

PRORAČUN CILINDRIČNOG ZUPČASTOG PARA

vežba

B1

Polazni podaci

A1 Oznaka elektromotora prema katalogu **ATB - Sever Subotica**

zadato

1.ZK 200 L-6

Niskonaponski trofazni zatvoreni motori sa kaveznim rotorom

Type	Output power P_k kW	Rated speed n_k min^{-1}	Efficiency η %	Power factor $\cos \varphi$	Rated current I_k A	Rated torque T_k Nm	I_1/I_k	T_1/T_k	T_s/T_k	Torque class KR	Moment of inertia J kgm^2	Mass kg
1500 min^{-1}												
1ZK 63 A-4	0.12	1310	60.0	0.66	0.44	0.87	3.0	1.8	2.1	13	0.00027	4.4
1ZK 63 B-4	0.18	1330	63.0	0.74	0.56	1.29	3.2	2.2	2.1	13	0.00037	5
1ZK 71 A-4	0.25	1340	63.0	0.76	0.75	1.80	3.2	1.7	1.9	13	0.00038	5.3
1ZK 71 B-4	0.37	1340	62.0	0.75	1.1	2.60	3.5	2.0	2.1	13	0.00055	6.3
1ZK 80 A-4	0.55	1375	69.0	0.75	1.5	3.80	3.8	1.9	2.0	13	0.0009	8.2
1ZK 80 B-4	0.75	1375	72.0	0.75	2.0	5.20	3.8	2.1	2.2	13	0.0011	9
1ZK 90 S-4	1.1	1410	74.0	0.78	2.8	7.50	4.1	2.0	2.3	16	0.0023	13.2
1ZK 90 L-4	1.5	1405	77.0	0.78	3.6	10	4.6	2.1	2.8	16	0.0032	15.8
2ZK 100 L-4	2.2	1410	78.0	0.81	5.0	15	5.4	2.2	2.8	16	0.0054	20.5
2ZK 100 Ld-4	3	1410	76.0	0.80	7.1	20	5.7	2.4	2.7	16	0.0071	22.6
2ZK 112 M-4	4	1420	81.0	0.82	8.6	27	6.5	2.9	3.0	16	0.013	28.4
1ZK 132 S-4	5.5	1450	85.0	0.82	11.4	36	6.5	2.5	3.1	16	0.019	53
1ZK 132 M-4	7.5	1450	86.0	0.80	15.7	49	6.5	2.4	3.2	16	0.025	64
2200 min^{-1}												
2ZKI 315 L-4	315	1487	95.4	0.88	542	2023	7.7	2.0	2.8	13	6.0	1720
2ZKI 355 Mk-4	250	1491	95.7	0.90	419	1600	7.3	2.0	3.0	10	7.6	1750
2ZKI 355 M-4	315	1492	96.0	0.90	535	2016	7.3	2.1	3.2	13	9.9	1930
2ZKI 355 Md-4	355	1492	96.2	0.89	592	2272	8.3	2.5	3.2	13	13.0	2150
2ZKI 355 Lk-4	400	1492	96.3	0.90	666	2560	8.4	2.6	3.3	13	14.5	2545
2ZKI 355 L-4	450	1492	96.4	0.90	748	2880	8.5	2.6	3.3	13	17.0	2770
2ZKI 355 Ld-4	500	1492	96.5	0.91	822	3200	8.5	2.6	3.3	13	19.0	2920

A2 Nominalna snaga elektromotora

$$P_N = 22\text{kW}$$

A3 Broj obrtaja elektromotora

$$n_N = 970\text{min}^{-1}$$

A4 Prenosni odnos zupčastog para

zadato

$$i = 3.15$$

A5 Broj zubaca pogonskog zupčanika

zadato

$$z_1 = 21$$

A6 Broj zubaca gonjenog zupčanika

$$z_2 = i z_1 = 66.15 \quad \text{usvajam tako da zbir zubaca bude neparan broj}$$

$$z_2 = 66$$

A7 Kinematski prenosni odnos

$$u = \frac{z_2}{z_1}$$

$$u = 3.143$$

A8 Ugao nagiba bočne linije

zadato

$$\beta = 12^\circ$$

A9 Modul prema SRPS M.C1.015

Tab. 4.2 str. 98 ME II

$$m_n = 8\text{mm}$$

Таблица 4.2. СТАНДАРДНЕ ВЕЛИЧИНЕ МОДУЛА m_n у mm

Група I:	1	1,25	1,5	2	2,5	3	4	5	6	8	10	12	16	20	25	32	40	50
Група II:		1,125	1,375	1,75	2,25	2,75	3,5	4,5	5,5	7	9	11	14	18	22	28	36	45

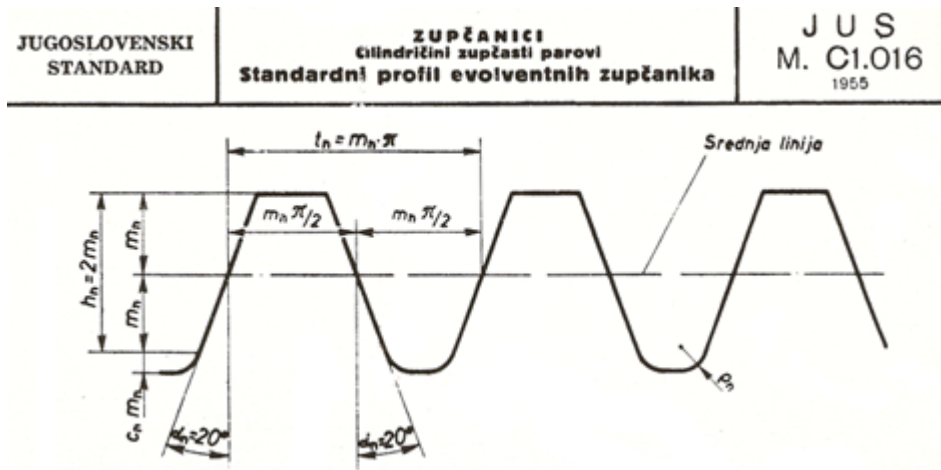
A10 Čeoni modul

$$m_t = \frac{m_n}{\cos(\beta)}$$

$$m_t = 8.179 \text{ mm}$$

A11 Standardni profil evolventnih zupčanika

prema SRPS M.C1.016



Ugao nagiba profila

$$\alpha_n = 20^\circ$$

Faktor temenog zazora

$$c_n = 0.1 \div 0.3 \quad \text{usvajam}$$

$$c_n = 0.25$$

Poluprečnik zaobljenja alata

$$\rho_n = \frac{c_n m_n}{1 - \sin(\alpha_n)}$$

$$\rho_n = 3.04 \text{ mm}$$

Temeni zazor

$$c = c_n m_n$$

$$c = 2 \text{ mm}$$

Visina noge zupca

$$h_f = m_n(1 + c_n)$$

$$h_f = 10 \text{ mm}$$

A12 Materijal pogonskog zupčanika

zadato

C60 (Č1730)

Dinamička izdržljivost bokova pogonskog zupčanika

Tab. 4.5 str. 133 ME II

$$\sigma_{Hlim} = 520 \frac{\text{N}}{\text{mm}^2}$$

Dinamička izdržljivost podnožja pogonskog zupčanika

Tab. 4.5 str. 133 ME II

$$\sigma_{Flim} = 210 \frac{\text{N}}{\text{mm}^2}$$

Таблица 4.5

МАТЕРИЈАЛ ЗА ЗУПЧАНИКЕ (издржљивост зупчаника епрувета)

Ознака	Тврдоћа језгра-бока	Трајна динамичка издржљивост у N/mm ²		Статичка чв. подн. σ_{FS} N/mm ²
		σ_{Hlim} сред. вредност	σ_{Flim} средња вред.	
Побољшани или нормализовани челици HV 10				
Č.1331	140	480	192	600
Č.1530	185	520	205	800
Č.1731	210	520	210	900
Č.4130	260	700	270	900
Č.4131	260	700	270	950
Č.4732	280	730	275	1100
Č.5431	310	770	285	1300

A13 Materijal gonjenog zupčanika

Tab. 4.5 str. 133 ME II

C22 (Č1331)

A14 Kvalitet izrade zupčanika

zadato

IT 7

Geometrija zupčanika



B1 Prečnik podeone kružnice pogonskog zupčanika

$$d_1 = m_t z_1$$

$$d_1 = 171.753 \text{ mm}$$

B2 Prečnik podeone kružnice gonjenog zupčanika

$$d_2 = m_t z_2$$

$$d_2 = 539.796 \text{ mm}$$

B3 Ugao nagiba profila alata u ceonom preseku

$$\alpha_t = \text{atan} \left(\frac{\tan(\alpha_n)}{\cos(\beta)} \right)$$

$$\alpha_t = 20.4103^\circ$$

B4 Nulto osno rastojanje

$$a = \frac{d_1 + d_2}{2}$$

$$a = 355.775 \text{ mm}$$

B5 Stvarno osno rastojanje

(zaokruziti na blizu peticu)

$$a_w = 355 \text{ mm}$$

B6 Prečnik kinematske kružnice pogonskog zupčanika

$$d_{w1} = 2a_w \frac{z_1}{z_1 + z_2}$$

$$d_{w1} = 171.379 \text{ mm}$$

B7 Prečnik kinematske kružnice gonjenog zupčanika

$$d_{w2} = u d_{w1}$$

$$d_{w2} = 538.621 \text{ mm}$$

B8 Ugao dodirnice

$$\alpha_{wt} = \text{acos} \left[\frac{m_t (z_1 + z_2) \cos(\alpha_t)}{2a_w} \right]$$

$$\alpha_{wt} = 20.0717^\circ$$

B9 Involut funkcija

$$\text{inv}(\alpha_{wt}) = \tan(\alpha_{wt}) - \alpha_{wt}$$

$$\text{inv}(\alpha_{wt}) = 0.015071$$

$$\text{inv}(\alpha_t) = \tan(\alpha_t) - \alpha_t$$

$$\text{inv}(\alpha_t) = 0.015874$$

B10 Zbir koeficijenata pomeranja profila

$$X = \frac{(\operatorname{inv}(\alpha_{wt}) - \operatorname{inv}(\alpha_t)) (z_1 + z_2)}{2 \tan(\alpha_n)}$$

$$X = -0.096$$

B11 Parcijalni koeficijent pomeranja pogonskog zupčanika

$$x_1 = 0$$

B12 Parcijalni koeficijent pomeranja gonjenog zupčanika

$$x_2 = X - x_1$$

$$x_2 = -0.0960$$

B13 Prečnik podnožne kružnice pogonskog zupčanika

$$d_{f1} = d_1 + 2x_1 m_n - 2h_f$$

$$d_{f1} = 151.753 \text{ mm}$$

B14 Prečnik podnožne kružnice gonjenog zupčanika

$$d_{f2} = d_2 + 2x_2 m_n - 2h_f$$

$$d_{f2} = 518.259 \text{ mm}$$

B15 Prečnik temene kružnice pogonskog zupčanika

$$d_{a1} = 2a_w - d_{f2} - 2c$$

$$d_{a1} = 187.741 \text{ mm}$$

B16 Prečnik temene kružnice gonjenog zupčanika

$$d_{a2} = 2a_w - d_{f1} - 2c$$

$$d_{a2} = 554.247 \text{ mm}$$

B17 Prečnik osnovne kružnice pogonskog zupčanika

$$d_{b1} = d_1 \cos(\alpha_t)$$

$$d_{b1} = 160.97 \text{ mm}$$

B18 Prečnik osnovne kružnice gonjenog zupčanika

$$d_{b2} = d_2 \cos(\alpha_t)$$

$$d_{b2} = 505.907 \text{ mm}$$

B19 Podeoni korak u normalnoj ravni

$$p_n = \pi m_n$$

$$p_n = 25.133 \text{ mm}$$

B20 Podeoni korak u ceonoj ravni

$$p_t = \pi m_t$$

$$p_t = 25.694 \text{ mm}$$

B21 Osnovni (sprežni) korak

$$p_{tb} = p_t \cos(\alpha_t)$$

$$p_{tb} = 24.081 \text{ mm}$$

B22 Aktivna dužina dodirnice

$$g_\alpha = \frac{1}{2} \left(\sqrt{d_{a1}^2 - d_{b1}^2} + \sqrt{d_{a2}^2 - d_{b2}^2} \right) - a_w \sin(\alpha_{wt})$$

$$g_\alpha = 39.665 \text{ mm}$$

B23 Stepen sprežanja profila

$$\epsilon_\alpha = \frac{g_\alpha}{p_{tb}} \quad \text{po SRPS -u} \quad 1 < \epsilon_\alpha < 2$$

$$\epsilon_\alpha = 1.647$$

B24 Širina sprezanja

Širina pogonskog zupčanika

usvojeno

$$b_1 = 140 \text{ mm}$$

Širina gonjenog zupčanika

usvojeno

$$b_2 = 135 \text{ mm}$$

$$b_w = \min(b_1, b_2)$$

$$b_w = 135 \text{ mm}$$

B24 Stepen sprezanja bočnih linija

$$\varepsilon_\beta = \frac{b_w \sin(\beta)}{p_n} \quad 1 < \varepsilon_\beta < 1.5$$

$$\varepsilon_\beta = 1.117$$

B25 Ukupni stepen sprezanja

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$\varepsilon_\gamma = 2.7639$$

B26 Lučna debljina zupca na podeonj kružnici

$$s_{n1} = m_n(0.5\pi + 2x_1 \tan(\alpha_n))$$

$$s_{n1} = 12.566 \text{ mm}$$

$$s_{n2} = m_n(0.5\pi + 2x_2 \tan(\alpha_n))$$

$$s_{n2} = 12.007 \text{ mm}$$

B27 Tetivna debljina zupca

$$s_{t1} = d_1 \sin\left(\frac{s_{n1}}{d_1}\right)$$

$$s_{t1} = 12.555 \text{ mm}$$

$$s_{t2} = d_2 \sin\left(\frac{s_{n2}}{d_2}\right)$$

$$s_{t2} = 12.006 \text{ mm}$$

B28 Tetivna visina zupca

$$h_{t1} = \frac{d_{a1}}{2} - \frac{d_1}{2} \cos\left(\frac{s_{n1}}{d_1}\right)$$

$$h_{t1} = 8.224 \text{ mm}$$

$$h_{t2} = \frac{d_{a2}}{2} - \frac{d_2}{2} \cos\left(\frac{s_{n2}}{d_2}\right)$$

$$h_{t2} = 7.292 \text{ mm}$$

B29 Ugao α_{tx1}

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

$$\alpha_{tx1} = 20.41^\circ$$

B30 Ugao α_{tx2}

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

$$\alpha_{tx2} = 19.956^\circ$$

B31 Ugao nagiba bočne linije na osnovnom cilindru

$$\beta_b = \text{asin}(\sin(\beta) \cos(\alpha_n))$$

$$\beta_b = 11.267^\circ$$