Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 129 (2017) 90–96

Energy Procedia

www.elsevier.com/locate/procedia

IV International Seminar on ORC Power Systems, ORC2017
13-15 September 2017, Milano, Italy

Thermodynamic study of ORC at different working and peripheral conditions

Talieh Rajabloo[a,b,c*]

[a]*Department of Mechanical and industrial engineering, University of Brescia, Italy*
[b]*Energyville, Thor Park 8300, 3600 Genk, Belgium*
[c]*Flemish Institute for Technology Research (VITO), Boeretang 200, Mol 2400, Belgium*

Abstract

Power generation from low temperature sources using Organic Rankine Cycle (ORC) was studied in this paper. A thermodynamic model was achieved in Aspen plus environment and the best working conditions were obtained for on-design conditions. Furthermore, off-design analysis is conducted for the cycle in this study. Results depict the effect of peripheral conditions on performance of the cycle. In addition, the effect of some possible working fluid defects on the performance of the cycle is considered at off-design conditions.

Peer-review under responsibility of the scientific committee of the IV International Seminar on ORC Power Systems.

Keywords: Organic Rankine cycles, thermodynamic, working fluid, on- and off-design

1. Introduction

Organic Rankine Cycles (ORC) are suitable for conversion of low temperature heat to electric power. Operation of ORC is based on the same principles as that of a steam Rankine cycle, but differs from the latter in the usage of low-boiling-point organic fluids as a working fluid, which enables power generation at low heat source temperatures [1-7]. Generally, working fluids for ORC systems include hydrocarbons and synthetic refrigerants [8-11].

Moreover, organic fluids can, possibly, decompose while exposed to the heat resulting in mixture of working fluid.

Corresponding author. Tel.: +32 465 437542 ; fax: + 32 14 33 55 99
E-mail address: talieh.rajabloo@vito.be

1876-6102
Peer-review under responsibility of the scientific committee of the IV International Seminar on ORC Power Systems.
10.1016/j.egypro.2017.09.165

Consequently, the physical properties of the working fluid change. Overall, the calculation of the molecule bond energies can help estimation of the thermal stability of the pure components. However, the actual threshold temperature for the decomposition of working fluids depend on the surrounding environment, materials, different plant operating conditions and impurities resulted from the possible corrosions of cycle components [12].

This project is conducted based on a previous study [1] in which the on-design results of ORC were obtained for pure and mixture of working fluids with two types of evaporator. In this study the cycle with shell and tube evaporator is the reference case and all primary assumptions are reported in the mentioned study. Furthermore, different environmental conditions beside the hot source changes affect ORC performance. Thus, off-design analysis is necessary to find the effect of various peripheral conditions on the cycle performance. In addition, the effect of partial thermal decomposition of organic fluid was studied in a previous study [7] in which the main decomposed products were taken into account as binary mixture working fluid considering two main scenarios: (i) the most volatile components can be removed; (ii) the most volatile is not removed and the behaviour of the mixture is primarily defined by the amount of this compound. In this study, however, model is modified for the cycle with all decomposed products. The thermodynamic calculations were carried out by the program Aspen Plus v8.0 [13].

Nomenclature

Cond.	Condensation	P	Pressure (bar)
Evap.	Evaporation	K	Stodola's constant
η_T	efficiency of turbine (-)	T	Temperature (°C)
η_G	Efficiency of generator (-)	Q	Heat rate (W)
η_{Cycle}	Thermal efficiency of cycle (-)	$\dot{M}$	mass flow rate (kg.s^{-1})
η_{Fan}	Efficiency of fan (-)	W_{Net}	Net power (W)
η_P	efficiency of pump (-)	W_F	Fan power consumption (W)
η_{PD}	Efficiency of pump driver (-)		

2. General assumptions, system description and modeling of ORC

Based on our previous results [1] the thermodynamic model was obtained with the Peng-Robinson equation of state for isopentane as working fluid. This cycle is composed of a pump, an evaporator, a turbine and a condenser. Figure 1 depicts the simple scheme of the considered organic Rankine cycle (ORC). General assumptions for on-design of ORC plant are available in table 1. To complete the on-design model, minimum temperature approach of heat exchangers (ΔT_{min}) were fixed equal to 5 °C. As for evaporator, constant ΔT_{min} gives the right amount of mass flow rate of working fluid [1]. Besides, constant ΔT_{min} of condenser determines the condensation pressure. Therefore, results of on-design model gave us the essential parameters to calculate physical characteristics of the cycle components. Then based on these validated data, off-design analysis were conducted.