$\boxed{\text{Tut 8}}$ Design

Worm gears

- $p_x \text{ (worm)} = p_t \text{ (gear)}$
- $\lambda_{worm} = \psi_{gear}$
- $d_G = \dfrac{N_G\, p_t}{\pi}$
- $L = p_x N_w$
- $\tan\lambda = \dfrac{L}{\pi d_w}$
- $V_s = \dfrac{V_w}{\cos\lambda}$
- $V_w = \omega_w r_w$
- $V_g = \omega_w * \dfrac{N_w}{N_g} * r_g$

- $W_{wt} = -W_{ga} = W_x = W\cos(\phi_n \sin\lambda + \mu\cos\lambda)$

  $W_{wr} = -W_{gr} = W_y = W\sin\phi_n$

  $W_{wa} = -W_{gt} = W_z = W(\cos\phi_n \cos\lambda - \mu\sin\lambda)$

- Efficency $= \eta = \dfrac{\cos\phi_n - \mu\tan\lambda}{\cos\phi_n + \mu\cot\lambda}$ (Not given)

  * $\eta = \dfrac{H_o}{H}$

- $H = H_o + H_l$

  * $H_o = W_{tg} \cdot V_{tg}$

  * $H_l = \mu W \cdot V_s$

  $\}$ Not given

- $W_{tg} = \beta\,(K_s\, d_g^{0.8}\, F_e\, K_m\, K_v)$

  * $\beta = 0.0131$

  * $K_s - K_m - K_v \rightarrow$ tables

  * $d_g \rightarrow$ gear diam

  * $F_e \rightarrow$ smaller of $\frac{2}{3} d_w$ or F_g

Direction of Forces: • get type of worm (right / left)

• use (right/left) hand rule on worm to get W_{wa}

$\boxed{\text{Tut 9}}$ Design

Bearings :

Let $F_{eq} = F_r$

- get $C_R = k_A \, F_{eq} \left[\dfrac{L_D \, n_D}{L_R \, n_R \, 6.84} \right]^{1/a} \left[\dfrac{1}{\left(\ln \frac{1}{R}\right)^{1/1.17a}} \right]$ (only this equation given)

  * $L_D \rightarrow$ life in hours $\qquad L_R = 500\,h$
  * $n_D \rightarrow$ rpm $\qquad n_R = \frac{100}{3}$ rpm
  * $R \rightarrow$ reliability
  * $a \rightarrow 3$ ball bearing or $\frac{10}{3}$ roller bearing
  * $k_A = 1.2$

- From table choose bearing with $C > C_R$ calculated
- Calculate e from table using $\frac{F_a}{C_o}$
- $\dfrac{F_a}{F_r} \begin{cases} \leq e & F_{eq} = F_r \\ > e & F_{eq} = X F_r + Y F_a \end{cases}$ (X and Y from table using e)

$\boxed{\text{Tut 10}}$

Taper

- Check tut 10 for tables (tables given)
- get case , calulate $F_{Aa}, F_{Ar}, F_{Ba}, F_{Br}$ (let $Y = 1.5$)
- Make same check $\dfrac{F_a}{F_r} \begin{cases} \leq e & F_{eq} = F_r \\ > e & F_{eq} = 0.4 F_r + Y F_a \end{cases}$
- then get C_R using same equation

Tut 11 Design

Journal bearing

* $S = \left(\frac{r}{c}\right)^2 \frac{\mu N}{P}$

  - $r = d/2$
  - c: clearance
  - $\mu \rightarrow$ graph
  - $\Rightarrow$ N: rev/s Not rpm

- $P = \frac{W}{l \cdot d}$ $W \rightarrow$ radial force, $l \cdot d \rightarrow$ area

  ↑ Not given

* $T_{var} = \frac{\gamma C_H \Delta T}{P}$

  - γ and C_H given
  - $T_{var} \rightarrow$ graph

* $T_{av} = T_i + \frac{\Delta T}{2}$

* Power loss $= H = (T)(\omega)$

  $= (f W r)(2\pi N)$ Not given

  get 'f' from $\rightarrow \left(\frac{r}{c}\right) f \rightarrow$ graph

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Tut 12 Clutshes

All given

	Uniform wear	Uniform pressure
Force	$F = \frac{\pi P_a d (D-d)}{2}$	$F = \frac{\pi P_a (D^2-d^2)}{4}$
Torque	$T = \frac{f F (D+d)}{4} * m$	$T = \frac{\pi}{12} f P_a (D^3-d^3) * m$

$\rightarrow$ m : number of friction surfaces

P_a : maximum pressure (greater in uniform wear)

T : Torque (greater in uniform pressure)

$\boxed{\text{Tut 13}}$ Design

Disk breaks	Uniform wear	Uniform pressure
Force	$F = (\theta_2 - \theta_1) P_{max} r_i (r_o - r_i)$	$F = \frac{1}{2}(\theta_2 - \theta_1) p (r_o^2 - r_i^2)$
Torque	$T = \frac{1}{2}(\theta_2 - \theta_1) f P_{max} r_i (r_o^2 - r_i^2)$	$T = \frac{1}{3}(\theta_2 - \theta_1) f p (r_o^3 - r_i^3)$

NB: θ in rad

- equiv. radius : $r_e = \frac{r_i + r_o}{2}$
- Force location : $r_f = \frac{\cos\theta_1 - \cos\theta_2}{\theta_2 - \theta_1} \; \frac{r_i + r_o}{2}$

} Not given

Band brake

Torque : $T = (P_1 - P_2) r$

$$\boxed{\frac{P_1}{P_2} = e^{f\theta}}$$

- θ : angle of contact in rad
- $P_1 > P_2$

$\boxed{\text{Tut 14}}$ Drum Brake

Moment due Friction : $M_f = \frac{f P_a b r}{\sin\theta_a}\left[r(1 - \cos\theta_2) - \frac{a}{2}\sin^2\theta_2 \right]$

Moment due Normal Force : $M_N = \frac{P_a b r a}{\sin\theta_a}\left[\frac{\theta_2}{2} - \frac{1}{4}\sin 2\theta_2 \right]$

Torque : $T = \frac{f P_a b r^2 (\cos\theta_1 - \cos\theta_2)}{\sin\theta_{max}}$

$$F = \begin{cases} \frac{M_N - M_F}{c} & \text{self locking} \\ \frac{M_N + M_F}{c} & \text{Normal case} \end{cases}$$

} Not given

$\boxed{\text{Tut 15}}$ Design

Belt drive

- $\frac{P_1}{P_2} = e^{f\theta}$ (neglecting centrifugal force)

- $\frac{P_1 - mv^2}{P_2 - mv^2} = e^{f\theta}$

- $\sigma_{max} = \frac{Force}{Area} = \frac{P_1}{wt}$

$m = wt \times \rho$ (mass per unit length)

For initial tightening

$$P_i = \frac{P_1 + P_2}{2}$$