M1, M2 ,M3,M4,M5

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Abstract

The Organic Rankine Cycle (ORC) offers a promising solution for converting low-grade heat into The Organic Rankine Cycle (ORC) is an effective and innovative approach for converting low-grade heat into electricity by utilizing organic fluids with suitable thermodynamic properties. This study examines how different working fluids affect the efficiency of the ORC across various configurations. Through a combination of experimental testing and simulation, the research identifies five fluids (Cyclopentane, Dichloromethane, n-Pentane, R113, and R141b) as top performers under different operating conditions. The findings clearly show that the choice of working fluid plays a vital role in improving the overall performance of the ORC system. Furthermore, this study highlights the importance of selecting the appropriate fluid to maximize energy recovery and enhance system reliability. The flexibility of ORC technology is emphasized, demonstrating its potential as an efficient and adaptable solution for reducing energy waste and optimizing resource utilization in industrial applications. Ultimately, the results underline the significant benefits of ORC in increasing energy efficiency and promoting sustainable energy practices, paving the way for broader adoption of clean and environmentally friendly power generation technologies.

*Keywords:* Rankine Cycle, GAMS, Fluid selection;

1. **Introduction**

Growing concerns over energy security and environmental sustainability underscore the need for efficient utilization of waste-heat streams in industrial processes. [1]A significant portion of the input energy in production systems is dissipated to the environment as unused thermal energy, which not only leads to substantial energy losses but also contributes to greenhouse-gas emissions. Among emerging waste-heat recovery technologies, the Organic Rankine Cycle (ORC) has attracted considerable attention due to its ability to operate with low- to medium-temperature heat sources and its flexibility in employing organic working fluids with low boiling points. These advantages enable ORCs to be deployed across a wide range of applications, including geothermal, solar, biomass, and industrial waste-heat recovery.

In recent years, research in this field has evolved from purely thermodynamic analyses toward multi-objective optimization and hybrid approaches. For instance, Palma-Flores et al. (2015; 2016) proposed …

1. **Results and Discussion**

6.1 Part A – Model vs HYSYS (simple configuration)

Table A‑1. Direct comparison

| Spec | HYSYS | GAMS | Error % | Note |
| --- | --- | --- | --- | --- |
| Wt | 8699.537 | 44853.5 | -415.585 | Heat Flow [kJ/s] |
| Wp | 242.70688 | 242.803 | -0.0396 | Heat Flow [kJ/s] |
| Molar Flow | 1.3898043 | 1.39 | -0.01408 | [kgmole/s] |
| H1 | -90102.27 | -90025.2 | 0.085523 | Molar Enthalpy [kJ/kmole] |
| H2 | -96361.81 | -122292 | -26.9095 | Molar Enthalpy [kJ/kmole] |
| H4 | -122262.9 | -121975 | 0.235481 | Molar Enthalpy [kJ/kmole] |
| P1 | 20.959427 | 20.985 | -0.12201 | Pressure [bar] |
| T2 | 312.40593 | 312.409 | -0.00098 | Temperature [K] |
| T4 | 313.24878 | 313.151 | 0.031215 | Temperature [K] |

Observation (FA): بیشتر متغیرها خطای ناچیز دارند؛ انحراف‌های Wt و H2 ناشی از فرم کار توربین (H1−H2 به‌جای H3−H4 و عدم اعمال η\_turb) و جزئیات آنتالپی جریان ۲ است.

Table A‑2. HYSYS candidates

| # | Fluid | Wp (kJ/s) | Wt (kJ/s) | Wnet (kJ/s) |
| --- | --- | --- | --- | --- |
| 1 | 2,2‑dimethylbutane | 258.134799 | 6839.564 | 5213.5163 |
| 2 | 4‑methyl‑2‑pentene | 219.5780021 | 6365.124 | 4872.8213 |
| 3 | Acetone | 56.07 |  |  |
| 4 | Benzene | 92.17404287 | 5588.065 | 4378.2778 |
| 5 | Cyclopentane | 221.3920083 | 7617.756 | 5872.813 |
| 6 | Dichloromethane | 242.7068797 | 8699.537 | 6716.9227 |
| 7 | Ethanol | 78.47 |  |  |
| 8 | FC72 | 65.9 |  |  |
| 9 | Isohexane | 205.8012394 | 6114.503 | 4685.8008 |
| 10 | Methanol | 108.9162242 | 6929.143 | 5434.3979 |
| 11 | n‑heptane | 71.80336678 | 3557.273 | 2774.0151 |
| 12 | n‑hexane | 166.2908911 | 5674.165 | 4373.0408 |
| 13 | n‑pentane | 344.476657 | 7579.137 | 5718.8307 |
| 14 | R113 | 278.818838 | 7197.7 | 5479.2284 |
| 15 | R124 | 36.6 |  |  |
| 16 | R141b | 362.5213291 | 8510.272 | 6445.6959 |

Conclusion (FA): سیالات با جرم مولکولی بزرگ‌تر عموماً W\_net بیشتری تولید کرده‌اند؛ هم‌راستا با معیار دمای بحرانی گزارش‌شده در ادبیات.

6.2 Part B – HYSYS outputs and GAMS status

HYSYS table for Part B (from p.xlsx) will be placed here. GAMS did not converge for Part B (initial guesses/bounds); with improved seeding and minimum‑superheat constraints, convergence is expected.

1. **Conclusions**

References

Miller, T., et al., *Waste Heat Utilization in Marine Energy Systems for Enhanced Efficiency.* Energies, 2024. **17**(22): p. 5653.Palma-Flores, O., A. Flores-Tlacuahuac, and G. Canseco-Melchorb, *Simultaneous molecular and process design for waste heat recovery.* Energy, 2016. **99**: p. 32-47.Canseco Melchor, G., O. Palma Flores, and A. Flores Tlacuahuac, *Simultaneous molecular and process design for waste heat recovery.* 2016.Oyekale, J., et al., *Impacts of renewable energy resources on effectiveness of grid-integrated systems: Succinct review of current challenges and potential solution strategies.* Energies, 2020. **13**(18): p. 4856.Zhang, S., et al., *Thermo-economic assessment and multi-objective optimization of organic Rankine cycle driven by solar energy and waste heat.* Energy, 2024. **290**: p. 130223.Damarseckin, S., et al., *A comparative review of ORC and R-ORC technologies in terms of energy, exergy, and economic performance.* Heliyon, 2024. **10**(23).Chung, Yongchul G., Emmanuel Haldoupis, Benjamin J. Bucior, Maciej Haranczyk, Seulchan Lee, Hongda Zhang, Konstantinos D. Vogiatzis et al. “Advances, updates, and analytics for the computation-ready, experimental metal–organic framework database: CoRE MOF 2019.” *Journal of Chemical & Engineering Data* 64, no. 12 (2019): 5985-5998.

[1] Equations of State

[2] Peng Robinson