PUMPE

ZAKON SLIČNOSTI I DIMENZIJSKA ANALIZA

DIMENZIJSKA ANALIZA OSNOVNIH PARAMETARA

Dimenzijskom analizom organiziramo veličine koje utječu na rad pumpi:

- ρ -gustoća vode [kg/m^3],
- ω -kutna brzina vrtnje rotora [rad/s],
- D -promjer kola rotora [m],
- Δp -prirast tlaka kroz pumpu [Pa],
- Q -protok vode kroz pumpu [m^3/s],
- P -snaga pumpe [W].

BEZDIMENZIJSKI PARAMETRI

- Bezdimenzijska specifična energija

$$\psi = \Pi_1 = \frac{\Delta p}{\rho \omega^2 D^2} = \frac{gH}{\omega^2 D^2}$$

Bezdimenzijski protok

$$\varphi = \Pi_2 = \frac{Q}{\omega \cdot D^3}$$

Bezdimenzijska snaga

$$C_P = \frac{P}{\rho \cdot \omega^3 \cdot D^5}$$

Efikasnost

$$\eta = \frac{\Delta p \cdot Q}{P} = \frac{\psi \cdot \varphi}{C_P}$$

BEZDIMENZIJSKI BROJ OKRETAJA - BRZOHODNOST

$$C_{\omega} = \Pi_4 = \frac{\omega \cdot \sqrt{Q}}{\left(\frac{\Delta p}{\rho}\right)^{3/4}} = \frac{\sqrt{\varphi}}{\psi^{3/4}}$$

ZAKON SLIČNOSTI

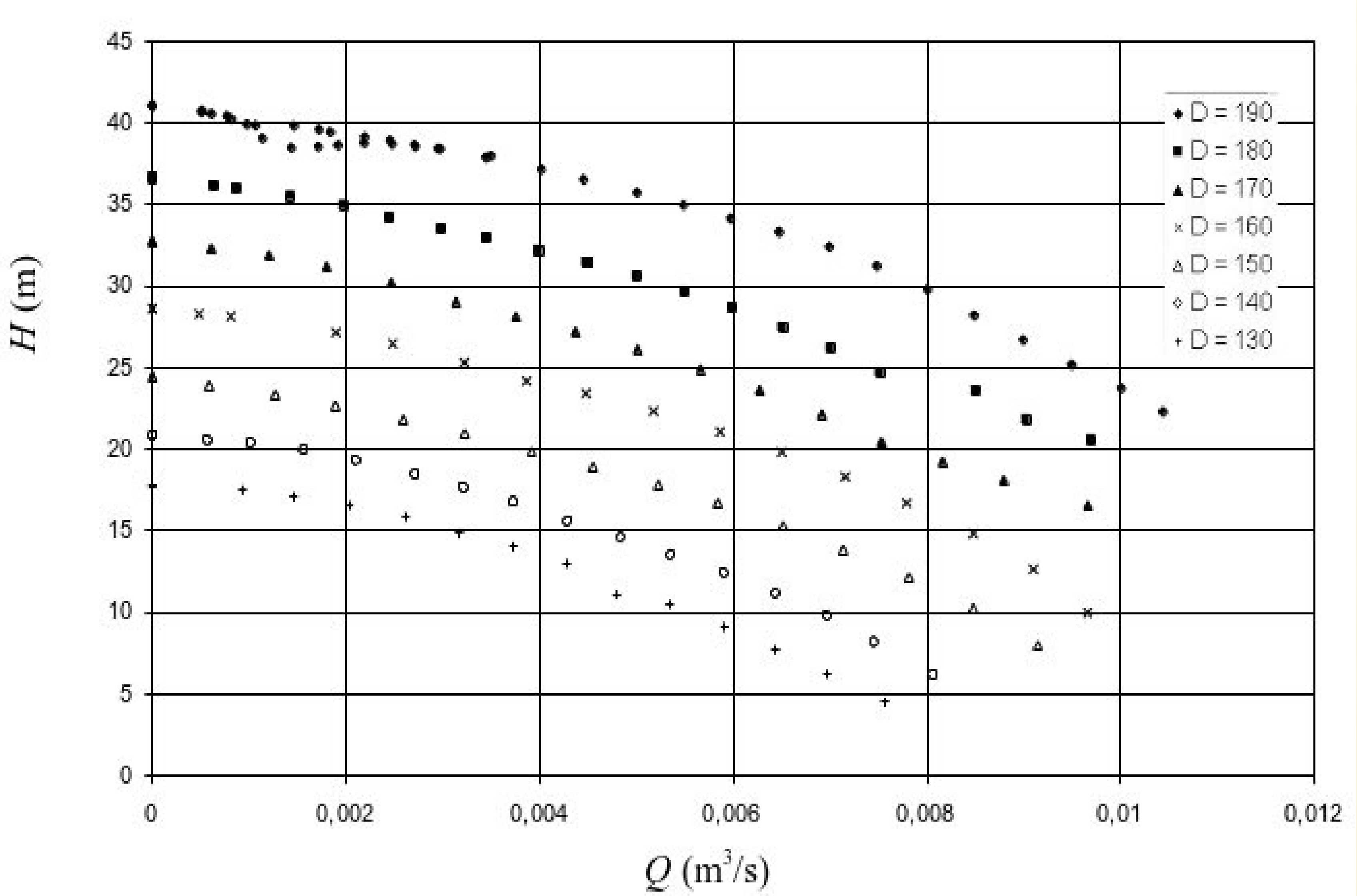
Rad pumpi je definiran bezdimenzijskim krivuljama

$$\psi = \mathrm{f}(\varphi) \quad \text{i} \quad C_\mathrm{P} = \mathrm{f}(\varphi)$$

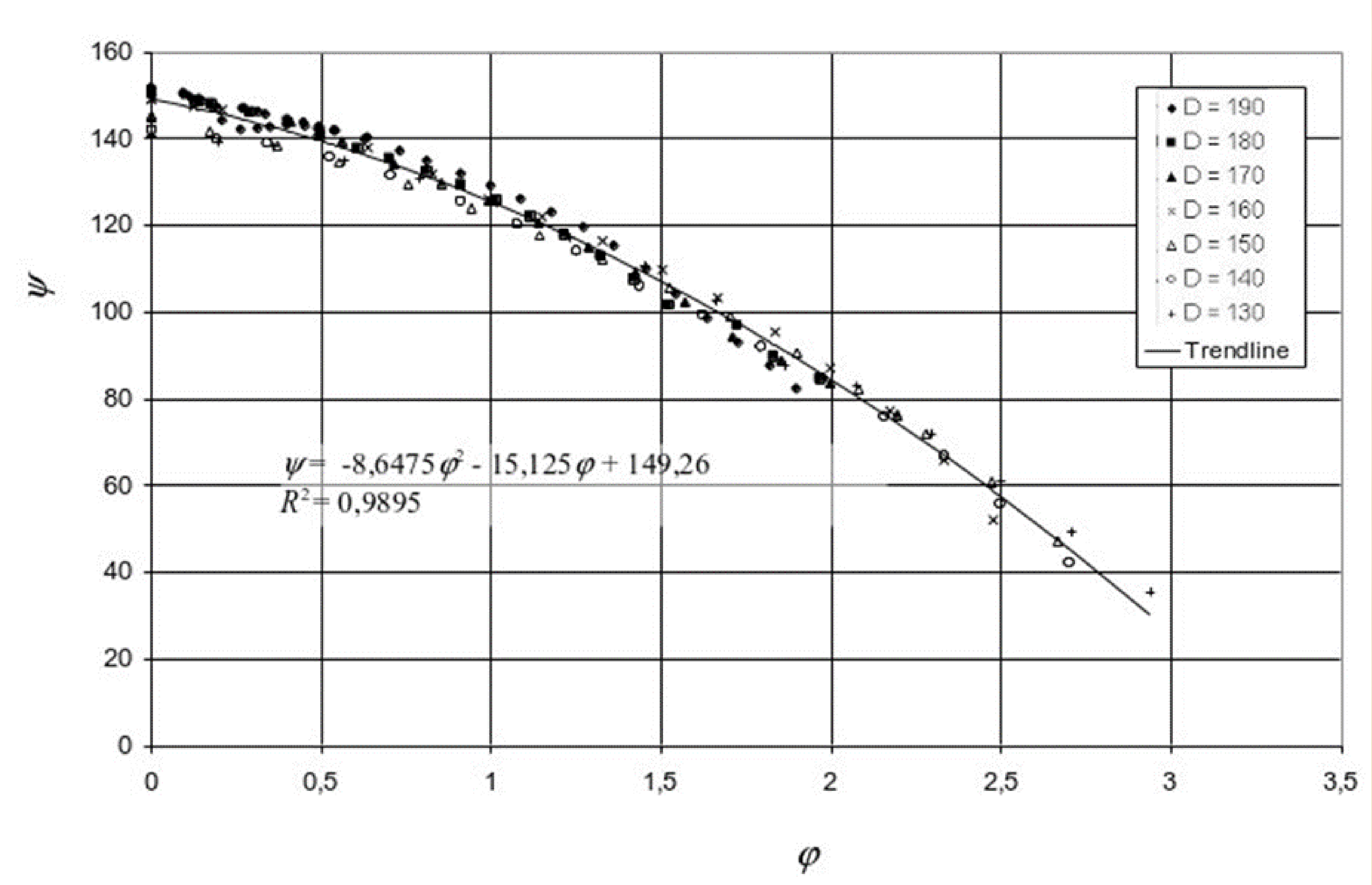
Dvije slične pumpe moraju:

1. biti geometrijski slične
2. imati iste sve bezdimenzijske krivulje

JEDINSTVO IB - SERIJA



JEDINSTVO IB BEZDIMENZIJSKE KARAKTERISTIKE



ZAKON SLIČNOSTI

- Kada dvije slične pumpe rade u istoj radnoj točci to znači da su im i π parametri isti. Sva tri bezdimenzijska parametra (visina dobave, protok i snaga) moraju biti isti za obje slične pumpe.

$$\psi = \frac{\Delta p_1}{\rho_1 {\omega_1}^2 {D_1}^2} = \frac{\Delta p_2}{\rho_2 {\omega_2}^2 {D_2}^2}$$

$$\varphi = \frac{Q_1}{\omega_1 \cdot {D_1}^3} = \frac{Q_2}{\omega_2 \cdot {D_2}^3}$$

$$C_P = \frac{P_1}{\rho_1 \cdot {\omega_1}^3 \cdot {D_1}^5} = \frac{P_2}{\rho_2 \cdot {\omega_2}^3 \cdot {D_2}^5}$$

ZAKON SLIČNOSTI – SPECIFIČNI SLUČAJ

Specijalni slučaj –pumpa radi s istim fluidom ali na raznom broju okretaja

$$\psi = \frac{\Delta p_1}{\rho_1 {\omega_1}^2 {D_1}^2} = \frac{\Delta p_2}{\rho_2 {\omega_2}^2 {D_2}^2} \qquad \frac{\Delta p_1}{\Delta p_2} = \frac{{\omega_1}^2}{{\omega_2}^2}$$

$$\varphi = \frac{Q_1}{\omega_1 \cdot {D_1}^3} = \frac{Q_2}{\omega_2 \cdot {D_2}^3} \qquad \frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2}$$

$$C_P = \frac{P_1}{\rho_1 \cdot {\omega_1}^3 \cdot {D_1}^5} = \frac{P_2}{\rho_2 \cdot {\omega_2}^3 \cdot {D_2}^5} \qquad \frac{P_1}{P_2} = \frac{{\omega_1}^3}{{\omega_2}^3}$$

SLIČNOST PUMPI– ISTI FLUID I ISTA PUMPA

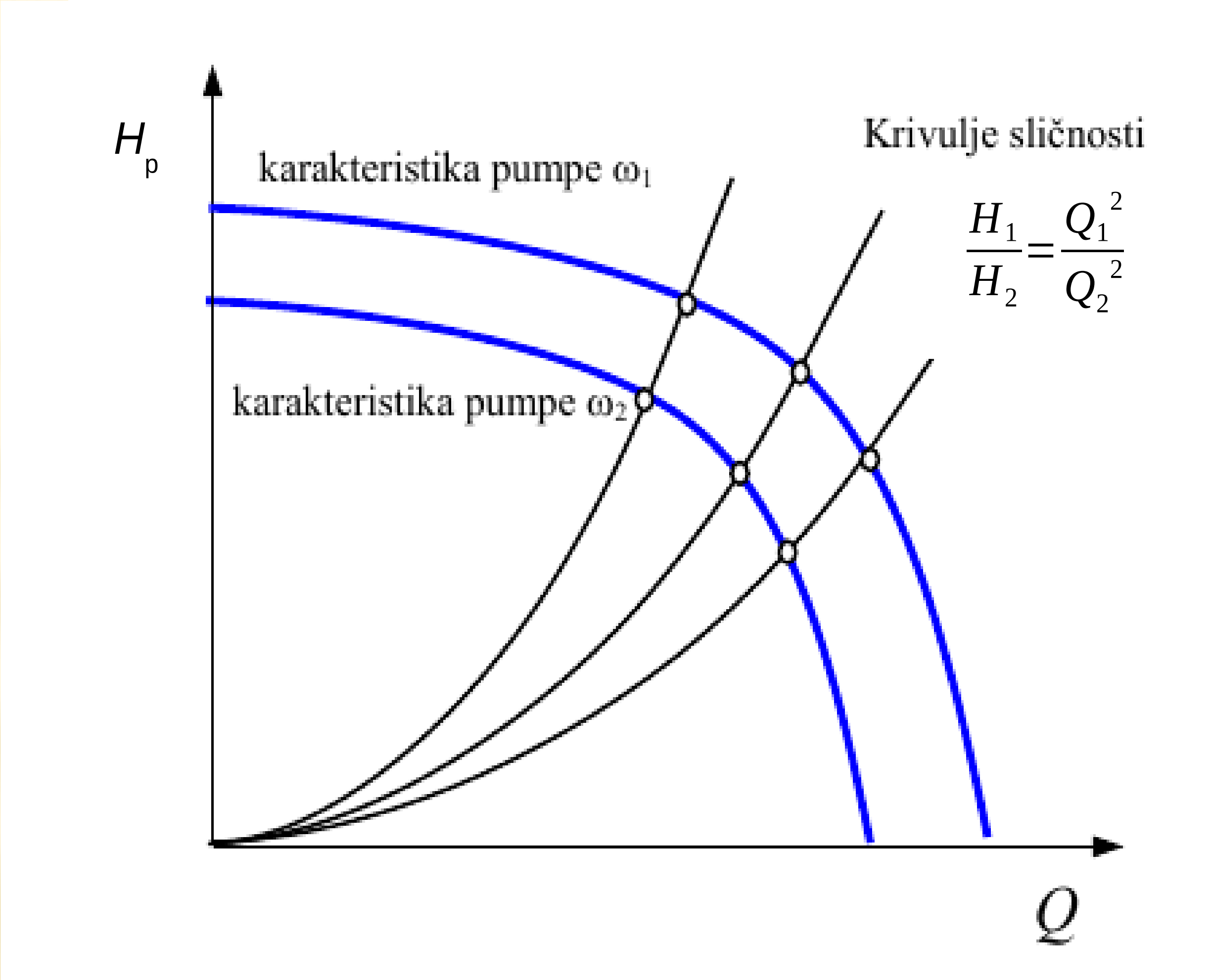
$$\frac{\Delta p_1}{\Delta p_2} = \frac{{\omega_1}^2}{{\omega_2}^2}$$

$$\frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2}$$

$$\frac{P_1}{P_2} = \frac{{\omega_1}^3}{{\omega_2}^3}$$

$$\frac{\Delta p_1}{\Delta p_2} = \frac{H_1}{H_2} = \frac{{Q_1}^2}{{Q_2}^2}$$

$$\frac{P_1}{P_2} = \frac{{Q_1}^3}{{Q_2}^3}$$



ZAKON SLIČNOSTI – SPECIFIČNI SLUČAJ

Specijalni slučaj – slične pumpe rade s istim fluidom i na istom broju okretaja

$$\psi = \frac{\Delta p_1}{\rho_1 \omega_1^2 D_1^2} = \frac{\Delta p_2}{\rho_2 \omega_2^2 D_2^2}$$

$$\varphi = \frac{Q_1}{\omega_1 \cdot D_1^3} = \frac{Q_2}{\omega_2 \cdot D_2^3}$$

$$C_P = \frac{P_1}{\rho_1 \cdot \omega_1^3 \cdot D_1^5} = \frac{P_2}{\rho_2 \cdot \omega_2^3 \cdot D_2^5}$$

$$\frac{\Delta p_1}{\Delta p_2} = \frac{D_1^2}{D_2^2}$$

$$\frac{Q_1}{Q_2} = \frac{D_1^3}{D_2^3}$$

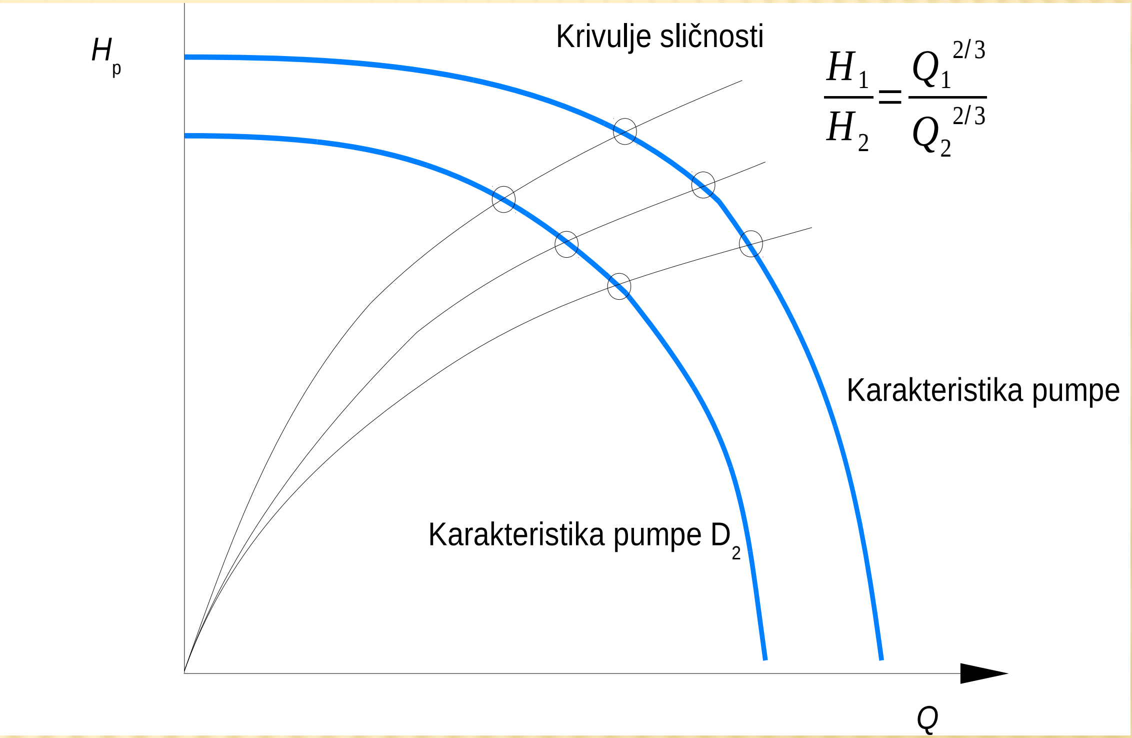
$$\frac{P_1}{P_2} = \frac{D_1^5}{D_2^5}$$

SLIČNOST PUMPI– ISTI FLUID I BROJ OKRETAJA

$$\frac{\Delta p_1}{\Delta p_2} = \frac{{D_1}^2}{{D_2}^2}$$

$$\frac{Q_1}{Q_2} = \frac{{D_1}^3}{{D_2}^3}$$

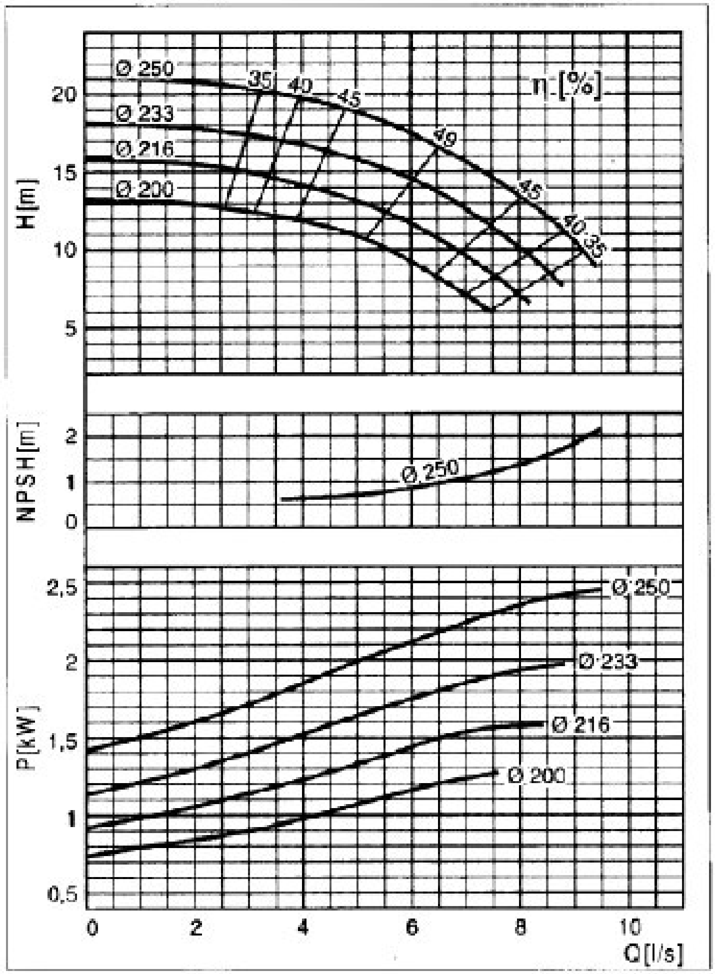
$$\frac{P_1}{P_2} = \frac{{D_1}^5}{{D_2}^5}$$



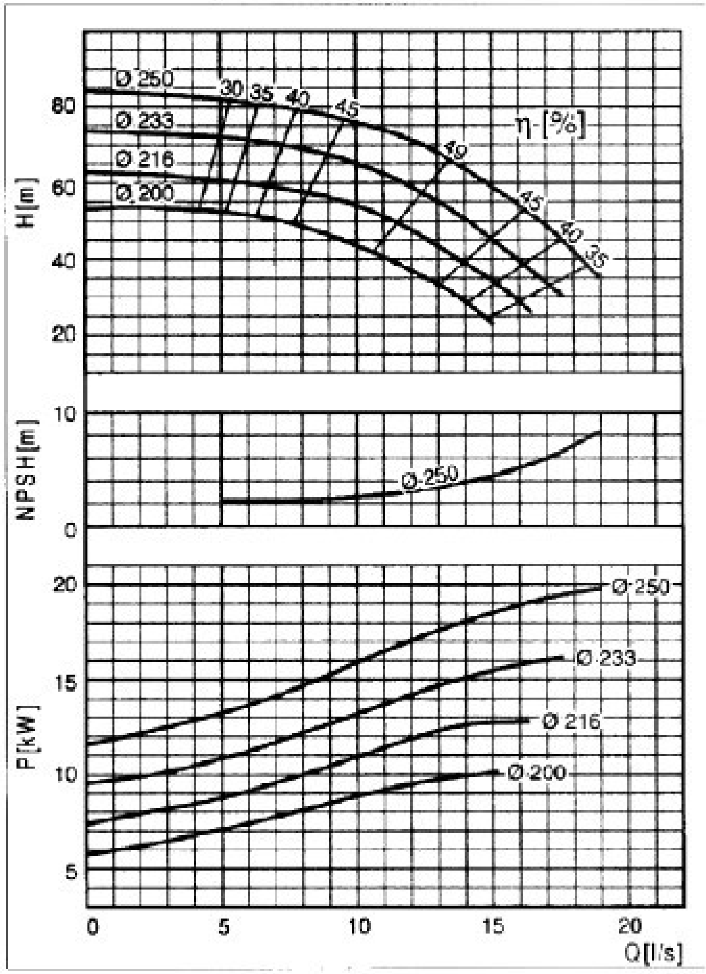
$$\frac{\Delta p_1}{\Delta p_2}=\frac{H_1}{H_2}=\frac{{Q_1}^{2/3}}{{Q_2}^{2/3}}$$

$$\frac{P_1}{P_2}=\frac{{Q_1}^{5/3}}{{Q_2}^{5/3}}$$

KK 25-6,5 n=24,2s⁻¹



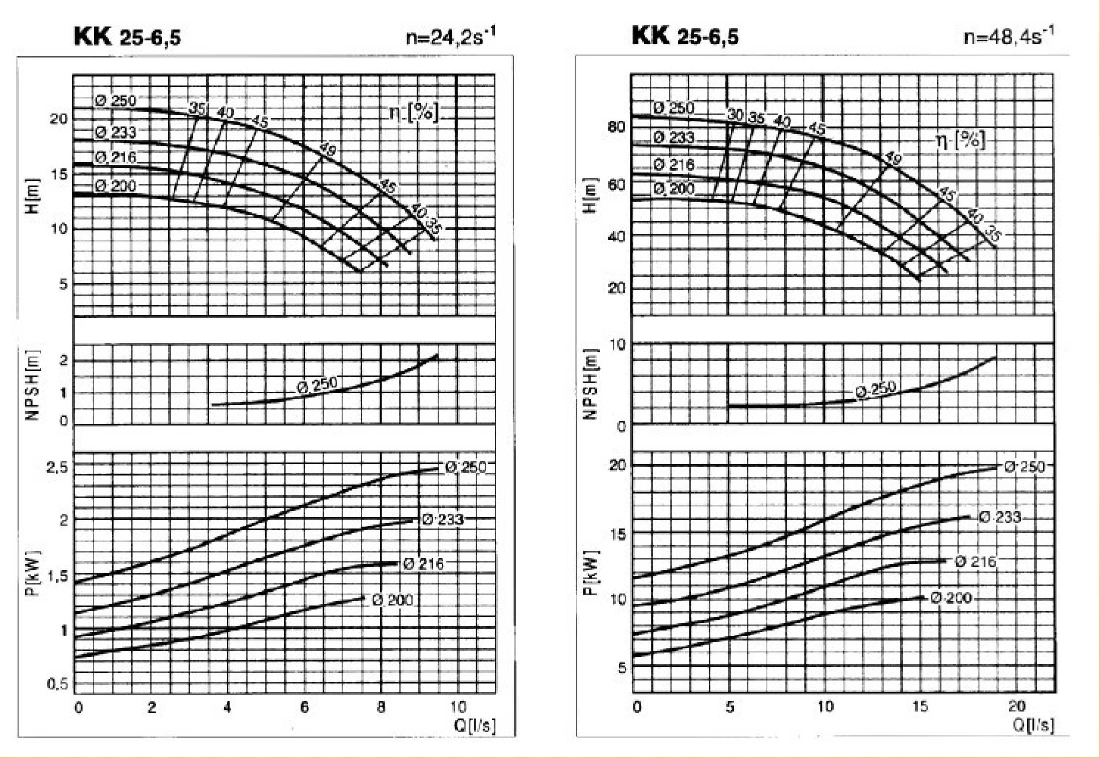
KK 25-6,5 n=48,4s⁻¹



ENERGETSKE KARAKTERISTIKE PUMPE

ENERGETSKE KARAKTERISTIKE PUMPE

- Visina dobave u zavisnosti o protoku,
- Snaga u ovisnosti o protoku,
- Efikasnost u ovisnosti o protoku,
- Neto pozitivna usisna visina u ovisnosti o protoku.

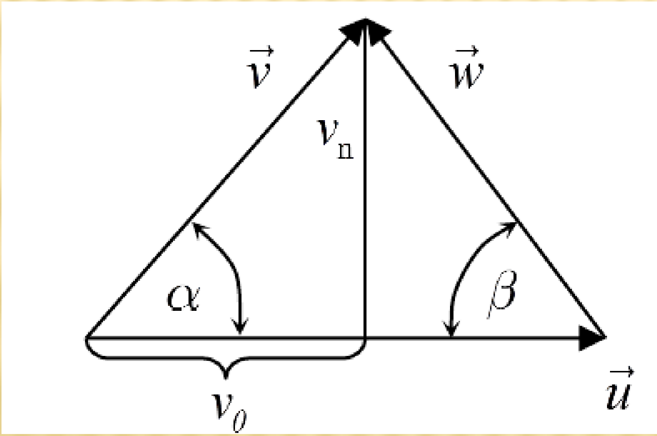


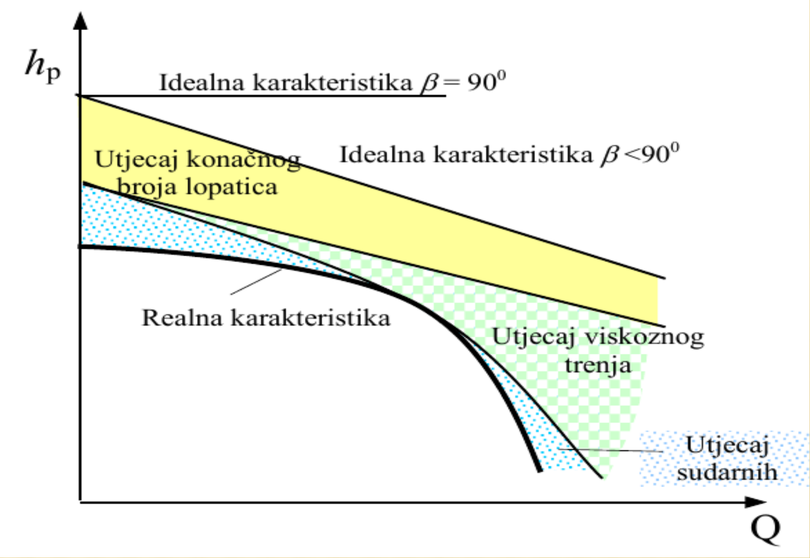
EULEROVE JEDNADŽBE ZA TURBOSTROJEVE

$$h_p = \frac{1}{g}(u_2 v_{2\theta} - u_1 v_{1\theta})$$

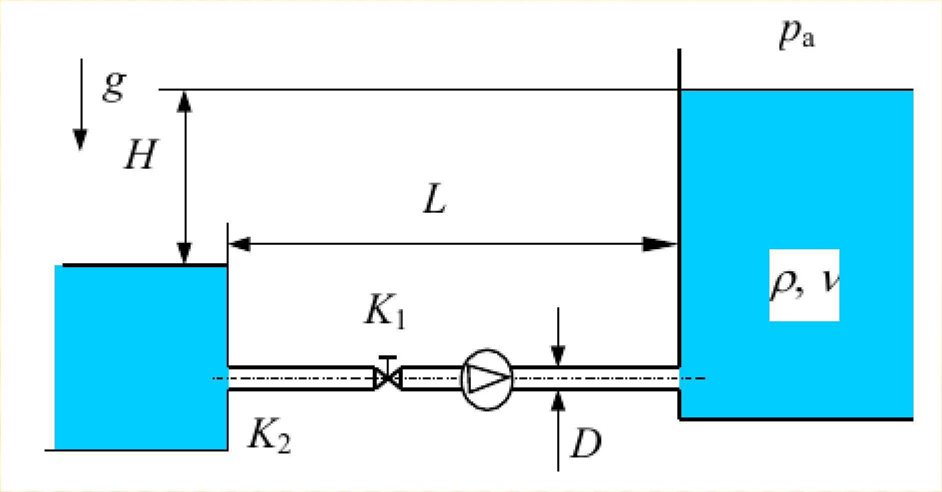
$$h_p = \frac{1}{g}\Big(u_2 \underbrace{v_{2\theta}}_{(u_2 - w_2 cos(\beta))} - u_1 \underbrace{v_{1\theta}}_{0}\Big) = \frac{1}{g}(u_2(u_2 - w_2 cos\beta))$$

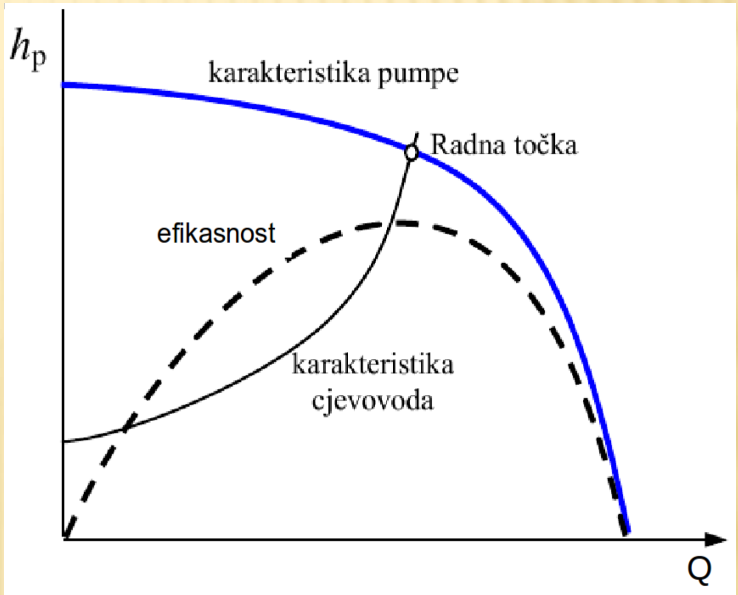
$$h_p = \frac{1}{g}\left(\omega_2 r_2\left(\omega_2 r_2 - \frac{Q}{A}cos\beta\right)\right) = \frac{1}{g}\left(\omega_2^2 r_2^2 - \omega_2 r_2 \frac{Q}{A} cos\beta\right)$$





RADNA TOČKA

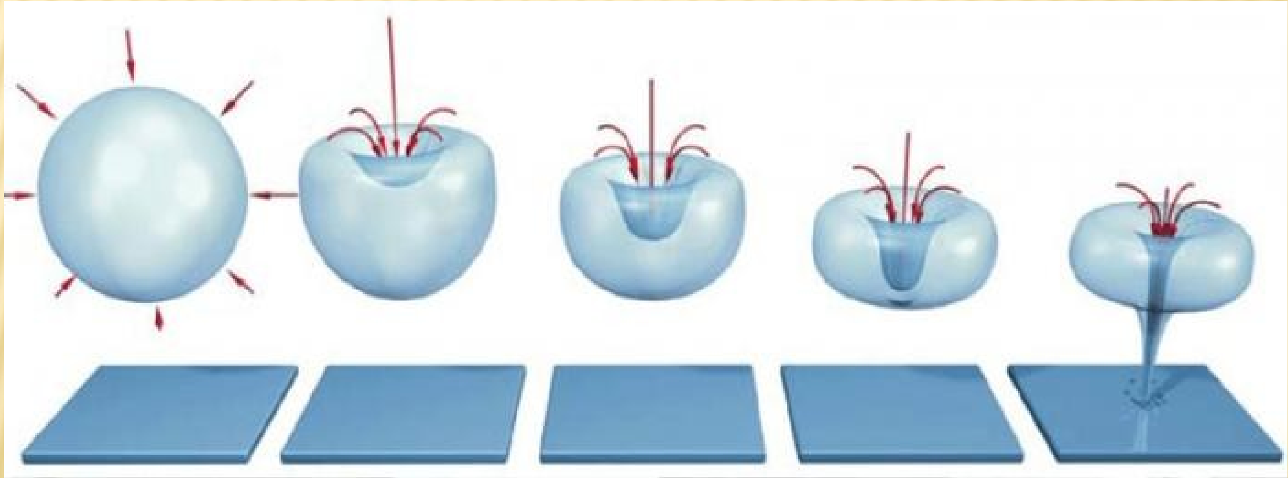




$$h_p = H + \lambda \frac{L}{D}\frac{8Q^2}{D^4\pi^2 g} + K_1\frac{8Q^2}{D^4\pi^2 g} + K_2\frac{8Q^2}{D^4\pi^2 g} + \frac{8Q^2}{D^4\pi^2 g}$$

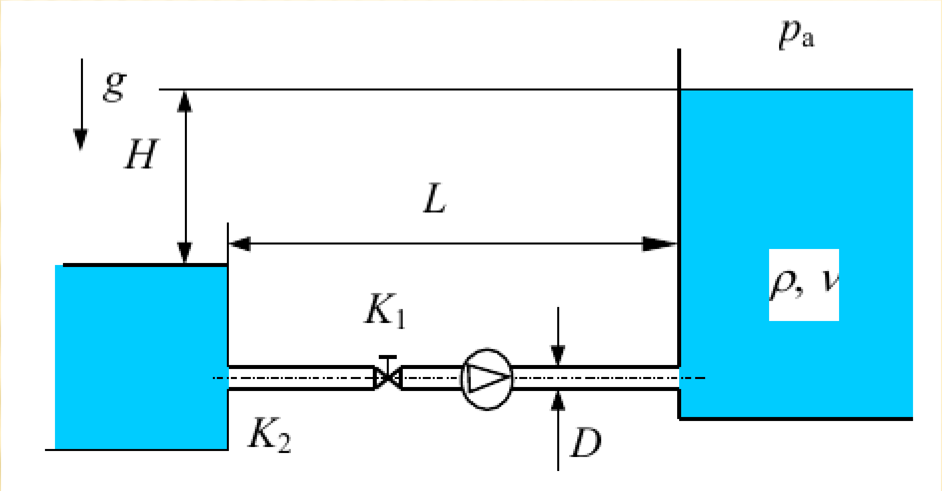
$$h_p = H + \left(\lambda \frac{L}{D}\frac{8}{D^4\pi^2 g} + K_1\frac{8}{D^4\pi^2 g} + K_2\frac{8}{D^4\pi^2 g} + \frac{8}{D^4\pi^2 g}\right)Q^2 = H + K \cdot Q^2$$

KAVITACIJA



RASPOLOŽIVA NETO POZITIVNA USISNA VISINA

Net Positive Suction Head Available



$$NPSH = H_t - \frac{p_v}{\rho\, g}$$

gdje je H_t totalni tlak na ulazu u pumpu, a p_v tlak zasićenja.

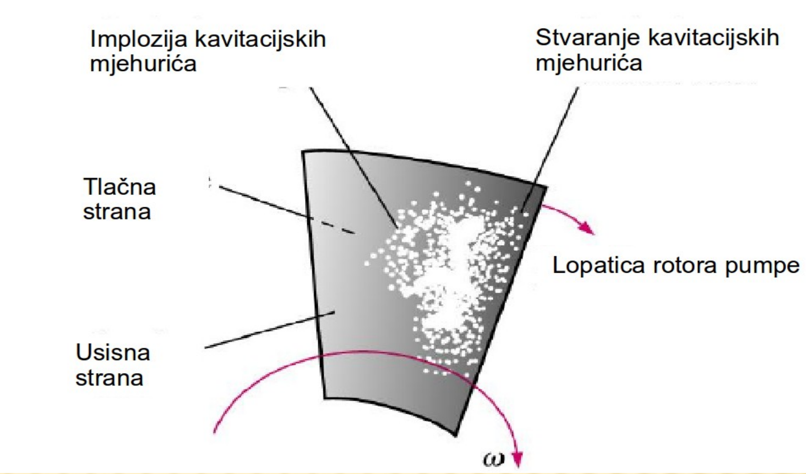
$$\frac{p_a}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \lambda \frac{L_u}{D} \frac{v^2}{2g} + (K_1 + K_2) \frac{v^2}{2g}$$

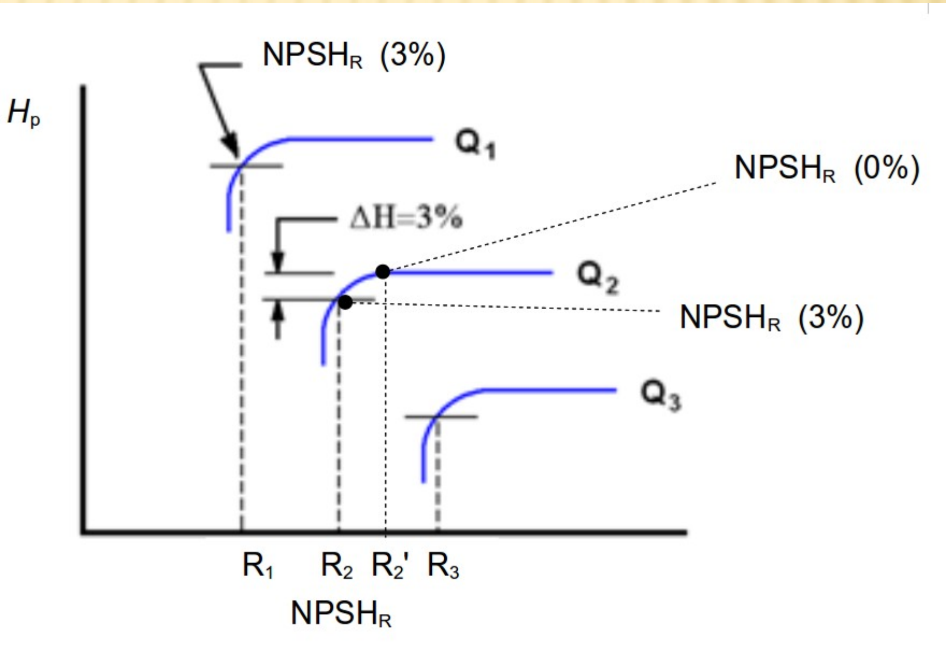
$$\frac{p_a}{\rho g} + \frac{v_1^2}{2g} + z_1 - \lambda \frac{L_u}{D} \frac{v^2}{2g} - (K_1 + K_2) \frac{v^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 = H_t = NPSH_A + \frac{p_v}{\rho g}$$

$$\frac{p_a}{\rho g} + \frac{v_1^2}{2g} + z_1 - \lambda \frac{L_u}{D} \frac{v^2}{2g} - (K_1 + K_2) \frac{v^2}{2g} > \frac{p_v}{\rho g}$$

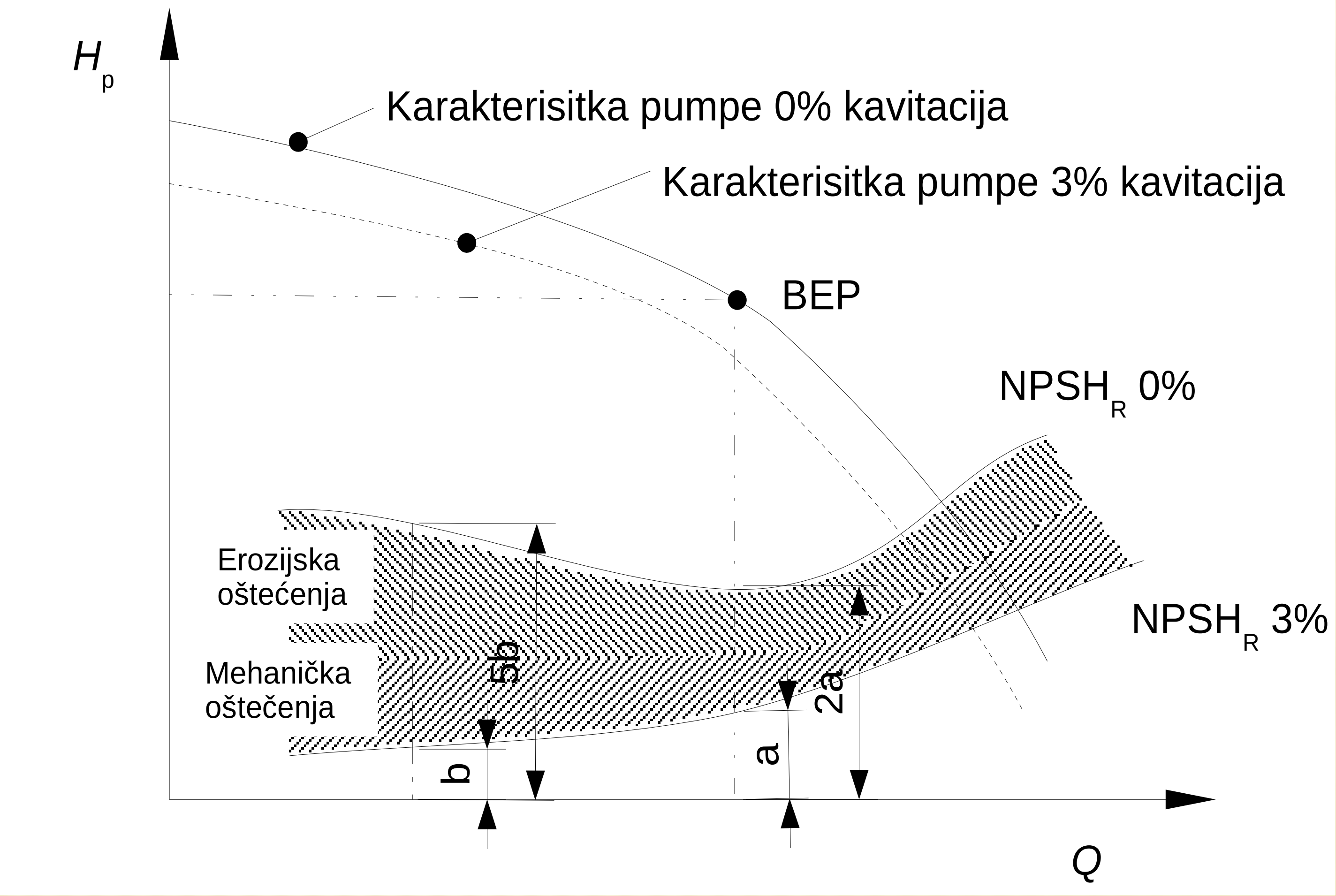
$$NPSH_A = H_t - \frac{p_v}{\rho g}$$

POTREBNA NETO POZITIVNA USISNA VISINA

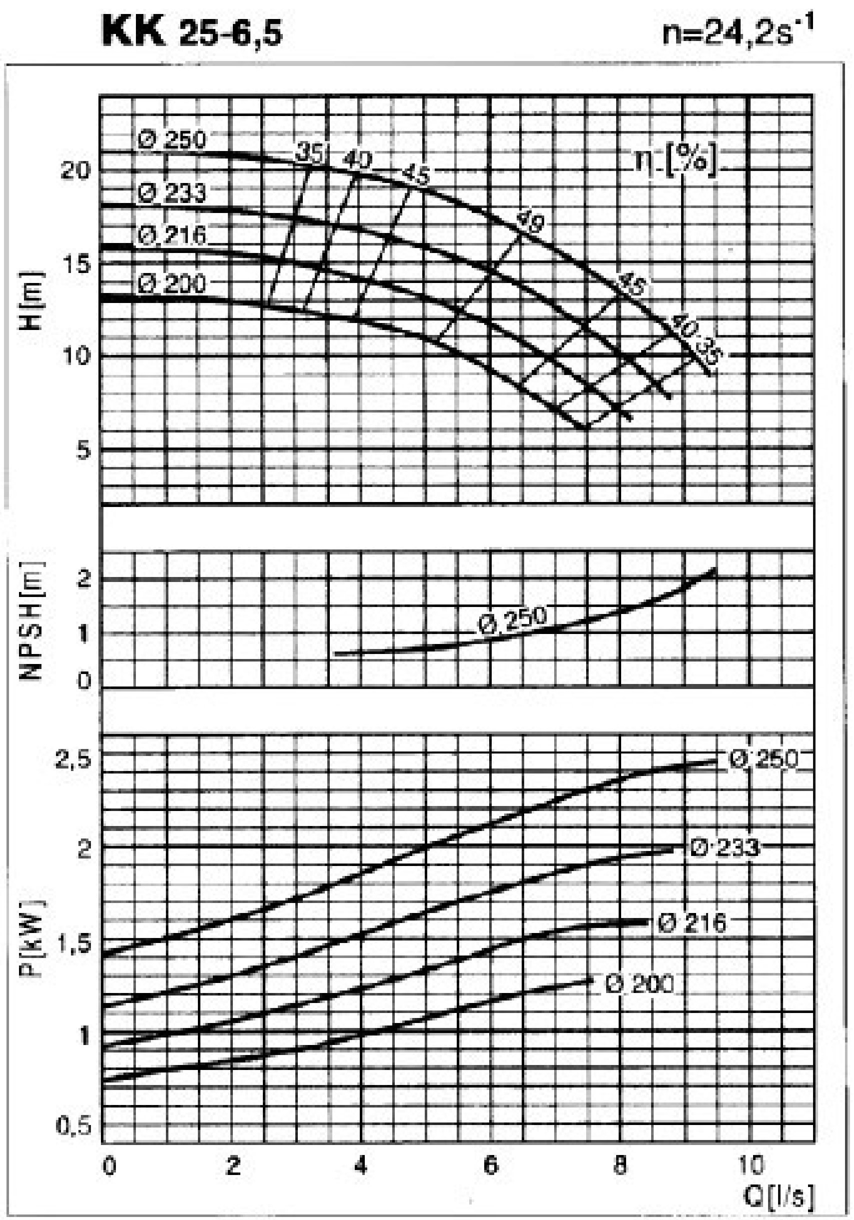


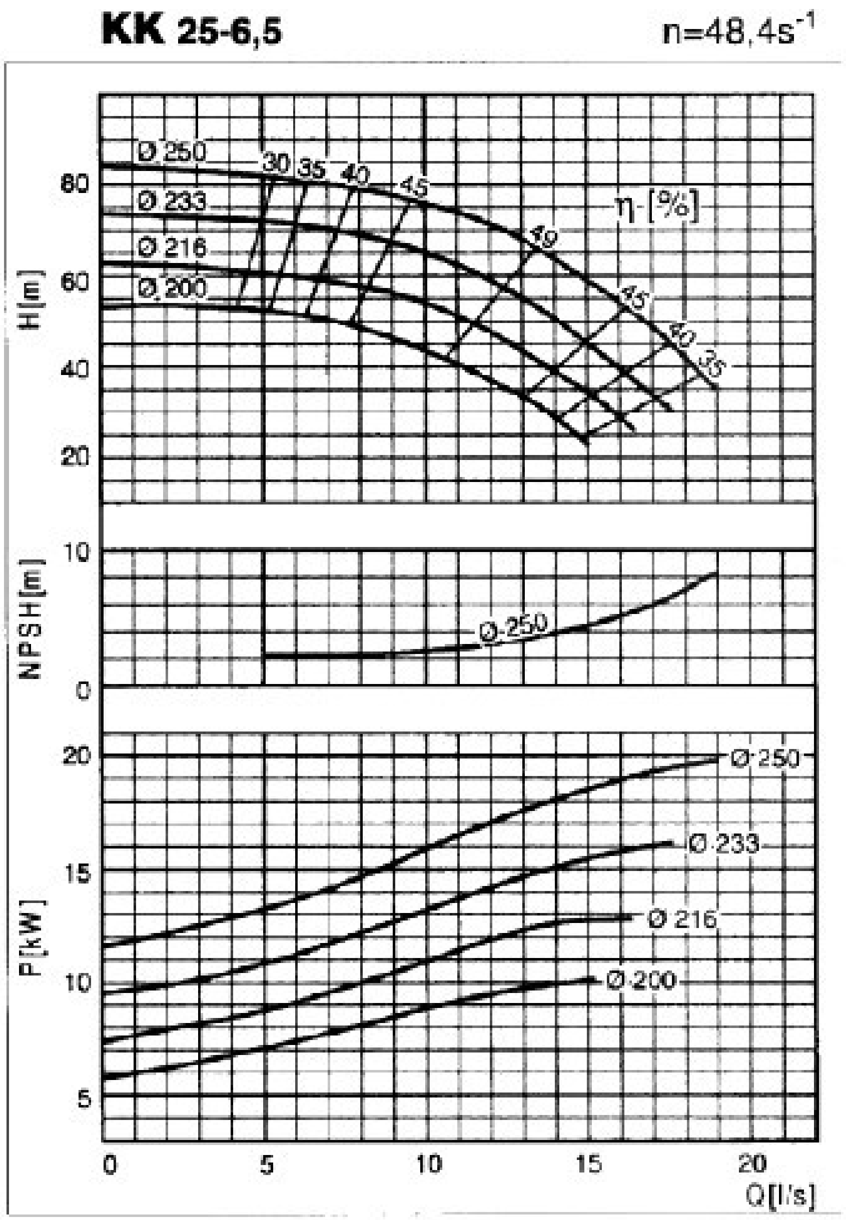


NPSH ZA 0% I 3% PADA VISINE DOBAVE

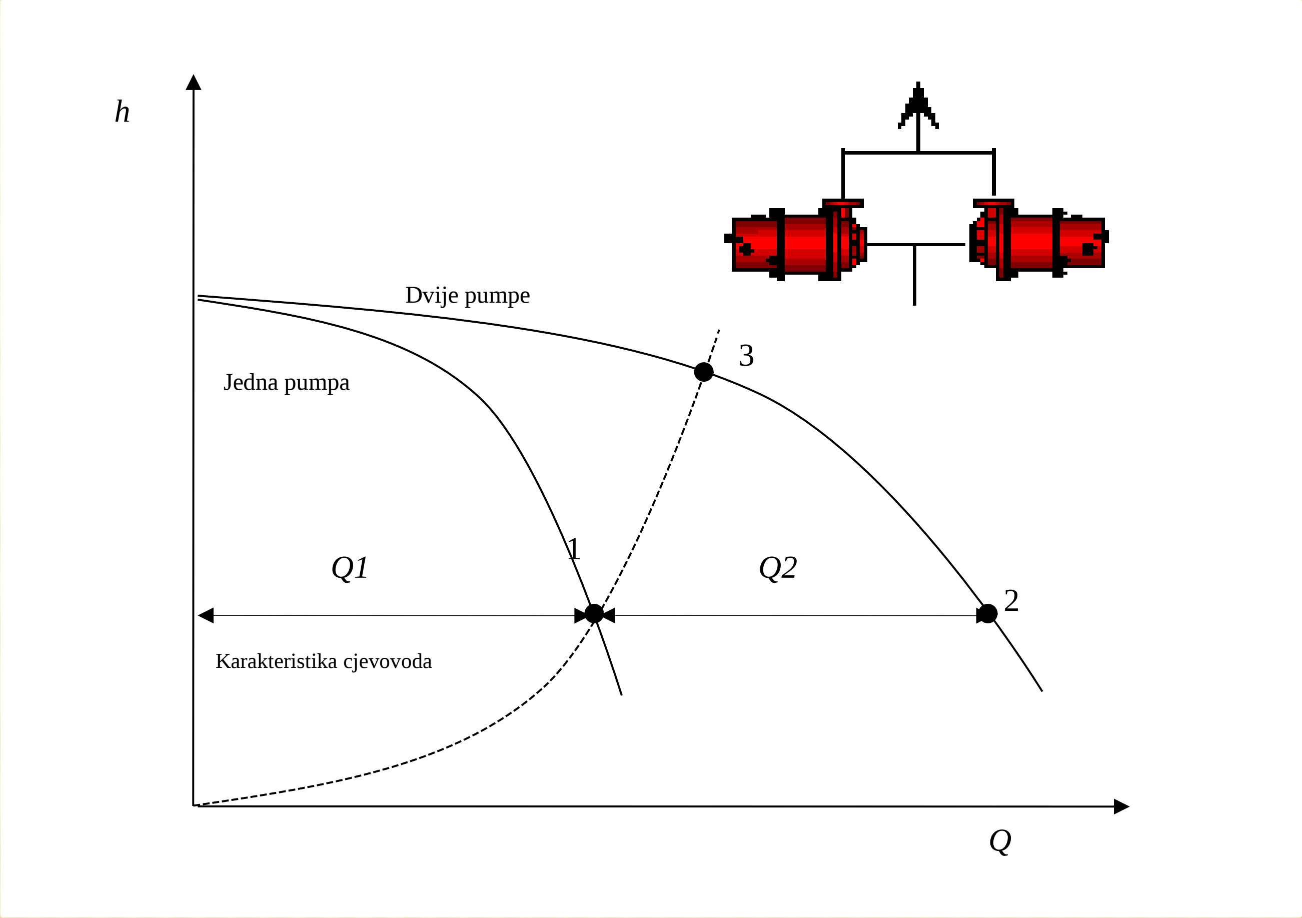


$$NPSH_A > NPSH_R$$

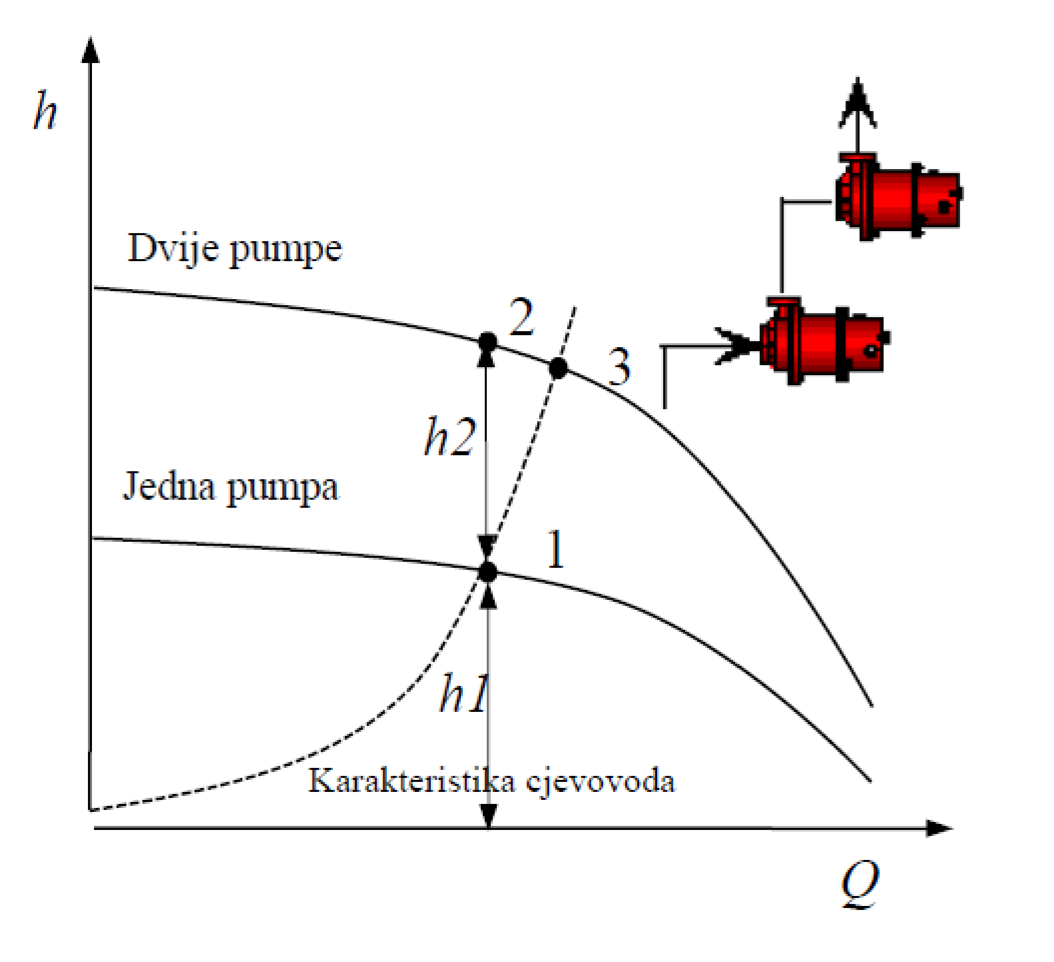

KK 25-6,5
n=24,2s-1
H[m]
NPSH[m]
P[kW]
η [%]
Ø 250
Ø 233
Ø 216
Ø 200
Q[l/s]


KK 25-6,5
n=48,4s-1
H[m]
NPSH[m]
P[kW]
η [%]
Ø 250
Ø 233
Ø 216
Ø 200
Q[l/s]

PARALELNI RAD PUMPI

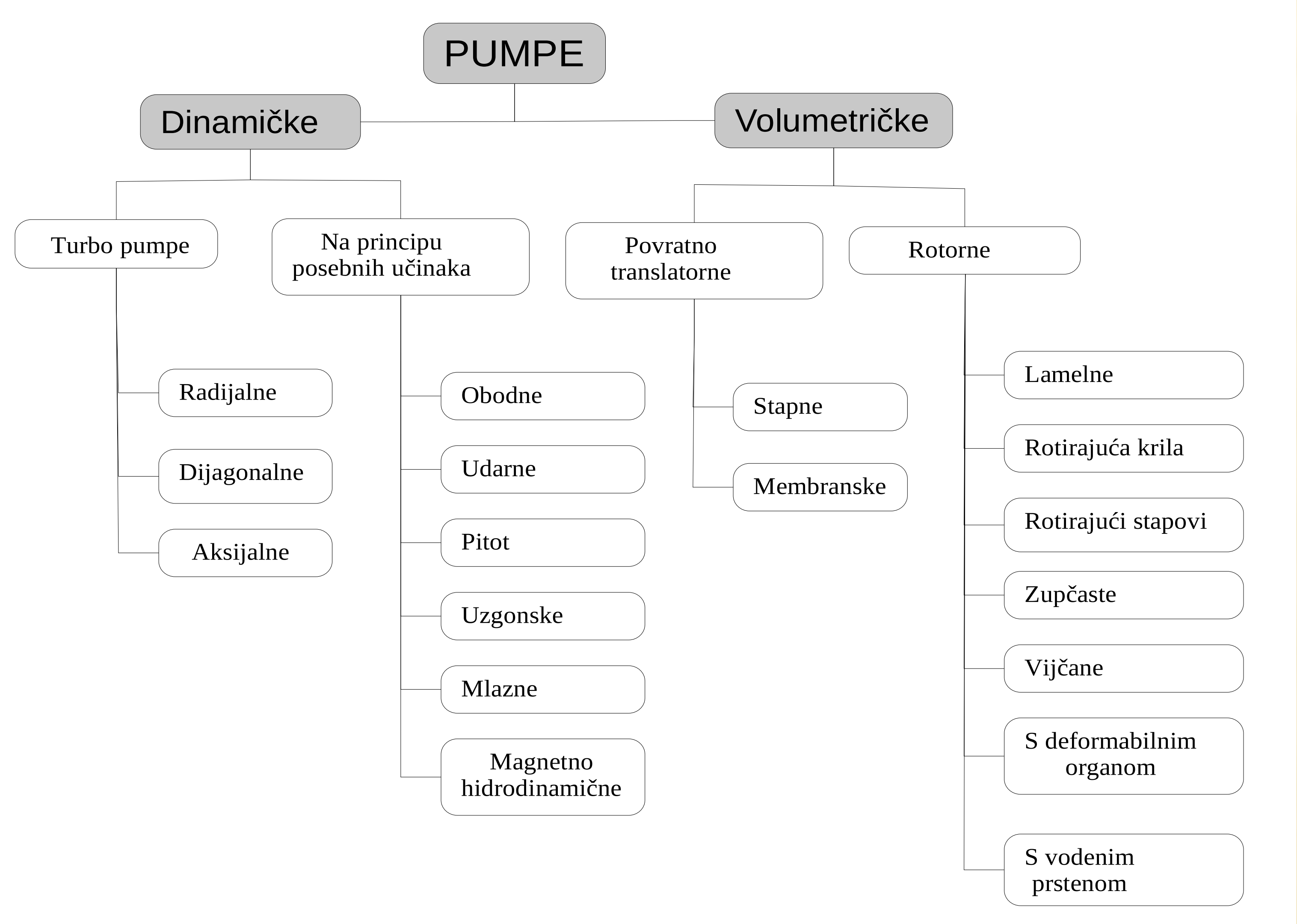


SERIJSKI RAD PUMPI



TIPOVI PUMPI

PODJELA PUMPI



BRZOHODNOST

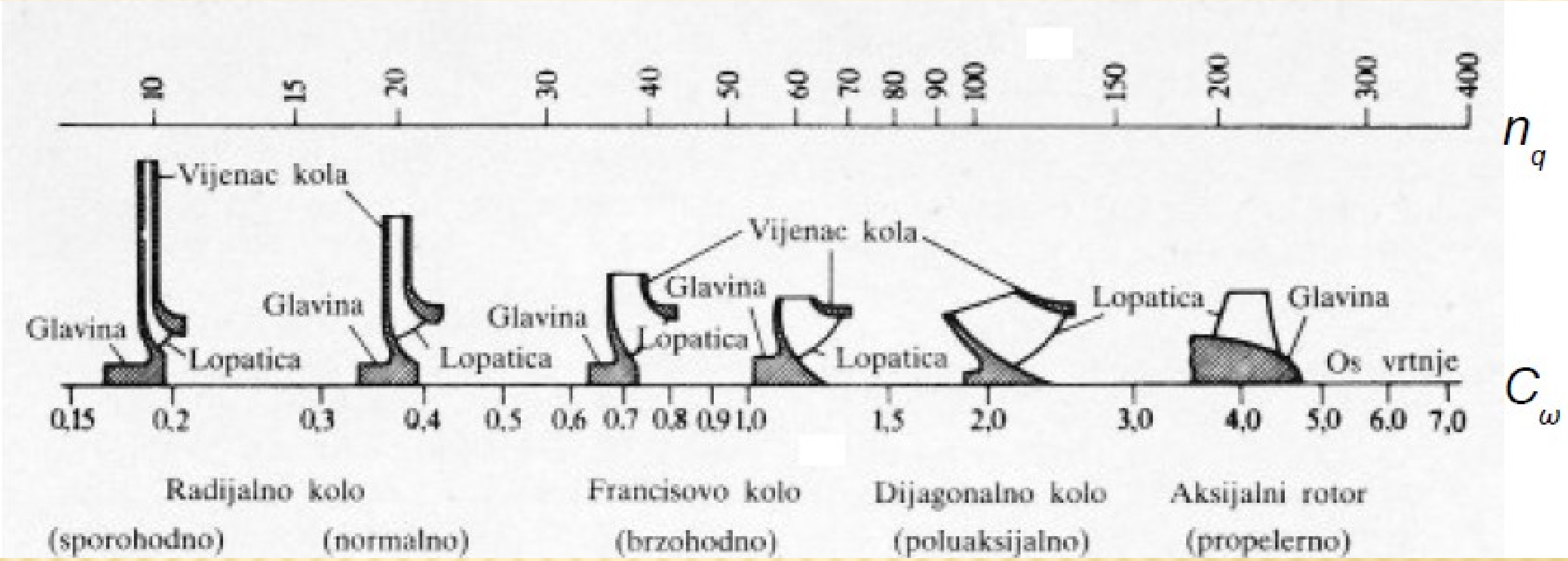
$$C_\omega = \frac{\omega \cdot \sqrt{Q}}{\left(\frac{\Delta p}{\rho}\right)^{3/4}} = \frac{\omega \cdot \sqrt{Q}}{(g \cdot H)^{3/4}} \qquad n_q = \frac{n \cdot \sqrt{Q}}{(H)^{3/4}} \qquad n_q = 52.919 \cdot C_\omega$$

gdje je n_q specifična brzina vrtnje u okretajima u minuti, n broj okretaja osovine u okretajima u minuti, Q metrima kubnim po satu, H u metrima.

$$N_s = \frac{n \cdot \sqrt{Q}}{(H)^{3/4}} \qquad N_s = 2733.016 \cdot C_\omega$$

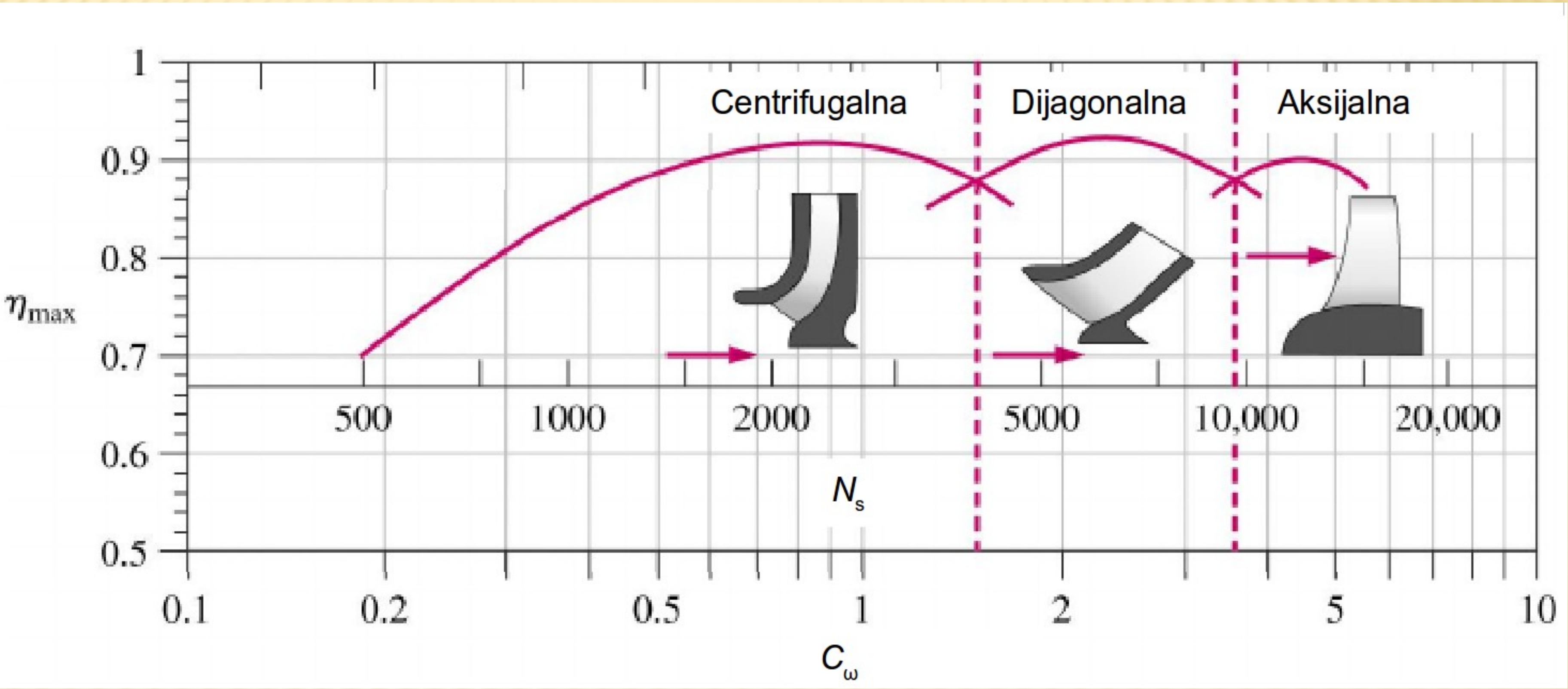
gdje je N_s specifična brzina vrtnje u okretajima u minuti, n broj okretaja osovine u okretajima u minuti, Q galoni u minuti, H u stopama

BRZOHODNOST

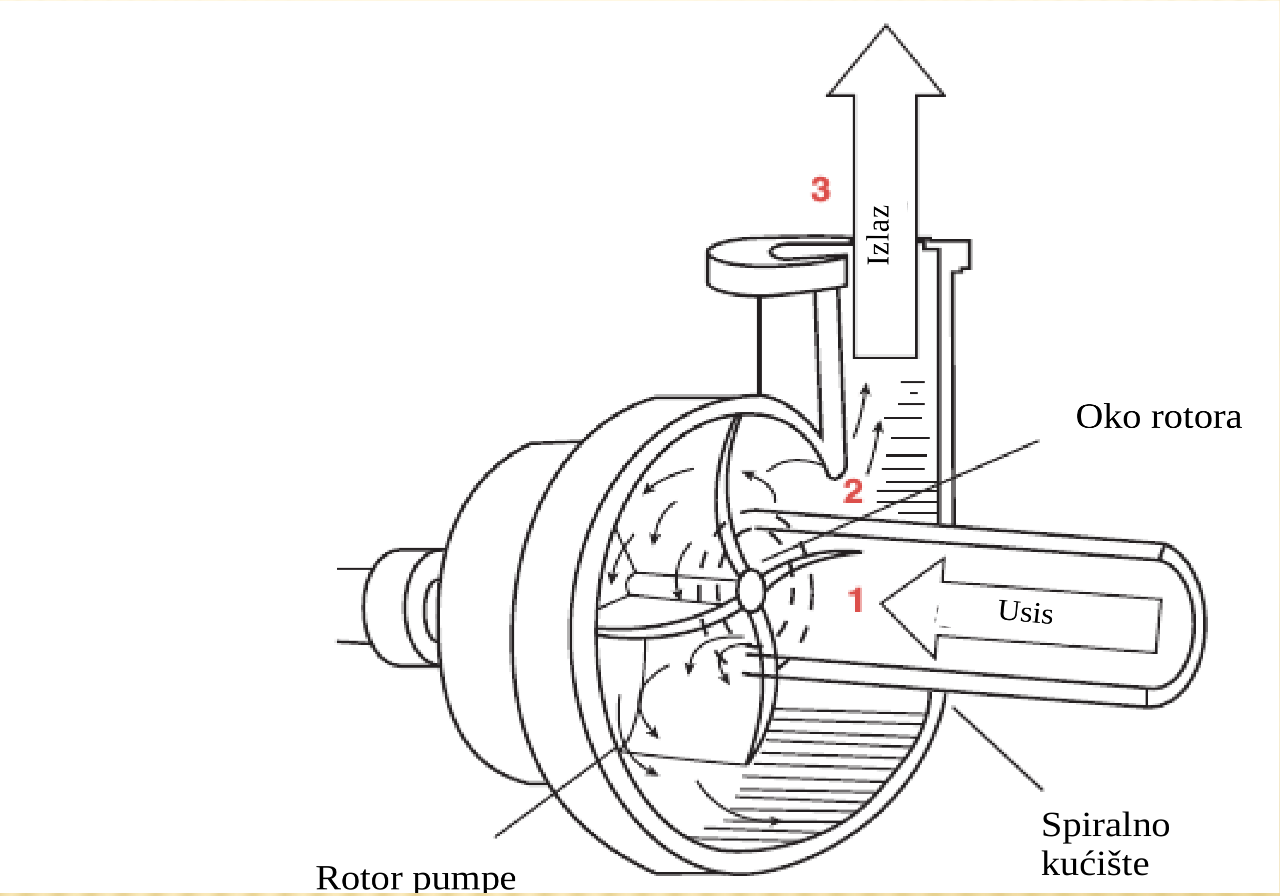


Centrifugalni rotor Frencis rotor Dijagonalni rotor Propelerni rotor

BRZOHODNOST



IZGLED PUMPE I GLAVNI DJELOVI



IZGLED PUMPE I GLAVNI DJELOVI

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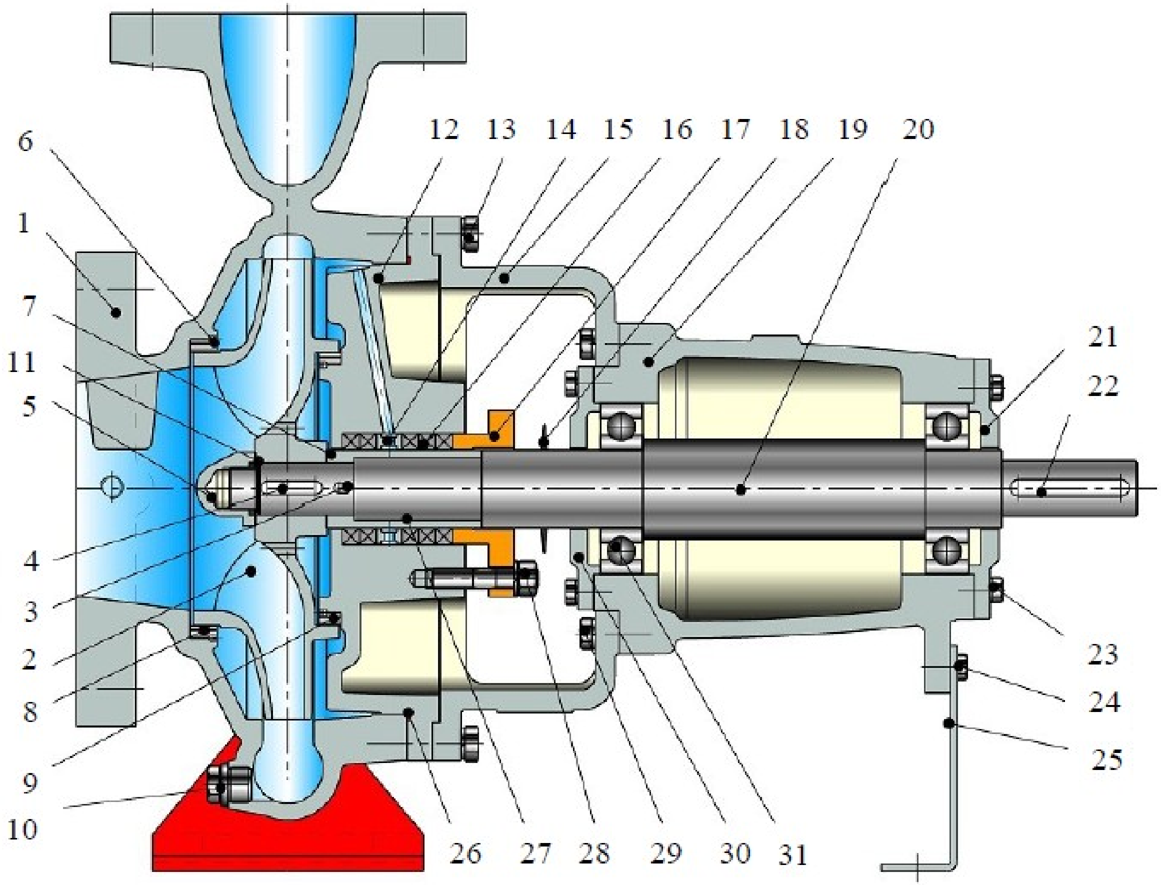
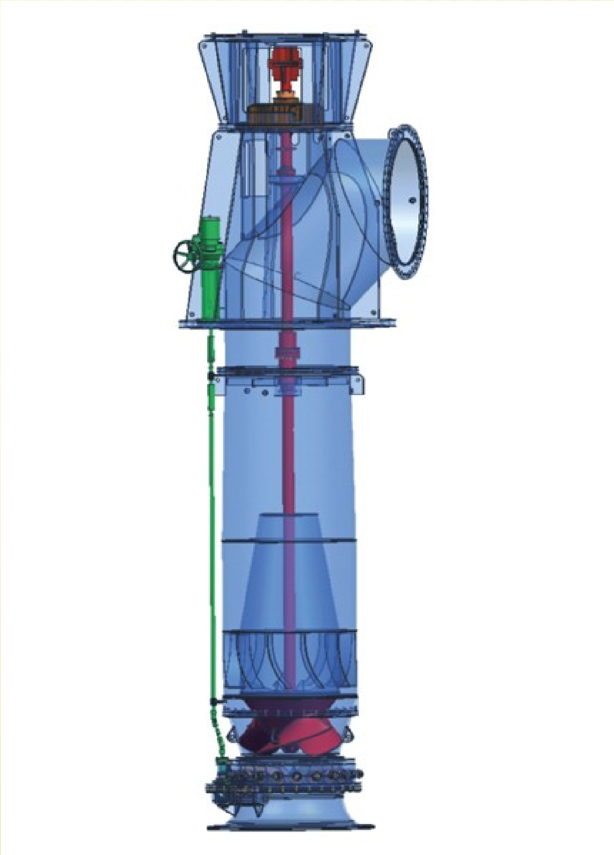


Slika 62: Dijelovi centrifugalne pumpe

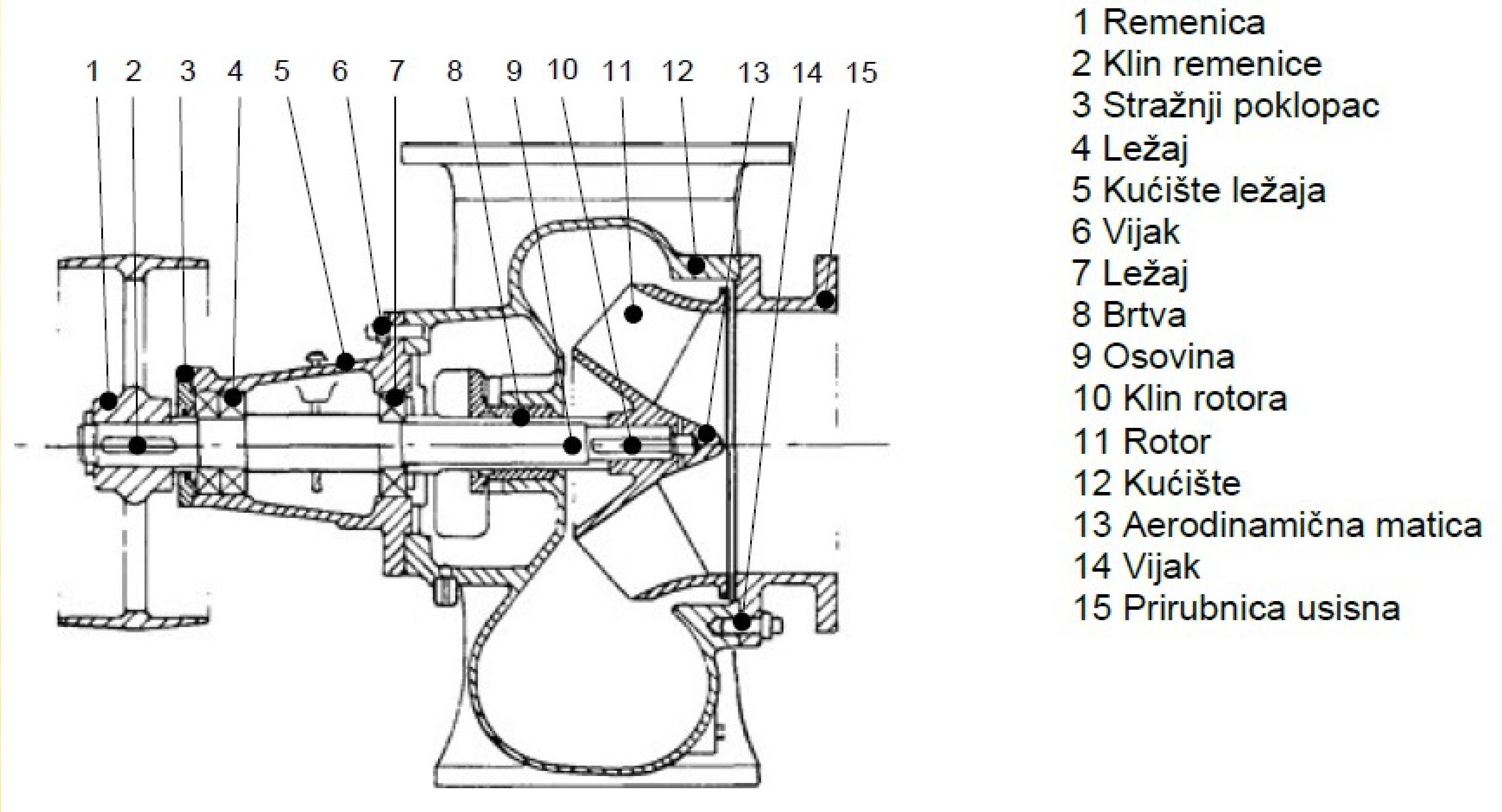
1 Kućište pumpe
2 Rotor
3 Klin puškice
4 Klin rotora
5 Aerodinamična matica
6 GRUB vijak
7 Zaptivka
8 Brtva
9 Brtva
10 Vijak za ispust vode
11 Zaptivka
12 Poklopac kućišta
13 Vijci
14 Privodni kanal
15 Nosač kućišta
16 Brtva
17 Pritezač brtve
18 Centrifugalni prsten
19 Kućište ležaja
20 Vratilo
21 Stražnji poklopac
22 Klin
23 Vijak
24 Vijak
25 Nogica
26 O – ring
27 Puškica
28 Vijak pritezača brtve
29 Ispust ulja
30 Prednji poklopac
31 Ležaj

ROTOR CENTRIFUGALNE PUMPE

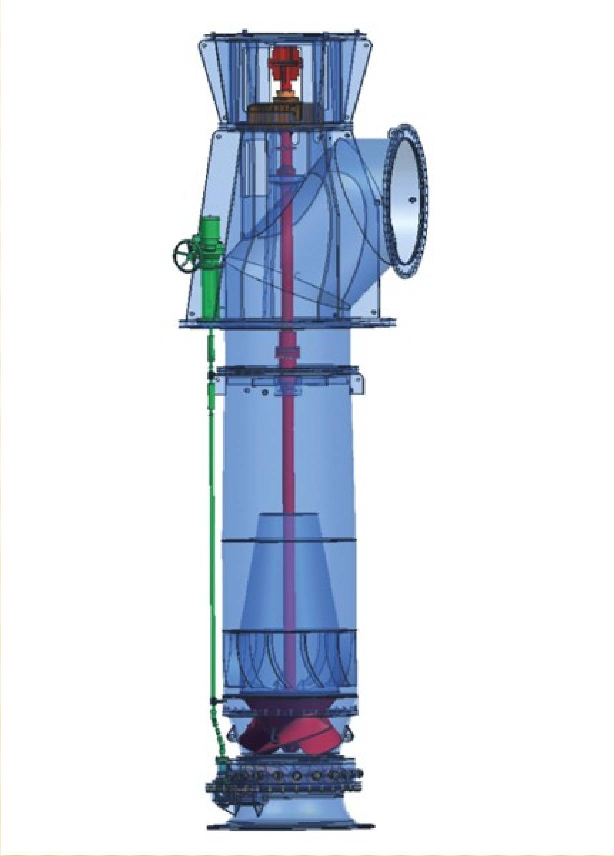
DIJAGONALNA PUMPA

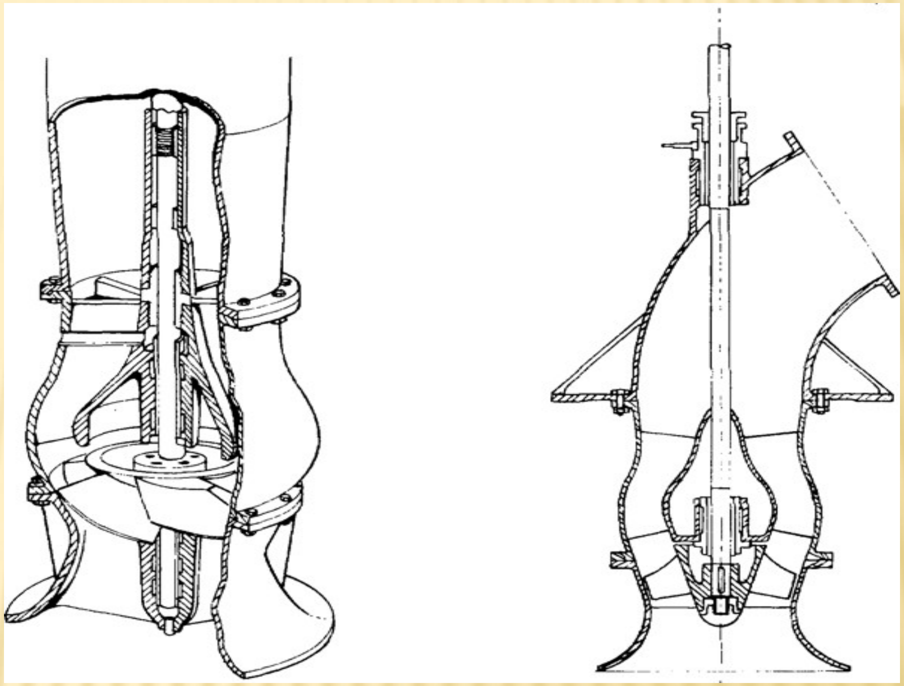


DIJAGONALNA PUMPA



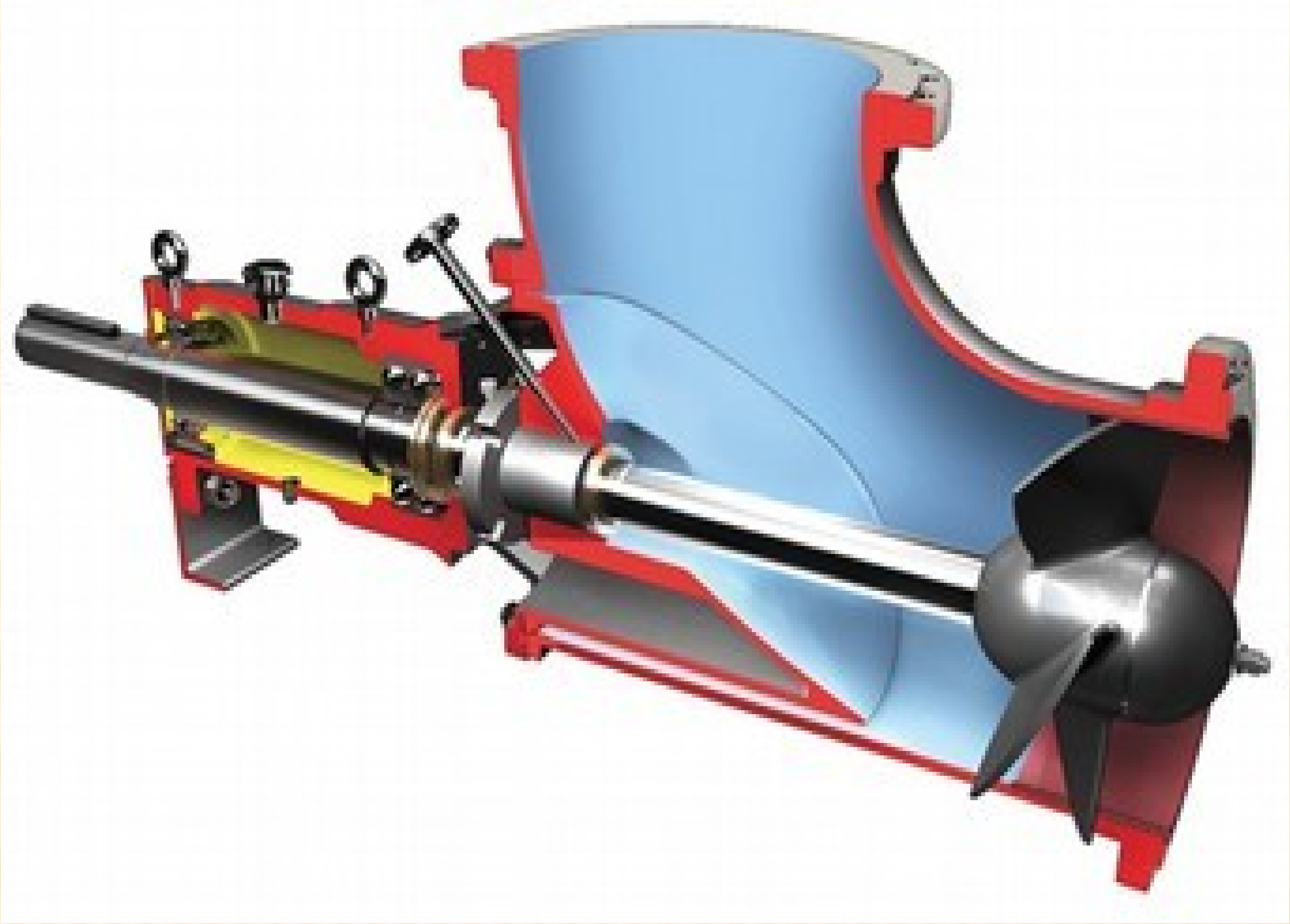
DIJAGONALNA PUMPA



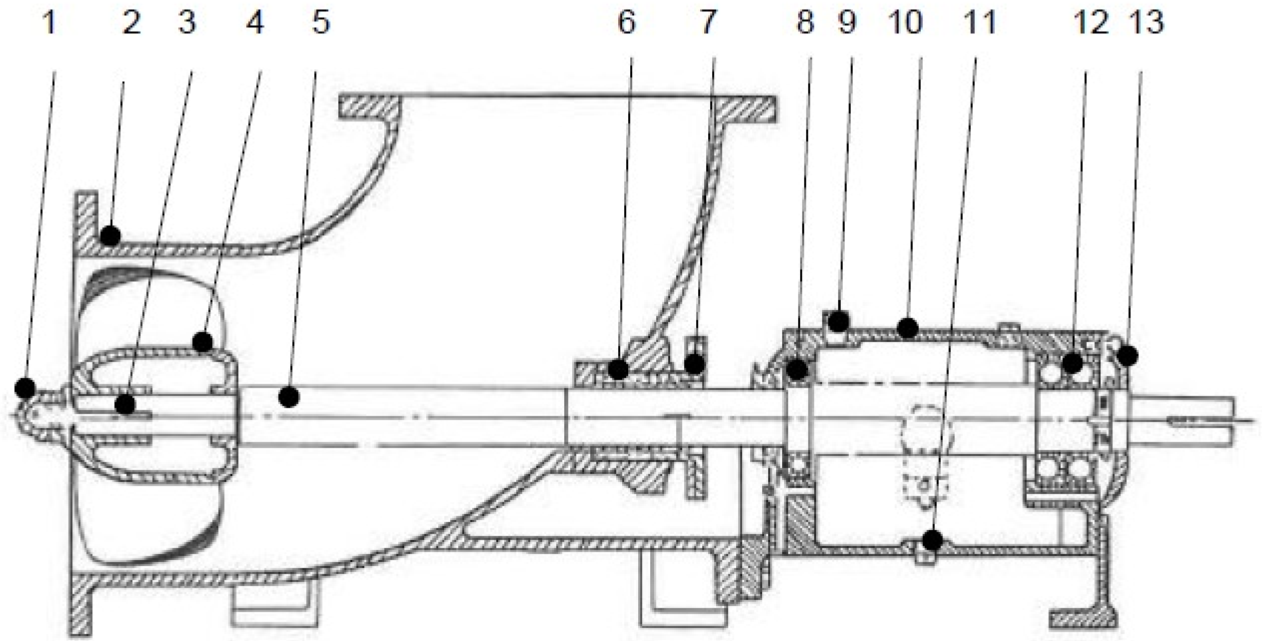


AKSIJALNA PUMPA - PROPELERNA

AKSIJALNA PUMPA - PROPELERNA



AKSIJALNA PUMPA - PROPELERNA



1 Aerodinam. matica
2 Kućište pumpe
3 Klin
4 Rotor
5 Osovina
6 Brtva
7 Priteg brtve
8 Ležaj
9 Uljev ulja
10 Kućište ležaja
11 Ispust ulja
12 Ležaji
13 Stražnji poklopac