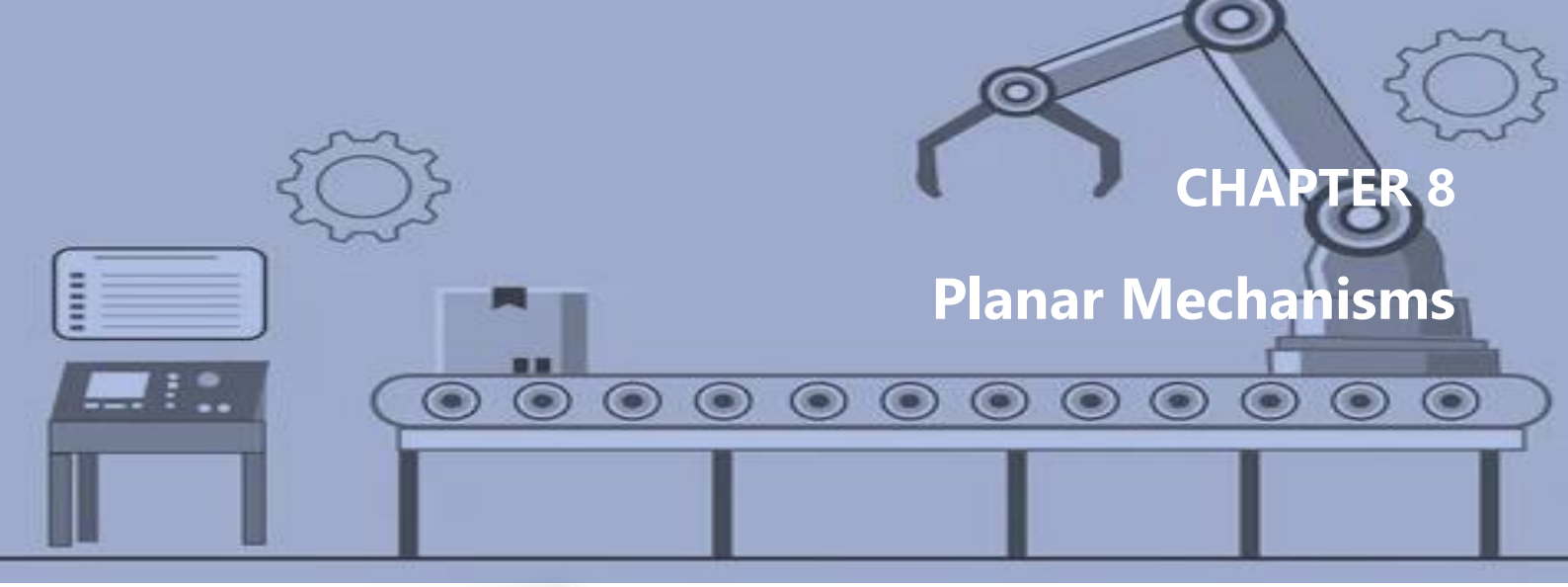

CHAPTER 8

Planar Mechanisms

Learning Outcomes

- Introduction to Planar Mechanism
- Types of Mechanism
- Applications of Planar Mechanism

Mechanical systems are an essential part of our daily lives, from automobiles and industrial machines to robotic arms and household appliances. Many of these systems function using **planar mechanisms**, which are mechanisms where all parts move within a single, flat plane. These mechanisms help control movement efficiently, making them a key component in various engineering applications.

Planar mechanisms are popular because they are **simple to design, reliable, and highly effective** in controlling motion. They are used in systems such as **car steering, machine tools, and robotic linkages**, where precise movement in two dimensions is required. Understanding these mechanisms allows engineers to develop machines that operate smoothly and perform tasks with accuracy.

In this chapter, we will explore **the basics of planar mechanisms**, their **types**, and **real-world applications**. We will also look at the mathematical principles that help in designing these mechanisms, ensuring their efficiency in different machines and industries.

Planar Mechanisms

1. What are Planar Mechanisms?

Planar mechanisms are **mechanical systems** where all the parts move within a **flat, two-dimensional plane**. This means the parts move only back and forth or rotate, without moving up or down (out of the plane). These types of mechanisms are used in many machines and tools because they are simple and effective.

2. Key Features of Planar Mechanisms

Motion in a Single Plane

- All parts of the mechanism move in one flat plane. There's no motion above or below this plane.

Types of Movement

- **Rotation:** A part spins around a fixed point (like the hands of a clock).
- **Translation:** A part moves straight in a line (like a sliding drawer).
- **Combination:** Some mechanisms combine both rotation and translation (like a car engine's piston).

Types of Joints (Connections between Parts)

- **Revolute Joint (Pin Joint):** Allows parts to rotate around a fixed point.
- **Prismatic Joint (Sliding Joint):** Allows parts to move in a straight line.
- **Higher Pair Joint:** Parts touch at a point or line, instead of a surface (like cams in machines).

Types of Planar Mechanisms

1. **Linkage Mechanisms:** These mechanisms have several links (rigid parts) connected by joints to create motion.

Four-Bar Mechanism

- **Structure:** Four parts connected by four moving joints.
- **Use:** Turns one rotational movement into another controlled movement.
- **Examples:**
  - Windshield wipers.
  - Bicycle suspension systems.

Slider-Crank Mechanism

- **Structure:** A rotating crank, a connecting rod, and a sliding piston.
- **Use:** Converts rotational motion into linear motion.
- **Examples:**
  - Car engines (pistons moving up and down).
  - Steam engines.

Quick-Return Mechanism

- **Structure:** A mechanism that moves quickly in one direction and slowly in the other.
- **Use:** Increases efficiency in machines that shape or cut materials.
- **Examples:**
  - Machines used for metalworking.
  - Shaping machines.

2. Cam and Follower Mechanism

- **Structure:** A rotating part (cam) pushes another part (follower) to create specific movements.
- **Use:** Controls precise movements in machines.
- **Examples:**
    - Engines (controlling when valves open and close).
    - Automatic machines for packing or stamping.

3. Gear and Rack Mechanisms

- **Structure:** Gears transfer motion from one part to another.
- **Use:** Controls the speed or direction of movement.
- **Examples:**
    - Steering systems in cars (rack and pinion).
    - Clocks (gear trains).

Real-Life Applications of Planar Mechanisms

In Cars

1. **Engines:** Slider-crank mechanisms change the rotating motion of the crankshaft into the back-and-forth motion of the pistons.
2. **Suspension Systems:** Four-bar linkages help control the movement of car wheels.
3. **Steering Systems:** The rack and pinion mechanism allows smooth steering.

In Factories

1. **Press Machines:** Slider-crank mechanisms are used in machines that press or mold materials.
2. **Shaping Machines:** Quick-return mechanisms are used to make metalworking more efficient.
3. **Conveyor Systems:** Gears and linkages help move materials along the assembly line.

In Robots and Automation

1. **Robotic Arms:** Planar mechanisms help control the movement of robotic joints.
2. **Pick-and-Place Systems:** Cam and linkage systems help robots pick up and place items precisely.
3. **Parallel Linkages:** Help robots move with high accuracy.

In Everyday Products

1. **Folding Furniture:** Four-bar linkages make it possible to fold or unfold furniture.
2. **Scissor Lifts:** These lifts use parallelogram linkages to move up and down.
3. **Wristwatches:** Geneva mechanisms are used to control the movement of hands on clocks.

Understanding the Math behind Planar Mechanisms

The **degree of freedom (DOF)** tells us how many independent movements the system can have. For example, a simple **four-bar mechanism** has one degree of freedom, meaning it can rotate in only one way. To calculate the **DOF**, we use this simple formula:

$$DOF = 3(n-1) - 2j_1 - j_2$$

Where:

- n is the number of parts (links),
- j1 is the number of simple joints (like revolute or sliding joints),
- j2 is the number of complex joints.

Pros and Cons of Planar Mechanisms

Advantages

- **Simple and easy to design**
- **Efficient in moving things**
- **Uses fewer parts, making it cheaper to build**
- **Used in many types of machines, from cars to robots**

Disadvantages

- **Can only move in two dimensions (not very flexible)**
- **Not as strong as 3D mechanisms**
- **Parts can wear out over time due to constant movement**

Chapter Highlights

Planar mechanisms are systems where all parts move in a **single flat plane**, using motions like **rotation** and **translation**. They are simple, cost-effective, and widely used in **cars, machines, robots**, and **everyday tools**.

Common types include:

- **Four-bar linkages** (e.g., wipers, suspension),
- **Slider-crank** (e.g., car engines),
- **Quick-return**, **cam and follower**, and **gear-rack systems**.

They use joints like **revolute**, **sliding**, and **higher pair**. The **degree of freedom (DOF)** helps determine how the mechanism moves.

Advantages: Simple, efficient, and low-cost.
Disadvantages: Limited to 2D motion and can wear out over time.

Exercise

Multiple-Choice Questions (MCQs)

1. What is a planar mechanism?
   a) A system that works in 3D space
   b) A system with random motion
   c) A system where all parts move in one flat plane
   d) A system with vertical motion only
2. Which of the following is a revolute joint?
   a) Sliding drawer
   b) Rotating fan blade
   c) Lifting jack
   d) Conveyor belt
3. Slider-crank mechanism converts:
   a) Linear motion into heat
   b) Rotational motion into linear motion
   c) Electrical energy into motion
   d) Sound into motion
4. Which of these mechanisms is used in shaping machines?
   a) Slider-crank
   b) Cam and follower
   c) Quick-return
   d) Gear and rack
5. What type of motion does a prismatic joint allow?
   a) Rotation
   b) Vibration
   c) Translation
   d) None
6. Which mechanism is commonly used in wristwatches?
   a) Slider-crank
   b) Geneva mechanism
   c) Quick-return
   d) Rack and pinion
7. The four-bar mechanism consists of:
   a) Two gears and two followers
   b) Four links and four revolute joints
   c) A crank and a cam
   d) Three gears and a chain
8. Rack and pinion mechanism is used in:
   a) Car engines
   b) Car steering
   c) Piston heads
   d) Robotic grippers

9. The degree of freedom (DOF) in a simple four-bar mechanism is:
   a) 2
   b) 0
   c) 3
   d) 1
10. Which mechanism uses a rotating cam to push a follower?
   a) Four-bar linkage
   b) Slider-crank
   c) Cam and follower
   d) Geneva mechanism

Fill in the Blanks

1. In a planar mechanism, all parts move in a _____ plane.
2. A _____ joint allows rotation around a fixed point.
3. The _____ mechanism is commonly used in car engines.
4. The _____ mechanism enables faster return strokes in machines.
5. The degree of freedom (DOF) tells how many _____ movements a mechanism can make.

True or False

1. Planar mechanisms allow movement in three dimensions.
2. The cam and follower mechanism is used for precise movement control.
3. A prismatic joint allows rotational motion.
4. Scissor lifts use four-bar linkages.
5. Planar mechanisms are less complex and cost-effective.

Assertion-Reason Questions

1. **Assertion (A):** Planar mechanisms are widely used in machines and tools.
   Reason (R): They allow motion in three-dimensional space.
   a) Both A and R are true, and R is the correct explanation of A.
   b) Both A and R are true, but R is not the correct explanation of A.
   c) A is true, but R is false.
   d) A is false, but R is true.
2. **Assertion (A):** A slider-crank mechanism converts rotational motion into linear motion.
   Reason (R): It consists of a crank, a connecting rod, and a sliding piston.
   a) Both A and R are true, and R is the correct explanation of A.
   b) Both A and R are true, but R is not the correct explanation of A.
   c) A is true, but R is false.
   d) A is false, but R is true.
3. **Assertion (A):** Cam and follower mechanisms are used in watch mechanisms.
   Reason (R): They are used to control valve timing in engines.
   a) Both A and R are true, and R is the correct explanation of A.
   b) Both A and R are true, but R is not the correct explanation of A.
   c) A is true, but R is false.
   d) A is false, but R is true.

4. **Assertion (A):** The four-bar mechanism has only one degree of freedom.
   Reason (R): All links in the mechanism can move independently.
   a) Both A and R are true, and R is the correct explanation of A.
   b) Both A and R are true, but R is not the correct explanation of A.
   c) A is true, but R is false.
   d) A is false, but R is true.
5. **Assertion (A):** Rack and pinion mechanisms are used in car steering systems.
   Reason (R): They convert rotational motion into linear motion.
   a) Both A and R are true, and R is the correct explanation of A.
   b) Both A and R are true, but R is not the correct explanation of A.
   c) A is true, but R is false.
   d) A is false, but R is true.

Short Answer Questions

1. What is the main characteristic of a planar mechanism?
2. Name two types of joints used in planar mechanisms.
3. Where is the slider-crank mechanism commonly used?
4. What is the function of the cam and follower mechanism?
5. Mention one advantage and one disadvantage of planar mechanisms.

Long Answer Questions

1. Explain the working of a four-bar linkage mechanism with examples.
2. Describe the quick-return mechanism and its application.
3. What is the significance of the degree of freedom (DOF) in planar mechanisms?
4. How are planar mechanisms used in robotics and automation?
5. Differentiate between revolute and prismatic joints with examples.