Abstract

Over the last years, the increase in energy consumption coupled with ever more stringent regulations on pollutants emissions and the massive advent of renewables in the energy market, have promoted the development of distributed energy systems and thus of an increasing interest towards small and micro power generation systems. In this context, the ORC progressively became the leading technology in the field of low size energy conversion systems (<100 kW) and low temperature applications (<150°C). Nonetheless, this technology still deserves further developments, especially regarding the design of specific components, which should grant features of reliability, acceptable performance level and, often even more important, affordable price in order to ensure the attractiveness of the whole energy system. It is the case of the small and micro expanders (tens to few kW scale). A possible solution for micro–size expanders is the Tesla expander, which is a viscous bladeless turbine that holds the desired characteristics of low cost and reliability. This expander was first developed by N. Tesla at the beginning of the 20th century, but it did not stir up much attention due to the strong drive towards large centralized power plants, where this technology becomes no longer competitive against those belonging to bladed expanders. In the recent years, due to the increasing appeal towards micro power generation and energy recovery from wasted flows, this cost effective expander technology rose a renovated interest.

In the present study, a 2D numerical model is realized and a design procedure of a Tesla turbine for ORC applications is proposed. A throughout optimization method is developed by evaluating the losses of each component and by introducing an innovative rotor model. The main optimizing parameters of the turbine, such as the rotor inlet/outlet diameter ratio, channel width–rotor diameter ratio and tangential velocity–rotational speed ratio at rotor inlet are highlighted and assessed.

The 2D model results are further exploited through the development of 3D computational investigation, which allows an accurate comprehension of the flow characteristics, which are difficult to depict with a 2D code.

Finally, two prototypes are designed, realized and tested. The former one is designed to work with air as working fluid, with the stator made in ABS with additive manufacturing technique, in order to show a possible cost effective way of realization. The obtained experimental results of this prototype well match the numerical predictions. A 94 W net power output with 11.2% efficiency are measured.

The second prototype is designed to work with organic fluids (specifically with R404A), and it is ultimately tested with R1233zd(E). A standard metal manufacturing

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is followed for this prototype. The achieved experimental results confirmed the validity and the large potential applicative chances of this emerging technology, especially in the field of micro sizes, low inlet temperature and low expansion ratios. 371 W net power output at 10% shaft efficiency are obtained.

The experimental results allowed the validation of numerical models, which was among the main objectives of this work. In this way, the numerical procedure may be reliably employed as the tool for the accurate and optimised design of Tesla turbines for organic Rankine cycles but also for applications with gas like air.

As a final remark, it can be affirmed that the operability of the Tesla expander was demonstrated in this work. Thus, it may be considered as a suitable and realizable solution to tackle one of the present issues related to micro expanders, namely high costs and low reliability, which, moreover, suffers off design conditions only to a limited extent.

The realization of a reliable design tool is another fundamental outcome of the present work.