Power Transmission.

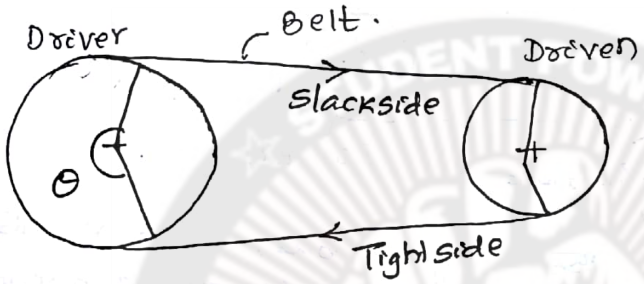
Power may be transmitted from one point to another by belts, ropes, chains and gears. Belts and ropes are used when the distance between two pulleys are at considerable distance apart. Chains and gears are used when the shafts are at a small distance apart.

Types of transmission system.

1. Belt drive
2. Rope drive
3. chaindrive.
4. Gear drive.

Note: Ropedrive & chain drive not in syllabus

Belt drives.



VIJAYA. B
M.E,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology
Rajanukunte, Bengaluru-560 064

It consists of driven pulley and driven pulley which are connected by an endless belt. Due to frictional grip that exists between the belt and pulley surface, power transmission takes place.

Terminology.

Driver: In a transmission system, the ~~gear~~ pulley. which drives or which supplies power to another mechanical element is known as driver.

Driven: The ~~gear~~ pulley/wheel which follows the driver or which receives power from the driver is termed as driven ~~gear~~ pulley or follower.

Tightside: The portion/side of the belt where the maximum tension prevails is called tight side. It is denoted by T_1 and expressed in N.

Slack side: The portion/side of the belt which has minimum tension is called slack side. It is denoted by T_2 and expressed in N.

Arc/Angle of contact: It is the portion of belt which is in contact with pulley surface. It is denoted by 'θ' and measured in degrees.

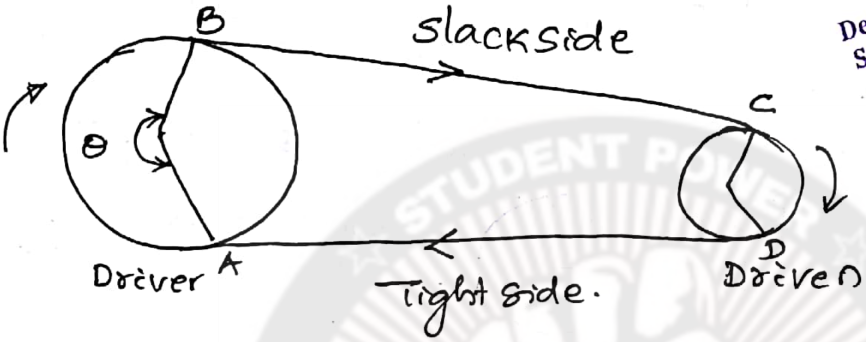
Belt Materials

(i) Rubber (ii) Leather (iii) Canvas (iv) cotton. (v) Balata. (vi) Steel.

Classification of Belt drives.

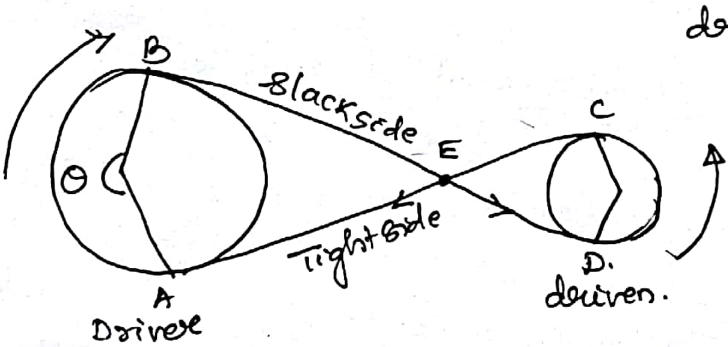
(i) open belt drive.
(ii) Cross belt drive.

open belt drive.



In the fig shown above, the arrangement consists of driver & driven pulleys rotate in the same direction. The driver pulley pulls the belt from one side and delivers it to other side. Hence, the tension in the lower side is more than that in the delivering side. ∴ upper side is known as slack side and lower side is known as Tight side.

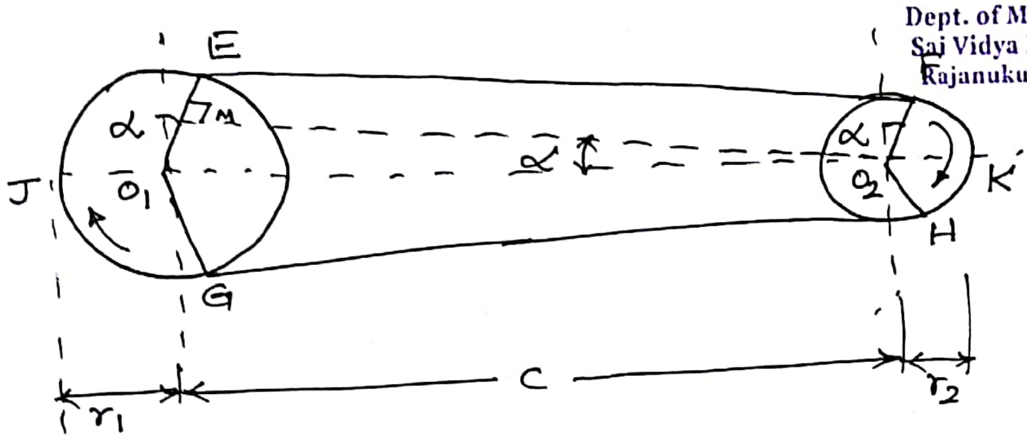
cross belt drive



The arrangement consists of driver and driven pulleys which rotate in the opp. directions.
At point E, where the belt crosses rubbing action takes place which results in excessive wear & tear.

Length of an open Belt.

VIJAYA. B
M.E.,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology
Rajanukunte, Bengaluru-560 064



Consider an open belt drive system as shown in fig.

Let r_1 = radius of Larger pulley.
r_2 = radius of smaller pulley.
C = distance b/w centres of two pulleys (O_1 to O_2)
L = Total Length of the belt.

The belt Leave the Larger pulley at E and G and smaller pulley at F and H. Draw O_2M parallel to EF. from geometry of fig, $O_2M \perp O_1E$.

Let $\angle MO_2O_1 = \alpha$ radians

Length of belt L = Arc GJE + EF + Arc FKH + HG.
= 2 (Arc JE + EF + Arc FK) —(i)

$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E - EM}{O_1O_2} = \frac{r_1 - r_2}{C}. \quad \sin\alpha = \alpha$$

$\therefore \alpha = \frac{r_1 - r_2}{C}$ —(ii) $\therefore$ Arc JE $= r_1\left(\frac{\pi}{2} + \alpha\right)$ —(iii)

Arc FK $= r_2\left(\frac{\pi}{2} - \alpha\right)$ --(iv)

$$EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2} = \sqrt{C^2 - (r_1 - r_2)^2}$$

$$= C\sqrt{1 - \left(\frac{r_1 - r_2}{C}\right)^2}$$

Expanding by binomial theorm.

$$EF = C\left[1 - \frac{1}{2}\left(\frac{r_1 - r_2}{C}\right)^2 + \dots\right] = C - \frac{(r_1 - r_2)^2}{2C} \quad \text{--(v)}$$

Substituting (iii), (iv) & (v) in (i) we get

$$L = \pi(r_1 + r_2) + 2\alpha(r_1 - r_2) + 2C - \frac{(r_1 - r_2)^2}{C}.$$

From eqⁿ (ii) we know, $\alpha = \frac{r_1 - r_2}{c}$

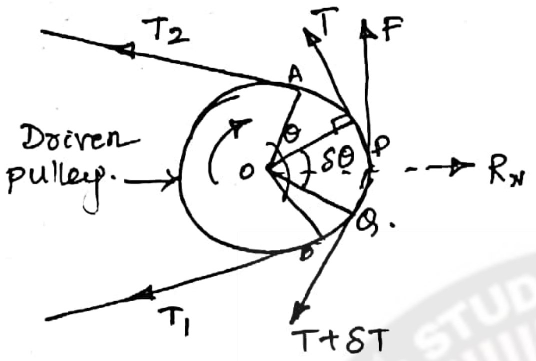
$$\therefore L = \pi(r_1+r_2) + 2\frac{(r_1-r_2)^2}{c} + 2c - \frac{(r_1-r_2)^2}{c}$$

$$L_{open} = \pi(r_1+r_2) + 2c + \frac{(r_1-r_2)^2}{c}$$

lly

$$L_{cross} = \pi(r_1+r_2) + 2c + \frac{(r_1+r_2)^2}{c}.$$

Ratio of Tension of a Flat Belt drive.



Let T_1 = Tension in belt on tight side
T_2 = Tension in belt on slack side
θ = Angle of contact

Resolving forces horizontally and Equating them

$$R_N = (T+\delta T)\sin\frac{\delta\theta}{2} + T\sin\frac{\delta\theta}{2} \quad \text{---(i)}$$

Since $\delta\theta$ is very small.

$$\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}.$$

$$R_N = T.d\theta. \quad \text{---(ii)}$$

Now resolving the forces vertically

$$\mu \times R_N = (T+\delta T)\cos\frac{\delta\theta}{2} - T\cos\frac{\delta\theta}{2} \quad \text{...(iii)}$$

$$R_N = \frac{\delta T}{\mu} \quad \text{---(iv)}$$

equating (ii) and (iv), $T\,\delta\theta = \frac{\delta T}{\mu}$ or $\frac{\delta T}{T} = \mu\delta\theta.$

$$\int_{T_1}^{T_2}\frac{\delta T}{T} = \mu\int_0^{\theta}\delta\theta.$$

$$\log_e\left(\frac{T_1}{T_2}\right) = \mu\theta \quad \text{or} \quad \frac{T_1}{T_2} = e^{\mu\theta} \quad \text{---(v)}$$

$$\therefore 2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta.$$

VIJAYA. B
M.E,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology
Rajanukunte, Bengaluru-560 064

VIJAYA. B
M.E.,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology
Rajanukunte, Bengaluru-560 064

Centrifugal Tension.

$T_{t_1} = T_1 + T_c$

$T_{t_2} = T_2 + T_c$

$T_c = mv^2$ = Centrifugal tension.

m = mass of belt/length (kg/m)

v = linear velocity (m/s).

Power transmitted by a belt drive.

$$P = \frac{(T_1 - T_2) \times V}{60 \times 1000} \text{ kW}.$$

$T_1 - T_2$ = Effective pull.

Definitions.

1. **SLIP**: It is defined as the sliding of belt from the pulley surface. It is the relative motion between pulley and the belt passing over it. It is expressed as a percentage (S)

   Note: Slip occurs due to (i) low coefficient of friction between belt & pulley surface (ii) smaller angle of contact.

2. **CREEP**: The relative motion between pulley & belt which tends to increase the length of belt is called creep.

   Note: Slip and creep reduces the velocity ratio and power transmission.

3. **VELOCITY RATIO**: It is defined as the ratio of speed of driven pulley to the speed of driving pulley (or) the ratio of dia. of driving pulley to the dia of driven pulley.

$$V.R = \frac{N_2}{N_1} = \frac{d_1}{d_2}.$$

Note: (i) $V.R = \frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}$ .... when thickness of belt is considered.

(ii) $V.R = \frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{S}{100}\right)$ ... when slip of belt is considered.

(iii) $V.R = \frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left(1 - \frac{S}{100}\right)$ .. both slip & thickness of belt is considered.

List of formulae
Module-4 (Belt Drives)

1. Velocity ratio = $V.R = \frac{N_2}{N_1} = \frac{d_1}{d_2}$.

2. Velocity ratio (considering thickness of belt) = $\frac{N_2}{N_2} = \frac{d_1+t}{d_2+t}$.

3. Velocity ratio (considering slip of belt) = $\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1-\frac{s}{100}\right)$

4. Velocity ratio (thickness & slip of belt) = $\frac{N_2}{N_1} = \frac{d_1+t}{d_2+t}\left(1-\frac{s}{100}\right)$

5. Velocity of belt drive = $V = \frac{\pi d N}{60}$ m/min.

6. Length of belt drive

   (open belt) → $L = 2c + \pi(r_1+r_2) + \frac{(r_1-r_2)^2}{c}$.

   (cross belt) → $L = 2c + \pi(r_1+r_2) + \frac{(r_1+r_2)^2}{c}$.

7. Tension in belt drive (Ratio). $\frac{T_1}{T_2} = e^{\mu\theta}$. θ° in rad. $\left(\times \frac{\pi}{180}\right)$

8. Power transmitted $P = \frac{(T_1-T_2)\times V}{60\times 1000}$ KW.

N_1 = speed of driver d_1 = dia. of driver
N_2 = speed of driven d_2 = dia. of driven.
t = thickness of belt drive s = % slip in belt drive.
c = Centre distance b/w pulleys.
r_1 = radius of driver r_2 = radius of driven
μ = coefficient of friction θ = angle of contact.

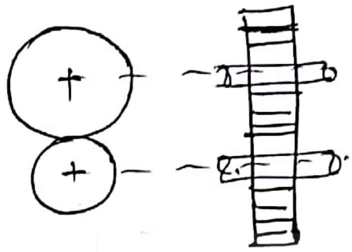
VIJAYA. B
M.E,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology

Gear Drives.

Gear is a mechanical element having teeth on its periphery. Gear drives are used to transmit power over short distances. They are preferred where the constant velocity ratio is of important such as watch mechanisms.

Types of Gears.

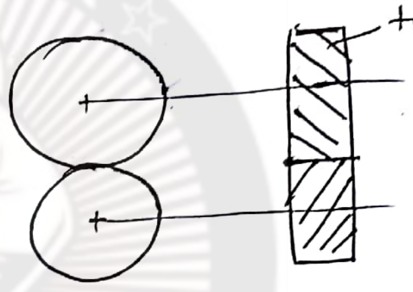
1. **SPUR GEAR:** Simplest and most common type of gear. used for transmission of rotary motion between parallel shafts.



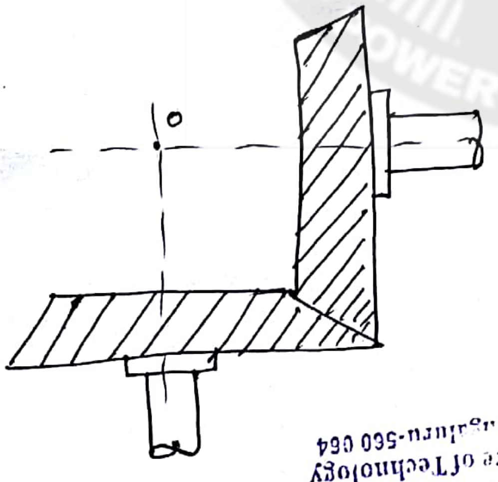
They are commonly used in automobile gear boxes, watches etc....

2. **HELICAL GEAR:**

Helical gears also connect two shafts which are parallel but their teeth are cut at an helix angle as shown in fig.



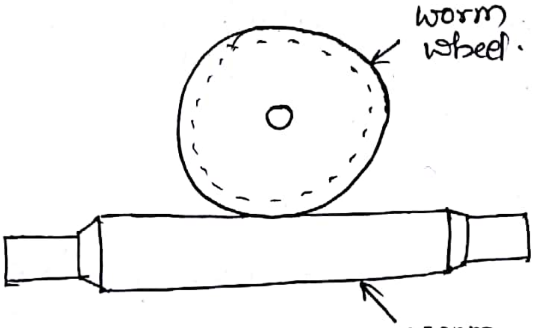
3. **BEVEL GEAR**



Bevel gears are normally used to transmit power between two shafts inclined to one another and are 90° angle.

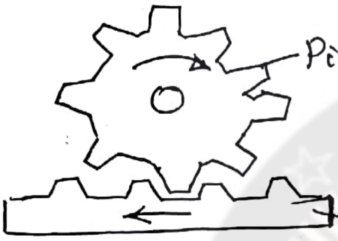
Note: when two bevel gears have axes at right angles and are of equal sizes they are called mitre gears

4. Worm Gear.



In this arrangement, small gear is referred to as worm gear and larger as worm wheel.
Its used for transmission of power at high velocity ratio

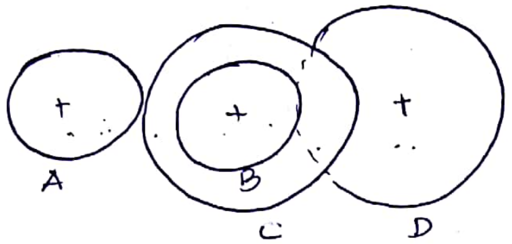
5. Rack and Pinion.



Rack and pinion is one form of the spur gear
The rack has two teeth in single plane and pinion has the tooth on periphery
This device is used for converting rotary motion of pinion into linear motion of rack or vice versa.

VIJAYA. B
M.E.,(Ph.D),MIE
Associate Professor
Dept. of Mechanical Engineering
Sai Vidya Institute of Technology
Rajanukunte, Bengaluru-560 064

P. A simple gear train consists of ~~three~~ four wheels A, B, C, D having ~~40~~, 20, 25, 50 and 75 teeth respectively. A meshes with C and B is a compound gear with C. B meshes with D. If A has a speed of 300 rpm, what is the speed of D ? Sketch the gear train.



$T_A = 20$ $\quad N_A = 300$

$T_B = 25$

$T_C = 50$.

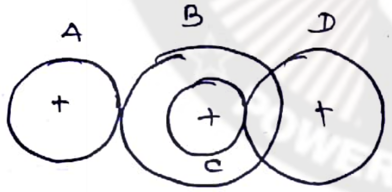
$T_D = 75$.

$$\frac{N_D}{N_A} = \frac{T_B \times T_A}{T_D \times T_C}$$

$\therefore N_D = 40 \text{ rpm}$

P. A compound gear consists of A B C & D having 20, 30, 40 & 60 teeth respectively. A is keyed to driver shaft and D is keyed to driven shaft. B and C are compound gears. B meshes with A and C meshes with D. If A rotates at 180 rpm what is the rpm of D.

$T_A = 20 \quad T_B = 30 \quad T_C = 40 \quad T_D = 60$.



$$VR = \frac{N_D}{N_A} = \frac{T_C \times T_A}{T_B \times T_D}.$$

$$\frac{N_D}{180} = \frac{20 \times 40}{30 \times 60}.$$

$\therefore N_D = 80 \text{ rpm}$

P. A simple gear train consists of 4 gears 1, 2, 3, 4.

$N_1 = 210$ rpm $\quad N_2 = 100$ rpm $\quad N_3 = 150$ rpm $\quad N_4 = ?$

$d_1 = 100$ mm $\quad d_2 = 150$ mm $\quad d_3 = 20$ mm $\quad d_4 = 75$ mm.

If the 1st gear rotates in clock wise direction what is the direction of last gear.

$N_4 = 250$ rpm. direction of last gear CCW.

ROBOTICS

A Robot is a machine, designed to resemble and perform work like a human being using a set of defined programs.

A Robot is a general purpose programmable multifunctional manipulator processing certain human like operations & characteristics.

A Robot is made up of a number of joints and links. Each joint consists of two links, an input link and output link. The joint provides controlled relative motion between the two links.

Types of joints.

(i) Rotational joint.
(ii) Revolving joint
(iii) Orthogonal joint
(iv) Linear joint
(V) Twisting joint.

Robots designed for industrial purposes are called Industrial Robots.

The physical configuration of a robot depends on its movements in the number of possible directions known as DEGREES OF FREEDOM.

The Mechanical joints of the robot are responsible to achieve the following desired motions.

Linear motion:

These occur in the x and Y directions when one part moves along the outside of another part such as in rack and pinion system.

Extension motion:

It is similar to telescoping motion produced when one part moves within another part.

Rotational motions

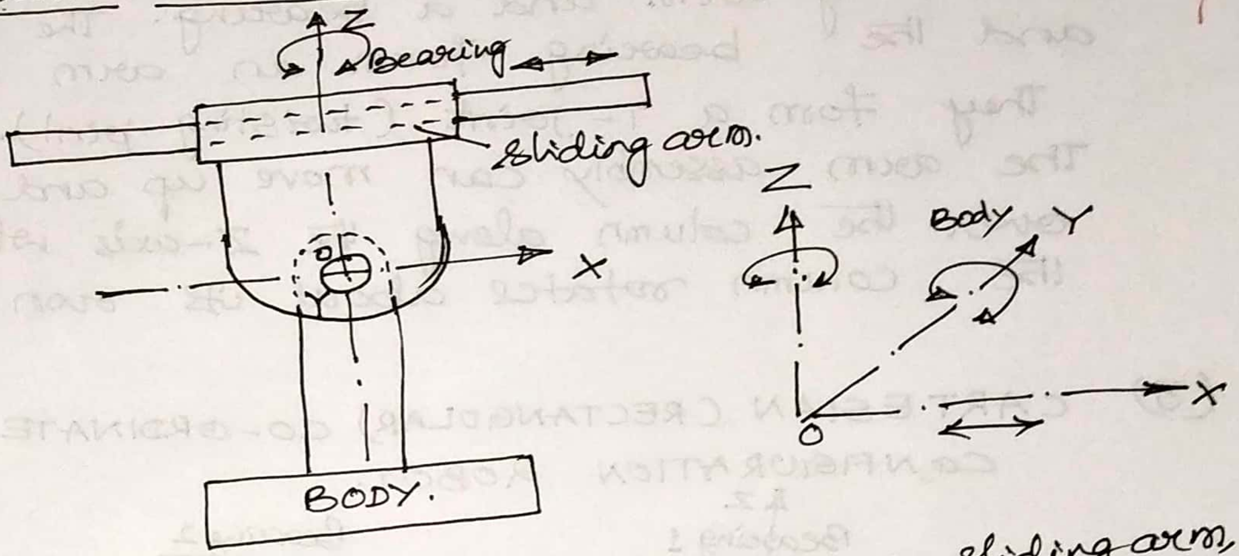
It is caused by a part moving about something other than its centre.

Classification of Robots Based on their configuration

(i) Polar or spherical configuration robots.
(ii) cylindrical configuration robots.
(iii) Cartesian or rectangular Co-ordinate configuration robots.
(iv) Jointed-arm configuration robots.
(v)

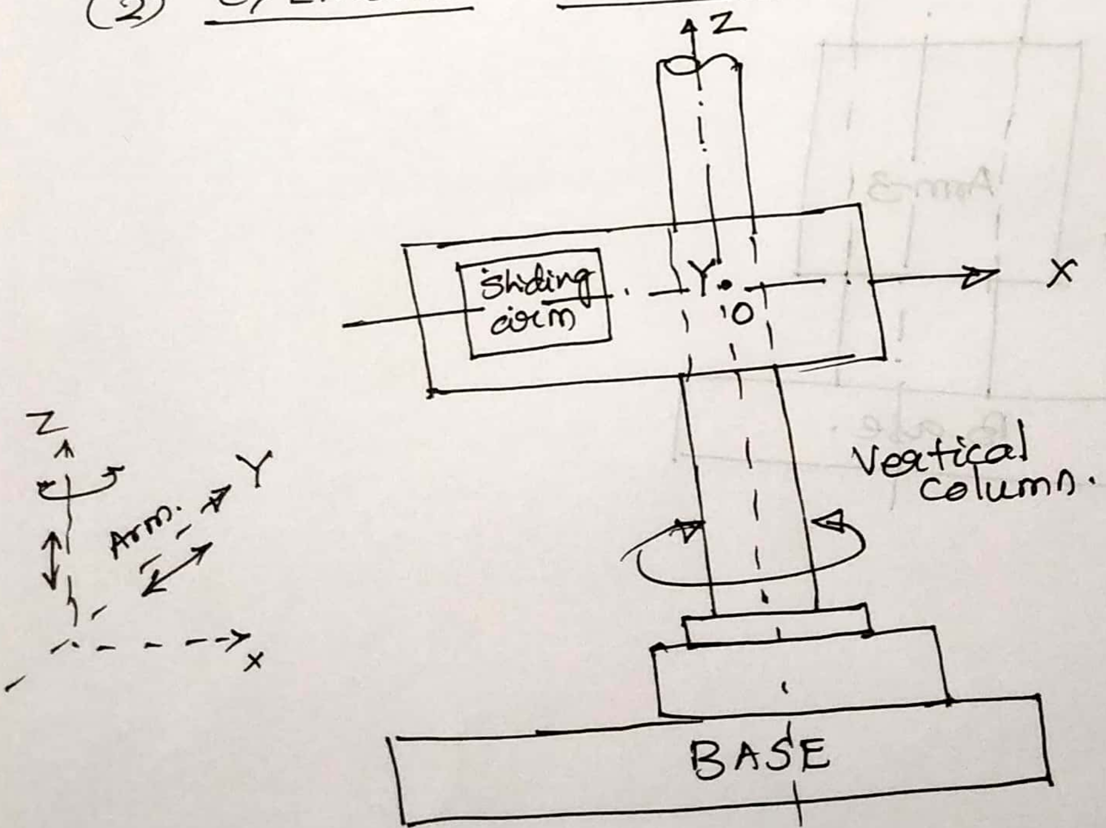
--- contd in page 3.

(1) POLAR (SPHERICAL) CONFIGURATION ROBOT.



It consists of a body, a sliding arm, and a bearing. They form a linear joint. The body can rotate about both Y and Z axes. However the sliding arm can only reciprocate in and out along the bearing on the x-axis.

(2) CYLINDRICAL CONFIGURATION ROBOT.



It consists of a vertical column, a base, a sliding arm and a bearing. The arm and the bearing form an arm assembly. They form a T-joint (twisting joint). The arm assembly can move up and down over the column along the Z-axis while the column rotates about its own axis.

(3) CARTESIAN (RECTANGULAR) CO-ORDINATE CONFIGURATION ROBOT.