CHAPTER

9

TRANSMISSION OF POWER

LEARNING OBJECTIVES

1. To know about the Transmission of power.
2. To know about the types of transmission of power like open belt and cross belt.
3. To know about the gear transmission and their types

TABLE OF CONTENT

9.1. Introduction
9.2. Power Transmission
9.3. Belt Drive
9.4. Gears
9.5. Gear Train
9.6. Abstract of Transmission of Power

9.1 INTRODUCTION

- A source of power is always needed in workshop processes particularly in cutting and forming of metals. Electricity as a means of conveying power to machinery is widely adopted. The electrical energy is converted into rotational energy by means of an electric motor and the machine converts the input of rotational energy into various form of useful work.
- It is the movement of energy from its place of generation to a location where it is applied to perform useful work.

9.2. POWER TRANSMISSION

Power transmission devices are very commonly used to transmit power from one shaft to another. Belt, chains and gears are used for this purpose. When the distance between the shafts is large, belts and ropes are used and for intermediate distance chains can be used. Gear drive is used for short distances.

When power is transmitted by gears and chain, there is no slip in velocity ratio. It is called positive drive. When power is transmitted by a belt drive, there is always a possibility of some slip between the belt and the faces of the pulleys, so the character of motion transmitted is non-positive.

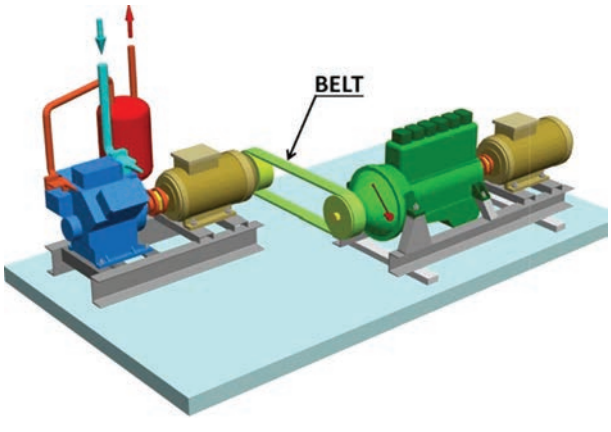


Figure 1 Transmission of Power

The common method of transmitting power are

1. Belt drive.
2. Gear drive.
3. Chain drive.
4. Clutch drive.
5. Rope drive.

9.3. BELT DRIVE

Belt drive is one of the common methods of transmitting motion and power from one shaft to another by means of a thin inextensible band running over two pulleys.

In a belt drive arrangement, the shaft which transmits the rotational power is known as the driving shaft. The pulleys mounted on the driving shaft is known as driver (or) driving pulley. The shaft which receives the rotational power is known as driven shaft and the pulley mounted on it is known as follower or driven pulley. The transmission of power becomes possible because of the grip between the pulley and the belt. Belt drive is generally used in mills and factories.

9.3.1. Types of Belt Drive

The belt drives are divided into two types.

1. Open-belt drive.
   a) Simple belt drive
   b) Compound belt drive
2. Crossed belt drive.

Open-belt Drive

In this type of belt drive the belt is not crossed. The belt connects the top portions of the pulleys directly. The grip between the belt and the pulley is minimum. The driver and the follower rotate in the same direction.

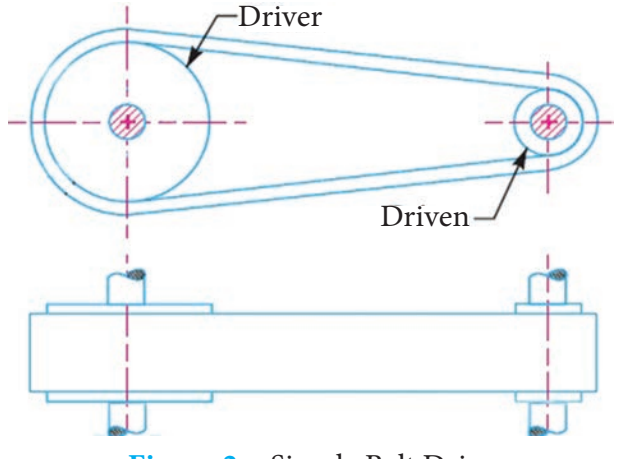


Figure 2 Simple Belt Drive

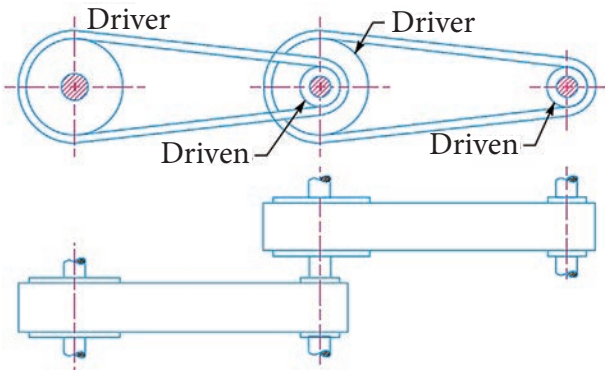


Figure 3 Compound Belt Drive

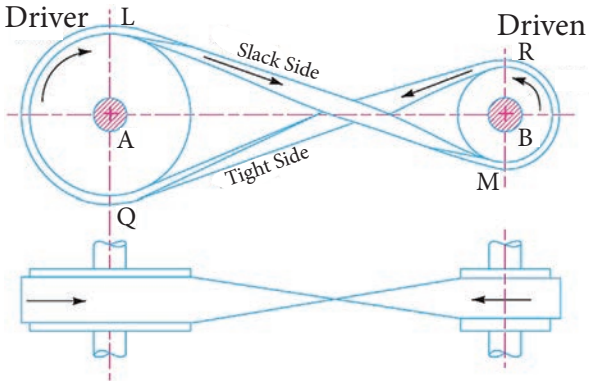


Figure 4 Crossed Belt Drive

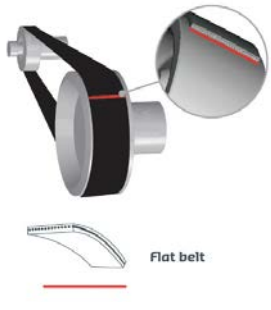
Cross belt Drive

In this type of belt drive, the belt is crossed between the pulleys. The belt connects the top portion of the driver with the lower portion of follower. The grip between the belt and pulley is greater because of the crossed nature of the belt. The pulleys connected by the cross belt arrangement rotate in the opposite directions. If the driver rotates in clockwise direction, the follower will rotate in the anticlockwise direction.

9.3.2. Types of Belt

Belt is usually made from leather, rubber and canvas thread in a moulded form. The two ends of a belt are connected by hooks and pins. Generally two forms of belts are used.

1. Flat belt.
2. V –belt.

Type of Belt	Description	Picture
Flat Belt	• Cross section thickness 0.75mm to 5mm. • Transmission of power is low • Flat face pulleys are used • Distance between two shafts are more	
V- Belt	• Cross section thickness 8mm to19mm. • Transmission of power is high • V-groove pulleys are used. • Distance between two shafts are less	

9.3.3. Velocity Ratio of a Belt Drive

Velocity ratio of a belt drive is the ratio of number of revolutions of follower to the number of revolutions of driver in a particular time.

If D_1 and D_2 are the diameter of driver and follower and N_1 and N_2 are the number of revolutions per minute of the driver and the follower.

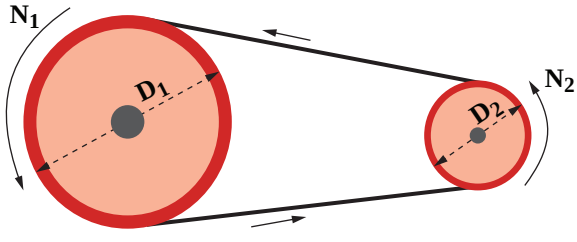


Figure 5 Velocity Transmission

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{D_1}{D_2}$$

Though the theoretical value of velocity ratio is calculated as above, it differs from it because of the thickness of the belt and belt slip. These factors should also be taken into account in calculating the actual velocity ratio.

The speed of the shaft or the pulley is expressed in Revolutions Per Minute (RPM). If we want to increase the speed of the follower with respect to the driver, the pulley on the driven shaft should be smaller in size (diameter) than the pulley on the driving shaft. If we want to decrease the speed of the follower, the pulley on the driven shaft should be larger in size.

$$D_1N_1 = D_2N_2$$

EXAMPLE 1

Pulley of diameters 360 mm and 60 mm are connected by a belt drive. Find the velocity ratio.

$D_1 = 360$ mm

$D_2 = 60$ mm

Driver pulley speed = N_1

Driven pulley speed = N_2

Driving pulley diameter(D_1) = 360 mm

Driven pulley diameter (D_2) = 60 mm

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{D_1}{D_2} = \frac{6}{1} = \frac{360}{60} = 6:1$$

Velocity ratio = 6:1

EXAMPLES 2

Two pulleys of diameters of 500 mm and 250mm are connected by means of a open belt drive. If the larger pulley rotates at a speed of 400 rpm in clockwise direction, find the speed and direction of rotation of the smaller pulley.

$D_1 = 500$ mm $\qquad$ $D_2 = 250$ mm

$N_1 = 400$ rpm

Driving pulley diameter (D_1) = 500 mm

Driven pulley diameter (D_2) = 250 mm

Driver pulley speed N_1 = 400 rpm

Driven pulley speed N_2 = ?

$$D_1N_1 = D_2N_2$$

$$N_2 = \frac{D_1N_1}{D_2}$$

$$= \frac{500 \times 400}{250}$$

N_2 = 800 rpm clockwise direction

EXAMPLES 3

Two shafts are connected by a belt drive. On one of the shafts, a pulley of 200 mm diameter is fitted and it rotates at a speed of 3000 rpm in anticlockwise direction. What should be the diameter of the driven pulley if it is to rotate at a speed of 1500 rpm in clockwise direction? What should be the type of belt drive?

$D_1 = 200$ mm $\qquad D_2 = ?$

$N_1 = 3000$ rpm $\qquad N_2 = 1500$ rpm

Driving pulley diameter $(D_1) = 200$mm

Driven pulley diameter $(D_2) = ?$

Driving pulley speed $N_1 = 3000$ RPM

Driven pulley speed $N_2 = 1500$ RPM

$$D_1N_1 = D_2 N_2$$

$$D_2 = \frac{D_1N_1}{N_2}$$

$$= \frac{200 \times 3000}{1500}$$

$$= 200 \times 2$$

$D_2 = 400$ mm

The diameter of the pulley is 400 mm and the belt should be connected in cross belt method.

9.3.4. Belt Slip

When power is transmitted through belt driver, the follower of the driver will not rotate at the estimated speed. It will rotate at a lower speed only. The main reason for this defect is slackness of the belt.

Belt slip is the difference between the distance covered by a point on the pulley and the distance covered by a point on the belt per minute. Belt slip is always expressed in percentage.

$$\text{Belt slip (S)} = \frac{\text{Estimated speed} - \text{Actual speed} \times 100}{\text{Estimated speed}}$$

If D_1 and D_2 are the diameters of the pulleys and N_1 and N_2 are their speed in rpm and 'S' is the amount of belt slip in percentage.

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{D_1}{D_2} \times \frac{(100 - s)}{100}$$

EXAMPLE 4

A driving pulley of diameter 120 mm rotates at a speed of 400 rpm. The driven pulley of diameter 80 mm connected by a belt drive rotates at speed of 588rpm. Find the percentage of belt slip.

$D_1 = 120$ mm $\qquad D_2 = 80$ mm

$N_1 = 400$ rpm $\qquad N_2 = ?$

Driving pulley diameter $(D_1) = 120$ mm

Driven pulley diameter $(D_2) = 80$ mm

Driving pulley speed $N_1 = 400$ RPM

Driven pulley speed $N_2 = ?$

$$D_1N_1 = D_2 N_2$$

$$N_2 = \frac{D_1N_1}{D_2}$$

$$= \frac{120 \times 400}{80}$$

$$N_2 = 600 \text{ RPM}$$

Estimated speed $N_2 = 600$ RPM

Actual speed $N_2 = 588$ RPM

The estimated speed of the driven pulley is 600 rpm. But it rotates at 588 RPM.

$$\text{Belt slip\%} = \frac{\text{Estimated speed} - \text{Actual speed} \times 100}{\text{Estimated speed}}$$

$$= \frac{600 - 588}{600} \times 100$$

$$= \frac{12}{600} \times 100$$

$$= 2$$

9.3.5. Belt Drive Advantages and Disadvantages

Advantages

1. Absorbs noise and vibrations
2. Protects from overload
3. Needs little maintenance
4. Allows misalignment (Parallel shafts)

Disadvantages

1. Speed ratio is not constant (Slip & Stretch)
2. Speed limited- 2000 m/min
3. Endless belts needs special attention to install
4. Belt may slip from Pulley while rotate

9.4. GEARS

Gears are used to transmit power between rotating parts to operate various machines. The power transmission is achieved without any slip. It is also advantageous in the sense that higher velocity ratio can be achieved in limited space.

Only parallel shafts are connected by belt drive whereas parallel non-parallel and perpendicular shafts are connected by means of gears to transmit power.

9.4.1. Forms of Gears

There are different forms of gears namely:

1. Spur gear.
2. Helical gear.
3. Bevel gear.
4. Rack and pinion gear.
5. Worm and worm gear.

Spur Gear

Spur gears have their teeth elements parallel to the rotating shafts. These gears are used to transmit power between parallel shafts. A small sized gear is called pinion.

Figure 6 Spur Gear

Helical Gears

If the teeth elements are twisted or helical, they are known as helical gears. These gears may be used for connecting shafts that are at an angle in the same plane or in different planes. They are smooth acting because there will always be more than one tooth in contact. Depending upon helix, the helical gears are classified as right hand type or left hand type.

Figure 7 Helical Gear

Bevel Gears

The power is transmitted between two shafts which are at right angles through bevel gears. It is in the shape of a truncated cone having all the teeth elements on the conical surface.

Figure 8 Bevel Gear

Rack and Pinion Gears

This type of gear is used to convert rotary motion into linear motion or vice versa. The rack gears are straight and flat and have no curvature. This type of gear is used in lathe and drilling machine.

Figure 9 Rack and Pinion Gear

Worm and Worm Gears

Worm and worm gear are used to transmit power between two perpendicular shafts. Worm may be single threaded or multi-threaded. The worm gear resembles a spur gear. In this gearing the worm will always be the driver. This gearing is used where a large speed reduction is desired. It is useful in indexing head, rotary table and in the feed rod of lathe.

Figure 10 Worm and Worm Gear

9.5. GEAR TRAIN

Gear drive is used where moderate to large amount of power is to be transmitted at constant velocity ratio. If the driving gear rotates in the clockwise direction, the follower will rotate in the anti- clockwise direction. The velocity ratio of a gear drive depends on the number of teeth present on the driving gear and the driven gear.

9.5.1. Velocity Ratio of Gear Drive

Velocity ratio of a gear drive is the ratio of number of revolutions of driven shaft of driven gear to the number of revolutions of driving shaft or driving gear in a particular time.

If N_1 and N_2 are driving gear and driven gear are the number of revolution of driving gear and driven gear and T_1 and T_2 are the number of teeth of the driving gear and the driven gear.

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$

Example 5

If a gear having 48 teeth rotates at a speed of 600rpm. In clock-wise direction, what will be speed and direction of rotation of a gear having 72 teeth which is in mesh with the first one ?

T_1 = 48 teeth T_2 = 72 teeth

N_1 = 600 rpm N_2 = ?

Number of teeth on the driving gear (T_1) = 48 teeth

Number of teeth on the driven gear (T_2) = 72 teeth

Number of rotational of driving gear (N_1) = 600 rpm.

Number of rotational of driven gear (N_2) = ?

$$\frac{T_1}{T_2} = \frac{N_2}{N_1}$$

$$N_2 = \frac{T_1 \times N_1}{T_2}$$

$$= \frac{48 \times 600}{72} = 400 \text{ rpm}$$

N_2 = 400 rpm Anti clock wise direction

9.5.2. Simple Gear Train

If a gear train is arranged by keeping only one gear on a shaft, it is called simple gear train.

The net velocity ratio of the gear drive is determined by the number of teeth present on the first and the last gears of the drive. The intermediate gears of the drive using only to fill the gap between the driving shaft and the driven shaft, is called Ideal gear. It is also useful in changing the direction of rotation of the follower without changing the speed.

In simple gear train, if the total number of gears are in odd number then the first and last gear rotates in the same direction.

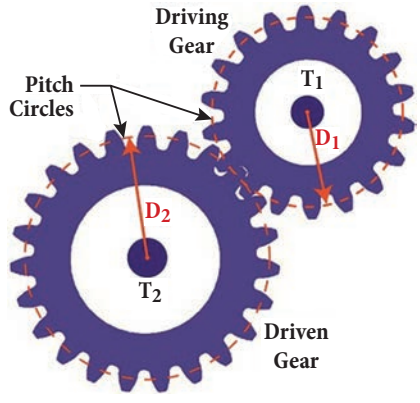


Figure 11 Simple Gear Drive

Example 6

Gears A, B, C and D are connected by a simple gear train. The number of teeth on them are 75, 45, 60 and 50. If the gear D rotates at a speed of 360 rpm in clock-wise direction, what will be the speed of the gear A.

T_1 = 75 teeth T_2 = 45teeth

T_3 = 60 teeth T_4 = 50teeth

Number of teeth on the driving gear (T_1) = 75 teeth

Number of teeth on the ideal gear (T_2) = 45 teeth

Number of teeth on the ideal gear (T_3) = 60 teeth

Number of teeth on the driver gear (T_4) = 50 teeth

Number of rotational of driven gear N_4 = 360 rpm

$T_1 N_1 = T_4 N_4$

$$N_1 = \frac{T_4 \times N_4}{N_1} \qquad N_1 = \frac{50 \times 360}{75}$$

$$N_1 = \frac{2 \times 360}{3} = 240 \text{ rpm}$$

N_1 = 240 RPM Anti clock wise direction

9.5.3. Compound Gear Train

If the gear drive is arranged by keeping more than one gear on a shaft, it is called compound gear train. The net velocity ratio of the gear drive is influenced by the intermediate gear also, so it is possible with a compound gear train to attain a higher velocity ratio in limited space. The direction of rotation of the follower with respect to the driver is determined by a number of intermediate gears on separate shafts.

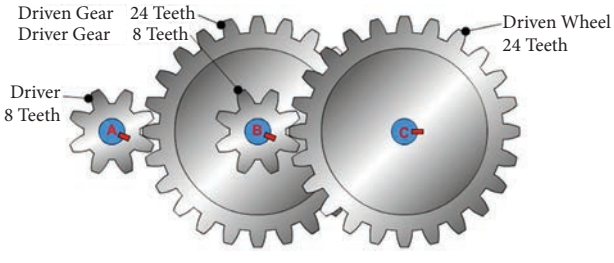


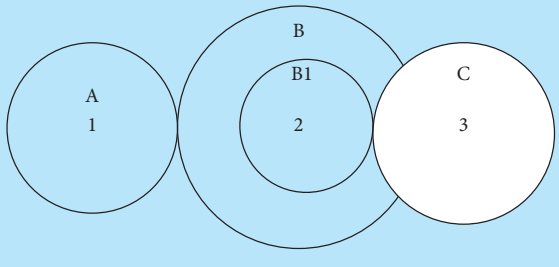
Figure 12 Compound Gear Train

Two gears mounted in the same shaft. So rotational speed are same. ($N_2 = N_3$)

Velocity ratio: $\frac{N_4}{N_1} = \frac{T_1}{T_2} \times \frac{T_3}{T_4}$

Example 7

A compound gear train is arranged in which the driving shaft 1 and shaft 3 through intermediate shaft 2. The gear A on shaft 1 has 40 teeth which rotates at 900 rpm in clock wise direction. It meshes with a gear B of 80 teeth on shaft 2. This shaft has another gear with 50 teeth which meshes with a gear, C on shaft 3. What is the speed and direction of rotation of the gear on shaft 3 which has 60 teeth?



$T_A = 40$teeth $\quad T_B = 80$teet $\quad T_C = 60$teeth

$N_A = 900$rpm $\quad T_{B1} = 50$teeth

Number of teeth on the driving gear (T_A) = 40 teeth

Number of teeth on the intermediate shaft gear (T_B) = 80 teeth

Number of teeth on the intermediate shaft gear (T_{B1}) = 50 teeth

Number of teeth on the driver gear (T_C) = 60 teeth

Number of rotational of driving gear (N_A) = 900 rpm

$$N_B = \frac{T_A N_A}{T_B}$$

$$N_B = \frac{40 \times 900}{80}$$

$N_B = 450$ RPM

Two gears (N_B and N_{B1}) mounted in the same shaft. So rotational speed are same.

$N_B = N_{B1} = 450$ RPM

$$N_C = \frac{T_{B_1} \times N_{B_2}}{T_c}$$

$$= \frac{50 \times 450}{60}$$

$= 375$ RPM

$N_C = 375$ RPM Anti clock wise direction

9.5.4. Advantages and Disadvantages of Gears

Advantages of Gears

1. By using gear train, large velocity ratio can be obtained with minimum space
2. Gears are mechanically strong, So higher loads can be lifted
3. They are used for positive drive, so its velocity ratio remains constant.
4. Gears require only lubrication, hence less maintenance is required.

Disadvantages of Gears

1. They are not suitable for large velocities.
2. They are not suitable for transmitting motion over a large distance.
3. They have no flexibility
4. Gear operation is noisy.

9.6. ABSTRACT OF TRANSMISSION OF POWER

1. Methods of transmitting power	1. Belt drive 2. Chain drive 3. Gear drive
2. Transmitting motion of Belt drive	1. Belt Slip 2. Belt are used to distance between the connected shafts is high.
3. Transmitting power, chain and gears	1. No slip in velocity ratio 2. Chains are used to connect small gab between the shafts.
4. Velocity ratio without slips	Positive drive (Chain drive, Gear drive)
5. Velocity ratio with slip	Non – Postive Drive(Belt drive)
6. Shaft which transmits the rotational power is connected with electric motor.	Driving PULLEY
7. Shaft which receives the Rotational power is Known as driven shaft and Pulley mounted on it is Known as	FOLLOWER (or) DRIVEN PULLEY
8. The transmission of power becomes possible because of the _____ between pulley and belt	Grip
9. Open belt drive	The driver and the follower Rotate in the same direction

10. Cross belt drive	1. The driver and the follower rotate in opposite direction. 2. The grip between the belt and pulley is greater
11. Types of belt	1. Flat belt 2. V–belt
12. The thickness of a flat belt	0.75mm to 5mm
13. The efficiency of the flat belt	98%
14. The thickness of the V_belt	8mm to 19mm
15. The efficiency of the V_belt	70% to 98%
16. Velocity ratio of a belt drive	$\frac{N_2}{N_1} = \frac{D_1}{D_2}$ D_1, D_2 are the diameter of driver and follower. N_1, N_2 are the number of revolutions perminute of the driver and follower.
17. Velocity ratio depends on	1. Thickness of the belt 2. Slip of the belt.
18. Belt slip (%) (s)	$S = \frac{\text{Estimated speed} - \text{Actual speed}}{\text{Estimated speed}} \times 100$
19. Velocity Ratio with considering slip	$\frac{N_2}{N_1} = \frac{D_1}{D_2} \times \left(\frac{100 - s}{100}\right)$
20. Spur gears	1. Gear teeths are parallel to the shaft axis. 2. These gears are used to Transmit power between Parallel shafts.
21. Helical gears	1. The teeth are inclined to the shaft axis 2. They are smooth acting Because there will always engage more than one tooth in contact
22. Bevel gears	1. The teeth elements on the conical surface. 2. The power is transmitted Between two shafts which are at right angles though bevel gears.
23. Rack and pinion gears	1. The rack gears are straight and flat and pinion are rotate. 2. This type of gear is used to convert rotary motion into linear motion or Vice versa

24. Worm and worm gears	1. worm may be single threaded or multi threaded. 2. This gearing is used where a large speed reduction. 3. Worm and worm gear are used to transmit power between two perpendicular (90°) shafts.
25. Two gears are rotates with each other	1. Driving gear rotates in the clockwise direction 2. The follower will rotate in the anti-clock wise direction.
26. Velocity ratio of gear rive	$\frac{N_2}{N_1} = \frac{T_1}{T_2}$ T_1 and T_2 are the number of teeth on the driving gear and the driven gear. N_1 and N_2 are the number of revolutions of driver and follower
27. Simple gear train	1. If a gear train is arranged by keeping only one gear on a shaft 2. If the total number of gears are in odd number then the first and the last gear & rotates in the same direction.
28. Compound gear train	1. If the gear drive is arranged by keeping more than one gear on a shaft. 2. The net velocity ratio of the gear drive is influenced by the intermediate gear also.

GLOSSARY

1. Spur Gear - நேர்ப்பல்லிணை
2. Helical Gear - நெளிவுப்பல்லிணை
3. Bevel Gear - சரிவுப்பல்லிணை
4. Rack and Pinion - தட்டை மற்றும் சிறு பல்லிணை

ACTIVITIES

1. Make a open belt drive, cross belt drive and chain drive by using scrab material.

QUESTIONS

PART A

I. Choose the correct option :

1. Power is transmitted between shafts at moderate distance by
   a) belt drive b) gear drive
   c) chain drive d) friction drive

2. The diameter of the driving pulley is 200 rpm. The velocity ratio of the drive is 4. The diameter of the driven Pulley is
   a) 100cm b) 25cm
   c) 40cm d) 50cm

3. Velocity ratio of a gear drive is
   a) $D_1N_1 = D_2N_2$
   b) $\frac{N_T - N_A}{N_T} \times 100$
   c) $= \frac{T_1}{T_2} = \frac{N_2}{N_1}$
   d) RPM

PART B

II. Answer the following questions in one or two sentences:

4. Expand r.p.m.
5. What are the types of belt drive?
6. Mention any two forms of gear?
7. What is an idle gear?
8. What is a bevel gear?
9. What are methods by which power can be transmitted?

PART C

III Answer the following questions in about a page?

10. Explain velocity ratio?
11. Draw a simple gear train and explain.
12. Draw a compound gear and explain.
13. Explain power transmission by a belt drive.
14. Explain velocity ratio.
15. Draw a simple gear and explain.
16. Draw a compound gear and explain.

PART D

IV. Answer the following questions in detail:

17. Explain open belt drive with a diagram.
18. Draw and explain cross belt drive.