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Development of micro-scale axial and radial turbines for low-temperature heat source driven organic Rankine cycle

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ABSTRACT

Most studies on the organic Rankine cycle (ORC) focused on parametric studies and selection working fluids to maximize the performance of organic Rankine cycle but without attention for turbine design features which are crucial to achieving them. The rotational speed, expansion ratio, mass flow rate and turbine size have markedly effect on turbine performance. For this purpose organic Rankine cycle modeling, mean-line design and three-dimensional computational fluid dynamics analysis were integrated for both micro axial and radial-inflow turbines with five organic fluids (R141b, R1234yf, R245fa, *n*-butane and *n*-pentane) for realistic low-temperature heat source <100 °C like solar and geothermal energy. Three-dimensional simulation is performed using ANSYS^{R17}-CFX where three-dimensional Reynolds-averaged Navier-Stokes equations are solved with k-omega shear stress transport turbulence model. Both configurations of turbines are designed at wide range of mass flow rate (0.1–0.5) kg/s for each working fluid. The results showed that *n*-pentane has the highest performance at all design conditions where the maximum total-to-total efficiency and power output of radial-inflow turbine are 83.85% and 8.893 kW respectively. The performance of the axial turbine was 83.48% total-to-total efficiency and 8.507 kW power output. The maximum overall size of axial turbine was 64.685 mm compared with 70.97 mm for radial-inflow turbine. R245fa has the lowest overall size for all cases. The organic Rankine cycle thermal efficiency was about 10.60% with radial-inflow turbine and 10.14% with axial turbine. Such results are better than other studies in the literature and highlight the potential of the integrated approach for accurate prediction of the organic Rankine cycle performance based on micro-scale axial and radial-inflow turbines.