Study on A Small Scale Solar Powered Organic Rankine Cycle Utilizing Scroll Expander

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There is a great amount of the low grade heat from the factories, solar energy, and geothermal.

The problems of environmental pollution such as the ozonosphere depletion and global warming phenomena.

Recovery of the low grade heat for electrical generation and refrigeration maybe a solution.
The principle of ORC cycle is similar with traditional Rankine cycle. The driven temperature of ORC cycle can be much lower than that of Rankine cycle depending on the choice of the working fluid.
Principle design of the system

Solar collector → Water pump → Heat recuperator → Working fluid pump → Liquid reservoir → Condenser → Cooling water circuit → Scroll expander → Heat supply → Electricity → Heat supply → Solar collector
## Working conditions of ORC

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>30°C</td>
</tr>
<tr>
<td>Boiling temperature</td>
<td>70-120°C</td>
</tr>
<tr>
<td>Condensing temperature</td>
<td>15°C</td>
</tr>
<tr>
<td>Boiling pressure</td>
<td>1~2MPa</td>
</tr>
</tbody>
</table>
Theoretical energy efficiency

Among R134a, R152a, R717, and R12, R12 shows the best performance while R717 shows the worst performance.

\[ \eta_I = \frac{\dot{w} - \dot{w}_{pump}}{\dot{q}} \]
Theoretical energy efficiency

The energy efficiency of R600 and R600a showed the better performance than other four working fluids.

\[ \eta_I = \frac{\dot{W} - \dot{W}_{pump}}{\dot{q}} \]
R600 and R600a showed different performances for different driven temperature. If considering the temperature lower than 100°C, R600a showed the best performance.
As one of the most important components of the solar ORC, a scroll expander test bench using heated compressed air as working fluid is designed and constructed.
Internal efficiency of the expander
Energy efficiency based on the performance of expander

![Graph showing energy efficiency based on temperature and pressure.]
Exergy efficiency based on the performance of expander
Energy efficiency under the condition of that the internal efficiency of the expander is 80%.

If the water collected by the solar energy is 90°C, the power generated by 5 kW hot water is about 0.6 kW.
Conclusions

In this paper a solar Organic Rankine Cycle (ORC) using scroll expander was investigated to convert the low temperature heat into electricity for the small-scale system.

- Compared with the other four working fluids, R600 and R600a could achieved highest first law efficiency and second law efficiency under the same working conditions.

- The internal efficiency of scroll expander was around 50%.

- The energy efficiency of the system is less than 0.1 if the heating temperature is lower than 100°C considering the internal efficiency of the expander, although the exergy efficiency can be as high as 0.3.
Perspective of the technology

- The internal efficiency of the expander is the critical limitation of the system. If the performance can be improved to 80% the electrical generation performance will be improved effectively.

- The technology can be utilized for the places with abundant solar energy and without electricity for the cogeneration of the hot water and the electricity.
Questions?

• Thank you!