Rankine Cycle Modifications & Optimization

Last time we introduced the Carnot cycle and showed that by operating this cycle in the vapor dome we can come close to approximating the Carnot.

There are several modifications to the Rankine cycle that can increase the efficiency of the cycle.

1) Lowering the Condenser Pressure

By lowering the condenser pressure we decrease the temperature at which heat is rejected from the cycle and decrease entropy generated.

Problems? Increased amount of liquid in turbine, not go below pump.

2) Superheating the steam to higher temperatures

By increasing the temperature of the steam leaving the boiler, this also makes it easier to decrease the condenser pressure.

Problems? Added problems in boiler.

Our best metals limit boiler to 628°C (1160°F)
3) Increasing the boiler pressure

Increasing the boiler pressure increases the average temperature that heat is added to the steam, increasing efficiency. Problems? The slight increase in stress on boiler... but we lose work from part of the diagram. How can we recapture this lost work?

4) Reheating the steam

By adding a second hot HEX & a second turbine to our system, we can use Reheat in our Rankine cycle to increase efficiency further.

* Example: \( T_0 = 825 \text{ k}, T_C = 30 \text{ k}, P_0 = 6 \text{ MPa}, \eta_T = 0.9, \eta_P = 0.5, \Delta T = 20 \text{ k}, \Delta T_{\text{cool}} = 5 \text{ k}, \Delta T_b = 25 \text{ k}. \) Find: Optimal pressure for reheat loop.
How do we start?

Make a diagram, table & figure out what we know.

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>P</th>
<th>x</th>
<th>h</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>300+5</td>
<td>0.0</td>
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<td>Boiler</td>
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<td>HPT</td>
<td>825-25 = P₂</td>
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<tr>
<td>Extract</td>
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<tr>
<td>LPT</td>
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<tr>
<td>Condenser</td>
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→ Assume fluid entering pump is saturated liquid.

→ Assume no pressure drop across heat exchangers.

→ Assume a reheat pressure initially, we're trying to optimize this.

→ Now go to EES