UNIT 2
MECHANICAL SYSTEM DESIGN

- *Chapter 3-System Theories*
- *Chapter 4-System Modeling*

CHAPTER 3

System Analysis

System Analysis

- Mathematical way of comparing cost, benefit and risks by reducing complex problem to its components.
- First used in 1950 for analyzing alternative nuclear weapon scenarios.
- Goal is enabling managerial decision making.
- Use of different mathematical techniques is done.

Origin of system analysis

- British scientists during WWII laid foundation of modern system analysis by their work in RADAR technology.
- Integration is a key concept in system.
- First paper on system analysis was by Mc Kean on development of govt. policy in area of water supply in mid 50s.
- In 1959 several projects were completed on electronic data processing in urban planning.
- GE used this concept in
  - In policy making and long term cooperate strategy.
  - In atomic merchant marine.
  - Development of gold mining industry.

- The existence of computers today owes its existence to the development in system analysis and design.

Problem solving potential of system analysis

- R. AN D. cooperation used system analysis to study future possibility of extraterrestrial transportation.
- SRI used system analysis to solve problem of interaction between science and society.
- SRI also applied this concept to problems of industrialization in developing countries.
- System analysis also has application in sociology and politics.
- The creation of automated navigation system was brought by system analysis.

Framework for analysis of system

- Define the system under study:
  - Most important and it sets horizons for analysis.
- Define a measure of effectiveness:
  - What it is that we want to maximize or minimize.
- Construct a model:
  - E=f(X,Y)
  - X is control variable and Y is uncontrollable variables.
- Generate alternative based on analysis.
- Weight and decide:
  - That which course of action to take based on balancing of quantitative and non quantitative factors.

Black box approach

- Here detailed internal functioning within a component is ignored and component is simply regarded as a device which transforms input into output, it s called black box.
- It gives overall understanding of operation of system.
- Here we can lump closely linked components together and replace them by black box.
- Initially accurate consideration is not needed but later it is must.

Black box understanding

- Given as input and taken as output and not considering what is happening inside system is black box approach.
- If internal interacting collection of system is considered it may be called white box.

Component integration approach

- Look closely at environment of a system, it too consist of systems interacting with each others environments.
- A group of interacting people make family, firm, city.
- Mutual interaction of component system is like a glue that make sum of components.
- With respect to whole parts are seen as subsystems and with respect to parts, whole is a subsystem.

State theory approach

- State of a system is represented by a set of one or more key variables whose values completely define the condition of the system at any instant of time.
- Key variables are state variables.
- State of system tells complete history and determines future behavior.
- To analyze emerging system number of state variables should be sufficient to allow future predictions.
- System state Is represented by minimum number of independent variables which contain enough information and past history.
- An analysis of dynamic behavior of system can be done by "Equation of state".

Process of decision making

- Look for both desirable and non desirable alternatives.
- Check the possibilities of attaining results from these alternatives.
- Decision criteria is the course of action which maximizes the final desirability.

Steps in decision process approach

- First: a clear goal by planning and analysis.
- Second: Develop mean of attaining goal.
- Third: evaluate feasible alternatives, get knowledge of hazards, pitfalls, constraints to each alternatives.
- Fourth: Optimum selection is done.
- Fifth: time variables considered. Decision analysis done.
- Final: Implement and verify the decision that will give feedback to various steps in order to achieve the goal in a desired way.

CHAPTER 4

System Modeling

Model

- A highly developed field of science.
- Used in all fields.
- A model is a representation of system in conventional fashion so that conjectures made about the system can be tested readily.

Model Definition

- As per one definition if a system M, independent of system S, is used to gain more information about system S, then M is model of S.
- Scale modes of different engineering objects are created for aesthetic reasons.
- Organizations charts, Maps of cities, Electrical circuit of a complex physical system.
- So model is an abstraction of system.

Type of Models

- Iconic: have physical resemblance to system.
- Analog: they are real systems with mathematical formulas.
- Mathematical: they are represented by conditions imposed on real system and reaction of system to those conditions using symbols.

Terms related to modelling

- System variables: attributes those vary with time and apace.
- Input variables: Those whose values are determined outside the system or its model.
- Output variables: their values are determined inside the system.

  - STUDY EXAMPLES FROM BOOK.

A few common conceptual models

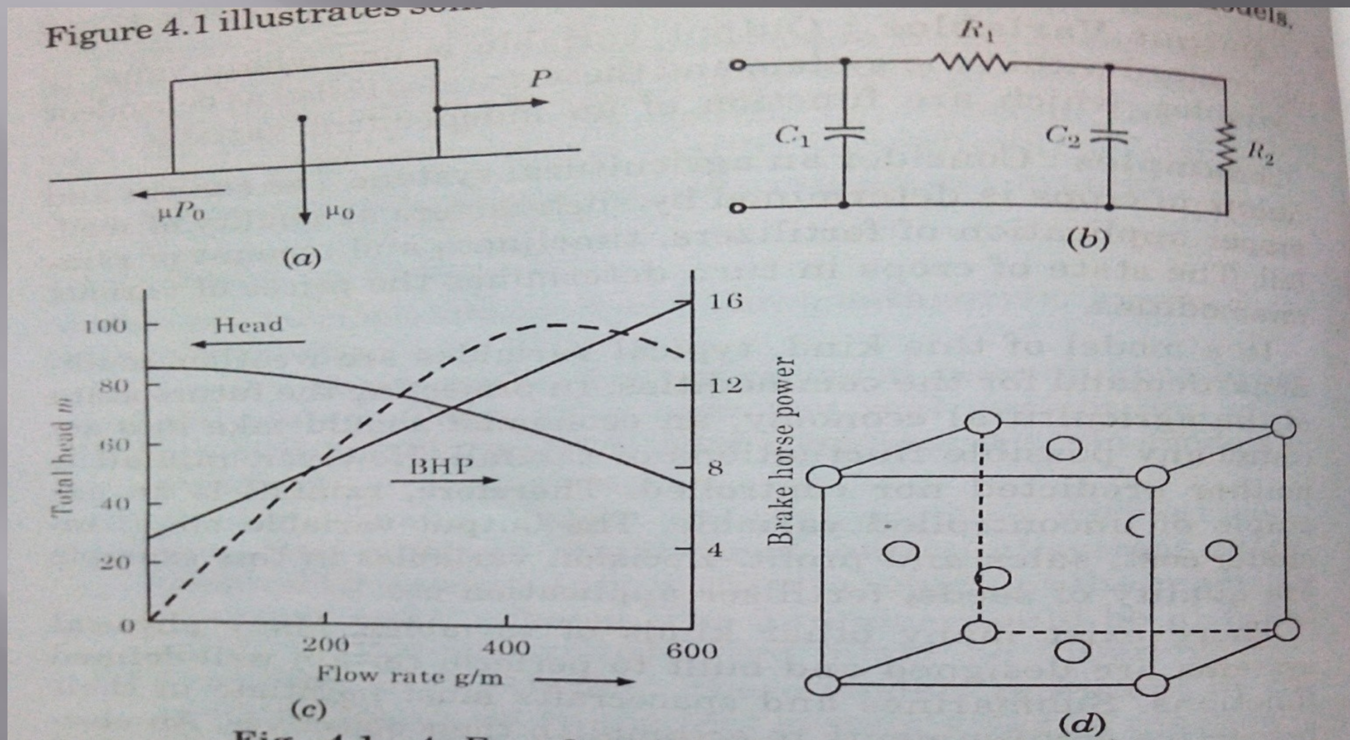


Fig. 4.1 *A Few Common Conceptual Models*
(a) Free body diagram
(b) Electric circuit diagram
(c) Graphic representation
(d) Crystal lattice.

Need For Modelling

- Engineers use models for thinking, control, communication and training.
- They help us to take decision controlled alternatives.
- Save cost for analysis.

Purpose of developing the models

- Understanding
- Learning
- Improvement
- Optimization
- Decision making

Mathematical Modelling

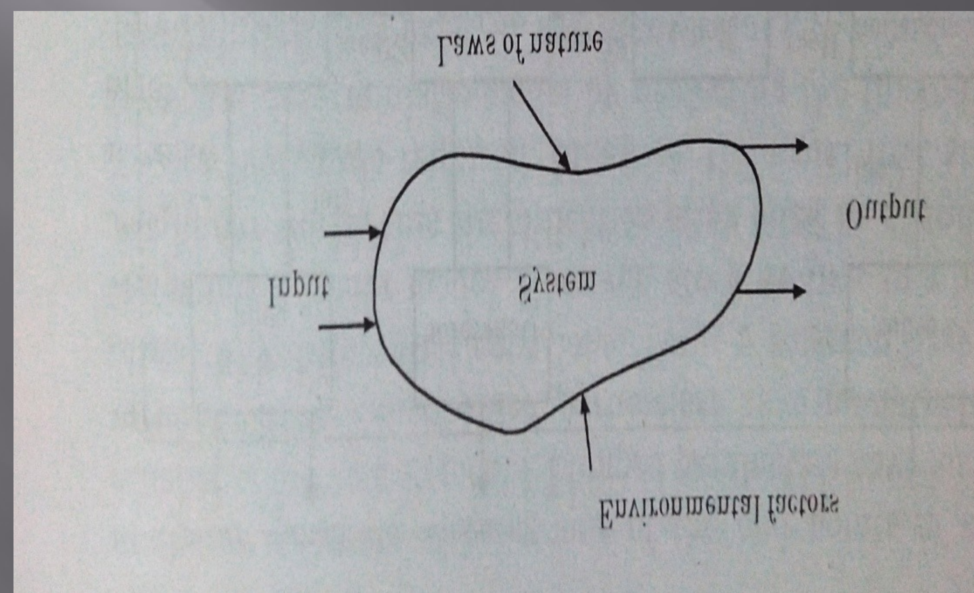
Steps.

1. Derive a mathematical model to characterize essential parts on real situation.
2. Do mathematical calculation.
3. Translate the solution back to real situation via a reverse modelling process.

Mathematical Modelling Concepts

- First step is to devise a Conceptual model that represented the real system to be analyzed.
- Assumptions must be considered.

- Generalized system Concept is shown in figure for Mathematical modelling



Other examples

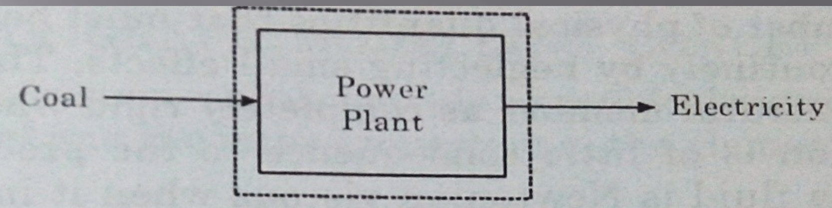


Fig. 4.3 *Overall Model for a Steam Power Plant*

But on further reflection we realize that the basic elements of the plant are given by the block diagram in Fig. 4.4. However, each of these components is a complex piece of engineering equipment, so the total power plant system might be better modelled by Fig. 4.5.

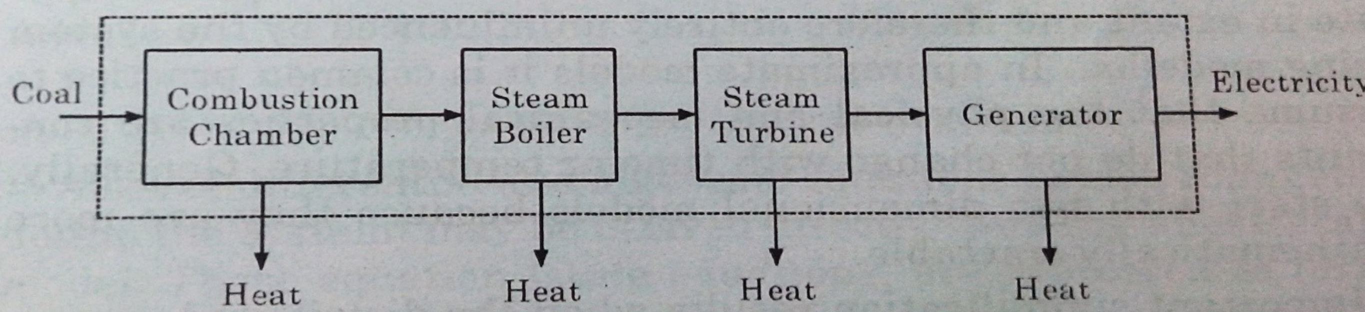
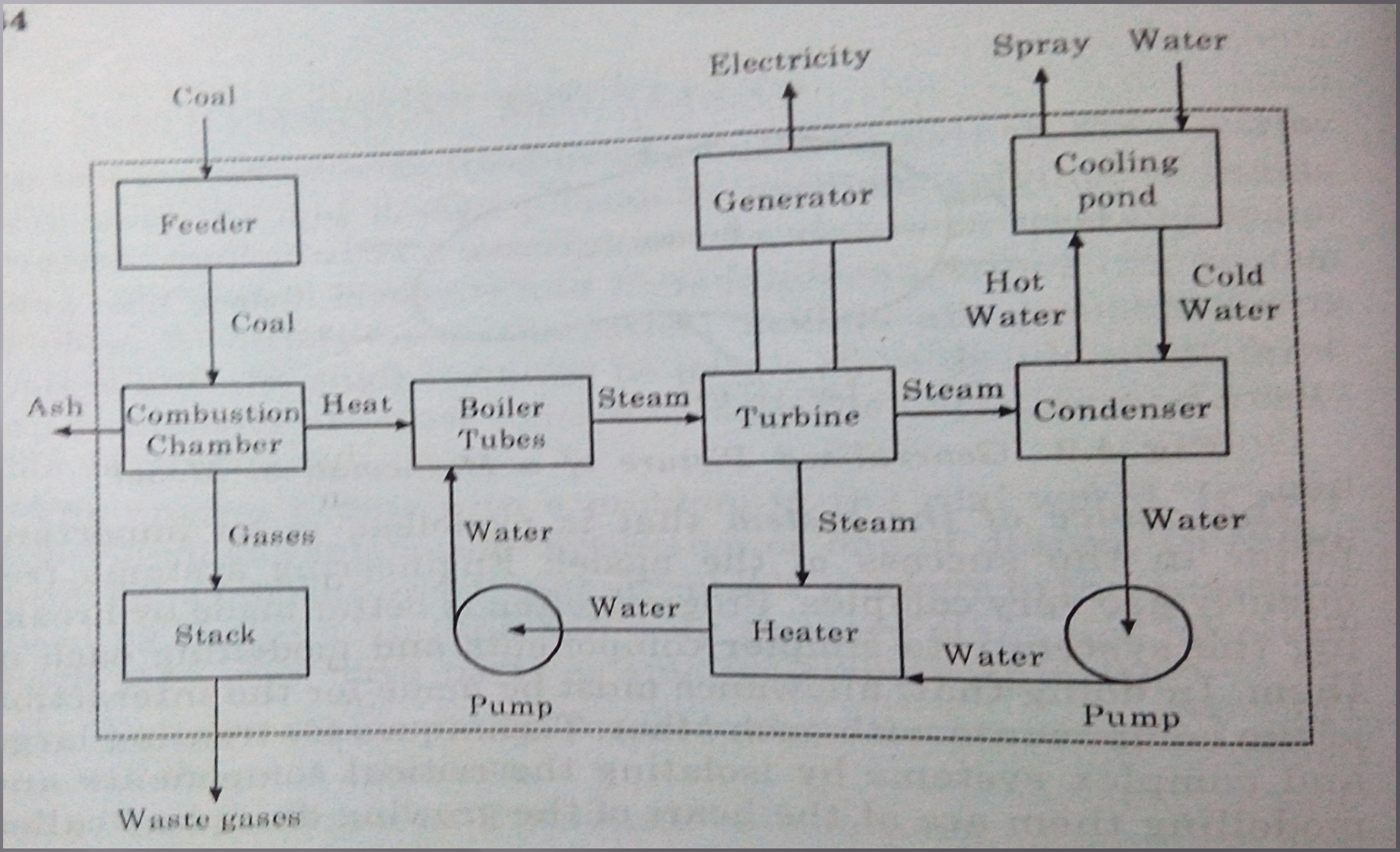


Fig. 4.4 *Block Diagram of Major Components of Power Plant*

Coal fired power plant



Lumped and distributed parameters

- A system is said to have lumped parameter if it can be analyzed in term of end points of a finite number of discrete elements. They have just single value.
- Distributed parameters have many values and expressed by differential equations.
- For simplicity we assume linear models.

Linear graph modelling concepts.

- They simply provide a general graphical representation of system model and the inter-connection of elements.
- A set of differential and algebraic equations may be derived from linear graph model.

Steps for linear modelling

1. Determine system order n and select a set of state variables from linear graph system representation.
2. Generation of a set of state equations and system A and B matrices, using a well defined methodology.
3. Determine a suitable set of output equations and derivation of appropriate C and D matrices.

Modelling of a few Mechanical Systems

4.7 MODELLING OF A FEW MECHANICAL SYSTEMS

1. Series mass spring damper combination

$$f - K.x - BDx = MD^2x$$

$$\Rightarrow \quad f = (MD^2 + BD + K)x$$

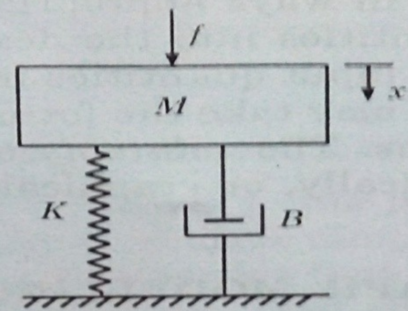


Fig. 4.7

2.

$$f - K.x = MD^2x$$

$$\Rightarrow \quad f = (MD^2 + K).x$$

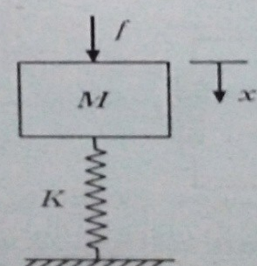


Fig. 4.8

Modelling of a few Mechanical Systems

4.

$$f - K_1(x-y) = 0$$
$$K_1(x-y) - (K_2 + BD)(y-z) = 0$$
$$(K_2 + BD)(y-z) - K_3 z = 0$$

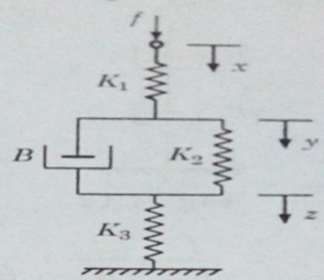


Fig. 4.10

Solving these equations for any of the relationship between x, y, z and f. For example for y to f and z to y

$$y = \frac{K_2 + K_3 + BD}{K_3 (K_2 + BD)} f$$

$$z = \frac{K_2 + BD}{K_2 + K_3 + BD} f$$

5. Series mechanical elements (Grounded chair representation)

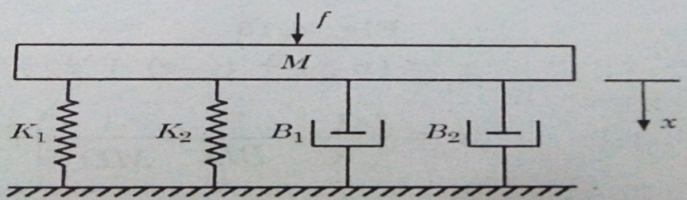


Fig. 4.11

$$f = (K_1 + K_2 + B_1 D + B_2 D + MD^2)x$$

Parallel mechanical elements

Parallel mechanical elements

Hint:

1. For parallel elements, the same force f is transmitted through each element
2. The total deflection is sum of the individual deflections of each element.

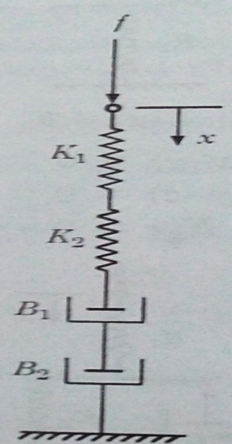


Fig. 4.12

$$x = \frac{f}{K_1} + \frac{f}{K_2} + \frac{f}{B_1 D} + \frac{f}{B_2 D}$$

we equate it with $f = Zx$ where z is impedance then

$$Z = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{B_1 D} + \frac{1}{B_2 D}}$$

Other examples

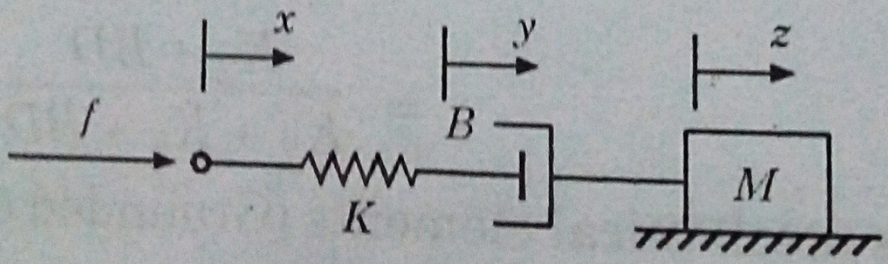


Fig. 4.13

$$x = (x-y) + (y-z) + z$$

$$\Rightarrow \quad x = \left(\frac{1}{K} + \frac{1}{BD} + \frac{1}{MD^2}\right) f$$