TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Mechanical Science and Engineering Bitzer Chair of Refrigeration, Cryogenics and Compressor Technology

Modular Organic Rankine Cycle (ORC) Systems for Low-Enthalpy Waste Heat

Benedikt Meyer (benedikt.meyer@tu-dresden.de) // Christiane Thomas // Ullrich Hesse

Motivation

The Organic Rankine Cycle (ORC) is a well known and proven technology for power generation out of high-enthalpy sources like large geothermal sources, exhaust gas from combustion engines and gas turbines or high temperature waste heat from industrial processes. Indeed, in the field of low-enthalpy sources where an ORC system with an electrical net power output below 100 kW_{el} is needed, the technology is still not widespread. Nevertheless it is very important to focus on these systems because the low-enthalpy sources have the largest share among the industrial waste heat. Currently this unexploited potential of energy is not used due to the low efficiency and the high specific costs which results in a very challenging economic operation.

Key issues

Modularization and Standardization

To overcome theses economical reasons for small size ORC systems in the range on 10 to 100 kW_{el} it is important to reduce the manufacturing, developing and component costs by modularization and standardization. Currently, some manufacturers connect ORC modules in parallel to scale the system to the desired size of power. Indeed, it is important to further improve the level of modularization by covering the entire range of power and temperature using one kind of standardized module.

Objectives

- Standardized ORC modules consist of identical components (esp. HX, expander and pump) with the same size and dimensions
- Adapting an ORC power plant to the diverse heat source conditions by connecting standardized modules in parallel (scaling to power) and in series (scaling to temperature)

Challenges of a Series Connection

- To minimize the number of modules in series, it is worth extracting a high amount of heat from the waste heat stream in each module. This requires large temperature differences in the stream per module.
- Pump and expander have to deal with different evaporation pressure levels. This results in varying pressure ratios.
- The efficiency increases with higher temperatures.

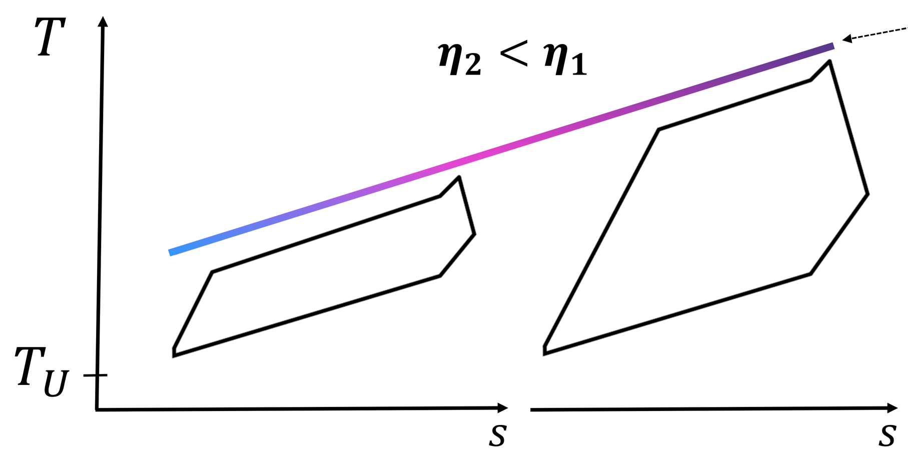

Fig. 1: T-s-chart of a series connection of two ORC-modules

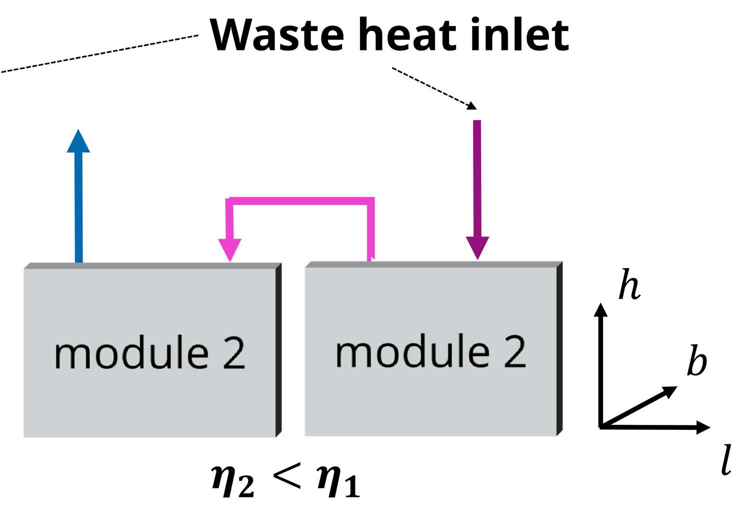

Fig. 2: Series connection of two ORC-modules

$P_{el,2} = P_{el,1}$

$(h \cdot b \cdot l)_2 = (h \cdot b \cdot l)_1$

➢ objective

$(h \cdot b \cdot l)_2 > (h \cdot b \cdot l)_1$

$P_{el,2} < P_{el,1}$

Series and parallel connection of identical ORC modules with different generators

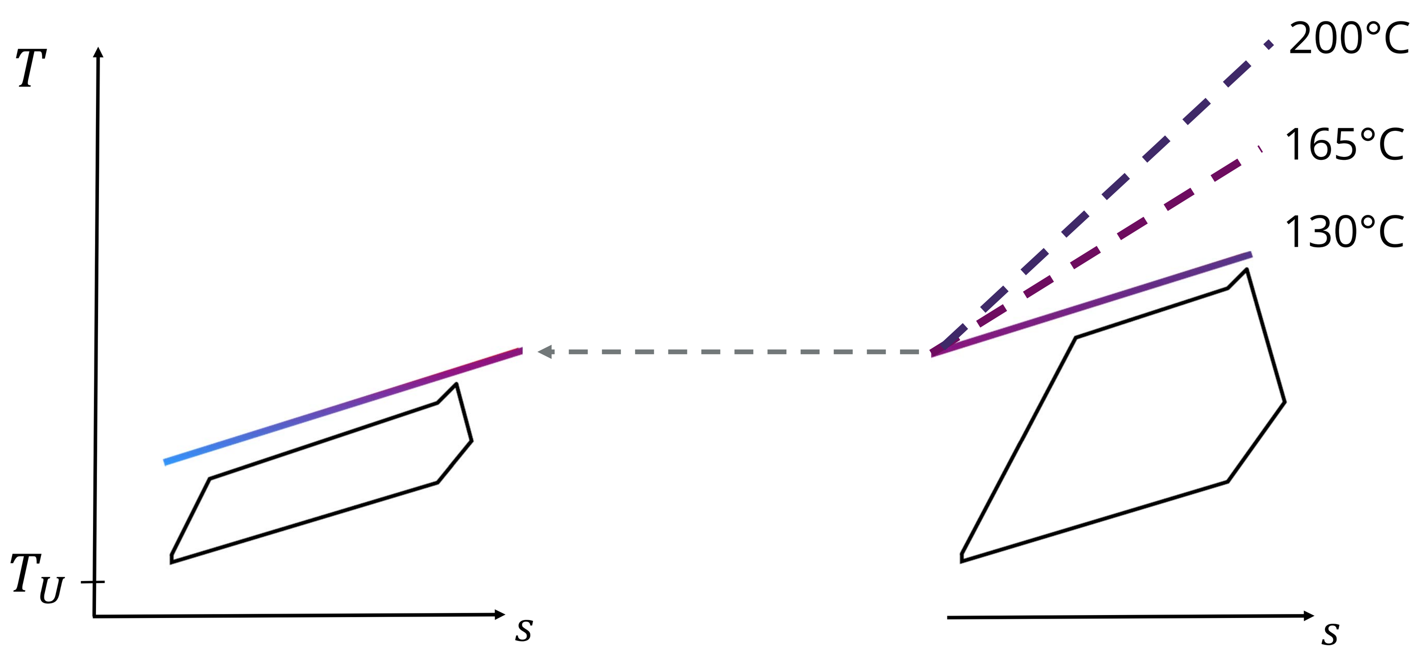

Fig. 3: T-s-chart of the sources and the ORC-processes at different temperature levels

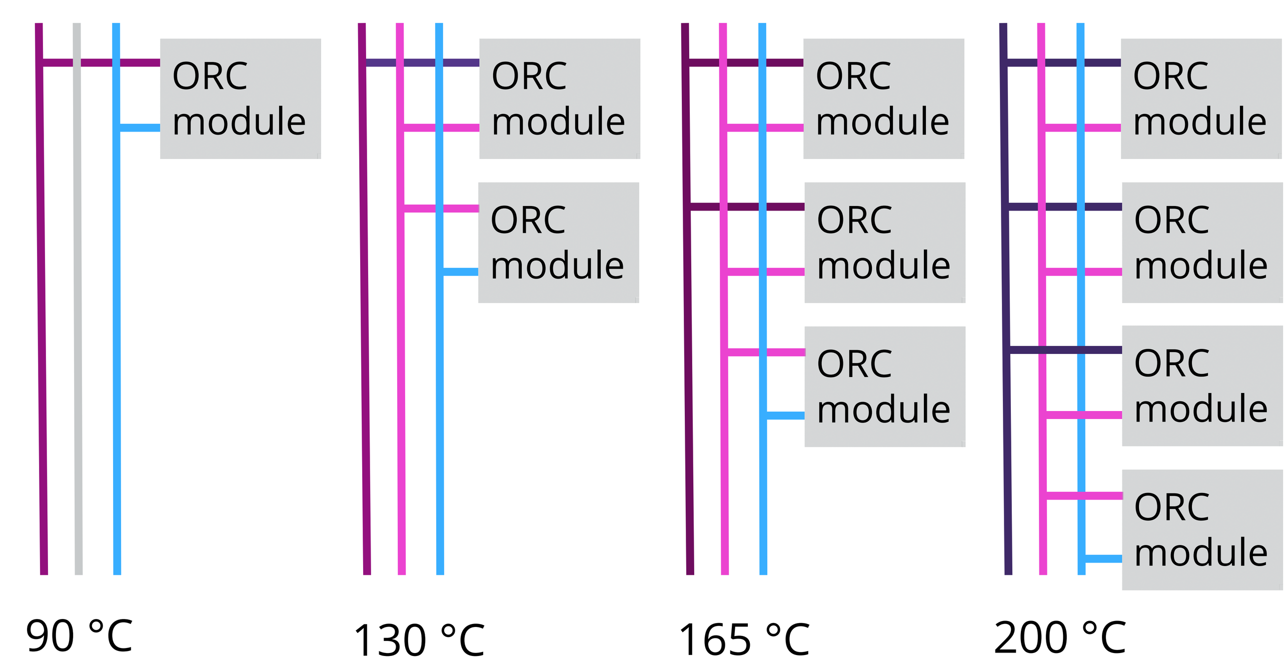

Fig. 5: Connection of ORC-modules at different temperature levels

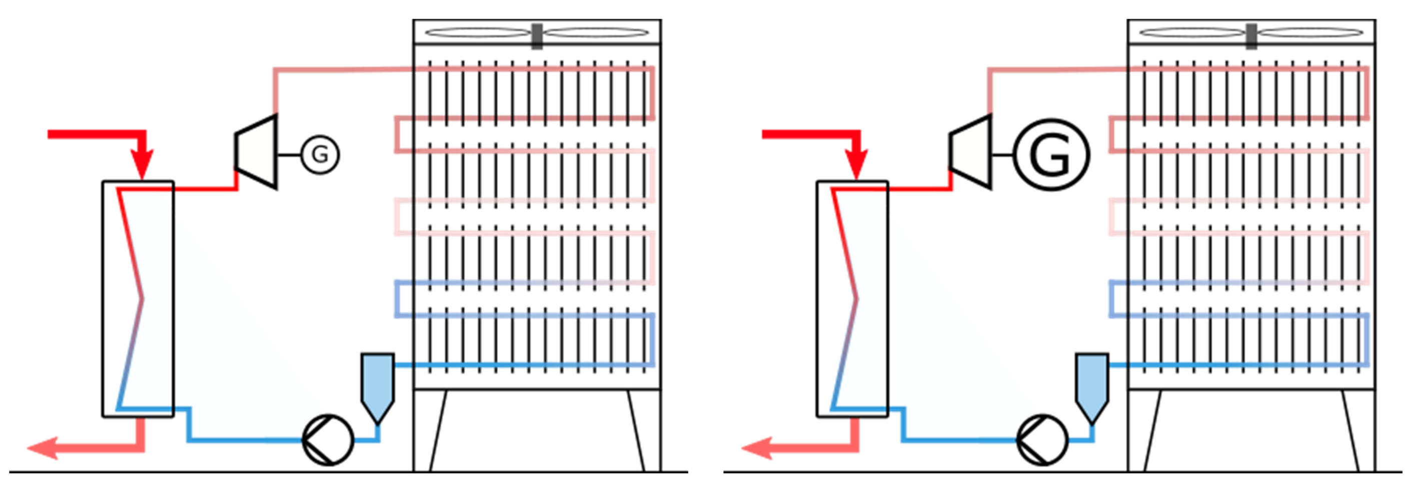

Fig. 4: Two types of identical ORC-modules with different generator sizes

Conclusion

- Zeotropic mixtures with large temperature glides are necessary
- Gear pump and screw expander with slide valve allow variable pressure levels
- Different sizes of the generator for different types of modules are appropriate

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