Homework 9

Wednesday, April 21, 2021 8:05 PM

"I pledge my honor I have abided by the Stevens Honor system."
- Alex Gaskins

Mechanical Energy

1. A river flowing steadily at a rate of 175 m³/s is being considered for hydroelectric power generation. It is determined that a dam can be built to collect water and release it from an elevation difference of 80 m to generate power. Determine how much power can be generated from this river water after the dam is filled. Is the answer you get realistic? (15)

$\dot{m} = \rho \dot{V} = 1000(175) = 175000$

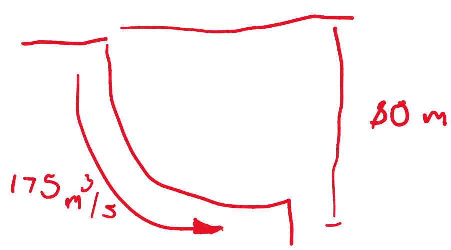
$P = \dot{m} g h$

$v_1 = v_2 ; \Delta V = 0$

$P = 175000(9.81)(80)$

$\boxed{P = 137.34 \text{ MW}}$

∴ Realistic



2. A typical 50 cm diameter room fan is desired to generate an airflow of 7.5 m/s. How much power does this fan require? Is this answer realistic? Why or why not? [15]

$\rho = 1.225 \text{ kg/m}^3$

$A = \frac{1}{4}(\pi (d)^2)$

$\dot{m} = \rho A v = 1.225(\frac{1}{4}(\pi(.5)^2))(7.5)$

$P = \dot{m} v (v) = 1.225(\frac{1}{4}(\pi(.5)^2))(7.5)(7.5)(7.5)$

$P = 13.5297(7.5)$

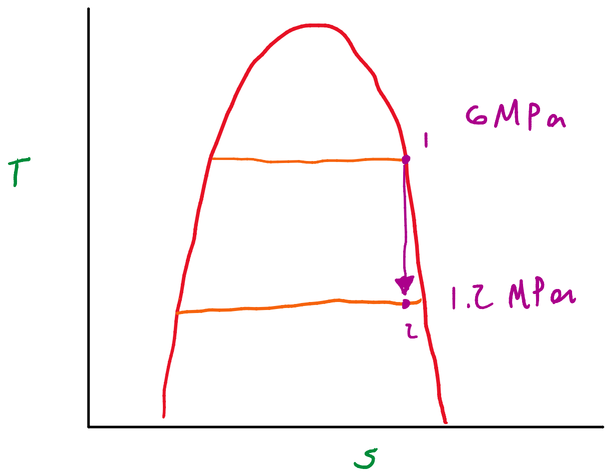
$P = 101.478 \text{ W}$

∴ Realistic because energy is lost as heat and due to air resistance

Entropy

3. Steam enters a steady-flow adiabatic nozzle with a low inlet velocity (assume ~0 m/s) as a saturated vapor at 6 MPa and expands to 1.2 MPa. [15]
   a. Under what conditions is the velocity from this nozzle maximized? Sketch the T-s diagram for this process.

For the maximum exit velocity, $h_1 - h_2$ should also be maximized, requiring an isentropic process.



b. Determine the maximum possible exit velocity in m/s.

@6MPa $h_1 = h_g = 2784.6$ kJ/kg $\quad s_1 = s_g = 5.8902$ kJ/kgK

@1.2 MPa $h_{f_2} = 798.33$ kJ/kg $\quad h_{fg2} = 1985.4$ kJ/kg

$s_{f_2} = 2.2159$ kJ/kgK $\quad s_{fg2} = 4.3058$ kgK

$s_1 = s_2$

$s_{f_2} + x\, s_{fg2} = s_1$

$2.2159 + x(4.3058) = 5.8902$

$x = \dfrac{5.8902 - 2.2159}{4.3058}$

$x = .853$

$h_2 = h_{f_2} + x(h_{fg2})$

$h_2 = 798.33 + .8533(1985.4)$

$h_2 = 2492.47$ kJ/kg

$h_1 + \dfrac{V_1^2}{2} = h_2 + \dfrac{V_2^2}{2}$

$\ldots \quad 0 = \quad V_2^2$

$$h_1 - h_2 + 0 = \frac{V_2^2}{2}$$

$$(2784.6(10^3)) - (2492.47(10^3)) = \frac{V_2^2}{2}$$

$$\boxed{V_2 = 764.37\ m/s}$$

4. Helium gas is compressed from 90 kPa and 30°C to 450 kPa in a reversible, adiabatic process. Determine the final temperature and the work done, assuming the process takes place (a) in a piston-cylinder device and (b) in a steadyflow compressor. [15]

$$T_2 = 303\left(\frac{450}{90}\right) = 576.9\ K$$

$$E_i - E_o = \Delta E = W_{in} = m(u_2 - u_1)$$

$$w_{in} = c_v(T_2 - T_1)$$

$$W_{in} = 3.1156(576.9 - 303)$$

$$\boxed{W_{in} = 853.4\ kJ/kg}$$

$$\dot{W} + \dot{m}h_1 - \dot{m}h_2 = 0$$

$$\dot{W} = \dot{m}(h_2 - h_1) = c_p(T_2 - T_1)$$

$$\dot{W} = 5.1926(576.9 - 303)$$

$$\boxed{\dot{W} = 1422.3\ kJ/kg}$$

5. Argon gas enters an adiabatic compressor at 14 psia and 75°F with a velocity of 60 ft/s, and it exits at 200 psia and 240 ft/s. If the isentropic efficiency of the compressor is 87 percent, determine (a) the exit temperature of the argon and (b) the work input to the compressor. [20]

$$T = T\left(\frac{P_2}{\ }\right)^{\frac{k-1}{k}} = 526\left(\frac{200}{\ }\right)^{\frac{1.667-1}{1.667}} = 1553\ R$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 536\left(\frac{200}{14}\right)^{\frac{1.667-1}{1.667}} = 1553\ R$$

$$KE = \frac{V_2^2 - V_1^2}{2} = \frac{(240)^2 - (60)^2}{2} = \frac{27000}{25037} = 1.078\ \frac{Btu}{lbm}$$

$$\eta = \frac{h_s - h_1 + KE}{h_2 - h_1 + KE} = \frac{c_p(T_s - T_1) + KE}{c_p(T_2 - T_1) + KE}$$

$$\eta(c_pT_2 - c_pT_1) + \eta(KE) = c_p(T_s - T_1) + KE$$

$$\eta c_p T_2 = c_pT_s - c_pT_1 + KE + c_pT_1 - \eta KE$$

$$T_2 = \left(1 - \frac{1}{\eta}\right)\left(T_1 - \frac{KE}{c_p}\right) + \frac{T_s}{\eta}$$

$$T_2 = \left(1 - \frac{1}{.87}\right)\left(536 - \frac{1.078}{.1253}\right) + \frac{1553}{.87}$$

$$\boxed{T_2 = 1706\ R}$$

$$\dot{W} + \dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right)$$

$$w + c_pT_1 + \frac{V_1^2}{2} = c_pT_2 + \frac{V_2^2}{2}$$

$$w = c_p(T_2 - T_1) + KE = .1253(1706 - 536) + 1.078$$

$$\boxed{w = 147.68\ \frac{Btu}{lbm}}$$