubation: Put full day involvement with problem
3. Stage 3-Inspiration: A solution or path toward the solution suddenly emerges.
4. Stage 4-Verification: The inspire solution is checked against desired results.

Concurrent Engineering(Simultaneous Engineering)

- A design approach where product design and manufacturing are merged in an intimate way.
- It is a recognition that many of the high costs of manufacturing are designed at product development stage.
- A parallel execution of different development tasks in multidisciplinary teams to obtain an optimum product in minimum time and cost.

Concurrent Engineering(Simultaneous Engineering) Cont.

- It provides a systematic and integrated approach to introduction and design of product.
- The subsets include design for manufacture, design for assembly, design for maintainability, design for disposal and so on effective CE practice requires good communications between functions associated with product life cycle.
- Integration of all company resources is needed for product development.

Three T's of CE

1. Tools: Today's CE needs 3d CAD solid models.

   which is faster and more flexible.

Rapid prototyping has caused industries to rethink from "A picture is worth a thousand words" to "A prototype is worth a thousand words"

Three T's of CE

2. Training:

- People are needed to get together to do work.
- Employee adaptability to environmental changes is well known as a tool for manufacturing competitiveness.

Three T's of CE

3. Time:

- If company only focus on reducing cycle time, it will get poor yield quality produced at a premium cost.
- A hurried implementation of CE without careful planning may cause backfire.
- Even to become comfortable with a new CAD/CAM system it takes eight months.

Objectives of CE

- Decrease product development time and quality.
- Improves profit.
- Greater competitiveness.
- Better control on design and manufacturing cost.
- Close integration between departments.
- Enhances repo of company and team spirit.

Benefits of CE

- 30-70% reduced development cycle time.
- 65-90% fewer engineering changes.
- 20-90% reduction in time to market.
- 200-600% improvement in product quality.
- 5-50% high sales.
- 20-120 % high investment returns.
- 100-200% higher customer satisfication.

Weakness of CE

- Insufficient product specification, leading to an excessive amount of modification.
- Little attention to manufacturability issues of product at design stages.
- Estimated costings are usually degree of magnitude in error, mainly due to uncontrolled late design change cost.
- Likelihood of late changes usually leads to expensive changes to tooling and other equipments.

PROBLEM FORMULATION

Chapter-2

Problem Formulation

- Steps included
  - Defining the problem
  - Forming model

- Most of practicing engineers face problem because they have difficulty in these initial steps.

Defining the problem

- Translate real problem into paper and pencil question.
- Defining it will need skill, understanding and judgment
- An engineering analyst must begin by a quantitavely answerable question.

Model formulation and making assumption

- Model is an idealized approximation to real situation.
- Proper assumptions taken into account.
- Both analytical as well as experimental models are used.
- Model formation is a process of abstraction.
- Model results should have meaningful results.

Nature of engineering problems

1. Apparent problem: when originator does not think too close to problem. Eg. Traffic congestion in a city.
2. Real problem.

Examples of engineering problems are:

- Problem of landing gear of a shuttle landing on moon surface.
- Problem of automobile accident and casualties.

Need

- A personal, unfulfilled vacancy that determines and organizes all psychological activities in direction of filling the vacancy.
- Need causes origin of new things.
- Designer must keep in mind that ultimately it is customer who will pay for product so his need must be fulfilled.
- All info and questionable data should be collected for a product.

Type of need

1. **Biological**: stems from tissue hunger. It gives engineering designer his basic needs.
2. **Psychological-Social:** May be in-born or acquired from the culture. They motivate people to seek:
    1. Security
    2. Response to and from others
    3. Group approval and status
    4. New experience and knowledge.

Need statement

- "Exactly what is needed" is determined by designer.
- Wrong need statement cause money and resource wastage.
  - Following is some preliminary need statement:
    - Bicycle: Manually operated device at low cost or light weight and transportation over short distance at a speed greater than a walking man..
    - Electronic iron: an electronic device for removing wrinkles from clothes.

Formulation of a need statement

- Example-*Design of a new lawn mover that would be most popular product in market.*
  - Different ideas evaluated but none is successful.
- New statement- *Design an effective means of maintain lawns that will be popular with consumers.*

Here new statement is focused on function instead of a specific mean of solution. So an innovative solution "*weed eater*" is developed

Analysis of statement of need

- Early statements of needs must be translated into statement of goals as sometime it may transform itself into other needs.
  - Example of change of need: In supersonic fighter jet it is generally thought that decrease flight resistance is obtained by smoothing body of fuselage and point nose for streamline action but analysis gave better results with bulging nose and narrow fuselage.
- So start with well defined needs, identify resources, quantify the constrains and then present some method.

Identification of need

- Recognizing a need often highly creative art.
- A sensitive person is more creative.
- A need is easily recognized after someone stated it.
- Definition of problem includes all specifications.

Need analysis and its requirements

- A process of transforming need statements into statements of goals by customer satisfaction and adequate profit
- After study of need a basic design is made.
- Then get the material as per requirement.
- Finally carry out the design work with an eye to economy of manufacture.
- Keep in mind the future needs.
- Four aspects of obtaining definition are
  - Specification
  - Standard of performance
  - Resources
  - Environmental factors.
- ***Study need analysis for a hand drying system in a hostel dining hall.***

Example

- Manufacture bricks from flyash from thermal power plant. Discuss needs, resources, constraints, criterion.
  1. Need: manufacture bricks and how users will like those bricks.
  2. Resources: transportations and funds.
  3. Constraints: availability of flyash, labour, plant type, land , demand, volume of sale etc.
  4. Criterion: acceptance of new bricks by user, payoff of initial investment and earn a profit sufficient to warrant risk involved in starting the project.

Checklist of items before conducting need analysis

1. Preliminary need statement.
2. Desired output
    1. Standard of performance:
    2. Specifications
3. Environmental factors
4. Resources and constraints
    1. Constraints on production.
    2. Constraints on operation.
    3. Constraints on design process.

Need based development

- After need established its requirement must be carefully spelled out as per specifications.
- Once a product plan is established next step is to plan “HOW TO CAPTURE CUSTOMER’S NEEDS”.
- Diversities must be considered, reconciled and balanced to develop a truly successful product.
- A customer representative is must needed on product development team.
- Current and potential customers are considered for need based development.
- Customer needs have to be converted into a set of product requirements that can be acted upon by engineering.
- Several valid assumptions can be considers according to product specifications and market demands.

Important points in problem formulation

- After problem forming formulate a set of design goals.
- General design goals like safety, environmental awareness, public acceptance etc.
- Specifications of product comes in specific design goals must be defined.
- These specifications represent the quantitative boundaries within which the design solution must fit.
- Extensive research may be necessary to identify the appropriate design specification.

Hierarchical nature of system

- A typical structure where a higher level system is composed of components which are themselves system composed of sub-systems.

- Here we take apparent engineering problem as a part of large problem an engineering system as a component of large system.

Environment of product

- A designer must consider the environment for which the product is designed.
  - Eg. Damage by corrosion must be avoided.
- Other common environmental factors are:
  - Dirt
  - Heat
  - Cold
  - Vibration
    - Study the effects of above factors.

Environmental Factors on which a designer should pay attention

1. Ambient temperature
2. Ambient pressure
3. Ambient humidity
4. Climatic conditions
5. Seismatic factors
6. Contaminants
7. Safety/legal requirements.

Influence of environmental factor in design of a production system

- Ambient temperature
- Ambient pressure
- Ambient humidity
- Indoor/outdoor location
- Seismic factors
- Vibration

Categories of problem constraints

- Physical constraints: size, weight etc.
- Functional constraints: like for 1000 hours must transport at least 50 people.
- Economical constraints: initial cost, lifetime cost etc.
- Legal constraints: govt. safety requirements, policies
- Human factor constraints: strength, hearing and visual capabilities.