PRORACUN CILINDRICNOG ZUPCASTOG PARA

Polazni podaci

A1 Nominalna snaga $P = 100kW$

A2 Broj obrtaja pogon. masine $n_1 = 1400min^{-1}$

A3 Broj zubaca pogonskog zupcanika $z_1 = 19$ usvojiti od 18 do 25

A4 Broj zubaca gonjenog zupcanika $z_2 = 30$ savet da z1+z2 bude neparan broj

A5 Prenosni odnos $u = \frac{z_2}{z_1}$ $u = 1.579$

A6 Ugao nagiba bocne linije $\beta = 12deg$ usvojiti od 5 do 25 stepeni

A7 Modul $m_n = 6mm$ Tab. 4.2 str. 98

A8 Ceoni modul $m_t = \frac{m_n}{\cos(\beta)}$ $m_t = 6.134\,mm$

A9 Ugao nagiba profila $\alpha_n = 20deg$

A10 Faktor visine temenog dela alata $h_{a0x} = 1.25$

A11 Faktor poluprecnika zaobljenja alata $r_{oa0x} = 0.25$

A12 Visina noge zupca $h_{fp} = 1.25 \cdot m_n$ $h_{fp} = 7.5\,mm$ od 10 do 40 % preko mn

A13 Temeni zazor $c = h_{fp} - m_n$ $c = 1.5\,mm$

A14 Sirina zupcanika $b = 130mm$ usvojeno

A15 Kvalitet izrade IT 7 zadato

A16 Materijal pogonskog zupcanika C.1531 nitriran Tab. 4.5 str. 133

A17 Materijal gonjenog zupcanika C.1331 usvojiti losiji materijal u odnosu na z1

A18 Dinamicka izdrzljivost bokova pog. zupcanika $\sigma_{Hlim} = 950\frac{N}{mm^2}$ Tab. 4.5 str. 133

A19 Dinamicka izdrzljivost podnozja pog. zupcanika $\sigma_{Flim} = 300\frac{N}{mm^2}$ Tab. 4.5 str. 133

A20 Srednja hrapavost $R_a = 1.6 \times 10^{-6} m$ Tab. 1.1 str. 32 MEI

Geometrija zupcanika

B1 Precnik podeone kruznice pog. zupcanika $d_1 = m_t \cdot z_1$ $d_1 = 116.547\,mm$

B2 Precnik podeone kruznice gonj. zupcanika $d_2 = m_t \cdot z_2$ $d_2 = 184.021\,mm$

B3 Ugao nagiba profila alata u ceonom preseku $\alpha_t = \operatorname{atan}\left(\frac{\tan(\alpha_n)}{\cos(\beta)}\right)$ $\alpha_t = 20.41\,deg$

B4 Nulto osno rastojanje $a_r = \frac{(d_1 + d_2)}{2}$ $a_r = 150.284\,mm$

B5 Osno rastojanje $a = 150mm$ (zaokruziti na blizu peticu)

B6 Precnik kinematske kruznice pog.zupcanika $d_{w1} = 2 \cdot a \cdot \frac{z_1}{z_1 + z_2}$ $d_{w1} = 116.327\,mm$

B7 Precnik kinematske kruznice gonj.zupcanika $d_{w2} = u \cdot d_{w1}$ $d_{w2} = 183.673\,mm$

B8 Ugao dodirnice $\alpha_{wt} = \operatorname{acos}\left[\frac{m_t \cdot (z_1 + z_2) \cdot \cos(\alpha_t)}{2 \cdot a}\right]$ $\alpha_{wt} = 20.117\,deg$

B9 Involut funkcija $inv(x) = \tan(x) - x$

B10 Zbir koef. pomeranja profila $X = \left(inv(\alpha_{wt}) - inv(\alpha_t)\right) \cdot \frac{(z_1 + z_2)}{2 \cdot \tan(\alpha_n)}$ $X = -0.047$

B11 Parcijalni koef. pomeranja pogonskog zupcanika $x_1 = 0$

B12 Parcijalni koef. pomeranja gonjenog zupcanika $x_2 = X - x_1$ $x_2 = -0.05$

B13 Precnik podnozne kruznice pog.zupcanika $d_{f1} = d_1 + 2 \cdot x_1 \cdot m_n - 2 \cdot h_{fp}$ $d_{f1} = 101.547\,mm$

B14 Precnik podnozne kruznice gonj.zupcanika $d_{f2} = d_2 + 2 \cdot x_2 \cdot m_n - 2 \cdot h_{fp}$ $d_{f2} = 168.457\,mm$

B15 Precnik temene kruznice pog.zupcanika $d_{a1} = 2 \cdot a - d_{f2} - 2 \cdot c$ $d_{a1} = 128.543\,mm$

B16 Precnik temene kruznice gonj.zupcanika $d_{a2} = 2 \cdot a - d_{f1} - 2 \cdot c$ $d_{a2} = 195.453\,mm$

B17 Precnik osnovne kruznice pog.zupcanika $d_{b1} = d_1 \cdot \cos(\alpha_t)$ $d_{b1} = 109.23\,mm$

B18 Precnik osnovne kruznice gonj.zupcanika $d_{b2} = d_2 \cdot \cos(\alpha_t)$ $d_{b2} = 172.468\,mm$

B19 Podeoni korak u normalnoj ravni $p_n = \pi \cdot m_n$ $p_n = 18.85\,mm$

B20 Podeoni korak u ceonoj ravni $p_t = \pi \cdot m_t$ $p_t = 19.271\,mm$

B21 Osnovni (sprezni) korak $p_{et} = p_t \cdot \cos(\alpha_t)$ $p_{et} = 18.061\,mm$

B22 Aktivna duz.dodirnice $g_\alpha = \frac{1}{2} \cdot \left(\sqrt{d_{a1}^2 - d_{b1}^2} + \sqrt{d_{a2}^2 - d_{b2}^2}\right) - a \cdot \sin(\alpha_{wt})$ $g_\alpha = 28.273\,mm$

B23 Stepen sprezanja profila $\varepsilon_\alpha = \frac{g_\alpha}{p_{et}}$ $\varepsilon_\alpha = 1.565$ mora biti $1 < \varepsilon_\alpha < 2$

B24 Stepen sprezanja bocnih linija $\varepsilon_\beta = \frac{b \cdot \tan(\beta)}{p_t}$ $\varepsilon_\beta = 1.434$ iskustveno $1 < \varepsilon_\beta < 1.5$

B25 Ukupni stepen sprezanja $\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$ $\varepsilon_\gamma = 2.999$ najpogodnije u pogledu dinamike ako je ceo broj

B26 $\alpha_{tx1} = \operatorname{atan}\left[\frac{1}{\cos(\alpha_t)}\cdot\sqrt{\sin(\alpha_t)^2 + 4\cdot\frac{x_1}{z_1}\cdot\left(1+\frac{x_1}{z_1}\right)}\right]$ $\alpha_{tx1} = 20.41\,\text{deg}$

B27 $\alpha_{tx2} = \operatorname{atan}\left[\frac{1}{\cos(\alpha_t)}\cdot\sqrt{\sin(\alpha_t)^2 + 4\cdot\frac{x_2}{z_2}\cdot\left(1+\frac{x_2}{z_2}\right)}\right]$ $\alpha_{tx2} = 19.92\,\text{deg}$

B28 Ugao nagiba bocne linije $\beta_b = \operatorname{asin}(\sin(\beta)\cdot\cos(\alpha_n))$ $\beta_b = 11.267\,\text{deg}$

B29 Merni broj zubaca z1 $z_{w1r} = \frac{z_1}{\pi}\cdot\left(\frac{\tan(\alpha_{tx1})}{\cos(\beta_b)^2} - \text{inv}(\alpha_t)\right) - \frac{2\cdot x_1\cdot\tan(\alpha_t)}{\pi} + 0.5$ $z_{w1r} = 2.744$

na blizi ceo broj $z_{w1} = 3$

B30 Merni broj zubaca z2 $z_{w2r} = \frac{z_2}{\pi}\cdot\left(\frac{\tan(\alpha_{tx2})}{\cos(\beta_b)^2} - \text{inv}(\alpha_t)\right) - \frac{2\cdot x_2\cdot\tan(\alpha_t)}{\pi} + 0.5$ $z_{w2r} = 3.958$

na blizi ceo broj $z_{w2} = 4$

B31 Mera preko zubaca pogonskog zupcanika

$$W_1 = m_n\cdot\cos(\alpha_n)\cdot\left[\pi\cdot(z_{w1} - 0.5) + z_1\cdot\text{inv}(\alpha_t)\right] + 2\cdot x_1\cdot m_n\cdot\sin(\alpha_n) \qquad W_1 = 45.983\,\text{mm}$$

B32 Mera preko zubaca gonjenog zupcanika

$$W_2 = m_n\cdot\cos(\alpha_n)\cdot\left[\pi\cdot(z_{w2} - 0.5) + z_2\cdot\text{inv}(\alpha_t)\right] + 2\cdot x_2\cdot m_n\cdot\sin(\alpha_n) \qquad W_2 = 64.487\,\text{mm}$$

Opterecenje

C1 Faktor spoljasnih dinamickih sila $K_A = 1.25$ Tab.4.3 str.127 za ravnomeran rad

C2 Ugaona brzina pogonskog zupcanika $\omega_1 = 2\cdot\pi\cdot n_1$ $\omega_1 = 146.608\,s^{-1}$

C3 Obrtni moment na pogonskom vratilu $T_1 = \frac{P}{\omega_1}$ $T_1 = 682.093\,N\cdot m$

C4 Obimna sila na podeonom cilindru pog.zupcanika $F_{t1} = \frac{2\cdot T_1}{d_1}$ $F_{t1} = 1.171\times 10^4\,N$

C5 Obimna sila na podeonom cilindru gonj.zupcanika $F_{t2} = F_{t1}$ $F_{t2} = 1.171\times 10^4\,N$

C6 Obimna brzina zupcanika $v = \frac{d_1}{2}\cdot\omega_1$ $v = 8.543\,\frac{m}{s}$

C7 Parametar brzine $\frac{v\cdot z_1}{100} = 1.623\,\frac{m}{s}$

C8 Faktor unutrasnjih dinamickih sila $K_{V\beta} = 1.07$ Sl. 4.47 str. 128

$K_{V\alpha} = 1.13$

za $\varepsilon_\beta = 1.434$ $\varepsilon_\beta > 1$ $K_V = K_{V\beta}$ $K_V = 1.07$

C9 Faktor raspodele opterecenja $K_{H\beta} = 1.08$ Tab. 4.4 str. 130 za $\frac{b}{d_1} = 1.115$

C10 Ukupni faktor opterecenja $K_H = K_A\cdot K_{V\beta}\cdot K_{H\beta}$ $K_H = 1.445$

Nosivost u odnosu na cvrstocu bokova zubaca

D1 Faktor elasticnosti materijala $Z_{Ec} = 189\sqrt{\frac{N}{mm^2}}$ za kontakt celik po celiku

$Z_{Esl} = 163\sqrt{\frac{N}{mm^2}}$ za kontakt celik po sivi liv

D2 Uticaj elasticnosti materijala $Z = 2.5 \cdot Z_{Ec} \cdot \cos(\beta)$ $Z = 462.175\sqrt{\frac{N}{mm^2}}$

D3 Radni napon boka zupca $\sigma_H = Z \cdot \sqrt{\frac{F_{t1}}{b \cdot d_1} \cdot \frac{u+1}{u} \cdot K_H}$ $\sigma_H = 623.975 \frac{N}{mm^2}$

D4 Kriticni napon bokova $\sigma_{Hkr} = \sigma_{Hlim}$ $\sigma_{Hkr} = 950 \frac{N}{mm^2}$

D5 Stepen sigurnosti obzirom na bok zupca $S_H = \frac{\sigma_{Hkr}}{\sigma_H}$ $S_H = 1.5$ **zadovoljava**

D6 Dozvoljeni stepen sigurnosti protiv razaranja bokova zubaca $S_{Hd} = 1.2$

SHd = 1.2 do 2 po preporuci

Nosivost u odnosu na cvrstocu podnozja zubaca

E1 Faktor koncentracije napona $Y_\Pi = 1.92$ za $m_n = 6\,mm$

$Y_\Pi = 2$ za $m_n \le 5$ i $R_a \le 10 \cdot \mu m$

$Y_\Pi = 1.7 \div 2$ za $m_n > 5$ i/ili $R_a > 10 \cdot \mu m$

manje vrednosti uzimati za vece Ra

E2 Kriticni napon $\sigma_{FM} = Y_\Pi \cdot \sigma_{Flim}$ $\sigma_{FM} = 576 \frac{N}{mm^2}$

E3 Faktor oblika zupca $Y_{Fa} = 2.91$ Tab.4.8 str.139

$z_n = \frac{z_1}{\cos(\beta)^3}$ $z_n = 20.3$ i $x_1 = 0$ iz geometrije

E4 Faktor koncentracije napona $Y_{Sa} = 1.66$ Sl.4.54 str.137

E5 Faktor polozaja $Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_\alpha}$ $Y_\varepsilon = 0.729$

E6 Uticaj oblika kosozubih zupcanika $Y_\beta = 1 - \varepsilon_\beta \cdot \frac{\beta}{120deg}$ $Y_\beta = 0.857$

E7 Faktor raspodele opterecenja $K_{F\beta} = 1.06$ Tab.4.4 str.130 za $K_{H\beta} = 1.08$

E8 Napon u podnozju zupca $\sigma_F = Y_{Fa} \cdot Y_{Sa} \cdot Y_\varepsilon \cdot Y_\beta \cdot \frac{F_{t1}}{b \cdot m_n} \cdot K_A \cdot K_V \cdot K_{F\beta}$ $\sigma_F = 64.188 \frac{N}{mm^2}$

E9 Stepen sigurnosti obzirom na lom zupca $S_F = \frac{\sigma_{FM}}{\sigma_F}$ $S_F = 9$ **zadovoljava**

$S_{Fd} = 1.4$ preporuka za dozvoljeni stepen sigurnosti