ORGANIC RANKINE CYCLE RECOVERING STAGE HEAT FROM MSF DESALINATION DISTILLATE WATER

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Overview

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1. Study Objective

- Part of a project aiming improvement of the MSF desalination holistic system efficiency.
- Recover heat from MSF desalination to power ORC to enhance system performance.
- Compare between R134a and R245fa refrigerants based on energy and exergy approach at different powering MSF stage parameters.
2. MSF Desalination Process Description.

- 75% of the world’s total desalted water in 2003 was produced using the MSF process.
- MSF Desalination is characterized over other desalination technologies by:
  - Highest production among other desalination (reaches to 91000 m$^3$/day).
  - High reliability and easy to control.
  - Low performance degradation over the years.
  - Less effect of seawater condition change.
- However, MSF desalination was the lowest exergy efficiency among all desalination technologies and highest power consumption.
2. **MSF Desalination Process Description.**

- The produced distillate from each stage moves to next stage in a common distillate corridor.
- Part from stage produced distillate re-flashes and re-condenses again when it moves to next stage since it maintains at lower pressure.
3. MSF Desalination Improvement.

- Distillate re-flashing and re-condensing phenomena reduces the MSF stage performance since this distillate occupies some of the area that should be used by flashing vapour.
- The effect of this phenomena increases more and more as MSF stages number rise due to increase of the accumulative distillate produced.
- Few studies addressed this issue (Sommariva et al. and Mussati et al.) suggesting extracting this distillate could enhance unit production.
- First implementation of distillate extraction from MSF was carried out on Layyah MSF unit 9 in Sharjha in UAE based on patent of Awerbuch and Sommariva and played the pivotal role on increasing unit product by 2% and distillate purity.
- Helal et al. pointed out necessity of utilizing the extracted distillate enthalpy before reconnect it with main product.
3. MSF Desalination Improvement.

- The extracted distillate owned a suitable parameters to power low grade heat technologies (e.g., ORC, MED desalination and Absorption chiller).
- A real MSF desalination unit in Oman was modelled and validated against vendor data.
- Produced distillate parameters for the first eight stages only will be considered in this study since they owned suitable temperature to power ORC (100 °C- 65 °C).
4. ORC Modelling and Validation.

- An actual ORC unit was modelled using IPSEpro software and validated against real unit data.

- Keeping actual unit equipment design specification constant, two refrigerants R134a and R245fa were tested at different operating parameters from MSF stages and Oman cooling water condition.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Existing unit</th>
<th>Model result</th>
<th>Difference [%]</th>
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<tbody>
<tr>
<td>Gross power</td>
<td>kW</td>
<td>250</td>
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<td>Net power</td>
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<td>Pump power consumption</td>
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<td>ORC efficiency</td>
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<td>Cooling water flow</td>
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<td>97.7</td>
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<td>Refrigerant flow</td>
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<td>Evaporator outlet temperature</td>
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<td>Evaporator heat transfer</td>
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<td>Condenser heat transfer</td>
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<td>Evaporator heat conductance</td>
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<td>98.0</td>
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<tr>
<td>Condenser heat conductance</td>
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<td>594</td>
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<td>Evaporator effectiveness</td>
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<tr>
<td>Condenser effectiveness</td>
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<td>Evaporator NTU</td>
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<td>Condenser NTU</td>
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<td>1.45</td>
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</table>
5. Energy and Exergy analysis of ORC.

- The results showed that produced power rises as number of MSF stages increases up to optimal stage and then drops.
- R134a generate more gross power than R245fa, but R245fa produces higher net power.

- 22.5 % of R134a gross power consumed by refrigerant pump.
- Only 5.4% in case of R245fa.
5. Energy and Exergy analysis of ORC.

- **Energy efficiency**: describes how much work output extracted from the input energy.

- **Exergy efficiency**: express how much actual work obtained from maximum possible theoretical available work.

- **Energy efficiency for both refrigerants** were observed reducing as number of MSF stages recovered increases due to decrease of powering temperature despite of distillate mass flow rate.
5. Energy and Exergy analysis of ORC.

- R245fa achieved higher exergy efficiency than R134a.
- Both refrigerants exergy efficiency increasing till optimal stage and then dropping (stage 3 for R245fa and stage 7 for R134a)
5. Energy and Exergy analysis of ORC.

- For both refrigerants evaporator was the main contributor for exergy destruction and then turbine.

R134a

R245fa
6. Conclusion.

- MSF desalination performance could be enhanced by extracting distillate from distillate corridor which reduces re-flashing and re-condensing phenomena.
- ORC unit was modelled and validated against existing unit.
- Investigation for powering ORC was carried out using two different refrigerants R134a and R245fa.
- The recovered sensible heat found able to generate up to 520 kW and 453 kW for ORC with R245fa and R134a respectively.
- Energy efficiency was observed reducing as number of recovered MSF stages increase.
6. Conclusion.

- Exergy efficiency was observed increasing till the optimal recovered stage and then dropping.
- ORC with R245fa owned higher exergy efficiency than R134a, optimal stage for R245fa was 3 while it was 7 for R134a.
- For both refrigerants evaporator was main contributor for exergy destruction followed by turbine.
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