ME 24-221
THERMODYNAMICS I

Solutions to Quiz 7
December 1, 2000
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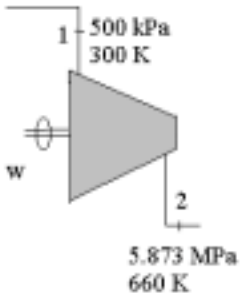
Given:



Air; Compressor
State 1: P_1 = 500 kPa; T_1 = 300 K
State 2: P_2 = 5.873 Mpa; $T_{2,ac}$ = 660 K
Variable specific heats

To Find: Isentropic efficiency η_s

Solution: ***Solution using variable specific heats***

Use Table A.7 for Air, variable specific heats.

From FLT, for CV; SSSF

Work done actually: $w_{ac} = h_1 - h_{2,ac}$

h_1 = 300.473 kJ/kg ; P_{r2} = 1.11458; (for 300 K)

$h_{2,ac}$ = 670.776 kJ/kg (for 660 K)

Hence, $\underline{w_{ac}} = h_1 - h_{2,ac}$ = 300.473 – 670.776 = <u>-370.303</u> kJ/kg (actual work *on* the CV)

Work done Isentropically: $w_s = h_1 - h_{2,s}$

If the process were isentropic then, $\frac{P_{r2}}{P_{r1}} = \frac{P_2}{P_1} \Rightarrow P_{r2} = P_{r1}\frac{P_2}{P_1} = 1.11458\frac{5873}{500} = 13.092$

For P_{r2} = 13.092, $T_{2,s}$ = 600 K. Therefore, $h_{2,s}$ = 607.316

Hence, $\underline{w_s} = h_1 - h_{2,s}$ = 300.473 – 607.316 = <u>-306.843</u> kJ/kg (isentropic work *on* CV)

Isentropic efficiency (for compressor) $\eta_s = \frac{w_s}{w_{ac}} = \frac{306.843}{370.303} = \mathbf{0.828;\ i.e.,\ 82.8\%}$

Solution using constant specific heats

When specific heats are constant, then $k = \frac{C_p}{C_v}$ is a constant. For air, Cp = 1.004 kJ/kg.K, C_v = 0.717 kJ/kg.K and k = 1.4.

Hence $T_{2,s} = T_1\left[\frac{P_2}{P_1}\right]^{\left(\frac{k-1}{k}\right)} = 300\left[\frac{5873}{500}\right]^{\left(\frac{1.4-1}{1.4}\right)} = 606.4627\,\text{K}$

$\underline{w_{ac}} = h_1 - h_{2,ac} = C_p(T_1 - T_{2,ac}) = 1.004(300 - 660) = \underline{-361.44}$ kJ/kg (actual work *on* CV)

$\underline{w_s} = h_1 - h_{2,s} = C_p(T_1 - T_{2,s}) = 1.004(300 - 606.4627) = \underline{-307.6885}$ kJ/kg (isentropic work *on* CV)

Isentropic efficiency (for compressor) $\eta_s = \frac{w_s}{w_{ac}} = \frac{307.6885}{361.44} = \mathbf{0.85;\ i.e.,\ 85\%}$