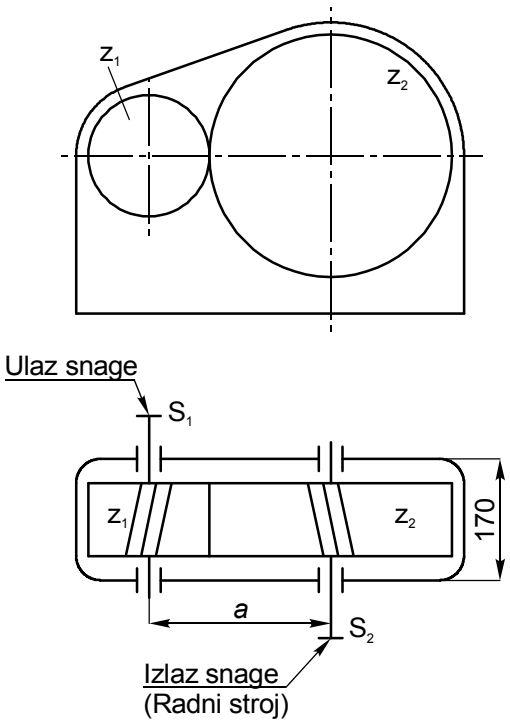
ISPIT IZ »ELEMENTI KONSTRUKCIJA III«

Za pogon radnog stroja potrebno je izraditi jednostepeni reduktor.



Poznati su slijedeći podaci:

- snaga na spojci radnog stroja 22 kW;
- brzina vrtnje elektromotora 16 o/s;
- prijenosni odnos reduktora 3;
- nagib boka zubi 12°;
- broj zubi manjeg zupčanika 16;
- pogon je ravnomjeran, bez udara, jednosmjeran;
- kvalitet ozubljenja 8;
- materijal zupčanika Č 1731;
- potrebna sigurnost zupčanika je 1,3 odnosno 1,7;
- stupanj korisnog djelovanja zupčastog para 0,97;
- stupanj korisnog djelovanja spojke 0,95;
- stupanj korisnog djelovanja uležištenja vratila 0,99.

TREBA IZRAČUNATI:

1. Standardni osni razmak

2. Postojeću sigurnost zuba zupčanika z_1(savijanje u korijenu zuba)

3. Aksonometrijski skicirati vratilo većeg zupčanika sa ucrtanim smjerom rotacije i silama koje djeluju.

Vrijeme za izradu: 1 sat i 45 min.

$P_{RS} = 22\,\text{kW}$
$n_{EM} = 16\,\text{s}^{-1}$
$i = 3$
$= 12°$
$z_1 = 16$
$z_2 = z_1 \cdot i = 16 \cdot 3 = 48$
$K_A = 1$

kvaliteta ozubljenja 8
materijal zupčanika Č 1731 → proračun boka zuba
$S_H = 1{,}3$
$S_F = 1{,}7$
$\eta_z = 0{,}97$
$\eta_s = 0{,}95$
$\eta_v = 0{,}99$

Orjentacijski proračun modula na opteretivost bokova **[1] str. 257**

$$m_n \geq \sqrt[3]{\frac{i+1}{1} \cdot \frac{2 \cdot T_{1max} \cdot \cos^2}{z_1 \cdot \quad \cdot \pi \cdot \quad ^2_{HP}} \cdot K_{H\alpha} \cdot K_{K\beta} \cdot Z_M^2 \cdot Z_H^2 \cdot Z_\varepsilon^2}$$

Moment radnog stroja

$$T_{RS} = \frac{P_{RS}}{2 \cdot \pi \cdot n_{RS}} = \frac{P_{RS}}{2 \cdot \pi \cdot n_{RS}} = \frac{P_{RS}}{2 \cdot \pi \cdot \frac{n_{EM}}{i}} = \frac{22 \cdot 10^3}{2 \cdot \pi \cdot \frac{16}{3}} = 657\,\text{Nm}$$

Okretni moment zupčanika z_1

$$T_1 = \frac{T_{RS}}{\text{i} \cdot \eta_{s2} \cdot \eta_{v2} \cdot \eta_z} = \frac{657}{3 \cdot 0{,}95 \cdot 0{,}99\,0{,}97} = 240\,\text{Nm}$$

$T_{1max} = T_1 \cdot K_I \cdot K_v$

$K_I = K_A = 1$ [1] 169.1

$K_v = 1$ ne uzimamo u obzir [1] 136.1

$T_{1max} = T_1 = 240\,\text{Nm} = 240 \cdot 10^3\,\text{Nmm}$

$= 25$ - odabrano [1] 197.1

$_{Hlim} = 620\,\text{N/mm}^2$ [1] 169.1

$$_{HP} = \frac{_{Hlim}}{S_H} = \frac{620}{1{,}3} = 477\,\text{N/mm}^2$$

$K_{H\alpha} = 1$

$K_{H\beta} = 1$

$Z_M = 190\,\sqrt{\text{N/mm}^2}$ Č/Č [1] 179.1

$Z_H = 2{,}5$

$Z_\varepsilon = 1$

$$m_n \geq \sqrt[3]{\frac{3+1}{3} \cdot \frac{2 \cdot 240 \cdot 10^3 \cdot \cos 12^\circ}{16^2 \cdot 25 \cdot 477^2} \cdot 1 \cdot 1 \cdot 190^2 \cdot 2{,}5^2 \cdot 1} = 4{,}56$$

Standardni modul $m_n = (4{,}5\ \text{mm})\ 5\ \text{mm}$ [1] 8.1

Računski osni razmak

$$a = \frac{z_1 + z_2}{2} \cdot \frac{m_n}{\cos} = \left(\frac{16+48}{2} \cdot \frac{4{,}5}{\cos 12^\circ} = 147{,}22\ \text{mm} \right) = \frac{16+48}{2} \cdot \frac{5}{\cos 12^\circ} = 163{,}57\ \text{mm}$$

Standardni osni razmak $\boxed{a_w = (140\ \text{mm}) = 160\ \text{mm}}$ [1] 87.1

Mogućnost korekcije profila

$|a - a_w| \leq m_n$

$|147{,}22 - 140| = 7{,}22 > 4{,}5$ korekcija prifila nije moguća, prelazimo na veći modul

$|163{,}57 - 160| < 5$

Opteretivost korjena zuba **[1] str. 252**

$$_{F1} = \frac{F_{t1}}{b \cdot m_n} \cdot Y_{Ft} \cdot Y_{\varepsilon 1} \cdot Y_{\beta 1} \cdot K_{F\alpha 1} \cdot K_{F\beta 1} \leq \ _{FP1}$$

$$F_{t1} = K_1 \cdot \frac{2 \cdot T_1}{d_{w1}} = K_A \cdot \frac{2 \cdot T_{1max}}{z_1 \cdot m_n} \cdot \cos$$

Raspodjela faktora pomaka profila [1] 243.1

$$a_w = a \cdot \frac{\cos\ _t}{\cos\ _{tw}}$$

$$\cos\ _{tw} = \frac{a}{a_w} \cdot \cos\ _t$$

$$\tan\ _t = \frac{\tan\ _n}{\cos} = \frac{\tan 20^\circ}{\cos 12^\circ} = 0{,}37210$$

$$_t = 20{,}41^\circ$$

$$\cos\ _{tw} = \frac{163{,}57}{160} \cdot \cos 20{,}41^\circ = 0{,}95813$$

$$_{tw} = 16{,}64^\circ$$

$$x_1 + x_2 = (z_1 + z_2) \cdot \frac{\text{ev}_{\text{tw}} - \text{ev}_{\text{t}}}{2 \cdot \tan_{\text{n}}}$$

$$\text{ev}_{\text{tw}} = \tan_{\text{tw}} - \widehat{\text{tw}} = \tan 16{,}64° - \frac{16{,}64°}{180°} \cdot \pi = 8{,}45049 \cdot 10^{-3}$$

$$\text{ev}_{\text{t}} = \tan_{\text{t}} - \widehat{\alpha}_{\text{t}} = \tan 20{,}41° - \frac{20{,}41°}{180°} \cdot \pi = 0{,}015874$$

$$x_1 + x_2 = (16 + 48) \cdot \frac{8{,}45049 \cdot 10^{-3} - 0{,}015874}{2 \cdot \tan 20°} = -0{,}65$$

$$\left.\begin{array}{l} x_1 = -0{,}20 \\ x_2 = -0{,}45 \end{array}\right\} \text{ podrezanost zuba !!!} \qquad \text{[1] 74.1}$$

$$b = \quad \cdot m_{\text{n}} = 25 \cdot 5 = 125 \text{ mm}$$

$$Y_{\text{F}} = f(z_1 = 16;\ \ = 12°;\ x_1 = -0{,}20) = 3{,}65 \qquad \text{[1] 152.1}$$

$$_{\alpha 1} = \frac{\sqrt{r_{\text{a1}}^2 - r_{\text{b1}}^2} + \sqrt{r_{\text{a2}}^2 - r_{\text{b2}}^2} - a_{\text{w}} \cdot \sin_{\text{tw}}}{m_{\text{t}} \cdot \pi \cdot \cos_{\text{t}}}$$

$$d_{\text{a1}} = d_1 + 2 \cdot m_{\text{n}} \cdot (1 + x_1) = z_1 \cdot \frac{m_{\text{n}}}{\cos \beta} + 2 \cdot m_{\text{n}} \cdot (1 + x_1) = 16 \cdot \frac{5}{\cos 12°} + 2 \cdot 5 \cdot (1 - 0{,}20) = 89{,}787 \text{ mm}$$

$$d_{\text{b1}} = d_1 \cdot \cos_{\text{t}} = z_1 \cdot \frac{m_{\text{n}}}{\cos} \cdot \cos_{\text{t}} = 16 \cdot \frac{5}{\cos 12°} \cdot \cos 20{,}41° = 76{,}653 \text{ mm}$$

$$d_{\text{a2}} = d_2 + 2 \cdot m_{\text{n}} \cdot (1 + x_2) = z_2 \cdot \frac{m_{\text{n}}}{\cos \beta} + 2 \cdot m_{\text{n}} \cdot (1 + x_2) = 48 \cdot \frac{5}{\cos 12°} + 2 \cdot 5 \cdot (1 - 0{,}45) = 250{,}862 \text{ mm}$$

$$d_{\text{b2}} = d_2 \cdot \cos_{\text{t}} = z_2 \cdot \frac{m_{\text{n}}}{\cos} \cdot \cos_{\text{t}} = 48 \cdot \frac{5}{\cos 12°} \cdot \cos 20{,}41° = 229{,}958 \text{ mm}$$

$$m_{\text{t}} = \frac{m_{\text{n}}}{\cos} = \frac{5}{\cos 12°} = 5{,}112 \text{ mm}$$

$$_{\alpha} = \frac{\sqrt{\frac{89{,}787^2 - 76{,}653^2}{4}} + \sqrt{\frac{250{,}862^2 - 229{,}958^2}{4}} - 160 \cdot \sin 16{,}64°}{5{,}112 \cdot \pi \cdot \cos 20{,}41°} = 1{,}84$$

$$Y_{\varepsilon 1} = \frac{1}{_{\alpha}} = \frac{1}{1{,}84} = 0{,}54$$

$Y_{\beta 1} = f(\quad = 12°;\ _{\beta} = 1{,}65) = 0{,}9$ [1] 254,1

$$_{\beta} = \frac{b \cdot \tan}{m_t \cdot \pi} = \frac{125 \cdot \tan 12°}{5{,}112 \cdot \pi} = 1{,}65$$

$$F_t = \frac{2 \cdot T_{1max}}{d_{w1}} = \frac{2 \cdot T_{1max}}{d_1 \cdot \frac{\cos\ _t}{\cos\ _{wt}}} = \frac{2 \cdot T_{1max}}{z_1 \cdot \frac{m_n}{\cos} \cdot \frac{\cos\ _t}{\cos\ _{tw}}} = \frac{2 \cdot 240 \cdot 10^3}{16 \cdot \frac{5}{\cos 12°} \cdot \frac{\cos 20{,}41°}{\cos 16{,}64°}} = 6000\,\mathrm{N}$$

$$\frac{F_t}{b} = \frac{6000}{125} = 48\,\frac{\mathrm{N}}{\mathrm{mm}}$$

$K_F\ = 1 + 2 \cdot (q_L - 0{,}5) \cdot (\ _{\alpha} - 1) = 1 + 2 \cdot (1 - 0{,}5) \cdot (1{,}84 - 1) = 1{,}84$

$q_L = 1$ [1] 158.1

$K_{F\ 1} = 1$ (ne uzimamo u obzir)

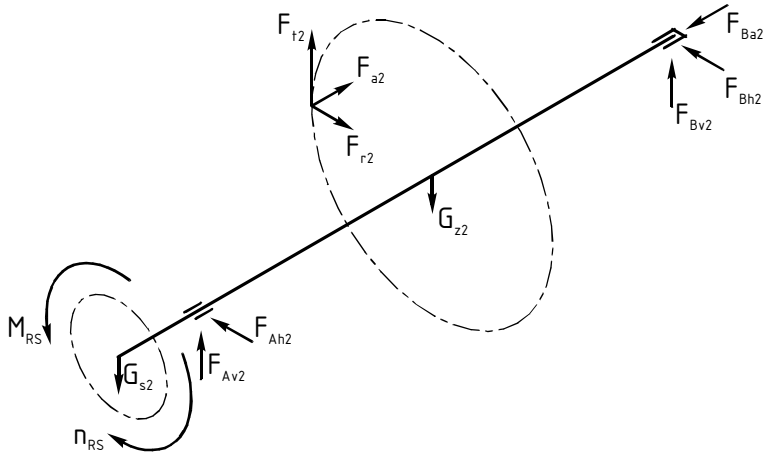
$$_F = \frac{6000}{125 \cdot 5} \cdot 3{,}65 \cdot 0{,}54 \cdot 0{,}9 \cdot 1{,}84 \cdot 1 = 31\,\frac{\mathrm{N}}{\mathrm{mm}^2}$$

$$_{FP1} = \frac{_{Flim1}}{s_F}$$

$_{Flim1} = 220\,\mathrm{MPa}$ [1] 169.1

$$s_F = \frac{_{Flim1}}{_{F1}} = \frac{220}{31} = 7{,}1$$

Sile koje opterećuju vratilo većeg zupčanika



Literatura

[1] E. Oberšmit, "Ozubljenja i zupčanici", SNL, Zagreb 1982