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.

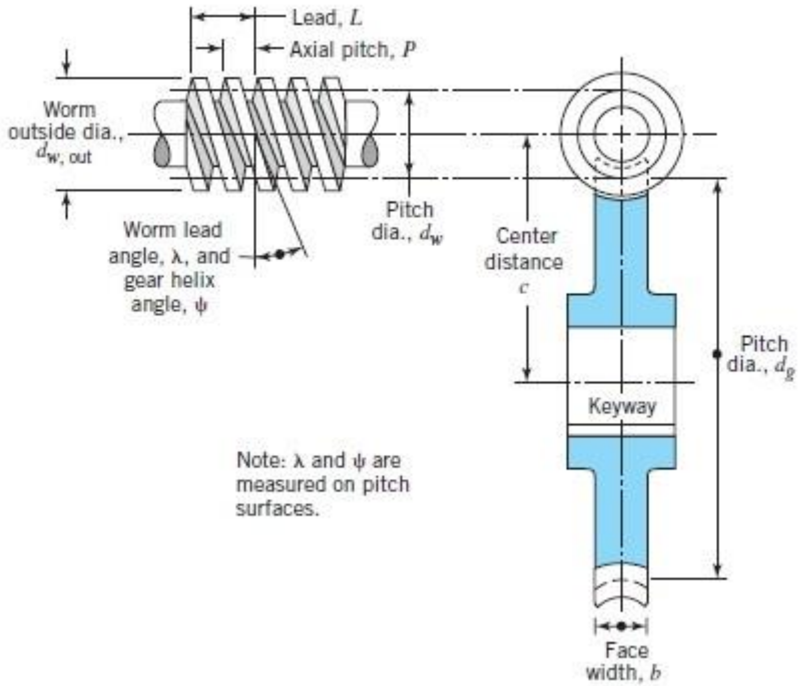
The worm gear drive is employed to transmit power between non-parallel and non-intersecting shafts whose axes are usually at 90°. Since they are having sliding contact their operation is smooth and noiseless, but their efficiency is lower because of power loss caused due to friction.

DRAWBACKS

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

Velocity ratio = $\frac{o\ h\ o}{o\ h\ (o\ o)}$

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 $\geq 1.24\sqrt[3]{\frac{[\ \ ]}{[\ \ ]_{..1}}}$ **(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

$V_s = \frac{11}{601000 \cos}$

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

$= \frac{\tan \tan}{(+)}$ $= \tan^{-1}$ **(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**

$\geq \frac{1}{} + 1 \left(\quad \right) \sqrt[3]{\left[\frac{540}{\frac{1}{}[\ \ ]}\right]^2 [\ \ ]}$ **(PSG 8.44)**

$= 97420 \, ^{k}\, m \quad \frac{}{1}$ **(PSG 8.15 and 8.44)**

$= \frac{1}{} = 20 \ = 11$ **(PSG 8.44)**

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

η = 0.86 **(PSG 8.46)**

z_1 = 3x20 = 60

$= 97420 \ ^{18} \ 20\frac{0.86}{600}$ = 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

$$\geq \left(\frac{60}{11} + 1\right) \sqrt[3]{\left[\frac{540}{\frac{60}{11} 1590}\right]^2 50270 \geq 37.4}$$

3. **MINIMUM AXIAL MODULE**

$$\geq 1.24 \sqrt[3]{\frac{[\ \ ]}{[\ ..]_1}}$$

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)**

$z_v = 60/\cos^3 15.15 = 66.8 \approx 67$

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

$$\geq 1.24 \sqrt[3]{\frac{50270}{60110.493550}} \geq 0.82 \text{ cm} \geq 8.2 \text{ mm}$$

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

$V_s = \frac{11}{601000 \cos}$ d_1=qm_x=11x12=132 mm ; v= 15.255°

$$= \frac{132600\ 601000}{\cos 15.255} = 4.29\ /$$

$V_s = \frac{}{19100}\sqrt{^2 + ^2}$ $= \frac{12600}{19100}\sqrt{3^2 + 11^2}$ = 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

$$= \frac{540}{\left(\frac{1}{}\right)}\sqrt{\left\{\frac{\left(\frac{1}{}\right)}{}\right\}^3 [\quad]} = \frac{540}{\left(\frac{60}{11}\right)}\sqrt{\left\{\frac{\left(\frac{60}{11}\right)}{42.6}\right\}^3 50270} = 1300 \text{ kgf/cm}^2 < [\sigma_c] = 1490 \text{ kgf/cm}^2$$

Hence the design is safe.

b. Bending stress

$\sigma_b = \frac{1.9[\quad]}{^3 ..1} = \frac{1.950270}{1.2^3 11600.493}$ = 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

$\lambda = \frac{1}{}$ = 215/πx12 = 5.7 ≈ 6 **(PSG 8.48)**

Length of worm = $6 \times \pi \times m_x = 6 \times \pi \times 12$ = 226 mm

9. WIDTH OF WORM WHEEL

Face width = $0.75 d_1 = 0.75 \times 132 = 99$ mm ≈ 100 mm **(PSG 8.48)**

10. PARAMETERS OF WORM

Reference diameter $d_1 = q \times m_x$ = 132 mm **(PSG 8.43)**

Tip diameter $d_{a1} = d_1 + 2f_o m_x = 132 + (2 \times 1 \times 12)$ = 156 mm

Root diameter $d_{f1} = d_1 - 2f_o m_x = 132 - (2 \times 1 \times 12)$ = 103.2 mm

Pitch diameter $'_1 = m_x(q+2x) = 12(11+2 \times 0)$ = 132 mm

11. PARAMETERS OF WHEEL

Reference diameter $d_2 = z_1 m_x = 60 \times 12$ = 720 mm

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

Root diameter $d_{f2} = (z-2f_o)m_x - 2c = (60-2)12 - (2 \times 0.2 \times 12)$ = 691.2 mm

Pitch diameter $'_2 = d_2$ = 720 mm.

12. EFFICIENCY OF WORM GEAR DRIVE

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

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

$$= \tan^{-1} 0.03 = 1.72°$$

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

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

1. Under what situation, bevel gears are used?[AU, NOV-07]

Bevel gears are used to transmit power between two intersecting shafts.

2. What are the advantages of spiral bevel gears over straight bevel gears?

Spiral bevel gears are smoother in action and quieter than straight bevel gears.

3. What is the difference between an angular gear and a miter gear? [AU MAY-13]

When the bevel gears connect two shafts whose axes intersect at an angle other than a right angle, then they are known as angular bevel gears.

When equal bevel gears connect two shafts whose axes intersect at right angle, then they are known as miter gears.

4. Why is the efficiency of worm gear drive comparatively low?

The efficiency of worm gear drive is lower because of power loss due to friction caused by sliding.

5. What are the forces acting on a bevel gear?[AU, MAY-09]

a. Tangential force

b. Axial force

c. Radial force

6. Under what situation, worm gears are used? [AU NOV-08]

The worm gears are used to transmit power between two non-intersecting non-parallel shafts and

for high speed ratios as high as 300:1

7. How can you specify a pair of worm gear?

A pair of worm gear are specified as:($z_1/z_2/q/m_x$)

Z_1 = number of starts on the worm

Z_2 = number of teeth on the worm wheel

q=diameter factor

m_x= axial module.

8. Differentiate self-locking and over running worm drives.

The drive is called self-locking, if μ>=cosαtanγ

The drive is called overrunning, if μ<cosγ.tanγ

9. What is a crown gear? [AU MAY-10]

A bevel gear having a pitch angle of 90 degree and a plane for its path surface is known as a crown gear.

10. What kind of contact occurred between worm and wheel?

Meshing of wheel teeth and worm wheel occur with sliding action.

11. Define lead

Lead of worm is defined as the distance, measured axally, between the corresponding points of adjacent teeth for the same helix. Based on the number of starts lead can be varied from pitch.

Usually Lead = number of starts x pitch

12. In which gear drive self locking is available

In worm gear drive self locking is available.

Ex.Determine the dimensions of a pair of worm and worm wheel for transmitting 2kW at a worm speed of 1200 rpm. The desired ratio is about 12.choosing proper materials decide all the dimensions.

Ex. A helical gear with 30^0 helix angle has to transmit 35kW at 1500 rpm. With a speed reduction ratio 2.5. If the pinion has 24 teeth, determine the necessary module for 20^0 full depths the teeth. Assume 15Ni 2Cr 1 Mo 15 material for both pinion and wheel

PROBLEMS FROM ANNA UNIVERSITY EXAMS

Design a worm gear drive with a standard center distance to transmit 7.5 kW from a worm rotating at 1440 rpm to a worm wheel at 20 rpm [April/may2010]

A 2 kW power is applied to a worm shaft at 720 rpm. The worm is of quadraple start type with 50 mm as pitch circle diameter. The worm gear has 40 teeth with 5 mm modules. The pressure angle in the diameteral plane is 20^0.Determine (i) the lead angle of worm,(ii)velocity ratio,and (iii)centre distance.Also calculate efficiency of the worm gear drive,and power lost in friction. [April/may2008][May/june2014]

A hardened steel worm rotates at 1440 rpm and transmits 11 kW to a phosphor bronze gear with gear ratio of 15.Design the worm gear drive and determine the power loss by heat generation. [April/may2009]

Design a worm gear drive to transmit 12 kW at 1200 rpm. Speed reduction desired is 30:1The worm is made of hardened steel and the wheel of phosphor bronze. Check the heating capacity of gears and determine the efficiency. [April/may2012]

Design worm and gear speed reducer to transmit 22 kW at a speed of 1440 rpm.The desired velocity ratio is 24:1.An efficiency of at least 85% is desired. Assume that the worm is made of hardened steel and the gear of phosphor bronze. Take the centre distance as 100 mm. [April/may2009]

A hardened steel worm rotates at 1440 rpm and transmits 12 kW to a phosphor bronze gear. The speed of the worm wheel should be 60+/-3% rpm. Design the worm gear drive if an efficiency of at least 82% is desired. [April/may2010]

Design a worm gear drive for a speed reducer to transmit 15 kW at 1440 rpm of the worm shaft. The desired wheel speed is 60 rpm. Select suitable worm and wheel materials [Nov/Dec2012]

Design a worm gear drive to transmit 22.5 kW at a worm speed of 1440 rpm. Velocity ratio is 24:1. An efficiency of at least 85% is desired. The temperature rise should be restricted to 40°C. Determine the required cooling area. [AU, N/D 2011] [AU, M/J 2013]

Design a worm gear drive to transmit 12kW at 1440 rpm with a speed ratio of 20. Use steel worm and cast iron wheel. [AU, N/D 2012]

Design a worm gear and determine the power loss by heat generation. The hardened steel worm rotates at 1500 rpm and transmits 10 kW to a phosphor bronze gear with gear ratio of 16.[AU, M/J 2012]

Design a worm drive or a speed reducer to transmit 15 kW at 1440 rpm of the worm shaft. The desired wheel speed is 60 rpm. Select a suitable worm and wheel materials. [AU, M/J 2011]

4 DESIGN OF GEAR BOXES

REUIREMENTS OF A SPEED GEAR BOXES:

1. It should provide the designed series of spindle speeds.
2. It should transmit the required amount power to the spindle.
3. It should provide the smooth and silent operation of transmission.
4. It should have simple construction.
5. Mechanism of gear boxes should be easily accessible so that it is easy to carry out maintenance.

The speeds in gear boxes can be arranged in arithmetic progression (A.P.), geometric progression (G.P) and logarithmic progression (L.P).

ADVANTAGES OF GEOMETRIC PROGRESSION:

1. The speed loss minimum.
   i.e. speed loss = desired optimum speed-available speed.
2. Number of gears to be employed is minimum.
3. G.P. provides more even numbers of spindle speeds at each step.
4. The layout is comparatively compact.
5. Productivity of the machining operation .i.e surface area of the metal removed in unit time is constant in the whole speed range.

TYPES OF GEAR BOXES:

1. Sliding mesh gear box
2. Constant mesh gear box

SLIDING MESH GEAR BOX:

Sliding mesh gear boxes are commonly used in general purpose machine tools. In order to mesh gear on main shaft with appropriate gears on the spindle shaft for obtaining different speeds they are moved to the right or left. It derives its name from the fact that the meshing of gear takes place by sliding of gears on each other.

CONSTANT MESH GEAR BOX:

It derives its name from the fact that all the gears whether of the counter shaft or the main shaft are constant in mesh with each other. It is also known as silent or quite gear box. It givesquiter operation and makes gears changing easier by employing helical gears for constant mesh. In order to connect the required gear wheel by means of teeth on the side of the gear wheel, a separate sliding member is employed.

PREFERRED NUMBERS:

Preferred numbers are the conventionally rounded off values derived from geometric series. There are five basic series denoted as R5,R10,R20,R40 and R80 series. The symbol R is used as tribute to French engineer Charles renard who introduced primary numbers first.

(PSG7.19, 20)

STEP RATIO (OR) SERIES RATIO (OR) PROGRESSION RATIO (φ):

When the spindle speeds are arranged in geometric progression, then the ratio between the two adjacent speeds is known as step ratio or progression ratio.

If N_1,N_2…….N_n are the spindle speeds arranged in geometric progression then

$$\frac{2}{1} = \frac{3}{2} = \frac{4}{3} \ldots\ldots \frac{}{-1} = o$$

If n is the number of steps of speed, then

$$\frac{}{1} = {}^{-1} \quad (\quad)$$

Or

$$= {}^{-1} (\quad)$$

STRUCTURAL FORMULA:

Let n- number of speeds available at the spindle

P_1 ,P_2 , P_3… = Stage numbers in the gear box

X_1 , X_2 , X_3…= Characteristic of the stage

$$(=)_{1\ 1} .(\ 2\ )_{3\ 3} .(_{4\ 4}) \quad (\quad)$$

Where X_1=1 , X_2=P_1 , X3=P_1.P_2 , X_4=P_1.P_2.P_3