B.Tech in Mechanical Engineering

Department of Mechanical Engineering, Tezpur University

ME214: Kinematics of Machinery	L-T-P-CH-CR: 2-1-0-3-3
Prerequisite	Engineering Mechanics (ME102)

Introduction

Machine design is an essential activity while doing engineering analysis for solving the real-life problems. Hence, for the undergraduate students of mechanical engineering, a course highlighting the critical aspects of machines and its investigation is a must.

The subject matter of the course mentioned above can be divided mainly into two distinct and vital field of studies, namely kinematics and dynamics. Hence, the design of the present curriculum is such that it includes two different courses on the theory of machines; ME 214 (Theory of Machines I) and ME313 (Theory of Machines II).

In kinematics, we study the motion of a mechanical system without considering the cause of the movement. The main focus is to explore how the motion gets transferred and transformed in a mechanism or a machine.

Syllabus

Introduction: Basic kinematic concepts; Kinematic Pairs; Plane and Space Mechanisms; Kinematic Chains; Kinematic Diagrams, Limit and Disguise of Revolute Pairs; Kinematic Inversion; Equivalent Linkages; Mobility and Range of Movement.

Kinematic Analysis of Plane Mechanisms: Displacement Analysis; Instantaneous Centre of Velocity; Aronhold-Kennedy Theorem of Three Centres; Velocity and Acceleration Analysis (Graphical & Analytical); Velocity and Acceleration Images.

Dimensional Synthesis of Linkages: Three Position Synthesis (Graphical Method); Four Position Synthesis (Point-Position Reduction); Dead-Centre Problems; Importance of Chebyshev Accuracy Points in Approximate Synthesis.

Cams: Classification of Followers and Cams; Radial Cam Nomenclature; Description of Follower Movement; Analysis of Follower Motion; Determination of Basic Dimensions of Cams.

Gears: Gearing Action; Fundamental Law of Gearing; Properties and Characteristics of Involute Action; Introduction to Helical, Spiral, Bevel, and Worm Gears; Gear Trains.

Course Objective

As the authors of one of the textbooks put it, "the major objectives of the subject theory of mechanism and machine are to provide the engineers the necessary tools to systematically synthesize a system which means scientifically arriving at the critical shapes and dimensions of the bodies constituting the system." In particular, the objectives of the course are

- to introduce the important concepts like kinematic pairs, degrees of freedom, kinematic chains, kinematic inversions, etc.,
- to introduce analytical and graphical methods for kinematic analysis of planar mechanisms,
- to introduce various problems related to the dimensional synthesis of the linkages,
- to introduce fundamentals of cams and different types of gears and gear trains;

Course Outcome

The course of kinematics of machinery being a fundamental course for the undergraduate students in Mechanical Engineering. The expectation is that after going through this course, the students,

CO1: would be able to appreciate and apply the framework acquired during this course to analyze and synthesize the mechanisms and machines for real-life problems/situations.

CO2: would be able to evaluate kinematic parameters related to motion of planar mechanisms using graphical and analytical methods.

CO3: would be able to use the principle of kinematic inversion to solve synthesis problems related to motion generation, path generation, and function generation.

CO4: would be able to understand and analyze the use of cams and gears for generating complex coordinated movements.

CO5: would get motivated to take up advanced courses like robotics etc.

Mapping of CO to PO

	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	3	3	3	3	3	×	×	2	3	3	3	3
CO2	3	2	×	×	×	×	×	×	×	1	3	3
CO3	3	2	×	3	×	×	×	×	×	1	×	3
CO3	3	2	×	×	×	×	×	×	×	1	3	3
CO5	2	×	×	×	1	×	×	×	×	1	×	3

Textbooks

1. Ghosh, A., Mallik, A. K., *Theory of Mechanisms and Machines*, Third Edition, EWP publications, New Delhi, Reprint 2014.
2. Rattan, S. S., *Theory of Machines*, MacGraw Hill Education, New Delhi, 2014.

Reference books

1. Rao, J. S., Dukkipati R. V., *Mechanism and Machine Theory*, New Age International Publishers, New Delhi, 2006.
2. Bevan, T., *The Theory of Machines*, Pearson, New Delhi, Third edition, 2014.
3. Uicker, J.J., Pennock, G. R. and Shigley, J. E., *Theory of Machines and Mechanisms*, Oxford University Press, New Delhi, Third edition, 2007.

Lesson Plan
ME214: Kinematics of Machinery
L-T-P-CH-CR:2-1-0-3-3

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Module 1: Introduction

Number of classes: 11

1. General Introduction
    - Difference between a mechanism and a machine
    - Plane and Spatial mechanisms
    - Kinematic pairs
        - Lower, Higher, Wrapping pairs
    - Kinematic chains and their classifications
    - Kinematic diagram
2. Kinematic Inversion
    - 3R1P, 2R2P, 4R chains
3. Mobility and Range of movement
    - Kutzbach equation and Grübler's criterion
    - Redundant link, joint, dof
4. Number synthesis
    - Minimum number of binary links in a constrained mechanism with revolute pairs
    - Constrained motion of a kinematic chain having n links with simple hinges
5. Grashof's criterion
    - Difference between Grashof and Non-Grashof chains

Intended Learning Outcomes

it is expected that, after going through this module the students will be able

- to differentiate between a mechanism and a machine,
- to differentiate between the planar- and spatial-mechanisms,

- to differentiate between and identify kinematic pairs,
- to determine the degree of freedom of a given kinematic chain,
- to be able to see the mechanical systems around them in a new light.

Module 2: Kinematic Analysis of Plane Mechanisms

Number of classes: 13

1. Displacement Analysis (Graphical & Analytical)
    - quick return ratio
    - transmission angle
2. Instantaneous Centre of Velocity
    - Aronhold-Kennedy Theorem of Three Centres
    - Velocity analysis using instantaneous centres
3. Velocity and Acceleration Analysis (Graphical & Analytical)
4. Velocity and Acceleration Images.

Intended Learning Outcomes

it is expected that, after going through this module the students will be able

- to perform the position analysis of single dof plane mechanisms graphically/analytically,
- to locate instantaneous centres (IC) of a planar-mechanism,
- to perform velocity analysis using method of IC,
- to draw velocity and acceleration diagram for 3R1P and 4R mechanisms, and analyse the same,
- to be able to solve velocity and acceleration problems for 3R1P and 4R plane mechanisms.

Module 3: Dimensional Synthesis of Linkages

Number of classes: 6

1. Three Position Synthesis (Graphical Method)
2. Four Position Synthesis (Point-Position Reduction)
3. Dead-Centre Problems
4. Chebyshev Accuracy Points

Intended Learning Outcomes

it is expected that, after going through this module the students will be able

- to appreciate the importance of Chebyshev accuracy points in approximate synthesis,
- will be able to use the principle of kinematic inversion to solve synthesis problems related to
  - motion generation,
  - path generation,
  - function generation.

Module 4: Cams and Gears

Number of classes: 10

1. Cams
   - Classification of Followers and Cams
   - Radial Cam Nomenclature
   - Description of Follower Movement
   - Analysis of Follower Motion
   - Basic Dimensions of Cams.
2. Gears
   - Gearing Action
   - Fundamental Law of Gearing
   - Properties and Characteristics of Involute Action
   - Introduction to Helical, Spiral, Bevel, and Worm Gears
   - Gear Trains