⑦ Differential gearing

WG - control input
CS - Main Drive-input
FS - Main Drive-output

} Numerous differential functions can be obtained by combinations of the speed and rotational direction of the 3 basic elements

Advantages:

- Zero backlash
- consistent performance
- High position Accuracy
- High Torque-to-weight Ratio
- Affordable precision

II. Cycloidal Drive

* It provides very high reduction ratio with compact design.

→ It can achieve higher reduction ratios of up to 10 times in the same space.

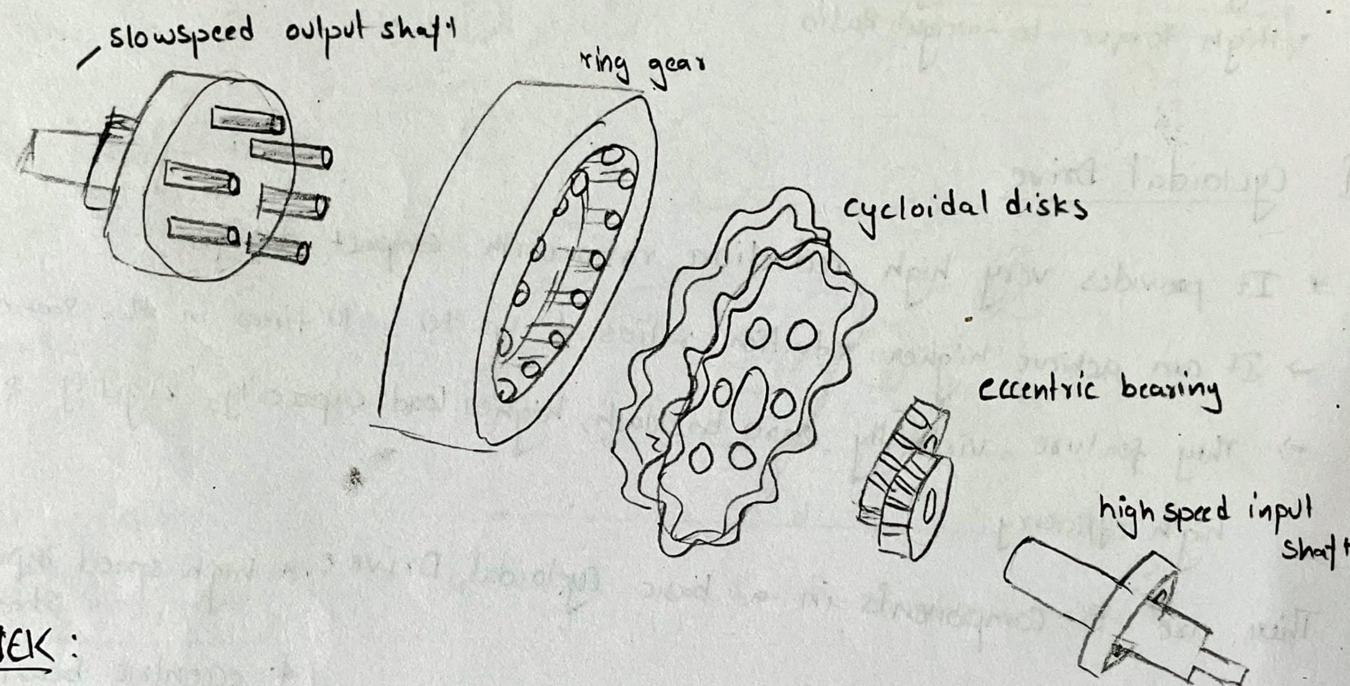
⇒ They feature virtually zero backlash, higher load capacity, rigidity & high efficiency.

There are 5 components in a basic cycloidal Drive:
* high speed input shaft
* eccentric bearing
* cycloidal disks
* ring gear
* slow speed output shaft.

* The input shaft is mounted eccentrically to a rolling-element bearing (typically a cylindrical roller bearing), causing the cycloidal disc to wobble in a circle. The cycloidal disc will independently rotate around the bearing as it is pushed against the ring gear.

⇒ The number of pins on the ring gear is larger than the number of pins on the cycloidal disc. This causes the cycloidal disc to rotate around the bearing faster than the input shaft is moving it around, giving an overall rotation in the direction opposing the rotation of the input shaft.

⇒ The cycloidal disc has holes that are larger (by an amount equal to the eccentricity of the input shaft) than the output roller pins that go inside them. The output pins will move around in the holes to achieve steady rotation of the output shaft from the wobbling movement of the cycloidal disc.



TRICK :

$$\text{Ratio} = \frac{n}{N-n}$$

n = no. of lobes on the cycloidal disk

N = no. of rollers

eg: To get 15 : 1 ratio reduction

take n = 15 = no. of lobes
N = 16 = no. of roller pins

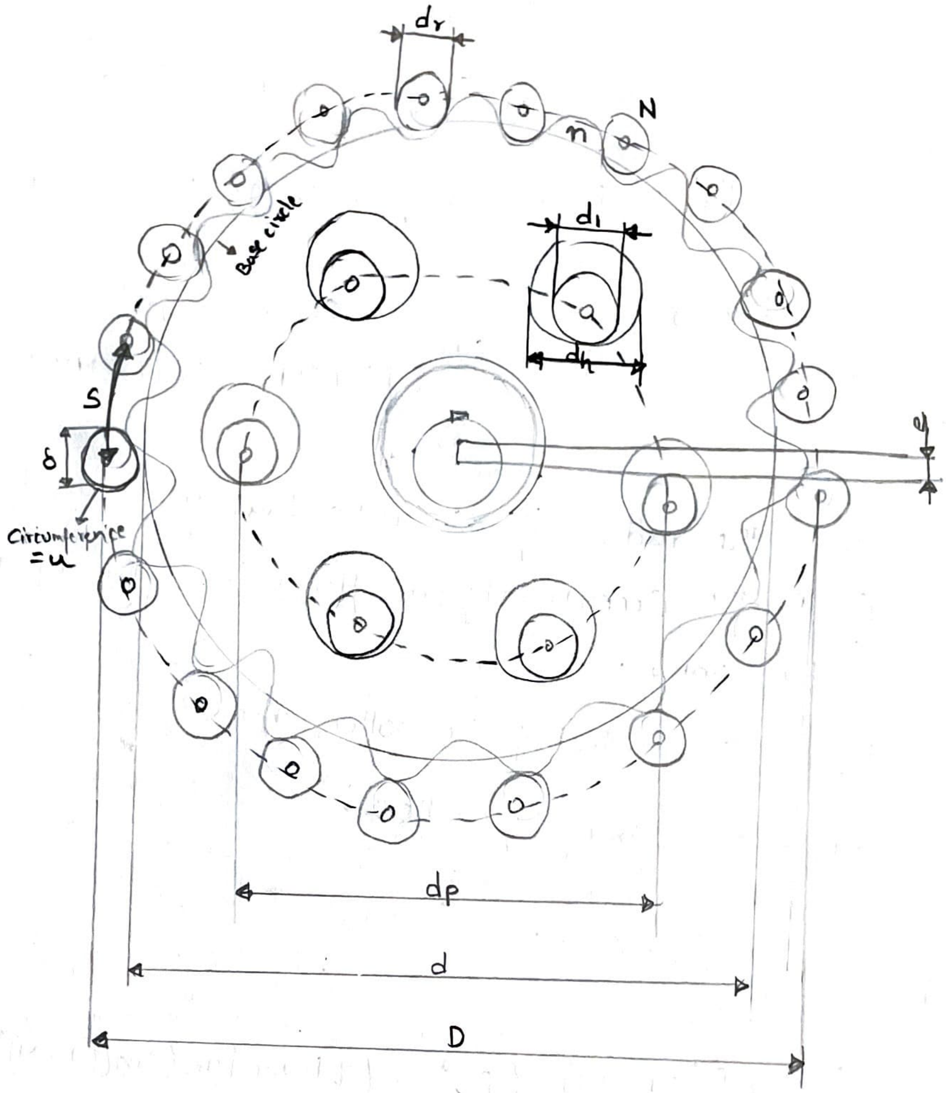
$$R = \frac{15}{1} = 15:1$$

GEOMETRY OF THE CYCLOIDAL DISC

(i) Transmission ratio

$$\boxed{i = \frac{n}{N-n}}$$

N = no. of roller pins
n = no. of lobes



(ii) Rolling circle diameter

$$\boxed{\delta = \frac{D}{N}}$$

(iii) Base circle diameter

$$\boxed{d = i \cdot \delta}$$

(iv) Eccentricity

$$\boxed{e \leq \frac{\delta}{2}}$$

(v) Hole diameter

$$\boxed{d_h = d_1 + 2 \cdot e}$$

(vi) Parametric eq^n refrence profile

$$x = \frac{d+\delta}{2} \sin(\phi) - e \cdot \sin\left(\phi + \frac{d}{\delta}\phi\right)$$

$$y = \frac{d+\delta}{2} \cos(\phi) - e \cdot \cos\left(\phi + \frac{d}{\delta}\phi\right)$$

d : base circle diameter

δ : rolling circle diameter

e : eccentricity

φ : angle (parameter) = 0 --- 2π

For Rotor : Cycloidal disk

⇒ These Two eq^{n}s define the Rotor's shape :

$$X = R\cos(\theta) - R_r\cos(\theta - \psi) - E\cos(N\theta)$$

$$Y = -R\sin(\theta) + R_r\sin(\theta - \psi) + E\sin(N\theta)$$

where,
$$\psi = -\tan^{-1}\left[\frac{\sin((1-N)\theta)}{(R/EN) - \cos((1-N)\theta)}\right] ; \quad 0^\circ \le \theta \le 360^\circ$$

⇒ R is the radius of the rotor that you want (Pitch circle Diameter)

⇒ E is the Eccentricity (or offset) from the input shaft to the center of the rotor.

⇒ R_r is the radius of the rollers ~~and~~

⇒ N is the number of rollers.

Eq. to use in CAD:

$$X = (R^*\cos(t)) - (R_r^*\cos(t + \arctan(\sin((1-N)^*t) / ((R/EN) - \cos((1-N)^*t))))) - (E^*\cos(N^*t))$$

$$Y = (-R^*\sin(t)) + (R_r^*\sin(t + \arctan(\sin((1-N)^*t) / ((R/EN) - \cos((1-N)^*t))))) + (E^*\sin(N^*t))$$

★★★
★ NOTE :
★★ * Cycloidal drives are not operated with a single cycloidal disk as it will create unbalances & viberations at high speeds

⇒ So, A second identical cycloidal disk is mounde with a 180° offset this compensates for the unbalance

20:1 reduction cycloidal drive.

* 20 teeth on the disk
21 - roller pins or teeth on casing

Shape: 2 diff types of equations - Explicit equations
Parametric

Explicit eq^n are used when we have single variable eq^ns
- Parametric curves works the same way but they use 2 eq^ns to
- define a curve

we use parametric eq^n:

⇒ 2 eq^ns that define the Rotor's shape:

$$X = R\cos\theta - R_r\cos(\theta-\psi) - E\cos(N\theta)$$

$$Y = -R\sin\theta + R_r\sin(\theta-\psi) + E\sin(N\theta)$$

where

$$\psi = -\tan^{-1}\left[\frac{\sin((1-N)\theta)}{(R/EN) - \cos((1-N)\theta)}\right]; 0 \leq \theta \leq 360$$

R - radius of rotor

E - eccentricity (offset) from the input shaft to the center of the rotor

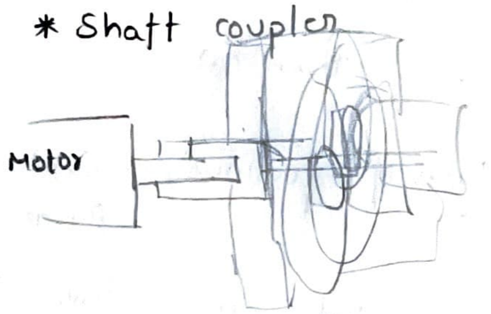
R_r - radius of the Rollers

N - no. of rollers

4 Key components

* Shaft coupler

* Bushings -



Ratio : 20 : 1 - No backlash
- Backdrivable

output flange - $\boxed{\text{3D printed cycloidal Reducer}}$ - Ball bearing - casing
vid name

⇒ 21 - pins - Bushings - ϕ | * I designed & built - Vid no - 8

X

Lets make it with inbuilt walls

① 6mm Dia - Roller Dia - 21

② reduction ratio : 20 : 1

$8 = \frac{D}{}$

$21 \times 2 \times \pi \times$

rollers ⇒ $N_r = 21$ ⇒ $R_r = \frac{6}{2}$ mm = 3 mm

outside perimeter $R = \frac{80}{2} = 40$ mm

$n = 20$

radius of eccentric cam $= R_e$

E = eccentricity

$N = 21$

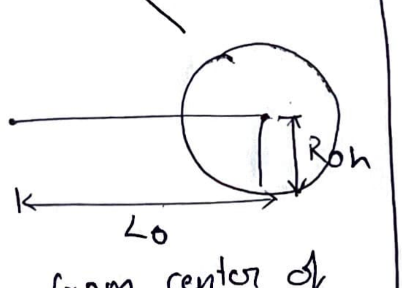
$\delta = 6$

output holes ⇒ $N_o = 6$

$D = 126$

$d = 120$

$e = 1$



from center of the disk

$d_e = 3$

$d_n = 5$

* eccentricity : e = 1

⇒ <u>Epitrochoid</u> <u>parametric Equations</u> :

* 20:1

eccentric amount = 1.37 mm

Ring pin diameter = 8 mm

Ring pin pitch dia = 80.00 mm

Cycloidal curve plot num par tooth = 6

* Center hole dia = 32 mm

* output pin dia = 4.9

* center to pin dt = 50 mm

Zuan peng : 10:1

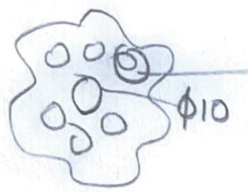
$N = 11$ $\quad e = 1$

$n = 10$

$D_r = 3 \Rightarrow R_r = 1.5$; $R = 15.5$

$S = \frac{32.7}{360} \times 2 \times \pi \times 15.5 = 8.846$

$= 9.424777$



case 1 :

$D \Rightarrow R = 40$

$E = 1$ $\quad$ 20:1

$dr \Rightarrow R_r = 3.5$

$N = 21$

$d_p = 25$

$d_h = d_e + 2c = 5$

$d_e = 3$

E

* ~~B~~ FDM 3D printing

└ Fused Deposition modelling

* two disks with 180 degree phase difference which eliminates viberations at high speeds. – to increase torque capacity.

* to maximise efficiency, we employ bearings for outer rollers & output pins.

* "Needle roller bearings" – large contact area allowing high torque & efficiency in a compact design.

⇒ <u>off-the-shelf components</u>:

- to minimise cost of the design, it is advisible to use standard off the shelf components.
- roller, bearings, screws, nuts, washers

$n = 20$

$N = 21$

$\boxed{d = 60}$

$\delta = 3$

$D = 63$

$D = 70 \Rightarrow R = 35$

$R_y \Rightarrow$

$2\pi r \times \frac{\theta}{360}$