Formeln EVK

SL: $i_p = \sqrt{2}\,(1 + e^{-\frac{tR}{L}})\, I_K'' = \sqrt{2}\,\kappa\, I_K''$; $I_{th} = I_K'' \sqrt{m+n}$; $I_{th} = I_{thr} \sqrt{\frac{t_{kr}}{t_K}}$

$S_{th} = S_{thr} \sqrt{\frac{1}{t_K}}$;

$$S_{th} = \frac{I_{th}}{A} = \sqrt{\frac{K_{20} \cdot \rho \cdot c}{\alpha_{20} \cdot t_{kr}} \ln \frac{1 + \alpha_{20}(T_K - 20°C)}{1 + \alpha_{20}(T_b - 20°C)}}$$

Schaltbedingte Spannungsanhebungen

$d = \frac{\Delta S_A}{S_{kV}} \cos(\Psi - \varphi_A)$

Stationäre Spannungsanheb.: $\Delta u = \frac{S_{rA\,max}}{S_{kV}} \cos(\Psi - \varphi_E)$

Thermodynamik

Innere Energie: $dU = m\, c_v\, dT$ äußere Arbeit: $dW = -F dx = -pA dx = -p dV$

$$pV = m R_m T \;;\; pV = M R T$$

Isobar: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $W_{12} = -p_1 (V_2 - V_1) \hat{=} -\int_1^2 p\,dV$ $Q_{12} = M c_p (T_2 - T_1)$

$dW = p\,dV = M R\, dT$ $dH = M c_p\, dT$

Isochor: $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $W_{12} = 0$ $Q_{12} = M c_v (T_2 - T_1)$

$c_p = c_v + R$ $c_v = \frac{fR}{2}$ $\frac{c_p}{c_v} = \kappa = 1 + \frac{2}{f}$

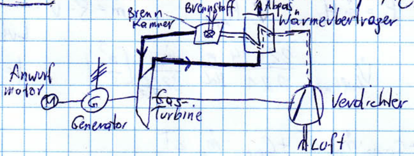
Isotherm: $p_1 V_1 = p_2 V_2$ $-W_{12} = p_1 V_1 \ln \frac{V_2}{V_1} = m R T_1 \ln \frac{V_2}{V_1}$ $Q_{12} = -W_{12}$

Isentrop: $\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\frac{c_p - c_v}{c_v}} = \left(\frac{V_2}{V_1}\right)^{\kappa - 1}$ $W_{12} = \frac{mR}{\kappa - 1}(T_2 - T_1) = \frac{p_2 V_2 - p_1 V_1}{\kappa - 1}$ $dQ = 0 = m c_v dT + p dV$

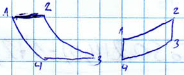
$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\kappa - 1}{\kappa}}$ $\left(\frac{p_1}{p_2}\right) = \left(\frac{V_2}{V_1}\right)^{\kappa}$

Carnot-Prozess:  2x isotherm, 2x isentrop, $\eta_{car} = 1 - \frac{T_3}{T_1} = \frac{Q_{zu} - Q_{ab}}{Q_{zu}}$

Gasturbine:



offene Gasturbienanlage

Joule Prozess: 

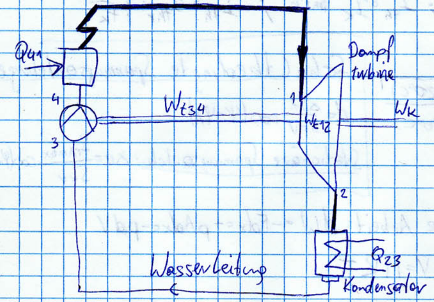
2x isobar, 2x isentrop

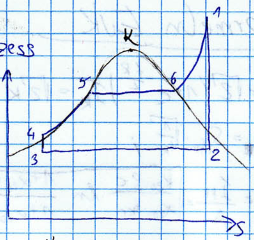
abgegebene Nutzarbeit $= W_{id} = Q_{12} - Q_{34} = -m c_p (T_1 - T_2 + T_3 - T_4)$ $\eta_{th} = 1 - \frac{T_3 - T_4}{T_2 - T_1}$ $\frac{T_2}{T_3} = \frac{T_1}{T_4}$

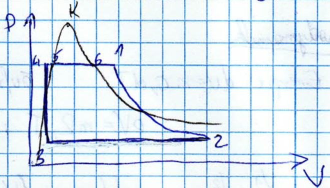
Arbeitsverhältnis $r_w = \frac{W_{id}}{W_{23}} = 1 - \frac{T_1}{T_2}$

$\eta_{thj} = 1 - \frac{T_4}{T_1} = 1 - \left(\frac{p_4}{p_1}\right)^{\frac{\kappa - 1}{\kappa}}$

Clausius-Rankine-Prozess — Dampfkreisprozess







umgesetzte Nutzwärme: $w_{cr} = q_{41} - q_{23} = h_1 - h_4 - (h_2 - h_3)$

$\eta_{th} = \frac{w_{cr}}{q_{zu}} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$ Arbeitsverhältnis $r_w = \frac{w_{cr}}{w_{12}} = 1 - \frac{h_4 - h_3}{h_1 - h_2}$

$h_4 = h_3 + v_3 (p_4 - p_3)$

Wärmeauskopplung: $\eta_{th} = \frac{h_1 - h_2}{h_1 - h_3}$ ... reiner Kondensatbetrieb ohne Wärmeauskopplung

$\eta_{HKW} = \eta_K \frac{(h_1 - h_{2'})\eta_G + (h_{2'} - h_{3'})\eta_H}{h_1 - h_{3'}}$ ... mit Wärmeauskopplung

GuD: $\eta_{GD} = \frac{W_G + W_D}{Q_{zu}} = \eta_G + \eta_D (1 - \eta_G)$

Stöchiometrische Verbrennung: Brennstoffe im Verhältnis der Molekulargewichte verbrannt

Luftbedarf $V_{Luft} = \frac{V_{O_2L}}{0{,}21}$ $P_{th} = \dot m H_{u,m} = \dot V \cdot H_{u,V}$ $\dot m = \rho \cdot \dot V$

$\frac{\dot m_{O_2}}{32} = \frac{\dot m_C}{12} + \frac{\dot m_H}{4} + \frac{\dot m_S}{32} - \frac{\dot m_{O_2B}}{32}$ $\dot V_{Luft,min} = \frac{22{,}414 \frac{m^3}{kmol}}{0{,}21} \cdot \frac{\dot m_{O_2}}{32 \frac{kg}{kmol}} \left[\frac{m_n^3}{s}\right]$

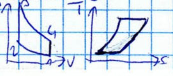
Luftüberschusszahl $\lambda = \frac{\dot V_{O_2}}{V_{O_2,min}} = \frac{V_{Luft,H}}{V_{Luft,min}}$

$P_{th} = c_{p,CO_2} \dot m_{CO_2} \Delta T + c_{p,H_2O} \dot m_{H_2O} \Delta T + c_{p,O_2} \dot m_{O_2} \Delta T + c_{p,N_2} \dot m_{N_2} \Delta T$

H - 1 S - 32
C - 12 Ca - 40
N - 14
O - 16
} Molekulargewicht $\left[\frac{kg}{kmol}\right]$

Gips: $CaSO_4 2(H_2O)$ - 172 $\frac{kg}{kmol}$

Stirlingprozess: 2x isochor, 2x isotherm



Verdichtungsverhältnis $\varepsilon = \frac{V_1}{V_2}$; Nutzarbeit $W_{St} = Q_{34} + Q_{12} = mR(T_3 - T_1)\ln\varepsilon$

$\eta_{th} = \frac{W_{St}}{Q_{34}} = 1 - \frac{T_1}{T_3}$

$r_{WSt} = \frac{W_{St}}{W_{34} + W_{41}} = \frac{1}{\frac{1}{\eta_{th}} + \frac{1}{\ln\varepsilon}}$

Wärmepumpe: Leistungszahl $\varepsilon_{W,car} = \frac{1}{1 - \frac{T_3}{T_1}} = \frac{Q_{21}}{W_{zu}} = \frac{1}{\eta_{car}}$

Kältemaschine: $\varepsilon_{K,car} = \frac{Q_{43}}{W_{zu}} = \frac{Q_{43}}{Q_{43} - Q_{21}} = \frac{T_3}{T_1 - T_3}$

$\varepsilon_{W,car} = 1 + \varepsilon_{K,car}$