rekuperacni vymenik tepla, kde dochazi k ochlazeni procesnich plynu chladici vodou

SPALINY

$m_{sp} = 0{,}003107$

$t_{sp;in} = 900$

$t_{sp;out} = 20 + t_{sat}$

$p_{sp} = 1$

$d_{in} = 0{,}0084$

$d_{out} = 0{,}012$

slozeni spalin

$xO2 = 0{,}07$

$xCO2 = 0{,}12$

$xAr = 0{,}006$

$xH2O = 0{,}1$

$xN2 = 0{,}7$

$M_{O2} = 32$

$M_{CO2} = 44$

$M_{Ar} = 40$

$M_{H2O} = 18$

$M_{N2} = 28$

$R = 8314{,}3$

VODA

$t_{w;in} = 15$

$t_{w;out} = 40$

$$t_{w;str} = \frac{t_{w;in} + t_{w;out}}{2}$$

teplota rosneho bodu

$pp_{sp;H2O} = p_{sp} \cdot xH2O$

$t_{sat} = \mathbf{T}_{sat}\,(\text{Water} ; P = pp_{sp;H2O})$

hmotnostni zlomky

$$wO2 = \frac{xO2 \cdot M_{O2}}{xO2 \cdot M_{O2} + xCO2 \cdot M_{CO2} + xAr \cdot M_{Ar} + xH2O \cdot M_{H2O} + xN2 \cdot M_{N2}}$$

$$wCO2 = \frac{xCO2 \cdot M_{CO2}}{xO2 \cdot M_{O2} + xCO2 \cdot M_{CO2} + xAr \cdot M_{Ar} + xH2O \cdot M_{H2O} + xN2 \cdot M_{N2}}$$

$$wAr = \frac{xAr \cdot M_{Ar}}{xO2 \cdot M_{O2} + xCO2 \cdot M_{CO2} + xAr \cdot M_{Ar} + xH2O \cdot M_{H2O} + xN2 \cdot M_{N2}}$$

$$wH2O = \frac{xH2O \cdot M_{H2O}}{xO2 \cdot M_{O2} + xCO2 \cdot M_{CO2} + xAr \cdot M_{Ar} + xH2O \cdot M_{H2O} + xN2 \cdot M_{N2}}$$

$$wN2 = \frac{xN2 \cdot M_{N2}}{xO2 \cdot M_{O2} + xCO2 \cdot M_{CO2} + xAr \cdot M_{Ar} + xH2O \cdot M_{H2O} + xN2 \cdot M_{N2}}$$

entalpie

$$i_{O2;in} = \mathbf{h}(O2 ; T = t_{sp;in}) - \mathbf{h}(O2 ; T = 0)$$

$$i_{CO2;in} = \mathbf{h}(CO2 ; T = t_{sp;in}) - \mathbf{h}(CO2 ; T = 0)$$

$$i_{Ar;in} = \mathbf{h}(Ar ; T = t_{sp;in}) - \mathbf{h}(Ar ; T = 0)$$

$$i_{H2O;in} = \mathbf{h}(Water ; T = t_{sp;in} ; P = p_{sp} \cdot xH2O) - \mathbf{h}(Water ; T = 0{,}1 ; P = p_{sp} \cdot xH2O)$$

$$i_{N2;in} = \mathbf{h}(N2 ; T = t_{sp;in}) - \mathbf{h}(N2 ; T = 0)$$

$$i_{sp;in} = wO2 \cdot i_{O2;in} + wCO2 \cdot i_{CO2;in} + wAr \cdot i_{Ar;in} + wH2O \cdot i_{H2O;in} + wN2 \cdot i_{N2;in}$$

$$i_{O2;out} = \mathbf{h}(O2 ; T = t_{sp;out}) - \mathbf{h}(O2 ; T = 0)$$

$$i_{CO2;out} = \mathbf{h}(CO2 ; T = t_{sp;out}) - \mathbf{h}(CO2 ; T = 0)$$

$$i_{Ar;out} = \mathbf{h}(Ar ; T = t_{sp;out}) - \mathbf{h}(Ar ; T = 0)$$

$$i_{H2O;out} = \mathbf{h}(Water ; T = t_{sp;out} ; P = p_{sp} \cdot xH2O) - \mathbf{h}(Water ; T = 0{,}1 ; P = p_{sp} \cdot xH2O)$$

$$i_{N2;out} = \mathbf{h}(N2 ; T = t_{sp;out}) - \mathbf{h}(N2 ; T = 0)$$

$$i_{sp;out} = wO2 \cdot i_{O2;out} + wCO2 \cdot i_{CO2;out} + wAr \cdot i_{Ar;out} + wH2O \cdot i_{H2O;out} + wN2 \cdot i_{N2;out}$$

$$i_{w;in} = \mathbf{h}(Water ; T = t_{w;in} ; P = 5)$$

$$i_{w;out} = \mathbf{h}(Water ; T = t_{w;out} ; P = 5)$$

hmotnostni tok vody

Q_{sp}=Q_w

$$\Delta = i_{sp;in} - i_{sp;out}$$

$$Q_{sp} = m_{sp} \cdot (i_{sp;in} - i_{sp;out})$$

$$Q_{sp} = m_w \cdot (i_{w;out} - i_{w;in})$$

stredni teplota spalin

$$t_{sp;str} = \frac{t_{sp;in} - t_{sp;out}}{2}$$

hustota spalin

$$\rho_{O2} = \rho(O2 ; T = t_{sp;str} ; P = p_{sp})$$

$\rho_{CO2} = \rho(\text{CarbonDioxide}; T = t_{sp;str}; P = p_{sp})$

$\rho_{Ar} = \rho(\text{Argon}; T = t_{sp;str}; P = p_{sp})$

$\rho_{H2O} = \rho(\text{Water}; T = t_{sp;str}; P = p_{sp})$

$\rho_{N2} = \rho(\text{Nitrogen}; T = t_{sp;str}; P = p_{sp})$

$\rho_{sp} = \rho_{O2} \cdot xO2 + \rho_{CO2} \cdot xCO2 + \rho_{Ar} \cdot xAr + \rho_{H2O} \cdot xH2O + \rho_{N2} \cdot xN2$

pocet trubek

$$m_{sp} = \frac{\pi \cdot d_{in}^2}{4} \cdot w_{sp} \cdot \rho_{sp} \cdot n_{tr}$$

$n_{tr} = 19$

vypocet viskozity spalin

$\eta_{CO2} = \textbf{Visc}(\text{CarbonDioxide}; T = t_{sp;str}; P = 1{,}01325)$

$\eta_{Ar} = \textbf{Visc}(Ar; T = t_{sp;str})$

$\eta_{O2} = \textbf{Visc}(O2; T = t_{sp;str})$

$\eta_{H2O} = \textbf{Visc}(H2O; T = t_{sp;str})$

$\eta_{N2} = \textbf{Visc}(N2; T = t_{sp;str})$

$\sigma_{N2} = \textbf{sigma}_{LJ}(N2) \cdot 10^{10}$

$\sigma_{CO2} = \textbf{sigma}_{LJ}(CO2) \cdot 10^{10}$

$\sigma_{O2} = \textbf{sigma}_{LJ}(O2) \cdot 10^{10}$

$\sigma_{Ar} = \textbf{sigma}_{LJ}(Ar) \cdot 10^{10}$

$\sigma_{H2O} = \textbf{sigma}_{LJ}(H2O) \cdot 10^{10}$

$$\sigma_{CO2N2} = \frac{\sigma_{N2} + \sigma_{CO2}}{2}$$

$$\sigma_{CO2O2} = \frac{\sigma_{O2} + \sigma_{CO2}}{2}$$

$$\sigma_{CO2Ar} = \frac{\sigma_{Ar} + \sigma_{CO2}}{2}$$

$$\sigma_{CO2H2O} = \frac{\sigma_{H2O} + \sigma_{CO2}}{2}$$

$$\sigma_{N2O2} = \frac{\sigma_{N2} + \sigma_{O2}}{2}$$

$$\sigma_{N2Ar} = \frac{\sigma_{N2} + \sigma_{Ar}}{2}$$

$$\sigma_{N2H2O} = \frac{\sigma_{N2} + \sigma_{H2O}}{2}$$

$$\sigma_{ArO2} = \frac{\sigma_{O2} + \sigma_{Ar}}{2}$$

$$\sigma_{ArH2O} = \frac{\sigma_{H2O} + \sigma_{Ar}}{2}$$

$$\sigma_{O2H2O} = \frac{\sigma_{O2} + \sigma_{H2O}}{2}$$

ek= Lennard-Jonesuv potencial

$$ek_{N2} = \mathbf{ek}_{LJ}(N2)$$

$$ek_{CO2} = \mathbf{ek}_{LJ}(CO2)$$

$$ek_{O2} = \mathbf{ek}_{LJ}(O2)$$

$$ek_{Ar} = \mathbf{ek}_{LJ}(Ar)$$

$$ek_{H2O} = \mathbf{ek}_{LJ}(H2O)$$

$$ek_{CO2N2} = (ek_{N2} \cdot ek_{CO2})^{0,5}$$

$$ek_{CO2O2} = (ek_{CO2} \cdot ek_{O2})^{0,5}$$

$$ek_{CO2Ar} = (ek_{Ar} \cdot ek_{CO2})^{0,5}$$

$$ek_{CO2H2O} = (ek_{H2O} \cdot ek_{CO2})^{0,5}$$

$$ek_{N2Ar} = (ek_{N2} \cdot ek_{Ar})^{0,5}$$

$$ek_{N2O2} = (ek_{N2} \cdot ek_{O2})^{0,5}$$

$$ek_{N2H2O} = (ek_{N2} \cdot ek_{H2O})^{0,5}$$

$$ek_{ArO2} = (ek_{Ar} \cdot ek_{O2})^{0,5}$$

$$ek_{ArH2O} = (ek_{Ar} \cdot ek_{H2O})^{0,5}$$

$$ek_{O2H2O} = (ek_{O2} \cdot ek_{H2O})^{0,5}$$

$$T°_{CO2N2} = \frac{t_{sp;str} + 273,15}{ek_{CO2N2}}$$

$$T°_{CO2O2} = \frac{t_{sp;str} + 273,15}{ek_{CO2O2}}$$

$$T°_{CO2Ar} = \frac{t_{sp;str} + 273,15}{ek_{CO2Ar}}$$

$$T°_{CO2H2O} = \frac{t_{sp;str} + 273,15}{ek_{CO2H2O}}$$

$$T°_{N2Ar} = \frac{t_{sp;str} + 273,15}{ek_{N2Ar}}$$

$$T°_{N2O2} = \frac{t_{sp;str} + 273,15}{ek_{N2O2}}$$

$$T°_{N2H2O} = \frac{t_{sp;str} + 273,15}{ek_{N2H2O}}$$

$$T°_{ArO2} = \frac{t_{sp;str} + 273,15}{ek_{ArO2}}$$

$$T°_{ArH2O} = \frac{t_{sp;str} + 273,15}{ek_{ArH2O}}$$

$$T°_{O2H2O} = \frac{t_{sp;str} + 273,15}{ek_{O2H2O}}$$

$$\omega_{CO2N2} = \frac{1,06036}{T°_{CO2N2}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{CO2N2})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{CO2N2})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{CO2N2})}$$

$$\omega_{CO2O2} = \frac{1,06036}{T°_{CO2O2}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{CO2O2})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{CO2O2})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{CO2O2})}$$

$$\omega_{CO2Ar} = \frac{1,06036}{T°_{CO2Ar}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{CO2Ar})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{CO2Ar})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{CO2Ar})}$$

$$\omega_{CO2H2O} = \frac{1,06036}{T°_{CO2H2O}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{CO2H2O})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{CO2H2O})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{CO2H2O})}$$

$$\omega_{N2Ar} = \frac{1,06036}{T°_{N2Ar}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{N2Ar})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{N2Ar})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{N2Ar})}$$

$$\omega_{N2O2} = \frac{1,06036}{T°_{N2O2}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{N2O2})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{N2O2})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{N2O2})}$$

$$\omega_{N2H2O} = \frac{1,06036}{T°_{N2H2O}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{N2H2O})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{N2H2O})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{N2H2O})}$$

$$\omega_{ArO2} = \frac{1,06036}{T°_{ArO2}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{ArO2})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{ArO2})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{ArO2})}$$

$$\omega_{ArH2O} = \frac{1,06036}{T°_{ArH2O}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{ArH2O})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{ArH2O})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{ArH2O})}$$

$$\omega_{O2H2O} = \frac{1,06036}{T°_{O2H2O}{}^{0,1561}} + \frac{0,193}{\exp(0,47635 \cdot T°_{O2H2O})} + \frac{1,03587}{\exp(1,52996 \cdot T°_{O2H2O})} + \frac{1,76474}{\exp(3,89411 \cdot T°_{O2H2O})}$$

$$D_{CO2N2} = \left[\frac{0,00266 \cdot (t_{sp;str} + 273,15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0,5} \cdot \sigma_{CO2N2}{}^{2} \cdot \omega_{CO2N2}}\right] \cdot 10^{-4}$$

$$D_{CO2O2} = \left[\frac{0,00266 \cdot (t_{sp;str} + 273,15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0,5} \cdot \sigma_{CO2O2}{}^{2} \cdot \omega_{CO2O2}}\right] \cdot 10^{-4}$$

$$D_{CO2Ar} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{CO2Ar}{}^{2} \cdot \omega_{CO2Ar}}\right] \cdot 10^{-4}$$

$$D_{CO2H2O} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{CO2H2O}{}^{2} \cdot \omega_{CO2H2O}}\right] \cdot 10^{-4}$$

$$D_{N2Ar} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{N2Ar}{}^{2} \cdot \omega_{N2Ar}}\right] \cdot 10^{-4}$$

$$D_{N2O2} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{N2O2}{}^{2} \cdot \omega_{N2O2}}\right] \cdot 10^{-4}$$

$$D_{N2H2O} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{N2H2O}{}^{2} \cdot \omega_{N2H2O}}\right] \cdot 10^{-4}$$

$$D_{ArO2} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{ArO2}{}^{2} \cdot \omega_{ArO2}}\right] \cdot 10^{-4}$$

$$D_{ArH2O} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{ArH2O}{}^{2} \cdot \omega_{ArH2O}}\right] \cdot 10^{-4}$$

$$D_{O2H2O} = \left[\frac{0{,}00266 \cdot (t_{sp;str} + 273{,}15)^{(3/2)}}{p_{sp} \cdot \left[2 \cdot \left[\frac{1}{M_{CO2}} + \frac{1}{M_{N2}}\right]\right]^{0{,}5} \cdot \sigma_{O2H2O}{}^{2} \cdot \omega_{O2H2O}}\right] \cdot 10^{-4}$$

$$\phi_{CO2N2} = 6/5 \cdot A_{CO2N2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{CO2}}{101325 \cdot M_{CO2} \cdot D_{CO2N2}}$$

$$\phi_{CO2O2} = 6/5 \cdot A_{CO2O2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{CO2}}{101325 \cdot M_{CO2} \cdot D_{CO2O2}}$$

$$\phi_{CO2Ar} = 6/5 \cdot A_{CO2Ar} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{CO2}}{101325 \cdot M_{CO2} \cdot D_{CO2Ar}}$$

$$\phi_{CO2H2O} = 6/5 \cdot A_{CO2H2O} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{CO2}}{101325 \cdot M_{CO2} \cdot D_{CO2H2O}}$$

$$\phi_{N2Ar} = 6/5 \cdot A_{N2Ar} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{N2}}{101325 \cdot M_{N2} \cdot D_{N2Ar}}$$

$$\phi_{N2O2} = 6/5 \cdot A_{N2O2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{N2}}{101325 \cdot M_{N2} \cdot D_{N2O2}}$$

$$\phi_{N2H2O} = 6/5 \cdot A_{N2H2O} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{N2}}{101325 \cdot M_{N2} \cdot D_{N2H2O}}$$

$$\phi_{N2CO2} = 6/5 \cdot A_{N2CO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{N2}}{101325 \cdot M_{N2} \cdot D_{CO2N2}}$$

$$\phi_{ArCO2} = 6/5 \cdot A_{ArCO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{Ar}}{101325 \cdot M_{Ar} \cdot D_{CO2Ar}}$$

$$\phi_{ArN2} = 6/5 \cdot A_{ArN2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{Ar}}{101325 \cdot M_{Ar} \cdot D_{N2Ar}}$$

$$\phi_{ArO2} = 6/5 \cdot A_{ArO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{Ar}}{101325 \cdot M_{Ar} \cdot D_{ArO2}}$$

$$\phi_{ArH2O} = 6/5 \cdot A_{ArH2O} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{Ar}}{101325 \cdot M_{Ar} \cdot D_{ArH2O}}$$

$$\phi_{O2CO2} = 6/5 \cdot A_{O2CO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{O2}}{101325 \cdot M_{O2} \cdot D_{CO2O2}}$$

$$\phi_{O2N2} = 6/5 \cdot A_{O2N2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{O2}}{101325 \cdot M_{O2} \cdot D_{N2O2}}$$

$$\phi_{O2Ar} = 6/5 \cdot A_{O2Ar} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{O2}}{101325 \cdot M_{O2} \cdot D_{ArO2}}$$

$$\phi_{O2H2O} = 6/5 \cdot A_{O2H2O} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{O2}}{101325 \cdot M_{O2} \cdot D_{O2H2O}}$$

$$\phi_{H2OO2} = 6/5 \cdot A_{H2OO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{H2O}}{101325 \cdot M_{H2O} \cdot D_{O2H2O}}$$

$$\phi_{H2OCO2} = 6/5 \cdot A_{H2OCO2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{H2O}}{101325 \cdot M_{H2O} \cdot D_{CO2H2O}}$$

$$\phi_{H2ON2} = 6/5 \cdot A_{H2ON2} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{H2O}}{101325 \cdot M_{H2O} \cdot D_{N2H2O}}$$

$$\phi_{H2OAr} = 6/5 \cdot A_{H2OAr} \cdot \frac{R \cdot (t_{sp;str} + 273{,}15)^{(3/2)} \cdot \eta_{H2O}}{101325 \cdot M_{H2O} \cdot D_{ArH2O}}$$

$$suma_{CO2} = \phi_{CO2N2} \cdot \frac{xN2}{xCO2} + \phi_{CO2O2} \cdot \frac{xO2}{xCO2} + \phi_{CO2Ar} \cdot \frac{xAr}{xCO2} + \phi_{CO2H2O} \cdot \frac{xH2O}{xCO2}$$

$$suma_{N2} = \phi_{N2Ar} \cdot \frac{xAr}{xN2} + \phi_{N2O2} \cdot \frac{xO2}{xN2} + \phi_{N2H2O} \cdot \frac{xH2O}{xN2} + \phi_{N2CO2} \cdot \frac{xCO2}{xN2}$$

$$suma_{Ar} = \phi_{ArN2} \cdot \frac{xN2}{xAr} + \phi_{ArO2} \cdot \frac{xO2}{xAr} + \phi_{ArCO2} \cdot \frac{xCO2}{xAr} + \phi_{ArH2O} \cdot \frac{xH2O}{xAr}$$

$$suma_{O2} = \phi_{O2N2} \cdot \frac{xN2}{xO2} + \phi_{O2CO2} \cdot \frac{xCO2}{xO2} + \phi_{O2Ar} \cdot \frac{xAr}{xO2} + \phi_{O2H2O} \cdot \frac{xH2O}{xO2}$$

$$suma_{H2O} = \phi_{H2ON2} \cdot \frac{xN2}{xH2O} + \phi_{H2OO2} \cdot \frac{xO2}{xH2O} + \phi_{H2OAr} \cdot \frac{xAr}{xH2O} + \phi_{H2OCO2} \cdot \frac{xCO2}{xH2O}$$

$$\eta_{sp} = \frac{\eta_{Ar}}{1 + suma_{Ar}} + \frac{\eta_{CO2}}{1 + suma_{CO2}} + \frac{\eta_{N2}}{1 + suma_{N2}} + \frac{\eta_{O2}}{1 + suma_{O2}} + \frac{\eta_{H2O}}{1 + suma_{H2O}}$$

merna tepelna kapacita

$$cp_{CO2} = \mathbf{Cp}(CO2 ; T = t_{sp;str})$$

$$cp_{O2} = \mathbf{Cp}(O2 ; T = t_{sp;str})$$

$$cp_{Ar} = \mathbf{Cp}(Ar ; T = t_{sp;str})$$

$$cp_{H2O} = \mathbf{Cp}(H2O ; T = t_{sp;str})$$

$$cp_{N2} = \mathbf{Cp}(N2 ; T = t_{sp;str})$$

$$cp_{sp} = cp_{CO2} \cdot wCO2 + cp_{O2} \cdot wO2 + cp_{Ar} \cdot wAr + cp_{H2O} \cdot wH2O + cp_{N2} \cdot wN2$$

$$A_{CO2O2} = \frac{\left[1 + \left[\frac{\lambda_{CO2;tr}}{\lambda_{O2;tr}}\right]^{0,5} \cdot \left[\frac{M_{CO2}}{M_{O2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{CO2}}{M_{O2}}\right]\right]^{0,5}}$$

$$A_{CO2N2} = \frac{\left[1 + \left[\frac{\lambda_{CO2;tr}}{\lambda_{N2;tr}}\right]^{0,5} \cdot \left[\frac{M_{CO2}}{M_{N2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{CO2}}{M_{N2}}\right]\right]^{0,5}}$$

$$A_{CO2Ar} = \frac{\left[1 + \left[\frac{\lambda_{CO2;tr}}{\lambda_{Ar;tr}}\right]^{0,5} \cdot \left[\frac{M_{CO2}}{M_{Ar}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{CO2}}{M_{Ar}}\right]\right]^{0,5}}$$

$$A_{CO2H2O} = \frac{\left[1 + \left[\frac{\lambda_{CO2;tr}}{\lambda_{H2O;tr}}\right]^{0,5} \cdot \left[\frac{M_{CO2}}{M_{H2O}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{CO2}}{M_{H2O}}\right]\right]^{0,5}}$$

$$A_{N2Ar} = \frac{\left[1 + \left[\frac{\lambda_{N2;tr}}{\lambda_{Ar;tr}}\right]^{0,5} \cdot \left[\frac{M_{N2}}{M_{Ar}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{N2}}{M_{Ar}}\right]\right]^{0,5}}$$

$$A_{N2O2} = \frac{\left[1 + \left[\frac{\lambda_{N2;tr}}{\lambda_{O2;tr}}\right]^{0,5} \cdot \left[\frac{M_{N2}}{M_{O2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{N2}}{M_{O2}}\right]\right]^{0,5}}$$

$$A_{N2H2O} = \frac{\left[1 + \left[\frac{\lambda_{N2;tr}}{\lambda_{H2O;tr}}\right]^{0,5} \cdot \left[\frac{M_{N2}}{M_{H2O}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{N2}}{M_{H2O}}\right]\right]^{0,5}}$$

$$A_{N2CO2} = \frac{\left[1 + \left[\frac{\lambda_{N2;tr}}{\lambda_{CO2;tr}}\right]^{0,5} \cdot \left[\frac{M_{N2}}{M_{CO2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{N2}}{M_{CO2}}\right]\right]^{0,5}}$$

$$A_{ArCO2} = \frac{\left[1 + \left[\frac{\lambda_{Ar;tr}}{\lambda_{CO2;tr}}\right]^{0,5} \cdot \left[\frac{M_{Ar}}{M_{CO2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{Ar}}{M_{CO2}}\right]\right]^{0,5}}$$

$$A_{ArN2} = \frac{\left[1 + \left[\frac{\lambda_{Ar;tr}}{\lambda_{N2;tr}}\right]^{0,5} \cdot \left[\frac{M_{Ar}}{M_{N2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{Ar}}{M_{N2}}\right]\right]^{0,5}}$$

$$A_{ArO2} = \frac{\left[1 + \left[\frac{\lambda_{Ar;tr}}{\lambda_{O2;tr}}\right]^{0,5} \cdot \left[\frac{M_{Ar}}{M_{O2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{Ar}}{M_{O2}}\right]\right]^{0,5}}$$

$$A_{ArH2O} = \frac{\left[1 + \left[\frac{\lambda_{Ar;tr}}{\lambda_{H2O;tr}}\right]^{0,5} \cdot \left[\frac{M_{Ar}}{M_{H2O}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{Ar}}{M_{H2O}}\right]\right]^{0,5}}$$

$$A_{O2CO2} = \frac{\left[1 + \left[\frac{\lambda_{O2;tr}}{\lambda_{CO2;tr}}\right]^{0,5} \cdot \left[\frac{M_{O2}}{M_{CO2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{O2}}{M_{CO2}}\right]\right]^{0,5}}$$

$$A_{O2N2} = \frac{\left[1 + \left[\frac{\lambda_{O2;tr}}{\lambda_{N2;tr}}\right]^{0,5} \cdot \left[\frac{M_{O2}}{M_{N2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{O2}}{M_{N2}}\right]\right]^{0,5}}$$

$$A_{O2Ar} = \frac{\left[1 + \left[\frac{\lambda_{O2;tr}}{\lambda_{Ar;tr}}\right]^{0,5} \cdot \left[\frac{M_{O2}}{M_{Ar}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{O2}}{M_{Ar}}\right]\right]^{0,5}}$$

$$A_{O2H2O} = \frac{\left[1 + \left[\frac{\lambda_{O2;tr}}{\lambda_{H2O;tr}}\right]^{0,5} \cdot \left[\frac{M_{O2}}{M_{H2O}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{O2}}{M_{H2O}}\right]\right]^{0,5}}$$

$$A_{H2OO2} = \frac{\left[1 + \left[\frac{\lambda_{H2O;tr}}{\lambda_{O2;tr}}\right]^{0,5} \cdot \left[\frac{M_{H2O}}{M_{O2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{H2O}}{M_{O2}}\right]\right]^{0,5}}$$

$$A_{H2OCO2} = \frac{\left[1 + \left[\frac{\lambda_{H2O;tr}}{\lambda_{CO2;tr}}\right]^{0,5} \cdot \left[\frac{M_{H2O}}{M_{CO2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{H2O}}{M_{CO2}}\right]\right]^{0,5}}$$

$$A_{H2ON2} = \frac{\left[1 + \left[\frac{\lambda_{H2O;tr}}{\lambda_{N2;tr}}\right]^{0,5} \cdot \left[\frac{M_{H2O}}{M_{N2}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{H2O}}{M_{N2}}\right]\right]^{0,5}}$$

$$A_{H2OAr} = \frac{\left[1 + \left[\frac{\lambda_{H2O;tr}}{\lambda_{Ar;tr}}\right]^{0,5} \cdot \left[\frac{M_{H2O}}{M_{Ar}}\right]^{0,25}\right]^2}{\left[8 \cdot \left[1 + \frac{M_{H2O}}{M_{Ar}}\right]\right]^{0,5}}$$

$\lambda_{CO2;tr} = 0,987$

$\lambda_{O2;tr} = 0,965$

$\lambda_{Ar;tr} = 1,104$

$\lambda_{H2O;tr} = 0,344$

$\lambda_{N2;tr} = 1,141$

$$\psi_{CO2O2} = \left[\phi_{CO2O2} \cdot \left[1 + \left[\frac{M_{CO2} - M_{O2}}{M_{CO2} + M_{O2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{CO2O2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{CO2O2}}\right] \cdot \left[\frac{M_{O2}}{M_{CO2} - M_{O2}}\right]\right]$$

$$\psi_{CO2N2} = \left[\phi_{CO2N2} \cdot \left[1 + \left[\frac{M_{CO2} - M_{N2}}{M_{CO2} + M_{N2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{CO2N2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{CO2N2}}\right] \cdot \left[\frac{M_{N2}}{M_{CO2} - M_{N2}}\right]\right]$$

$$\psi_{CO2Ar} = \left[\phi_{CO2Ar} \cdot \left[1 + \left[\frac{M_{CO2} - M_{Ar}}{M_{CO2} + M_{Ar}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{CO2Ar}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{CO2Ar}}\right] \cdot \left[\frac{M_{Ar}}{M_{CO2} - M_{Ar}}\right]\right]$$

$$\psi_{CO2H2O} = \left[\phi_{CO2H2O} \cdot \left[1 + \left[\frac{M_{CO2} - M_{H2O}}{M_{CO2} + M_{H2O}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{CO2H2O}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{CO2H2O}}\right] \cdot \left[\frac{M_{H2O}}{M_{CO2} - M_{H2O}}\right]\right]$$

$$\psi_{N2Ar} = \left[\phi_{N2Ar} \cdot \left[1 + \left[\frac{M_{N2} - M_{Ar}}{M_{N2} + M_{Ar}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{N2Ar}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{N2Ar}}\right] \cdot \left[\frac{M_{Ar}}{M_{N2} - M_{Ar}}\right]\right]$$

$$\psi_{N2O2} = \left[\phi_{N2O2} \cdot \left[1 + \left[\frac{M_{N2} - M_{O2}}{M_{N2} + M_{O2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{N2O2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{N2O2}}\right] \cdot \left[\frac{M_{O2}}{M_{N2} - M_{O2}}\right]\right]$$

$$\psi_{N2H2O} = \left[\phi_{N2H2O} \cdot \left[1 + \left[\frac{M_{N2} - M_{H2O}}{M_{N2} + M_{H2O}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{N2H2O}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{N2H2O}}\right] \cdot \left[\frac{M_{H2O}}{M_{N2} - M_{H2O}}\right]\right]$$

$$\psi_{N2CO2} = \left[\phi_{N2CO2} \cdot \left[1 + \left[\frac{M_{N2} - M_{CO2}}{M_{N2} + M_{CO2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{N2CO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20,6}{30 - 8 \cdot A_{N2CO2}}\right] \cdot \left[\frac{M_{CO2}}{M_{N2} - M_{CO2}}\right]\right]$$

$$\psi_{ArCO2} = \left[\phi_{ArCO2} \cdot \left[1 + \left[\frac{M_{Ar} - M_{CO2}}{M_{Ar} + M_{CO2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{ArCO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{ArCO2}}\right] \cdot \left[\frac{M_{CO2}}{M_{Ar} - M_{CO2}}\right]\right]$$

$$\psi_{ArN2} = \left[\phi_{ArN2} \cdot \left[1 + \left[\frac{M_{Ar} - M_{N2}}{M_{Ar} + M_{N2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{ArN2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{ArN2}}\right] \cdot \left[\frac{M_{N2}}{M_{Ar} - M_{N2}}\right]\right]$$

$$\psi_{ArO2} = \left[\phi_{ArO2} \cdot \left[1 + \left[\frac{M_{Ar} - M_{O2}}{M_{Ar} + M_{O2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{ArO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{ArO2}}\right] \cdot \left[\frac{M_{O2}}{M_{Ar} - M_{O2}}\right]\right]$$

$$\psi_{ArH2O} = \left[\phi_{ArH2O} \cdot \left[1 + \left[\frac{M_{Ar} - M_{H2O}}{M_{Ar} + M_{H2O}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{ArH2O}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{ArH2O}}\right] \cdot \left[\frac{M_{H2O}}{M_{Ar} - M_{H2O}}\right]\right]$$

$$\psi_{O2CO2} = \left[\phi_{O2CO2} \cdot \left[1 + \left[\frac{M_{O2} - M_{CO2}}{M_{O2} + M_{CO2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{O2CO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{O2CO2}}\right] \cdot \left[\frac{M_{CO2}}{M_{O2} - M_{CO2}}\right]\right]$$

$$\psi_{O2N2} = \left[\phi_{O2N2} \cdot \left[1 + \left[\frac{M_{O2} - M_{N2}}{M_{O2} + M_{N2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{O2N2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{O2N2}}\right] \cdot \left[\frac{M_{N2}}{M_{O2} - M_{N2}}\right]\right]$$

$$\psi_{O2Ar} = \left[\phi_{O2Ar} \cdot \left[1 + \left[\frac{M_{O2} - M_{Ar}}{M_{O2} + M_{Ar}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{O2Ar}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{O2Ar}}\right] \cdot \left[\frac{M_{Ar}}{M_{O2} - M_{Ar}}\right]\right]$$

$$\psi_{O2H2O} = \left[\phi_{O2H2O} \cdot \left[1 + \left[\frac{M_{O2} - M_{H2O}}{M_{O2} + M_{H2O}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{O2H2O}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{O2H2O}}\right] \cdot \left[\frac{M_{H2O}}{M_{O2} - M_{H2O}}\right]\right]$$

$$\psi_{H2OCO2} = \left[\phi_{H2OCO2} \cdot \left[1 + \left[\frac{M_{H2O} - M_{CO2}}{M_{H2O} + M_{CO2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{H2OCO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{H2OCO2}}\right] \cdot \left[\frac{M_{CO2}}{M_{H2O} - M_{CO2}}\right]\right]$$

$$\psi_{H2OO2} = \left[\phi_{H2OO2} \cdot \left[1 + \left[\frac{M_{H2O} - M_{O2}}{M_{H2O} + M_{O2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{H2OO2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{H2OO2}}\right] \cdot \left[\frac{M_{O2}}{M_{H2O} - M_{O2}}\right]\right]$$

$$\psi_{H2ON2} = \left[\phi_{H2ON2} \cdot \left[1 + \left[\frac{M_{H2O} - M_{N2}}{M_{H2O} + M_{N2}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{H2ON2}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{H2ON2}}\right] \cdot \left[\frac{M_{N2}}{M_{H2O} - M_{N2}}\right]\right]$$

$$\psi_{H2OAr} = \left[\phi_{H2OAr} \cdot \left[1 + \left[\frac{M_{H2O} - M_{Ar}}{M_{H2O} + M_{Ar}}\right]^2\right] \cdot \left[\frac{15}{4 \cdot A_{H2OAr}} - 1\right]\right] \cdot \left[1 + \left[\frac{20{,}6}{30 - 8 \cdot A_{H2OAr}}\right] \cdot \left[\frac{M_{Ar}}{M_{H2O} - M_{Ar}}\right]\right]$$

$$suma_{k;CO2} = 1 + \psi_{CO2O2} \cdot \frac{xO2}{xCO2} + \psi_{CO2N2} \cdot \frac{xN2}{xCO2} + \psi_{CO2Ar} \cdot \frac{xAr}{xCO2} + \psi_{CO2H2O} \cdot \frac{xH2O}{xCO2}$$

$$suma_{k;N2} = 1 + \psi_{N2O2} \cdot \frac{xO2}{xN2} + \psi_{N2CO2} \cdot \frac{xCO2}{xN2} + \psi_{N2Ar} \cdot \frac{xAr}{xN2} + \psi_{N2H2O} \cdot \frac{xH2O}{xN2}$$

$$suma_{k;O2} = 1 + \psi_{O2CO2} \cdot \frac{xCO2}{xO2} + \psi_{O2N2} \cdot \frac{xN2}{xO2} + \psi_{O2Ar} \cdot \frac{xAr}{xO2} + \psi_{O2H2O} \cdot \frac{xH2O}{xO2}$$

$$suma_{k;Ar} = 1 + \psi_{ArO2} \cdot \frac{xO2}{xAr} + \psi_{ArN2} \cdot \frac{xN2}{xAr} + \psi_{ArCO2} \cdot \frac{xCO2}{xAr} + \psi_{ArH2O} \cdot \frac{xH2O}{xAr}$$

$$suma_{k;H2O} = 1 + \psi_{H2OO2} \cdot \frac{xO2}{xH2O} + \psi_{H2ON2} \cdot \frac{xN2}{xH2O} + \psi_{H2OAr} \cdot \frac{xAr}{xH2O} + \psi_{H2OCO2} \cdot \frac{xCO2}{xH2O}$$

$$\lambda_{CO2} = \mathbf{k}\,(CO2\ ;\ T = t_{sp;str})$$

$\lambda_{N2} = \mathbf{k}(N2 ; T = t_{sp;str})$

$\lambda_{Ar} = \mathbf{k}(Ar ; T = t_{sp;str})$

$\lambda_{O2} = \mathbf{k}(O2 ; T = t_{sp;str})$

$\lambda_{H2O} = \mathbf{k}(H2O ; T = t_{sp;str})$

$$\lambda_{sp} = -1 \cdot \left[\frac{\lambda_{CO2}}{suma_{k;CO2}} + \frac{\lambda_{N2}}{suma_{k;N2}} + \frac{\lambda_{O2}}{suma_{k;O2}} + \frac{\lambda_{Ar}}{suma_{k;Ar}} + \frac{\lambda_{H2O}}{suma_{k;H2O}} \right]$$

vypocet soucinitele prestupu tepla spalin

$$Re_{sp} = \frac{w_{sp} \cdot d_{in}}{\nu_{sp}}$$

$$\nu_{sp} = \frac{\eta_{sp}}{\rho_{sp}}$$

$$a_{sp} = \frac{\lambda_{sp}}{1000 \cdot cp_{sp} \cdot \rho_{sp}}$$

$$Pr_{sp} = \frac{\nu_{sp}}{a_{sp}}$$

$Pr_{air} = \mathbf{Pr}(Air_{ha} ; T = t_{sp;str} ; P = 1)$

$Pr_{voda} = \mathbf{Pr}(Steam_{IAPWS} ; T = 30 ; P = 5)$

$Nuss_{sp} = 0{,}023 \cdot Re_{sp}^{0,8} \cdot Pr_{sp}^{0,4}$

$$l_{char} = \pi \cdot \frac{d_{out}}{2}$$

$$\alpha_{sp} = Nuss_{sp} \cdot \frac{\lambda_{sp}}{d_{in}}$$

vypocet soucinitele prestupu tepla vody

uhel trubek 60°

$t_{t1} = 1{,}732 \cdot d_{out}$

$t_{t2} = 0{,}5 \cdot d_{out}$

$t_p = 0{,}15$ *roztec prepazek*

$s_p = 0{,}015$ *tloustka prepazky*

$d_{svazek} = 4 \cdot t_{t1} + d_{out}$

$d_{trubkovnice} = d_{svazek} + t_{t1}$

$n_{tr;v} = 3$ *pocet trubek mimo prepazku*

$S_n = (t_p - s_p) \cdot d_{trubkovnice}$

$$x6 = \frac{t_{t1}}{d_{out}}$$

$$x7 = \frac{t_{t2}}{d_{out}}$$

$$x8 = \frac{n_{tr;v}}{n_{tr}}$$

$$Re_w = \frac{w_w \cdot l_{char}}{\frac{\eta_w}{\rho_w}}$$

$$w_w = \frac{m_w}{S_n \cdot \rho_w \cdot \left[1 - \frac{\pi}{4 \cdot x6}\right]}$$

$$\rho_w = \rho(\text{Water}; T = t_{w;str}; P = 5)$$

$$cp_w = \mathbf{Cp}(\text{Water}; T = t_{w;str}; P = 5)$$

$$\eta_w = \mathbf{Visc}(\text{Water}; T = t_{w;str}; P = 5)$$

$$\lambda_w = \mathbf{k}(\text{Water}; T = t_{w;str}; P = 5)$$

$$Pr_w = \frac{1000 \cdot cp_w \cdot \eta_w}{\lambda_w}$$

$$y2 = \left[\frac{Pr_w}{Pr_w \cdot S_n}\right]^{0,11}$$ *pro smer tepelneho toku do mp ^{0,25} ven z mp ^{0,11}*

$$y3 = 1 + \frac{2}{3 \cdot x7}$$

$$y4 = 1$$

$$y5 = 1 - x8 + 0,524 \cdot x8^{0,32}$$

$$y7 = 1$$

pro diry v prepazce 0,0132

$$d_{p;in} = 0,0132$$

$$d_p = 0,115$$

$$S_{tp} = \left[n_{tr} - \frac{n_{tr;v}}{2}\right] \cdot \frac{\pi \cdot (d_{p;in}^{\ 2} - d_{out}^{\ 2})}{4}$$

$$S_{ps} = \frac{\pi}{4} \cdot (d_{trubkovnice}^{\ 2} - d_p^{\ 2}) \cdot \left[360 - 2 \cdot \frac{\mathbf{arccos}\left[2 \cdot \frac{d_p}{d_{trubkovnice}} - 1\right]}{360}\right]$$

$$S_{wz} = d_{trubkovnice} - d_{svazek} + \left[(t_{t1} - d_{out}) \cdot \left[\frac{d_{svazek} - d_{out}}{t_{t1}}\right]\right] \cdot (t_p - s_p)$$

*y6=0,4*S_{tp}/($S_{tp+S,ps}$)+(1-0,4*$S_{tp/(S,tp+S,ps)}$)*exp(-1,5*($S_{tp+S,ps}$)/$s_{,wz}$)*

y6 uvazejeme pro ($s_{tp+s,ps}$)/$s_{wz<}$=0,8

v tomto pripade vychazi neco pres 90 --> neuvazujeme zkratove proudy v prepazce

$y6 = 1$

$s_{ss} = (d_{trubkovnice} - d_{svazek} - t_{t1} + d_{out}) \cdot (t_p - s_p)$

$Nuss_{lam} = 0{,}664 \cdot Re_w^{0{,}5} \cdot Pr_w^{(1/3)}$

$$Nuss_{turb} = \frac{0{,}0037 \cdot Re_w^{0{,}8} \cdot Pr_w}{1 + 2{,}443 \cdot Re_w^{-0{,}1} \cdot (Pr_w^{(2/3)} - 1)}$$

$Nuss_w = y2 \cdot y3 \cdot y4 \cdot y5 \cdot y6 \cdot y7 \cdot (0{,}3 + (Nuss_{lam}^{\ 2} + Nuss_{turb}^{\ 2})^{0{,}5})$

$$\alpha_w = \frac{Nuss_w \cdot \lambda_w}{l_{char}}$$

$\lambda_{ocel} = 15$ *AISI 316*

$$k_l = \frac{\pi}{\frac{1}{\alpha_{sp} \cdot d_{in}} + \frac{1}{2 \cdot \lambda_{ocel}} \cdot \ln\left[\frac{d_{out}}{d_{in}}\right] + \frac{1}{\alpha_w \cdot d_{trubkovnice}}}$$

$Q_{sp} \cdot 1000 = k_l \cdot l \cdot \delta_{t;ln}$

$$k_s = \frac{1}{\frac{d_{out}}{d_{in}} \cdot \frac{1}{\alpha_{sp}} + \frac{d_{out}}{2 \cdot \lambda_{ocel}} \cdot \ln\left[\frac{d_{out}}{d_{in}}\right] + \frac{1}{\alpha_w}}$$

$Q_{sp} \cdot 1000 = k_s \cdot S \cdot \delta_{t;ln}$

$$\delta_{t;ln} = \frac{t_{sp;in} - t_{w;out} - (t_{sp;out} - t_{w;in})}{\ln\left[\frac{t_{sp;in} - t_{w;out}}{t_{sp;out} - t_{w;in}}\right]}$$

$$l_{trubky} = \frac{l}{19}$$

tlakova ztrata hrdel spalin se nezapocitava do celkove tlakove ztraty vymeniku ale do ztraty potrubi

$d_{hs,in}$=0,05 {volím}
w_{hs}=m_{sp}/(((pi$d_{hs,in}$2)/4)*rho,sp)*
*Re_{hs}=(w_{hs}*d,hs,in)/(eta_{sp}/rho,sp)*
$psi_{13,s}$=1,4 {Re>2320}

$DELTA_{p,hs}$=$psi_{13,s}$((rho$_{sp}$*$w_{,hs}$2)/2)*

ztraty trenim v TP

$\lambda_{ts} = \frac{64}{Re_{sp}}$ *pro Re<2320*

$$k_r = \frac{k_{ocel}}{d_{in}}$$

$k_{ocel} = 0{,}0002$

$$z_{1s} = \frac{l_{trubky}}{d_{in}}$$

$$z_{2s} = \left[\frac{t_{w;str}}{t_{sp;str}}\right]^{0,81}$$

$$\Delta_{p;ts} = \lambda_{ts} \cdot \frac{\rho_{sp} \cdot w_{sp}^{2}}{2} \cdot z_{1s} \cdot z_{2s}$$

mistni ztraty v TP

$$\psi_{11} = 0,7$$

$$\Delta_{p;ms} = \psi_{11} \cdot \frac{\rho_{sp} \cdot w_{sp}^{2}}{2}$$

$$\Delta_{p;sp} = \Delta_{p;ts} + \Delta_{p;ms}$$

tlakova ztrata hrdel vody se stejn jako u spalin nezapocitava

$d_{hw,in}$=0,05
*w_{hw}=m_w/(((pi*$d_{hw,in}$2)/4)*$rho_{,w}$)*
*Re_{hw}=(w_{hw}*$d_{,hw,in}$)/($eta_{w/rho,w}$)*
$psi_{13,w}$=2 {Re<2320}

$DELTA_{p,hw}$=$psi_{13,w}$((rho_{w}*$w_{,hw}$2)/2) {mala protoze je mala rychlost vody}*

ztraty trenim v MP

$$\Delta_{p;to} = 2 \cdot \lambda_{tw} \cdot (n_p - 1) \cdot \rho_w \cdot w_{zw}^{2} \cdot z_{2w} \cdot z_{3w} \cdot z_{4w}$$

$$c1 = 26,2$$

$$a_1 = \frac{6,59}{1 + 0,14 \cdot Re_w^{a_3}}$$

$$a_2 = -0,913$$

$$a_3 = 0,52$$

$$t_t = 0,012 - 0,0084$$

$$n_p = 7$$

$$\lambda_{tw} = c1 \cdot \left[\frac{1,33}{\frac{t_t}{d_{out}}}\right]^{a_1} \cdot Re_w^{a_2}$$

$$w_{zw} = \frac{m_w}{S_{wz} \cdot \rho_w}$$

$$z_{2w} = \left[\frac{48}{t_{w;str}}\right]^{0,14}$$

$$z_{3w} = y7$$

$$z_{4w} = \mathbf{exp}\left[-1{,}33 \cdot \left[1 + \left[\frac{S_{ps}}{S_{ps} + S_{tp}}\right] \cdot \left[\frac{S_{ps} + S_{tp}}{S_{wz}}\right]^{x_{13}}\right]\right]$$

$$x_{13} = -0{,}15 \cdot \left[1 + \frac{S_{ps}}{S_{ps} + S_{tp}}\right] + 0{,}8$$

$\Delta_{p;tn} = 0{,}0015$

$\Delta_{p;tv} = 0{,}0082$

$\Delta_{p;tw} = \Delta_{p;to} + \Delta_{p;tn} + \Delta_{p;tv}$

SOLUTION

Unit Settings: SI C bar kJ mass deg

$\alpha_{sp} = 19{,}72$ | $\alpha_w = 1442$ | $a_1 = 2{,}829$
$a_2 = -0{,}913$ | $a_3 = 0{,}52$ | $A_{ArCO2} = 1{,}057$
$A_{ArH2O} = 2{,}001$ | $A_{ArN2} = 0{,}9772$ | $A_{ArO2} = 1{,}07$
$A_{CO2Ar} = 0{,}9452$ | $A_{CO2H2O} = 1{,}852$ | $A_{CO2N2} = 0{,}9187$
$A_{CO2O2} = 1{,}007$ | $A_{H2OAr} = 0{,}6235$ | $A_{H2OCO2} = 0{,}6455$
$A_{H2ON2} = 0{,}6138$ | $A_{H2OO2} = 0{,}651$ | $A_{N2Ar} = 1{,}01$
$A_{N2CO2} = 1{,}062$ | $A_{N2H2O} = 2{,}036$ | $A_{N2O2} = 1{,}087$
$A_{O2Ar} = 0{,}9356$ | $A_{O2CO2} = 0{,}9846$ | $A_{O2H2O} = 1{,}826$
$A_{O2N2} = 0{,}9192$ | $a_{sp} = 0{,}00004855$ | $c1 = 26{,}2$
$cp_{Ar} = 0{,}5203$ | $cp_{CO2} = 1{,}122$ | $cp_{H2O} = 2{,}074$
$cp_{N2} = 1{,}097$ | $cp_{O2} = 1{,}027$ | $cp_{sp} = 1{,}152$
$cp_w = 4{,}179$ | $\Delta = 973{,}6$ | $\Delta_{p,ms} = 5{,}997$
$\Delta_{p,sp} = 13{,}6$ | $\Delta_{p,tn} = 0{,}0015$ | $\Delta_{p,to} = 0{,}0197$
$\Delta_{p,ts} = 7{,}601$ | $\Delta_{p,tv} = 0{,}0082$ | $\Delta_{p,tw} = 0{,}0294$
$\delta_{t,ln} = 286$ | $D_{ArH2O} = 0{,}001469$ | $D_{ArO2} = 0{,}001475$
$D_{CO2Ar} = 0{,}001208$ | $D_{CO2H2O} = 0{,}001151$ | $D_{CO2N2} = 0{,}001158$
$D_{CO2O2} = 0{,}001208$ | $d_{in} = 0{,}0084$ | $D_{N2Ar} = 0{,}001405$
$D_{N2H2O} = 0{,}001412$ | $D_{N2O2} = 0{,}0014$ | $D_{O2H2O} = 0{,}001478$
$d_{out} = 0{,}012$ | $d_p = 0{,}115$ | $d_{p,in} = 0{,}0132$
$d_{svazek} = 0{,}09514$ | $d_{trubkovnice} = 0{,}1159$ | $ek_{Ar} = 143{,}2$
$ek_{ArH2O} = 340{,}4$ | $ek_{ArO2} = 130{,}3$ | $ek_{CO2} = 195{,}2$
$ek_{CO2Ar} = 167{,}2$ | $ek_{CO2H2O} = 397{,}4$ | $ek_{CO2N2} = 139$
$ek_{CO2O2} = 152{,}1$ | $ek_{H2O} = 809{,}1$ | $ek_{N2} = 98{,}94$
$ek_{N2Ar} = 119$ | $ek_{N2H2O} = 282{,}9$ | $ek_{N2O2} = 108{,}3$
$ek_{O2} = 118{,}5$ | $ek_{O2H2O} = 309{,}6$ | $\eta_{Ar} = 0{,}00004267$
$\eta_{CO2} = 0{,}00003133$ | $\eta_{H2O} = 0{,}00002514$ | $\eta_{N2} = 0{,}00003217$
$\eta_{O2} = 0{,}00003809$ | $\eta_{sp} = 0{,}00002435$ | $\eta_w = 0{,}0008416$
$i_{Ar,in} = 468{,}3$ | $i_{Ar,out} = 34{,}24$ | $i_{CO2,in} = 996{,}5$
$i_{CO2,out} = 55{,}91$ | $i_{H2O,in} = 4398$ | $i_{H2O,out} = 2622$
$i_{N2,in} = 996{,}5$ | $i_{N2,out} = 68{,}3$ | $i_{O2,in} = 922{,}2$
$i_{O2,out} = 60{,}29$ | $i_{sp,in} = 1196$ | $i_{sp,out} = 222{,}8$
$i_{w,in} = 63{,}46$ | $i_{w,out} = 168$ | $k_l = 0{,}519$
$k_{ocel} = 0{,}0002$ | $k_r = 0{,}02381$ | $k_s = 13{,}65$
$l = 20{,}38$ | $\lambda_{Ar} = 0{,}03253$ | $\lambda_{Ar,tr} = 1{,}104$
$\lambda_{CO2} = 0{,}04691$ | $\lambda_{CO2,tr} = 0{,}987$ | $\lambda_{H2O} = 0{,}05668$
$\lambda_{H2O,tr} = 0{,}344$ | $\lambda_{N2} = 0{,}04937$ | $\lambda_{N2,tr} = 1{,}141$
$\lambda_{O2} = 0{,}05582$ | $\lambda_{O2,tr} = 0{,}965$ | $\lambda_{ocel} = 15$
$\lambda_{sp} = 0{,}02842$ | $\lambda_{ts} = 0{,}06287$ | $\lambda_{tw} = 34{,}05$
$\lambda_w = 0{,}6108$ | $l_{char} = 0{,}01885$ | $l_{trubky} = 1{,}073$
$M_{Ar} = 40$ | $M_{CO2} = 44$ | $M_{H2O} = 18$
$M_{N2} = 28$ | $M_{O2} = 32$ | $m_{sp} = 0{,}003107$
$m_w = 0{,}02894$ | $Nuss_{lam} = 10{,}36$ | $Nuss_{sp} = 5{,}829$
$Nuss_{turb} = 0{,}1508$ | $Nuss_w = 44{,}51$ | $\nu_{sp} = 0{,}00004792$
$n_p = 7$ | $n_{tr} = 19$ | $n_{tr,v} = 3$

ω_{ArH2O} = 1,07
ω_{CO2H2O} = 1,132
ω_{N2Ar} = 0,8183
ω_{O2H2O} = 1,037
ϕ_{ArN2} = 1,325
ϕ_{CO2H2O} = 2,046
ϕ_{H2OAr} = 1,058
ϕ_{H2OO2} = 1,099
ϕ_{N2H2O} = 2,957
ϕ_{O2CO2} = 1,733
$pp_{sp,H2O}$ = 0,1
Pr_{voda} = 5,421
ψ_{ArCO2} = -40,5
ψ_{ArO2} = 16,97
ψ_{CO2N2} = 8,452
ψ_{H2OCO2} = -3,193
ψ_{N2Ar} = -8,796
ψ_{N2O2} = -26,4
ψ_{O2H2O} = 8,119
Q_{sp} = 3,025
Re$_w$ = 75,8
ρ_{H2O} = 0,3143
ρ_{sp} = 0,5082
σ_{Ar} = 3,35
σ_{CO2} = 3,941
σ_{CO2N2} = 3,799
σ_{N2} = 3,656
σ_{N2O2} = 3,542
$suma_{Ar}$ = 247,2
$suma_{k,Ar}$ = 916,2
$suma_{k,N2}$ = -1,736
$suma_{O2}$ = 20,8
S_{ps} = 0,06006
S_{wz} = 0,02553
$t_{sp,in}$ = 900
t_t = 0,0036
$t_{w,in}$ = 15
$T°_{ArH2O}$ = 2,028
$T°_{CO2H2O}$ = 1,737
$T°_{N2Ar}$ = 5,799
$T°_{O2H2O}$ = 2,229
wH2O = 0,06173
w_{sp} = 5,806
x6 = 1,732
xAr = 0,006
xN2 = 0,7
y2 = 1,58
y5 = 1,132
z_{1s} = 127,7
z_{3w} = 1

ω_{ArO2} = 0,8331
ω_{CO2N2} = 0,8443
ω_{N2H2O} = 1,008
ϕ_{ArCO2} = 1,667
ϕ_{ArO2} = 1,383
ϕ_{CO2N2} = 1,009
ϕ_{H2OCO2} = 1,399
ϕ_{N2Ar} = 1,474
ϕ_{N2O2} = 1,593
ϕ_{O2H2O} = 2,627
Pr_{air} = 0,7091
Pr_w = 5,759
ψ_{ArH2O} = 5,718
ψ_{CO2Ar} = 30,12
ψ_{CO2O2} = 10,37
ψ_{H2ON2} = -7,535
ψ_{N2CO2} = -8,166
ψ_{O2Ar} = -14,68
ψ_{O2N2} = 31,81
R = 8314
ρ_{Ar} = 0,6959
ρ_{N2} = 0,4879
ρ_w = 996,6
σ_{ArH2O} = 2,996
σ_{CO2Ar} = 3,646
σ_{CO2O2} = 3,685
σ_{N2Ar} = 3,503
σ_{O2} = 3,428
$suma_{CO2}$ = 8,256
$suma_{k,CO2}$ = 61,84
$suma_{k,O2}$ = 308,8
S_n = 0,01565
s_{ss} = 0,00162
t_p = 0,15
$t_{sp,out}$ = 65,81
t_{t1} = 0,02078
$t_{w,out}$ = 40
$T°_{ArO2}$ = 5,299
$T°_{CO2N2}$ = 4,967
$T°_{N2H2O}$ = 2,44
wAr = 0,00823
wN2 = 0,6722
w_w = 0,003396
x7 = 0,5
xCO2 = 0,12
xO2 = 0,07
y3 = 2,333
y6 = 1
z_{2s} = 0,1105
z_{4w} = 0,03457

ω_{CO2Ar} = 0,8787
ω_{CO2O2} = 0,8606
ω_{N2O2} = 0,8034
ϕ_{ArH2O} = 2,594
ϕ_{CO2Ar} = 0,9947
ϕ_{CO2O2} = 1,06
ϕ_{H2ON2} = 1,084
ϕ_{N2CO2} = 1,881
ϕ_{O2Ar} = 1,349
ϕ_{O2N2} = 1,396
Pr_{sp} = 0,9869
ψ_{11} = 0,7
ψ_{ArN2} = 12,27
ψ_{CO2H2O} = 4,781
ψ_{H2OAr} = -3,02
ψ_{H2OO2} = -5,072
ψ_{N2H2O} = 9,659
ψ_{O2CO2} = -12,04
p_{sp} = 1
Re_{sp} = 1018
ρ_{CO2} = 0,7669
ρ_{O2} = 0,5576
S = 0,7748
σ_{ArO2} = 3,389
σ_{CO2H2O} = 3,291
σ_{H2O} = 2,641
σ_{N2H2O} = 3,149
σ_{O2H2O} = 3,035
$suma_{H2O}$ = 10,1
$suma_{k,H2O}$ = -59,31
$suma_{N2}$ = 0,9168
s_p = 0,015
S_{tp} = 0,0004156
t_{sat} = 45,81
$t_{sp,str}$ = 417,1
t_{t2} = 0,006
$t_{w,str}$ = 27,5
$T°_{CO2Ar}$ = 4,129
$T°_{CO2O2}$ = 4,538
$T°_{N2O2}$ = 6,375
wCO2 = 0,1811
wO2 = 0,07682
w_{zw} = 0,001138
x8 = 0,1579
xH2O = 0,1
x_{13} = 0,501
y4 = 1
y7 = 1
z_{2w} = 1,081

50 potential unit problems were detected.