Gépészmérnöki (BSc) alapszak

Levelező tagozat

2. félév

MH M1

Áramlás- és hőtechnikai Gépek Tanszéke

2006/2007 tanév

II. félév

Műszaki hőtan

GEAHT 101 BL

A házi feladat megoldása

1.

(a) $$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}}$$

$$T_1 = t_1 + 273{,}15 = 423{,}15\ K$$

$$T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} = 423{,}15 \left(\frac{1}{3}\right)^{\frac{1{,}4-1}{1{,}4}} = 309{,}15\ K$$

$$t_2 = T_2 - 273{,}15 = 36{,}00\ °C$$

$$t_{2v} = 36{,}00 + \Delta t = 36{,}00 + 16 = 52{,}00\ °C$$

$$T_{2v} = 325{,}15\ K$$

(b) $$\cancel{q_{12}} + w_{t12} = h_2 - h_1 + \frac{\cancel{c_2^2 - c_1^2}}{\cancel{2}} + g\cancel{(z_2 - z_1)}$$

$$w_{t12} = c_{p0}\left(T_2 - T_1\right)$$

$$-w_{t12} = c_{p0}\left(t_1 - t_2\right) = 1004\left(150 - 36\right) =$$

$$= 114456\ \frac{J}{kg}$$

$$-P = \dot{m}\left(-w_{t12}\right) = 14 \cdot 114456 = 1{,}602\ MW$$

(c) $$\Delta s_{irr} = s_{2v} - s_1 = c_{p0} \ln \frac{T_{2v}}{T_1} - R \ln \frac{p_2}{p_1}$$

$$R = c_{p0} \frac{\kappa - 1}{\kappa} = 1004 \cdot \frac{0{,}4}{1{,}4} = 286{,}857 \frac{J}{kg\,K}$$

$$\Delta s_{irr} = 1004 \ln \frac{325{,}15}{423{,}15} - 286{,}857 \ln \frac{1}{3} =$$

$$= 50{,}65 \frac{J}{kg\,K}$$

$$\dot{S}_{irr} = \dot{m}\,\Delta s_{irr} = 14 \cdot 50{,}65 = 709{,}1 \frac{W}{K}$$

$$\frac{T_{2v}}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \rightarrow \frac{n-1}{n} = \frac{\ln \frac{T_{2v}}{T_1}}{\ln \frac{p_2}{p_1}}$$

$$\frac{n-1}{n} = \frac{\ln \frac{325{,}15}{423{,}15}}{\ln \frac{1}{3}} = 0{,}2397935 \rightarrow n = 1{,}315432$$

$$c_n = c_{v0} \frac{n-\kappa}{n-1} = \frac{c_{p0}}{\kappa} \cdot \frac{n-\kappa}{n-1}$$

$$c_n = \frac{1004}{1{,}4} \cdot \frac{1{,}315432 - 1{,}4}{0{,}315432} = -192{,}26755 \frac{J}{kg\,K}$$

$$\Delta s_{irr} = c_n \ln \frac{T_{2v}}{T_1} = -192{,}26755 \cdot \ln \frac{325{,}15}{423{,}15} = 50{,}65 \frac{J}{kg\,K}.$$

2.

A Karaffa példatárból (373. és 391. old.):

$p_0 = 0{,}035$ bar $\rightarrow$ $t_0 = 26{,}69\,^\circ C$

$v_0' = 0{,}0010033 \frac{m^3}{kg}$ $\rightarrow$ $\varrho_0' = 996{,}71 \frac{kg}{m^3}$

$v_0'' = 39{,}480 \frac{m^3}{kg}$ $\rightarrow$ $\varrho_0'' = 0{,}02533 \frac{kg}{m^3}$

$h_0' = 111{,}84 \frac{kJ}{kg}$ $h_0'' = 2549{,}9 \frac{kJ}{kg}$ $r_0 = 2438{,}1 \frac{kJ}{kg}$

$s_0' = 0{,}3907 \frac{kJ}{kgK}$ $s_0'' = 8{,}5224 \frac{kJ}{kgK}$;

$p_2 = p_3 = p_4 = p_5 = 150$ bar $t_5 = 500\,^\circ C$

$v_5 = 0{,}02079 \frac{m^3}{kg}$ $\rightarrow$ $\varrho_5 = 48{,}10 \frac{kg}{m^3}$)

$h_5 = 3309{,}7 \frac{kJ}{kg}$)

$s_5 = 6{,}3471 \frac{kJ}{kgK}$.

(a) $q_{be} = h_5 - h_2 \approx h_5 - h_0' =$

$= 3309{,}7 - 111{,}84 = 3197{,}86 \frac{kJ}{kg}$)

$\dot{Q} = \dot{m} q_{be} = \frac{6 \cdot 10^5}{3600} \cdot 3{,}19786 = 532{,}977$ MW .

(b) $s_6 = s_5 = s_0' + x_6\left(s_0'' - s_0'\right)$;

$$x_6 = \frac{s_5 - s_0'}{s_0'' - s_0'} = \frac{6,3471 - 0,3907}{8,5224 - 0,3907} = 0,7325 \ ;$$

$$h_6 = h_0' + x_6\left(h_0'' - h_0'\right) = 111,84 +$$

$$+ 0,7325\left(2549,9 - 111,84\right) = 1897,72 \ \frac{kJ}{kg} \ .$$

(c) $w_t = w_{56} = h_6 - h_5$,

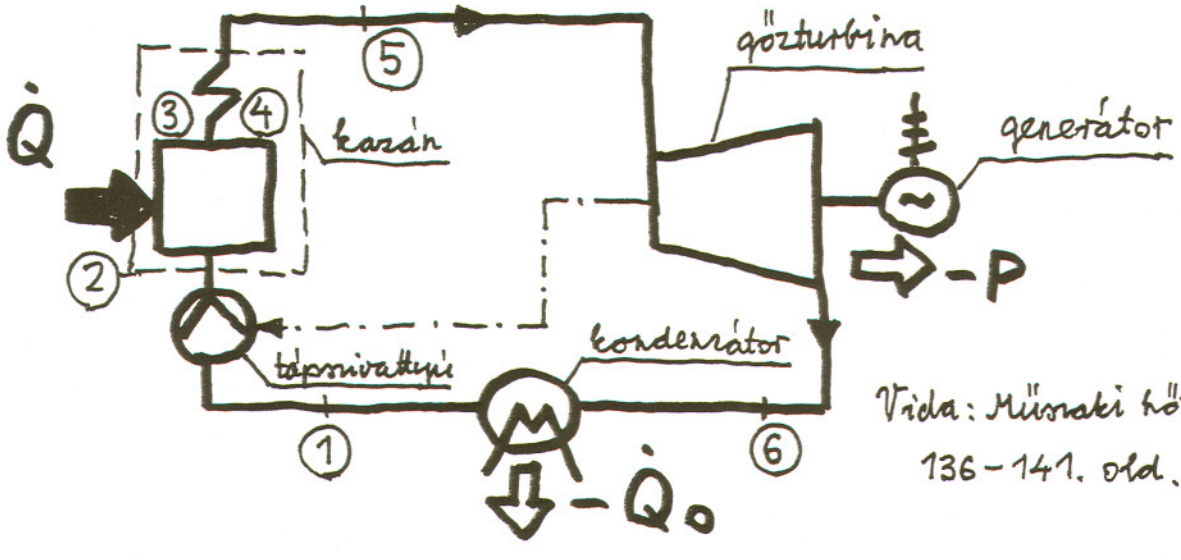
$$-w_t = h_5 - h_6 = 3309,7 - 1897,72 = 1411,98 \ \frac{kJ}{kg} \ ,$$

$$-P = \dot{m}\left(-w_t\right) = \frac{600000}{3600} \cdot 1,41198 = 235,33 \ MW \ .$$

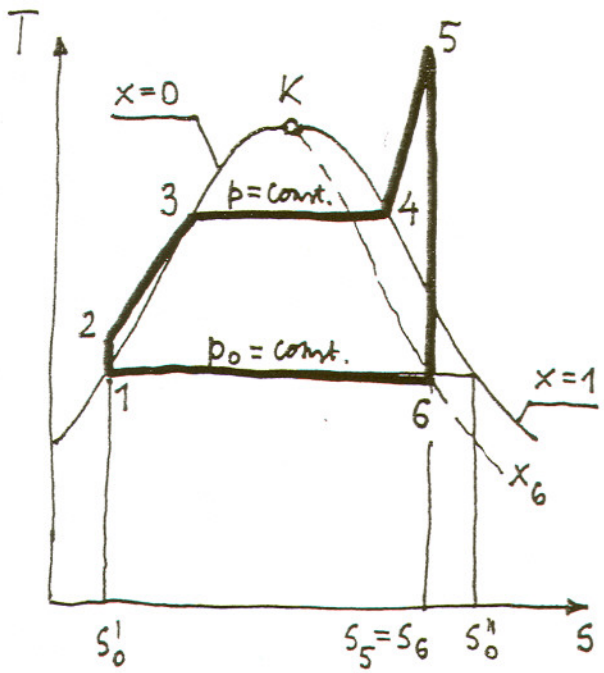
(d) $P + \dot{Q} + \dot{Q}_0 = 0$

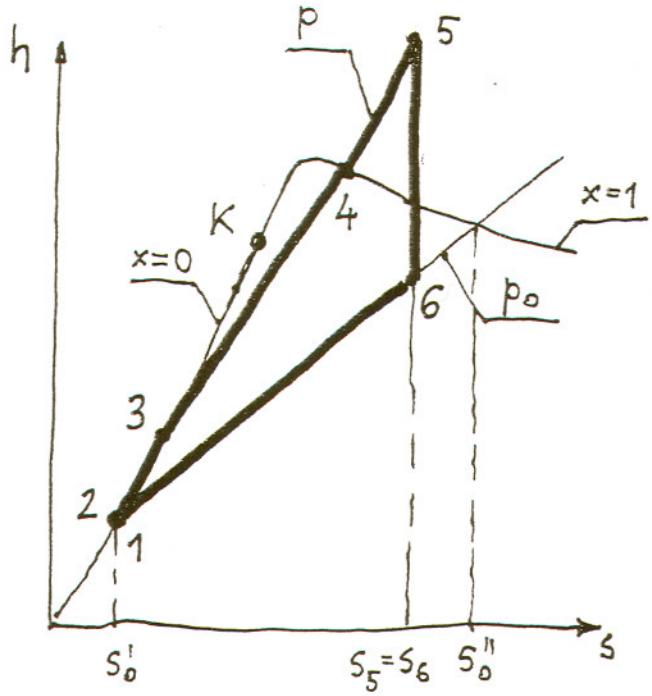
$$-\dot{Q}_0 = \dot{Q} - (-P) = 532,977 - 235,33 = 297,65 \ MW \ ,$$

$$\eta_t = \frac{-P}{\dot{Q}} = \frac{235,33}{532,977} = 44,15\ \% \ .$$



Vida: Műszaki hőtan
136-141. old.





1-2 izentropikus nyomásnövekedés (tápszivattyú)

2-3-4-5 izobár hőközlés → 2-3 vízmelegítés
3-4 elpárologtatás
4-5 túlhevítés

5-6 izentropikus expanzió

6-1 izobár hőelvonás (kondenzáció)

Rankine, William John Macquorn (1820-1872) skót mérnök és fizikus

Clausius, Rudolf (Julius Emanuel) (1822-1888) német fizikus

3.

$$p_{t1} = \exp\left\{23{,}6961 - \frac{4102{,}99}{237{,}431 + 2}\right\} = 706\ \text{Pa},$$

$$x_1 = 0{,}622 \cdot \frac{706}{\frac{101300}{0{,}9} - 706} = 0{,}003926\ \frac{\text{kg}}{\text{kg}}$$

$$(h_{1+x})_1 = c_{pl}\, t_1 + x_1 (r_0 + c_{pg}\, t_1) =$$

$$= 1004{,}6 \cdot 2 + 0{,}003926 \left(2500{,}9 \cdot 10^3 + 1863 \cdot 2\right) =$$

$$= 11842 \ \frac{J}{kg} \ ,$$

$$x_1 = x_2 \ ,$$

$$(h_{1+x})_2 = 1004{,}6 \cdot 27{,}5 + 0{,}003926 \left(2500{,}9 \cdot 10^3 + 1863 \cdot 27{,}5\right) =$$

$$= 37646 \ \frac{J}{kg} \ ,$$

$$p_g = \varphi\, p_{t1} = 0{,}9 \cdot 706 = 635{,}4 \ Pa \ ,$$

$$\varrho = \frac{p}{R_l\, T} \left(1 - 0{,}378 \ \frac{p_g}{p}\right) = \frac{101300}{287{,}05 \cdot 275{,}15} \left(1 - 0{,}378 \ \frac{635{,}4}{101300}\right) =$$

$$= 1{,}2826 \cdot 0{,}9976 = 1{,}2795 \ \frac{kg}{m^3} \ ,$$

$$\dot{m} = \varrho \dot{V} = 1{,}2795 \cdot \frac{10000}{3600} = 3{,}554 \ \frac{kg}{s} \ ,$$

$$\dot{m} = \dot{m}_l + \dot{m}_g = \dot{m}_l \, (1+x) \ ,$$

$$\dot{m}_l = \frac{\dot{m}}{1+x} = \frac{3{,}554}{1{,}003926} = 3{,}54 \ \frac{kg}{s} \ ,$$

$$\dot{Q} = \dot{m}_l \left[(h_{1+x})_2 - (h_{1+x})_1\right] =$$

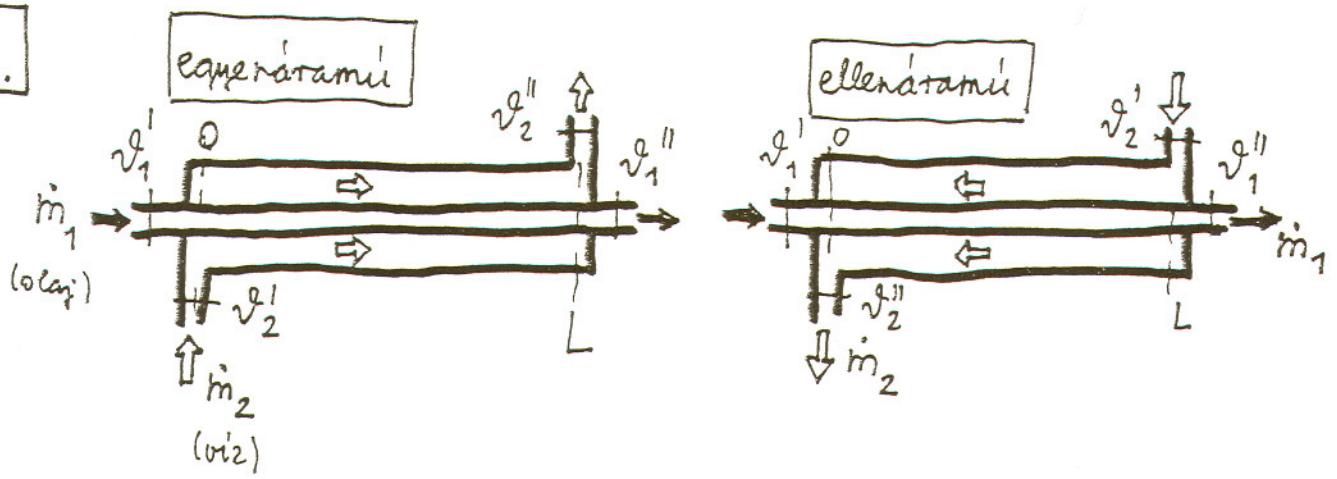
$$= 3{,}54 \left(37646 - 11842\right) = 91{,}346 \ kW \ ,$$

$$p_t(27{,}5\,^\circ\mathrm{C}) = 3674\ \mathrm{Pa}$$

$$\varphi_2 = \frac{101300}{3674} \cdot \frac{0{,}003926}{0{,}622 + 0{,}003926} = 0{,}173$$

$$\varphi_2 = 17{,}3\ \%$$

4.



(a) $$\dot{W}_1 = \dot{m}_1 c_1 = \frac{800}{3600} \cdot 1675 = 372{,}222\ \frac{\mathrm{W}}{\mathrm{K}}$$

$$\dot{W}_2 = \dot{m}_2 c_2 = \frac{1100}{3600} \cdot 4190 = 1280{,}278\ \frac{\mathrm{W}}{\mathrm{K}}$$

$$\dot{W}_1 \left(\vartheta_1' - \vartheta_1''\right) = \dot{W}_2 \left(\vartheta_2'' - \vartheta_2'\right)$$

$$\vartheta_2'' = \vartheta_2' + \frac{\dot{W}_1}{\dot{W}_2}\left(\vartheta_1' - \vartheta_1''\right) = 12 + \frac{372{,}222}{1280{,}278}(95-50) = 25{,}1\,^\circ\mathrm{C}$$

$$\dot{Q} = \dot{W}_1 \left(\vartheta_1' - \vartheta_1''\right) = 372{,}222\,(95-50) = 16{,}75\ \mathrm{kW}$$

(b) $$\dot{Q} = kA \underbrace{\frac{(\Delta\vartheta)_0 - (\Delta\vartheta)_L}{\ln \dfrac{(\Delta\vartheta)_0}{(\Delta\vartheta)_L}}}_{\Delta\vartheta_m}$$

Egyenáramú:

$$(\Delta\vartheta_m)_{egy} = \frac{(\vartheta_1' - \vartheta_2') - (\vartheta_1'' - \vartheta_2'')}{\ln\frac{\vartheta_1' - \vartheta_2'}{\vartheta_1'' - \vartheta_2''}} = \frac{83 - 24{,}9}{\ln\frac{83}{24{,}9}} = 48{,}257\,K$$

Ellenáramú:

$$(\Delta\vartheta_m)_{ell} = \frac{(\vartheta_1' - \vartheta_2'') - (\vartheta_1'' - \vartheta_2')}{\ln\frac{\vartheta_1' - \vartheta_2''}{\vartheta_1'' - \vartheta_2'}} = \frac{69{,}9 - 38}{\ln\frac{69{,}9}{38}} = 52{,}340\,K$$

(c) $$A = \frac{\dot{Q}}{k\,\Delta\vartheta_m}$$

Egyenáramú

$$A_{egy} = \frac{\dot{Q}}{k\,(\Delta\vartheta_m)_{egy}} = \frac{16750}{76 \cdot 48{,}257} = 4{,}567\,m^2$$

ellenáramú

$$A_{ell} = \frac{\dot{Q}}{k\,(\Delta\vartheta_m)_{ell}} = \frac{16750}{76 \cdot 52{,}340} = 4{,}211\,m^2$$