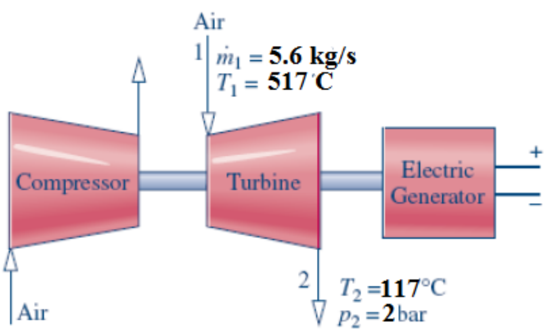
CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT

ME 211 THERMODYNAMICS I
Fall 2015

CHAPTER 4 EXAMPLES
SOLUTIONS

16)Figure given below shows a turbine operating at a steady state that provides power to an air compressor and an electric generator. Air enters the turbine with a mass flow rate of 5.6 kg/s at 517°C and exits the turbine at 117°C, 2 bar. The turbine provides power at a rate of 800 kW to the compressor and at a rate of 1200 kW to the generator. Air can be modeled as an ideal gas, and kinetic and potential energy changes are negligible. determine (a) the volumetric flow rate of the air at the turbine exit, in m^3/s, and (b) the rate of heat transfer between the turbine and its surroundings, in kW.



(a)Solution:

To determine the volumetric flow rate of the air at the turbine exit, proceed as follows:

At the steady state the mass flow rate at the inlet and the exit are equal.

$$\dot{m}_1 = \dot{m}_2$$

Here,
Mass flow rate at the inlet $(\dot{m}_1)$ is 5.6 kg/s,

Mass flow rate at the exit is $\dot{m}_2$.

Write the expression for volumetric flow rate $(\mathrm{AV})_2$ at the exit

$$(\mathrm{AV})_2 = \dot{m}_2 v$$
$$= \dot{m}_2\left(\frac{RT_2}{P_2}\right)$$

Here,

Gas constant (R) is $286.9\ \text{N}\cdot\text{m/kg}\cdot\text{K}$

Pressure (P_2) of air at exit is 2 bar

Exit temperature of air is 110°C

Substitute corresponding values in the expression of volumetric flow rate $(\text{AV})_2$ at the exit

$$(\text{AV})_2 = (5.6\ \text{kg/s})\frac{(286.9\ \text{N}\cdot\text{m/kg}\cdot\text{K})(390\ \text{K})}{2\times10^5\ \text{N/m}^2}$$

$$= 3.13\ \text{m}^3/\text{s}$$

Hence, the volumetric flow rate of the air at the turbine exit is $\boxed{3.13\ \text{m}^3/\text{s}}$.

(b)

To determine rate of heat transfer between the turbine and its surrounding, proceed as follows:

Calculate total transfer rate of power $\dot{W}_{cv}$

$$\dot{W}_{cv} = \dot{W}_{cv1} + \dot{W}_{cv2}$$

Here,

Transfer rate of power to turbine $\dot{W}_{cv1}$ is 800 kW

Transfer rate of power to generator $\dot{W}_{cv2}$ is 1200 kW

Substitute corresponding values in the expression of $\dot{W}_{cv}$

$$\dot{W}_{cv} = 800\ \text{kW} + 1200\ \text{kW}$$

$$= 2000\ \text{kW}$$

Write the energy rate balance expression

$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \dot{m}\left[(h_1 - h_2) + \frac{(\text{V}_1^2 - \text{V}_2^2)}{2} + g(z_1 - z_2)\right]$$

The control volume shown in the sketch is at steady state also by the given statement the kinetic and potential energy is neglected. Therefore the above transform to the following below expression:

$$\dot{Q}_{cv} = \dot{W}_{cv} + \dot{m}(h_2 - h_1)$$

Here,
From table A-22, the specific enthalpy (h_1) at the inlet is 810.99 kJ/kg
From table A-22, the specific enthalpy (h_2) at the exit is 390.88 kJ/kg

Substitute corresponding values in the expression of $\dot{Q}_{cv}$

$$\begin{aligned}\dot{Q}_{cv} &= 2000\text{ kW} + (5.6\text{ kg/s})(390.88 - 810.99)\text{ kJ/kg} \\ &= 2000\text{ kW} + (5.6\text{ kg/s})(-420.11)\text{ kJ/kg} \\ &= 2000\text{ kW} - 2352.61\text{ kW} \\ &= -352.61\text{ kW}\end{aligned}$$

Hence, the rate of heat transfer between the turbine and its surrounding is $\boxed{-352.61\text{ kW}}$