Energy Conversion and Management 133 (2017) 411–426

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Three dimensional optimization of small-scale axial turbine for low temperature heat source driven organic Rankine cycle

Ayad Al Jubori [a,b,*], Raya K. Al-Dadah [a], Saad Mahmoud [a], A.S. Bahr Ennil [a], Kiyarash Rahbar [a]

[a] The University of Birmingham, School of Engineering, Mechanical Engineering Department, Edgbaston, Birmingham B152TT, UK
[b] University of Technology, Baghdad, Iraq

ARTICLE INFO

Article history:
Received 31 July 2016
Received in revised form 29 September 2016
Accepted 24 October 2016
Available online 3 November 2016

Keywords:
Small-scale axial turbine
ORC
Mean-line design
CFD
3D optimization
Multi-objective genetic algorithm

ABSTRACT

Advances in optimization techniques can be used to enhance the performance of turbines in various applications. However, limited work has been reported on using such optimization techniques to develop small-scale turbines for organic Rankine cycles. This paper investigates the use of multi-objective genetic algorithm to optimize the stage geometry of a small-axial subsonic turbine. This optimization is integrated with organic Rankine cycle analysis using wide range of high density organic working fluids like R123, R134a, R141b, R152a, R245fa and isobutane suitable for low temperature heat sources <100 °C such as solar energy to achieve the best turbine design and highest organic Rankine cycle efficiency. The isentropic efficiency of the turbine in most of the reported organic Rankine cycle studies was assumed constant, while the current work allows the turbine isentropic efficiency to change (dynamic value) with both operating conditions and working fluids. Three-dimensional computational fluid dynamics analysis and multi-objective genetic algorithm optimization were performed using three-dimensional Reynolds-averaged Navier-Stokes equations with k-omega shear stress transport turbulence model in ANSYS[R17]-CFX and design exploration for various working fluids. The optimization was carried out using eight design parameters for the turbine stage geometry optimization including stator and rotor number of blades, rotor leading edge beta angle, trailing edge beta angle, stagger angle, throat width, trailing half wedge angle and shroud tip clearance. Results showed that using working fluid R123 for a turbine with mean diameter of 70 mm, the maximum isentropic efficiency was about 88% and power output of 6.3 kW leading to cycle thermal efficiency of 10.5% showing an enhancement of 14.08% compared to the baseline design. Such results highlight the potential of the 3D optimization technique to improve the organic Rankine cycle performance.