CO3(DAC)

A clutch is a mechanical device used in various applications to connect and disconnect two rotating shafts, allowing them to spin independently or be mechanically linked together. Its primary function is to transmit power from one shaft to another when engaged and to interrupt the power transmission when disengaged. Clutches are commonly found in vehicles, machinery, and various industrial and mechanical systems. Here are the main functions and applications of clutches:

Function of a Clutch:

1. **Power Transmission**: The primary function of a clutch is to transmit power from the engine to the transmission or another component in a mechanical system. In vehicles, it connects the engine's crankshaft to the gearbox input shaft.
2. **Engagement and Disengagement:** Clutches allow for the controlled engagement and disengagement of power transmission. When engaged, the clutch links the rotating shafts, allowing power transfer. When disengaged, it separates the shafts, preventing power transfer.
3. **Speed Control:** Clutches enable speed control by allowing the operator to select different gears (in the case of a vehicle) or control the speed of a machine by engaging or disengaging the clutch as needed.

   Spur gears are a type of cylindrical gear in which the teeth are cut parallel to the axis of the gear. They are among the most common and simplest types of gears, widely used in various mechanical systems and gear trains. Here, I'll discuss some terminology related to spur gears and mention a few types of gear trains where spur gears are commonly used.

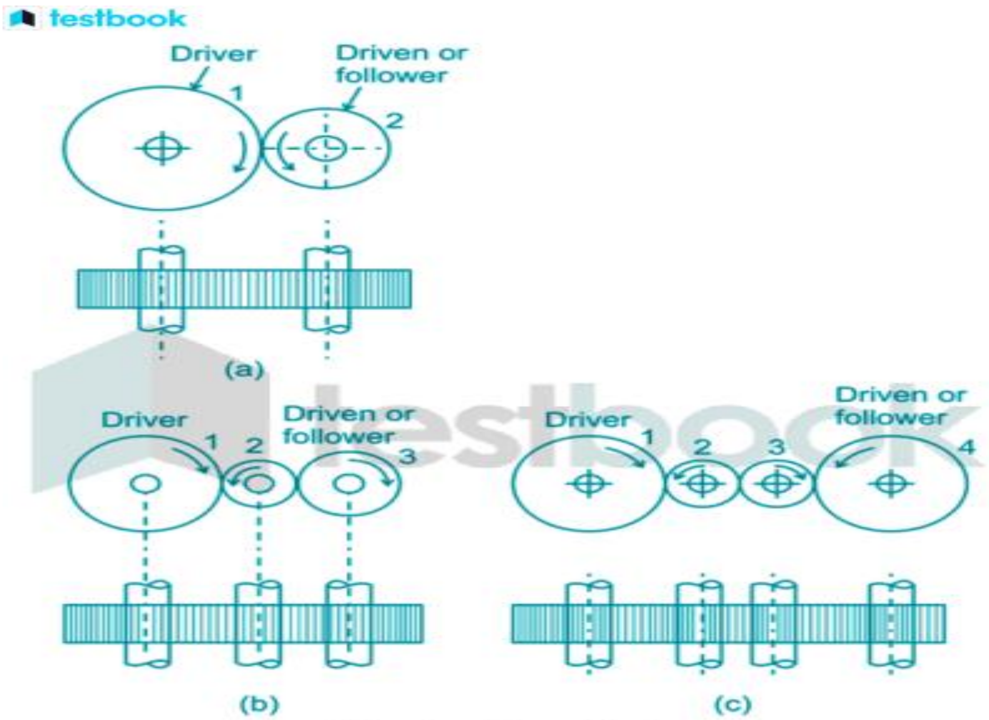
Terminology Related to Spur Gears:

1. **Pitch Circle:** The imaginary circle that passes through the point where the teeth of two meshing gears make contact. The radius of this circle is called the pitch radius.
2. **Pitch Diameter (D):** The diameter of the pitch circle. It is calculated as D = 2 * Pitch Radius.
3. **Number of Teeth (N):** The number of teeth on a gear. It's an essential parameter for gear design and calculations.
4. **Module (m):** A measure of the size of a gear. It is the ratio of the pitch diameter to the number of teeth. Mathematically, m = D / N.
5. **Addendum (a):** The radial distance from the pitch circle to the top of the gear tooth.
6. **Dedendum (b):** The radial distance from the pitch circle to the bottom of the gear tooth.
7. **Pressure Angle (α):** The angle between the tangent to the pitch circle and the line of action of the tooth force. A common pressure angle is 20 degrees.

8. **Center Distance (C):** The distance between the centers of two meshing gears. It affects the gear ratio and determines whether gears are in mesh.

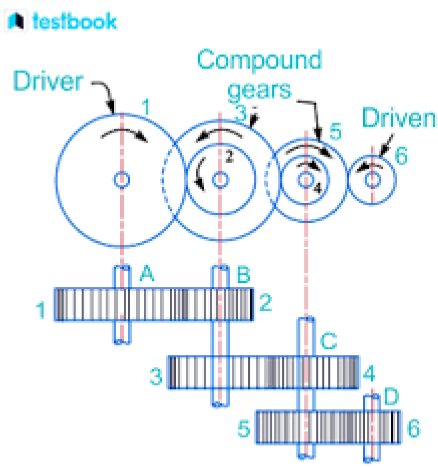
Types of Gear Trains Using Spur Gears:

1. **Simple Gear Train:** In a simple gear train, two or more spur gears are meshed together. They may be used to transmit motion between parallel shafts. The gear ratio is determined by the number of teeth on each gear.

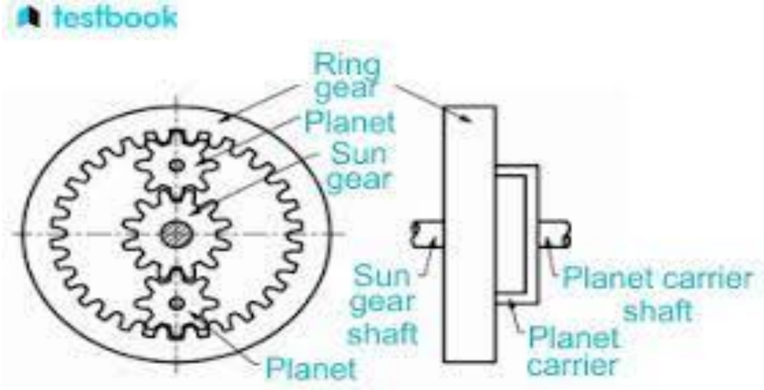


Simple Gear Train

2. **Compound Gear Train:** A compound gear train consists of two or more gear pairs in series. It combines the advantages of different gear ratios and is often used to achieve complex gear reductions.

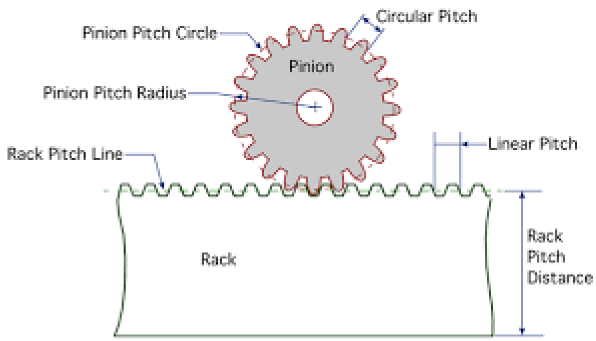


3. **Planetary Gear Train (Epicyclic Gear Train):** In this type of gear train, one or more gears rotate around a central sun gear. It's used for speed and direction control in various applications, including automatic transmissions in vehicles.

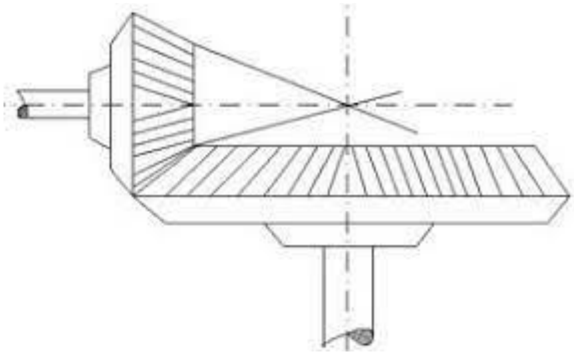


Simple Epicyclic Gear Box

4. **Rack and Pinion:** A rack is a flat, toothed bar, and a pinion is a small spur gear. The pinion meshes with the rack to convert rotational motion into linear motion. This system is used in steering mechanisms, elevators, and other linear motion applications.



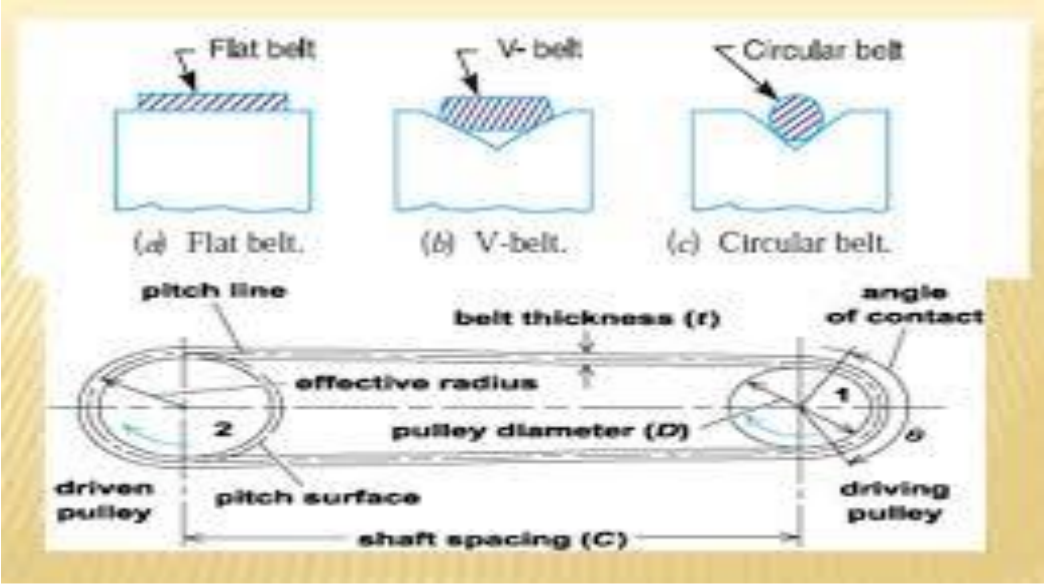
5. **Intersecting Shaft Gear Train:** In this arrangement, the shafts of the gears intersect. It is commonly used when the input and output shafts need to change direction, such as in right-angle drives.



6. **Parallel Shaft Gear Train:** Spur gears on parallel shafts are used to transmit motion and power between shafts that are parallel to each other. The gear ratio depends on the number of teeth on the gears.

Types of Belts:

Belts are flexible looped elements used to transmit mechanical power from one shaft to another. There are several types of belts used in various applications:



Flat Belts: These are simple, flat, and rectangular belts made of rubber or fabric-reinforced materials. They are suitable for low-power transmission and are often used in industrial machinery.

V-Belts (or Vee Belts): V-belts have a trapezoidal cross-section and are designed to fit into V-grooves on pulleys. They are commonly used for higher power transmission in applications like automotive engines and industrial machinery.

Timing Belts: Timing belts have teeth on the inner surface, which mesh with pulley teeth to ensure precise and synchronous power transmission. They are commonly used in engines for camshaft and crankshaft synchronization.

Materials for Belts:

Belts can be made from various materials, depending on their intended application:

1. **Rubber:** Rubber is a common material for belts due to its flexibility, durability, and resistance to wear. It is used in V-belts, timing belts, and flat belts.
2. **Fabric:** Fabric-reinforced belts combine fabric layers with rubber to increase strength and flexibility. They are often used in flat belts and conveyor belts.
3. **Neoprene:** Neoprene belts are resistant to heat and oil, making them suitable for demanding industrial applications.
4. **Polyurethane:** Polyurethane belts offer high strength, flexibility, and resistance to wear. They are used in timing belts and other specialized applications.

Slip and Creep of Belts:

Slip and creep are two important phenomena associated with belt drives:

Slip: Slip occurs when the driven pulley (output) rotates at a slightly different speed than the driver pulley (input). This speed difference is due to the friction between the belt and the pulleys. Slip is undesirable in most cases as it results in power loss and reduced efficiency.

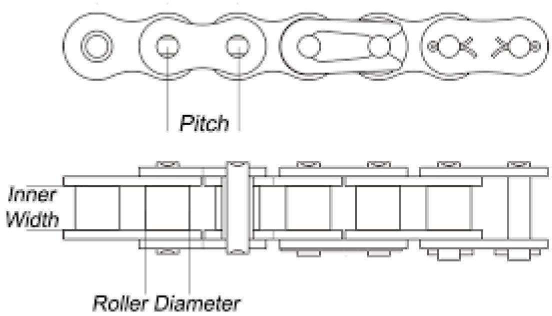
Creep: Creep is the gradual movement of a belt over time in the direction of motion. It can occur due to factors like belt stretching or uneven wear. Creep can lead to misalignment and reduced performance in belt-driven systems.

To prevent slip and minimize creep, proper tensioning of the belt is essential. Belt tensioners or idler pulleys are often used to maintain the correct tension in the belt, ensuring efficient power transmission and reducing the likelihood of slip and creep.

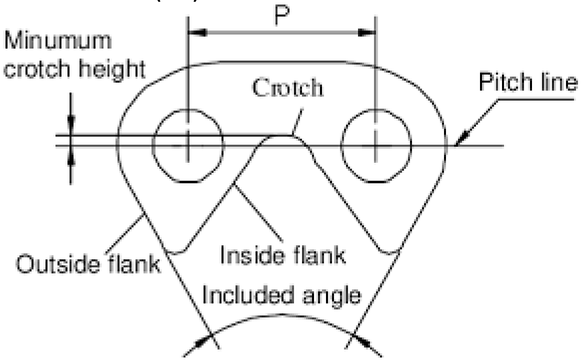
Chain drives are a type of mechanical power transmission system that use a chain to transmit power between two or more rotating shafts. They are widely used in various applications due to their durability and efficiency. Below is an outline of the types, advantages, and disadvantages of chain drives:

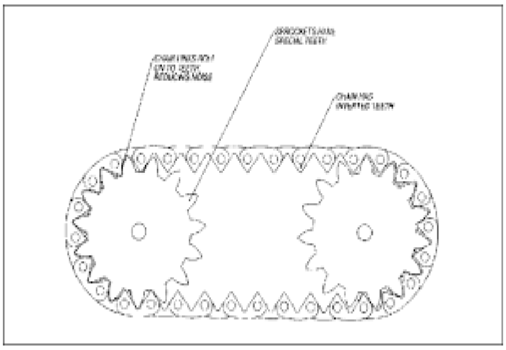
Types of Chain Drives:

1. **Roller Chains:** Roller chains are the most common type of chain drive. They consist of cylindrical rollers that engage with the teeth of sprockets. Roller chains are widely used in motorcycles, bicycles, industrial machinery, and conveyor systems.



2. **Silent Chains (Inverted-Tooth Chains):** Silent chains feature a series of toothed links that engage with matching sprockets. They are used in applications where quiet operation is essential, such as some automotive timing drives.





3. **Leaf Chains:** Leaf chains consist of interlocking, leaf-shaped plates that are connected by pins. They are used in applications that require high tensile strength, such as forklifts and lifting equipment.

Advantages of Chain Drives:

1. **High Efficiency**: Chain drives have minimal power loss due to friction, making them highly efficient for power transmission.
2. **High Load Capacity:** Chains can handle heavy loads and transmit substantial torque, making them suitable for demanding industrial applications.
3. **Durability**: Chains are durable and have a long service life when properly maintained. They can withstand harsh environmental conditions and heavy use.
4. **Precise Speed Control:** Chain drives offer precise control over the speed and position of the driven equipment, especially when using multiple sprockets with different diameters.
5. **Wide Range of Speed Ratios:** Chain drives can achieve a wide range of speed ratios by varying the sizes of the sprockets.
6. **No Slip:** Unlike belts, chain drives do not experience slip, ensuring a direct and consistent power transfer.

Disadvantages of Chain Drives:

1. **Maintenance:** Chain drives require regular maintenance, including lubrication and tension adjustment. Neglecting maintenance can lead to wear and reduced efficiency.
2. **Noise and Vibration:** Chain drives can produce noise and vibration, which may be undesirable in some applications. Silent chains can mitigate this issue to some .

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Example 6.1 : *A plate clutch having a single driving plate with contact surfaces on each side is required to transmit a torque of 840 Nm. The outer diameter of contact surface is to be 300 mm. The coefficient of friction is 0.4. Assuming uniform pressure of 0.17 N/mm², determine the inner diameter of the friction surface.*

Solution :

Torque, $T = 840 \text{ Nm} = 840 \times 10^3 \text{ Nmm}$

Outer diameter, $d_1 = 300 \text{ mm}$

$\therefore \quad r_1 = 150 \text{ mm}$

Coefficient of friction, $\mu = 0.4$

Uniform pressure, $p = 0.17 \text{ N/mm}^2$

Axial thrust

$$W = p\,\pi\,(r_1^2 - r_2^2) = 0.17\ \pi\,(150^2 - r_2^2)$$

$$= 0.534\,(150^2 - r_2^2)$$

and Torque, $T = n \cdot \dfrac{2}{3}\,\mu W \left[\dfrac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$

Where n = number of contacting surfaces = 2

$$\therefore\quad T = 2 \times \frac{2}{3} \times 0.4 \times 0.534\,(150^2 - r_2^2)\left[\frac{150^3 - r_2^3}{150^2 - r_2^2}\right]$$

$$840 \times 10^3 = 0.285\,(150^3 - r_2^3)$$

or $r_2^3 = 150^3 - \dfrac{840 \times 10^3}{0.285}$

$r_2 \approx 75 \text{ mm}$

or $d_2 = 75 \times 2 = 150 \text{ mm}$

Inner diameter = **150 mm Ans.**

Example 6.2 : *A single disc clutch with both sides of the disc effective is used to transmit 10 kW power at 900 rpm. The axial pressure is limited to 0.085 N/mm². If the external diamter of the friction lining is 1.25 times the internal diameter, find the required dimensions of the friction lining and axial force exerted by the springs. Assume uniform wear. The co-efficient of friction may be taken as 0.3.* **[March 2006]**

Solution :

Power, $P = 10\text{ kW} = 10 \times 10^3\text{ W}$

Speed, $N = 900\text{ rpm}$

Axial pressure, $p = 0.085\text{ N/mm}^2$

Outer radius, $r_1 = 1.25\ r_2$; r_2 = Inner radius.

Coefficient of friction, $\mu = 0.3$

Friction forque, $T = \frac{60P}{2\pi N} = \frac{60 \times 10 \times 10^3}{2\pi \times 900}$

$= 106.103\text{ Nm} = 106103\text{ Nmm}$

For uniform wear p.r = constant; and p is maximum at r_2

$\therefore\quad p.\ r_2 = c = 0.085\ r_2$

load, $W = 2\pi c (r_1 - r_2)$

$= 2\pi \times 0.085\ r_2 (r_1 - r_2) = 0.534\ r_2 (1.25\ r_2 - r_2)$

$W = 0.1335\ r_2^2$ ..... (i)

Frictional torque,

$$T = n.\mu W \left[\frac{r_1 + r_2}{2}\right] = 2 \times 0.3 \times 0.1335\ r_2^2 \left(\frac{1.25r_2 + r_2}{2}\right)$$

$$106103 = 0.0901 r_2^3$$

$$r_2 = \sqrt[3]{\frac{106103}{0.0901}} = 105.6\text{ mm}$$

$\therefore\quad r_1 = 1.25 \times 105.6 = 132\text{ mm}$

Dimensions of friction lining

Outer radius, r_1 = **132 mm Ans.**

Inner radius, r_2 = **105.6 mm Ans.**

Axial load, $W = 0.1335\ r_2^2$

$= 0.1335 \times 105.6^2 =$ **1488.7 N Ans.**

Example 6.3 : *In a single disc clutch the outside diameter of contact surface is 280 mm and inside diameter is 180 mm. If $\mu = 0.2$ and the allowable intensity of pressure is 0.12 N/mm², calculate*

(a) Axial force

(b) Power transmitted at 900 rpm.

Solution :

Outside radius, $r_1 = \frac{280}{2} = 140\text{ mm}$

Inside radius, $r_2 = \frac{180}{2} = 90\text{ mm}$

Allowable intensity of pressure, $p = 0.12 \text{ N/mm}^2$

Coefficient of friction, $\mu = 0.2$

Speed, $N = 900$ rpm

(a) Axial force :

$$W = 2\pi c (r_1 - r_2)$$
$$= 2\pi (0.12 \times 90)(140 - 90) = \mathbf{3392.92 \text{ N}} \textbf{ Ans.}$$

(b) Power transmitted :

Assume, $n = 2$

Frictional torque, $T = n\mu W \left[\frac{r_1 + r_2}{2}\right]$

$$= 2 \times 0.2 \times 3392.92 \left[\frac{140 \times 90}{2}\right]$$
$$= 156074 \text{ Nmm} = 156.074 \text{ Nm}$$

Power, $P = \dfrac{2\pi NT}{60} = \dfrac{2\pi \times 900 \times 156.074}{60}$

$$= 14709 \text{ W} = \mathbf{14.709 \text{ kW}}$$ **Ans.**

Example 6.4 : *A multi-disc clutch has three discs on the drivin[g] shafts and two discs on the driven shafts. The inner radius of contact [is] 40 mm and outer radius is 70 mm. Assuming uniform wear and coefficie[nt] of friction as 0.1, find the maximum axial intensity of pressure betwee[n] surfaces for transmitting 4 kW at 750 RPM.*

Solution :

Number of contact surfaces, $n = (n_1 + n_2 - 1)$
$= [(3 + 2) - 1] = 4$

Outer radius, $r_1 = 70$ mm

Inner radius, $r_2 = 40$ mm

Coefficient of friction $\mu = 0.1$

Power, $P = 4 \times 10^3$ W

Speed, $N = 750$ RPM.

Torque transmitted, $T = \dfrac{P \times 60}{2\pi N} = \dfrac{4 \times 10^3 \times 60}{2.\pi.750}$

$= 50.93 \text{ Nm} = 50930 \text{ Nmm}$

Also, $T = n.\mu.W\left(\frac{r_1 + r_2}{2}\right)$

$$50930 = 4 \times 0.1 \times W\left(\frac{70+40}{2}\right)$$

or $W = 2315$ N

For uniform wear :

$$W = 2\pi C(r_1 - r_2), \text{ where } C = p\, r_2$$

$$2315 = 2.\pi \times p \times 40\,(70 - 40)$$

Maximum intensity of pressure,

$$p = \frac{2315}{2.\pi \times 40 \times 30}$$

$$= \mathbf{0.307\ N/mm^2} \quad \textbf{Ans.}$$

Example 6.5 : *In a multiple disc clutch four pairs of contact surfaces whose outer diameter is 300 mm and inner diameter is 200 mm are used. If $\mu = 0.2$ and axial intensity pressure is not to exceed 0.13 N/mm^2. Calculate the follooing*

(a) Axial force

(b) Power transmitted at 500 rpm

Solution :

Outer radius, $r_1 = \frac{300}{2} = 150$ mm

Inner radius, $r_2 = \frac{200}{2} = 100$ mm

Coefficient of friction, $\mu = 0.2$

No. of contact surfaces, $n = 4$

Axial force on each surface

$$W = 2\pi c\,(r_1 - r_2)$$

$$= 2\pi\,(0.13 \times 100)\,(150 - 100) = 4084.07 \text{ N}$$

Torque, $T = n\mu W\left[\frac{r_1 + r_2}{2}\right]$

$$= 4 \times 0.2 \times 4084.07\left[\frac{150+100}{2}\right]$$

$$= 408407 \text{ Nmm} = 408.407 \text{ Nm}$$

BELT PROBLEMS

Example 11.4 : *Two pulleys 60 cm and 40 cm diameters are connected by a belt. Central distance between the pulleys is 6 m. Find the length of belt required, for (a) Open belt drive (b) Crossed belt drive.*

Solution :

Given : Dia. of first pulley, $d_1 = 60$ cm
Dia. of second pulley, $d_2 = 40$ cm
Central distance, $d = 6$ m; 600 cm

(a) Length of open belt :

$$L_o = \pi (r_1 + r_2) + \frac{(r_1 - r_2)^2}{d} + 2d$$

$$= \pi (30 + 20) + \frac{(30 - 20)^2}{600} + 2 \times 600$$

$$= 157 + 0.167 + 1200$$

$$= \mathbf{1357.17\ cm}\quad \textbf{Ans.}$$

(b) Length of crossed belt :

$$L_c = \pi (r_1 + r_2) + \frac{(r_1 + r_2)^2}{d} + 2d$$

$$= \pi (30 + 20) + \frac{(30 + 20)^2}{600} + 2 \times 600$$

$$= \mathbf{1361.17\ cm}\quad \textbf{Ans.}$$

Note : The difference between L_c and L_o (= 4 cm) may be obtained by using the relation

$$L_c - L_o = \frac{(r_1 + r_2)^2}{d} - \frac{(r_1 - r_2)^2}{d}$$

$$= \frac{(50)^2}{600} - \frac{10^2}{600} = \mathbf{4\ cm}$$

Example 11.21 : *A belt 100 mm wide and 9.5 mm thick is used to transmit power. If the safe permissible stress in belt material is 1.75 N/mm², calculate the absolute maximum power that can be transmitted by the belt. Assume ratio of belt tensions as 2 and mass of belt per metre length as 0.95 kg.*

Solution :

Given : Width of belt, $b = 100$ mm

Thickness, $t = 9.5$ mm

Permissible stress, $\sigma_t = 1.75$ N/mm²

Mass of belt, $m = 0.95$ kg

Ratio of belt tensions,

$$\frac{T_1}{T_2} = 2$$

$$T_{max} = \sigma_t . b.t = 1.75 \times 100 \times 9.5 = 1662.5 \text{ N}$$

For maximum power transmission,

Centrifugal tension,

$$T_c = \frac{T_{max}}{3} = \frac{1662.5}{3} = 554.16 \text{ N}$$

Also, optimum belt speed,

$$v = \sqrt{\frac{T_{max}}{3\ m}} = \sqrt{\frac{1662.5}{3 \times 0.95}} = 24.15 \text{ m/s}$$

Maximum power,

$$P = (T_{max} - T_c)\left(1 - \frac{1}{e^{\mu\theta}}\right) . v$$

$$= (1662.5 - 554.16)\left(1 - \frac{1}{2}\right).24.15 = 13383.2 \text{ W}$$

$$= \mathbf{13.3832\ kW\ Ans.}$$

GEAR PROBLEMS

Example 12.2 : *Find the pitch diameter, diametral pitch and module of a toothed gear having 36 teeth and a circular pitch of 13 mm.* **[Nov. 2002]**

Solution :

Given : No. of teeth, $T = 36$

Circular pitch, $p = 13$ mm

(a) Pitch circular diameter d;

$$p = \frac{\pi d}{T}$$

or $$d = \frac{p.T}{\pi} = \frac{13 \times 36}{\pi}$$

$$= \mathbf{149\ mm\ Ans.}$$

(b) Diametral pitch, p_d

$$p_d = \frac{T}{d} = \frac{36}{149} = \mathbf{0.24\ Ans.}$$

$$\text{Module, } m = \frac{1}{p_d} = \mathbf{4.2\ mm\ Ans.}$$

Example 12.3 : *A gear of 44 teeth has pitch circle diameter of 352 mm. What is its module, circular pitch and dedendum ?*

Solution :

Number of teeth, $T_g = 44$

PCD, $d = 352$ mm

$$\text{Module, } m = \frac{d}{T_g} = \frac{352}{44} = \mathbf{8\ mm\ Ans.}$$

$$\text{Circular pitch, } p_c = \frac{\pi d}{T_g} = \frac{\pi \times 352}{44}$$

$$= \mathbf{25.13\ mm\ Ans.}$$

or $p_c = m\pi = 8\pi = 25.13$ mm

Dedendum $= 1.25\ m = 1.25 \times 8 =$ **10 mm Ans.**

Example 12.4 : *A gear having 80 teeth meshes with a pinion having 30 teeth. Calculate the distance between the centres of the gears, if the circular pitch is 12 mm.*

Solution :

Given : Number of teeth on gear $T_1 = 80$

Number of teeth on pinion $T_2 = 30$

Circular pitch, $p = 12$ mm

We have,

$$\text{Circular pitch } p = \frac{\pi d}{T} \quad \text{or } d = \frac{p.T}{\pi}$$

$$\therefore \text{ Pitch circle dia. of gear, } d_1 = \frac{12 \times 80}{\pi} = 305.6 \text{ mm}$$

$$\text{Pitch circle dia. of pinion, } d_2 = \frac{12 \times 30}{\pi} = 114.6 \text{ mm}$$

$$\text{Centres distance of the gears, } C = \frac{d_1 + d_2}{2} = \frac{305.6 + 114.6}{2}$$

$$= \mathbf{210.1\ mm\ Ans.}$$

Example 12.15 : *A three speed sliding gear box of a motor car is required to give speed ratio of 4 : 1, 2.5 : 1and 1.5 : 1 for the first, second and third gear respectively. Diametral pitch of all gears is 0.3 and the centre distance between mating gears is 70 mm. Find suitable number of teeth for various gears, if the number of teeth on pinion is 14.*

Solution :

Given : No. of teeth on pinion, $T_A = 14$

Diametral pitch, $p_d = 0.3$

Central distance, $C = 70$ mm

The arrangement of gears for sliding gear box is shown in Fig. 12.12. Since the pitch of gears is same

$$T_A + T_B = T_C + T_D = T_E + T_F = T_G + T_H$$

Central distance,

$$C = \left(\frac{T_A + T_B}{2}\right) m = \left(\frac{T_A + T_B}{2}\right) \cdot \frac{1}{p_d}$$

$$\therefore \quad T_A + T_B = 2 \times 70 \times 0.3 = 42$$

First Gear :

$$\text{Train value} = \frac{N_G}{N_A} = \frac{T_A \times T_H}{T_B \times T_G} = \frac{1}{4} = \frac{1}{2} \times \frac{1}{2}$$

$$\frac{T_A}{T_B} = \frac{1}{2} \Rightarrow T_B = 2T_A = 2 \times 14 = 28 \text{ teeth}$$

$$T_A + T_B = T_H + T_G = 42 \qquad \text{.......... (i)}$$

$$\text{Also,} \quad \frac{T_H}{T_G} = \frac{1}{2} \Rightarrow T_G = 2T_H \qquad \text{.......... (ii)}$$

Solving (i) and (ii)

$$T_H = 14; \text{ and } T_G = 28$$

Second Gear :

$$\text{Train value} = \frac{N_E}{N_A} = \frac{T_A \times T_F}{T_B \times T_E} = \frac{1}{2.5}$$

$$= \frac{T_F}{2T_E} = \frac{1}{2.5} \qquad \left(\because \frac{T_A}{T_B} = \frac{14}{28} = \frac{1}{2}\right)$$

$$= \frac{T_F}{T_E} = \frac{2}{2.5} = \frac{1}{1.25}$$

or $T_E = 1.25\ T_F$ .... (iii)

Also, $T_A + T_B = T_E + T_F = 42$ .... (iv)

Solving equations (iii) and (iv)

$$T_F = 18.66 = 19; \text{ and } T_E = 23 \text{ teeth}$$

Third Gear :

$$\text{Train value} = \frac{N_C}{N_A} = \frac{T_A \times T_D}{T_B \times T_C} = \frac{1}{1.5}$$

$$= \frac{T_D}{2\,T_C} = \frac{1}{1.5}$$

$T_C = 0.75\ T_D$ .... (v)

and $T_A + T_B = T_C + T_D = 42$ .... (vi)

From equation (v) and (vi)

$$T_C = 18; \text{ and } T_D = 24$$

Thus, for first gear :

$$T_A = T_H = 14, \text{ and}$$

$$T_B = T_G = 28$$

for second gear :

$$T_A = 14,\ T_F = 19$$

$$T_B = 28,\ T_E = 23$$