3.2 WORM GEAR DIVE:

When a speed reducer is required to have a very high velocity ratio of about 100 or even more, sometimes upto 500, then by two ways, this requirement may be fulfilled. One is by using spur, helical and bevel gears individually or in combined form in multistage arrangement. Sometimes by using another type of gear drive known as worm gear drive. This much of speed ratio may be obtained in a single step itself.

In worm gear drive, the driving member is similar to Archimedean screw and the driven member is similar to helical gear with curved teeth and also the pitch surface of this helical gear is slightly concaved (i.e. shallow type pitch surface). In this drive, the driving member is known as worm instead of calling as pinion and the driven member is known as worm gear or worm wheel and the power is transmitted from the worm to worm wheel by sliding contact in contrast with spur, helical or bevel gear where the power is transmitted by rolling contact.

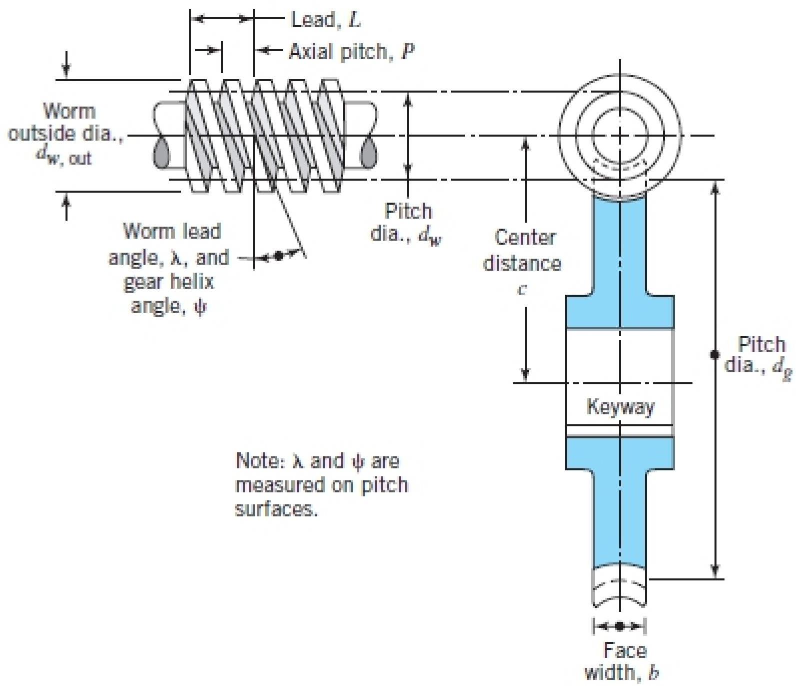
The worm gear drive is employed to transmit power between non-parallel and non-intersecting shafts whose axes are usually at 90°. Since they are having sliding contact their operation is smooth and noiseless, but their efficiency is lower because of power loss caused due to friction.

DRAWBACKS

1. Maximum power that can be transmitted is 100 kW.
2. Heat is produced due to sliding friction.

Velocity ratio = $\frac{Number\ of\ teeth\ on\ gear}{Number\ of\ threads\ (starts\ on\ worm)}$

3.2.1 WORM GEAR NOMENCLATURE



DESIGN PROCEDURE

STEP-1-MATERIAL SELECTION

Worm – steel

Worm wheel - bronze

STEP-2-MINIMUM AXIAL MODULE

Minimum axial module $m_x \geq 1.24\sqrt[3]{\frac{[M_t]}{[\sigma_b].q.z_1 y_v}}$ **(PSG 8.44)**

Select next standard module **(PSG 8.2)**

STEP-3-CENTRE DISTANCE

Estimate maximum centre distance based on surface compressive strength. **(PSG 8.44)**

Centre distance a= $0.5m_x(q+z)$

Find out diameter factor q

STEP-4-ACTUAL SLIDING VELOCITY

$V_s = \frac{\pi d_1 n_1}{60 x 1000 x \cos v} \frac{m}{s}$

Note the corresponding design surface stress from **(PSG 8.45)**

STEP-5-INDUCED COMPRESSIVE STRESS AND BENDING STRESS

From **(PSG 8.44)**

STEP-6-LENGTH OF WORM

(PSG 8.48)

STEP-7-NUMBER OF TEETH ON WORM

$\lambda = L_1/\pi m_x$ **(PSG 8.48)**

STEP-8-FACE WIDTH OF WORM WHEEL

(PSG 8.48)

STEP-9-OTHER PARAMETERS OF WORM AND WORM WHEEL

STEP-10-EFFICIENCY OF THE DRIVE

$\eta = \frac{\tan v}{\tan (v+\rho)}$ $\rho = \tan^{-1} \mu$ **(PSG 8.49)**

Example. The input to worm gear shaft is 18 kW and 600 rpm. Speed ratio is 20.The worm is to be of hardened steel and wheel is made of chilled phosphor bronze considering wear strength, design worm and worm wheel.

GIVEN

Power to be transmitted = 18 kW

Speed of worm = 600 rpm

Speed ratio = 20

Material for worm = hardened steel

Material for wheel = phosphor bronze

SOLUTION

1. **MATERIAL SELECTION**

For worm = steel **(PSG 8.45)**

For wheel = bronze

$[\sigma_c] = 1590$ kgf/cm^2

$[\sigma_b] = 550$ kgf/cm^2

V_s=3 m/s

2. **MINIMUM CENTRE DISTANCE**

$$a \geq \left(\frac{z_1}{q}+1\right)\sqrt[3]{\left[\frac{540}{\frac{z_1}{a}[\sigma_c]}\right]^2[M_t]}$$ **(PSG 8.44)**

$$M_t = 97420x\frac{kW}{n_1}xix\eta$$ **(PSG 8.15 and 8.44)**

$i = \frac{z_1}{z} = 20 \quad q = 11$ **(PSG 8.44)**

z = No of starts on worm = 3 **(PSG 8.44)**

$\eta = 0.86$ **(PSG 8.46)**

z_1 = 3x20 = 60

$M_t = 97420x\frac{18}{600}x20x0.86$ = 50270 kgf-cm

$[M_t]$ =M_t.k.k_d k=1 for constant load; k_d=1 for sliding velocity 3 m/s

= 50270x1x1 =50270 kgf-cm

$$a \geq \left(\frac{60}{11}+1\right)\sqrt[3]{\left[\frac{540}{\frac{60}{11}x1590}\right]^2 x50270} \geq 37.4\ cm$$

3. **MINIMUM AXIAL MODULE**

$$m_x \geq 1.24\sqrt[3]{\frac{[M_t]}{[\sigma_b].q.z_1 y_v}}$$

y_v = form factor for virtual no of teeth **(PSG 8.18)**

$z_v=z/\cos^3\gamma$; γ = lead or helix angle = $\tan^{-1}(z/q)$ =$\tan^{-1}(3/11)$=15.15° **(PSG 8.44)**

$z_v=60/\cos^3 15.15$ = 66.8 ≈ 67

y_v= 0.493 for z_v=67 **(PSG 8.18)**

$m_x \geq 1.24\sqrt[3]{\frac{50270}{60x11x0.493x550}}$ ≥ 0.82 cm ≥ 8.2 mm

Take m_x= 10 mm.

4. **CENTRE DISTANCE**

a = 0.5m_x(q+z+2x) = 0.5x10(11+60) = 355 mm; x=0

since it is less than the minimum centre diatance let m_x=12 mm

a= 0.5x12(11+60) = 426 mm = 42.6 cm (o.k)

5. **SLIDING VELOCITY**

$V_s = \frac{\pi d_1 n_1}{60x1000x\cos v}$ d_1=qm_x=11x12=132 mm ; v= 15.255°

$$= \frac{\pi X132X600}{60x1000x\cos 15.255} = 4.29\ m/s$$

$V_s = \frac{m_x.n}{19100}\sqrt{z^2+q^2}$ = $\frac{12x600}{19100}\sqrt{3^2+11^2}$ = 4.29 m/s

Since the adequate data are not available for surface strength for sliding velocity beyond 4 m/s, it is assumed that [σ_c]=1490 kgf/cm^2 **(PSG 8.45)**

6. **CHECKING THE STRESSES**

a. **Compressive stress**

$$\sigma_c = \frac{540}{\left(\frac{z_1}{q}\right)}\sqrt{\left\{\frac{\left(\frac{z_1}{q}\right)}{a}\right\}^3[M_t]} = \frac{540}{\left(\frac{60}{11}\right)}\sqrt{\left\{\frac{\left(\frac{60}{11}\right)}{42.6}\right\}^3 50270}$$ = 1300 kgf/cm^2< [σ_c] = 1490 kgf/cm^2

Hence the design is safe.

b. **Bending stress**

$\sigma_b = \frac{1.9[M_t]}{m_x^3.q.z_1 y_v} = \frac{1.9x50270}{1.2^3x11x60x0.493}$ = 170 kgf/cm^2< [σ_b] = 550 kgf/cm^2

Hence the design is safe.

7. **LENGTH OF WORM**

L ≥ (12.5+0.09z_1)m_x ≥ (12.5+0.09x60)12 ≥ 214.8 mm ≈ 215 mm **(PSG 8.48)**

8. **NO OF TEETH ON WORM**

$\lambda = \frac{L_1}{\pi m_X}$ = 215/πx12 = 5.7 ≈ 6 **(PSG 8.48)**

Length of worm = 6xπxm_x=6xπx12 = 226 mm

9. **WIDTH OF WORM WHEEL**

Face width = 0.75d_1 =0.75x132=99 mm≈ 100 mm **(PSG 8.48)**

10. **PARAMETERS OF WORM**

Reference diameter d_1=qxm_x = 132 mm **(PSG 8.43)**

Tip diameter d_{a1}=d_1+2$f_o$$m_x$ = 132+(2x1x12) = 156 mm

Root diameter d_{f1}=d_1-2$f_o$$m_x$ = 132-(2x1x12) = 103.2 mm

Pitch diameter d'_1 =m_x(q+2x) = 12(11+2x0) = 132 mm

11. **PARAMETERS OF WHEEL**

Reference diameter d_2=$z_1$$m_x$=60x12 = 720 mm

Tip diameter d_{a2}=(z+2f_o+2x)m_x = (60+2)=744 mm

Root diameter d_{f2}=(z-2f_o)m_x-2c=(60-2)12-(2x0.2x12) = 691.2 mm

Pitch diameter d'_2 = d_2 = 720 mm.

12. **EFFICIENCY OF WORM GEAR DRIVE**

$\eta = \frac{\tan v}{\tan(v+\rho)}$ **(PSG 8.49)**

Tanρ = μ = friction coefficient = 0.03 for sliding velocity v_s=4.29 m/s

$$\rho = \tan^{-1} 0.03 = 1.72°$$

$\eta = \frac{\tan 15.255}{\tan(15.255+1.72)}$ = 0.893 = 89.3 %

SPECIFICATION

SL NO	SPECIFICATION	WORM	WHEEL
1.	Material	steel	bronze
2.	No of teeth	6	60
3.	Module	12 mm	12mm
4.	Reference diameter	132 mm	720mm
5.	Tip diameter	156 mm	744 mm
6.	Root diameter	103.2 mm	691.2 mm
7.	Length of worm	226 mm	
8.	Face width of worm wheel		100mm
9.	Centre distance	426 mm	
10.	Efficiency	89.3%	

Two mark questions