TT TEXTBOOK TESTBANKS

Test Bank for Fundamentals of Thermodynamics 11th Borgnakke

TEST BANK SAMPLE PREVIEW

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Test Bank for Fundamentals of Thermodynamics 11^{th} Edition by Borgnakke

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Thermo I, FINAL EXAM, 2 hours

Open book, no solved problems

Problem 1 (30 Points)

A 3.3 L American minivan engine running at 2000 RPM has a compression ratio of 10:1. The state before compression is 50 kPa, 280 K and after expansion the T is 750 K. Use constant specific heats for solution.

a) What is the highest T and P in the cycle?
b) What is the specific heat transfer added by combustion?
c) What is the mean effective pressure?
d) How much power does the engine produce?

Problem 2 (20 Points)

An adiabatic mixing chamber receives a flow of 1 kg/s steam at 400 kPa, 600°C and a flow of 2 kg/s steam at 1000 kPa, 200°C which is being throttled down to 400 kPa. The steady flow exits at 400 kPa.

a) What is the exit temperature?
b) Find the total entropy generation rate.

Problem 3 (20 Points)

Nitrogen at 600 kPa, 127°C is in a 0.5 m^3 piston-cylinder and now goes through a polytropic compression to 1800 kPa with n = 1.3.

a) Find the final temperature.
b) Find the process work.
c) Find the heat transfer in the process.

Problem 4 (30 Points)

An insulated tank contains 0.5 m^3 air at 100 kPa, 300 K. A reversible adiabatic compressor pushes ambient air at 100 kPa, 300 K into the tank until the tank pressure is 1000 kPa and stops.

a) How much mass was in the tank at the start of the process?
b) What is the final mass in the tank?
c) How much work input does the compressor require?

Thermo I FINAL EXAM, SOLUTION

Problem 1 (30 Points) This is a basic 4-stroke Otto cycle given by: CR, P_1, T_1, T_4

$$v_1 = RT_1/P_1 = 0.287 \text{ kJ/kg-K} \times 280 \text{ K}/50 \text{ kPa} = 1.6072 \text{ m}^3\text{/kg} = v_4$$

$$v_2 = v_1/CR = 0.16072 \text{ m}^3\text{/kg}$$

Combustion $v_3 = v_2$. Highest T and P are after combustion.

Expansion $T_4 = 750$ K so relate back to state 3

$$P_4 = RT_4 / v_4 = 0.287 \text{ kJ/kg-K} \times 750 \text{ K}/ 1.6072 \text{ m}^3\text{/kg} = 133.93 \text{ kPa}$$

$$P_3 = P_4 \, CR^k = 133.93 \text{ kPa} \times 10^{0.4} = \mathbf{3364.1 \ kPa}$$

$$T_3 = T_4 \, (v_4/v_3)^{k-1} = T_4 \ CR^{k-1} = 750 \times (10)^{0.4} = \mathbf{1883.9 \ K}$$

Compression: $T_2 = T_1(CR)^{k-1} = 280 \text{ K} \times (10)^{0.4} = 703.33$ K

$$q_H = u_3 - u_2 = C_v(T_3 - T_2) = 0.717 \, (1883.9 - 703.33) = \mathbf{846.49 \ kJ/kg}$$

To get the net work

$$\eta = 1 - CR^{1-k} = 1 - 10^{-0.4} = 0.602$$

$$w_{net} = \eta \, q_H = 0.602 \times 846.49 = 509.5 \text{ kJ/kg}$$

OR

$$q_L = u_4 - u_1 = C_v(T_4 - T_1) = 0.717 \text{ kJ/kg-K}(750 - 280)\text{K} = 336.99 \text{ kJ/kg}$$

$$w_{net} = q_H - q_L = 846.49 - 336.99 = 509.5 \text{ kJ/kg} \qquad]$$

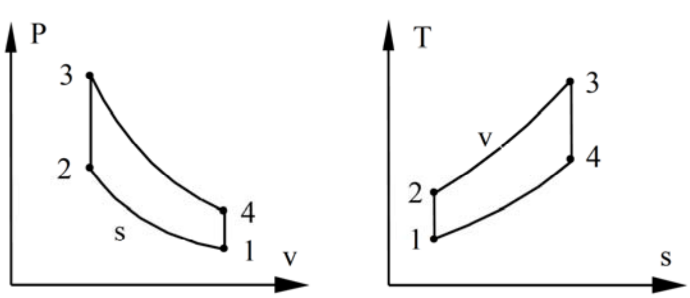
Displacement and mep from net work

$$P_{meff} = w_{net}/(v_1 - v_2) = 509.5 \text{ kJ/kg} /(1.6072 \times 0.9) \text{ m}^3\text{/kg} = \mathbf{352.2 \ kPa}$$

Total power from Eq. 10.11 and 4 stroke cycle

$$\dot{W} = P_{meff} V_{displ} \frac{RPM}{60} \frac{1}{2} = 352.2 \text{ kPa} \times 0.0033 \text{ m}^3 \times \frac{2000}{60} \text{ s}^{-1} \times \frac{1}{2}$$

$$= \mathbf{19.4 \ kW}$$



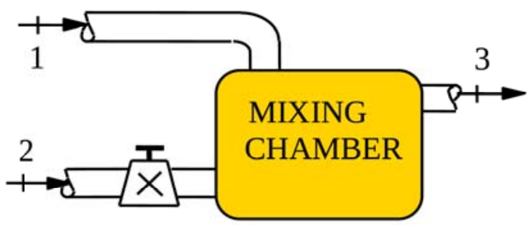
Problem 2 (20 Points)

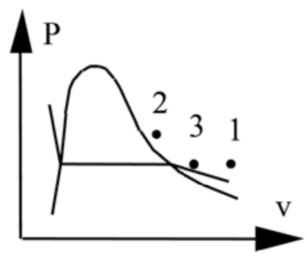
CV: Mixing chamber including valve, $\dot{Q} = 0$.

Continuity Eq.4.9: $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

Energy Eq.4.10: $\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

Entropy Eq.7.7: $\dot{m}_1 s_1 + \dot{m}_2 s_2 + \dot{S}_{gen} = \dot{m}_3 s_3$





From the energy equation, properties from B.1.3:

$$h_3 = (\dot{m}_1/\dot{m}_3)\, h_1 + (\dot{m}_2/\dot{m}_3)\, h_2 = \frac{1}{3}\, h_1 + \frac{2}{3}\, h_2$$

$$= [\, 3702.44 + 2 \times 2827.86] / 3 = 3119.39 \text{ kJ/kg}$$

Now state 3 (P, h)

$$T_3 = 300 + 100 \times \frac{3119.39 - 3066.75}{3273.41 - 3066.75} = 300 + 100 \times 0.2547 = \mathbf{325.5^oC}$$

$$s_3 = 7.5661 + 0.2547\ (7.8984 - 7.5661) = 7.65074 \text{ kJ/kgK}$$

Entropy generation from entropy equation

$$\dot{S}_{gen} = \dot{m}_3 s_3 - \dot{m}_1 s_1 - \dot{m}_2 s_2$$

$$= 3 \times 7.65074 \ \ - 8.4557 - 2 \times 6.6939 = \mathbf{1.109\ kW/K}$$

Problem 3 (20 Points)

CV nitrogen, this is a control mass.

Energy Eq.: $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Process eq.: polytropic: $Pv^n = C$, with $n = 1.3$

State 1 (P_1, T_1):

$$m_1 = P_1V_1/RT_1 = 600 \text{ kPa} \times 0.5 \text{ m}^3/(0.2968 \text{ kJ/kg-K} \times 400 \text{ K}) = 2.527 \text{ kg}$$

State 2 (P_2, on process path) polytropic and ideal gas gives

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 400 \times \left(\frac{1800}{600}\right)^{0.3/1.3} = \mathbf{515.42\ K}$$

Polytropic process work term from Eq.6.29

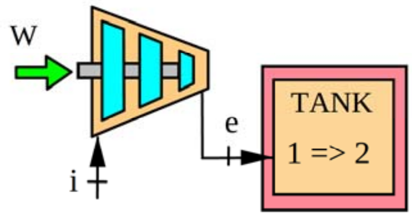
$$ {}_1W_2 = m\frac{R}{1 - n}(T_2 - T_1) = 2.527 \text{ kg} \times \frac{0.2968}{-0.3} \text{ kJ/kg-K} \times (515.42 - 400) \text{ K}$$
$$= \mathbf{-288.55\ kJ}$$

From the energy equation (use constant specific heats)

$$ {}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = mC_v(T_2 - T_1) + {}_1W_2$$
$$= 2.527\text{kg} \times 0.745 \text{ kJ/kg-K} \times (515.42 - 400) \text{ K} - 288.55 \text{ kJ}$$
$$\mathbf{= -71.26\ kJ}$$

Comment: process is internally reversible (Q leaves at local T which varies through process) but potentially externally irreversible.

Problem 4 (30 Points)



C.V. The tank volume and the compressor.
This is a transient problem (filling of tank).

Continuity Eq.4.20: $m_2 - m_1 = m_{in}$

Energy Eq.4.21: $m_2u_2 - m_1u_1 = {}_1Q_2 - {}_1W_2 + m_{in}h_{in}$

Entropy Eq.7.12: $m_2s_2 - m_1s_1 = \int dQ/T + {}_1S_{2\ gen} + m_{in}s_{in}$

Process: Adiabatic ${}_1Q_2 = 0$, Process ideal ${}_1S_{2\ gen} = 0$, $s_1 = s_{in}$

$$m_2s_2 = m_1s_1 + m_{in}s_{in} = (m_1 + m_{in})s_1 = m_2s_1 \quad => \quad s_2 = s_1$$

Constant s: Assume constant specific heats leads to polytropic process Eq.6.28

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 300\left(\frac{1000}{100}\right)^{0.2857} = 579.19 \text{ K}$$

$m_1 = P_1V_1/RT_1 = 100 \text{ kPa} \times 0.5\text{m}^3/(0.287 \text{ kJ/kg-K} \times 300 \text{ K}) =$ **0.5807 kg**

$m_2 = P_2V_2/RT_2 = 1000 \text{ kPa} \times 0.5 \text{ m}^3/(0.287 \text{ kJ/kg-K} \times 579.19 \text{ K})$

= **3.0079 kg**

$$m_{in} = m_2 - m_1 = 2.4272 \text{ kg}$$

Work from the energy equation

$${}_1W_2 = m_{in}h_{in} + m_1u_1 - m_2u_2 = m_{in}C_PT_{in} + m_1C_vT_1 - m_2C_vT_2$$

$$= [\ 2.4272 \times 1.004 \times 300 + 0.5807 \times 0.717 \times 300$$

$$- 3.0079 \times 0.717 \times 579.19\ ] \text{ kg} \times \text{kJ/kg-K} \times \text{K}$$

$$= -393.14 \text{ kJ}$$

$W_{in} =$ **393.14 kJ**