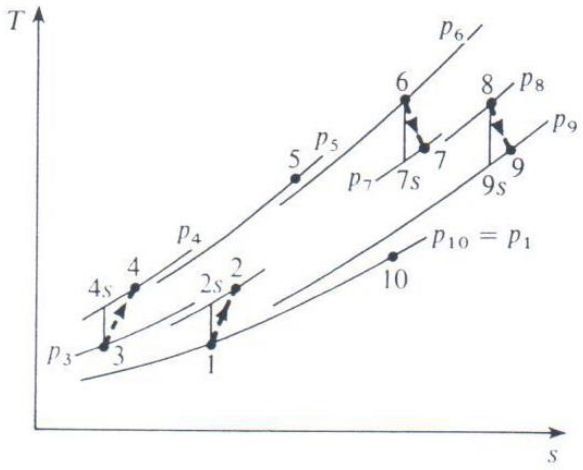
Example 9

For the gas turbine generating set of example 8 recalculate the cycle efficiency and the work ratio, taking the following pressure losses into account but assuming all other assumptions still apply: air side of HE, 0.3bar; gas inside of HE and exhaust duct, 0.05bar; intercooler, 0.15bar; each combustion chamber, 0.2bar.

Take the ambient pressure of 1.01bar, a pressure ratio for each compressor of 3:1 as previously calculated and find a new overall pressure ratio for the compression. All other data are unchanged. χs describe losses.



Previously known,

$T_{2s} = 394.20\text{K}; \quad T_2 = T_4 = 420.75\text{K}; \quad W_{in}$ per compressor stage $= 133.41\text{kJ/kg}$

$$P_3 = \left(r_p \times P_1\right) - \chi_{intercooling} = (3 \times 1.01) - 0.15 = 2.88\text{bar}$$
$$P_4 = \left(r_p \times P_3\right) = 3 \times 2.88 = 8.64\text{bar}$$

$$r_{p\,overall,new} = \frac{P_4}{P_1} = \frac{8.64}{1.01} = 8.55 \text{ compare with } r_{p\,overall,old} = 9$$

$$P_6 = P_4 - \chi_{HE,a} - \chi_{cc} = 8.64 - 0.3 - 0.2 = 8.14\text{bar}$$

Previously known,

$$W_{out,HPturb} = 272.27; \quad T_7 = 686.24\text{K}; \quad T_{7s} = 644.46\text{K}; \quad \frac{P_6}{P_7} = 4.19$$

Then

$$P_7 = \frac{P_6}{4.19} = \frac{8.14}{4.19} = 1.94\text{bar}$$

Then,

$$P_8 = (P_7 - \chi_{cc}) = (1.94 - 0.2) = 1.74 bar$$

$$P_{10} = P_1 = 1.01 bar$$

Therefore,

$$P_9 = P_{10} + \chi_{HE} = 1.01 + 0.05 = 1.06 bar$$

$$\frac{P_8}{P_9} = \frac{1.74}{1.06} = 1.64$$

$$\frac{T_8}{T_{9s}} = \left(\frac{P_8}{P_9}\right)^{\gamma/\gamma-1} = (1.64)^{0.333/1.333}$$

Therefore,

$$T_{9s} = \frac{T_8}{(1.64)^{\gamma-1/\gamma}} = \frac{923}{(1.64)^{0.333/1.333}} = 815.51K$$

$$\eta_{LT} = \frac{T_8 - T_9}{T_8 - T_{9s}} = 0.85$$

$$T_9 = T_8 - (T_8 - T_{9s}) \times \eta_{LT} = 923 - (923 - 815.51) \times 0.85 = 831.63K$$

$$W_{out,LT} = C_{pg}(T_8 - T_9) = 1.15(923 - 831.63) = 105.08 kJ / kg$$

$$Thermal ratio = \frac{T_5 - T_4}{T_9 - T_4}$$

$$0.75 = \frac{T_5 - 420.75}{831.63 - 420.75}$$

$$T_5 = 728.91K$$

$$q_{in} = C_{pg}(T_6 - T_5) + C_{pg}(T_8 - T_7) = 1.15(923 - 728.91) + 1.15(923 - 686.24) = 495.47 kJ / kg$$

$$\eta_{cycle} = \frac{W_{out,net}}{q_{in}} = \frac{105.08}{495.47} = 0.2120$$

This compares with the previous value of 28.73% when pressure losses are neglected.

The gross work of the plant is;

$$W_{gross} = Workout_{HT} + Workout_{LT} = 272.27 + \frac{105.08}{0.98} = 379.49 kJ/kg$$

$$Workratio = \frac{W_{net}}{W_{gross}} = \frac{105.08}{379.49} = 0.2769$$

$$Power = \dot{m} \times Workratio$$

$$\dot{m} = \frac{Power}{Workout_{net}} = \frac{5000}{105.08} = 47.58 kg/s$$