

## Course Material

Name of the Course : **Kinematics of Machines (KOM)**

Name of the Unit : Subject Overview

Name of the Topic :

- **Objectives:**

1. To understand the basic components and layout of linkages in the assembly of a system / machine.
2. To understand the principles in analyzing the assembly with respect to the displacement, velocity, and acceleration at any point in a link of a mechanism.
3. To understand the motion resulting from a specified set of linkages, design few linkage mechanisms and cam mechanisms for specified output motions
4. To understand the basic concepts of toothed gearing and kinematics of gear trains and the effects of friction in motion transmission and in machine components.

- **Outcomes:** Upon completion of this course, Students should be able to

1. Understand the basics of mechanism
2. Calculate velocity and acceleration in simple mechanisms
3. Develop CAM profiles
4. Solve problems on gears and gear trains
5. Examine friction in machine elements

- **Pre-requisites:** Basic knowledge in Engineering Mechanics

- **Pre-test MCQs:**

1. What is not the condition for the equilibrium in three dimensional system of axis?

a)  $\sum F_x=0$

b)  $\sum F_y=0$

c)  $\sum F_z=0$

d)  $\sum F \neq 0$

Answer: d

2. We first make equilibrium equations and then the free body diagram and then solve the question.

a) True

b) False

Answer: b

3. If solving the question in 3D calculations is difficult, then use the 2D system and then equate the total net force to zero.

a) True

b) False

Answer: a

4. The tendency of rotation of the body along any axis is also called \_\_\_\_\_

a) Moment of inertia

b) Moment of couple

c) Torque

d) Force

Answer: c

5. The moment of the force is the product of the force and the perpendicular distance of the axis and the point of action of the force.

a) True

b) False

Answer: a

6. The basic type of motion of a body is translation motion only.

a) True

b) False

Answer: b

7. The simplification of the couple is done on the basis of the \_\_\_\_\_

a) The clockwise of the anti-clockwise rotation sign convention

b) The simplification is not possible

c) The couple is a vector and thus can't be simplified

d) The couple is a scalar and can't be simplified

Answer: a

8. Free body diagrams don't play any role in making the calculations on the conditions of the equilibrium of the body.

a) True

b) False

Answer: b

9. What does Newton's second law states?

a) The rate of change of momentum is equal to the force applied

b) For every reaction, there is an opposite reaction

c) The body is tend to be rotated if the force is applied tangentially

d) The body is rest until a force is applied

Answer: a

## Theory behind:

### Kinematic Link or Element

Each part of a machine, which moves relative to some other part, is known as a kinematic link (or simply link) or element. A link may consist of several parts, which are rigidly fastened together, so that they do not move relative to one another.

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### Types of Links

1. Rigid link.
2. Flexible link.
3. Fluid link.

### Types of Constrained Motions

Following are the three types of constrained motions :

1. Completely constrained motion.
2. Incompletely constrained motion.
3. Successfully constrained motion.

### Inversion of Mechanism

We have already discussed that when one of links is fixed in a kinematic chain, it is called a mechanism. So we can obtain as many mechanisms as the number of links in a kinematic chain by fixing, in turn, different links in a kinematic chain. This method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as inversion of the mechanism.

A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower.

### Motion of the Follower

The follower, during its travel, may have one of the following motions.

1. Uniform velocity,
2. Simple harmonic motion,
3. Uniform acceleration and retardation, and
4. Cycloidal motion.

In precision machines, in which a definite velocity ratio is of importance (as in watch mechanism), the only positive drive is by means of gears or toothed wheels. A gear drive is also provided, when the distance between the driver and the follower is very small.

### Comparison Between Involute and Cycloidal Gears

In actual practice, the involute gears are more commonly used as compared to cycloidal gears, due to the following advantages :

### Advantages of involute gears

1. The most important advantage of the involute gears is that the centre distance for a pair of involute gears can be varied within limits without changing the velocity ratio. This is not true for cycloidal gears which requires exact centre distance to be maintained.
2. In involute gears, the pressure angle, from the start of the engagement of teeth to the end of the engagement, remains constant. It is necessary for smooth running and less wear of gears. But in cycloidal gears, the pressure angle is maximum at the beginning of engagement, reduces to zero at pitch point, starts decreasing and again becomes maximum at the end of engagement. This results in less smooth running of gears.
3. The face and flank of involute teeth are generated by a single curve where as in cycloidal gears, double curves (i.e. epi-cycloid and hypo-cycloid) are required for the face and flank respectively. Thus the involute teeth are easy to manufacture than cycloidal teeth. In involute system, the basic rack has straight teeth and the same can be cut with simple tools.

### Advantages of cycloidal gears

1. Since the cycloidal teeth have wider flanks, therefore the cycloidal gears are stronger than the involute gears, for the same pitch. Due to this reason, the cycloidal teeth are preferred specially for cast teeth.
2. In cycloidal gears, the contact takes place between a convex flank and concave surface, whereas in involute gears, the convex surfaces are in contact. This condition results in less wear in cycloidal gears as compared to involute gears. However the difference in wear is negligible.
3. In cycloidal gears, the interference does not occur at all. Though there are advantages of cycloidal gears but they are outweighed by the greater simplicity and flexibility of the involute gears.

The belts or ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. The amount of power transmitted depends upon the following factors :

1. The velocity of the belt.
2. The tension under which the belt is placed on the pulleys.
3. The arc of contact between the belt and the smaller pulley.
4. The conditions under which the belt is used.

A brake is a device by means of which artificial frictional resistance is applied to a moving machine member, in order to retard or stop the motion of a machine. In the process of performing this function, the brake absorbs either kinetic energy of the moving member or potential energy given up by objects being lowered by hoists, elevators etc.

## Types of Brakes

The brakes, according to the means used for transforming the energy by the braking elements, are classified as :

1. Hydraulic brakes e.g. pumps or hydrodynamic brake and fluid agitator,
2. Electric brakes e.g. generators and eddy current brakes, and
3. Mechanical brakes.

## Friction Between Lubricated Surfaces

When lubricant (i.e. oil or grease) is applied between two surfaces in contact, then the friction

may be classified into the following two types depending upon the thickness of layer of a lubricant.

1. Boundary friction (or greasy friction or non-viscous friction). It is the friction, experienced between the rubbing surfaces, when the surfaces have a very thin layer of lubricant. The thickness of this very thin layer is of the molecular dimension. In this type of friction, a thin layer of lubricant forms a bond between the two rubbing surfaces. The lubricant is absorbed on the surfaces and forms a thin film. This thin film of the lubricant results in less friction between them. The boundary friction follows the laws of solid friction.

2. Fluid friction (or film friction or viscous friction). It is the friction, experienced between the rubbing surfaces, when the surfaces have a thick layer of the lubricant. In this case, the actual surfaces do not come in contact and thus do not rub against each other. It is thus obvious that fluid friction is not due to the surfaces in contact but it is due to the viscosity and oiliness of the lubricant.

## Applications:

1. Design of machine structures and its elements.
2. Mechanisms in internal combustion engines and other automotive parts.
3. Mechanisms for various machine structures and power transmission elements.
4. Braking systems and clutches in automotive applications, bearings for machine structures etc.

## MCQ – Post test:

1. The method of obtaining different mechanisms by fixing in turn different links in a kinematic chain, is known as
  - a) structure
  - b) machine

- c) inversion
- d) compound mechanism

Answer: c

2. If the number of links in a mechanism are equal to 1, then the number of possible inversions are equal to
- a)  $1 - 2$
  - b)  $1 - 1$
  - c) 1
  - d)  $1 + 1$

Answer: c

3. A kinematic chain is known as a mechanism when
- a) none of the links is fixed
  - b) one of the links is fixed
  - c) two of the links are fixed
  - d) none of the mentioned

Answer: b

4. The inversion of a mechanism is
- a) changing of a higher pair to a lower pair
  - b) turning its upside down
  - c) obtained by fixing different links in a kinematic chain
  - d) obtained by reversing the input and output motion

Answer: c

5. The mechanism forms a structure, when the number of degrees of freedom (n) is equal to
- a) 0
  - b) 1
  - c) 2
  - d) -1

Answer: a

6. The size of a cam depends upon
- a) base circle
  - b) pitch circle
  - c) prime circle
  - d) pitch curve

Answer: a

7. The cam follower generally used in automobile engines is
- a) knife edge follower
  - b) flat faced follower
  - c) spherical faced follower

d) roller follower

Answer: c

8. The common normal to the curves of the two teeth must not pass through the pitch point.

a) True

b) It must pass

c) It may or may not pass

d) None of the listed

Answer: b

9. Which of the following is not true about gears?

a) Positive drive

b) Constant velocity ratio

c) Transmit large power

d) Bulky construction

Answer: d

10. Herringbone gear can be used in

a) Intersecting shafts only

b) Parallel shafts only

c) Both intersection and parallel shafts

d) None of the mentioned

Answer: b

11. Two pulleys of diameters  $d_1$  and  $d_2$  and at distance  $x$  apart are connected by means of an open belt drive. The length of the belt is

a)  $\pi / 2 (d_1 + d_2) 2x + (d_1 + d_2)^2 / 4x$

b)  $\pi / 2 (d_1 - d_2) 2x + (d_1 - d_2)^2 / 4x$

c)  $\pi / 2 (d_1 + d_2) 2x + (d_1 - d_2)^2 / 4x$

d)  $\pi / 2 (d_1 - d_2) 2x + (d_1 + d_2)^2 / 4x$

Answer: c

12. Due to slip of the belt, the velocity ratio of the belt drive

a) decreases

b) increases

c) does not change

d) none of the mentioned

Answer: a

13. Clutch and coupling perform the same action.

a) Both being permanent joints

b) No they are different type of joints

c) Both being temporary joints

d) None of the listed

Answer: b

14. If number of contacting surfaces are 5, then number of disks required in multi disk clutch are?

a) 4

- b) 5
- c) 6
- d) Can't be determined

Answer: c

15. The coefficient of friction is high in multi disk plate clutch.

- a) Yes
- b) Coefficient of friction is less
- c) Coefficient of friction is high
- d) None of the listed

Answer: b

## Conclusion

- This subject is helpful in designing the machine structures and its elements.
- Mechanisms in internal combustion engines and other automotive parts are clearly understood.
- Mechanisms for various machine structures and power transmission elements are well known.
- Braking systems and clutches in automotive applications, bearings for machine structures etc are learnt.

## Demo Videos

1. <https://www.youtube.com/watch?v=3eVQA6AyE7A>
2. [https://www.youtube.com/watch?v=Qp1T4oFe\\_gQ](https://www.youtube.com/watch?v=Qp1T4oFe_gQ)
3. <https://www.youtube.com/watch?v=jTfUFQ-sbas>
4. <https://www.youtube.com/watch?v=P7RkmGK1AtM>

## References

1. Amitabh Ghosh and Ashok Kumar Mallik, Theory of mechanism and Machines – 3<sup>rd</sup> Edition, Affiliated East West Press Limited, 2017.
2. R.S. Khurmi & Gupta. J.K, A text book of Theory of Machines, S. Chand & Co., 2008, 14<sup>th</sup> Edition.
3. J.E.Shigley and J.J.Vicker Jr. Theory of Machines and Mechanism, 2<sup>nd</sup> ed. Mc GrawHill ISE 1995



## **Assignments**

1. Describe the various inversions of a four bar mechanism.
2. Explain the detailed procedure to draw a cam with a knife edge follower performing simple harmonic motion.
3. Compare involute and cycloidal teeth gears.
4. Explain the working of an automobile differential with suitable sketches.
5. Explain the types of lubrication in machines.