

Design of Machines and Mechanical Systems (PC-BTM711)

Session 12 A

Module 1: Worm Gear Design *Calculations*

Example 2

It is required to design a worm gear speed reducer unit composed of worm wheel made of **sand cast and chilled phosphor bronze** and worm made of **case-hardened steel 10C4**. The center distance is **200 mm** and transmission ratio is to be **20**. The worm speed is **1500 rpm**. Design the drive and find out following.

- i. **Power transmitting capacity based on bending failure**
- ii. **Power transmitting capacity based on wear failure**
- iii. Required **effective surface area of drive**, given – ambient heat transfer coefficient = 15 W/sq.m/deg.C , temperature rise of lubricating oil above surrounding temperature is to be maintained below 50 deg.C .

Given $a = 200 \text{ mm}$, $i = 20$, $n_1 = 1500 \text{ rpm}$

(i) Selection of parameters

From DDB T 23.8, $a = 200 \text{ mm}$ & $i = 20$

$$z_1/z_2/q/m = 2/39/8/85$$

(ii) Power transmission capacity based on bending failure

$$(M_t)_1 = 17.65 X_{b1} S_{b1} m l_r d_2 \cos \gamma$$

$$(M_t)_2 = 17.65 X_{b2} S_{b2} m l_r d_2 \cos \gamma$$

bending stress factor

$$S_{b1} = 28.2$$

(DDB T 23.15, 10 C4 steel)

$$S_{b2} = 6.4$$

(" , P.B. Sand cast & chilled)

Speed factors

$$n_1 = 1500 \text{ rpm}, n_2 = \frac{1500}{20} = 75 \text{ rpm}$$

$$X_{b1} = 0.24$$

(DDB T 23-16, $n_1 = 1500$)

$$X_{b2} = 0.44$$

(" , $n_2 = 75$)

From DDB eq. 23.22

$$l_r = (d_{a1} + 2c) \sin^{-1} \left[\frac{F}{(d_{a1} + 2c)} \right]$$

$$d_{a1} = m(q+2) = 8.5(8+2) = 85 \text{ mm}$$

$$c = 0.2 m \cos \gamma$$

$$\left(\tan \gamma \right) = \frac{z_1}{q} = \frac{2}{8} \Rightarrow \gamma = 14.04^\circ$$

$$= 0.2 \times 8.5 \times \cos 14.04^\circ$$

$$= 1.6492 \text{ mm}$$

$$F = 2m \sqrt{q+1} = 2 \times 8.5 \sqrt{8+1} = 51 \text{ mm}$$

$$l_r = (85 + 2 \times 1.6492) \left\{ \sin^{-1} \left(\frac{51}{(85 + 2 \times 1.6492)} \right) \times \frac{\pi}{180} \right\}$$

$$= 54.37 \text{ mm}$$

$$d_2 = m z_2 = 8.5 \times 39 = 331.5 \text{ mm}$$

$$(M_t)_1 = 17.65 \times 0.24 \times 28.2 \times 8.5 \times 54.37 \times 331.5 \times \cos(14.04^\circ)$$

$$= \boxed{17.7540 \times 10^6 \text{ N-mm}}$$

$$(M_t)_2 = 17.65 \times 0.44 \times 6.4 \times 8.5 \times 54.37 \times 331.5 \times \cos(14.04^\circ)$$

$$= \boxed{7.3870 \times 10^6 \text{ N-mm}} \quad \leftarrow M_e$$

$$\therefore \text{Torque capacity for bending} = \boxed{7.3870 \times 10^6 \text{ N-mm}}$$

Power transmission capacity based on bending failure

$$\text{kW} = \frac{2\pi n_2 (M_t)}{60 \times 10^6} = \frac{2\pi \times 75 \times 7.3870 \times 10^6}{60 \times 10^6}$$

$$= \boxed{58.02 \text{ kW}}$$

(ii) Power transmission capacity based on wear failure

$$(M_t)_3 = 18.64 X_{c1} \cdot S_{c1} \cdot Y_z (d_2)^{1.8} \times m$$

$$(M_t)_4 = 18.64 X_{c2} \cdot S_{c2} \cdot Y_z (d_2)^{1.8} \times m$$

Speed factors (DDB T 23.20)

Rolling velocity
(DDB eq. 23.29)

$$V_s = \frac{\pi d_1 n_1}{60000 \cos \gamma}$$

$$\left\{ \begin{array}{l} d_1 = m q \\ = 8.5 \times 8 \\ = 68 \text{ mm} \end{array} \right.$$

$$= \frac{\pi \times 68 \times 1500}{60,000 \times \cos 14.04^\circ} = \boxed{5.5 \text{ m/s}}$$

From DDB T 23.20

$$\text{For } V_s = 5.5 \text{ m/s}, n_1 = 1500 \text{ rpm}$$

$$X_{c1} = 0.108$$

$$\text{For } V_s = 5.5 \text{ m/s}, n_2 = 75 \text{ rpm}$$

$$X_{c2} = 0.24$$

Surface stress factors (DDB 23.18)

$$\text{Worm (Steel)} \rightarrow S_{c1} = \underline{\underline{4.93}} \quad \checkmark$$

$$\text{Wheel (P.B)} \rightarrow S_{c2} = \underline{\underline{1.27}}$$

Zone factor (DDB T 23.19)

$$z_1 = 2, q = 8$$

$$\Rightarrow Y_z = 1.144$$

$$(M_t)_3 = 18.64 \times 0.108 \times 4.93 \times 1.144 \times (331.5)^{1.8} \times 8.5 \\ = \boxed{3.3223 \times 10^6 \text{ N}\cdot\text{mm}}$$

$$(M_t)_4 = 18.64 \times 0.24 \times 1.27 \times 1.144 \times (331.5)^{1.8} \times 8.5 \\ = \boxed{1.9019 \times 10^6 \text{ N}\cdot\text{mm}} \quad \star$$

Torque capacity against wear failure

$$= \boxed{1.9019 \times 10^6 \text{ N}\cdot\text{mm}}$$

Power transmission capacity against wear failure

$$\text{kW} = \frac{2\pi \times 75 \times (1.9019 \times 10^6)}{60 \times 10^6}$$

$$= \boxed{14.94 \text{ kW}} \quad \star$$

(iv) Thermal consideration

Efficiency of worm gear drive (DDB T23.11)

$$\eta = \frac{\cos \alpha - \mu \tan \gamma}{\cos \alpha + \underline{\mu} \cot \gamma}$$

→ assume as 20°

From DDB T 23.12

$$\text{For } V_s = 5.5 \text{ m/s}$$

$$\mu = 0.024$$

$$\eta = \frac{\cos 20^\circ - 0.024 \times \tan 14.04^\circ}{\cos 20^\circ + 0.024 \times \cot 14.04^\circ}$$
$$= 0.9015$$

$$KW = \frac{k (t - t_0) \times A}{1000 (1 - \eta)}$$

$$14.94 = \frac{15 \times 50 \times A}{1000 (1 - 0.9015)}$$

$$\therefore \boxed{A = 1.9621 \text{ m}^2}$$