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Comparative energetic analysis of high-temperature subcritical and transcritical Organic Rankine Cycle (ORC). A biomass application in the Sibari district

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ABSTRACT

The present work aims to analyse the energetic performances of Organic Rankine Cycles (ORCs) for small-scale applications. To this purpose, a parametric energy analysis has been performed to define the proper system configurations for a biomass power plant. Saturated and superheated conditions at the turbine inlet have been imposed and subcritical and transcritical cycles have been investigated. Furthermore, the effect of operating conditions and the impact of internal regeneration on system performances have been analysed.

Finally, the possible exploitation of the biomass resulting from the pruning residues of peach trees in the Sibari district (Southern Italy) has been evaluated for the ORC configurations optimised during the energetic analysis.

The analysis shows that ORCs represent a very interesting solution for small-scale and decentralised power production. Moreover, the results highlight the large influence of the maximum temperature and the significant impact of the internal regeneration on the power plant performances.

1. Introduction

Nowadays, the Organic Rankine Cycle (ORC) represents a promising solution for power production. The ORC process guarantees high efficiencies for small-scale applications and/or low temperature heat sources, compared with other alternative technologies [1–5]. Furthermore, the system shows high flexibility and safety and low costs and maintenance requirements [6–10].

The use of an organic fluid represents the main difference between ORCs and conventional Rankine cycles and the choice of the working fluid is considered a fundamental key for the maximisation of the ORC global efficiency [11–17]. To this purpose, the heat source level and the application influence significantly the selection of the proper fluids and the definition of the suitable operating conditions. Particularly, ORC technology can be adopted to recover heat from different energy sources, both at low and at medium/high temperature.

Solar radiation, geothermal energy, and waste heat from industrial processes represent typical energy sources for ORC low temperature applications [18–21]. Hydrocarbons, fluorocarbons or hydrofluorocarbons are usually adopted as working fluids in these applications [4,21–24].

The Organic Rankine Cycles can be coupled also with internal combustion engines or gas turbines in order to recover their wasted heat at medium temperature [24–27]. As an example, Chacartegui et al. [28] demonstrated that combined cycles based on commercial gas turbines and ORCs represent an interesting and competitive solution for power production. Specifically, among the analysed working fluids for ORC bottoming cycle, toluene and cyclohexane guarantee the highest global performances in combined cycle power plants [28].

Furthermore, Organic Rankine Cycles can be used for the energy exploitation of agricultural residues and biomass (i.e., high temperature applications) [29–34]. In particular, power production and cogeneration from biomass are among the most effective solutions for reliable and sustainable energy supply in small-scale applications, where conventional power plants are technologically and economically unfeasible [21,29–34]. Biomass ORC plants guarantee several advantages compared with conventional installations in terms of costs, maintenance requirements, partial load performances and start-up procedures [31–33]. Furthermore, the use of an appropriate dry organic fluid eliminates the erosion problem of the turbine blades, improves turbine efficiency (up to 85–90%) and life, and lessens mechanical stress in comparison with water-steam turbine of the same size [32–34]. Following Schuster

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