Basic gear rules

①

$r_f = 0.35\,m$

Circular Pitch $= P_c = \frac{\pi d}{N}$

tooth thickness $= \frac{P}{2}$

External Gears

Pitch diameter $= d$

Base circle diameter $= d\cos\phi$

Addendum " " $= d + 2a = d + 2m = d + \frac{2}{P}$

Dedundm " " $= d - 2b = d - (2)(1.25)m = d - \frac{2(1.25)}{P}$

Central distance $= C = \left(\frac{N_p + N_g}{2}\right)m = \frac{d_p + d_g}{2}$

Clearance $= c = b - a$

- Dimetral Pitch $= P = \frac{N}{d} = \frac{1}{m}$

Circular Pitch $= P_c = P = \pi m$

$\left.\right\}$ $pP = \pi$

Base pitch $= P_b = P_c\cos\phi$

$$C.r = \frac{L_{ab}}{P_b} = \sqrt{(r_{ap})^2 - (r_{bp})^2} + \sqrt{(r_{ag})^2 - (r_{bg})^2} - C\sin\phi \Big/ \pi m\cos\phi$$

Internal gears

$d_a = d - 2m = d - \frac{2}{P}$

$d_d = d + (2)(1.25)(m) = d + \frac{(2)(1.25)}{P}$

$C = \left(\frac{N_g - N_p}{2}\right)m$

$$C.r = \frac{L_{ab}}{P_b} = \sqrt{(r_{ag})^2 - (r_{bg})^2} - \sqrt{(r_{ap})^2 - (r_{bp})^2} + C\sin\phi \,/\, \pi m\cos\phi$$

Interference

External gear

$$N_{P\,min} = \frac{2K}{(1+2V_R)(\sin\phi)^2}\left(V_R + \sqrt{(V_R)^2 + (1+2V_R)(\sin\phi)^2}\right)$$

$$N_{g\,max} = \frac{(N_p)^2(\sin\phi)^2 - 4K^2}{4K - 2N_p(\sin\phi)^2}$$

$K = 1 \rightarrow$ full depth
$= 0{,}8 \rightarrow$ stub

Internal gear

$$\frac{\sqrt{(r_{ag})^2 - (r_{bg})^2} - (r_{bg} - r_{bp})}{\tan\phi}$$

Backlash

$$B = 2C'(\underbrace{\operatorname{Inv}\phi}_{\tan\phi - \phi} - \underbrace{\operatorname{Inv}\phi'}_{\tan\phi' - \phi'})$$

$\uparrow$ rad

$$\cos\phi' = \frac{C}{C'}\cos\phi$$

$$R_p' = \frac{N_p}{N_p + N_g}C' \qquad R_g' = C' - R_p'$$

$$t' = 2R'\left(\frac{t}{2R} - (\tan\phi - \phi) - (\tan\phi' - \phi')\right)$$

t' → Thickness

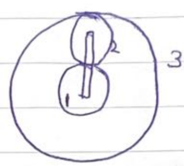
Gear trains

$$V_R = \frac{\omega_{in}}{\omega_{out}} = \frac{N_{out}}{N_{in}} \quad (\text{Ext: neg}, \quad \text{Int: pos}$$

Meshed gears have same: $m, P, \emptyset, t, P_c, a, b$

In Planetray gears:-

$$\frac{\omega_3 - \omega_{arm}}{\omega_1 - \omega_{arm}} = \frac{-N_1}{N_2} \times \frac{N_2}{N_3}$$



In general:-

$$\frac{\omega_L - \omega_{arm}}{\omega_F - \omega_{arm}} = \frac{\text{driven teeth}}{\text{driver} \ ''}$$

First, last

Same Direction (+)

Negative if opposite direction

Force analysis

$$F_t = \frac{2T}{d}$$

$$F_r = F_t \tan\emptyset$$

Notes

$T_g \neq T_p$

Check forces analysis

حلو بس ركز

ASaish حلو

Power :-

$$H_p = \frac{F_t\, V}{33000}, \qquad V = \frac{\pi\, d\, n}{12}$$

$$= \frac{T\, n^{r}}{63025} \quad \text{RPM}$$

Re solve on planetary force analysis

$$W = F_t\, V, \qquad V = \frac{\pi\, d\, n}{60}$$

Helical gears

$$d = \frac{N}{P} = N m$$

$$m_F = \frac{b}{P_a} > 1.125$$

$$a = \frac{1}{P_n} = m_n$$

Spur gear teeth number $N_e = \frac{N}{\cos^3 \psi}$

$$b = \frac{1.25}{P_n} = 1.25\, m_n$$

F_t / Power

$$F_r = F_t \tan \phi$$

$$P_a = \frac{P}{\tan \psi} \quad \text{(axial Pitch)}$$

$$F_t = F_b \cos \psi$$

$$F_a = F_t \tan \psi$$

$$P = P_n \cos \psi$$

$$\tan \phi_n = \tan \phi \cos \psi$$

Note

F_b

F_a [illegible]

F_t

F_n

F_b, F_r [illegible]

Design and Spur gear Selection ③

Bending stress of spur gear according to AGMA

$$\sigma = \frac{F_t\, P}{b\, J}\, K_o\, K_m\, K_v \qquad \text{U.S}$$

$$\sigma = \frac{F_t\, K_a\, K_m\, K_v}{b\, J\, m} \qquad \text{S.I}$$

$\sigma \to \sigma_g$, σ_p.

$F_t \longrightarrow$ Power or given

$P \longrightarrow$ given

$b \longrightarrow$ given

$J \longrightarrow$ Figur 14-6
- $\rightarrow$ lower line : Q_v is low
- $\rightarrow$ higher lines : Q_v is high

$$(\text{S.I})\ K_v = \text{Dynamic factor} = \left(\frac{A + \sqrt{200V}}{A}\right)^{B}$$

$$V = \frac{\pi d n}{60} \quad n \leftarrow \text{rev/min}$$

$$B = \frac{(12 - Q_v)^{\frac{2}{3}}}{4}$$

$$A = 50 + 56(1 - B)$$

Q_v
- $\rightarrow$ 8-12 accurate
- $\rightarrow$ for less commericial

(U.S) $K_V = \left(\dfrac{A + \sqrt{V}}{A}\right)^{B}$ $= \dfrac{\pi d n}{12}$ fpm

K_o = over load factor = Table (5)
Power source (motor)
① Driven machine (نوع الآلة)

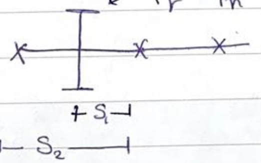
$b \leq 40''$ / $b/d < 10$ / straddle

$K_m = C_{mc}\left[C_{pf}\, C_{pm} + C_{ma}\, C_e \right] + 1 = C_{mf}$

$C_{mc} = \begin{cases} 0.8 & \text{crowned} \\ 1 & \text{uncrowned} \end{cases}$

C_{pm} = Eq (   )

if in middle $S_1 = 0$



C_{pf} = Eq (   )

$C_{ma} = A + Bb + Cb^2$ $(A, B, C) \rightarrow$ Table 14-10 / Figure 14-11

C_e = Eq (   )

(U.S) $K_V = \left(\frac{A + \sqrt{V}}{A}\right)^B = \frac{\pi d n}{12}$ fpm

K_o = over load factor = Table (5)
Power source (motor)
Driven machine (نوع الآلة)

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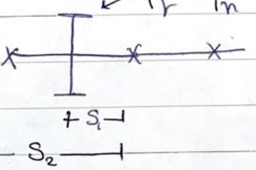

C_{pf} = Eq (   )

$C_{ma} = A + Bb + Cb^2$ $(A, B, C) \rightarrow$ Table 14-10 / Figure 14-11

C_e = Eq (   )

Bending strength of spur gear

g ← p

$$S_e = S_t \frac{K_L K_t}{K_r}$$

endurance limit

fatigue limit

- S_t : Table 14-4 / Figure 14-3, 14-4

H_B given or assumed if σ known

Pay ATTENTION for MPa, PSI

To find life:-

$$\frac{L_p}{L_g} = \frac{\omega_p}{\omega_g}$$

$L = 60 L_h n_{rpm}$ (rev)

K_L Figure 14.14

- K_R : $R \neq 99\%$ Table 14-10

K_t : $K_t = \frac{460 + T}{620}$ F° if $T > 250$ F°

Factor of safety

- $n = \frac{S_e}{\sigma}$

flip denomenator or numerator (study)

Rim Factor

$m_B = \dfrac{t_R}{h_t}$

$m_B < 1.2 \qquad K_B = 1.6 \ln\left(\dfrac{2.242}{m_B}\right)$

Figure 14-16

$m_B \geq 1.2 \qquad K_B = 1$

Contact Stress

same g.f

$\sigma_c = C_p \sqrt{\dfrac{F_t C_o C_m C_v}{b I d_p}} = \text{psi or Mpa}$

$C_o = K_o$
$C_m = K_m$
$C_v = K_v$

C_p = Table 14–8

Ext

$I = \dfrac{\sin\phi \cos\phi}{2} \dfrac{R}{R+1}, \quad R = \dfrac{N_g}{N_p} = \pm\dfrac{d_g}{d_p}$

− if internal

Contact Strength

$$S_{fe} = S_c \frac{C_L \, C_t \, C_H}{C_R}$$

S_c : Figure 14-5

C_L : Figure 14-15

C_R : Table 14-10

$$C_t = K_t = \frac{620}{400 + T} \qquad t > 250°F$$

$$C_H = \begin{cases} 1 & \text{if } \frac{H_p}{H_g} < 1.2 \\ = 1 + A'(V_R - 1), \quad A = 8.98 \times 10^{-3} \frac{H_p}{H_g} - 8.29 \times 10^{-3} & \text{if } 1.7 > \frac{H_p}{H_g} > 1.2 \end{cases}$$

Design and Helical gear Selection ⑥

Bending Stress

$$\sigma = \frac{\boxed{F_t \ P \ K_o \ K_m \ K_v}}{\boxed{b} J}$$

σ_g σ_p

b → Same as Spur gear

- J: Figure 14-7, 14-8 $\quad J'_{75}$ → when $N=75$ of mating gear

→ $J = K_J \, J_{75}$ $\quad K_J$: Figure 14-8

- othe analysis, S_e, S_t, S_{ef} Same as Spur gear

Contact Strength

$$\sigma_c = C_p \sqrt{\frac{F_t \, C_o C_m C_v}{b \, I \, d_p}}$$

same g.P

same

$\cancel{b' = \frac{b}{\cos\psi} (C.R)(0.95)}$

$$I = \frac{\sin\phi \cos\phi}{2 m_N} \cdot \frac{R}{R+1}$$

$m_N = \frac{1}{0.95 C.R}$

- $C.R = \frac{L_{ab}}{P_{bn}}$ r changes to n

$P_{bn} = P_n \cos\phi_n$

Bearings

$$C^a L_{10} = F_r^a L \qquad C = F_r \left(\frac{L}{L_{10}}\right)^{1/a}$$

$$a = \begin{cases} 3 : & \text{ball bearins} \\ 10/3 : & \text{roller " } \end{cases}$$

Bearing Selection:-

$$C_{10} = K_a \; F_e \left(\frac{L}{K_r L_{10}}\right)^{1/a}$$

K_a Table 11-5

$$K_r = X_0 + (\theta - X_0)(1 - R)^{1/b}$$ Table 11-6

$F_e = F_r \;\&\; F_t$ No Axial load

$$F_e = \max \begin{cases} V F_r \\ V X F_r + Y F_a \end{cases}$$ with Axial load

and to find C_{10} we need C_0

C_o ; Table 11-2

Table 11-1 → get e → compare $\frac{F_a}{F_r}$ with e → X, Y

F_{eq} ✓ → get C

Back to Table 11-2 : check if $C_{calc} < C_{table}$ choose another

Tapered Bearings

Timken :- $F_a = \frac{0.4\, F_r}{K}$ ← K = 0.75 steep angle, K ≈ 1.5 shallow angle

$L_{10} = 3000\ hr$

$n = 500\ rpm$

T_e → Direct connection

$$F_{eA} = 0.4 F_{rA} + K_A \left(\frac{0.47 F_{rB}}{K_B} + T_e \right)$$

$$F_{eB} = 0.4 F_{rB} + K_B \left(\frac{0.47 F_{rA}}{K_A} - T_e \right)$$

T_e → InDirect connection

$$F_{eA} = 0.4 F_{rA} + K_A \left(\frac{0.47 F_{rB}}{K_B} - T_e \right)$$

$$F_{eB} = 0.4 F_{rB} + K_B \left(\frac{0.47 F_{rA}}{K_A} + T_e \right)$$

$F_D = \max \{ F_e, F_r \}$ → F_{DA} and F_{DB}

$$C = K_a F_D \left(\frac{L_D n_D}{L_{10} n_{10}} \right)^{\frac{3}{10}}$$

$$C = K_a F_e \left(\frac{L_D \, n_D}{f_e \, f_v \, K_r \, L_R n_R} \right)^{3/10}$$

$$K_r = 4.48 (1-R)^{\frac{2}{3}}$$

f_t Figure 11-16

f_v viscosity factor Figure 11-17

Variable loading

$$\frac{l_1}{L_1} + \frac{l_2}{L_2} + \frac{l_3}{L_3} = 1$$

$$F_{eq} = F_1^a \frac{l_1}{\Sigma l} + F_2^a \frac{l_2}{\Sigma l} + \frac{F_3^a}{\Sigma l}$$

To obtain L_i

$$F^a L_i = \underbrace{C^a}_{\text{from table 11-2}} \underbrace{L_{10}}_{10^6}$$

$$F_1^a l_1 + F_2^a l_2 + F_3^a l_3 = F_1^a L_1 = F_2^a L_2 = F_3^a L_3 = C^a L_{10}$$