Abstract

More and more people are faced with the effects of global warming in their day-to-day lives. This fact, alongside the ever-growing world's energy demand, creates an increasing need for the efficient use of different energy resources. The low-temperature heat-conversion technology of the Organic Rankine Cycle (ORC) can help fulfil this need by contributing its share towards a carbon and climate neutral future and by improving the efficient use of already available energy resources. ORC's transform low-temperature heat into useful work, making it possible to use renewable heat energy sources such as concentrated solar, geothermal heat and waste heat.

The organic Rankine cycle is a thermodynamic cycle that is derived from the Rankine cycle. The Rankine Cycle, a fundamental cycle in thermodynamics, serves as the cornerstone for a vast majority of power generation systems. This cycle, characterized by its four-stage process of pressurisation, heat addition, expansion, and heat rejection, forms the basis for most high power steam power plants worldwide. The organic Rankine cycle is similar in design but differs in some key parts of its execution. First, organic Rankine cycles use an organic compound as the working fluid instead of water. Second, organic Rankine cycles operate at much lower temperatures than Rankine cycles. And third, organic Rankine cycles can be much smaller in size and be built for smaller power applications. Because of these reasons, ORC's are an excellent candidate for a plethora of renewable sources.

In this paper, the organic Rankine cycle is applied to the renewable energy source of geothermal energy. The goal of the analysis is to determine a realistic cycle efficiency of such an ORC, using an optimal working fluid. Furthermore, some additional exploration on the sizing of components with respect to the cycle efficiency is carried out. To do so, the literature on the subject is thoroughly explored. In the exploration of the literature, first, the general theoretical backbone of ORC is examined. Next, the large range of working fluids are investigated and their efficiencies and environmental/health impact assessed. Then, the different cycle designs are discussed. Afterwards, the different key components of the cycle are considered. And finally, the applications of ORC are looked into, with special attention given to geothermal energy.

From this literature study, the baseline parameters for an ORC model using a geothermal heat source are derived (a heat source temperature of 150°C, a heat sink temperature of 12°C, a mass flow rate of 10 kg/s and a mechanical power output 400 kW). Then, a baseline model is constructed with the key building blocks of an ORC, namely: a pump, an expander, a condenser and an evaporator. Afterwards, the baseline model is expanded by considering the recuperator in the heat-regeneration cycle. Next, additional real-world considerations are added by looking at losses due to friction, heat transfer, and entropy increases in the expander and heat exchanger. Then, an optimal working fluid is selected using the real-world model by considering cycle efficiency, environmental impact and health-and safety concerns. In addition, the trade-off between cycle efficiency and installation sizing is discussed. Finally, a sensitivity analysis is carried out to act as a robustness check on the results and the effect of a variable heat source is considered.

The results of the analysis show that, from a techno-economic standpoint, the most optimal cycle has a cycle efficiency of 19%. This was achieved by using isobutane (R600a) as a working fluid, with turbine inlet and outlet temperature and pressure of 145 °C and 30 bar, and 73 °C and 3.5 bar, respectively.