Problem 1
An internal combustion engine operates on the ideal Diesel cycle. Consider the second and third processes in the cycle

2nd Process: Constant Pressure Heating
3rd Process: Isentropic Expansion

The following operating conditions apply

Volume at Bottom Dead Center: 0.4 liters
Compression Ratio: 7.5
Cutoff Ratio: 1.7
Pressure of Constant Pressure Heating: 6 MPa
Maximum Cycle Temperature: 1900 K

Determine
a. Work output of these two processes
b. Availability of the air after the isentropic expansion

Answer:

a. \( W_{1-2} = P_1(V_2 - V_1) = (6000)(9.07 \times 10^{-5} - 5.33 \times 10^{-5}) = 0.224 \text{ kJ} \)
\( W_{2-3} = m(u_2 - u_3) = (9.9802 \times 10^{-4})(1582.6 - 931.92) = 0.644 \text{ kJ} \)
\( W_{\text{tot}} = 0.868 \text{ kJ} \)
\[
\Psi_3 = m \left[ u_3 - u_0 - T_0 \left( s_3^o - s_0^o - R \cdot \ln \left( \frac{P_3}{P_0} \right) \right) \right]
\]

b. \[= (9.9802 \times 10^{-4}) \left[ 931.92 - 212.64 - (298)(3.1773 - 1.6953 - (0.287)\ln \left( \frac{858.2}{100} \right) \right] \]
\[= 0.459 \text{ kJ} \]

**Problem 2**

Saturated liquid water flowing at 85 kg/s leaves the condenser of a steam power cycle operating at a pressure of 7.5 kPa. It then passes through a pump that raises its pressure to 5 MPa which is followed by an open feedwater heater. Steam at 5 MPa and 300°C also enters the open feedwater heater. Determine

a. Pump power required
b. Mass flow rate of steam into the open feedwater heater.

c. Pump power required for a pump isentropic efficiency of 63%

**Answer:**

<table>
<thead>
<tr>
<th>Node</th>
<th>T(°C)</th>
<th>P(kPa)</th>
<th>Phase</th>
<th>h(kJ/kg)</th>
<th>s(kJ/kg·K)</th>
<th>( \dot{m} ) (kg/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.29</td>
<td>7.5</td>
<td>Sat.Liq.</td>
<td>168.75</td>
<td>0.5763</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>40.45</td>
<td>5000</td>
<td>Sub.Liq.</td>
<td>173.82</td>
<td><strong>0.5763</strong></td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>5000</td>
<td>Sup.Vap.</td>
<td>2925.7</td>
<td>6.2111</td>
<td>47.03</td>
</tr>
<tr>
<td>4</td>
<td>263.94</td>
<td>5000</td>
<td>Sat.Liq.</td>
<td>1154.5</td>
<td>2.9207</td>
<td><strong>132.03</strong></td>
</tr>
</tbody>
</table>

*Italicized* values from steam tables. *Bold* values calculated.

b. \[
\dot{m}_3 = \dot{m}_2 \frac{h_2 - h_4}{h_3 - h_4} = (85) \frac{173.82 - 1154.05}{1154.05 - 2925.7} = 47.03 \text{ kg/s}
\]
\[
\dot{m}_4 = \dot{m}_2 + \dot{m}_3 = 85 + 47.03 = 132.03 \text{ kg/s}
\]
a. \[
\dot{W}_{\text{pump}} = \dot{m}_1 (h_1 - h_2) = (85)(168.75 - 173.82) = -430.95 \text{ kW}
\]
c. \[
\dot{W}_{\text{act}} = \dot{W}_{\text{ideal}} \frac{\eta_s}{\eta_s} = \frac{-430.95}{0.63} = -684 \text{ kW}
\]