ON THE OPTIMIZATION OF ORC SYSTEMS

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1. Introduction

Subcritical and transcritical Rankine cycles operating between a low temperature heat source (T_{in} = 100, 165 and 230 °C) of fixed volume flowrate (1.2 10^3 m^3/h, idealized as atmospheric air at P_{in} = 101 kPa) and a fixed temperature heat sink (water at T_{p,in} = 10 °C) have been analyzed using the principles of classical and finite-size thermodynamics. The model of the system and its validation have been presented elsewhere.

Optimum operating conditions (pressure of the working fluid during heat addition, P_{ev}, and temperature difference DT between the working fluid and the two external fluids) and the corresponding values of several system characteristics have been determined for different net power outputs using the variable metric method for each of the following objectives: maximum thermal efficiency, minimum total exergy destruction, minimum total thermal conductance of the two heat exchangers U_{At} and minimum turbine size SP.

Typical results with R134a as the working fluid are presented.

2. Assumptions and Model

2.1 Assumptions:
- Each component is an open system in steady-state operation
- Kinetic and potential energy are neglected
- At exit from condenser the working fluid is saturated liquid
- Pressure and heat losses are neglected
- Fixed temperature heat sink (water at T_{p,in} = 10 °C)

2.2 Equations:
- Conservation of mass and energy for each component
- Relations between thermodynamic properties
- Definition of turbine and pump efficiencies

2.3 Performance indicators:
- Thermal efficiency (θ_{th})
- Non dimensional total exergy losses : (β)
  \[ β = \frac{W_{ref}}{M_e η_{th}} \]
- Non dimensional net output : (α)
  \[ α = \frac{W_{ref}}{W_{ref}} \]

3. Results for R134a

- T_{th,in} = 100 °C (Subcritical Cycle)
  DT (5 - 25) °C
  W_{ref} = 6897 kW

- T_{th,in} = 165 °C (Transcritical Cycle)
  DT (5 - 25) °C
  W_{ref} = 17565 kW

- T_{th,in} = 230 °C (Transcritical Cycle)
  DT (5 - 25) °C
  W_{ref} = 31158 kW

4. Conclusions

- At the turbine outlet the fluid is always superheated vapor.
- The lowest exergy losses as well as the smallest total conductance and turbine are obtained with T_{th,in} = 100 °C while the highest thermal efficiencies are obtained with T_{th,in} = 230 °C.
- The combinations of P_{ev} and DT which maximize η_{th} and minimize β are essentially identical. For these conditions α has no effect on η_{th}. On the other hand β as well as SP and U_{At} increase with α, albeit at different rates. In all these cases the pinch in the high temperature heat exchanger occurs at the heat source inlet.
- The combinations of P_{ev} and DT which minimize U_{At} and SP are different from each other and from those which maximize η_{th}. The conditions which minimize U_{At} give turbine sizes not much bigger than the corresponding minimum size; on the other hand, the conditions which minimize SP give a UA_{th} significantly bigger than the corresponding minimum values.

T-s Diagram of subcritical cycle

T-s Diagram of transcritical cycle