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Modelling and parametric analysis of small-scale axial and radial-outflow turbines for Organic Rankine Cycle applications

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HIGHLIGHTS

- 1D design and 3D analysis for small-scale axial and radial-outflow are conducted.
- Different configurations of axial and radial-outflow are investigated.
- Five working fluids (R141b, R245fa, R365mfc, Isobutane, n-Pentane) are considered.
- The maximum axial turbine efficiency and power are 82.5% and 15.15 kW.
- The maximum ORC thermal efficiency based on axial turbine 11.74%.

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ABSTRACT

The existing literature pays limited attention to the design and 3D analysis of small-scale axial and radial–outflow turbines that can be utilised in Organic Rankine Cycles (ORC) for power generation with a low–temperature (<100 °C) heat source and low mass flow rate. Turbine efficiency significantly affects an ORC's efficiency because the turbine is considered a key component of the ORC. Therefore, obtaining high cycle thermal efficiency requires high turbine efficiency and power output. This work presents an integrated mathematical model for developing efficient axial and radial-outflow (centrifugal) turbines using a range of organic working fluids (R141b, R245fa, R365mfc, isobutane and n–pentane). This mathematical approach integrates mean-line design and 3D CFD analysis with ORC modelling. The ANSYS[R17]CFX is used to predict 3D viscous flow and turbine performance. To achieve accurate prediction, the ORC/turbines model uses real gas formulations based on the REFPROP database. The results showed that the axial turbine performed better, with efficiency of 82.5% and power output of 15.15 kW, compared with 79.05% and 13.625 kW from the radial–outflow turbine, with n-pentane as the working fluid in both cases. The maximum cycle thermal efficiency was 11.74% and 10.25% for axial and radial-outflow turbines respectively with n-pentane as the working fluid and a heat source temperature of 87 °C. The large tip diameter of the axial turbine was 73.82 mm compared with 108.72 mm for the radial-outflow turbine. The predicted results are better than others in the literature and highlight the advantages of the integrated approach for accurate prediction of ORC performance based on small-scale axial and radial-outflow turbines.

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