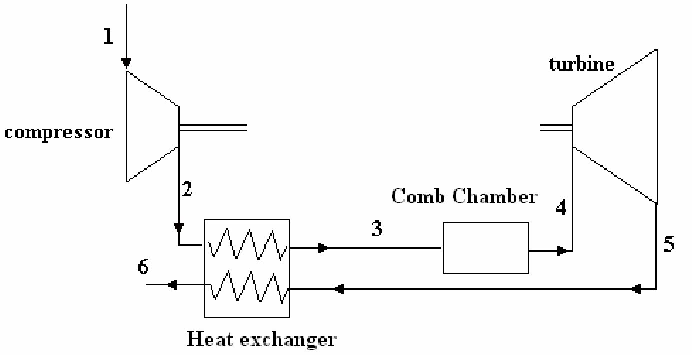
Q2 A schematic of a regenerative gas turbine is shown. Air ($\gamma = 1.4$) enters the compressor at a pressure of 1 bar and a temperature of 20°C. The compressor has an isentropic efficiency of 85% and a pressure ratio of 10:1. The expansion process in the turbine is polytropic, that is $pv^n$ = constant, with n = 1.35. The plant exhaust gas temperature, that is point 6, is 20°C higher than that at the compressor outlet.




Assume that $p_6 = p_5 = p_1 = 1$ bar, $T_4 = 1000^oC$ and the specific heat capacity is constant throughout the cycle with $C_P = 1.005$ kJ/kgK.
(a) Sketch the T-s diagram for the cycle illustrating the regenerative heat exchange process.
(b) Calculate,
(i) the heat transfer in the heat exchanger
(ii) the heat supplied in the combustion chamber
(iii) the cycle efficiency.

**SOLUTION**

$$T_{2'} = T_1\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} = 293(10)^{\frac{1.4-1}{1.4}} = 565.7\ \text{K}$$

$$\eta_{IS} = 0.85 = \frac{T_{2'} - T_1}{T_2 - T_1} = \frac{565.7 - 293}{T_2 - 293} \quad T_2 = 613.8\ \text{K}$$

$T_5 = T_4/r_p^{(1-1/n)} = 1273/(10)^{0.259} = 730$ K

Heat Exchanger with same specific heat and mass flow at all points

$T_6 = T_2 + 20 = 633.8$ K

$(T_3 - T_2) = (T_5 - T_6) \qquad T_3 = T_5 - T_6 + T_2 = 730 - 633.8 + 613.8 = 710$ K

It willbe assumed that m = 1 kg throughout

HEAT EXCHANGER

Heat Transfer = m $c_p$ $(T_3 - T_2)$ = 1 x 1.005 x (710 - 613.6) = 99.75 kJ/kg

COMBUSTION CHAMBER

Q(in) = m $c_p$ $(T_4 - T_3)$ = 1 x 1.005 (1273-710) = 565.8 kJ/kg

The main problem here is the turbine has a heat loss since the expansion is polytropic and we either need to find the heat loss or the power output in order to find the cycle efficiency.

For a steady flow process the work done is :

$$W(out) = \frac{mR}{n-1}(\Delta T) = \frac{1 \times 0.287}{1.35 - 1}(1273 - 730) = 445.36\ \text{kJ/k}$$

(Turbine)

W(in)= $mc_p(T_2 - T_1)$ = 1 x 1.005 (613.8 - 293) = 322.4 kJ/kg (Compressor)

W(nett) = W(out) - W(in) = 123 kJ/kg

$\eta_{th}$ = W(nett)/Q(in) = 123/565.8 = **0.22 or 22%**