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Utilization of Waste Heat from Condenser of Steam Power Plant Using Organic Rankine Cycle

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Abstract

Steam power plants are one of the most popular plants for power production. Condenser is one of the important components of the steam power plants, where exiting fluid from the turbine is condensed. This process releases some heat to the environment. The aim of the present work is energy and exergy analysis of recovering the waste heat using Organic Rankine Cycle (ORC). To reach the best results, three working fluids (toluene, R600a and n-heptane) are selected as working fluids in the ORC. A parametric study is also performed to reveal effect of steam cycle condenser pressure on the cycle performance.

Results showed that toluene has the best performance from the energy and exergy viewpoints. Boiler has the highest and pumps have the lowest exergy destruction values among the system components. Also, increasing the steam cycle condenser pressure decreases the net produced power and increases the total energy and exergy efficiencies.

Keywords: *energy-exergy-waste heat recovery-Rankine cycle-organic fluid*

Introduction

Developing techniques for designing efficient and cost-effective energy systems is one of the foremost challenges that energy engineers face. In a world with finite natural resources and increasing energy demand by developing countries, it becomes increasingly important to understand the mechanisms which degrade energy and resources and to develop systematic approaches for improving the design of energy systems and reducing the impact on the environment.

Organic Rankine cycle (ORC) shows great potential because of its desirable thermal efficiency, low maintenance requirements, and high reliability [1]. A dual-loop organic Rankine cycle (ORC) system has been designed to recover the waste heat of a diesel engine. The high-temperature (HT) loop utilizes the heat load of the engine exhaust gas, and the low-temperature (LT) loop uses the heat load of the jacket cooling water and the residual heat of the HT loop, sequentially [2]. The working fluid candidates for the LT loop are chosen to be R123, R236fa and R245fa. Devotta and Holland [3] compared the cycle efficiency of 24 working fluids using four performance indicators for the selection of the appropriate working fluid for the Rankine cycle. Muhammad et al. [4] in their experimental investigations used a small scale (1 kW range) organic Rankine cycle system for net electrical power output ability, using low-grade waste heat from steam. The system was designed for waste steam in the range of 1–3 bars. Mohammadkhani et al. [5] analyzed utilization of waste heat from Gas Turbine-Modular Helium Reactor (GT-MHR) using two ORCs, exergoeconomically.

In the present work, the main objective is to do energy and exergy analysis for the waste heat recovery of the steam power plant condenser using ORC. Comparative investigations are performed for three working fluids; toluene, R600a and n-heptane. Moreover, a parametric study is performed to reveal effects of steam cycle condenser pressure on the cycle performance.

System description and assumptions made

Fig. 1 shows schematics of the proposed system.

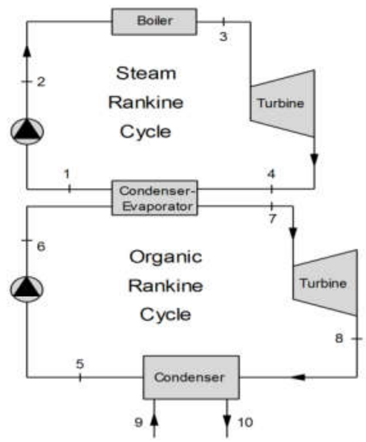

Fig. 1: schematic diagram of the system

As can be seen from Fig. 1, the system consists of high and low temperature loops. The high-temperature (steam Rankine cycle) loop contains pump, boiler, steam turbine, condenser and the associated connecting pipes, while the low temperature (ORC) which has the same components but uses the organic fluid as working fluid. The energy demand of upper loop is provided from fossil fuel. The condenser in the upper loop also acts as evaporator for the lower loop, which means that the rejected heat from the condenser of the high-temperature loop is used to evaporate the organic working fluid of the low-temperature loop.

The considered assumptions during the study are shown in Table 1.

Table 1: Considered assumptions

Parameter	Value
Minimum pressure of upper loop (P_1, P_4)	100 (kPa)
Maximum pressure of upper loop (P_2, P_3)	16700 (kPa)
Pumps isentropic efficiency (η_P)	85%
Steam turbine isentropic efficiency (η_{ST})	80%
Steam turbine inlet temperature (T_3)	541 (°C)
Steam mass flow rate ($\dot{m}_s$)	320 (kg/s)
Condenser-Evaporator pinch point temperature difference ($\Delta T_{PP,CE}$)	5 (°C)
Condenser pinch point temperature difference ($\Delta T_{PP,C}$)	3 (°C)
ORC turbine isentropic efficiency (η_{OT})	85%

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