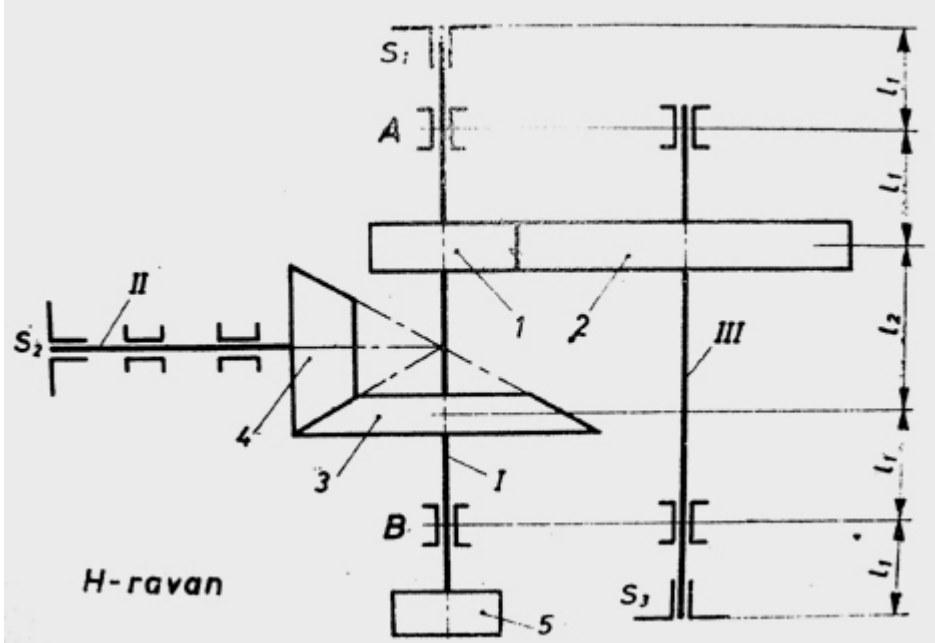
Pro\Machine

OSNOVE KONSTRUISANJA - MATURSKI RAD

Proracun zupcastog prenosnika - ZADATAK 6

Prenosnik na datoj skici prima snagu preko spojnice S1, a predaje je preko spojnica S2 i S3 i zupcanika z5.



Podaci:

- snaga na spojnici S_2 je $P_{S2} = 3.7 \cdot kW$
- snaga na spojnici S_3 je $P_{S3} = 3.7 \cdot kW$
- snaga na zupcaniku z_5 je $P_5 = 3.7 \cdot kW$
- broj obrtaja $n_1 = 960 \cdot min^{-1}$
- precnici $d_1 = 100 \cdot mm$, $d_5 = 100 \cdot mm$, $d_{m3} = 300 \cdot mm$
- prenosni odnos $i_{1,2} = 3$, $i_{3,4} = \frac{1}{3}$,
- duzine $l_1 = 200 \cdot mm$, $l_2 = 400 \cdot mm$,
- koeficijent neravnomernosti opterecenja $K_A = 1.25$,
- tezine elemenata za prenos snage zanemariti,
- stepen iskoriscenja zupcastih prenosnika je $\eta_z = 0.98$
- stepen iskoriscenja lezaja zanemariti

Potrebno je:

1. Odrediti snagu za pogon penosnika, a zatim i aktivne sile i shemu opterecenja vratila I,

2. Dimenzionisati vratilo I od C.0545 ako su veze vratila i elemenata za prenos ostvarene klinovima bez nagiba,

3. Proveriti dinamicki stepen sigurnosti na mestu 1,

4. Odrediti vek lezaja A klase 60 koji prima samo radijalno opterecenje,

5. Izabrati materijal zupcanika 1 ako je $z_1 = 20,\ \phi = 0.6,$ IT 8,

6. Usvojiti standardni modul konicnog zupcastog para ako je $z_3 = 60$

Napomena: Ostale potrebne vrednosti usvojiti

Resenje

Job. 1

$$P_1 = \frac{P_{S3}}{\eta_z} \qquad P_1 = 3.776\,\text{kW}$$

$$P_3 = \frac{P_{S2}}{\eta_z} \qquad P_3 = 3.776\,\text{kW}$$

$$P_{S1} = P_1 + P_3 + P_5 \qquad P_{S1} = 11.251\,\text{kW}$$

$$T_1 = \frac{P_1}{\omega_1}\cdot K_A$$

$$\omega_1 = 2\cdot\pi\cdot n_1 \qquad \omega_1 = 100.531\,\text{s}^{-1}$$

$$K_A = 1.25$$

$$T_1 = \frac{P_1}{\omega_1}\cdot K_A \qquad T_1 = 46.945\,\text{N}\cdot\text{m}$$

$$T_3 = \frac{P_3}{\omega_1}\cdot K_A \qquad T_3 = 46.945\,\text{N}\cdot\text{m}$$

$$T_5 = \frac{P_5}{\omega_1}\cdot K_A \qquad T_5 = 46.006\,\text{N}\cdot\text{m}$$

$$F_{t1} = \frac{2\cdot T_1}{d_1} \qquad F_{t1} = 938.892\,\text{N}$$

$$F_{t3} = \frac{2 \cdot T_3}{d_{m3}} \qquad F_{t3} = 312.964\,N$$

$$F_{t5} = \frac{2 \cdot T_5}{d_5} \qquad F_{t5} = 920.115\,N$$

$$\alpha_n = 20 \cdot deg$$

$$F_{r1} = F_{t1} \cdot \tan(\alpha_n) \qquad F_{r1} = 341.729\,N$$

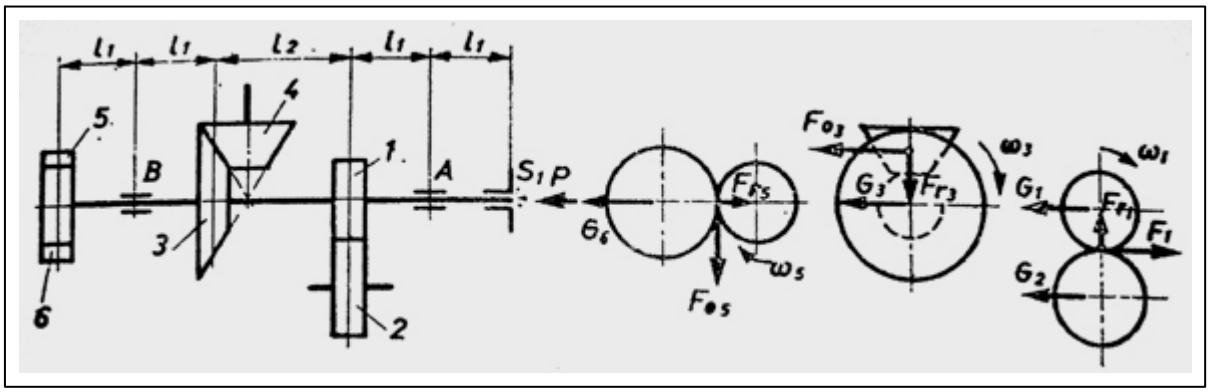
$$F_{r5} = F_{t5} \cdot \tan(\alpha_n) \qquad F_{r5} = 334.894\,N$$

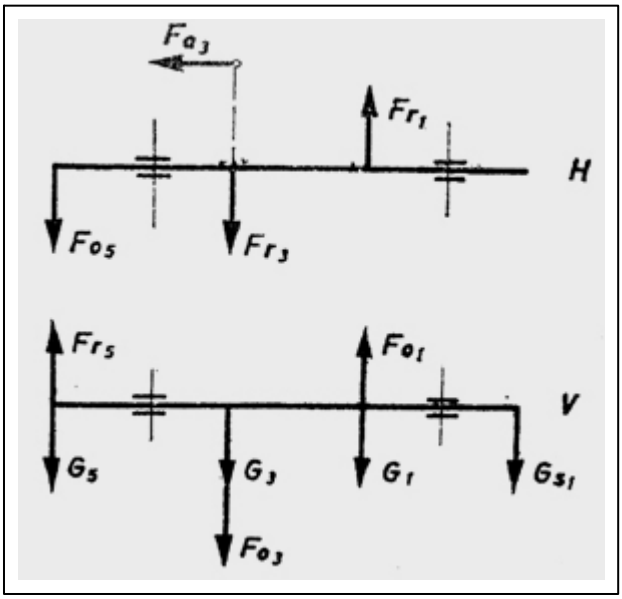
$$F_{r3} = F_{t3} \cdot \tan(\alpha_n) \cdot \cos(\delta_3)$$

$$\tan(\delta_3) = \frac{1}{i_{3,4}} \qquad \delta_3 = \operatorname{atan}\left(\frac{1}{i_{3,4}}\right) \qquad \delta_3 = 71.565\,deg$$

$$F_{r3} = F_{t3} \cdot \tan(\alpha_n) \cdot \cos(\delta_3) \qquad F_{r3} = 36.021\,N$$

$$F_{a3} = F_{t3} \cdot \tan(\alpha_n) \cdot \sin(\delta_3) \qquad F_{a3} = 108.064\,N$$





Job. 2

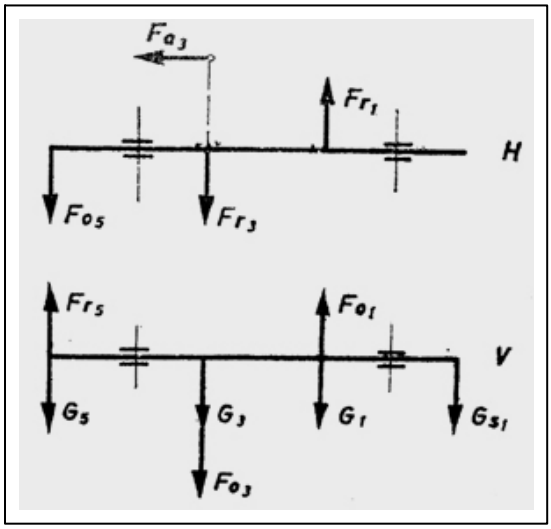
$$\sum_V M_B = 0 \qquad F_{AV}\cdot(2\cdot l_1 + l_2) + F_{t1}\cdot(l_1 + l_2) - F_{t3}\cdot l_1 - F_{r5}\cdot l_1 = 0$$

$$F_{AV} = \frac{F_{t3}\cdot l_1 - F_{t1}\cdot(l_1 + l_2) + F_{r5}\cdot l_1}{2\cdot l_1 + l_2} \qquad F_{AV} = -542.205\ \text{N}$$

$$\sum_H M_B = 0 \qquad F_{AH}\cdot(2\cdot l_1 + l_2) + F_{r1}\cdot(l_1 + l_2) + F_{a3}\cdot\frac{d_{m3}}{2} - F_{r3}\cdot l_1 + F_{t5}\cdot l_1 = 0$$

$$F_{AH} = \frac{F_{r3}\cdot l_1 - F_{a3}\cdot\frac{d_{m3}}{2} - F_{r1}\cdot(l_1 + l_2) - F_{t5}\cdot l_1}{2\cdot l_1 + l_2} \qquad F_{AH} = -497.582\ \text{N}$$

Momenti savijanja u V ravni



$M_{S1V} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{S1V} = 0\ \text{N}\cdot\text{m}$

$M_{AV} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{AV} = 0\ \text{N}\cdot\text{m}$

$M_{1V} = F_{AV}\cdot l_1$ $\qquad M_{1V} = -108.441\ \text{N}\cdot\text{m}$

$M_{3V} = F_{AV}\cdot(l_1 + l_2) + F_{t1}\cdot l_2$ $\qquad M_{3V} = 50.234\ \text{N}\cdot\text{m}$

$M_{BV} = F_{r5}\cdot l_1$ $\qquad M_{BV} = 66.979\ \text{N}\cdot\text{m}$

$M_{5V} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{5V} = 0\ \text{N}\cdot\text{m}$

Momenti savijanja u H ravni

$M_{S1H} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{S1H} = 0\ \text{N}\cdot\text{m}$

$M_{AH} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{AH} = 0\ \text{N}\cdot\text{m}$

$M_{1H} = F_{AH}\cdot l_1$ $\qquad M_{1H} = -99.516\ \text{N}\cdot\text{m}$

$M_{3+\varepsilon H} = F_{AH}\cdot(l_1 + l_2) + F_{r1}\cdot l_2$ $\qquad M_{3+\varepsilon H} = -161.858\ \text{N}\cdot\text{m}$

$M_{3-\varepsilon H} = F_{AH}\cdot(l_1 + l_2) + F_{r1}\cdot l_2 + F_{a3}\cdot\frac{d_{m3}}{2}$ $\qquad M_{3-\varepsilon H} = -145.648\ \text{N}\cdot\text{m}$

$M_{BH} = -F_{t5}\cdot l_1$ $\qquad M_{BH} = -184.023\ \text{N}\cdot\text{m}$

$M_{5H} = 0\cdot\text{N}\cdot\text{m}$ $\qquad M_{5H} = 0\ \text{N}\cdot\text{m}$

Rezultujuci moment savijanja

$M_{S1} = \sqrt{M_{S1V}^2 + M_{S1H}^2}$ $M_{S1} = 0\ N{\cdot}m$

$M_A = \sqrt{M_{AV}^2 + M_{AH}^2}$ $M_A = 0\ N{\cdot}m$

$M_1 = \sqrt{M_{1V}^2 + M_{1H}^2}$ $M_1 = 147.183\ N{\cdot}m$

$M_{3+\varepsilon} = \sqrt{M_{3V}^2 + M_{3+\varepsilon H}^2}$ $M_{3+\varepsilon} = 169.474\ N{\cdot}m$

$M_{3-\varepsilon} = \sqrt{M_{3V}^2 + M_{3-\varepsilon H}^2}$ $M_{3-\varepsilon} = 154.068\ N{\cdot}m$

$M_B = \sqrt{M_{BV}^2 + M_{BH}^2}$ $M_B = 195.833\ N{\cdot}m$

$M_5 = \sqrt{M_{5V}^2 + M_{5H}^2}$ $M_5 = 0\ N{\cdot}m$

Momenti uvijanja

$T_{S1} = \frac{P_{S1}}{\omega_1}\cdot K_A$ $T_{S1} = 139.895\ N{\cdot}m$

$T_A = T_{S1}$ $T_A = 139.895\ N{\cdot}m$

$T_{v1} = T_{S1}$ $T_{v1} = 139.895\ N{\cdot}m$

$T_{v3} = T_{S1} - T_1$ $T_{v3} = 92.95\ N{\cdot}m$

$T_B = T_5$ $T_B = 46.006\ N{\cdot}m$

$T_{v5} = T_5$ $T_{v5} = 46.006\ N{\cdot}m$

Idealni moment savijanja

$M_i = \sqrt{M^2 + (\alpha\cdot T)^2}$

gde je za materijal vratila C.0545

Zatezna cvrstoca T.2.3.str.44 ME I $R_m = 500\cdot\frac{N}{mm^2}$

Savojna dinamicka izdrzljivost pri naizmenicno promenljivom opterecenju

T.2.3.str.45 ME I $\sigma_{D(-1)s} = 220\,\frac{N}{mm^2}$

Uvojna dinamicka izdrzljivost pri jednosmernom promenljivom opterecenju

T.2.3.str.45 ME I $\tau_{D(0)u} = 170\,\frac{N}{mm^2}$

Koeficijent svodjenja napona $\alpha = \frac{\sigma_{D(-1)s}}{2\cdot\tau_{D(0)u}}$ $\alpha = 0.647$

Stepen sigurnosti $S = 4$

Dozvoljeni napon na savijanje $\sigma_d = \frac{\sigma_{D(-1)s}}{S}$ $\sigma_d = 55\,\frac{N}{mm^2}$

$M_{iS1} = \sqrt{M_{S1}^2 + (\alpha\cdot T_{S1})^2}$ $M_{iS1} = 90.52\,N\cdot m$

$M_{iA} = \sqrt{M_A^2 + (\alpha\cdot T_A)^2}$ $M_{iA} = 90.52\,N\cdot m$

$M_{i1} = \sqrt{M_1^2 + (\alpha\cdot T_{v1})^2}$ $M_{i1} = 172.791\,N\cdot m$

$M_{i3} = \sqrt{M_{3+\varepsilon}^2 + (\alpha\cdot T_{v3})^2}$ $M_{i3} = 179.83\,N\cdot m$

$M_{iB} = \sqrt{M_B^2 + (\alpha\cdot T_B)^2}$ $M_{iB} = 198.083\,N\cdot m$

$M_{i5} = \sqrt{M_5^2 + (\alpha\cdot T_{v5})^2}$ $M_{i5} = 29.768\,N\cdot m$

Idealni precnici

$d_{iS1} = \sqrt[3]{\frac{32\cdot M_{iS1}}{\pi\cdot\sigma_d}}$ $d_{iS1} = 25.593\,mm$

$d_{iA} = \sqrt[3]{\frac{32\cdot M_{iA}}{\pi\cdot\sigma_d}}$ $d_{iA} = 25.593\,mm$

$d_{i1} = \sqrt[3]{\frac{32\cdot M_{i1}}{\pi\cdot\sigma_d}}$ $d_{i1} = 31.748\,mm$

$d_{i3} = \sqrt[3]{\frac{32\cdot M_{i3}}{\pi\cdot\sigma_d}}$ $d_{i3} = 32.174\,mm$

$d_{iB} = \sqrt[3]{\frac{32\cdot M_{iB}}{\pi\cdot\sigma_d}}$ $d_{iB} = 33.227\,mm$

$d_{i5} = \sqrt[3]{\frac{32\cdot M_{i5}}{\pi\cdot\sigma_d}}$ $d_{i5} = 17.666\,mm$

Stvarni precnici

$d_{S1} = 1.2 \cdot d_{iS1}$ $d_{S1} = 30.712\,mm$ $d_{S1} = 35 \cdot mm$

$d_A = 35 \cdot mm$

$d_1 = 1.2 \cdot d_{i1}$ $d_1 = 38.098\,mm$ $d_1 = 40 \cdot mm$

$d_3 = 1.2 \cdot d_{i3}$ $d_3 = 38.608\,mm$ $d_3 = 40 \cdot mm$

$d_B = 35 \cdot mm$

$d_5 = 1.2 \cdot d_{i5}$ $d_5 = 21.199\,mm$ $d_5 = 25 \cdot mm$

Job. 3

Na mestu 1 imamo savijanje i uvijanje

$S_\sigma = \frac{[\sigma]}{\sigma}$ $S_\tau = \frac{[\tau]}{\tau}$

$[\sigma] = \sigma_{D(-1)M} = \sigma_{D(-1)s} \cdot \frac{\xi_{1\sigma} \cdot \xi_{2\sigma}}{\beta_{k\sigma}}$ $[\tau] = \tau_{D(0)M} = \tau_{D(0)u} \cdot \frac{\xi_{1\tau} \cdot \xi_{2\tau}}{\beta_{k\tau}}$

$\xi_{1\sigma} = 0.84$ $\xi_{1\tau} = 0.78$

$\xi_2 = 0.9$

$\beta_k = (\alpha_k - 1) \cdot \eta_k + 1$

$\alpha_k = 3.6$

$t = 4.9 \cdot mm$

$r = 0.5 \cdot mm$

$\frac{r}{t} = 0.102$

$\eta_k = 0.65$

$\beta_k = (\alpha_k - 1) \cdot \eta_k + 1$ $\beta_k = 2.69$

$[\sigma] = \sigma_{D(-1)s} \cdot \frac{\xi_{1\sigma} \cdot \xi_2}{\beta_k}$ $[\tau] = \tau_{D(0)u} \cdot \frac{\xi_{1\tau} \cdot \xi_2}{\beta_k}$

$[\sigma] = 61.829 \frac{N}{mm^2}$ $[\tau] = 44.364 \frac{N}{mm^2}$

$\sigma_1 = \frac{M_1}{W_{x1}}$ $\tau_1 = \frac{T_{v1}}{W_{o1}}$

$M_1 = 147.183\,N{\cdot}m$ $T_{v1} = 139.895\,N{\cdot}m$

$W_{x1} = \frac{d_1^{\,3}\cdot\pi}{32}$ $W_{x1} = 6.283\times 10^{3}\,mm^3$ $W_{o1} = \frac{d_1^{\,3}\cdot\pi}{16}$ $W_{o1} = 1.257\times 10^{4}\,mm^3$

$\sigma_1 = \frac{M_1}{W_{x1}}$ $\sigma_1 = 23.425\,\frac{N}{mm^2}$ $\tau_1 = \frac{T_{v1}}{W_{o1}}$ $\tau_1 = 11.132\,\frac{N}{mm^2}$

$S_\sigma = \frac{[\sigma]}{\sigma_1}$ $S_\sigma = 2.639$ $S_\tau = \frac{[\tau]}{\tau_1}$ $S_\tau = 3.985$

$$S = \frac{S_\sigma\cdot S_\tau}{\sqrt{S_\sigma^{\,2} + S_\tau^{\,2}}} \qquad S = 2.2$$

Job. 4

po uslovu zadatka 6007 samo radijalna sila (pokretan oslonac)

$d_A = 35\,mm$

$C = 12\cdot 10^{3}\cdot N$

Radijalna sila u osloncu

$F_{rA} = \sqrt{F_{AV}^{\,2} + F_{AH}^{\,2}}$ $F_{rA} = 735.917\,N$

Ekvivalentno dinamicko opterecenje

$F = F_r = F_{rA}$

$F = F_{rA}$ $F = 735.917\,N$

Radni vek lezaja

$$L_h = \frac{10^6}{n}\cdot\left(\frac{C\cdot f_t}{F}\right)^{\alpha}$$

$n_1 = 960\,min^{-1}$

$f_t = 1$

$\alpha = 3$

$L_h = \frac{10^6}{n_1}\cdot\left(\frac{C\cdot f_t}{F}\right)^{\alpha}$ $L_h = 7.527\times 10^{4}\,hr$

Job. 5.

$$\sigma_H = Z\cdot\sqrt{\frac{F_t}{b\cdot d_1}\cdot\frac{u+1}{u}\cdot K_H} \le \sigma_d = \frac{\sigma_{Hlim}}{S}$$

odakle je

$$\sigma_{Hlim} \ge S\cdot Z\cdot\sqrt{\frac{F_t}{b\cdot d_1}\cdot\frac{u+1}{u}\cdot K_H}$$

$S = 2$

$$Z_E = 189\cdot\sqrt{\frac{N}{mm^2}}$$

$Z = 2.5\cdot Z_E$ $\qquad Z = 472.5\sqrt{\frac{N}{mm^2}}$

$F_{t1} = 938.892\,N$

$d_1 = 100\cdot mm$

$b = \phi\cdot d_1$ $\quad b = 60\,mm$ $\quad$ usvajam $\quad b = 60\cdot mm$

$u = i_{1,2}$ $\quad u = 3$

Ukupni faktor opterecenja $K_H = K_A\cdot K_V\cdot K_{H\beta}$

$K_A = 1.25$

Faktor unutrasnjih dinamickih sila Sl. 4.47 str. 128 ME II $K_{V\beta} = 1.07$

gde je:

$\omega_1 = 2\cdot\pi\cdot n_1$ $\qquad \omega_1 = 100.531\,s^{-1}$

$v = \frac{d_1}{2}\cdot\omega_1$ $\qquad v = 5.027\,\frac{m}{s}$

$\frac{v\cdot z_1}{100} = 1.005\,\frac{m}{s}$ $\quad$ i $\quad$ IT 8

za $\varepsilon\beta > 1$ $\quad K_V = K_{V\beta}$ $\qquad K_V = 1.07$

Faktor raspodele opterecenja Tab. 4.4 str. 130 ME II $K_{H\beta} = 1.06$

$K_H = K_A\cdot K_V\cdot K_{H\beta}$ $\qquad K_H = 1.418$

$\sigma_{Hlim} = S\cdot Z\cdot\sqrt{\frac{F_{t1}}{b\cdot d_1}\cdot\frac{u+1}{u}\cdot K_H}$ $\qquad \sigma_{Hlim} = 513.965\,\frac{N}{mm^2}$ $\quad$ usvajam $\quad$ C. 1530

Job. 6

Kod konicnih zupcastih parova vazi: $d_m = z \cdot m_m$

$$m_m = m - b \cdot \sin\left(\frac{\delta}{z}\right)$$

$$b = 0.33 \cdot R_m$$

$$R_m = \frac{d_m}{2 \cdot \sin(\delta)}$$

$\delta_3 = 71.565\,\text{deg}$ od ranije

$z_3 = 60$ zadato

$d_{m3} = 300\,\text{mm}$ zadato

$R_m = \dfrac{d_{m3}}{2 \cdot \sin(\delta_3)}$ $R_m = 158.114\,\text{mm}$

$b = 0.33 \cdot R_m$ $b = 52.178\,\text{mm}$ usvajam $b = 52 \cdot \text{mm}$

$m_m = \dfrac{d_{m3}}{z_3}$ $m_m = 5\,\text{mm}$

$m = m_m + b \cdot \sin\left(\dfrac{\delta_3}{z_3}\right)$ $m = 6.082\,\text{mm}$ usvajam standardan modul $m = 6 \cdot \text{mm}$